Abstract Book

AMOS 2024 Conference

Hyatt Hotel, Canberra

February 5 to 9, 2024

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Plenary Talks

Plenary Talk (Tuesday 6 Feb, 10:00-10:30), Blair Trewin

Global climate in 2023

Blair Trewin

Bureau of Meteorology, Melbourne, Australia

Abstract

2023 was a very warm year globally as the La Niña event in place at the start of the year transitioned towards El Niño, with monthly global temperatures reaching record high levels by mid-year. The warmth was especially pronounced in global oceans, with record high temperatures from April onwards, and particularly exceptional warmth in the eastern North Atlantic. Prolonged and intense heatwaves affected regions including the Mediterranean, the southern United States and southeast Asia, while subtropical South America saw numerous episodes of unseasonable warmth during the winter. Canada had by far its most severe wildfire season on record, while August wildfires in Hawaii were the most significant in terms of loss of life in the United States for more than a century. Antarctic sea ice extent was at record low levels for the time of year for most of the year.

New Zealand experienced its most costly weather disasters on record early in the year with two separate episodes of major flooding in the North Island, while Tropical Cyclone Freddy, one of the longest-lived cyclones on record, resulted in heavy loss of life through flooding in southern Africa. California experienced a very wet winter with exceptional mountain snowpacks and persistent flooding, while parts of south-central Europe, especially northern Italy and Slovenia, had destructive hailstorms and severe flooding during the year. Multi-year drought associated with La Niña persisted in subtropical South America, but eased in east Africa and the equatorial western Pacific.

Oral and Lightning Lecture Talks

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Session 1 (Thursday 8 Feb, 16:30-18:00), Talk 1

Shifting baselines: The MHW Dilemma

Alex Sen Gupta[1], Kathryn Smith[2], Neil Holbrook[3], Jessica Benthuysen[4], Thomas Frölicher[5], Alistair Hobday[6], Thomas Wernberg[7], Mads Thomsen[8], Smale Dan[2], Eric Oliver[9], Pippa Moore[10], Karen Filbee-Dexter[11], Mike Burrows[12]

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

A recent Nature Commentary suggested that the way that we have commonly defined marine heatwaves – using a fixed baseline period to define extreme thresholds – should be changed. The paper argues that using a fixed baseline will eventually lead to the somewhat strange outcome that extreme temperatures in the future persist most of the time. Instead, it is argued that anthropogenic-related warming should be removed from the temperature data prior to the calculation of marine heatwave characteristics.

Here we discuss the advantages and disadvantages of these and other baseline approaches. The new proposed approach removes the problem of MHW saturation. It also splits the temperature timeseries into components with different predictability characteristics. On the other hand, identifying the anthropogenic warming signal can be problematic. Moreover, when using MHW characteristics to provide information around MHW impacts, this approach fails to reflect the increasingly severe effects that MHWs are having on marine organisms. Finally, a new definition could cause confusion with regards to the communication of how MHW characteristics have changed in the past and will change in the future.

Session 1 (Thursday 8 Feb, 16:30-18:00), Talk 2

Sub-seasonal to seasonal drivers of Australian Marine Heatwaves

Catherine H Gregory[1,2], Neil J Holbrook[1,2], Andrew G Marshall[3,4,2], Claire M Spillman[5,6]

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

As marine heatwaves (MHWs) become more frequent and severe due to global warming, understanding the drivers and impacts of these events is crucial for effective marine resource management. This study investigates the influence of El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the Southern Annular Mode (SAM), the Sub-Tropical Ridge High (STRH), and the Madden Julian Oscillation (MJO) on sea surface temperature (SST) anomalies and MHWs around Australia. The aim is to improve subseasonal to seasonal (S2S) forecasting, which bridges the gap between short-term weather and long-term climate predictions. By analysing SST anomalies and identifying the additional weekly heat stress from MHWs during specific driver phases, a simple MHW hazard index is developed. The study also explores the influence of the MJO on tropical winds, which can directly modulate the impacts of La Niña. The research emphasizes the importance of considering multiple drivers and their compound effects on MHWs. By accounting for these interactions, S2S forecasts can provide more accurate predictions regarding the timing, intensity, and spatial extent of extreme thermal events. This knowledge enhances the ability of managers to adapt and allocate resources based on evolving climate conditions, enabling effective implementation of harm minimisation strategies. Overall, this study lays the groundwork for further exploration of driver relationships and highlights the significance of S2S forecasting in optimizing resource allocation and improving marine ecosystem management in the face of MHWs and their associated impacts.

Session 1 (Thursday 8 Feb, 16:30-18:00), Talk 3

Marine heatwaves in the Great Barrier Reef and Coral Sea, their mechanisms and impacts on shallow and mesophotic coral ecosystems

Zhi Huang[1], Ming Feng[2], Steven Dalton[3], Andrew Carroll[1]

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

This study identified major marine heatwaves (MHWs) occurring in the GBR and Coral Sea region over the last three decades (1992–2022) and mapped significant MHW events between 2015 and2022. We investigated the mechanisms of the MHWs and identified potential coral refugia. MHWs in this region have increased in frequency, intensity and spatial extent. El Niño, especially when it is in phase with positive Indian Ocean Dipole, was the key remote driver leading to intense MHWs. However, the more recent strong MHWs occurred without these climatic events, signifying the impacts of long-term climate change and local drivers. We also found that reduced wind speed and shoaling mixed layer depth, often together with reduced cloudiness, were the main local drivers pre-conditioning these MHWs. Anomalous air-sea heat flux into the ocean, mainly controlled by shortwave solar radiation (cloudiness) and latent heat flux (wind), was the most constant contributor to the 2015–16 and 2019–20 MHW events. However, local oceanographic dynamics, especially horizontal advection and turbulent mixing, played important roles in MHW heat budgets. This study confirmed that shallow-water coral bleaching severity was positively related to the cumulative MHW intensity. We identified the shallow reefs along the path of the North Queensland Current as potential coral refugia from bleaching because of the cooler waters upwelled from the ocean current. We also found that the mesophotic reefs in the Coral Sea Marine Park may be less susceptible to severe bleaching as the MHWs are more confined within the shallow mixed layer.

Session 1 (Thursday 8 Feb, 16:30-18:00), Talk 4

Coastal impacts of marine heatwaves: Tasmania's Huon estuary as a case study

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

Marine heatwaves (MHWs) are a considerable concern due to their ecosystem impacts, and increasing intensity, duration and extent in a warming ocean. A good understanding has been gained about the drivers and ecological impacts at the large scales. However, studies about the impact of MHWs in coastal areas and estuaries are very scarce. Remote sensing and climate models are not always appropriate to represent the coastal condition; therefore, field observations and higher resolution numerical models are more appropriate to study the impact of MHWs in coastal areas, estuaries, and the land-sea interface. MHWs in coastal environments have become an increasingly serious threat for pelagic and benthic ecology. Within coastal areas, estuaries represent environments with high productivity and biodiversity that sustain important economic activities like aquaculture and fisheries. Some negative impacts of MHWs in estuaries are associated with the proliferation of harmful algal blooms, kelps dieback, increased prevalence of oyster disease and abalone mortality, as well as poor performance in farmed salmon. This study investigates MHWs and their impacts in the Huon Estuary as a study case, and combines model outputs with observations. Preliminary results show that recent advective- and air-sea heat flux driven MHWs affected the temperature distribution throughout the water column along the estuary.

Session 1 (Thursday 8 Feb, 16:30-18:00), Talk 5

A proposed typology for subsurface marine heatwaves

Neil Malan[1], Alex Sen Gupta[1], Shujing Zhang[2,3], Martina Doblin[4], Amandine Schaeffer[1], Gabriela Semolini Pilo[5]

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

Marine heatwaves can be easily classified and identified at the surface of the ocean using satellite sea surface temperature. However, life also extends throughout the water column, making it crucial to understand marine extremes at depth, especially considering the prevalence of subsurface chlorophyll maxima throughout the world's oceans. In recent years, the number of studies concentrating on subsurface marine heatwaves has grown rapidly in number. We have learnt that subsurface marine heatwaves are common, and often last longer and are more intense than their counterparts at the surface. Subsurface marine heatwaves can be driven by several mechanisms and can be bottom or thermocline intensified.

However, as with any emerging field, there are a variety of approaches used to define subsurface marine heatwaves, and we have no common language with which to describe them. Unlike at the surface, we lack consistent, daily, gridded datasets, making the establishment of robust climatologies difficult and highly dataset dependent. This lack of consistency and common language makes understanding the biological impacts of subsurface marine extremes challenging.

In this work we propose a typology consisting of 5 types of marine heatwaves. We present examples of each type, and their most common driving mechanisms. Finally, using a simple biogeochemical model, discuss the impact on ecosystems these different marine heatwave types may have on ecosystems.

Session 1 (Thursday 8 Feb, 16:30-18:00), Talk 6

Understanding subsurface marine heatwaves

Shujing Zhang[1,2], Neil J. Holbrook[1,2], Alex Sen Gupta[3,4], Annie Foppert[5]

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

Marine heatwaves (MHWs) are prolonged warm ocean temperature extremes that can have substantial impacts on marine organisms. MHWs have been typically identified at the ocean surface using daily satellite sea surface temperature data. However, MHWs not only occur at the ocean surface but also in the subsurface. Several regional MHW studies have analysed different observations of water column temperatures and found that maximum temperature anomalies are often in the subsurface rather than at the surface. Moreover, some subsurface MHWs have been detected without associated surface warming. A recent study of bottom MHWs on the continental shelf of North America also showed that some bottom-intensified MHWs have higher intensity and longer duration than surface MHWs, which could have significant impacts on benthic species. Although there have been some regional studies of subsurface temperature extremes, there has been little research on the physical drivers of subsurface MHWs. Here we use monthly ocean temperature and salinity from gridded ARGO data since 2004 to detect subsurface MHWs in the upper 2000m of the Northeast Pacific Ocean and examine their drivers. We detected a subsurface MHW that persisted from 2015-2017, where subsurface temperature anomalies of 0.4^{o}C near 170m persisted for 1.5 years. By diagnosing temperature and salinity variations on isobaric and isopycnal surfaces, we have analysed how three oceanic processes “pure warming”, “pure freshening” and “pure heaving” affect the evolution of subsurface MHWs. This oceanic process diagnosis allows us to classify subsurface MHWs into different types that may have different impacts on pelagic marine species.

2. Floods and coastal impacts in a changing climate: past, present and future

Session 2A (Wednesday 7 Feb, 16:30-18:00), Talk 1

Towards a more flood resilient future: Updating the climate change considerations in the Australian Rainfall and Runoff Guidelines.

Conrad Wasko[1], Seth Westra[2], Leanne Wilkinson[3], Simon Koger[4]

[1]The University of Melbourne, Melbourne, Australia. [2]University of Adelaide, Adelaide, Australia. [3]Department of Climate Change, Energy, the Environment and Water, Australia. [4]Engineers Australia, Australia

Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

Severe flooding in 2022 in New South Wales and southeast Queensland emphasised the risks floods pose to our communities. Up-to-date guidance that ensures robust consideration of future flood risks is urgently required to ensure that asset owners, floodplain managers, insurers, engineering consultants, and private industry all have the information needed to account for climate change in estimating flood risk.

The Australian Government, led by the Department of Climate Change Energy, the Environment and Water and in partnership with Engineers Australia, is undertaking a co-design process with climate scientists and industry stakeholders to update the Interim Climate Change considerations, Chapter 6 of book 1 of the Australian Rainfall and Runoff: A Guide to Flood Estimation (Geoscience Australia, 2019).

To meet user needs, the project involves two rounds of consultation and the submission for peer review of a science review that will underpin the guidance. The first round of stakeholder input identified key priorities for the update and informed the scope of the science review to include, but not be limited to: estimates of uncertainty; summary of extreme rainfall changes across annual exceedance probabilities (AEP) up to and including the Probable Maximum Precipitation (PMP); and impacts of baseline choices. The second round of consultation on the draft guidance is planned for late 2023 with guidance published by mid 2024.

The presentation will include outcomes from the science review and proposed updates to the guidance.

This work is supported through a grant from the National Emergency Management Authority Disaster Risk Reduction Package.

Session 2A (Wednesday 7 Feb, 16:30-18:00), Talk 2

Managing Impacts of Tropical Cyclone Storm Surge via a New Decision Support Framework

Gaelle S Faivre, Darrell Strauss, Joanna Aldridge, Rodger Tomlinson

Griffith University, Southport, Australia

Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

Storm surge presents the greatest risk to life in a tropical cyclone, however its forecast is complicated by the high degree of uncertainty in both the forecast cyclone track and the sensitivity in storm surge magnitude to local bathymetry, cyclone track characteristics such as orientation to the coastline and intensity, as well as the dynamic timing with the astronomical tide. Presently, storm surge warnings are delivered to the public via text warnings and to emergency managers as a range of depths at the coastline. There is a need to enhance the storm surge warnings into a decision-making tool giving an indication of areas likely to be inundated.

The SurgeImpact project, funded by the Queensland Reconstruction Authority, is a collaboration of Griffith University, Queensland Fire and Emergency, Geoscience Australia, Department of Environment and Science, Queensland, and the Bureau of Meteorology. This project aims to develop an updated high resolution probabilistic storm surge inundation decision support tool. This product is intended for use by emergency managers in guiding evacuation decisions, planning of options for evacuation routes. This product will upgrade existing capability by extending into inundation modelling. It presents a novel probabilistic methodology taking the range of forecast cyclone tracks and their degree of uncertainty and generating the probabilistic hazard inundation surface at various points in time in the forecast as a cyclone approaches the coastline using multiple simulations on high performance computing. Impacts will be displayed leveraging Geoscience Australia's HazImp platform, to communicate the extent of storm tide inundation.

Session 2A (Wednesday 7 Feb, 16:30-18:00), Talk 3

Subseasonal to seasonal sea level forecasts for the Australian coastline

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Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

Subseasonal to seasonal variations in coastal water levels, associated with climate drivers such as the El Niño-Southern Oscillation and other weekly to monthly scale atmospheric and oceanographic processes, contribute to coastal sea level extremes by raising the baseline sea level on top of which storm surges and tides act. Along with astronomical tides these subseasonal to seasonal variations are potentially predictable weeks to months in advance, information that could be used to construct an early warning system for coastal flooding hazards. With this aim in mind, we present a comprehensive forecast skill assessment of the Bureau of Meteorology's seasonal prediction system, ACCESS-S2, for sea level around the Australian coastline at leads between 2 weeks and 7 months. ACCESS-S2 has seasonal skill on the North and West Coasts, where anomalies associated with tropical climate drivers and coastal trapped waves can reach up to 20 cm. Inclusion of the inverse barometer impact on sea level as a post-processing step increases skill in most regions due to ACCESS-S2's ability to forecast atmospheric pressure variations. Forecasts also show potential at subseasonal timescales, including along the South Coast. We discuss how different drivers of subseasonal to seasonal coastal sea level variability contribute to predictability. We also discuss the additional ingredients needed to construct a future probabilistic early warning system for Australian coastal flooding hazards.

Session 2A (Wednesday 7 Feb, 16:30-18:00), Talk 4

Extreme coastal waves due to East Coast Lows in a warming climate

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Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

East Coast Low (ECL) storms along the NSW coastline can result in substantial beach erosion and threats to adjacent coastal property and infrastructure. These erosion events are primarily driven by extreme wave heights generated by low-pressure systems, sometimes exceeding 8 m offshore but varying considerably as ECL storm waves approach the embayed coastline. Understanding possible changes in the extreme coastal wave climate caused by ECLs is critical for both coastal engineering design and planning of any future mitigation activities. This is complicated by climate change, which is projected to alter both the direction of future ECL storm tracks and their associated wind fields that generate large waves.

This study explores the potential future impacts of ECLs on coastal wave climate of NSW in a warming climate. A unique high-resolution atmospheric model of the SE Australia region (HiRes-MESECA) is used to simulate 12 ECLs from 2001-2016. Simulations are undertaken using both present conditions and a range of future climate scenarios. A triple-nested WaveWatch3 (WW3) wave model is then applied that simulates the propagation of the deepwater regional wave climate to the nearshore (i.e., to the 10m depth contour along the entire NSW coastline).

Somewhat surprisingly, the investigations from these simulations indicate that coastal waves that are anticipated to result from future ECLs may become less extreme at the coast, even under high range (RCP8.5) climate scenarios. These results have important implications for coastal engineering design, where the design life typically needs to consider climate change effects.

Session 2A (Wednesday 7 Feb, 16:30-18:00), Talk 5

Projections of coastal flood frequency changes for Australia

Ben Hague[1,2], Shayne McGregor[2], Stefan Talke[3], David Jones[1], Ruth Reef[2], Doerte Jakob[1], Brad Murphy[1]

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Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

The onset of chronic high tide flooding was described as the world's "most urgent adaptation challenge" by the Intergovernmental Panel on Climate Change's 6th Assessment report on Impacts, Adaptation and Vulnerability. Here we present the first sets of projections of high tide flooding for Australia to understand what this challenge will mean for Australian coastal managers and communities. Using two different projection methods, we show that the drivers of changes in flood heights differ from those for changes in flood frequencies under sea-level rise. Changes in heights of floods are expected to track changes in mean sea level very closely. In contrast, local and regional differences in flood threshold elevations, tidal ranges, and storm surge magnitudes all modulate how flood frequencies change in response to sea-level rise. This means that the locations with the largest increases in flood heights may not be the same locations that see the largest increases in flood frequencies under a given sea-level rise. Additionally, we show that if changes in sea-level variability are not well considered in projections this can have significant impacts on future estimates of coastal flood frequencies.

Session 2A (Wednesday 7 Feb, 16:30-18:00), Talk 6

Regional Extreme Climate Change Induced Coastal Flooding in the Georges River Catchment, Sydney, New South Wales, Australia

Wenjun Zhu[1], Xiao Hua Wang[1], William Peirson[2]

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Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

Coastal flooding is one of the most frequent climate-related natural hazards on the south-east Australian coast which centres over 55% of the Australian population. Flooding in such a densely populated region pose a sever threat to public safety, coastal infrastructure, ecological systems and the economy. For flood management and mitigation, it is crucial to comprehend flood events in changing climate. Although an increase in flooding is anticipated under global warming, few studies have projected the change in flood severity in an urban catchment. Here, the severity of future flood episodes in Georges River is investigated. The Watershed Bounded Network Model (WBNM), forced by the New South Wales and Australian Capital Territory Regional Climate Modelling Project version 1.5 (NARCliM1.5) under both historical scenarios and the Representative Concentration Pathway (RCP) 8.5 scenario, is applied to project Georges River flood hydrology in this study. This projection is used to investigate the changes in the magnitude of flood events in the George River in the high-emission future. Increases in rainfall at the 20 year average recurrent interval (ARI) are projected to be 25%, with significantly greater consequent increases in runoff and flooding. The projected 20 year ARI flood peak discharge increases by a factor of two, while the projected water level is approximately 2 metres higher at Liverpool, the head of the main channel of the estuary. Increased flooding will lead to greater risk to the resident communities as well as damage to industry and public infrastructure within the catchment.

Session 2B (Thursday 8 Feb, 09:30-10:30), Talk 1

How will floods in Australia differ under climate change?

Conrad Wasko[1], Michelle Ho[1], Danlu Guo[2], Declan O'Shea[1], Elisabeth Vogel[3,1], Rory Nathan[1], Ashish Sharma[3]

[1]The University of Melbourne. [2]Australian National University. [3]University of New South Wales

Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

he latest IPCC report on extreme events concluded that under global warming heavy precipitation will generally become more frequent and more intense – meaning more of our inhabited areas are likely to be impacted by flood events. Currently, flood adaptation efforts are hampered by the dearth of information on how flooding is projected to change. Here, we use downscaled climate model projections and catchment-specific rainfall-runoff models, calibrated to reproduce a range of flood quantiles that represent flood events of different magnitude and rarity, to investigate future changes to flooding in Australia. We show that projections of flooding follow historical trends – rarer floods more likely to increase, while frequent floods are largely projected to decrease.

To understand these future changes, we extend our analysis to project soil moisture and event runoff coefficients. Across Australia we find runoff coefficients are projected to decrease meaning that for the same of amount of rainfall we can expect less runoff, largely due to drier soil moisture conditions – particularly for southern parts of Australia. But for rarer events, projected changes in flooding follow the projected increase in extreme rainfall across Australia. These results suggest that events that cause reservoir storages to spill will increase, posing an increased risk to infrastructure safety while more frequent floods that constitute environmental flows as well a large portion of reservoir inflows will decrease. Future water resource planning will need to account for reduced runoff yields and significant work remains if adaptation efforts are to reflect these projected changes.

Session 2B (Thursday 8 Feb, 09:30-10:30), Talk 2

The Non-Stationary Influence of Climate Modes of Variability on Extreme Water Levels Around Australia

Julian G O'Grady[1], Kathleen L McInnes[2]

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Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

Extreme water levels pose the significant threats of coastal inundation and erosion to coastal communities, ecosystems, and critical infrastructure. Understanding the relationship between these events and the underlying climatic drivers is crucial for effective adaptation and mitigation strategies. Traditional analyses of extreme water levels have often assumed stationarity, neglecting the dynamics between these events and climate variability and change. This study investigates the influence of climate drivers, such as El Niño–Southern Oscillation and the Southern Annular Mode, on exceedance probabilities for extreme water level return levels. Non-stationary extreme value analysis is applied to hourly tide gauge observations for the network of gauges around Australia. Extreme value distributions are fitted to annual maxima with a covariate for the climate drivers, allowing the parameters of the distributions to change with the climate drivers. The Akaike information criterion is used to test the significance of including these additional nonstationary parameters. The findings indicate the regional influence of climate drivers on extreme water levels, with ENSO playing a significant role in driving extreme water levels in the north of the continent. This work will help inform both retrospectives of past high water level events and the predictability future extreme water level.

Session 2B (Thursday 8 Feb, 09:30-10:30), Talk 3

First approach at a revised sea level rise allowance for coastal planning purposes in Western Australia

Lucya Roncevich, Fangjun Li, Frederic Saint-Cast

Department of Transport, Fremantle, Australia

Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

In Western Australia a 0.9m allowance for sea level rise (SLR) is used over a 100-year planning timeframe, based on 2007 SLR projections from the Intergovernmental Panel on Climate Change (IPCC) AR4 and Australian regional projections from CSIRO. A need to revisit the SLR allowance was identified with the recent release of the IPCC AR6 reports.

The first approach for review of the SLR allowance was to consider the equivalent scenario in the AR6. The 0.9m allowance is based on the 95th percentile of the A1FI scenario including the allowance for 'scaled-up ice sheet discharge'. The SSP5-8.5 Low Confidence Upper scenario was considered directly comparable, however, projected SLR values for the SSP5-8.5 Low Confidence Upper scenario are substantially greater than other SLR projections in the AR6, with a large diversion projected from 2050.

Due to the large SLR values, use of this scenario would likely reduce flexibility and future options when planning climate change adaptation actions, and result in maladaptation. Finding the right balance between maladapting and a precautionary approach for planning purposes is important. So where to next?

Other SLR scenarios were investigated, however there wasn't a clear and transparent means to recommend a different scenario.

Further work is needed including identifying a suitable decision making process within government to determine the risk tolerance; improving understanding of the different AR6 scenarios, particularly ice sheet processes and the suitability of Median or Upper projections; and determining the likelihood of future GHG emission scenarios.

Session 2B (Thursday 8 Feb, 09:30-10:30), Talk 4

Future changes to extreme rainfall in Australia: a meta-analysis

Timothy H Raupach[1,2,3], Acacia Pepler[4,3], Conrad Wasko[5], Seth Westra[6], Andrew Dowdy[7,5], Jason Evans[1,2,3]

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Session

2. Floods and coastal impacts in a changing climate: past, present and future

Abstract

Design flood estimation requires, as input, possible values of extreme rainfall under climate change. Here, we present a meta-analysis that assesses the level of consensus between different sources of evidence for the scaling of extreme rainfall with warming temperatures. The analysis is based on a systematic review of the latest science on design flood estimation inputs for Australia, from which 40 manuscripts that quantified rainfall intensity to temperature change relationships were identified. Where possible, we extracted the reported changes and converted them to percentage change in rainfall amount per degree of warming. We chose to focus on daily and hourly duration categories and events as rare or rarer than once per year. While it is understood that mechanisms for producing extreme rainfall differ geographically across Australia, there was insufficient evidence in some regions to produce a per-region meta-analysis. There is some evidence that rarer extremes increase more with temperature than more common extremes, yet this evidence was not sufficient to quantify the changes by return period in the meta-analysis. Multiple co-authors independently weighted each scaling estimate by type of evidence, methodology used, data amount and region covered, and theoretical considerations, to determine overall scaling estimates. The authors then formed a consensus view of the central estimate and likely range (66%) for rainfall scaling per degree of warming. These estimates of extreme rainfall scaling will form a key component of updated flood guidance for Australia.

3. Physical processes contributing to extreme coastal sea levels

Session 3 (Tuesday 6 Feb, 16:30-18:00), Talk 1

Multi-site testing of stochastic earthquake tsunami models at Australian tide-gauges.

Gareth Davies

Geoscience Australia

Session

3. Physical processes contributing to extreme coastal sea levels

Abstract

Hazardous tsunamis are rare in Australia but could be generated by several mechanisms, including large plate-boundary earthquakes in locations that efficiently direct wave energy to our coast. With few hours between detection and tsunami arrival, prior planning is important to guide emergency response and risk mitigation. This drives interest in tsunami hazard information; which areas could be inundated, how likely, and how confident can we be? In practice the hazard is uncertain because historical records are short relative to tsunami frequencies, while long-term sedimentary records are sparse. Hazard assessments thus often follow a probabilistic approach where many alternative tsunami scenarios are simulated and assigned uncertain occurrence rates. This relies on models of stochastic earthquakes and their occurrence rates, which are not standardised, but depend on the scenario earthquake magnitude and other information from the source region. In this study we test three different stochastic tsunami models from the 2018 Australian Probabilistic Tsunami Hazard Assessment (PTHA18), an open-source database of earthquake-tsunami scenarios and return periods. The three models are tested against observations from twelve historical tsunamis at multiple tide gauges in Australia. For each historical tsunami, and each of the three models, sixty scenarios with similar earthquake location and magnitude are sampled from the PTHA18 database. A nonlinear shallow water model is used to simulate their effects at tide gauges in NSW, Victoria and Western Australia. The performance and statistical biases of the three models are assessed by comparing observations with the 60 modelled scenarios, over twelve separate tsunamis.

Session 3 (Tuesday 6 Feb, 16:30-18:00), Talk 2

A range of physical processes contribute to non-tidal residual water levels

Charitha B Pattiaratchi

The University of Western Australia, Perth, Australia

Session

3. Physical processes contributing to extreme coastal sea levels

Abstract

Storm surges (non-tidal water level) are a hazard, which result in coastal inundation, erosion, and possible loss of lives and is usually defined as the difference between the observed water level and the predicted tide. But there are many different physical processes that contribute to storm surge. Tropical storms (cyclones, hurricanes, typhoons) are among the most energetic forcing agents for the coastal ocean. Physical processes that influence the non-tidal water level associated with storms systems can persists for up to 14 days, beginning 3–4 days prior to storm landfall and ceasing up to 10 days after landfall. There is an additional contribution due to the influence of surface gravity waves (wave set-up). The storms also generate long waves with periods in the order of hours to days, which influence the water levels and currents both locally and many thousands of kilometres away. The components of a storm surge include: (1) forerunner, an increase in the mean water level up to several days prior to storm landfall; (2) meteotsunami; (3) continental shelf seiches; (4) edge waves with periods of ~six hours, that move both directions along the coast; and, (5) continental shelf waves, which propagate in a single direction with the coast on their left (right) in the southern (northern) hemisphere, with the restoring force being the Coriolis force. In this presentation, we use field measurements and numerical modelling from Western Australia (North West Shelf and south-west) to identify these processes and define their contribution to the storm surge

Session 3 (Tuesday 6 Feb, 16:30-18:00), Talk 3

Modelling tropical cyclone induced storm surge loss using machine learning techniques

Maxime Marin

Risk Frontiers, Sydney, Australia

Session

3. Physical processes contributing to extreme coastal sea levels

Abstract

In the context of global sea level rise, coastal flooding losses due to storm surge events are a growing threat for Australians. Such events are commonly observed during tropical cyclones (TCs). Catastrophe loss (CAT-Loss) models are widely used in the insurance industry to estimate natural hazards financial loss based on stochastic sampling of historical events repeated over thousands of years. The loss associated with storm surge during a TC is often ignored in traditional TC CAT-Loss models due to the complexity of modelling extreme sea level events in Monte-Carlo simulation infrastructures. Here, we present a machine learning modelling approach to include storm surge risk within Risk Frontiers' TC loss model - CyclAUS. Storm surge water levels are modelled using Convolutional Neural Networks trained on a coastal sea level reanalysis dataset, spanning the Australian coastline at a 25 km resolution. Outputs from CyclAUS, simulating 50000 years of current climatology TCs around Australia, are then fed to point-based individual storm surge models to extract a maximum sea level height. Storm surge model validation shows that our machine learning approach has comparable skills to hydrodynamic solutions, while demanding far fewer computational resources, thus enabling its implementation into stochastic CAT-loss models.

Session 3 (Tuesday 6 Feb, 16:30-18:00), Talk 4

The effects of wave-current interactions on coastal sea levels

Xiao Hua Wang

UNSW, Canberra, Australia

Session

3. Physical processes contributing to extreme coastal sea levels

Abstract

Understanding the wave-current interactions (WCI) is crucial to accurate modelling of wave, tides and storm surge in the coastal oceans. In this talk, I will use case studies to show WCI can greatly modify sea level and wave height via tide-induced water level changes and current advection/refraction of wave energy. More specifically, model results show that WCI affects wave set-up in the surf zone due to a balance between cross-shore pressure gradient and wave radiations stress gradient. Furthermore, the water level is the dominant factor in significant wave height modulation when the wave propagates into shallower regions from the deeper ocean, whereas the current modulates the deep ocean wave height. Wave energy dissipation related to whitecapping processes plays a greater role in reducing the wave height nearshore than the dissipation due to depth-induced breaking and bottom friction.

Session 3 (Tuesday 6 Feb, 16:30-18:00), Talk 5

Assessment of different CMIP6 regional wind wave climate downscaling approaches for South-East Australia

Matteo Lorenzo[1], Alberto Meucci[2,3], Jin Liu[2,4], Jozef Syktus[5], Claire Trenham[6], Vanessa Hernaman[3], Ron Hoeke[3], Miguel Onorato[1], Ian R. Young[2]

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Session

3. Physical processes contributing to extreme coastal sea levels

Abstract

Wind waves play a crucial role in coastal dynamics and can significantly impact coastal sea levels, especially during extreme events. Ocean winds are changing as the Earth is warming, and hence the waves. The Australian Climate Service (https://www.acs.gov.au/), recognised wind waves as a crucial element to support future coastal climate mitigation and adaptation strategies. Wind wave climate future projections are, however, plagued by uncertainties. One of the primary sources of uncertainty originates from the resolution of the Coupled Model Intercomparison Project (CMIP) General Circulation Model (GCM) surface wind speed products. We hereby assess different approaches to regional wind wave climate modelling, to understand the impact of the CMIP6 GCM wind speed resolution. We evaluate the Southeast Australia wave climate results from an unstructured grid regional wave model nested in a global wave model. We compare 30 years (1985-2014) of historical wave climate simulations using wind vectors from the CMIP6 Meteorological Research Institute (MRI) CMIP, AMIP, and HighResMIP experiments (nominal resolutions of ~150 km for CMIP and AMIP, and 25 km for HighResMIP). We then compare these results with the wave model forced by the MRI CMIP surface winds dynamically downscaled with the Conformal Cubic Atmospheric Model (CCAM) (~12.5 km resolution). The findings indicate that the wind wave climate models yield divergent results, particularly at the extremes where the most interest lies for future coastal sea level projections. We discuss the reasons for the differences and propose the best way forward for developing regional wind wave climate projections.

4. Atmospheric Dynamics of Climate and Extreme Weather

Session 4A (Tuesday 6 Feb, 14:00-15:30), Talk 1

Subtropical and eddy-driven jet influence on southeast Australian rainfall

Roseanna McKay, Irina Rudeva, Acacia Pepler

Bureau of Meteorology, Melbourne, Australia

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

The subtropical jet, eddy-driven jet, and their interactions play important roles in synoptic rainfall over southeastern Australia. However, understanding and analysis of their roles is relatively limited. This study takes advantage of a detailed jet database calculated from 3-hourly ERA5 reanalysis data to improve our understanding of how the atmospheric jets relate to synoptic rainfall extremes in southeast Australia through the seasons. There are seasonal differences in where the jets are located and how they are structured during extreme rainfall events, with winter patterns appearing more zonally aligned and summer patterns more meridionally elongated. The typical jet structures associated with rainfall, associated dynamics, and relationship to the larger-scale circulation will also be discussed.

Session 4A (Tuesday 6 Feb, 14:00-15:30), Talk 2

Synoptic-dynamical view of droughts in southern Murray-Darling Basin

Chenhui Jin

Monash University, Australia. The ARC Centre of Excellence for Climate Extremes, Australia

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Australia is a country prone to drought and has experienced several severe droughts in its recent history. Most studies have linked large-scale modes of variability to Australian droughts, whereas few studies investigate droughts from the perspective of weather systems. In the current study, a wide range of weather systems (cyclones, anticyclones, fronts, warm conveyor belts, potential vorticity streamers, and cut-off lows) are investigated in association with heavy rainfall days that are important to meteorological drought in the southern Murray-Darling Basin. Two distinct phases (development and recovery) of drought are identified based on the standardised precipitation index.

This study shows that heavy rainfall days produce less rain during the development phase of drought in the southern Murray-Darling Basin, compared to the recovery phase. The rainfall reduction in the development phases is mainly due to a reduction in the frequency and intensity of rainfall associated with warm conveyor belts. On heavy rainfall days, warm conveyor belts are less frequent and weaker in the vicinity of the southern Murray-Darling Basin during drought development, whereas they are more frequent, intense, and persistent over this region during recovery from drought. Moreover, the spatiotemporal evolution of rainfall is consistent with the ascending branch of warm conveyor belts, supporting the importance of warm conveyor belts to rainfall.

Regarding the source of moisture on heavy rainfall, there is a notable decrease in moisture transport over the Coral Sea during the development of drought, whereas strong moisture divergence is identified in this region during the recovery phase.

Session 4A (Tuesday 6 Feb, 14:00-15:30), Talk 3

The meteorology behind the 2022 Great Barrier Reef coral bleaching event

Lara S Richards[1,2,3], Steven T Siems[1,2], Michael Manton[1], Yi Huang[4,2,3], Daniel Harrison[5,2]

[1]Monash University. [2]Reef Restoration and Adaptation Program. [3]ARC Centre of Excellence for Climate Extremes. [4]The University of Melbourne. [5]Southern Cross University

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Over the last 25 years, 7 thermal coral bleaching events (CBEs) have occurred on the Great Barrier Reef (GBR), with 4 being declared mass CBEs. While the science behind thermal coral bleaching mechanisms is well established, little is known about how the local and synoptic-scale meteorology drives these events. Drops in local wind speed and cloud cover often occur during CBEs and are strongly correlated with spikes in sea temperature.

During 2022, the 4th mass CBE occurred on the GBR under strong La Niña conditions. This event severely impacted the central GBR, where Davies Reef observations showed a sea temperature spike of 2°C from February 20th to March 10th. By looking at the evolution of the local and synoptic-scale meteorology preceding, during and after the bleaching event, the effects of wind speed and direction can be seen over the reef. A surface heat budget analysis shows the direct impacts of local cloud cover and winds on the sea temperatures, where the loss of wind-driven latent heat flux appears to drive local heating.

The 2022 bleaching event featured large drops in wind speed and changes from south-easterly trade winds to warm and moist northerly winds. The bleaching event then ends when the trades are re-established. We show that losing the trade winds is a common occurrence for GBR CBEs spanning back to 1998 where a cluster analysis and synoptic composites are used to further understand the weather-related to coral bleaching.

Session 4A (Tuesday 6 Feb, 14:00-15:30), Talk 4

Stratified flow over topography in the Large Rotating Annulus

Kial D Stewart, Callum J Shakespeare

Australian National University, Canberra, Australia

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Interactions between stratified flows and topography play a fundamental role in Earth's climate and weather. In the Climate & Fluid Physics Laboratory at the Australian National University, we use laboratory experiments with a differentially-heated rotating annulus to explore stratified flow-topography interactions in a dynamical regime of strong background geostrophic turbulence. An idealised topographic ridge is differentially-rotated at a range of angular velocities around the base of the annulus to impose a relative velocity between the stratified fluid and the ridge. Despite the simple, idealised setup of the laboratory configuration, the experiments exhibit rich dynamics that include, but are not limited to, lee waves, internal bores, baroclinic instabilities, boundary currents, largescale gyres, blocking, and, of course, geostrophic eddies. Here we present findings from recently published and ongoing experiments that characterise the complicated flow dynamics in terms of simple bulk parameters, with the aim of improving their representation in coarse-resolution numerical general circulation models.

Session 4A (Tuesday 6 Feb, 14:00-15:30), Talk 5

The impact of Zonal Wavenumber 3 in the Southern Hemisphere

Valentina Ortiz-Guzmán[1,2], Martin Jucker[1,2], Steven Sherwood[1,2]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

The Southern Hemisphere climate and weather are affected by several modes of variability and climate phenomena across different time and spatial scales. An additional key component of the atmosphere dynamics that greatly influences weather is quasi-stationary Rossby waves, which attract particular interest as they are often associated with synoptic scale extreme events. In the Southern Hemisphere extratropical circulation, the most prominent quasi-stationary Rossby wave pattern is the zonal wavenumber 3 (ZW3), which has been shown to have impacts on meridional heat and momentum transport in mid to high-latitudes, and on Antarctic sea-ice extent. However, little is known about its impacts outside of polar regions. In this work, we use ERA5 reanalysis data on monthly timescales to explore the influence of phase and amplitude of ZW3 on temperature and precipitation across the Southern Hemisphere midlatitudes. Our results show significant impact in various regions for all seasons. The most substantial effect is observed in precipitation over South East Brazil during austral summer, where different phases of the ZW3 force opposite anomalies. When using ZW3 phase and amplitude as prior information in a Bayesian approach, the probability of occurrence of precipitation extremes in this region increases up to seven times. Additionally, we find that this ZW3 weather signature is independent of the zonally symmetric Southern Annular Mode (SAM); neither is it linked to an El Niño Southern Oscillation (ENSO) or Indian Ocean Dipole (IOD) signal.

Session 4A (Tuesday 6 Feb, 14:00-15:30), Talk 6

Mechanisms of Intertropical Convergence Zone (ITCZ) edge intensification: insight from idealised models

Martin S Singh[1], Julia M Windmiller[2]

[1]Monash University, Melbourne, Australia. [2]Max Planck Institute for Meteorology, Hamburg, Germany

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Recent observational campaigns have revealed that the Atlantic Intertropical Convergence Zone (ITCZ) is often characterised by two separate convergence lines, which produce enhanced precipitation at its northern and southern edges. The causes of this "edge-intensification" remain relatively unexplored in the literature, but a similar enhancement of precipitation is observed at the tropical "moist margin", defined by a contour of vertically-integrated column moisture (Masunaga & Mapes 2020), raising the possibility that edge-intensification is a general property of tropical precipitation belts.

Here, we use convection permitting simulations of an idealised overturning circulation to investigate the mechanisms producing edge-intensification in a mock-Walker cell framework. The simulations are performed in a non-rotating channel domain of length 10 thousand kilometres with an imposed sinusoidal SST pattern driving a large-scale overturning. We find that the extent of edge intensification is sensitive to the radiative cooling profile. The results are interpreted using a convective quasi-equilibrium framework, and the role played by surface fluxes and the vertical profile of large-scale ascent is elucidated.

Masunaga, H., & Mapes, B. E. (2020). A mechanism for the maintenance of sharp tropical margins. Journal of the Atmospheric Sciences, 77(4), 1181-1197.

Session 4B (Tuesday 6 Feb, 16:30-18:00), Talk 1

The link between tropical convection and anticyclonic Rossby wave breaking on the dynamical tropopause over Australia

Michael A Barnes[1,2], Michael Reeder[1,2], Christian Jakob[1,2]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Transient Rossby waves are exceptionally important to the weather and climate of Australia. When these wave break, they can be especially impactful. Extremes such as heavy rainfall over eastern Australia and heatwaves in south-eastern Australia have both been found to be associated with anticyclonic Rossby wave breaking during austral summer. These climate extremes have in turn been shown to have statistical links to increased tropical convection in northern Australia. Here we investigate the role that tropical convection plays in modulating transient Rossby waves propagating along the mid-latitude wave guide. We show that when in phase, the divergent outflow from tropical convection advects tropospheric PV air into extratropical wave trains, producing enhanced upper-level anticyclonic Rossby wave breaking along the dynamical tropopause in preferential zones around the continent. When divergent outflow from the tropics acts in combination with moist processes within the wave train, a more slowly propagating wave packet produces more frequent and persistent zones of anticyclonic Rossby wave breaking at multiple isentropic levels.

Session 4B (Tuesday 6 Feb, 16:30-18:00), Talk 2

The Role of the Boundary Layer and the Physical Processes during Heatwaves in Southeastern Australia

Qinuo Huang[1,2], Michael Reeder[1,2], Christian Jakob[1,2], Malcolm King[1], Chun-Hsu Su[3]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Heatwaves are responsible for more deaths in Australia than any other natural disaster. Although undoubtedly important to the dynamics of heatwaves, the role of the boundary layer has received relatively little attention. The role of the boundary layer and the associated physical processes during summertime heatwaves in Victoria (Australia) is investigated using (i) a 16-year (2003 – 2018) record of commercial aircraft observations centred on Melbourne Airport (37.7 °S, 144.8 °E), (ii) the European Centre for Medium-Range Weather Forecasts (ECMWF) 5th Reanalysis (ERA-5), and (iii) a single column version of the UK Met Office Unified Model. The observations show that the day-time boundary layer is deeper during heatwaves than at other times, whereas the heatwave boundary layer during the night and early morning is shallower and more stable. A strong northerly nocturnal jet forms slightly below the top of the inversion, transporting warmer air above the boundary layer overnight (with cold horizontal advection but hot total advection within the boundary layer). A deep mixed layer develops rapidly after sunrise, mixing downward high momentum air from the nocturnal jet. For heatwaves lasting 3 days, the nocturnal jet progressively strengthens each night. The relative importance of surface fluxes, short and longwave radiation and adiabatic compression is to the development and maintenance of heatwaves in the region is assessed with the single column model. Heatwaves end in the late afternoon or evening following the passage of a coastal cold front and the onset of post-frontal cold air advection.

Session 4B (Tuesday 6 Feb, 16:30-18:00), Talk 3

Solving the mystery of 80% relative humidity over the global oceans

Callum Shakespeare, Michael Roderick

ANU, Australia

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Observations and models show that near-surface relative humidity over the ocean is nearly constant at around 80% in the current climate, and furthermore, exhibits only very small changes in projected future climates. This behaviour is despite large variations in evaporation rates, temperature, and wind speeds over the global oceans, which one might expect to significantly influence the relative humidity. This remarkable invariance of relative humidity underpins the fundamental Clausius-Clapeyron scaling that near-surface water vapour content increases at 6.5%/K — and yet has never been fully explained. In this presentation I will show how the invariance of relative humidity can be attributed to the existence of a "universal geometry" for moist convection above the ocean surface. A simple moisture balance model which encapsulates this geometry is able accurately predict the climatology of relative humidity over the global oceans with less than 3% error. The model predicts that the relative humidity depends weakly on the near-surface wind speed and air-surface temperature difference, and more strongly on the large-scale moisture convergence. The model is further verified by comparison with a large suite of convection-resolving simulations over uniform surfaces with varying properties. Our results provide a theoretical basis for understanding changes in relative humidity, water vapour feedbacks and the water cycle in current and future climates.

Session 4B (Tuesday 6 Feb, 16:30-18:00), Talk 4

Moisture perturbations in the tropics and their connection to the extratropics

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[1]Monash University, Melbourne, Australia. [2]Bureau of Meteorology, Melbourne, Australia

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Moisture is a key ingredient for rainfall, especially in the tropics. A recent study shows that heavy convective rainfall over tropical oceans is largely confined to the moist side of a critical humidity contour, aptly termed the “moist margin”. Here, we extend this definition to consider anomalies of the moist margin, which evolve in response to the synoptic-scale flow. These wet and dry anomalies are tracked through time as objects, allowing us to investigate the processes that govern their formation and decay. Objects produced by this novel approach encompass a variety of dynamical features such as tropical lows and cyclones, tropical waves, atmospheric rivers, and dry intrusions.

We show that wet and dry perturbations are tightly linked to rainfall anomalies, particularly in the shoulder regions of the tropics. Composite analysis and case studies reveal that the extratropical influence is vital for some of the most impactful events. We therefore employ a similar methodology to characterise extratropical waves, and study how extratropical objects interact with the tropical objects. A key result is that extratropical Rossby waves cause strong poleward excursions of the moist margin, but only when they refract towards the tropics and are close enough to tropical moisture.

Session 4B (Tuesday 6 Feb, 16:30-18:00), Talk 5

The synoptic-dynamics of heavy rainfall events in the Southern Murray-Darling Basin

Tess Parker[1,2], Ailie Gallant[1,2]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

We have previously shown that days with rainfall above 20 mm are responsible for a median of approximately 60% of the reduction in rainfall during drought development periods, and approximately 70% of the rainfall surplus during drought recovery periods, over much of Australia.

Here we present the results of an examination of the large-scale atmospheric conditions on heavy rainfall days over the southern Murray-Darling Basin, a region of great importance for agriculture and the environment, using ERA5 reanalysis data. We also present a determination of the relative importance of several precursor conditions at a range of lead times using an ensemble sensitivity analysis on ECMWF-TIGGE short-range forecast ensembles. Together, these results investigate the synoptic-dynamics of heavy rainfall events in this region, and reveal the relative importance of large-scale atmospheric flow conditions at a range of spatio-temporal scales.

Further analysis investigates the differences in the characteristics of heavy rainfall events in this region during periods of drought development, and recovery from drought.

Session 4B (Tuesday 6 Feb, 16:30-18:00), Talk 6

CMIP6 evaluation on the dynamical evolution of the SH polar vortex anomalies

Ghyslaine Boschat[1], Eun-Pa Lim[1], Julia Mindlin[2], Philipp Breul[3], Amy Butler[4], Alexey Karpechko[5], Isla Simpson[6], Natalia Calvo[7], Ryan Williams[8,9]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

The springtime stratospheric polar vortex variability over Antarctica is an important source of predictability of the southern annular mode (SAM) and associated southern hemisphere (SH) regional climate in austral spring-summer seasons. The Antarctic spring vortex anomalies often result from the poleward and downward progression of the meridional dipole anomalies of the SH stratospheric polar night jet with wave-mean flow feedback. This dynamical process is conveniently captured by the anti-correlation of the zonal mean zonal wind anomalies at 60°S in the upper stratosphere between winter and spring. In this study, we evaluate the ability of CMIP6 models to simulate the dynamical connections from the winter polar night jet to the spring polar vortex to its downward coupling to the tropospheric SAM. We examine zonal winds from 41 models at all available pressure levels with the historical forcings and the future forcings following the Shared Socioeconomic Pathway 5-8.5.

Our results show that models tend to simulate the observed anti-correlation between the winter and spring westerlies at much higher latitudes of 10-20°, which is significantly linked to the models' biases in the mean position of the winter stratospheric jet. Furthermore, the relationship between the stratospheric polar vortex and the surface SAM tends to be overestimated compared to the observed in winter, whereas it is skilfully simulated in spring. The identified winter stratospheric jet-spring vortex biases appear to affect the models' future projections of the Antarctic stratospheric vortex with increasing greenhouse gases by the end of the 21st century.

5. Extreme wind gusts and associated present and future risks

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 1

Tornado intensity, size, and vertical wind speed dependence, radar-based climatologies, and near-tornado thermodynamics

Joshua Wurman, Karen Kosiba

Flexible Array of Radars and Mesonets, Department of Atmospheric Sciences, University of Illinois, Boulder, USA

Session

5. Extreme wind gusts and associated present and future risks

Abstract

Our knowledge of tornadogenesis, evolution, and structure has advanced substantially, but many questions/hypotheses remain observationally unconfirmed/untested. These include the size and intensity distribution of tornadoes, the variability wind speeds with height and time, the thermodynamic properties of the air immediately surrounding and being ingested into tornadoes, and how tornado intensity, propagation speed and structure, including variations in wind with height and time, affect human-impacting damage.

DOW observations demonstrate that supercell-spawned tornadoes have a characteristic intensity, with peak ground-relative wind speeds above 60 m/s, and a characteristic diameter, near 300 m. These are in stark contrast to damage-based tornado intensity and size statistics. Damage-based intensity estimates were shown to be an average of 2 EF categories low compared to DOW-determined intensities, with extreme cases 4 EF categories different. DOW climatological analysis is being extended to incorporate many more tornadoes, to generalize these results, reduce statistical error, and permit additional tornado metrics to be quantified. DOW observations also reveal that, in contrast to other windstorms, the most intense winds in tornadoes occur very near the surface, perhaps below 10 m AGL.

Preliminary observations suggest that there is a distinct and localized change in the near-field thermodynamics during tornado evolution over short time and spatial scales, which suggest changes in storm processes.

Plans for the 2024 BEST (Boundary-layer Evolution and Structure of Tornadoes) project, focusing on the thermodynamic and kinematic structure of tornadoes <50-100 m AGL, using proximate DOW radars, PODNet, and Driftersondes will be presented.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 2

Evaluation of large-scale diagnostics for the severe convective wind gust events in New South Wales.

Greeshma Surendran[1,2], Steven C Sherwood[1,2], Jason P Evans[1,2], Moutassem El Rafei[1]

[1]University of New South Wales, Sydney, Australia. [2]ARC Centre of Excellence for Climate Extremes, Australia

Session

5. Extreme wind gusts and associated present and future risks

Abstract

Wind gusts are one of the extreme weather events that are known to cause damage to infrastructure, and they can be dangerous to aircraft, rapidly intensify bushfires, and even cause breathing difficulties. Severe convective wind gusts are bursts of wind speed >= 25 m/s and are formed when the downdraft from a thunderstorm sinks with high momentum to the ground level and diverges. Previous studies have examined the climatology and characteristics of severe convective wind gusts in Australia based on anemometer records and atmospheric reanalysis. These studies have calculated established diagnostics used for forecasting severe thunderstorms and statistically analyzed their ability to indicate observed severe convective winds. However, the sufficiency of these diagnostics is unknown. In this talk, we outline an approach employing a case study of six damaging wind gust events in NSW. Six selected events are analyzed using radar, satellite data, and various reanalysis flow fields including BARRA-SY to understand the weather associated with these events, to investigate and better understand the success or failure of the previously established large-scale diagnostics.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 3

Fine-Scale Tropical Cyclone Boundary Layer Structure

Karen A Kosiba, Joshua Wurman

University of Illinois, Boulder, USA

Session

5. Extreme wind gusts and associated present and future risks

Abstract

The tropical cyclone boundary layer (TCBL) is comprised of coherent structures likely responsible for significant transport of turbulent fluxes throughout the TCBL as well as regions of enhanced damage at the surface. DOW-observed TCBL structures include Tornado Scale Vortices, boundary layer rolls/streaks, and eyewall mesovortices. Results from several tropical cyclones will be discussed in the context of standard tropical cyclone wind models and the relationship between radar winds and derived quantities to anemometry.

DOWs collected data in Category 4 Laura in southwestern Louisiana, including fine-scale, near-surface data in the eyewall. Multiple sets of dual-Doppler analyses were conducted in order to optimize the retrievals of 2D/3D structures. Comparisons between the strength and size of the structures in the eyewall vs. rainbands will be presented.

DOWs and an array of surface based instruments, including a prototype, “POLENET”, which attaches existing infrastructure, allowing for a customizable observation level, were deployed in order to correlate observations at radar level with surface observations. Using corrections based on turbulence statistics and roughness lengths, a reduction factor was derived for the radar winds, allowing for comparison between radar level winds and winds observed at 1, 2, and 10 m. Turbulence characteristics, periodicity, and gust factors will be compared to radar-derivations of similar quantities.

A new field project, WASHABLE (Winds And Structures in Hurricane Associated Boundary Layers Experiment), is planned for 2024-2025. WASHABLE will deploy DOWs and other instrumentation to expand our understanding of TCBLs, including gust damage relationships and turbulent processes.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 4

Extreme wind events in Tasmania in 2021 and 2023

John D Holmes[1], Stephen E Oliver[2]

[1]JDH Consulting, Mentone, VIC, Australia. [2]Weather Solutions, Beaumaris, VIC, Australia

Session

5. Extreme wind gusts and associated present and future risks

Abstract

This paper will discuss two high wind events that affected southern Tasmania on 23/9/2021 and 31/7/2023. The maximum recorded 3-second gusts were 48 m/s and 56 m/s at Mount Wellington and Maatsuyker Island respectively. However, orographic and topographic effects amplified the measured values in both cases. In the paper, corrections will be made for these effects, and equivalent values for the standard conditions of flat, open country given; estimates will also be given for the average recurrence intervals (in years) for the corrected gusts.

The time histories of mean and gust wind speeds at Maatuykeer Island on 31/7/23 showed non-stationary features, with two high peak periods separated by about 12 hours with much lower wind speeds in the intervening period (see image below). The maximum values will be discussed in terms of the gradient wind speed, calculated from the gradient of barometric pressure, and other meteorological parameters. One-minute anemometer data will also be used to clarify the detailed wind readings in the vicinity of the peaks.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 5

What mechanisms contribute to the intensity of severe wind gusts in thunderstorm outflows?

Moutassem El Rafei[1], Steven Sherwood[1,2], Jason P Evans[1,2], Andrew Dowdy[3], Fei Ji[4]

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Session

5. Extreme wind gusts and associated present and future risks

Abstract

Convective downdrafts are a crucial part of convective systems and can cause local damage by generating severe surface gusts. These gusts can lead to substantial socioeconomic impacts, and the mechanisms behind their generation remain less understood. In this context, we study the mechanisms governing downdraft intensities and resulting strong surface winds using three-dimensional simulations of realistic severe gust events associated with Australian thunderstorm outflows. These simulations used the Weather Research and Forecasting (WRF) model with horizontal grid resolutions of 5 km, 1 km, and 200 m.

We show by quantifying the vertical momentum equation budgets that severe gusts can be associated with strong downdrafts that are considerably subsaturated, and where environmental dry air is entrained into their core at low altitudes. Our analysis indicates that the perturbation pressure vertical gradient and thermal buoyancy are the main contributors to the downdraft acceleration, while condensate loading plays a less significant role at mid and low levels.

Additionally, we analyse the variabilities of storm properties at various grid resolutions, including the draft strengths, hydrometeor contributions, and surface winds. Our analysis suggests that lower resolutions tend to underestimate the draft intensities and the corresponding straight-line winds, while noting a weak impact on hydrometeor contribution when moving from 1 km to 200 m resolution. Furthermore, coarser resolutions fail to capture the smaller turbulent structures that may impact the perturbation pressure-driven acceleration. This can result in a relatively minor contribution of the pressure perturbation gradient at coarse resolutions compared to thermal buoyancy and condensate loading.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 6 | Poster Session 2, Poster 07

Estimating convective wind gust distributions from the tail distribution

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Session

5. Extreme wind gusts and associated present and future risks

Abstract

Convective wind gusts can cause significant damage to infrastructure including buildings, transmission lines and both wind and solar farms. Infrastructure design and building codes are informed by the wind climatology, of which 50% of all wind-related building damage in Australia is associated with convective wind gusts. To better understand future straight-line convective wind gust risk, an accurate estimation of the current convective wind gust distribution is necessary. A significant problem is posed when there is insufficient data to estimate the complete convective wind gust distribution. In this work, we present a new approach of estimating the complete convective wind gust distribution using only the right-tail (severe wind gusts >= 90 km/hr) of the distribution. The resulting convective wind gust distribution can then be associated with atmospheric parameters indicative of convective thunderstorms, from which the future convective wind gust distribution may be determined.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 7 | Poster Session 2, Poster 05

Separation of daily maximum wind gust events for wind hazard assessment

Liang Hu, Craig Arthur, Nicole Allen

Geoscience Australia

Session

5. Extreme wind gusts and associated present and future risks

Abstract

An automatic algorithm for classifying wind gust events has been developed at Geoscience Australia, utilizing 1-minute weather observations from Automatic Weather Stations (AWS). This algorithm employs a comprehensive dataset of wind, temperature, dew point, and pressure measurements within a two-hour timeframe centred on the peak wind gust.

The classification methodology effectively segregates wind gust events into convective and non-convective categories. Initial development entails a subset of stations, employing visual classification verified by contemporaneous observer reports and weather radar data, to create a robust training dataset. The algorithm, based on the analysis of almost 1000 visually-classified events, demonstrates the capability to classify over 150,000 events in a matter of minutes.

Utilizing wind gust events from past 20 years via our algorithm, the spatial distribution, diurnal cycle and seasonal variation are investigated across Australia. Moreover, a comparative analysis of spatial and temporal disparities, along with radar characteristics, has been conducted for convective and non-convective gust events. Finally, the extreme values of wind gust events, including the 1% annual exceedance probability wind speed (using the Generalized Pareto Distribution) across Australia is shown in this presentation.

Session 5 (Wednesday 7 Feb, 16:30-18:00), Talk 8 | Poster Session 2, Poster 06

Trends in the tracking and power of tropical cyclones in the Coral Sea, over the last 50 years.

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Session

5. Extreme wind gusts and associated present and future risks

Abstract

Tropical cyclones (TCs) originating in the Coral Sea present significant hazards to coastal regions in their surroundings. This research was divided into two parts: 1) The first part investigated TC tracking trends in the Coral Sea. To do so, Coral Sea TC tracks over the last fifty years were grouped based on clustering of the wind-weighted centroids. Track variance and curvature were assessed. Three clusters of tracks were identified, each indicating a predominant direction of tracking. Track curvature was shown to increase from east to west. Only one cluster showed a statistically significant trend (decreasing) in frequency. Two of the clusters had diverging trends for power dissipation post-2004. For location of cyclone maximum intensity (LMI), only one cluster showed a statistically significant trend (equator-wards). 2) The second part investigated the correlation of the power dissipation index (PDI) of these TC tracks with climatological indices, using historical records. Results of the multi-linear regression model for all tracks showed three dominating indices for PDI: Niño 4 Sea Surface Temperature, the Dipole Mode Index and the Madden Julian Oscillation (MJO). For cluster 1 (south-east), the additional influence of the Southern Annular Mode (SAM) was apparent, whilst for cluster 2 (north-west), the same indices dominated as for the all-tracks model. For LMI, four indices were identified: the Indian Ocean East SST Anomaly, the MJO, the Southern Oscillation Index and the SAM. Overall, raised Niño 4 SST combined with a negative DMI and low MJO amplitude were shown to predict large increases in TC power.

6. Severe thunderstorms: processes, prediction, impacts, and changes

Session 6 (Thursday 8 Feb, 14:00-15:30), Talk 1

The Upgraded Lightning Prediction System of the Bureau

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Bureau of Meteorology, Melbourne, Australia

Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Lightning potential is information that is flowing into many of the Bureau of Meteorology's operational services and products such as Convective Outlooks or various public weather forecasts. For about twenty years the Bureau has operationally produced some form of lightning guidance of steadily improving quality. The latest upgrade of the current system, Calibrated Thunder, is characterised by a new form of local calibration scheme that takes into account the need to have a sufficient number of samples to calibrate over to achieve a robust production of calibrated thunder probabilities over all of Australia. It also extends over a calibration time period three times as long as its predecessor scheme. This new system was released into production in July 2023.

The presentation will introduce the changes applied to the upgraded lightning prediction guidance, present some examples of its application sourced from an operational environment, and showcase verification results that compare the system's performance relative to a sophisticated lightning climatology and to its predecessor scheme.

Session 6 (Thursday 8 Feb, 14:00-15:30), Talk 2

An hourly climatology of thunderstorms and associated environments in Australia

Rob Warren[1], Harald Richter[1], Ivor Blockley[1], Dean Sgarbossa[1], Todd Baker[2], Philip Perkins[3]

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Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Thunderstorms are associated with a range of hazards including lightning, large hail, destructive wind gusts, heavy rainfall that can lead to flash flooding, and tornadoes. Previous regional studies have used ground-based and spaceborne sensors to quantify thunder-day frequency and lightning flash density across Australia on annual and seasonal time scales. However, to date, no study has systematically analysed the distribution of thunderstorms on sub-daily timescales. Here, we use observations from the Weatherzone Total Lightning Network over an 8-year period (2015–2022) to quantify hourly thunderstorm frequency across Australia. A cluster analysis is employed to regionalise the continent based on the seasonal and diurnal cycles of lightning. We then use convective parameters, derived from a regional reanalysis (BARRA2), to characterise the environments of thunderstorms and their variability within and between regions. This analysis will inform future advances in thunderstorm forecasting; in particular, the development of a new machine learning–based probabilistic lightning prediction system.

Session 6 (Thursday 8 Feb, 14:00-15:30), Talk 3

Improving early warnings of epidemic thunderstorm asthma

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Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Thunderstorm asthma is a phenomenon in which high concentrations of pollen or other airborne allergens can interact with weather conditions to increase the incidence of asthma, sometimes to extreme levels. The major epidemic thunderstorm asthma (ETSA) event in November 2016 led to the creation of a new early warning system for ETSA risk developed by the Victorian Department of Health, the Bureau of Meteorology, the University of Melbourne and other university partners.

The mechanisms of thunderstorm asthma are not well understood. Ryegrass pollen was found to be the main allergen in the 2016 event, but the processes that cause pollen grains to rupture into tiny allergenic particles are uncertain. Convergence lines (such as occur in thunderstorm outflows) are a necessary precursor for ETSA in the Melbourne region during spring. The simple forecasting approach for ETSA risk combines forecasts of grass pollen concentration and the likelihood of severe thunderstorms with damaging winds.

Since the 2016 event progress has been made in several areas. Automated pollen monitoring has become more accurate and affordable, including sub-daily measurement to identify peaks of pollen concentrations. Machine learning has improved the automated forecasting of grass pollen concentration, continuously updating using the latest measurements. Including lower atmospheric moisture in the risk matrix improves the forecasts of ETSA events. A new near real-time syndromic surveillance system uses natural language processing to rapidly detect enhanced asthma in hospital triage reports and automatically alert the Department of Health's State Duty Officer to the possible occurrence of thunderstorm asthma.

Session 6 (Thursday 8 Feb, 14:00-15:30), Talk 4

Drivers of Perth's only recorded catastrophic hail event – The great hailstorm of March 2010

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Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

On the 22nd of March 2010, the city of Perth in Western Australia was impacted by a severe hailstorm. Hailstones up to 6cm in diameter—the largest ever recorded in the city—fell along a swath extending from the northern coastal suburbs to south Perth, resulting in major damage to cars and buildings. To date, the event remains WA's most costly natural disaster, with over AU$1.3 billion in insured losses (normalised to 2017 dollars). In this study, we use a combination of surface station data, radar observations, and convection-permitting simulations to better understand the meteorology of the event. A preliminary analysis of radar data indicates a severe multicell mode, where thunderstorms intensified as they propagated south along the coastal fringe towards Perth. Surface station observations suggest that the storm inflow was at least partly sourced from a modified sea-breeze airmass. Simulations using the Weather Research and Forecasting (WRF) model capture the event but are sensitive to model initialization time. Our results will highlight challenges and opportunities in improving the forecasting of such rare hail events, in a region that is not often prone to very severe hail.

Session 6 (Thursday 8 Feb, 14:00-15:30), Talk 5

Radar and environment-based hail damage estimates using machine learning

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Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Large hail events are typically infrequent, with significant time gaps between occurrences at specific locations. However, when these events do happen, they can cause rapid and substantial economic losses within a matter of minutes. It is crucial to accurately observe and understand hail phenomena to improve the mitigation of this impact. Weather radars provide a larger observation footprint, but current radar-derived hail size estimates exhibit low accuracy due to horizontal advection of hailstones as they fall, the variability of hail size distributions (HSD), complex scattering and attenuation, and mixed hydrometeor types. In this paper, we propose a new radar-derived hail product that is developed using a large dataset of hail damage insurance claims and radar observations. We use these datasets coupled with environmental information to calculate a Hail Damage Estimate (HDE) using a deep neural network approach aiming to quantify hail impact, with a critical success index of 0.88 and a coefficient of determination against observed damage of 0.78. Furthermore, we compared HDE to a popular hail size product (MESH), allowing us to identify meteorological conditions that are associated with biases on MESH. Environments with relatively low specific humidity, high CAPE and CIN, low wind speeds aloft and southerly winds at ground are associated with a negative MESH bias, potentially due to differences in HSD or mixed hydrometeors. In contrast, environments with low CAPE, high CIN, and relatively high specific humidity aloft are associated with a positive MESH bias.

Session 6 (Thursday 8 Feb, 14:00-15:30), Talk 6

Intensification of subhourly heavy rainfall

Hooman Ayat

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Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Short-duration rainfall extremes can cause flash flooding with associated impacts. Previous studies of climate impacts on extreme precipitation have focused mainly on daily rain totals. Subdaily extremes are often generated in small areas that can be missed by gauge networks or satellites and are not resolved by climate models. Here, we show a robust positive trend of at least 20% per decade in subhourly extreme rainfall near Sydney, Australia, over 20 years, despite no evidence of trends at hourly or daily scales. This trend is seen consistently in storms tracked using multiple independent ground radars, is consistent with rain-gauge data, and does not appear to be associated with known natural variations. This finding suggests that subhourly rainfall extremes may be increasing substantially faster than those on more widely reported time scales.

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 1

Insights into Southern Ocean cloud biases from a cloud-controlling factor (CCF) framework

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Numerous studies have shown than Global Climate Models (GCMs) underpredict cloudiness over the Southern Ocean (SO). Here, we validate SO cloud albedo (C) from CMIP6 outputs for the period 2000–2014 using standard and novel approaches. First, we quantify the model-observation C difference in the 50°–65° band. Next, we evaluate the way in which C changes with three key cloud controls [namely: sea surface temperature (SST), mid-level vertical velocity and surface wind], and how the frequencies of these vary, for both model and observations. We subsequently quantify the bias of C relative to each CCF with a simple metric, the “CCCF bias”. Contrary to expectations, the multimodel-mean of the Historical (full-coupled) experiment has a smaller C bias than that from the AMIP (atmospheric-only with prescribed SSTs). We find that this is due to error compensation, as a significant warm SST bias in the Historical runs is counteracted by a higher cloud sensitivity to SST, producing a greater amount of cloud albedo, more in line with observations. In other words, despite the smaller C bias in Historical, its CSST bias is greater when compared to AMIP. Furthermore, sorting out cloudiness by vertical velocity yields a significant model underestimation of low-clouds under subsidence conditions, an effect partly counteracted by higher cloud sensitivity in moderate-to-strong updrafts. We simultaneously apply our methodology to the North Pacific and Atlantic Oceans, and following on from a previous observational study, we evaluate the ability of CMIP6 in reproducing the hemispheric asymmetry of cloud albedo.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 2

Spurious Trends in Southern Hemisphere High Latitude Precipitation

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Physical climate processes at high-latitudes are highly sensitive to a changing climate, yet are poorly observed and understood relative to other regions of the globe. The Southern Ocean (SO) includes 10-15% of the world's oceans and many important processes in the climate system such as the storage and distribution of ocean heat content, Antarctic sea-ice processes and Antarctic bottom water development. Understanding precipitation over this vast region is imperative for closing global energy and hydrological budgets, but global climate models have trouble simulating radiation fluxes and clouds over the Southern Ocean. The lack of land and perilous conditions have meant that there are limited in situ rainfall observations of the SO. This makes understanding current and future global precipitation changes challenging. In this study, we have analysed a ranged of common satellite and reanalysis precipitation products over the high-latitude Southern Hemisphere and compared the observed trends to changes in the SAM (the leading mode of variability in this region). We observe strong positive precipitation trends that are incongruent with changes in the SAM and argue that these trends correspond with satellite sensor changes. Understanding whether such trends are real or measurement artefacts is important for climate model evaluation and understanding historic and future global precipitation changes.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 3

On the relationship between mesoscale cellular convection and meteorological forcing: Comparing the Southern Ocean against the North Pacific

Francisco Lang[1], Steven T Siems[2,3], Yi Huang[4,5], Tahereh Alinejadtabrizi[2,3,5], Luis Ackermann[6]

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Marine atmospheric boundary layer (MABL) clouds cover vast areas over the ocean and have important radiative effects on the Earth's climate system. These radiative effects are known to be sensitive to the local organization, or structure, of the mesoscale cellular convection (MCC). A convolution neural network model is used to identify the two ideal classes of MCC clouds, namely open and closed, over the Southern Ocean (SO) and Northwest Pacific (NP) from high-frequency geostationary Himawari-8 satellite observations. The results of the climatology show that MCC clouds are roughly distributed over the midlatitude storm tracks for both hemispheres, with peaks poleward of the 40◦ latitude. Open MCC clouds are more prevalent than closed MCC in both regions. An examination of meteorological forcing associated with open and closed MCC clouds is conducted to illustrate the influence of large-scale meteorological conditions. We establish the importance of the Kuroshio western boundary current in the spatial coverage of open and closed MCC across the NP, presumably through the supply of strong heat and moisture fluxes during marine cold air outbreaks events. In regions where the Estimated Inversion Strength (EIS), a key indicator of static stability, is higher, we observe a more frequent occurrence of closed MCCs. This behaviour contrasts markedly with that of open MCCs, whose formation and persistence are significantly influenced by the difference in temperature between the air and the sea surface.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 4

Precipitation over the Southern Ocean: New Insights from Ship-based Disdrometer and Dual-polarization Radar Observations

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Precipitation is a major component of the hydrologic cycle and plays a significant role in the sea ice mass balance in the polar regions. Over the Southern Ocean, large differences continue to exist among current precipitation products. This uncertainty arises from the absence of long-term, high-quality surface observational records of precipitation suitable for evaluation across a range of temporal and spatial scales. The recent deployments of the Ocean Rainfall And Ice-phase precipitation measurement Network (OceanRAIN) and the first-ever C-band, dual-polarimetric radar (OceanPOL) aboard the RV Investigator offer new opportunities in investigating the precipitation characteristics and processes over the region and how these features are being represented in model simulations, which have only been made possible before using satellite retrievals. Using multiple cruises of the RV Investigator, this study examines the macro- and micro-physical characteristics of precipitation over the Southern Ocean under various meteorological conditions using the OceanRAIN observations in conjunction with the rainfall retrieval and dual polarimetric measurements of the OceanPOL. The OceanRAIN information is also used to improve the rainfall retrieval algorithm currently employed in the OceanPOL dataset, which was originally developed based on the tropical ocean environment. Several analytical forms of particle size distribution commonly used in satellite retrieval algorithms are also evaluated. This research is leading toward more accurate, high-resolution precipitation estimates that are important in advancing the understanding of a range of climatological and meteorological processes as well as in evaluations of weather and climate models.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 5

Cloud and precipitation over the Southern Ocean and Antarctica in a high-resolution regional model

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Global climate models and reanalysis products have revealed large downwelling shortwave radiation biases over the Southern Ocean and coastal Antarctica. The biases are hypothesized to be caused by the incapability of models to accurately simulate the frequent occurrence of low-level mixed-phase clouds that contain both ice and supercooled liquid water in these regions. It's crucial to understand cloud representation in climate models over the Southern Ocean and Antarctica in order to better simulate the climate system. In this study, we use observations collected at Davis, Antarctica from the Precipitation over Land and The Southern Ocean (PLATO) field campaign in the austral summer of 2019 to assess the capability of the high-resolution regional Unified Model (UM) in reproducing precipitating clouds off Antarctica. We focus on an intense snowfall sublimation and precipitation event from 20 to 24 January 2019. The control run of the UM implements the Cloud AeroSol Interacting Microphysics (CASIM) scheme and bimodal cloud fraction scheme, running at the spatial resolution of 1.5-km and 0.1-km and at the temporal resolution of 10-min. Our results demonstrate that the high-resolution UM model can broadly capture the location, timing, and magnitude of strong vertical wind velocity during the sublimation period, with 0.1-km resolution better representing the magnitude of vertical velocity. Moreover, the model can capture the location, timing, and vertical structure of the clouds during the sublimation and precipitation periods.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 6

The Seasonality of Clouds and Aerosols over the low latitudes of the Southern Ocean as observed at the Kennaook/Cape Grim Baseline Air Pollution Station

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

For over 40 years, the Kennaook/Cape Grim Observatory (CGO) has been observing the atmospheric chemistry over the remote Southern Ocean. One of CGO's most enduring observations is that of the seasonal cycle in cloud condensation nuclei (CCN) during baseline conditions, which shows a peak CCN concentration during the summer season when biogenic activity is greatest and a minimum during the winter season.

In this study we examine the seasonality of the meteorology over the 'Roaring 40s' and how this affects the cloud cover and CCN concentration observed at CGO, even during baseline conditions. Using a simple k-means clustering, a synoptic typing is undertaken to demonstrate a strong correlation between the synoptic meteorology and the location (latitude) of the sub-tropical ridge, even for baseline conditions. In short, we observe a different synoptic meteorology for baseline conditions between summer and winter, primarily defined by the lower free troposphere, above the marine boundary layer. During the summer, when the subtropical ridge is furthest poleward, air masses from the lower latitudes (the continent) are found to be more prevalent in the lower free troposphere, having an impact on the baseline CCN concentration and radon concentration through entrainment into the marine atmospheric boundary layer.

Previous studies using satellite observations have noted a strong seasonal cycle in cloud cover across these latitudes, particularly for open and closed mesoscale circulation. We extend the analysis to examine the thermodynamics structure of these different synoptic classes and how they affect the marine boundary layer clouds and precipitation.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 7

Evaluation of the ORAC algorithm for geostationary liquid water cloud retrievals over the Southern Ocean

Andrew T Prata[1], Litai Kang[2], Steven T Siems[1], Roger Marchand[2], Daniel J V Robbins[1], Caroline A Poulsen[3], Michael J Manton[1], Roy G Grainger[4]

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Clouds and precipitation processes represent key uncertainties in climate models. Of particular interest is the bias in top-of-the-atmosphere radiation over the Southern Ocean (SO). This bias may be due to difficulties in parameterising cloud microphysical and precipitation processes in climate models. As liquid water clouds are prevalent across the SO, accurate estimation of their microphysical properties should lead to improved parameterisation schemes in climate models.

Geostationary satellite remote sensing provides a means to study cloud microphysical processes on a global scale, over remote regions (such as the SO) and at high temporal resolution (1-10 minutes). The Optimal Retrieval of Cloud and Aerosol (ORAC) algorithm was developed as an open-source code to retrieve cloud and aerosol properties from passive imager measurements with a rigorous treatment of uncertainty and a priori information. While ORAC has been verified previously, it has not been evaluated for the retrieval of effective radius and optical depth from geostationary measurements over the SO.

Here we present results from an evaluation of the ORAC algorithm against SOCRATES field campaign data from January-February 2018 for effective radius and optical depth. Our study builds directly upon previous evaluation work where 51 validation match-up points from aircraft measurements deemed suitable for comparison against Advanced Himawari Imager (AHI) retrievals. We also show how ORAC compares with other cloud retrieval algorithms applied to AHI. Finally, we explore reasons for biases due to the presence of precipitation, a cloud fraction of 1 and the assumed shape of the cloud droplet size distribution.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 8 | Poster Session 2, Poster 10

Evaluation of AMIP and Historical CMIP6 simulations of precipitation over the Southern Ocean

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

The Southern Ocean (SO) and its atmospheric coupling have a fundamental role in the regulation of the Earth's climate system. Several studies have found significant model biases in sea surface temperatures, albedo and cloud phase, and hypothesised their physical causes and impacts; yet the evaluation of simulated rainfall over the SO remains largely unexplored. Here, we assess the performance of CMIP6 models in reproducing mean and extremes of daily precipitation for this region during a 15-year period, with a special emphasis on physical processes.

Due to the historic scarcity of direct observations in this vast area, we rely on a series of satellite-based and reanalysis products, over which substantial uncertainty has been documented. For this reason, model bias is not referred to in absolute sense, but analysed in terms of observational bounds.

Biases are computed for conventional indices including annual total precipitation, daily intensity, wettest day of the year, duration of dry spells, and percentiles of extreme precipitation. Additional bias metrics are applied to distributions of frequency density, and amount contribution to rainfall.

Finally, process-oriented scores assess the ability of the models to properly simulate SO precipitation according to various ranges of vertical velocity, moisture convergence, and temperature at daily timescales; such scores are computed by separating precipitation sensitivity to these variables from their frequencies of occurrence. With the process-oriented scores we can identify cases in which models perform poorly, but due to compensating errors from the two components, precipitation biases are masked in the standard metrics.

Session 7A (Friday 9 Feb, 11:00-13:00), Talk 9 | Poster Session 2, Poster 11

Untangling the influence of Antarctic and Southern Ocean life on clouds

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Polar environments are among the fastest changing regions on the planet. Now is a crucial time to make significant improvements in our understanding of how ocean and ice biogeochemical processes are linked with the atmosphere. This is especially true over Antarctica and the Southern Ocean where observations are severely limited, and the environment is far from anthropogenic influences.

We have identified at least 22 large-scale measurement campaigns planned across Antarctica and the Southern Ocean in the next five years that will investigate interactions between biogeochemistry, aerosol, clouds, precipitation, and radiation. This will include both in-situ and remote sensing observations on a range of platforms including land stations, ships, and aircraft. The campaigns will be complimented by remotely operated platforms such as gliders, floats, and moorings.

These campaigns present an opportunity for interdisciplinary and international collaboration. To do this, we have established the Partnerships for Investigations of Clouds and the biogeoChemistry of the Atmosphere in Antarctica and the Southern Ocean (PICCAASO), an initiative to improve coordination and collaboration of upcoming campaigns. The goal of PICCAASO is to augment and amplify the scientific discoveries from each independent project.

Until we coordinate at a hemispheric scale to understand the processes linking biology to clouds, climate models will likely continue to exhibit biases in the simulated energy balance over this delicate region. Addressing these issues will require an international and interdisciplinary approach which we hope to foster and facilitate with the establishment of PICCAASO.

Session 7B (Friday 9 Feb, 14:00-15:30), Talk 1

On the relationship between atmospheric rivers and precipitation over the Southern Ocean as observed at Macquarie Island

Abhishek Kumar, Steven Thomas Siems, Andrew Prata

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Large uncertainties exist in nature of precipitation (i.e., amount, intensity, frequency and thermodynamic phase) over the remote Southern Ocean (SO) with significant differences existing between various reanalysis products and satellite products. This uncertainty is a direct consequence of the lack of high-quality surface observations across a range of spatial and temporal scales. Macquarie Island (MAC), located within the SO storm track (54.5° S, 158.9° E) offers arguably the single best record of precipitation record with daily rainfall records dating back to 1948.

Wang et al. (2015) examined the seasonal cycle in the monthly precipitation at the MAC station site, noting a single peak in March (100.7 mm*) and April (95.3 mm*) while being relatively constant for over half the year (Jun – Dec) with minimums in Nov (73.9 mm*) and July (75.4 mm*). This seasonality in precipitation is largely uncorrelated with well-established seasonal cycles in incoming SW radiation, sea surface temperature, sea ice, CCN concentration and the latitude of the SO storm track. More recently Reid et al. (2022) developed a climatology of atmospheric rivers over the Australian region, noting a similar peak in Autumn (March April May) over the Southern Ocean.

In this research we examine the correlation between these atmospheric rivers and the precipitation observed at Macquarie Island across a range of time scales. We go on to examine how atmospheric rivers are converted into precipitation through a case study.

*Bureau of Meteorology (http://www.bom.gov.au/climate/data/)

Session 7B (Friday 9 Feb, 14:00-15:30), Talk 2

Understanding Stratocumulus and Cumulus transition over the Southern Ocean: A case study using field observations and cloud-resolving model simulations

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Low-level clouds (cumulus and stratocumulus) are common over the remote Southern Ocean (SO) and play an important role in the radiation budget, enhancing the albedo and trapping outgoing longwave radiation. The macrophysics and microphysics of these clouds can be difficult to characterise due to the limited skill of satellite retrievals in the marine boundary layer and the common presence of multilayer clouds. These low-level clouds, which are commonly present in post-frontal conditions and the cold sector of extratropical cyclones, are the leading contributors to the large uncertainty in climate sensitivity in models.

Building off of field observations from the SOCRATES and CAPRICORN field campaigns, we use cloud-resolving model simulations to conduct a case study, where a large field of post-frontal open mesoscale cellular convection (MCC, cumulus) and closed MCC (stratocumulus), including their transition, are examined. Physical and dynamical processes in shaping the morphology of these clouds are investigated. The control simulation realistically captures the evolution of this event, including the macrophysics of these clouds and their thermodynamic profiles. Both observations and simulations suggest the presence of mixed phase with evidence of ice-multiplication (likely the Hallett-Mossop process), particularly in the open MCC. Sensitivity experiments are further conducted to investigate the role of sea surface temperature gradients, cloud ice production, and heat fluxes in driving the open-to-closed transition. Initial findings from the observations and numerical experiments will be presented. The implication of this study to improve the understanding of the SO cloud bias in climate models will also be discussed.

Session 7B (Friday 9 Feb, 14:00-15:30), Talk 3

Hierarchical cluster analysis of aerosol measurements from the CAMMPCAN voyages

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Aerosols play a significant role in the Earth's climate, and their interactions with clouds have been identified as a major source of uncertainty in the global energy budget. To further research this area and as part of the *Chemical and Mesoscale Mechanisms of Polar Cell Aerosol Nucleation* (CAMMPCAN) project, a suite of aerosol measurements were collected using the mobile air chemistry lab called AIRBOX onboard the icebreaker *Aurora Australis* on resupply voyages in 2018 and 2019. Hierarchical cluster analysis was applied to aerosol measurements to gain insights into the spatial patterns of aerosol properties and their potential sources. Derived clusters were combined with HYSPLIT modelled back trajectories to examine potential source regions of the measured aerosols. Additionally, external datasets were attached to the HYSPLIT back trajectories to provide further contextual information and aid in identifying potential sources, including the ERA5 Reanalysis, EASE Sea Ice dataset, and MODIS satellite products. The cluster analysis found distinct clusters that originated from different source regions, including the Southern Ocean, coastal Antarctica, and continental Antarctica. One identified cluster sourced from continental Antarctica exhibited a monomodal Aitken mode aerosol distribution, suggesting that these particles are likely unprocessed and newly formed. Another Antarctic cluster displayed a bimodal distribution but was also dominated by Aitken mode particles, suggesting that these aerosols may have undergone some degree of cloud processing or coagulation.

Session 7B (Friday 9 Feb, 14:00-15:30), Talk 4

Surface radiation biases in CERES over the Southern Ocean

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Global climate model results provide vital insight into the changing climate and are typically evaluated using the broad coverage of satellite data. CMIP6 models have demonstrated persistent biases in the radiation budget when measured against the Energy Balanced and Filled (EBAF) CERES satellite product, especially in surface absorbed shortwave radiation over the Southern Ocean. Comparison against other regional models, examination of feedback mechanisms, and investigation into the role Southern Ocean clouds play in controlling Antarctic sea ice in CMIP6 models are all ongoing. However, possible biases in the CERES-EBAF product itself have received little attention. Using CMIP6 biases across an established 'historical' run (2003-11-03 to 2013-11-30) as a basis, we evaluated the performance of the CERES Synoptic Radiative Fluxes and Clouds (SYN1deg) product using ship-based radiometer data across the same ten-year period. CERES-SYN1deg is a direct precursor to CERES-EBAF, and comparison of these products has shown minimal difference in the average surface radiation of each across the Southern Ocean. Compared with ship-based surface observations, we found non-negligible positive biases in CERES-SYN1deg shortwave radiation at the surface at high latitudes of the Southern Ocean. This potentially has implications for the magnitude of radiation biases in CMIP6.

Session 7B (Friday 9 Feb, 14:00-15:30), Talk 5

Validation and comparison of cloud properties retrieved from passive satellites over the Southern Ocean

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Cloud properties over the Southern Ocean (SO), both macro- and micro-physical properties (e.g., fractional cloud cover, cloud top height, thermodynamic phase, effective radius and optical depth), are known to be different from their counterparts over the North Pacific and Atlantic. In particular, SO clouds have been found to more commonly be composed of supercooled liquid water at cloud-top. Previous research has also found that mid- and low-level multi-layer clouds are present in more than half of the scenes over the SO high latitude regions (poleward of the ocean polar front), which is higher than their Arctic counterparts. Studies have found that ignoring the multi-layer structure of clouds can lead to errors in the retrieval of observations such as cloud top pressure, optical depth, and fraction, which results in bias in radiation impacts.

In this study, cloud properties retrieved from passive remote sensing satellites are validated against properties retrieved from active satellite products (i.e., merged CloudSAT-CALIOP) over the SO. Specifically, three different passive satellite products [MODerate Resolution Imaging Spectroradiometer (MODIS) Collection 6, Advanced Very-High-Resolution Radiometer (AVHRR) from the Satellite Application Facility on Climate Monitoring (CMSAF), and Pathfinder Atmospheres-Extended (PATMOS-x)] are evaluated.

Large uncertainties are present in these products with skills varying from day to day. The bias has been attributed to various factors such as atmospheric temperature inversion, sensitivity of the sensors to the cloud properties, and multi-layer cloud structures. It is observed that compared to the overall average and single-layer only scenes, multi-layer scenes have lower correlations and higher uncertainty.

Session 7B (Friday 9 Feb, 14:00-15:30), Talk 6

Evaluating the Australian Climate Model ACCESS-AM2 against Southern Hemisphere marine aerosol observations

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Session

7. The complex case of clouds over the Southern Ocean and Antarctic: from biological precursors to microphysics

Abstract

Natural marine aerosol are a significant source of climate model uncertainty. The interactions between aerosol, clouds and radiation are poorly represented in climate models, in part due to deficiencies in understanding of aerosol processes and a lack of detailed observations. This is particularly the case for the Southern Hemisphere.

Here we provide the first evaluation of the Australian Community Climate and Earth System Simulator atmosphere-only model (ACCESS-AM2) aerosol scheme against several vessel and station-based marine aerosol observations in the Australian region and Southern Ocean.

Overall, we found that model aerosol and CCN concentrations were found to be under-predicted compared to observations. Aerosol were predominantly under-predicted around East Australia while model CCN were predominantly under-predicted in the Southern Ocean. We then test the inclusion of boundary layer nucleation in model simulations and found improvements in terrestrial influenced aerosol concentrations along East Australia.

These results provide the first overview of how well the new generation ACCESS model can capture aerosol processes around Australia and the Southern Ocean. We highlight the need for increased understanding of aerosol properties around coastal Australia, not just the remote marine environment. We also suggest that boundary layer nucleation should be included for future model studies.

8. Compound events - characteristics, drivers, and impacts

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 1

The effect of hot-and-dry compound events on Australian crop production

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Session

8. Compound events - characteristics, drivers, and impacts

Abstract

Australia's climate is highly variable both in space and time and characterised by hydro-climate extremes, such as droughts and heatwaves. Such extremes are projected to become more frequent and/or intense under climate change. Agricultural production is particularly affected by hydro-climatic extremes which can have devastating effects on crop yields and livestock health.

Previous studies have shown that concurrent hot-and-dry extremes during the growing season are particularly damaging for crop yields, and the effect of such events is typically more harmful than the separate effects of dry or hot events alone. To ensure sustainable food production and agricultural water management it is crucial to understand the effect of climate change on hydroclimate extremes, particularly hot-and-dry compound events, and their impacts on Australian agricultural production.

This study aims to (1) investigate historical trends of compound hot-and-dry events across major agricultural production zones in Australia, (2) quantify the effect of such events on agricultural production in Australia historically, using climate, hydrological and agricultural observations, and (3) assess the risk of future compound event impacts on agriculture based on regional climate and hydrological projections information for Australia.

We found that hot-and-dry compound events show increasing trends across many important agricultural production zones in Australia with implications for future food production under climate change. Outcomes of this research may inform adaptation efforts in the agricultural sector towards risks from compound events and support the development of seasonal forecasts of hydro-climatic risk indicators for agricultural production in Australia.

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 2

Projected changes in severity of hot and dry compound events impacting Australia's agriculture sector

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Session

9. Compound Hydroclimate Events in a Changing Climate – Impacts & Challenges

Abstract

Compounding hot and dry events are projected to become more frequent and severe in Australia. These hazardous events already pose a major threat to water-dependent industries such as agriculture as they can exacerbate the depletion in soil moisture, which lead to increased crop stress as well as reduced crop yields. Compounding hot and dry events can also increase the risk of crop pests and diseases, which cause further damage crops and agricultural activities. In extreme cases, crop failure can occur, threatening regional food security and impacting global food markets. To illustrate this point, two of the major agricultural hubs; the Murray-Darling Basin and the southwestern corner of Australia, have been shown to be particularly vulnerable to increases in compound hot and dry conditions.

To understand the severity of future impacts from compounding hot and dry events on Australia's agricultural zones, we use heat stress indicators combined with modelled soil moisture data from the Bureau of Meteorology's Australian Water Outlook; (AWRA-L) model. We then investigate historical and future spatio-temporal variability in the frequency, intensity, and duration of compound heatwave and soil moisture drought events across Australia.

Our study provides critical information for farming communities to develop adaptation strategies in order to mitigate the impact of increased compounding hot and dry events.

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 3

Modelling temporally compounding extreme rainfall events

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[1]Monash University, Melbourne, Australia. [2]Monash University, Melbournes, Australia

Session

8. Compound events - characteristics, drivers, and impacts

Abstract

Clustering of extreme events in short periods of time often leads to heightened impacts. This was witnessed firsthand by communities in the Hawkesbury Rivers region who experienced 5 floods during the recent triple La Nina. This raises the question – How is the occurrence of extreme rainfall events in this region being impacted by natural variability and climate change? To better understand the processes driving the temporal clustering of extreme rainfall, we develop and fit a statistical model for the arrival distribution of extreme events. In statistics, commonly the arrival of rare events is modelled using a Poisson process. For applications in climate, where the arrival of extreme events is inherently non-stationary, the rate parameter of this Poisson process is modelled as time-varying. In-situ station data from the Hawksbury River's region is used to demonstrate the model, but this approach for modelling the arrival process of extreme events is generalisable to other locations and other variables. Using our model we identify which time-varying covariates of seasonality, large scale drivers, local weather conditions and warming trend have a significant influence on the temporal clustering of extreme events in the Hawksbury region.

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 4

Beef Stew(ing) – what might the future look like for northern Australian beef in a warmer world?

Tim Cowan[1,2], Matthew C Wheeler[2], Andrew Marshall[1,3], John Gaughan[4], David Cobon[1]

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Session

8. Compound events - characteristics, drivers, and impacts

Abstract

Across northern Australia's tropical and rangeland regions, grazing cattle are generally well acclimatized to the humid heat; however, heat stress is major cause of calf mortality and contributes to reduced fertility in heifers and bulls. This is both caused by the prolonged impacts from chronic heat stress that affect cattle in poor body condition, and more extreme heat events over a relatively short time that can lead to acute heat stress and higher risk of mortality. Heat stress in cattle is typically measured using the Temperature Humidity index (THI); however, the THI does not account for the heat gained or lost by an animal and assumes all cattle breeds are the same. A better suited metric that accounts for cattle breed diversity is the Heat Load index (HLI), which incorporates the effects of incoming solar, temperature, relative humidity and wind on heat lost or gained from cattle.

In this research, we will discuss our latest prototype forecast product development with respect to cattle heat stress that is being conducted through the Northern Australia Climate Program (NACP). This includes a 7-day forecast of Accumulated Heat Load using the Bureau of Meteorology's Australian Digital Forecast Database, a multi-week forecast of 'Cattle Comfort' using the Bureau's seasonal forecast system ACCESS-S2, and the first efforts to assess the likely future changes in cattle heat stress using CMIP6 models. We will discuss the challenges and opportunities for these products, and in turn, provide an assessment of what northern beef might face in a warmer world.

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 5

Streamflow reduction in Australia in response to changed rainfall patterns.

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Session

9. Compound Hydroclimate Events in a Changing Climate – Impacts & Challenges

Abstract

The reduction in rainfall in recent decades has translated into runoff response and many streamflow gauges across the country are recording flows much lower than the historic flow. More than 60% of Australia's hydrologic reference stations show a declining trend in streamflow, 20% of which are statistically significant. Hydrologic reference stations are gauges in catchments with little disturbance from human activities and with at least a 30-year record, hence good indicator of long-term impacts of climate change on streamflow.

Significant declines in annual streamflow have been observed in around half of gauges in the Murray–Darling Basin, the South Australian Gulf, Tasmania, Pilbara Gascoyne, and Lake Eyre Basin drainage divisions since 1975. In the Murray–Darling Basin, nearly half of the long-term streamflow gauges show a declining trend since records began in 1970. This is more severe in the northern Basin where there are statistically significant declining trends in the headwaters, including the Namoi, Border Rivers, Condamine–Culgoa and Gwydir River catchments. Seasonal streamflows are also dominated by decreasing trends. Among the temperate seasons, highest reduction in streamflow is in spring consistent with the gradual reduction in winter rainfall in the southern Australia.

Although decline in streamflow is dominant in the past two decades, there are inter-annual variabilities across the seasons. While rainfall reduction is the primary driver and often reflected in streamflow decline, the relationship can be compounded by other factors. In a warming climate high evaporative loss can amplify the streamflow decline beyond that of rainfall alone.

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 6

Applications of copula-based model for multivariate analysis of compound extreme events and development of financial risk transfer

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Session

9. Compound Hydroclimate Events in a Changing Climate – Impacts & Challenges

Abstract

Compound weather and climate events, often resulting from multiple climate drivers and hazards, have significant economic impacts. Even if these factors are not individually extreme, their combined effect can have severe repercussions for society and the environment. As such, it's crucial to evaluate the potential impact of compound events. Regrettably, existing risk assessments concentrate on single factors, neglecting scenarios where multiple factors are at play. This is problematic as climate-related calamities frequently result from compound events. There is still much to be discovered regarding comprehending, gauging, and anticipating these events. We present an analytical and modelling approach that utilises pair-copula constructions to improve the understanding of the impact of compound events. A copula is a mathematical tool that expresses the joint cumulative probability distribution of multiple variables, allowing for accurate risk assessment of compound events in present and future climates, considering associated uncertainties. We employed a copula framework to model the joint dependency of extreme hot and dry events in Australia. We demonstrate how the interplay between variables impacts the occurrence of multivariate extremes, highlighting the limitations of traditional single-variable statistical analysis in understanding these complex phenomena. A better understanding and quantification of combined events would enable the development of more effective adaptation and financial risk management plans. For instance, a new drought insurance index could be created that more accurately reflects drought losses. In conclusion, it is crucial to adopt a multivariate approach when assessing changes in climate extremes and their implications, and to formulate efficient risk management.

Session 8 (Tuesday 6 Feb, 11:00-13:00), Talk 7

Fast and accurate calculation of wet-bulb temperature for humid-heat extremes

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Session

8. Compound events - characteristics, drivers, and impacts

Abstract

It is well understood that heat extremes are increasing in frequency, intensity, and duration. However, since heat is typically examined using dry-bulb temperature only, the impact of humidity may not be captured and the impacts on human health underestimated.

A variety of indices are used to examine humid heat. One of the simplest is wet-bulb temperature (WBT), which is the temperature of a parcel of air cooled to saturation by evaporation of water into it. WBT therefore reflects not only air temperature, but also the ability of the body to cool via evaporation (i.e., sweating). On a thermodynamic diagram, WBT can be determined by finding the lifting condensation level (LCL) and then following the saturated adiabat that passes through this point back to the starting pressure. In practice, WBT is typically calculated using empirical equations; however, these can be inaccurate for extreme values or slow to evaluate.

Here, we present a fast and highly accurate calculation of WBT called NEWT (Noniterative Evaluation of Wet-bulb Temperature). This follows the diagrammatic calculation approach, using exact equations for the LCL and high-order polynomial fits to the saturated adiabats. WBT values calculated using NEWT are around an order of magnitude more accurate than those from the next best empirical method and are valid across a wider range of temperatures.

Here, we present a comparison of NEWT and existing WBT calculation methods using automatic weather station and reanalysis data for Australia. We also assess the ability of different reanalyses to reproduce observed trends in WBT.

10. Modelling, prediction and projections of climate variability and past and future climate change

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 1

Significantly wetter or drier future conditions for one to two thirds of the world's population

Ralph Trancoso[1,2], Jozef Syktus[2], Richard Allan[3], Jacky Croke[4], Ove Hoegh-Guldberg[2], Robin Chadwick[5,6]

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

Future projections of precipitation are uncertain, hampering effective climate adaptation strategies globally. Our understanding of changes across multiple climate model simulations under a warmer climate is limited by this lack of coherence across models. We address this challenge by introducing a novel approach to detect agreement in drier and wetter conditions evaluating continuous time-series with trends across 146 Global Climate Models (GCMs) under elevated greenhouse gas (GHG) emissions.

The approach detected agreement across multiple models in future wetting and drying trends, revealing critical information on how precipitation is projected to change under scenarios associated with continued GHG emissions. By looking into the time-series of individual models with flexible trend detection methods, the approach provides a more robust quantification of change, summarising critical multi-model information.

We show the hotspots of future drier and wetter conditions, including regions already experiencing water scarcity or excess. These patterns are projected to impact a significant portion of the global population, with approximately 3 billion people (38% of the world's current population) affected under an intermediate emissions scenario and 5 billion people (65.6% of the world population) under a high emissions scenario by the century's end. We provide the first country-level analysis quantifying the population exposed to significant changes in precipitation regimes, offering a robust framework for assessing multiple climate projections. These new findings can directly assist with designing 'fit for purpose' climate adaptation policies and reduce uncertainty in which direction precipitation is projected to change globally under different emissions pathways.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 2

Constraining temperature variability projections using SMILEs that best represent observed variability

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

Projecting how temperature variability is likely to change in the future is important for understanding future extreme events. This comes from the fact that such extremes can change due to both changes in the mean climate and its variability. The recent IPCC report found large regions of low model agreement in the change of temperature variability in both December, January, February (DJF) and June, July, August (JJA) when considering 7 Single Model Initial-Condition Large Ensembles (SMILEs). In this study we use the framework described by Suarez-Gutierrez et al, (2021) to constrain future projections of temperature variability by selecting the SMILEs that best represent observed variability. We use 11 SMILEs with CMIP5 and CMIP6 forcing and consider 9 ocean regions and 24 land regions. We then assess, for both DJF and JJA, whether temperature variability projections are constrained by selecting for models capture observed variability in individual regions and seasons. We identify MPI-GE and CESM2 as the SMILEs that capture observed variability sufficiently across most regions (28 & 28 out of 33 in DJF and 26 and 24 in JJA respectively). Whether temperature variability projections are constrained depends on both season and region. For example, in DJF over South East Asia the constraint does not change the already large spread of projections. Conversely, over the Amazon the constraint tells us temperature variability will increase in DJF whereas the entire model archive does not agree on the sign of the change.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 3

Developing ACCESS-ESM1.5 for the past warm world of the Miocene

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

We are currently developing the Australian community climate model ACCESS-ESM1.5 for deep time paleoclimate simulations. The first target for our experiments is the Miocene climate optimum (17-14.7 Ma); a warm interval up to 7 °C warmer than present day, with strong polar amplification, and CO2 concentrations around 450-600 ppm. These simulations require extensive changes to the boundary conditions, including the land-sea mask, topography-bathymetry, vegetation, river runoff and greenhouse gases. We are currently developing the tools to make such changes in ACCESS-ESM1.5, beginning with small perturbations, such as opening the Panama Seaway to test model perturbations. These simulations will be developed in parallel with simulations using the GFDL CM2.1 coupled climate model, which has been established as an efficient tool for reaching equilibrium paleoclimate scenarios. We will present preliminary results from our Miocene simulations.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 4

Can we predict ENSO categories? Multiyear ENSO prediction in retrospective forecast models

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

Efforts to forecast El Niño-Southern Oscillation (ENSO) typically focus on minimizing the absolute error between an observed and forecasted index like Niño3.4. However, for many stakeholders, advance knowledge of the simple presence or absence of El Niño or La Niña events is useful, with details of timing and magnitude being a secondary concern. In this study, we explore the possibility that existing forecast models may be able to issue simple annual categorical forecasts of ENSO phase with higher confidence and greater lead times than month-to-month forecasts.

We develop a simple category-based framework to assess model skill by representing the Niño3.4 time series as a Markov chain consisting of three categories: La Niña, neutral, and El Niño events, to determine whether predictions of the correct category can be made annually. We apply this framework to a multimodel hindcast dataset spanning 1960 to the present. Our findings are in agreement with the well-known dependence of predictive skill on the initial state, showing that forecast skill varies based on ENSO phase at the time of prediction. We find that models typically have the lowest annual prediction skill in this framework when initialized during a neutral state, while initialization from ENSO events shows higher skill but varies substantially between models. These variations in skill can be leveraged to develop confidence bounds on real-world ENSO forecasts, potentially aiding interpretation by stakeholders.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 5

The Indo-Pacific Maritime Continent barrier effect on ensemble MJO prediction

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

The Madden–Julian oscillation (MJO) is often observed to weaken or sometimes completely decay as its convective anomaly moves from the Indian Ocean over to the Maritime Continent (MC), which is known as the MC barrier effect on the MJO. The MC barrier effect on the Austral summertime MJO is explored in retrospective forecasts from subseasonal-to-seasonal (S2S) prediction models including ACCESS-S. We select a set of observed MJO events that are blocked by the MC and another set of continuously propagating MJO events that cross the MC into the western Pacific. Our analysis indicates that the blocked events are often associated with persistent higher surface pressures over colder sea surface temperatures in the central Pacific, suggesting the large-scale environment plays a role in promoting or inhibiting the MJO propagation across the MC region.

The predictive skill of the continuously propagating MJO events across the MC region is greater than for the blocked MJO events, especially in the ocean-atmosphere coupled models, which is related to the systematic eastward propagating behavior of the MJO convection. We identify the best MJO prediction models and they consistently exhibit greater prediction skills of the continuously propagating MJOs. In contrast, the performance of the all-model ensemble is not better than the best models. Realistic eastward propagation in the ocean-atmosphere coupled models suggests air-sea interaction over the western Pacific is critical to improving MJO prediction.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 6

Simulations of early Holocene climate variability in the Australian region from ACCESS-ESM1.5 model

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

The Australian Earth System Model ACCESS-ESM1.5, which participated in the Coupled Model Intercomparison Project Phase 6 (CMIP6) is also included as one of the Paleoclimate Model Intercomparison Project 4 (PMIP4) models that performed standard paleoclimate simulations, including the last Interglacial (lig127k) and mid-Holocene experiments. Understanding how the climate responded to past conditions could provide insight into how the large-scale climate processes change over time as well as whether models can simulate past climate variability. In this research, we examine the climate variability over the Australian region during early Holocene (9,000 years before present, or 9 ka) and the major abrupt cooling event at 8.2 ka in ACCESS-ESM1.5 model. The orbital configurations during the early and mid-Holocene period (including 8.2 ka) are substantially different to present, resulting in increased summer and reduced winter incoming solar radiation in the Northern Hemisphere, with decreased seasonality of insolation in the Southern Hemisphere. Freshwater forcing experiments are also performed for the 8.2 ka simulation to investigate the climate variability over Australia in response to the Atlantic Meridional Overturning Circulation (AMOC)-induced changes. Preliminary comparisons with available proxy reconstructions and other model simulations are also presented.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 7

Impact of AMOC shutdown on Australian precipitation under PI and LIG boundary conditions.

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

The strength of the Atlantic meridional overturning circulation (AMOC) has varied significantly over the last glacial cycle and recent studies have indicated that the AMOC will weaken over the coming century. Several modelling studies and paleo records have suggested that the AMOC could have weakened markedly during Heinrich stadials and that this weakening could be due to the iceberg discharges into the North Atlantic Ocean. The impact of an AMOC shutdown on Australian hydroclimate is uncertain. In this study, we investigate the response of Australian precipitation to the AMOC shutdown under pre-industrial (PI) and last interglacial (LIG) boundary conditions. The PI and LIG simulations are performed with the ACCESS-ESM1.5 model configuration with boundary conditions corresponding to the respective climates. We find that the AMOC shutdown leads to intensified austral summer precipitation, particularly over northern Australia, under both climate scenarios. This could be due to a southward shift of the subtropical ridge in the southern hemisphere leading to a negative pressure anomaly over the Indian sector. We also find that due to the northward position of the ITCZ in the LIG compared to PI, an AMOC shutdown leads to a larger strengthening of the Australian monsoon under LIG than PI boundary conditions.

Session 10A (Tuesday 6 Feb, 11:00-13:00), Talk 8

Impacts of Pacific Ocean SST bias and variability in the ACCESS-CM2 model

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

Coupled climate models have advanced significantly, yet biases in atmosphere and ocean persist affecting projections. Notably, CMIP models exhibit significant sea surface temperature (SST) biases across the Pacific Ocean, which have local and inter-basin impacts. This study aims to assess how Pacific Ocean SST biases and variability impact on the mean state and interannual variability in the Indian Ocean.

We use the ACCESS-CM2 model as it exhibits typical mean state biases, such as the classical cold tongue bias, making it suitable to understand the impacts of such mean state biases. We conduct three pacemaker-style experiments by restoring SST in the tropical Pacific Ocean to 1. seasonally varying model climatology; 2. observed seasonally varying climatology; 3. observed climatology with model anomalies superimposed, effectively retaining interannual variability whilst removing mean-state bias. A control simulation offers a comprehensive baseline for comparison.

Initial findings suggest that rectifying Pacific Ocean SST biases has a more pronounced effect on the Indian Ocean mean state climate compared to removing interannual variability. In experiments with bias removal, notable changes are observed in SST, surface winds, and thermocline depth in the Indian Ocean. The impacts are similar both with and without ENSO in the no-bias experiments, indicating Pacific interannual variability has limited influence on the mean state. On the other hand, when Pacific Ocean interannual variability is removed, there are more complex changes in Indian Ocean interannual variability, including reduced Indian Ocean Dipole strength. These results illustrate complex teleconnections between the Pacific and Indian Oceans in the ACCESS-CM2 model.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 1

ENSO: modeled internal variability and model evaluation

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

Climate models help us understand the complexity of Earth's climate, forecast the next seasons and predict the influence of anthropogenic forcings. It is therefore important to evaluate the performance of these models relative to observational datasets, to build confidence and to improve them. Earth's climate naturally fluctuates on intraseasonal to interdecadal timescales ('internal variability'), partly due to processes intrinsic to the climate system. This internal variability is present in climate model simulations, as evidenced by the varying climate conditions in a control experiment. This implies that any given analysis of model output has an error related to the simulated internal variability. In this presentation I will describe a simple methodology to estimate the precision of the analyzed quantity, using the example of evaluating El Niño–Southern Oscillation (ENSO) simulated by climate models from the 6th Coupled Model Intercomparison Project (CMIP6). The same methodology can be applied to other modes of variability, or to estimate the robustness of their changes under different forcings.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 2

Assessment of CMIP6 model capabilities in simulating the asymmetric response of precipitation to ENSO

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Abstract

El Niño Southern Oscillation (ENSO) is a prominent climate phenomenon affecting the variability of global precipitation. The precipitation response, during El Niño and La Niña phases, compared to neutral phase, are not mirror images of one another. In Australia, for instance, it gets much wetter during La-Nina, compared to the neutral phase, as it gets drier during El Niño, and this asymmetry plays an important role in drought breaks. In the present study, we assess the capability of 30 CMIP6 models and 20CR reanalysis, against GPCC precipitation and HadISST, in simulating the seasonal differences in asymmetric response of precipitation to ENSO across 46 AR6 Land regions, using a composite technique. We further examine our confidence in the models by analysing the effect of the choice of hindcast timing and length in simulating the asymmetric response. We find that most models under-estimate the asymmetric response, and some models have a response in the opposite direction, compared to observations and 20CR. This discrepancy arises mainly due to the inability of the models in accurately simulating the precipitation response during the three phases of ENSO.

This analysis is critical to better understand the fidelity of CMIP6 models in capturing asymmetric responses across different seasons and regions for better projections and planning of floods and droughts in a warmer climate.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 3

Drivers of Australian-Maritime Continent monsoon change in PMIP simulations of mid-Holocene and Last Glacial Maximum climate

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

The Australian-Maritime Continent monsoon (also known as the Indo-Australian monsoon) is a complex regional monsoon which is influenced by both local and remote drivers on a range of time scales. Future projections under global warming indicate strong agreement between climate models on an increase in monsoon precipitation over the Maritime Continent but low agreement on the direction of change over northern Australia. We examine the Australian-Maritime Continent monsoon in simulations of mid-Holocene (6,000 years before present) and Last Glacial Maximum (21,000 years before present) climate from the latest set of Paleoclimate Modelling Intercomparison Project (PMIP) global climate models. The mid-Holocene simulations demonstrate strong model agreement on the response of the monsoon to reduced Southern Hemisphere summer insolation and increased insolation in the pre-monsoon season. The mid-Holocene ensemble includes our ACCESS-ESM1.5 simulation, which shows a similar response to the other PMIP models. The Last Glacial Maximum simulations produce a more complex response, with less model agreement. Changes in seasonal heating and moisture transport due to the expanded continental shelf interact with dynamic and thermodynamic responses to global cooling and regional changes in temperature gradients.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 4

Regional impacts of climate stabilisation across multiple global warming levels

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Session

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Abstract

The 2015 Paris Agreement adopted by 192 parties states the goal of limiting global warming to well below 2, preferably 1.5 degrees Celsius above pre-industrial levels. These goals imply an ambition to stay at or below these levels long-term. Evidence is beginning to emerge that regional patterns of change at given global warming levels (GWLs) can be very different between transiently warming through given GWLs and stabilising at those same GWLs.

In this presentation, we explore regional climate change across multiple variables, with a particular focus on regional precipitation change. Using an ensemble of six 500-years long fixed concentration simulations across various levels of warming between 1.5 and 5 degrees above pre-industrial with the CMIP6-generation Earth System Model UKESM1.0, we show that precipitation trends opposite in sign to transient climate change projections occur in several regions for the same GWLs. Such differences have important implications for climate change risk assessments and adaptation discussions, which typically only include transient projections. Here, we provide examples where a transient and stabilised climate differ and discuss the possible mechanisms driving these differences.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 5 | Poster Session 1, Poster 09

Rainfall erosivity and soil erosion risk prediction in New South Wales, Australia – An improvement from NARCliM

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Session

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Abstract

Rainfall erosivity, a critical factor in the erosion process, is expected to be significantly impacted by climate change. The increase in soil erosion caused by high rainfall erosivity, and the subsequent loss of soil nutrients, can lead to reduced soil fertility, food production and ecosystem services. This research program under the New South Wales (NSW) Climate Change Adaptation Strategy aimed to predict rainfall erosivity and soil erosion risk across NSW under future climate change scenarios. In this study, daily rainfall erosivity and soil erosion risk were modelled by using Revised Soil Loss Universal Equation (RUSLE) method and bias corrected weather data (e.g., SILO). We investigated the impacts of climate change on rainfall erosivity and soil erosion risk across NSW using the updated NSW and Australian Regional Climate Modelling (NARCliM 1.5) daily precipitation projection in six downscaled General Circulation Models (GCMs). We conduct a comparative analysis on two scenarios, RCP4.5 and RCP8.5, for the historical (1985-2005) and far future (2060-2079) periods. The expected results of this study will include the spatio-temporal change of erosivity and erosion risk maps, a repeatable approach that can be scaled up to national scale and potential accessible via data portal. The outputs of these projects can support the planning of relevant climate adaptation actions and state-wide Climate Change Risk and Opportunities Assessment. This research project will also help scoping longer-term research priorities, such as adaptation options in high-risk areas.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 6 | Poster Session 1, Poster 11

The variability of climate over Australia and future changes

Ian G. Watterson

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

It is commonly said that Australia has a highly variable climate and that this variability is expected to increase with global warming. Typically, the focus of variability studies is the effect of the ENSO, IOD, and SAM modes on Australian rainfall and temperature. However, even for seasonal means of these two quantities and others, there is much interannual variability that is not linked to modes. How this overall variability might change in the future is not clear. My recent studies have used the ERA5 reanalysis over 1979-2019 to assess the variability linked to modes of seasonal mean rainfall, temperature, pressure, atmospheric moisture fluxes, and upper and lower tropospheric winds. Here, the overall variability is assessed, with averages of the standard deviation (of detrended series) at grid points over Australia compared with that over other land regions globally. To assess future change, CMIP6 simulations for the same period and for 2040-2079 have been evaluated. Quantities have been assessed for the 10 models for which the moisture flux is available, with another 25 models used for rainfall, temperature, and pressure. The overall variability simulated by the CMIP6 models for the recent climate compares well with that from ERA5. The variability in the future climate is calculated and scaled to give a projected change at the 2°C global warming level. For example, the four-season average of the standard deviation over Australia increases by 8% for rainfall, 7% for temperature, and 1% for pressure. The role of modes will be considered.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 7 | Poster Session 1, Poster 12

Recent trends in Budburst Timing and Frost Hazard across Australian wine regions

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Session

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Abstract

Frost is a significant hazard to winegrape production in Australia, causing severe damage, leading to substantial reductions of crop yields during the growing season, with lasting consequences for subsequent harvests. Evaluating the risk of frost in the winegrape industry is crucial, with the evolving climate adding complexity to the assessment; however, the correlation between climate change and frost remains debated in the literature. Adding another layer of intricacy to the climate change puzzle is the shifting timing of budburst, as post-budburst frost events carry higher consequences.

This research utilises Liles and Verdon Kidd's (2022) theoretical budburst dataset to assess the historic risk of frost after budburst across the Australian wine regions. Frost potential (defined as minimum temperature below 2oC) occurring after the budburst date was counted for each year 1910-2019. Mann-Kendall statistics then determined the trend for the median frost potential days within each wine region. The results were spatially varied, with half of wine regions shown to have experienced no trend in frost risk after budburst. However, increasing trends were identified for 30% of wine regions, primarily the elevated areas of NSW and Victoria. The remaining 20% of wine regions have experienced a decreasing trend, occurring for wine regions within South Australia and Western Australia.

This research demonstrates that recent climate variability and change in frost risk is complex and varies between different wine regions. It emphasises the importance of considering local climatic conditions when assessing the potential effects of climate change on frost-related hazards to grape production.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 8 | Poster Session 1, Poster 13

Spatial variation in rainfall projections: average to extremes.

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Session

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Abstract

Model simulated rainfall from the National Hydrological Projection (NHP) were used to identify the future changes in rainfalls for three locations across the county: Edinburgh (SA), Tindal (NT) and Townsville (Queensland). Four Global Climate Models under two emission scenarios from CMIP5 were selected considering their representation of the observed features of Australian climate.

In general, for annual and seasonal rainfall the patterns observed over the baseline period (1961-2020) remained similar in the projections. Although projected rainfalls indicate a range of plausible changes in the future, the projections agree on a drier future climate for Edinburgh, slightly wetter for Townsville and relatively wetter for Tindal. For Edinburgh, autumn rainfall is projected to decrease most, followed by summer.

While high rainfalls (top 1 per cent of the distribution) are projected to increase for the two northern locations and remain unchanged for Edinburgh, extremes are likely to increase everywhere. Although for Tindal annual rainfall is projected to be higher in RCP8.5, in contrast to Townsville, high rainfalls are intense in RCP4.5. Generalized extreme value distribution of annual maxima shows, bigger changes are observed at Edinburgh and Townsville for RCP 8.5 compared to Tindal where RCP4.5 projected bigger changes.

This study demonstrates steps taken to ensure a robust, best practice analysis and advice on future rainfall shifts across a range of locations and rainfall regimes. A customer-centric model is used to deliver intelligence based on needs within scientific limitations. The outcomes will greatly aid in planning for a more resilient asset into the future.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 9 | Poster Session 1, Poster 15

Untying the Gordian knot of Asian monsoon initiation using ensemble paleoclimate simulations.

Abhik Santra[1], David K Hutchinson[2], Dietmar Dommenget[1], Fabio A Capitanio[1], Julie M Arblaster[1], B N Goswami[3], Alex Farnsworth[4,5], Daniel J Lunt[4], Sebastian Steinig[4]

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Abstract

The timing and key factors for Asian summer monsoon initiation are debatable as recent proxy evidence and modeling studies suggested the presence of a wet-dry monsoonal climate from the Cretaceous period (145 million years ago, Ma). Capitalizing on an ensemble of paleoclimate simulations for the early Eocene (56-48 Ma), we show that the Asian wet season was considerably weaker and shorter than present in the absence of an elevated heat source like the Tibetan Plateau in the early Eocene. The deficient upper tropospheric meridional temperature gradient couldn't drive the seasonal northward migration of the precipitation band over South Asia. Additionally, the weaker cross-equatorial moisture flow was mechanically blocked by the Gangdese mountain along the southern edge of Asia, leading to significantly dry conditions in South Asia. The enhanced atmospheric greenhouse-gases were inadequate to strengthen the seasonal circulation and precipitation variability to the present level. We argue that an altered wet and dry seasonality over South Asia is not necessarily qualified as the Eocene 'monsoon'.

Further, a few sensitivity experiments are conducted in ocean-atmosphere coupled paleoclimate models to understand the role of possible tectonically constrained paleogeography on the Asian monsoon. We also investigate the Eocene-Oligocene transition (45-33 Ma) period and briefly discuss the uncertainty in the Asian monsoon inception, strength, and variability.

Session 10B (Tuesday 6 Feb, 14:00-15:30), Talk 10 | Poster Session 1, Poster 16

Identifying step changes in Victorian rainfall and their future likelihood

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Session

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Abstract

The cool season (April – October) rainfall over Victoria contributes about two-thirds of the annual total rainfall. However, since the beginning of the Millennium Drought in 1997, the cool season rainfall exhibited a statistically significant downward trend. Victoria experienced a 12% drop in cool season rainfall for the 1997-2018 period, relative to the 1900-1959 period average, leading to a disproportionate impact on water availability across the state. In a previous study, we showed that such a large magnitude of decline would have been unlikely without a contribution from increasing levels of greenhouse gases (GHGs) in the atmosphere. Climate models suggest that the cool season rainfall will continue to decline over the coming decades under a high-emission scenario.

Here we look at the recent rainfall change to see if it was declining gradually or there was an abrupt change. To examine this, we applied various step-change detection methods on full historical observations (i.e., 1900-2022) and found that Victorian rainfall indeed showed regime shifts, but there existed an inconsistency between some of the methods in detecting the timing of a step change. Here, we will discuss the strengths and weaknesses of the applied techniques and present the results based on the most appropriate method.

11. Realisation of Paris Agreement pledges

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 1

Understanding different climate changes in a net-zero emissions future

Andrew King[1], Tilo Ziehn[2], Alexander Borowiak[1], Josephine Brown[1], Liam Cassidy[1], Matthew Chamberlain[2], Andrea Dittus[3], Michael Grose[4], Seungmok Paik[5], Sarah Perkins-Kirkpatrick[6], Aditya Sengupta[1]

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Session

11. Realisation of Paris Agreement pledges

Abstract

To stop global warming, humanity needs to achieve close to net-zero greenhouse gas emissions. The Paris Agreement goal of limiting global warming well below 2°C above pre-industrial temperatures will only be achieved if humanity can get towards global net-zero emissions within the next 50 years. Many questions remain about the long-term implications of stabilising global temperatures in line with the Paris Agreement goals or missing this target but stabilising the climate at a higher global warming level. We have run bespoke millennium-length ACCESS-ESM-1.5 simulations under net-zero emissions at different global warming levels. Our analysis of these simulations finds continued climate changes on the local level well after cessation of greenhouse gas emissions, including continued warming over the Southern Ocean and neighbouring land regions. In contrast, the Northern Hemisphere land areas rapidly cool. There are also significant changes in regional precipitation as the climate stabilises post-net-zero which changes the frequency and intensity of heavy precipitation and meteorological drought locally.

We must gain a better understanding of potential future climates which evolve under near-zero greenhouse gas emissions. Policy-making is based on achieving net-zero emissions and we hope our work and similar analyses can increase understanding of climate changes under net-zero scenarios.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 2

Heatwaves in Net Zero "worlds"

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Session

11. Realisation of Paris Agreement pledges

Abstract

It is well documented that heatwaves will in increase in intensity, frequency and duration as climate change intensifies. Whilst there are regional variations in predicted trends, all scale against global warming thresholds. To date, the vast majority on the projected changes in heatwaves only considers until the end of the 21st Century. Moreover, these studies are on transient climate model simulations, where carbon emissions and mitigation strategies are not static.

New experiments from the Australian Community Climate and Earth System Simulator (ACCESS) provides a unique opportunity to understand how the climate may change one carbon emissions stabilize. Seven simulations exist, where emissions are set to zero at global warming levels between 1.3oC and 3.3oC from various points during the 21st Century determine by the SSP5.85 emissions scenario, thus accounting for warming targets set by the Paris Agreement, as well as target below and above this range. Moreover, each simulation is run for 1000 years, allowing for a rare opportunity to study ultra-long-term climate effects after successful and permanent implementations of net-zero policies.

This presentation will discuss how heatwaves – defined by metrics such as their intensity, duration and frequency – differ across net-zero "worlds", as well as compared to the transient parent run. Specifically, we will discuss if and when heatwaves trend start to decline, and how these changes spatially vary, both over Australia and over other global regions.

Findings of our work will highlight how important drastic net-zero targets are to reduce on-going unprecedented heatwaves.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 3

Hydrological Impacts of Global Warming in Australia: Assessing Future Hazards and Extreme Conditions

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Session

11. Realisation of Paris Agreement pledges

Abstract

Predicting the impacts of global warming on the hydrological cycle is crucial not only for climate change mitigation but also for adapting to potential future hazards. The Paris Agreement led to a significant shift in the approach to global climate change mitigation policy, focusing on the goal of limiting global warming to either 1.5 or 2°C above pre-industrial benchmarks. Therefore, climate projections are best understood based on different Global Warming Levels (GWLs) rather than Shared Socioeconomic Pathways to outline the predicted changes that Australia is likely to undergo.

We utilise the Bureau of Meteorology's landscape National Hydrological Projection (NHP) dataset to assess the changes in the runoff and soil moisture; providing an indication of changes in wet and dry conditions, within the identified future GWLs timeframes compared to current GWL period (1991-2020) across Australia. We identify the time periods in which GWLs of 1.5, 2 and 3°C above the pre-industrial mean value of 1850-1900 via a 20-year moving window, using the relevant NHP global climate models. This assessment is conducted using the 90th and 10th percentile of ensemble GCM data, representing extreme wet and dry conditions. We show the potential evolution of hydrological extremes under current, 1.5, 2, and 3ºC GWLs to assess the likelihood of amplified flood and drought risks in the future.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 4

CO_2 removal and climate impacts of forestation in Australia

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CSIRO, Aspendale, Australia

Session

11. Realisation of Paris Agreement pledges

Abstract

Meeting the Paris Agreement targets requires innovative carbon dioxide removal (CDR) strategies. Leveraging the terrestrial biosphere's natural carbon sinks potentially offers a feasible and affordable solution. While forestation may not be a complete solution on its own, it provides biomass that can be used in other technologies. Unfortunately, the existing CMIP6 forestation scenario projects no future change in forest cover in Australia and only provides a single climate state. This study addresses these shortcomings by assessing CDR by using ACCESS-ESM1.5 to expand natural forests (both for Australia and globally) under varying global warming levels. We replace crops with forest plant functional types and explore forestation's CO_2 uptake potential as well as the local temperature and precipitation impacts.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 5

Temperature overshoots and impacts on climate stabilisation

Tilo Ziehn[1], Andrew King[2], Josephine Brown[2], Liam Cassidy[2], Alexander Borowiak[2]

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Session

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Abstract

Global temperature will likely continue to increase until at least mid-century under all emissions scenarios considered. If we want to limit global warming to well below 2 °C, in line with the Paris Agreement, we must achieve net zero emissions and major economies are targeting net zero emissions by 2050. However, reaching net zero emissions will require major changes including carbon dioxide removal (CDR) and we are a long way off achieving this. A delay in emission reductions or the utilization of CDR technologies will lead to at least temporarily exceeding Paris agreement temperature targets. We therefore need to gain a better understanding of the impacts of potential temperature overshoots on the climate system and long-term climate stabilisation.

In this study we analyse simulations from the Australian Earth System Model - ACCESS-ESM1.5. We compare results from the SSP1-2.6 low emissions scenario with the SSP5-3.4 overshoot scenario based on 10 ensemble members from 2015 until 2300. Although both future scenarios lead to the same stabilized global warming level by about 2150, we find that the temperature overshoot has a big impact on the regional climate, leading, for example, to warmer temperatures over mainly the Southern Hemisphere and cooler temperatures over the Northern Hemisphere compared to the low emissions scenario.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 6

Project Global Temperature Changes after Net Zero are Small But Significant

Alex Borowiak

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Session

11. Realisation of Paris Agreement pledges

Abstract

To prevent continued global warming, global greenhouse gas emissions need to be reduced to near zero. Several highly idealised climate model experiments have been run within the framework of the Zero Emissions Commitment Model Intercomparison Project (ZECMIP), in order to understand the evolution of the climate after the CO2 cessation of emissions. One such experiment, which features an abrupt cessation of emissions at approximately 1.5℃, predicts a post net zero global average temperature change of -0.07℃, with a range of -0.36℃ to 0.29℃ between models.

The expected temperature changes after abrupt cessation of emissions are small in some models and may only be due to natural climate variability. We demonstrate that the changes 25 and 90 years after emissions cease are indeed likely to be significant, with most models undergoing a cooling of the global average temperature. Continued global warming is unlikely, with only one model showing a significant increase in temperature. On the local level, cooling was found in most land regions and almost all models simulated cooling in the Middle East, Central Asia, the Maritime Continent, and eastern North America. The Southern Ocean, in all models, was found to warm after the abrupt cessation of emissions. We also analysed how this small, but significant change in temperature impacts precipitation and other variables.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 7

The Southern Ocean as the freight train of the global climate under zero-emission scenarios with ACCESS-ESM1.5

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Session

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Abstract

We present climate projection experiments to explore the processes that drive increasing global average temperatures in Zero-Emission Commitment (ZEC) simulations despite decreasing atmospheric CO_2. The ACCESS-ESM1.5 shows the Southern Ocean to continue to warm locally in all ZEC simulations. In the simulation that branched after 2000 PgC, or after 3.5 C of warming from a pre-industrial climate, there is 0.37 C of extra warming after 50 years of zero emissions and further warming continues for at least several centuries.
Replicating the average global results with a relatively simple slab model demonstrates that the ongoing warming is due to the slow, "freight train" response of the Southern Ocean to changes in climate forcing rather than any single "tipping point" effect.

Session 11 (Friday 9 Feb, 11:00-13:00), Talk 8

Multi-decadal changes in climate and surface radiation patterns under net zero CO2 emissions

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Session

11. Realisation of Paris Agreement pledges

Abstract

Signatories to the Paris Agreement pledged to keep global warming to well below 2°C above pre-industrial levels and preferably below 1.5°C. Limiting global warming to Paris Agreement levels will require reaching at least net zero CO_2 emissions along with reductions in other greenhouse gases. Researchers have begun using state of the art Earth System Models to understand climate evolution after net zero CO_2 emissions are met and the geophysical drivers behind the climate response. Recently, there has been a focus on connecting global climate response to projected regional climate response after net zero, however regional changes are complex and the mechanisms behind regional changes require further investigation. In this study, we use results from Earth System Models included in the Zero Emissions Commitment Model Intercomparison Project (ZECMIP) to investigate mechanisms behind regional climate changes following CO_2 emissions cessation after multiple levels of cumulative CO_2 emissions. Our results suggest that global warming could continue for a century for higher cumulative CO_2 emissions levels even after net zero CO_2 emissions due to continued increase in longwave radiation being absorbed by the atmosphere and re-radiated back to Earth's surface. Regional climate changes after net zero are more nuanced and involve combinations of radiative changes such as adjustments in shortwave radiation reflected from the surface and shifts in the regional relationship between latent and sensible heat fluxes. Further investigation into regional temperature change patterns is ongoing.

12. Regional climate projections and applications

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 1

Should we bias correct boundary conditions for regional climate models?

Jason P Evans, Youngil Kim, Ashish Sharma

UNSW, Sydney, Australia

Session

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Abstract

One of the main limitations for regional climate modelling is the “Garbage in – garbage out” issue. That is, if the input boundary conditions from a GCM are far from realistic (garbage) then the regional climate model (RCM) is not able to correct this and will, in turn, produce garbage. This is a major problem given that all GCMs, even the best ones, contain biases. It has been proposed that performing bias correction of the GCM boundary conditions would alleviate this problem and produce better RCM simulations. In this talk we present evidence that bias correction of the boundary conditions does result in improved RCM simulations. We examine the affect of using various bias correction techniques, the role of the relaxation zone in transferring these corrections to the interior domain, and the importance of physical consistency within the boundary conditions. We show that the corrected boundary conditions improve multiple aspects of the simulated climate including: the mean climate, extremes, compound events and synoptic systems.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 2

Correcting Sub-Daily Multivariate Biases (SDMBC) in RCM Boundaries: Implications for the Diurnal Precipitation Cycle

Youngil Kim, Jason Evans, Ashish Sharma

University of New South Wales, Sydney, Australia

Session

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Abstract

Global climate models (GCMs) often inaccurately capture the diurnal cycle, especially for rainfall frequency and intensity. While many studies have employed regional climate models (RCMs), they often rely on the assumption that the diurnal patterns introduced by the GCMs are accurate. This assumption can lead to inconsistencies in predicting peak rainfall timing and intensity within the RCM domain. Hence, this study investigates whether advanced bias correction alternatives applied to lateral and lower boundary conditions can improve the representation of the diurnal cycle in an RCM domain. This study used two sophisticated bias correction alternatives: the multivariate bias correction (MBC) and the sub-daily multivariate bias correction (SDMBC). While MBC corrects multivariate relationships between the atmospheric variables daily, SDMBC refines these corrections at a sub-daily scale. We used the Weather Research and Forecasting model (WRF) with the Advanced Research WRF (ARW) core, version 4.2.1, for RCM simulations. The ERA5 dataset was used as the reference for bias corrections, with downscaling conducted over the Australasian Coordinated Regional Climate Downscaling Experiment (CORDEX) domain. The model performance was assessed using mean absolute errors (MAE) and mean bias. The results indicate that RCMs with bias-corrected boundaries are more accurate in representing rainfall timing and intensity. The results suggest that correcting biases at a sub-daily scale and multivariate relationships between the atmospheric variables in the RCM boundaries can improve the representation of the diurnal rainfall cycle within the domain, which is essential for regions that experience short but intense rainfall events.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 3

Observational uncertainty in evaluating added value of dynamical downscaling

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Session

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Abstract

Global Climate Models (GCMs) provide climate insights on a global scale, yet their coarse resolution may inadequately capture local climate. Thus, the issue arises of refining this climate information for local application. Regional Climate Models (RCMs) serve as the appropriate tool to dynamically downscale GCMs to local scales. However, the extent to which RCMs contribute, substantiating their superiority over GCMs, remains uncertain. To evaluate this, the concept of Added Value (AV) is employed. Assessing AV through downscaling is complicated due to observational uncertainties. The study assesses AV for monthly precipitation and temperature using multiple observational datasets. RCM ensemble outputs from the CORDEX-Australasia domain are used to quantify AV across Australia. Different statistical metrics are calculated against various observational datasets to evaluate the observational uncertainties in RCMs' performances and quantify AV. The results show observational product differences play an important role in evaluating climate model performance, while it is less important in AV assessment. This is due to AV being a comparative measure between a GCM and RCM and given observational dataset.

RCMs show enhanced performance with observational datasets combining station data and satellite-reanalysis estimates. In addition, high-resolution RCMs driven by coarse-resolution GCMs generally provide higher magnitude of positive AV, although temperature AV lacks consistency, with precipitation AV notably higher across both summer and winter. Notably, summer AV for precipitation surpasses that of winter. Finally, RCMs provide higher positive AV across Australia, particularly over the northern, coastal, and south-eastern regions, as well as within the complex topography of the Australian Alps.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 4

Constraining regional projections of rainfall over Australia

Rachael N. Isphording[1,2,3], Lisa V. Alexander[1,2,3], Margot Bador[4,5]

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Abstract

Projections of rainfall over Australia consistently show very high levels of uncertainty across different characteristics of rainfall (intensity and frequency of extremes, mean change, etc.). This uncertainty, defined here as low model agreement in the direction of change, has shown little improvement across CMIP generations or from downscaling initiatives (e.g. CORDEX). In this study, we seek to constrain regional projections of rainfall over Australia by applying an objective benchmarking framework to underpin our quantification of historical model skill and guide ensemble subsetting. Benchmarking differs from typical model evaluation in that it requires that performance expectations are set a priori. We investigate how historic model performance scales into the future and how we can optimize subsets from the CORDEX-Australasia ensemble based on the transitivity of our benchmarking choices. To prevent overfitting, we use model-as-truth experiments to perform out-of-sample tests to constrain rainfall projections. We find a strong relationship between the future change of mean and extreme rainfall across seasons. We also find that calibrating our ensemble to seasonal performance also reduces uncertainty in projections of extreme rainfall.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 5

Benchmarking of Australian high-resolution ensemble of regional climate projections

Xiaoxuan Jiang[1,2,3], Emma Howard[3], Rachael Isphording[4], Chun Hsu Su[3], Sarah Chapman[5], Benjamin Ng[6], Marcus Thatcher[6], Ralph Trancoso[5,7], Jozef Syktus[7], Michael Grose[8]

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Session

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Abstract

As Australian policymakers contend with the socio-economic impacts of climate change, regional climate models (RCMs) are important tools used to translate global warming trends into regional-scale risk assessments. Before RCMs can be applied for this purpose, their ability to accurately represent Australia's climatological temperature and precipitation must be established. Benchmarking is a rigorous evaluation methodology which assesses RCMs against a priori defined objective and meaningful thresholds.

This study evaluates the RCMs developed for the Australasian-region Coordinated Regional Downscaling Experiment (CORDEX-Australasia). We discuss important aspects of defining benchmarks and thresholds in a benchmarking framework. These RCMs are compared with their host Global Climate Model (GCM) from the historical Coupled Model Intercomparison Project phase 6 (CMIP6) from 1985 to 2014 over the Australian continent, focusing on daily-minimum temperature, daily-maximum temperature and precipitation, compared against AGCD. Firstly, the mean-state biases aggregated over Natural Resource Management (NRM) clusters are benchmarked against CMIP6 host models and found to have a good overall representation in each RCM Secondly, the climatological spatial patterns over the Australian continent are well-simulated in the RCMs. The spatial pattern of precipitation shows better performance in the RCMs than GCMs in summer. Thirdly, for all three variables, most of the RCMs preserve trends present in the GCMs. However, a few ensemble members fail to accurately simulate temperature trends in southern and eastern Australia. The rainfall seasonal cycle is well-simulated in each RCM in most NRM super-clusters. These results provide meaningful insights into the skills of downscaled simulations across Australian regions.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 6

Dynamical downscaling of CMIP6 models over New Zealand: assessing historical added value

Peter B Gibson

National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

Session

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Abstract

The coarse resolution of Global Climate Model (GCM) output remains problematic for direct use in climate change applications, especially in complex terrain settings like New Zealand. To address this, work is ongoing at NIWA to dynamically downscale the latest generation of GCMs from CMIP6. CCAM is the primary model used for downscaling, with a stretched grid configuration enabling 12km resolution over New Zealand, and 12-35km resolution over the wider Australia/South Pacific domain. Six GCMs have been selected for downscaling with CCAM based on a balance of: historical evaluation for the region, model independence, and warming rate. We begin by comparing biases from two other candidate RCMs (WRF and the UM) alongside CCAM, where each RCM is driven by reanalysis over the historical period. Each RCM has various strengths and weaknesses, though CCAM is shown to be very competitive for several metrics. The remainder of the presentation focuses on the added value from downscaling with CCAM, assessing the reduction in biases in the downscaled output relative to the host GCM. Added value is quantified in various settings including for standard climatological fields, interannual variability, extreme event indices, and tropical cyclones. Widespread instances of added value are demonstrated here, though the magnitude and extent of added value can vary across meteorological variables, error metrics, regions, and seasons.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 7

Projected climate change in mean and extremes from downscaled high-resolution CMIP6 simulations for Australia.

Jozef Syktus[1], Ralph Trancoso[2], Sarah Chapman[2], Rohan Eccles[2], Rayan McGloin[2], Nathan Toombs[2], Hong Zhang[2], Ove Hoegh-Guldberg[1]

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Abstract

Following the release of the CMIP6 global climate models (GCMs) projections, the Queensland Future Climate Science Program (QFCSP) started the downscaling of GCMs to update its high-resolution climate projections based on the latest scientific developments. The second phase of the QFCSP has produced the large ensemble of CMIP6 downscaled simulations for the Australasian region at 10 km spatial resolution and it has downscaled 15 CMIP6 simulations for three emissions scenarios (SSP1-2.6, SSP2-4.5 and SSP3-7.0) using CSIRO CCAM variable resolution climate model. This ensemble includes 5 simulations with coupled atmosphere-ocean CCAM for each of SSP scenarios.

Presentation will describe steps in producing a high-resolution CORDEX compliant downscaled simulations by illustrating our approach to model selection, bias-correction, ensemble averaging and data preparation for Australasian CORDEX domain submission to the NCI ESGF archive. The primary focus of presentation will be on projected changes in mean and extreme climate during the 21st Century.

Comparison of projected changes in temperature, precipitation from ensemble of CMIP6 host models and downscaled CCAM was completed for three SSPs scenarios over Australia. We found that the ensemble average downscaled the annual average warming for Australia by 2090 is 1.4°C for SSP126, 2.6°C for SSP245 and 3.75°C for SSP370 and is slightly larger than for CMIP6 equivalent ensemble average. Projected changes for precipitation show larger decrease in winter (JJA) and larger increase in summer (DJF) compared to CMIP6 host models. The analysis will also showcase projected changes in selected extreme indices and climate hazards for Australia.

Session 12A (Wednesday 7 Feb, 11:00-13:00), Talk 8

The NARCliM2.0 CORDEX-CMIP6 ensemble: evaluation and future projections over Australia and at convection permitting scale

Giovanni Di Virgilio[1,2], Fei Ji[3], Eugene Tam[3], Dipayan Choudhury[3], Carlos Rocha[3], Jason P Evans[4], Jatin Kala[5], Julia Andrys[5], Stephen White[3], Yue Li[3], Matthew Riley[3], Jyothi Lingala[5]

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Abstract

The NARCliM2.0 ensemble of two Weather Forecasting and Research regional climate model (RCM) simulations driven by five CMIP6 global climate models (GCMs) and contributing to the CORDEX-CMIP6 Australasia framework have recently completed simulation for SSP1-2.6 and SSP3-7.0 for 1951-2100 at two spatial scales: i) Australia at 20 km resolution; ii) convection-permitting scale over south-eastern Australia at 4 km. This is the first evaluation of the skill of NARCliM2.0 CORDEX-CMIP6-forced RCMs in simulating the recent climate as compared to CMIP5-forced RCMs. Overall, the CMIP6-RCMs produce improved representations of recent climate versus CMIP5-RCMs, for instance, by showing consistent reductions in cold bias for maximum temperature and wet/dry biases for precipitation, with performance improvements being particularly marked over southeast Australia at convection-permitting scale. Future climate projections under both emissions scenarios are examined for mid- and end-of-century changes in means and extremes of precipitation and temperature, as well as changes in future storm environments and fire weather. Under SSP3-7.0 projected temperature changes by 2030-50 exceed ~1.6K over several socio-economically important regions such as parts of eastern Australia. Although the NARCliM2.0 ensemble members show variation in the sign of projected precipitation, overall, far future changes are towards drying, particularly over the most populated areas of southeastern Australia. Projections of convective available potential energy (CAPE) show increases over the eastern coastline and particularly over heavily populated regions of the New South Wales coastline. These results and the NARCliM2.0 CORDEX-CMIP6 ensemble enable future assessments of regional climate changes, climate change impacts, and adaptation pathways for Australia.

Session 12B (Wednesday 7 Feb, 14:00-15:30), Talk 1

Evaluation of 4 km regional climate model simulations for southwest and northwest Western Australia using the Weather Research and Forecasting (WRF) model to dynamically downscale ERA5 re-analysis

Jatin Kala[1], Sean Lam[2], Julia Andrys[1], Jyothi Lingala[1], Giovanni di Virgilio[3], Fei Ji[3], Eugene Tam[3], Jason Evans[4], Christopher Thomas[4], Sharna Nolan[2], matthew Riley[3]

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Abstract

The Climate Science Initiative of Western Australia (WA) aims to produce the most up-to-date regional climate projections for the state, with particular focus on the southwest and northwest of WA, two regions that are critical to the state's economy and biodiversity. Following CORDEX protocols, the first phase of the project is to produce regional climate model simulations under historical climate by dynamically downscaling ERA5 re-analysis. We will present a comprehensive evaluation of our 4 km model simulations using the Weather Research and Forecasting (WRF) model, with two model configurations, over both the southwest and northwest of WA. Model evaluation is carried out against gridded observations of temperature and precipitation from the Australian Gridded Climate Data project, from 1981 to 2022. Our results show significant added value of the WRF simulations when compared against ERA5 re-analysis, especially for minimum and maximum temperatures. We will also provide an update on CMIP6 driven simulations under both historical and future scenarios.

Session 12B (Wednesday 7 Feb, 14:00-15:30), Talk 2

Toward dynamical downscaling of future climates at island scales in Tropical Pacific

Vishnu S Nair[1,2], Christophe menkes[3], Alexandre Peltier[4], Lola Corre[5], Agathe Drouin[5], Cyril Dutheil[6], Matthieu Lengaigne[6], Gilles Bellon[5], Sophie Martinoni-Lapierre[7], Victoire Laurent[7]

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Abstract

The CLIPSSA (CLImats du Pacifique, Savoirs locaux et Stratégies d'Adaptation) project aims to facilitate climate change adaptation strategies in Wallis and Futuna, French Polynesia, New Caledonia, and Vanuatu in the Southwest Pacific. The project aims at building an stronger knowledge of the region future climate and to analyse sectoral impacts of climate change. Toward those ends, uncertainties of future climates available from CMIP5 and CMIP6 models in the southwest Pacific region and in the South Pacific Convergence Zone (SPCZ) in general must be reduced. To address this, ALADIN 20km regional climate simulations are run in a series of experiments, The model skills are assessed based on precipitation, SPCZ and tropical cyclone characteristics. The model skills are more sensitive to domain size than model physics and cumulus parameterization. The domain giving better skills especially in terms of cyclones consists of part of the western Indian Ocean, incorporating Madden-Julian Oscillation-tropical cyclone interaction and a poleward extension consisting of middle latitude-tropical cyclone interaction.. Using this setup, a long-term ERA5 forced historical simulation well reproduces the interannual variation associated with the El-Nino Southern Oscillation, the primary mode of interannual variation. Then pseudo-warming experiments with emergent constraint using series of selected climate models at the boundaries are run from the ERA5 reference simulation for the next 100 years under 2 climate change scenarii. The high-resolution climate simulation provides a better understanding of future climate extremes, including heat waves, precipitation, drought, and cyclone activities, informing the formulation of climate change adaptation strategies in the region.

Session 12B (Wednesday 7 Feb, 14:00-15:30), Talk 3

Evaluation of the Conformal Cubic Atmospheric Model (CCAM) when simulating a Category 5 tropical cyclone over the Southern Pacific region with a variable resolution grid

Son Truong, Tony Rafter, Hamish Ramsay, Marcus Thatcher

Climate Science Centre, Melbourne, Australia

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Abstract

This study investigates the performance of CCAM in simulating the historically significant tropical cyclone event HINA over the Southern Pacific (170ºE,15ºS). Specifically, the study examines different configurations of the CCAM variable resolution grid used to improve climate simulation without a significant increase in computation. The TC HINA began on March 11 and ended on March 20, 1985, with a maximum wind speed intensity (MWSI) of 135kt and a minimum central pressure (MCP) of 910mb, classifying it as a Category 5 TC. To understand the impact of different resolution grids, we first simulate the TC at a uniform global resolution of 50km, then with a stretched grid configuration over the Australasia region (CORDEX domain). The study investigated the sensitivity of the simulated TC to the (i) initial condition, (ii) model's horizontal resolution (25km, 12.5km, 6.75km), and (iii) model's physics parameterization. The results show that all CCAM simulations underestimated the TC intensities (940-960mb) with the CORDEX grid, except for the 6.75km case, whose computation was costly. After moving the CORDEX centre domain (150ºE, 20ºS) further north-east (165ºE,10ºS), CCAM accurately reproduced the TC track, MWSI, MCP, and the wind and pressure relationship at 12.5km resolution. This finding suggests that the deterioration of the grid resolutions in other cubic faces of CCAM results in an inadequate amount of heat and moisture transport to fuel and intensify the cyclone simulated over the CORDEX domain. Our study illuminates the need for careful consideration around the placement of stretched grids to accurately simulate TCs, especially severe category.

Session 12B (Wednesday 7 Feb, 14:00-15:30), Talk 4

Analysis of Tropical Cyclone Activity over the Australian Region from NarCLiM CORDEX Simulations

Jyothi Lingala[1], Jatin Kala[1], Giovanni di Virgilio[2], Fei Ji[2], Eugene Tam[2], Julia Andrys[1], Stephen While[2], Carlos Vieirarocha[2], Dipayan Choudhury[2], Yue Li[2], Matthew Riley[2]

[1]Murdoch University, Perth, Australia. [2]NSW DPE, NSW, Australia

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Abstract

Tropical Cyclones (TCs) are intense low-pressure systems, bringing intense rainfall, strong winds, and storm surges that significantly affect coastal communities in Australia. A better understanding of regional-scale cyclone activity is particularly important under a warming climate. This study aims to investigate the TC climatology over the Australian region using Coordinated Regional climate Downscaling Experiment (CORDEX) simulations produced under historical (1951-2014) and future (2015-2100) scenarios (SSP126 and SSP370) as part of the NarCLiM project. We use the Tempest Extremes, an open-source algorithm, for identifying TCs from the regional climate model simulations driven with 5 CMIP6 GCMs. This algorithm detects storms based on the minimum sea level pressure criteria accompanied by a strong warm core in the upper atmosphere. The climatology of simulated TC tracks from 6-hourly data from historical simulations are evaluated against the available International Best Track Archive for Climate Stewardship (IBTracs, version V04) observations. We examine the frequency, intensity, track density and cyclogenesis shift in the projected storms. Furthermore, we aim to expand our knowledge upon previous studies that have highlighted a decrease in storms and increase in TC intensity over the Australian region.

Session 12B (Wednesday 7 Feb, 14:00-15:30), Talk 5

An Assessment of Model Projections of Climate-change Induced Extreme Storms on the South-eastern Coast of Australia

Wenjun Zhu[1], Xiao Hua Wang[1], William Peirson[2], Julio Salcedo-Castro[3,1]

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Abstract

General circulation models (GCMs) and their downscaled regional scale equivalents have been important tools for climate change studies. However, there has been limited assessment of the performance of GCM and downscaled models in simulating extreme storms in temperate coastal environments. This study assesses the model characterization of extreme storms in the heavily populated coast of south-eastern Australia. Twenty-year average recurrence interval (ARI) storm intensities derived from generalized extreme value (GEV) distributions based on observed and large-scale atmospheric model data are compared. Changes in extreme storms from past climate to a high-emission future scenario are also investigated.

Simulations of storm minimum surface pressures compared favourably with measured data. Both GCMs and downscaled models reproduced the observed decrease with increasing latitude along the coast in a 20 year ARI of minimum surface pressure. Both indicate that the minimum storm surface pressure should change negligibly in a high-emission future.

Although models underestimate the maximum 24-hour precipitation significantly, models' skills are improving significantly with CMIP epoch and downscaling. For the high-emission future scenario, the GCMs and NARCliM project 20 year ARI 24-hour rainfall will increase in the order of 25%. GCMs and corresponding downscale products presently do not represent the extreme value distributions of historical wind speed data well, overestimating at lower values of ARI and significantly underestimating in larger values of ARI. Significant changes in magnitude of 20 year ARI maximum daily average onshore wind speed are not projected under a high-emission future.

Session 12B (Wednesday 7 Feb, 14:00-15:30), Talk 6

Performance evaluation of 20CRv3 downscaling using WRF over southern Alaska with focus on temperature and precipitation in glaciated areas

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Abstract

Global warming has raised mean surface temperatures by 0.99 ± 0.15 °C from 1850–1900 to 2011–2020. The temperature rise has been greatest in the high latitudes. Alaska has one of the largest glaciated areas in the world, which is highly sensitive to climate change. Currently, the mass loss from Alaskan glaciers contributes to about a third of global sea level rise. Tidewater glaciers contribute non-linearly to sea level rise through their rapid retreat. Although internal controls strongly influence the tidewater glacier cycle, the ubiquitous retreat of Alaskan tidewater glaciers indicates climatic forcing is involved. Meteorological observations from this region are insufficient to assess the climatic influence across a tidewater glacier cycle. This project reconstructs the regional climate of southern Alaska by downscaling the NOAA-CIRES-DOE 20th Century Reanalysis (20CRv3) from 1837–2015. The Weather Research and Forecasting model (WRF) was used to downscale the reanalysis data to produce high-resolution 4-km (convection permitting) output. For 2010, five physics parametrisations were tested and evaluated using Global Surface Summary of the Day (GSOD) observational records. The leading parameterisation for temperature and precipitation (identified using RMSE, r2, and NME) was used to downscale the 179-year 20CRv3 dataset to reconstruct local climate and weather over southern Alaska over a significant part of a tidewater glacier cycle. The 20CRv3 downscaling has been compared to GSOD and ERA5 and will be used to assess the influence of climate on these glaciers for the downscaling period (1837–2015).

Session 12C (Wednesday 7 Feb, 16:30-18:00), Talk 1

Bringing the Australian climate science community together to help users: A National Partnership for Climate Projections

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Abstract

Recognising the demand from decision makers for high-quality, consistent and accessible climate information – the Department of Climate Change, Energy, the Environment and Water led the formation of a voluntary collaboration in 2022: the National Partnership for Climate Projections. It comprises key representatives from the Australian climate science community including federal, state and territory government agencies, universities, and Australian Government funded initiatives such as the National Environmental Science Program Climate Systems Hub and the Australian Climate Service. The aim of the NPCP is to develop consistent approaches to deliver comparable, robust, authoritative, fit-for-purpose future climate information to enable a wide range of users to assess their climate risks and plan more efficiently for potential opportunities.

The partners committed to work together to deliver the Climate Projections Roadmap for Australia. The roadmap outlines a collaborative approach to bring together existing initiatives from the partners, including the production (e.g., model selection), and delivery of climate projections. The partnership operates through three working groups focused on climate change science and projections, technology, computing and data, and climate services and user needs. This talk will focus on the goals of Working Group 3 – Climate Services and User Needs, and progress towards developing a federated understanding of user needs that integrates with delivery of climate data. Some key work of Working Group 3 to be outlined in the talk will include:

- mapping partner initiatives and users
- developing NPCP principles and standards for the communication, delivery and application of climate projections data and information.

Session 12C (Wednesday 7 Feb, 16:30-18:00), Talk 2

The CORDEX-Australasia multi-model ensemble and further downscaling: a new underpinning resource for climate change research and services

Michael R Grose[1], Giovanni Di Virgillio[2], Andrew Dowdy[3], Evans Jason[4], Howard Emma[5], Jatin Kala[6], Sean Lam[7], Chun-Hsu Su[5], Jozef Syktus[8], Marcus Thatcher[9], Trancoso Ralph[8]

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Abstract

A program of coordinated regional climate modelling was recommended by the Bushfire Royal Commission to help support climate change planning in Australia, as it provides valuable insights about future climate change in both space and time, including on climate extremes. Further Convection Permitting Modelling (CPM) at <4 km resolution has the potential to provide further insights, particularly for short-duration extremes and urban climate change.

A set of Australian-led climate simulations are now available, through the coordination of modelling effort under the CORDEX guidelines and through the National Partnership for Climate Projections, with contributions from the Australian Climate Service (including CSIRO and the Bureau), the NARCLIM2.0 program and Queensland Future Climate. This ensemble provides a significant new resource for climate change research and services in Australia. Through carefully selecting CMIP6 models as input and using a variety of regional climate models with different configurations, key questions on regional climate change can be explored in an organised way. All projections are available for SSP1-2.6 and SSP3-7.0, allowing the 'bookending' of a likely range of change by 2100, from the Paris Agreement to a plausible high scenario. Also, the ensemble enables analysis of Australia at 1.5, 2 and 3 °C global warming, and for 'low likelihood high warming' futures. Modelling for the intermediate SSP2-4.5 is available for some models. The ensemble also provides valuable context for further CPM programs for sub-domains or SSPs. Here we describe the key features of the ensemble and an overview of projections in the ensemble identified so far.

Session 12C (Wednesday 7 Feb, 16:30-18:00), Talk 3

Added value of regional climate projections for Australia

Christian Stassen[1], Emma Howard[1], Chun-Hsu Su[1], Benjamin Ng[2]

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Abstract

Climate projections are a valuable tool for understanding the likelihood of future climate change in the Australian region, including for enhanced planning and preparedness in relation to extreme events. With many types of extreme events projected to become more pronounced with climate change, there is an increasing need for robust fine-scale projections of key climate variables. Spatially and temporally high-resolution climate model output is generally needed in climate change impact and adaptation studies particularly when conducted on regional and local scales. Regional climate models (RCMs) provide such information by dynamically downscaling global climate model (GCM) information to these finer scales.

For RCMs to be useful it is essential that they improve some aspect of the simulated climate compared to a global model i.e., the RCM adds value compared to the GCM. The added value of two RCMs of the Australian Climate Service, the Bureau of Meteorology's BARPA and CSIRO's CCAM, is evaluated over the historical period (1985-2014) by comparing the model output against observations. The potential for added value is assessed for the future projections (2077-2099) by measuring how much the RCM climate change signal differs from its host GCM. Ultimately, the historical added value and the future potential added value are combined to a single normalised realised added value for both RCMs. We examine regions, seasons, and climate variables for which the RCMs demonstrate added value over their GCM counterparts and demonstrate the benefits of using a multi-model approach.

Session 12C (Wednesday 7 Feb, 16:30-18:00), Talk 4

Implementation of efficient bias correction methods for the Australian Climate Service

Alicia Takbash[1], Damien Irving[1], Justin R Peter[2], Thi Lan Dao[3,2], Arpit Kapoor[4,2], Andrew Gammon[2], Andrew Dowdy[3,2], Ulrike Bende-Michl[2], Doerte Jakob[2], Michael Grose[1]

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Session

12. Regional climate projections and applications

Abstract

Global Climate Models (GCMs) and Regional Climate Models (RCMs) are the primary sources of information to construct scenarios of how our climate will evolve. However, their outputs often disagree significantly with historical observations in space and time. Systematic errors (biases) make their direct output unsuitable for use as raw input to run impact models (e.g., hydrological, agricultural, and ecosystem models) to construct hazard scenarios. Making the output usable requires adjusting the biases to match historical observations, and the adjustments are then applied to the future GCM/RCM output.

One of the tasks of the Australian Climate Service is to produce bias-corrected RCM output so that there is a consistent set of bias-corrected high-resolution products available to the Australian community to assess climate risks and inform adaptation planning. Several bias-correction (BC) techniques, encompassing univariate and multivariate algorithms, are being investigated. Some preliminary analyses of the application of the BC techniques to CMIP6 RCM data will be presented.

Session 12C (Wednesday 7 Feb, 16:30-18:00), Talk 5

Projecting the future hydrodynamic environment of the Great Barrier Reef: a dynamic downscaling

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Session

12. Regional climate projections and applications

Abstract

The Great Barrier Reef (GBR) is facing multiple climatic threats, but it is unclear how the coastal physical conditions in the GBR will evolve into the future. While Global Climate Models (GCM's) can help us better understand these threats, GCM's spatial resolutions are too coarse to accurately represent shelf-break and coastal hydrodynamic processes. Moreover, GCM's rarely simulate tides which are crucial for advection and mixing at the coastal scale. Here, we aimed to address this limitation by constructing dynamically downscaled projections of the GBR that represent the fine scale processes that develop along the shelf-break and continental shelf that host the GBR. We utilized the eReefs modelling suite, an existing dynamic downscaling framework that is a key tool in the management of the GBR. New atmospheric and oceanic forcings for eReefs were derived from two high-resolution CMIP6 GCM's, representing two possible futures under a high forcing Shared Socio-economic Pathway. Developing these forcings involved removing drift and correcting regional biases in the GCM outputs. Furthermore, the riverine forcing was informed by hydrological projections of how catchment run-off could change through time. The downscaling configurations were validated against long-term observations and a historical hindcast and were found to reproduce coastal circulation patterns. Comparing historical and future runs revealed areas of persistent cold-water upwelling as well as areas that are heating quickly. This downscaling exercise allowed us to assess where the most vulnerable and the most resilient areas are within the GBR and could, therefore, inform forward-looking management decisions.

Session 12C (Wednesday 7 Feb, 16:30-18:00), Talk 6

Users' experience of weather forecasts and short-term climate information can affect their understanding of long-term climate projections

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Session

12. Regional climate projections and applications

Abstract

Rationale: Future climate projections are an important tool for climate change adaptation. A growing range of interactive online dashboards communicate future climate projections to users. Farmers represent an expert user-group for meteorological information, utilising multiple online weather products daily. Yet little is known of their use, or difficulties using, online multi-decadal climate products.

Method: From a synthesis of 52 in-depth interviews with Australian farmers, we detail farmers' initial experiences using My Climate View: an online dashboard providing location and commodity specific multi-decadal climate projections. A focus on users allows for identification of possible misunderstandings and difficulties in navigation.

Findings: Farmers demand for -and proficiency using- short term weather information was very high, supporting previous literature. In terms of long-term projections, My Climate View's future projections were valued by many users, with a variety of use cases identified. Yet familiarity with shorter term forecasts appeared to affect certain users' perceptions and opinions of long-term projections. Misconceptions included users confusing forecasts versus projections, and assumptions that projections were extrapolations of historic observations. These misconceptions can substantially affect trust and future use of climate services with potential negative ramifications for climate resilience.

Implications: User-led enquiries are vital to fully understanding end-users' experiences using climate products and can aid their development by revealing opportunities to reduce misunderstandings and improve trust. Farmers' own expertise can and should be considered a valuable research input into the design of longer-term climate projections.

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 1

Robust evidence of a slowdown of poleward ocean heat transport since 1979

Taimoor Sohail, Jan David Zika

UNSW, Sydney, Sydney, Australia

Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

Quantifying how heat is being absorbed and redistributed throughout the ocean is critical to understanding both global and regional climate change.

However, estimated trends in surface heat fluxes from atmospheric reanalyses vary greatly and do not match observed changes in ocean heat.

Heat enters the ocean at the sea surface and is moved throughout the ocean via mixing and ocean circulation.

While changes in ocean circulation are challenging to constrain the creation and destruction of water masses by surface fluxes and mixing (water mass transformation) must obey strict physical laws.

Here, we exploit these physical constraints via a novel approach called the Optimal Transformation Method (OMT). Using OMT, we adjust surface fluxes so that they are compatible with estimated changes in the distribution of heat and other tracers from ocean analyses and obey strict physical laws pertaining to water mass inventories.

Between 1979 to 2014, adjusted surface fluxes in the high latitudes (and particularly the Southern Ocean) have caused substantial warming, while heat fluxes into the equatorial and sub-tropical Indo-Pacific have reduced.

Balancing these fluxes changes, the transport of heat from the equator to the poles via the ocean, the critical pathway of the 'heat engine' of earth, has begun to slow.

Poleward heat transport into the Southern Ocean has dropped by ~65%, while poleward heat transport into the North Atlantic and North Pacific has dropped by approximately ~12% and ~28% respectively.

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 2

Changes In Ocean Oxygen Concentration since the 1960s.

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

In this study we use a new time-evolving atlas of ocean oxygen concentration to examine how the ocean oxygen inventory has changed since the 1960s. This atlas uses Data Interpolating Variational Analysis (DIVA) and explicitly includes advection and coastal boundary conditions. The velocity field comes from the CMCC Historical Ocean Reanalysis. The inclusions advection and coastal boundary conditions is novel in this global atlas and overcomes many of the difficulties associated with optimal interpolation.

We see a long-term decline in ocean oxygen inventory of -0.84% overall, 0.85% in the upper 100 m, 1.72% in the mid-ocean and 0.71% below 600 m depth. These results are consistent with prior studies (e.g. IPCC SROCC). In the mid-to-deep ocean we find that oxygen solubility changes can explain 11-29% of the oxygen decline.

The most striking result is that the Southern Ocean plays a major role in explaining total global ocean oxygen decline. Although only moderate relative declines (0.5-1%) compared to the oxygen minimum zones (OMZ) in the low-latitude oceans (up to 3% in the 100-600 m depth layer), the changes in the Southern Ocean extend from near the surface to the bottom. This Atlas also includes temporal variations in the oxygen change, in particular in the 1970s when oxygen in the southern hemisphere polar regions was increasing. A potential explanation of this increase in top-to-bottom oxygen is strong open ocean ventilation in the Maud Rise region.

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 3

Pathways and variability of the Circumpolar Deep Water access to ice shelf cavities in the Denman region

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

The Denman region is home to the Shackleton Ice Shelf, Scott Glacier, and Denman Glacier; the latter is the second largest contributor to the ice mass loss in East Antarctica. Melting the Antarctic ice shelves is driven predominantly by the ocean from below. The melt is most significant where the warm Circumpolar Deep Water (CDW) accesses the ice shelf cavity and reaches the grounding line. However, the relative contribution of the various processes regulating the CDW supply towards the ice shelf cavities in this region remains largely unknown. Here, we explore the CDW pathways in the Denman region using a high-resolution (roughly 1.4km) regional ocean-sea ice model, which includes thermodynamic ice shelves and tides. Using passive tracers released within a reservoir defined by the distribution of CDW offshore, we identify four major CDW pathways onto the continental shelf. The eastern pathway in Vincennes Bay is the dominant contributor to the CDW cross-shelf exchange, accounting for 55% of the total cross-shelf tracer exchange in the study region. However, most (82%) of the cross-ice shelf tracer flux originates from the central pathway in front of the Denman ice shelf. The tracer fluxes across the shelf and into the ice cavities show strong intra-annual variability, suggesting an important role played by the local ocean circulation in regulating the supply of CDW into the ice shelf cavities.

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 4

Unsupervised classification identifies warm, fresh and dense ocean regimes of the Antarctic margins

Taimoor Sohail, Jan David Zika

University of New South Wales, Sydney, Australia

Session

38. Antarctic and Southern Ocean Interactions

Abstract

The Antarctic margins are characterised by complex interactions of surface and ocean processes, producing distinct regions or `regimes'. Understanding where these regimes are and their future state is critical to understanding climate change. Based on a subjective assessment of ocean conditions, past research has identified fresh, dense and warm regimes in the Antarctic margins. In this work, we use an unsupervised classification tool, Gaussian Mixture Modelling, to objectively identify regimes around the Antarctic margins. Our objective method detects three regimes in an ocean model which match the subjectively identified fresh, dense and warm regimes, and indicates a future shrinking of the dense regime. Our method is adaptable to multiple datasets, enabling us to identify trends and processes in the Antarctic margins.

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 5

Antarctic Bottom Water pathways and variability in the Australian-Antarctic Basin

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Abstract

Antarctic Bottom Water (AABW) formation drives the lower limb of the meridional overturning circulation, affecting the Earth's climate, carbon cycle, and marine biological productivity. Recent findings note changes in AABW across the Southern Ocean, including freshening, warming, and contraction of the AABW layer. The challenging environment of Antarctica means in-situ observations are limited, hindering a comprehensive understanding of AABW circulation and variability. The global ocean model ACCESS-OM2-01 offers high-resolution data and a more accurate representation of AABW formation than previous models. This research targets the Australian-Antarctic Basin, examining AABW varieties from the Ross Sea and the continental shelf adjacent to the Adelie Land coast. We examine the interactions between these water masses and AABW export pathways using the ACCESS-OM2 model with 0.1-degree horizontal resolution. We use passive dye tracer concentration and horizontal advective fluxes to determine pathway locations and to investigate mixing of the AABW varieties. Ross Sea Bottom Water flows westward in the basin, with its core between 2000- and 3000-m isobaths, detectable as far west as 105E. Some Adelie Land Bottom Water merges with this flow, mixing with Ross Sea water, while another portion ventures to the abyss via numerous descending plumes. Despite Ross Sea Bottom Water having denser and larger transport near its origin compared to Adelie Land Bottom Water, the latter dominates in the abyssal depths of the Australian-Antarctic Basin. This dominance arises as much of the Ross Sea Bottom Water is exported eastward from the basin, coupled with its significant mixing on the westward trajectory.

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 6

Australia's 2019/20 Black Summer fire weather exceptionally rare over the last 2000 years; insights from a coastal East Antarctic ice core

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Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

The role of natural versus anthropogenic factors in Australia's record-breaking 2019/20 'Black Summer' fire weather remains unclear. Disentangling the relative influence of interannual to decadal climate variability from anthropogenic climate change on southeast Australian fire weather remains challenging due to large interannual rainfall variability and short observational records of fire weather (post 1950).

We reconstructed eastern Australian fire weather using an East Antarctic ice core sea-salt aerosol record that reflects the Southern Ocean atmospheric circulation anomalies and Antarctic stratospheric polar vortex strength required to pre-condition elevated fire danger over eastern Australia. We show the magnitude of the extreme 2019/20 Black Summer fire weather hazard is extremely rare over the Common Era (past 2000 years) with only six equivalent analogues, all prior to 1250 CE. Furthermore, the frequency of above average fire weather seasons in the decade preceding the Black Summer (74%) has only one equivalent analogue in the observation record (1980s) and four periods across the Common Era. The reconstruction also indicates that frequently used baselines for contextualising present day climate change, for example the pre-industrial period (1850-1900), may overestimate the increased frequency and severity of fire weather from anthropogenic forcing compared to Common Era natural variability.

Session 13A (Tuesday 6 Feb, 11:00-13:00), Talk 7

Can the Twentieth Century Reanalysis project (20CRv3) represent the synoptic conditions associated with increased snowfall in East Antarctica?

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Session

13. Antarctic and Southern Hemisphere extratropical atmosphere, ocean and ice interactions

Abstract

Weather systems in the southern Indian Ocean (SIO) drive East Antarctic precipitation variability and surface mass balance (SMB). However, long term variability in weather systems in this region is not well understood due to short instrumental records that are mostly limited to the satellite era. Ice core records from coastal East Antarctica suggest significant decadal variability in snowfall accumulation, but ~40 years of instrumental data is not enough to characterise climate variability in the high southern latitudes. We used self-organising maps to group weather patterns to investigate whether the Twentieth Century Reanalysis project (20CRv3) could represent the synoptic conditions that lead to snowfall in East Antarctica prior to the satellite era. We found that it is possible to use 20CRv3 to expand synoptic typing beyond the satellite era in the SIO. Annual precipitation at Law Dome as represented by 20CRv3 explains more than 50% of the variability in the annual accumulation in the Dome Summit South (DSS) ice core from 1950, compared to around 60% from 1979. Using 12 synoptic types (nodes), we found that the annual frequency of an individual node can explain up to 12% ($p<0.05$) of the variability in DSS annual accumulation in the 1948-2015, 1957-2015 and 1979-2015 periods. A linear combination of multiple nodes explain around 25% ($p<0.05$) of variability in DSS accumulation over both the 1979-2015 and 1957-2015 periods. These results will help contextualise Antarctic SMB variability over recent decades, with implications for better understanding the largest source of potential sea level rise.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 1

Will regional mid-latitude drying trends reverse if we reach climate stabilisation?

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Session

13. Antarctic and Southern Hemisphere extratropical atmosphere, ocean and ice interactions

Abstract

Changes from transient to equilibrium climate states following stabilisation of anthropogenic forcings will determine the long-term future of our climate, including the future of rainfall and drought. Several time-dependent processes play out over centuries to millennia as the climate stabilises, including the delayed warming of the Southern Ocean that sets up enhanced temperature gradient between the tropics and the Southern Ocean during the transient phase. It was previously found that the drying trend of the Southern Hemisphere mid-latitudes rebounds to a wetter climate partly in response to this stabilisation, but the regional pattern is highly non-uniform. In this study we look at LongRunMIP simulations over millennia following stabilisation at very high forcing and examine the circulation and rainfall response. We find that coincident with the peak meridional temperature gradient there is clear stabilisation and then reversal of mid-latitude annual drying. The response in atmospheric circulation in one case study has the character of a shift from positive to negative Southern Annular Mode (SAM). Some regions of the mid-latitudes, such as southern Australia, become drier and do not rebound to wetter conditions during the transition to an equilibrium climate state, whereas other regions such as eastern Australia may see transient drying that then rebounds to a wetter climate as a new equilibrium is reached. This study adds to growing evidence of a time-dependent response in rainfall and water availability to greenhouse gas emissions across key regions, including Australia, and further understanding is needed about short-term and long-term changes.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 2

Combined Impacts of Southern Annular Mode and Zonal Wave Three on Antarctic Sea Ice Variability

Michael D Eabry[1,2,3], Rishav H Goyal[1,2,3], Andréa S Tashetto[1,3], William R Hobbs[3,4], Alex Sen Gupta[1,2,3]

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

Large-scale modes of atmospheric variability in the southern mid-latitudes can influence Antarctic sea-ice concentrations (SIC) via diverse processes. For instance, variability in both Southern Annular Mode (SAM) and Zonal Wave Three (ZW3) have been linked to the abrupt 2015/16 sea-ice decline through changes in ocean-atmosphere momentum and heat fluxes. While SIC responses to each of SAM and ZW3 have been studied extensively, their interaction and synchronous impact on Antarctic sea-ice remain under-studied. In this study we investigate the interactions between SAM and ZW3 and associated combined impacts on Antarctic sea-ice using a 1,200-year simulation from a state-of-the-art climate model.

Our results suggest that zonal wind anomalies associated with SAM drive SIC anomalies in the marginal ice-zone via advection of ice normal to the ice-edge and Ekman drift. In contrast, meridional wind anomalies associated with ZW3 can have opposing dynamical and thermodynamical effects on SIC. Resultant SIC anomalies are also advected eastward, likely by the Antarctic Circumpolar Current.

The interaction of SAM and ZW3 leads to interesting regional SIC responses. Across most of western Antarctica, SIC anomalies generally coincide with the phase of ZW3-associated meridional wind anomalies, which are stronger near the ice-edge during negative SAM. This is likely due to modulation of background flow by SAM which can affect the location of ZW3 nodes close to the ice-zone. Over parts of eastern Antarctica, SIC anomalies can be sensitive to the sign of SAM, particularly in locations where the ice-edge has a prominent angle relative to the SAM-related zonal wind anomalies.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 3

Antarctic Sea Ice Response to the 2023 Transition from La Niña to El Niño

Stuart Anthony Browning

Risk Frontiers, Sydney, Australia

Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

The 2023 winter Antarctic sea ice extent anomaly was beyond anything observed during the satellite era. Media reporting implied that scientists were at a loss to explain the cause of this event. However, decades of existing research provide a robust context through which the sea ice deficit can be understood. The spatial pattern of sea ice anomalies throughout winter 2023 closely resembles the pattern of wind anomalies over the Southern Ocean: locations of sea ice deficit correspond to anomalously warm northerly winds, while locations of sea ice surplus correspond to regions of anomalously cold southern winds.

The pattern of winds and mean sea level pressure during June resembles the Pacific South American (PSA) 2-positive wave train emanating from convection anomalies in the western Pacific; and the PSA2 index had the highest winter values on record. By August the long wave pattern had transitioned from PSA2 positive to PSA1 negative, which has an opposite effect on the Amundsen Sea Low, and sea ice in the Bellingshausen Sea region recovered to almost normal levels.

PSA2 positive is typically associated with La Niña, while PSA1 negative is associated with El Niño. The sea ice anomalies in 2023 were at least in-part a response to strong atmospheric teleconnections associated with the tropical transition from persistent La Niña / IOD negative, to strong El Niño / IOD positive—the impacts of which were almost certainly amplified by extraordinary levels of global heat available for advection.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 4

Vulnerability of Antarctic ice shelves to swell induced breakup.

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

Weakening and loss of Antarctic ice shelves will be a major driver of future global sea level rise, as the decreased buttressing effect causes the adjacent ice sheet to speed up its outward flow into the sea. Two ice shelves that underwent large-scale calvings were the Wilkins and Voyeykov ice shelves in the late-2000s, which combined to remove over 2000km2 of ice from the continent. These calving events shared similarities as they occurred on ice shelves with thin outer margins, extensive surface crevassing and a significantly depressed sea ice barrier protecting the ice shelves. We showed that the loss of a sea ice barrier allows for more damaging ocean swell strains to reach the shelf, cyclically fatiguing it, and enhanced by both ice shelves being in their second season of high incoming strain. When paired with a weakened outer margin, the incoming swell strains eventually induced the shelves to calve. Using the Wilkins and Voyeykov calvings as an example, we also examine how vulnerable a selection of major ice shelves are to swell induced breakup following the record Antarctic sea ice lows of recent years.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 5 | Poster Session 1, Poster 31

Verification of a pressure-gradient algorithm to identify mid-latitude cyclones and their associated rainfall over southern Australia

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Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

Low pressure systems are associated with large proportions of total annual rainfall across Southern Australia, and improving the prediction of these systems has been identified as a key to improving seasonal rainfall forecasting. Studying the dynamics and variability of these weather systems in gridded datasets requires an identification algorithm that includes as many systems of interest as possible, and excludes all other weather systems of a different nature. In this work a simple algorithm is developed to identify low pressure systems and to classify them into different types of cyclones. We use the pressure-gradient method as the basis for such an algorithm, whereby a cyclone center is identified as any point with a lower value of pressure (or geopotential height) than all of its surrounding points, often with a minimum gradient. We compare the dataset of cyclones identified with this algorithm and datasets of cyclones from other methods, including widely-used automated identification schemes as well as a manual identification of cutoff lows in the Australian region. The Critical Success Index (CSI) is then used to quantify the similarities between cyclones identified by different algorithms. The CSI is also applied to the rainfall associated with the identified cyclones, to indicate the ability of the identification schemes to capture the rainfall-producing weather systems. It is shown that a simple pressure-gradient method applied at the synoptic scale has skill in identifying cyclonic rain systems in the southern Australian region at least equivalent to, and sometimes greater than, other well established identification methods.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 6 | Poster Session 1, Poster 27

Are the storm tracks shifting south?

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Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

Cool season rainfall in southwest and southeast Australia has been declining over recent decades, which has been linked to a reduction in rainfall from extratropical lows and cold fronts. Previously this rainfall decline had commonly been described as "a southward shift of the storm tracks", consistent with a positive trend in the Southern Annular Mode and expansion of the Hadley Cell. However, recent papers suggest that while rainfall related to weather systems may have decreased, changes in the frequency or location of fronts and lows are less robust. In this presentation, we use a range of methods of defining the storm track over the period 1959-2022, based on mean Eddy Kinetic Energy as well as the preferred locations of extratropical lows, cold fronts, high pressure systems, and subtropical jets, to reassess whether the storm tracks have indeed shifted south, either in the Australian region or across the southern hemisphere.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 7 | Poster Session 1, Poster 32

The semi-annual oscillation in observations and large model ensembles

Julie Arblaster[1], Ariaan Purich[1], Gerald Meehl[2]

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Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

The Semiannual Oscillation (SAO) is the dominant mode of variability in the seasonal cycle over the Southern Hemisphere mid- and high-latitudes involving a twice-annual expansion and contraction of the circumpolar trough around Antarctica. The observed SAO has undergone decadal timescale variability in its amplitude which is not well understood. It has also been shown to influence the development of different types of El Niño events. However the SAO's connection with other modes of variability has not been explored. In this study we first extend previous work to examine observed variability in the SAO, from station data and reanalyses, and its connection to modes of variability such as the Southern Annular Mode, El Niño Southern Oscillation and Interdecadal Pacific Oscillation. We then analyse long preindustrial control and historical simulations of CMIP6 models to attribute the role of anthropogenic forcing such as Antarctic ozone depletion in any observed changes. We will focus particularly on contrasting the simulation of the SAO and associated processes in large ensembles of the CESM2 and E3SMv2 models.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 8 | Poster Session 1, Poster 28

Insights into the modulation of sea salt variability in the Mount Brown South Cl- record

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Session

13. Southern Hemisphere extratropical variability and change: atmosphere, ocean, ice and their interactions

Abstract

The Mount Brown South (MBS) ice core (69°S, 86°E) has produced records of sea salt concentration and snow accumulation for examining past climate in East Antarctica. In a previous study, the sea salts, but not accumulation data, showed a significant, positive relationship with the ENSO from June to November. This study uses reanalysis data to provide insights into the mechanisms modulating this previously identified relationship for the winter season only. A teleconnection between the tropical Pacific and high-latitude winds that influences sea ice concentration in the vicinity of MBS was identified. Specifically, El Niño events are related to more sea ice, and La Niña events to less in an area to the northeast of the MBS site. Previous studies show that newly formed sea ice is a substantial source of sea salt. The MBS is a wet deposition site, and we show that sea salt is likely transported from the ENSO-affected area of sea ice via mesoscale storms that accompany high precipitation events. The storms themselves, and the accompanying precipitation show no significant differences between years of high and low sea salt concentration, which might help to explain the differences between the sea salt and accumulation data in the ice core record. Identifying the mechanisms modulating key variables such as sea salts and snow accumulation at ice core sites will provide further insights into what this valuable record can decipher about climate variability in the pre-instrumental period.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 9 | Poster Session 1, Poster 29

Unveiling Southern Ocean dynamics through direct numerical simulations: Insights into Antarctic gyre circulation and slope current

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

The Southern Ocean occupies a uniquely regal location in the globe, linking all the major ocean basins through its web of ocean circulation, thus serving as the hub of oceanic transport. Despite the presence of numerous studies, the exact nature of the physical processes that act on and affect the local and regional scale dynamics responsible for the rapid poleward heat transport and the melting of Antarctic ice shelves facilitated by the Southern Ocean remains unanswered. As a step towards better understanding of the role of important regional-scale circulation dynamics like the Weddell, Ross and Kerguelen gyre circulations, high fidelity direct numerical simulations of a closely Antarctic geometry were performed with a simplified bathymetry, forced only by the meridionally varying sea surface temperature. The results thus obtained were found to remarkably resemble the real-world system having slope current, bottom water formation and polar gyres, without any inclusion of wind forcing. The presented modus operandi extends solutions upward from the small turbulence scales to the large-scale processes like the well-known planetary mechanisms through down-scaling by utilizing the principles of dynamic similarity, producing energy-conserving flow solutions. Although limited by the absence of salinity and wind forcing, the study provides a practical proof to the applicability of the direct numerical simulations in understanding the dynamics of Southern Ocean including polar gyres and slope currents, onto which complexities can be added to further tune the system to accurately analyse the physical processes responsible for heat transport and bottom water formation.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 10 | Poster Session 1, Poster 26

Simulated trends and variability of Circumpolar Deep Water properties in the Southern Ocean.

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

Circumpolar Deep Water (CDW) is the warmest water mass in the Southern Ocean. Onshore transport of CDW contributes the most to heat transport to the Antarctic continental shelf. Observations indicate CDW has warmed, possibly explaining an increase in onshore heat transport and an acceleration of the Antarctic ice shelf melting in recent decades. There are plenty of dynamical mechanisms which could affect CDW warming, e.g., changes in surface wind stress, the Antarctic Circumpolar Current Front, upwelling, eddies and large-scale ocean circulations. However, because of sparse observations and the complexity between these dynamics and CDW, it is unclear how much CDW has warmed, how spatially variable the warming is, and what processes lead to CDW warming. We use the high resolution ocean-sea ice model ACCESS-OM2-01 - and first define CDW using different criteria, such as density, temperature and salinity. We then calculate the trend and variability of CDW temperatures between 1980 and 2018, to diagnose whether observed CDW warming is reproduced in the model. Finally, we determine the physical mechanisms of CDW changes and southward heat transport in temporal and spatial scales. We present regional variability of CDW trends around Antarctica and investigate the physical mechanisms that lead to changes in CDW, as well as the potential feedback due to climate change.

Session 13B (Tuesday 6 Feb, 14:00-15:30), Talk 11 | Poster Session 1, Poster 30

Record low Antarctic sea ice coverage indicates a new sea ice state

Ariaan Purich[1], Edward W. Doddridge[2]

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Session

38. Antarctic and Southern Ocean Interactions

Abstract

In February 2023, Antarctic sea ice set a record minimum; there have now been three record-breaking low sea ice summers in seven years. Following the summer minimum, circumpolar Antarctic sea ice coverage remained exceptionally low during the autumn and winter advance, leading to the largest negative areal extent anomalies over the satellite era. Here, we show the confluence of Southern Ocean subsurface warming and record minima and suggest that ocean warming has played a role in pushing Antarctic sea ice into a new low-extent state. In addition, this new state exhibits different seasonal persistence characteristics, suggesting that the underlying processes controlling Antarctic sea ice coverage may have altered.

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 1

Reconstructions and model simulations of regional sea surface temperatures place recent Great Barrier Reef temperatures into a multi-century context

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

High sea surface temperatures (SST) contributed to mass coral bleaching events on the Great Barrier Reef (GBR) in 2016, 2017, 2020 and 2022. Although rapidly rising global and regional sea surface temperatures have been attributed to climate change with very high confidence, the long-term context of SSTs in the GBR remains unclear, since local meteorology and ENSO can influence SST extremes, and other drivers such as water quality can influence coral bleaching. A landmark reconstruction of SSTs by Hendy et al., (2002) from 1700–2001 CE showed that mean GBR SSTs in 2002 were not unusually high relative to the past three centuries, and that SST and sea surface salinity were higher in the 1700s than in the 1900s. Since then, SSTs in the GBR have continued to increase and a network of higher resolution temperature-sensitive coral records has been developed. In this study, we deploy a network of SST-sensitive oxygen isotope and trace element coral records from the Coral Sea region to infer spatial-mean SSTs in Jan–Mar at annual resolution from 1617–1995. We then employ climate model simulations to separate the influence of climate change from natural variability. The recent thermal stress events exceeded the upper uncertainty bound of reconstructed SSTs between 1617–1900. This study illustrates how a clearer picture of the climate of past centuries, in tandem with targeted climate model experiments, can play a key role in contextualising natural and anthropogenic influences on significant ecosystems such as the iconic Great Barrier Reef.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 2

Australian precipitation extremes over the last 1000 years: How do ephemeral lake records compare against climate models?

Sophie Grunau, Timothy Cohen

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

The flooding in Queensland and NSW over the last years has affirmed the impacts that extreme precipitation has on people's lives and their livelihood. To be better prepared for such extremes in the future we need to know how often and under which climatic circumstances they occur. However, climate models for Australia still involve high uncertainty in predicting the likelihood of precipitation extremes that lead to large flooding events. This is attributed to the limited record of hydro-climatic paleo data across Australia. Though efforts have been made to improve the record of past precipitation extremes, previous studies have focused on high resolution at specific locations rather than a large spatial coverage.

Our project tackles this challenge by utilising the strongly link between precipitation and filling events of ephemeral lakes. The paleoenvironmental evidence collected from various ephemeral lakes in key quadrants of the country allows the establishment of a hydro-climatic paleo record on a large spatial scale. A timeframe of the last thousand years permits the comparison of frequency and magnitude to inter-annual variability of precipitation extremes in different regions across Australia. Ultimately, a comparison of the established record against other paleo data and an analysis of global climate simulations will result in an improved understanding of past precipitation extremes and the importance varying climatic drivers have in different regions across Australia.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 3

Comparing past and future drought severity in the Murray-Darling Basin

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

Managing future water security in the Murray-Darling Basin requires a thorough understanding of the likelihood of severe, multi-year drought events. However, instrumental records are too short to characterise baseline climate risks, particularly for infrequent extreme events like droughts.

We reconstructed over 800 years of Murray River streamflow using a suite of tree-ring chronologies from regions with strong climate teleconnections to the Murray-Darling Basin. The reconstruction (1190 - 2000 CE) captures a broad spectrum of natural climate variability, not fully represented in instrumental records, contributing to an improved understanding of the occurrence rate of multi-year droughts.

We use this extended record to benchmark the severity of the Millennium and Tinderbox droughts using bivariate models which account for the different distributions of the various drought elements (duration, magnitude, and peak) and the correlation between them.

To contextualise how future drought risk compares to the past seven centuries, we repeated the joint probability analysis considering future streamflow projections. We calculated projections of Murray River streamflow using an ensemble of four downscaled and bias-corrected CMIP5 climate models.

The Millennium Drought was exceptional compared to the palaeo-record, supporting previous studies that found that increasing temperatures are amplifying the impact of precipitation deficits in eastern Australia. Compared to the instrumental period droughts, climate models project an increase in future drought severity, with droughts of much longer duration and substantially higher magnitude than the Millennium Drought occurring in two projections. Such events should be considered in long-term water management planning, given the potential socio-economic and environmental consequences.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 4

Beyond Instrumental ENSO: Investigating Sequential Events through Past and Future Perspectives

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

he El Niño/Southern Oscillation (ENSO) phenomenon constitutes the largest single source of interannual climate variability on a global scale. While a single ENSO event can have a large impact, back-to-back (or even triple) events can have much longer lasting consequences. This was recently experienced during the 2020-2022 La Niña's, where parts of Australia and Asia were plagued by recurrent floods, while the Southwest USA and western South America suffered from a severe and extended drought. Based on the instrumental period alone, this protracted La Niña appears to be an irregular occurrence, with only two other similar events on record. However, instrumental records are too short to adequately determine the likelihood of infrequent events. Here, we analyse a range of available ENSO reconstructions and compare the occurrence of triple dip' La Niña or El Niño events with that suggested by the instrumental record and climate models. We also ask whether sequences of events, for example, strong El Niño's that follow multi-year La Niña events, are present in the palaeo record, and how this compares with model projections. Our results show that triple dip La Niña's are likely to occur, on average, 1.7 times per Century and are likely followed by an El Niño event based on a range of paleo reconstructions. The climate models are much more variable and some show both higher frequencies and almost a complete absence of these events.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 5

3000 years of effective infiltration in the Sydney basin from stalagmite trace elements

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

Palaeoclimate proxy records can extend our limited instrumental data for eastern mainland Australia, but there are no local, high-resolution centennial to millennial scale palaeoclimate records for the region to date. This has led to a reliance on remote archives to investigate past variability. Here we present a 3000-year hydroclimate record from strontium and yttrium variability in a stalagmite from Wombeyan Caves, NSW from 1050BCE to 2006CE. Principal component analysis reveals typical behaviour of strontium and yttrium as soluble and insoluble hydroclimate sensitive trace element endmembers, and a consistent negative correlation between them is strong evidence of hydroclimate control on their transport and incorporation into the stalagmite. Age control for the record prior to 1956 is provided by two radiocarbon-based age models featuring different approaches to account for the radioactively "dead" carbon fraction (DCF) sourced from the host rock, and a soil carbon continuum model post 1956 to model the transport of bomb-derived atmospheric carbon-14 into the cave. Key features of the record include a relatively wet Medieval Warm Period (MWP), an abrupt shift around 1300CE to drier conditions at the start of the Little Ice Age (LIA), a dry LIA punctuated with extreme wet episodes in the early 1400's and 1500's, and a gradual drying trend from 1700CE onwards. Of note is the unusual absence of large extremes post 1700CE relative to the earlier parts of the record. The record provides a valuable new local resource for investigating the drivers of eastern mainland Australian hydroclimate variability and extremes.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 6

Assessing rainfall deficits during the 2017-2019 eastern Australian drought, in the context of previous observations

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

The 2017-2019 eastern Australian drought was historically unprecedented in terms of the three-year cool-season and total rainfall deficit. Here we evaluate the degree to which this drought was unusual, given our prior empirical knowledge of the climate system. We use Linear Inverse Models (LIMs) to estimate the full distribution of Australian precipitation variability, based on the spatial and temporal covariance structure of the observed climate system. This overcomes one of the limitations of precipitation observations, which is that the observational record of precipitation is not long enough to quantify the full natural range of precipitation variability, particularly in terms of the statistics of multi-year events.

Although the total 2017-2019 rainfall deficit was historically unprecedented, we find that it was **not** outside the expected range of long-term internal variability. That is, given what we knew about Australian precipitation prior to the 2017-2019 drought, a three-year drought of equal severity was not unexpected. However, the total cool-season deficit **was** outside the expected range of variability.

The LIMs demonstrate that eastern Australian droughts of similar severity to the 2017-2019 drought are typically associated with El Niño-like sea surface temperature (SST) anomalies. However, only the final year of the drought coincided with a (weak) El Niño event. The SST anomalies observed during 2017 and 2018 are not reliably associated with negative precipitation anomalies in eastern Australia. SST anomalies of 2019 are typically associated with dry conditions across mainland Australia, particularly in the east.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 7 | Poster Session 2, Poster 17

Changing spatial characteristics of rainfall in Australia

Acacia Pepler

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

Extreme rainfall that covers a large spatial area, such as occurred in early February 2022, can cause significant impacts including widespread riverine flooding. However, while the intensity of heavy rainfall is likely to increase in a warmer climate, little is known about changes in spatial extent, which is sensitive to the dynamics of the associated synoptic systems. Using gridded rainfall observations from 1900-2022, we identify contiguous clusters of rainfall, allowing heavy rainfall to be classified based on its spatial extent. This is used to assess the links between synoptic systems and rainfall of varying spatial extent, as well as identifying whether there are long-term trends in the relative frequencies of widespread or localised heavy rainfall across Australia.

Session 14 (Friday 9 Feb, 11:00-13:00), Talk 8 | Poster Session 2, Poster 15

Identifying extreme periods in a new Common Era temperature reconstruction for southeastern Australia

Kathryn J Allen

University of Tasmania, Hobart, Australia

Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

Annually resolved temperature reconstructions for the entire Common Era are rare in the Southern Hemisphere (SH). Here, we introduce a new Common Era summer (Dec-Feb) temperature reconstruction ensemble for southeastern Australia based on tree rings. Statistically, this new 2000 year reconstruction represents a significant quality improvement on the original Mt Read Huon pine reconstruction that extends back ~ 4000 years. Explained variance in the most recent nests is up to 65%. The interannual relationship with temperature is limited to southeastern Australia, although the recent trend is consistent with global scale trends. Evidence for the Little Ice Age and Late Antique Little Ice Age appears limited to a relative absence of warm years, while the expression of the Medieval Climate Anomaly was dampened by the occurrence of frequent cool years. In contrast, the Roman Warm period is consistent with a high number of warm years. The coldest period, and biggest change in trend across multiple time scales, occurs during the 8th - 9th Century. Significant statistical relationships with Western Boundary Current extension regions in the Indian and Pacific Oceans suggests the record may provide insight into past summer variability in these regions. The reconstruction makes a significant contribution towards better understanding Southern Hemisphere temperature variability over the Common Era.

16. Tropical climate variability: dynamics, teleconnections, and change

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 1

The future of the El Niño–Southern Oscillation: using large ensembles to illuminate time-varying responses and inter-model differences

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Future changes in the El Niño–Southern Oscillation (ENSO) are uncertain, both because future projections differ between climate models and because the large internal variability of ENSO clouds the diagnosis of forced changes in observations and individual climate model simulations. By leveraging 14 single model initial-condition large ensembles (SMILEs), we robustly isolate the time evolving response of ENSO sea surface temperature (SST) variability to anthropogenic forcing from internal variability in each SMILE. We find non-linear changes in time in many models and considerable inter-model differences in projected changes in ENSO and the mean-state tropical Pacific zonal SST gradient. We demonstrate a linear relationship between the change in ENSO SST variability and the tropical Pacific zonal SST gradient although forced changes in the tropical Pacific SST gradient often occur later in the 21st century than changes in ENSO SST variability, which can lead to departures from the linear relationship. Single forcing SMILEs show a potential contribution of anthropogenic forcing (aerosols and greenhouse gases) to historical changes in ENSO SST variability, while the observed historical strengthening of the tropical Pacific SST gradient sits on the edge of the model spread for those models for which single forcing SMILEs are available. Our results highlight the value of SMILEs for investigating time-dependent forced responses and inter-model differences in ENSO projections. The non-linear changes in ENSO SST variability found in many models demonstrate the importance of characterising this time-dependent behaviour, as it implies that ENSO impacts may vary dramatically throughout the 21st century.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 2

Detecting ENSO Variance Changes in a Warmer World

Yann Y Planton[1], Jiwoo Lee[2], Andrew T Wittenberg[3], Peter J Gleckler[2], Éric Guilyardi[4], Shayne McGregor[1], Michael J McPhaden[5]

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Earth's climate naturally fluctuates on intraseasonal to interdecadal timescales ('internal variability'), partly due to processes intrinsic to the climate system. This internal variability is present in climate model simulations, as evidenced by the varying climate conditions in 'initial-condition large ensembles (LEs)'. These LEs allow to isolate the role of internal variability and better constrain climate projections. We analyzed the evolution of El Niño–Southern Oscillation (ENSO) as simulated by LEs from the 6th Coupled Model Intercomparison Project (CMIP6) and show that the ENSO variability is significantly increasing over the historical period and under future global warming. The magnitude of the internal variability in an LE and the size of said LE determine the increment needed to detect a significant change, reinforcing the need for properly size LEs. We found that the increased ENSO variability is linked to significant changes of the mean state of the tropical Pacific.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 3

Future projections of ENSO teleconnections with extremes in CMIP6

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

El Niño-Southern Oscillation (ENSO) is the most dominant source of climate variability globally and many of the most devastating impacts of ENSO are felt through extremes. Here we present ENSO teleconnections with three extreme indices from the collection defined by the Expert Team on Climate Change Detection and Indices (ETCCDI). We describe ENSO's global teleconnection patterns with extreme maximum temperatures (TXx), extreme minimum temperatures (TNn), and extreme 1-day rainfall (Rx1day) in the historical period. We find that the spatial pattern of the ENSO influence on extremes is like that of mean temperature and precipitation, but with some regional differences, such as in south-eastern Australia and Central America. We use fourteen models from the Coupled Model Intercomparison Project Phase Six (CMIP6) to assess changes in teleconnections under a future warming scenario and compare changes in the extreme teleconnection to changes in the mean. We find that more regions show an amplification of the historical ENSO teleconnection with mean temperature and precipitation than a dampening under a high-emissions climate projection. We find the response of the extremes to be very similar to the mean response, with even larger changes in some regions.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 4

Pacific climate variability and its regional impacts in warmer, stabilised climates

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

The El Niño Southern Oscillation (ENSO) in the tropical Pacific is the main mode of inter-annual climate variability and a key driver of regional climate across much of the globe. Future changes in its behaviour are highly policy-relevant as they would have large impacts across many regions and significantly affect ecosystems and livelihoods. In this presentation, we explore how ENSO variability evolves in multi-century experiments under fixed atmospheric concentrations of greenhouse gases, where global mean surface temperatures are slowly stabilising.

We show how ENSO variability and its teleconnections change in a range of climate models and experimental designs. Idealised projections under fixed atmospheric concentrations of greenhouse gases across multiple levels of global warming, from 1.5°C to 5°C, are evaluated for the UK Earth System Model 1 alongside abrupt forcing experiments with the Community Earth System Model 1 (among others). The differences in how ENSO and its teleconnections respond to further warming in long, multi-century experiments under constant forcing conditions are compared and contrasted to the expected ENSO changes in rapidly warming, transient climate change projections.

These differences are important to understand in the context of ambitious mitigation scenarios that aim to stabilise global temperatures at, or below, the Paris Agreement temperature targets.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 5

Insights into ENSO dynamics from a model analogue technique

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

The contribution of different climate variables in different basins to El Niño Southern Oscillation (ENSO) evolution is not entirely clear. The influence of different regions on ENSO is typically studied using initialised models, however the computationally cheaper model analogues technique shows similar predictive skill. This suggests that model analogues can provide insights into what lends skill to ENSO predictions, and thus what regions or variables are dynamically important for ENSO.

An ensemble of model analogues consists of climate states analogous to some target state, selected from a long model run (e.g. pre-industrial control). The evolution of these analogues is then used to predict the evolution of the target state. Forecast skill is affected by the weighting of regions and variables to select analogues, and provides an indication of the relevance of these regions and variables to ENSO. For example, analogues selected from tropical Pacific sea surface temperature (SST) and sea surface height (SSH) outperform those selected from just tropical Pacific SST at lead times longer than 6 months, indicating that SSH is relevant to ENSO evolution at those timescales.

While it is known that SSH helps forecasts overcome the spring predictability barrier, this result demonstrates the utility of model analogues for these types of questions. Our study investigates the impact of SSH, SST and wind stress in a variety of regions at different lead times. We also investigate analogue forecast skill for ENSO events of different sign, strength and locations, to delve into the processes that drive differences between events.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 6

Exploring the climate effects of sea surface temperature patterns through modified AMIP experiments

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Spatial patterns in tropical sea surface temperatures are extensively studied due to their impact on year to year variability via climate drivers such as the El Niño Southern Oscillation. Interest has recently turned towards longer timescales, where the teleconnections of long term trends in sea surface temperature patterns remains unclear and contribute to uncertainty in future projections. Adding to uncertainty is the fact that fully coupled general circulation models generally exhibit El Niño-like trends in sea surface temperatures compared to the observed cooling in the Eastern Tropical Pacific over the satellite era. Recent studies have suggested this difference represents a systematic bias in the models rather than differences in internal variability alone.

This work aims to understand the importance of the pattern effect on global and regional climates through novel atmospheric model simulations. Forcing atmospheric models with artificial yet realistic tropical sea surface temperature datasets produced using new statistical techniques, provides a simple method for studying the pattern effect while avoiding the potential biases of coupled models. This talk will compare the response of two atmospheric models, the AMIP configurations of ACCESS ESM 1.5, and CAM6, to three different sea surface temperature trend patterns which have been constructed via a linear inverse model. We will highlight the modelled role of the pattern effect on surface climate trends and global circulation, pointing to its varying strength in different regions, and will discuss differences and biases present in each of the models.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 7

The dynamics of the El Niño Southern Oscillation diversity in the Recharge Oscillator framework

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

This study investigates the ENSO dynamics for the eastern Pacific (EP) and central Pacific (CP) events in reference to the canonical ENSO (T). We use the recharge oscillator (ReOsc) model concept to describe the ENSO phase space, based on the interaction of sea surface temperature (T) and thermocline depth (h), for different types of ENSO events. The results show that dynamics of the CP and EP events are very different from each other and from T events. The canonical ENSO events fit closest to the idealised ReOsc model and have the most clearly oscillating ENSO phase space, suggesting it is the most predictable ENSO index. The EP-index is similar to the canonical ENSO, but the phase space transitions are less clear, suggesting less of an oscillatory nature, and is more focussed on extreme El Niño and discharge states. The CP-index, in turn, does not have a clear propagation through all phases and is strongly skewed towards the La Niña state. The interaction between CP and h is much weaker, making the mode less predictable.

Further, CMIP6 models are also used to analyse the ENSO dynamics and statistics for T-index. The characteristics out-of-phase cross-correlation between T and h is negative at time lag zero, which is quite different from the observations. The ENSO phase-dependent parameters also show biases relative to observations. These findings illustrate the distinct features and significant biases in CMIP6 model simulations, resulting in further investigation and improvement for a better understanding of ENSO dynamics within the ReOsc framework.

Session 16A (Friday 9 Feb, 11:00-13:00), Talk 8

The tropical Atlantic can force La Niña events, but not El Niño events

Peter van Rensch[1], Shayne McGregor[1,2], Dietmar Dommenget[1,2], Daohua Bi[3], Giovanni Liguori[4,1]

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

There have been many great advances in our understanding of the Atlantic influence on the Pacific. Studies have shown that warm tropical Atlantic sea surface temperature anomalies (SSTA) earlier in the year are linked to a developing La Niña later in the year. We show using observations and models that an asymmetry exists in the opposite side of this relationship, i.e., a cold Atlantic does not lead to an El Niño.

We used Atlantic pacemaker model experiments, where a fully coupled atmosphere and ocean model is forced with observed Atlantic SSTA, finding that modelled La Niña events tend of occur in unison with observed La Niña events. This unison in occurrence was not seen for El Niño events. In the model, the asymmetry arises due to the inability for cold western tropical Atlantic SSTA to initiate a tropical wide atmospheric response, which is seen for warm Atlantic SSTA.

The model also indicates that the Pacific initial state is an important factor for determining the efficacy of the Atlantic impact on the Pacific. The Atlantic is more able to force a La Niña event at the end of the year if the Pacific surface and subsurface is in a neutral condition at the beginning of the year.

Session 16B (Friday 9 Feb, 14:00-15:30), Talk 1

Forced changes and internal variability in the Pacific Walker Circulation over the past 800 years

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

The Pacific Walker Circulation (PWC) has a major influence on weather and climate worldwide. But our understanding of 1) its response to external forcings; and 2) its internal variability across timescales remains unclear. This is in part due to the length of the observational record, which is too short to disentangle forced responses from internal variability.

Here we assess the anthropogenic (and other) impacts on the PWC, using a new annually-resolved, multi-method, palaeoproxy-derived PWC reconstruction ensemble spanning 1200-2000. The reconstruction is derived from 59 palaeoclimate proxy records, mostly from the Iso2k database of water isotope proxy records. The ensemble comprises 4800 members that sample uncertainty from observational data, reconstruction method, and record chronologies.

We identify a significant PWC weakening in the 1-3 years following large volcanic eruptions, similar to the response seen in some climate models. However, we find no significant industrial-era (1850-2000) PWC trend relative to the preceding 650 years, which contrasts the PWC weakening simulated by most climate models. In fact, the strength of the PWC is not correlated with global mean temperature across timescales. We also find that the 1992-2011 PWC strengthening—previously attributed either to volcanic or anthropogenic aerosol forcing—was indeed anomalous, but not unprecedented as compared to the past 800 years. Hence it may have occurred due to decadal internal variability. The one place we did identify an industrial-era PWC change is in the power spectrum, where a post-1850 shift to lower-frequency variability suggests a subtle anthropogenic influence.

Session 16B (Friday 9 Feb, 14:00-15:30), Talk 2

ENSO diversity, transitions and projected changes

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Diverse characteristics of ENSO events occurring either in the Eastern Pacific (EP) and Central Pacific (CP), have led to a shift in the traditional view of tropical coupled ocean- atmosphere systems and present a challenge in light of recent changes and possible future ENSO behaviour. The probability of a transition from one type of event to another is influenced by multiple factors of which many are projected to change with global warming. Here we assess the likelihood of transition from one ENSO state to another in long instrumental records and climate models. We find specific transitions are more likely than others. For example, strong EP El Niño events are more likely to transition to La Niña events than to El Niño events. The strength of an El Niño event is found to be an important factor. Consecutive CP El Niño events, unlike consecutive EP El Niño events, are more likely to occur after a strong CP event. Under a high emission scenario, we find significant changes of transitions.

Session 16B (Friday 9 Feb, 14:00-15:30), Talk 3

Quantifying ENSOs impact on Australia's regional monthly rainfall risk

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

The El Nino-Southern Oscillation (ENSO) is considered an important driver of rainfall variability in Australia, amongst many other global locations. Despite knowledge of the expected modulation of seasonal rainfall by ENSO, there is no consistently used method to quantify what role ENSO played in driving the observed anomalous rainfall. In this manuscript we adapt the Fraction of Attributable Risk (FAR) method, commonly used to identify the anthropogenic impact on a particular event, to quantify the impact of ENSO on the occurrence of monthly rainfall anomalies. We explicitly calculate the ENSO induced change in risk for all observed spring precipitation rates for our eastern Australian regions, but also identify a prominent role for ENSO in driving large rainfall anomalies of spring 2022. Though we choose to focus on ENSOs impact on rainfall in various Eastern Australian regions, the results are applicable to other climate modes, regions and climatic variables.

Session 16B (Friday 9 Feb, 14:00-15:30), Talk 4

Variability of northern Australian rainfall drivers throughout the wet season

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Northern Australian rainfall is highly variable from subseasonal to seasonal, interannual and interdecadal timescales. Large-scale climate drivers such as the Madden-Julian Oscillation, Indian Ocean Dipole, El Nino-Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation contribute to this high variability. However, the influence of these climate drivers on northern Australian rainfall changes from austral spring through to autumn, which has implications for rainfall predictability over northern Australia. While the influence of local and remote sea surface temperatures (SSTs) on northern Australian rainfall peaks in November, this relationship decreases dramatically by January, after the onset of the Australian monsoon. The teleconnection with ENSO re-emerges in February, making ENSO a source of predictability from austral spring to the beginning of summer, and again for the later part of the monsoon season and beyond. The mechanisms that lead to the break-down (January) and re-establishment (February) of the SST-influence on northern Australian rainfall, as well as the key drivers for rainfall variability throughout the wet season, will be discussed.

Session 16B (Friday 9 Feb, 14:00-15:30), Talk 5

Can we forecast the retreat of northern Australia's rainy season?

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

According to the Bureau of Meteorology, the northern Australian wet season extends from November through to April. As the tropical dry season transition begins, crop farmers need to prepare for annual crops or pasture/fodder harvest, whilst beef producers start making decisions regarding herd numbers and feed rationing. Knowing if the last wet season rains (i.e., northern rainfall retreat; NRR) are likely to be later or earlier than usual would be valuable for agricultural industries as well as the infrastructure and tourism sectors. While the Bureau provides forecasts of the northern rainfall onset prior to September, there are no forecasts of the NRR. Here, we draw on three different NRR definitions and investigate whether there is any skill in forecasting the chance of an early or late retreat.

Based on the Australian Gridded Climate Data from 1950-2019, we find that, typically, NRRs occur ~1 week later than normal across the far northern tropics following La Niña events, but there is little change for El Niño. Retreats are also more common when the Madden Julian Oscillation is in phases 6 and 7, when convection passes through the western Pacific. Utilising the Bureau's seasonal forecast system, ACCESS-S2, we find that the model is moderately skillful in forecasting the NRR timing across the far northern regions at a lead time of ~2½ months, however, the skill is relatively poor in the subtropics and arid locations. We will highlight the various challenges of predicting the timing of the NRR at such long lead times.

Session 16B (Friday 9 Feb, 14:00-15:30), Talk 6

The Link Between the Madden-Julian Oscillation and Rainfall Trends in Northwest Australia

Alex Borowiak

The University of Melbourne

Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

The monsoon season in northwest Australia has experienced a rise in rainfall since the 1950s. Although previous studies have explored the reasons for this increase, the trend has not been fully explained. It is crucial to understand the cause of this trend to interpret climate projections and local water-sensitive services.

Our study examines the role of the Madden-Julian Oscillation (MJO) in explaining the rainfall increase. Since 1974, the MJO has had a longer duration in phases associated with increased rainfall in northwest Australia (Phases 5 and 6) during the monsoon. We have found that the rainfall trend in northwest Australia is only noticeable during MJO phases linked to increased rainfall, resulting in a significant change in daily rainfall distribution in these phases. The MJO has contributed to both an increase in the number of rain days each monsoon and the total rainfall each monsoon. The increasing occurrence of these MJO phases explains the majority of the rainfall increase, rather than an increase in daily rainfall that is independent of MJO phase, although there is some sensitivity to MJO definition.

19. Extreme weather and climate events: contextualisation and attribution

Session 19 (Friday 9 Feb, 14:00-15:30), Talk 1

Uplifting Extreme Event Attribution Science for Decision-Makers in Australia

Hannah Bourbon[1], Francine Machin[1], Eric Lede[2], Brenda Mackie[3], Helen Bloustein[4], David Putland[4], Sarah Bassett[5], Ramona Dalla Pozza[5], Pandora Hope[6]

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

Climate change is driving an increased frequency and intensity of extreme heat and rainfall events, which are exacerbating risks to communities, ecosystems and assets across Australia. In collaboration with the Bureau of Meteorology, the National Environmental Science Program Climate Systems Hub and the Australian Climate Service, 43 semi-structured interviews were undertaken with Australian decision-makers across the local, state and federal government levels to understand the diversity of attribution related decision-making needs. The results of these interviews were then used to investigate the capabilities of 48 attribution science, services and communications experts to meet these decision-making needs.

We present a comparative analysis of the diversity of attribution-related decision-making needs, as well as the existing capabilities, enablers, constraints, and pathways forward to meeting these needs. Results show that, to enhance outcomes, decision-makers require consistent, transparent and well-defined terminologies and methodologies, as well as increased emphasis on impact attribution, action-oriented communication and comprehensible science. Attribution scientists, services and communicators were readily able (or nearly able) to meet some of these needs to varying degrees, but many gaps still remained. These gaps were pervaded by barriers such as the wide-variety of attribution methods and their inherent strengths and weaknesses. Factors that facilitated closing these identified gaps included collaboration across the attribution space: from scientists to service providers to knowledge brokers. Multiple pathways to advance attribution science and services for decision-makers in Australia were identified, with each requiring the involvement of the full spectrum of attribution stakeholders – both in Australia and abroad.

Session 19 (Friday 9 Feb, 14:00-15:30), Talk 2

Quantifying human exposure to single and multi-variate emergence of local climate change

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

As the world warms due to human-caused greenhouse gas emissions we are increasingly seeing the effects of climate change through more frequent and intense extreme events and impacts on the local scale. Climate change emergence metrics are often used to quantify and investigate such changes. Previous studies have typically estimated the emergence of local climate changes using univariate techniques such as signal-to-noise. In this study we quantify local climate change using a sigma dissimilarity method which allows for multivariate emergence analysis and changes in different combinations of mean and extreme climate indices to be examined. We apply this technique to observational temperature and precipitation data across the globe and show that the local climate change signal is becoming increasingly clear, particularly in the tropics and lower-income regions, in combinations of both mean and extreme indices. A high proportion of people are already experiencing unfamiliar local climates in means and extremes. In El Niño years, we see particularly large population exposure to local climates outside the realm of natural variability. This study highlights the rapid climate changes affecting the world's most vulnerable people and the need for immediate greenhouse gas emissions reductions.

Session 19 (Friday 9 Feb, 14:00-15:30), Talk 3

Detection and attribution of changes in temperature and precipitation extremes over Aotearoa New Zealand

Dáithí Stone, Peter Gibson, Suzanne Rosier, Sam Dean, Raghav Srinivasan

NIWA, Wellington, New Zealand

Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

We present two ensembles of simulations over the past 40 years using CSIRO's CCAM model in the C288 configuration with 12km resolution over New Zealand tapering to 105km on the far side of the world (meaning 14-30km over Australia). The first ensemble is driven by observed radiative and ocean surface conditions, while the second ensemble is driven by naturalised versions of those conditions, e.g. with greenhouse gases at circa year-1850 levels and sea surface temperatures cooled accordingly. We use these simulations to perform a detection and attribution analysis of trends in daily temperature and precipitation extremes, using various indices of extreme weather.

Session 19 (Friday 9 Feb, 14:00-15:30), Talk 4

On the role of weather sampling in assessing record-breaking heat extremes

James S Risbey

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

The characterisation of record-breaking extremes is challenging because they are unprecedented in observations and may not have occurred or not been noticed in models. From the perspective of a fixed observation point, such extremes may be acutely sensitive to the precise configuration and location of the proximate weather systems. We investigate the role that weather variability can play for the example of the Pacific Northwest heatwave in June 2021. Weather sampling experiments using a large initial-condition ensemble indicate that the return period of this event is currently about 270 years, but it is difficult to constrain this estimate for sample sizes less than 1000 years. The use of an extreme value fit to smaller samples does not overcome the need for large samples. Because of the high sensitivity of heat extremes to weather configuration, smaller sample sizes are likely to substantially underestimate the value of the hottest day attainable in the region in a larger sample size. The characterisation of record-breaking extremes in climate projections requires large ensembles. The experiments here illustrate that, for smaller projection ensembles, record-breaking temperature extremes might not be observed in the projections, even at higher warming levels. This underscores the need to account for sampling in assessing models and changes in weather-sensitive extremes.

Session 19 (Friday 9 Feb, 14:00-15:30), Talk 5

Recent extreme weather events in Nepal and challenges in operational weather forecasting

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

In the recent few years, the frequency and intensity of extreme weather events over Nepal have been increased. This has intensified flood and landslide risks in the country. Most of these recent extreme events are not only of high intensity but also consisted of unusual characteristics. Reducing damages and dangers requires precise and timely forecasting of extreme events. While interpreting small- to large-scale features of high-intensity events in the complex terrain is challenging, unusual nature of these events has made prediction of such events further complicated.

This study analyses the role of the westerly wave in the extreme weather conditions during various severe weather events using observation and reanalysis data and data collected during field survey. The primary focus of this study is on recent three severe weather events: a) the first ever recorded tornado event in Nepal occurred on March 31, 2019 in Bara and Parsa districts in the eastern Terai plains; b) the heavy precipitation event occurred on June 14, 2021 in Manang district in the high Himalayas of northern Nepal), c) heavy rainfall event occurred during the post monsoon season from October 17 to October 21, 2021 over Nepal. This paper presents unusual characteristics of these events, their possible association with climate change and challenges they posed in the operational weather forecasting in Nepal.

Session 19 (Friday 9 Feb, 14:00-15:30), Talk 6

Monitoring extreme events at global scale – challenges and opportunities

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

Extreme climate events, their impact and context are monitored by numerous organisations, including the World Meteorological Organization as part of their annual global and regional State of the Climate reports. There are significant obstacles to comprehensive and consistent global reporting of these events in general, although some types of events (such as tropical cyclones) do have a reasonably robust global reporting infrastructure. These obstacles include a lack of available historical data in many parts of the world at the timescales required (typically daily) to allow climate context; for example, updated temperature extremes indices are largely unavailable for most of Africa, South America and south and west Asia. Impacts data are also frequently incomplete or difficult to obtain (sometimes because of language barriers), and often of unclear provenance.

A number of recent developments indicate potential for improved assessments in the future. The WMO Unified Data Policy adopted in 2021 includes historical climate data in the data types which are required to be freely exchanged, although no systematic infrastructure has yet been implemented to do so. The introduction of a daily component to the CLIMAT message will also facilitate ongoing updates of relevant data sets. Reanalysis and satellite data may also support assessment of some extremes.

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 1

Nonlinear impacts from ENSO and IOD to Australian and global economy under climate change

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

The El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are consequential climate phenomenons affecting extreme weather events often with largescale socioeconomic impacts on Australia and global countries. Elusive are issues to what extent the impact affects the macroeconomy, how long the impact lasts, and how the impact may change in a warming climate. Using a smooth nonlinear climate-economy model fitted with historical data, here we find a damaging impact from El Niño and pIOD which increases for a further several years after initial shock. We attribute a loss of US$3.9T and US$0.6T globally, with US$69B and US$38B in Australia, to the 2015-16 extreme El Niño and 2019 extreme pIOD events, far greater than estimates based on tangible losses. We find impacts from La Niña and nIOD are asymmetric and weaker. Under climate change, economic loss grows exponentially with increased ENSO and IOD variability. Exacerbated economic damage from changing ENSO and IOD should be considered in assessments of Australian and global mitigation strategies.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 2

Overview of the Tasmanian Risk Assessment for Climate Change (TRACC24)

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

The rapidly changing climate is already affecting Tasmania. For example, over the past 10 years, the State has experienced significant and devastating impacts, such as prolonged dry periods, flooding, bushfires, and record marine heatwaves. In 2022, in recognition of these climate-related impacts, the Tasmanian Government implemented a State-wide climate assessment be conducted every 5 years. The inaugural Tasmanian Risk Assessment for Climate Change (TRACC24) will be delivered by the Tasmanian Climate Change Office (CCO) in Renewables, Climate and Future Industries Tasmania (ReCFIT) in partnership with Deloitte and underscores Tasmania's commitment to adapt and thrive amid a changing climate.

Here we will present an overview of the TRACC24 first pass assessment encompassing the natural, social, economic and built value domains that will ultimately aid policy formulation across emergency management, infrastructure, energy, health, land use, and impacted industries. Specifically, we will present the development of physical and transition climate impact statements that were prioritised with key government, community and business stakeholders. TRACC24 identifies risks & opportunities and uses climate scenario analysis to inform and test climate strategies. As such it aligns with key areas of global major climate disclosure frameworks, such as ISSB IFRS S2 and TCFD. It is also consistent with leading climate change adaptation risk management frameworks.

We will summarise the physical hazards and transition drivers across multiple future scenarios out to 2050 and beyond, showing regional and sectoral variations, and describe the upcoming detailed climate assessment and adaptation prioritisation phases that will guide government action and pinpoint areas of vulnerability.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 3

Developing a multi-hazard tropical cyclone risk assessment for Australia

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Developing risk assessments are the first step to identifying potential impacts of extreme events and planning adaptation in a changing climate. Tropical cyclones (TCs) have long posed a significant threat to Australia's population, infrastructure, and environment. This threat may grow under climate change as projections indicate continuing rises in sea level and increases in rainfall during TC events. Previous Australian TC risk assessment efforts have focused on the risk from wind, whereas a holistic approach requires multi-hazard risk assessments that also consider impacts of other TC-related hazards. This study assessed and mapped TC risk nationwide, focusing on the impacts on population and infrastructure from the TC-related hazards of wind, storm surges, flooding, and landslides. Risk maps were created at the Local Government Area (LGA) level for all of Australia, using collated data on multiple hazards, exposure, and vulnerability. The results demonstrated that the risk posed by all hazards was highest for coastal LGAs of eastern Queensland and New South Wales, followed by moderate risk across Northern Territory and north-western Western Australia. Further enhancement and validation of risk maps developed in this study will provide decision makers with the information needed to reduce TC risk, save lives, and prevent damage to infrastructure.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 4

Drivers of wind risk in South East Queensland

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

South East Queensland (SEQ) is exposed to a range of severe storms that generate damaging winds, including east coast lows, thunderstorms and tropical cyclones. The risk posed by these storms is not well understood and, in a region that hosts a large proportion of Queensland's population and economic activity, it is important to understand these risks and potential benefits of mitigation actions, particularly in the context of climate change, urban planning and the socio-economic status of the population.

The primary objectives of the Severe Wind Hazard Assessment for South East Queensland (SWHA-SEQ) project (October 2020 – December 2022) were to improve the understanding of current wind risk in SEQ and to develop actionable information to inform future strategies to reduce this risk. Collaboration across fifteen partners in local government, insurance, emergency management, State government and academia has delivered valuable and actionable insights into the risk and resilience of SEQ at a local scale.

We discuss the relative contributions of different wind storms to the hazard profile, local influences on hazard and risk, and the intersection with community resilience indicators that assist in formulating targeted mitigation strategies. SEQ has a range of landscapes that influence the local hazard, including heavily urbanized lands, semi-rural communities in complex terrain and beachfront or canal estates. These landscapes, and the attributes of the buildings in them, contribute to the risk profile in varied and complex ways. We also explore the intersection of high-risk areas with socio-economic status to identify priority areas for potential retrofit programs.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 5

Linking Sea-level Extremes to their Impacts for Climate Risk Assessments

Ben Hague, Doerte Jakob

Bureau of Meteorology

Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Sea-level extremes and their associated coastal flood impacts will occur more frequently with continued sea-level rise. Here we use a new approach to estimate how the frequency of any historical or theoretical water level and its associated flood impacts change under sea level rise. This approach is shown to be robust and better represents historical water level variability than distribution-based methods often used in existing coastal risk assessments. The approach is versatile, enabling temporally seamless insights to support both short-term and long-range hazard assessment applications. This will be demonstrated by three short case studies. First, we apply the method to contextualise past flood events to support emergency management operations in Melbourne, Victoria. Second, we provide a first-pass assessment of the potential for flood regime change from predominantly riverine-driven to predominantly coastal-driven floods in Ballina, New South Wales. Finally, we estimate future flood hazards at Lakes Entrance, Victoria, where impacts are known but where tide gauge-based water level observations are unsuitable for climate studies.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 6

Delivering priority Climate Change Research to support the NSW Climate Change Adaptation Strategy

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

The NSW Climate Change Adaptation Strategy describes how the government will prepare for and position itself as a leader on climate change adaptation. The purpose of the strategy is to make NSW more resilient and adapted to the impacts of climate change. Climate change risk and opportunity assessments will be undertaken at various levels of government. In addition to the State wide risk assessment, each department's risk officer will identify individual agency risks and ensure climate change adaptation is being embedded into decision making.

To support the delivery of the strategy and the multiple risk assessments underway we have established a Climate Change Research Network (CCRN). The CCRN provides a framework to identify information gaps, prioritise key research, communicate our knowledge gaps, set up structures to resource information needs and help deliver science that will be stakeholder driven. Through the CCRN we engage directly with NSW government agencies responding to their data needs. The CCRN will work with and inform NARCliM on stakeholder needs around climate projections and identifying and prioritising research gaps. The CCRN ensures we are engaging with research on priority climate change risks, opportunities, and adaptation options. The network plays a key role in knowledge management and delivery between decision makers across the NSW government and researchers.

This presentation provides an overview of the CCRN and the approach taken to work directly between stakeholders and researchers to ensure our science is being end user driven.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 7

Impacts of climate change and sea-level rise on insured losses in New Zealand

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

New Zealand is highly exposed to the changing climate owing to its maritime position in the South Pacific and insured losses from weather events have a clear increasing trend. Two extreme events in 2023 – the Auckland Anniversary floods, and ex-TC Gabrielle generated losses exceeding previous weather-related losses by more than 10 times. Further, mandatory climate risk reporting for financial service companies provides impetus to understand climate change impacts.

Insurers are concerned with both climate impacts on longer return period events that produce catastrophic losses, such as riverine and coastal flooding, ex- and extra- tropical cyclones, hail and wildfire, as well as attritional losses due to more frequent storm activity and flooding. The changing frequency and severity of these events is important as is the correlation between such events as climate drivers themselves change and compound.

This review considers the potential for changes in New Zealand's extreme weather events based on a comprehensive range of evidence sources including downscaled studies, the underlying factors that influence their occurrence and intensity and national-scale flooding risk exposure assessments. Generally, we identify potential for increasing risk from extreme rainfall and hence flooding, ex-tropical cyclones, coastal hazards on the back of rising sea level, and wildfire, while impacts on hail and extratropical cyclone events are not well understood. We identify knowledge gaps for further research and priorities for mitigation and resilience efforts.

Session 21A (Thursday 8 Feb, 11:00-13:00), Talk 8

A national strategy for just adaptation

Kate Nairn

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Risk assessments help us understand who or what is at risk, when and where. While it's useful to understand what infrastructure, ecosystems, or populations are under threat from various climate impacts, traditional risk assessments often stick to easily quantifiable measurements. So we know our places are changing, how they are likely to change, and that we need to adapt to those changes. Adaptation is occurring, but is it fast enough, fair enough, inclusive enough? Future Earth Australia published *A National Strategy for Just Adaptation* to look at exactly that.

The Strategy takes the global concepts of climate change and justice and argues for solutions that are based on lived experiences, recognise and harness our diversity, and are deeply connected to place. Just adaptation is a process and a decision-support tool to look beyond the surface.

Just adaptation recognises sectoral and technological solutions are needed, but then goes further to scrutinise the structures and systems making people worse off. It calls to question how systemic structures play into the enduring imbalances of risk, wealth, and power and how those experiences are lived in place. For example: How does being an outdoor worker affect mental health? How do planning controls contribute to climate comorbidity? How does climate affect culture?

No one strives for unjust adaptation, but unfortunately many current adaptation strategies assume that outcomes are equally shared across populations or localities. Just adaptation provides the map to finding holistic, inclusive, and meaningful adaptations for all Australian communities.

Session 21B (Thursday 8 Feb, 14:00-15:30), Talk 1

Case studies in climate risk assessment from the dry edge of the cropping belt and downstream edge of the Murray Darling Basin.

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

South Australian grain farmers crop up to the dry edge of the grains belt. Climate risks of cropping have been assessed since Goyder's Line of Reliable Rainfall drawn in the 1860s. Despite a warming and drying climate, the grains industry shows a high degree of adaptive capacity with new varieties and management. There is a much shorter history of assessing climate risk in irrigated agriculture. Prior to the Millennium Drought (2002-2009) wine grape growers in Langhorne Creek at the end of the Murray River had access to high security water and were considered 'drought proof'. Severe water restrictions highlighted that few systems are more vulnerable than high value perennial agriculture.

This presentation reports on a series of workshops with low rainfall farmers and wine grape growers. We asked producers to identify their weather and climate risks in the current climate, discussed how these risks have changed in the recent past and how they are projected to change in the future. The discussion was informed by quantification of risk but focussed on adaptation and the limits to adaptation.

General lessons include starting with current weather and climate risks, effective ways of presenting climate information, trade-offs between complexity and transparency, the importance of acknowledging past and future adaptation, lukewarm responses to the notion of transformational change, concerns about policies and non-climate factors such as commodity prices. We conclude by summarising the lessons, including our mistakes and consider their application to agriculture in more favoured regions and other climate sensitive sectors.

Session 21B (Thursday 8 Feb, 14:00-15:30), Talk 2

Developing a state-wide awareness of coastal erosion and inundation hazards in Western Australia

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

In WA the Department of Transport (DoT) provides coastal hazard management advice and funding assistance to local governments.

There has been increasing demand over the last decade for coastal management advice and funding assistance. There have been many instances of local and state government ad hoc responses to coastal erosion.

Over the past 7 years DoT in partnership with the Department of Planning, Lands and Heritage has been progressing a work program to improve the state wide understanding of coastal hazards. There have been two major coastal hazard assessments undertaken as part of this work program.

In 2019 the Assessment of Coastal Erosion Hotspots in WA was completed. This identified 55 hotspots and 31 watchlist locations where coastal erosion is, or is expected to be, a threat to coastal values and assets in the short to medium term.

An Assessment of Coastal Inundation Hotspots in WA is currently underway to identify coastal inundation hotspots across WA. This study also focuses on the short to medium term.

Both studies have identified key challenges of undertaking a state-wide hazard assessment including the suitability of existing hazard assessment information, developing an assessment methodology suitable for state-wide application, and the prioritisation of hotspots.

The two studies have provided a starting point to prioritise resources, improve understanding and awareness of coastal hazards within state and local governments, and in the case of the 2019 erosion study underpinned a 5-year coastal management program funding boost.

Session 21B (Thursday 8 Feb, 14:00-15:30), Talk 3

Food Production n The Future: A Climate Impact Assessment Framework For Primary Industries In New South Wales

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Primary producers in New South Wales (NSW) are increasingly being impacted by climate change. These industries are critical to ensuring food security for communities, and thus, developing viable pathways to climate change adaptation for primary industries is becoming increasingly pressing.

There is a driving need for comprehensive information across the range of primary industries to inform effective policy and planning at a state and regional level. Integrative, cross-sector analysis of vulnerability to climate change across the primary sector can highlight future risks and opportunities and identify where incremental or transformational adaptation might be necessary.

Here we present a scalable approach to modelling climate change impacts on primary industries. Our framework uses a transparent multi-criteria analyis modelling approach combining data from published research and expert elicitation, and is particularly amenable to describing under-researched commodities. A key feature of this project is that the models for all commodities were developed in a consistent way, and the climate impact assessments use the same historical and future climate projection data. This allows direct comparison and integration of the outputs between commodities and biosecurity threats.

We demonstrate the use of this framework to model mid-21st century climate impacts for 28 commodities and 14 biosecurity risks. The commodities were selected based on economic value to NSW, size of the industry in NSW or importance as an emerging or growing industry for NSW. The resulting sector-wide climate impact assessment of primary industries provides guidance to the primary sector on navigating the challenges of climate change.

Session 21B (Thursday 8 Feb, 14:00-15:30), Talk 4

The Australian Climate Service Drought Hazard Team

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

As a recurring natural phenomenon, drought profoundly impacts Australia's agricultural productivity, water availability, ecosystem health, and socio-economic stability, making its thorough understanding crucial for informed mitigation and adaptation strategies.

In support of the National Climate Risk Assessment a team of climate hazard experts had been established to better understand drought and changes in aridity across Australia under global warming. This team is one of ten covering natural hazards of importance at a national level in Australia – identified via the National Climate Risk Assessment. The hazard teams, part of the ACS's Program 3 on Future Hazards, unite the ACS Partners CSIRO, Bureau of Meteorology, Geoscience Australia, and the Australian Bureau of Statistics, as well as other experts from across Australia, including those at universities. The teams aim to provide reliable information about historical, current, and projected climate conditions and hazards by adopting established good practices, developing new methodologies where necessary, leveraging top-tier scientific knowledge, and following a structured process

This presentation will introduce the leaders and members of the drought hazard team and will delve into the initial actions taken and the progress achieved since its formation in 2023. This will encompass a broad outline of the team's key activities and an assessment of the level of maturity in drought research and services for Australia.

Session 21B (Thursday 8 Feb, 14:00-15:30), Talk 5

Climate extremes in a changing climate: Bridging knowledge gaps

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Session

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Abstract

The NSW Bushfire and Natural Hazards Research Centre was established in response to the 2020 NSW Bushfire Inquiry and 2022 NSW Flood Inquiry. This new centre builds on the work of the former NSW Bushfire Risk Management Research Hub. Led by Western Sydney University (WSU) in collaboration with five other universities, the consortium focuses on diverse aspects of bushfire research spanning six themes: the environment, community, prevention, data management, operations, and future capability. The establishment of a new climate and weather theme augments the capacity of the Research Centre to conduct advanced research, including modelling, that addresses bushfires and floods in the context of the evolving challenges of a changing climate. It will employ researchers and train a new generation of students to enhance research impact and share findings with government, NSW businesses, and communities. The climate and weather theme will have a particular focus on weather extremes that lead to flooding or increased flood impacts.

The Research Centre is designed to channel research findings through data, tools, publications, and websites across eight government departments, fulfilling both the inquiries' recommendations. The Research Centre will span many fields of science with frontline agencies playing a lead role in shaping the research direction. It aims to provide scientific answers and support community knowledge as well as shape effective policies for environmental decision-making for future climate extremes. Research outputs will improve NSW's ability to plan for and respond to future flood events through enhanced mitigation and adaptation measures based on changing climate risks.

Session 21C (Thursday 8 Feb, 16:30-18:00), Talk 1

Directions for climate change adaptation research in Western Australia

Emily A S Gifford

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Western Australia covers an area of 2.5 million square kilometres, the size of Western Europe and one third of Australia's landmass. The government of Western Australia also has jurisdiction over Western Australia state waters, extending along the 20,000km coastline. Unsurprisingly, the state experiences a spectrum of weather conditions influenced by tropical cyclones in the north and Antarctic cold fronts in the south. The broad geographic expanse of the state means that climate resilience requires an efficient approach.

In recent years, Western Australia's engagement on climate resilience has upsurged in a short period of time, particularly in the public sector. Climate science, risk and adaptation programs have expanded rapidly on local, regional and state scales. Simultaneously, decision makers are requesting useful and timely research outputs to aid their adaptation planning. Research programs need to avoid duplication and meet high priority needs at relevant.

In order to drive needed adaptation research pathways that address the state's urgent and broad adaptation needs, the Department of Water and Environmental Regulation has initiated the Adaptation Research Hub. The Hub is working to promote access for end users to information; open lines of communication to connect researchers to end users; and identify and address research gaps.

In its first year, the Hub has commenced mapping existing research programs and collating a wish list of research outputs. In this presentation we will discuss methods employed to ensure that Western Australia is efficiently addressing its research needs, and summarise early findings on future research themes.

Session 21C (Thursday 8 Feb, 16:30-18:00), Talk 2

The NARCliM2.0 CORDEX-CMIP6 regional climate model ensemble: climate change projections over Australia

Giovanni Di Virgilio[1,2], Fei Ji[3], Eugene Tam[3], Dipayan Choudhury[3], Carlos Rocha[3], Jatin Kala[4], Julia Andrys[4], Jason P Evans[5], Stephen White[3], Yue Li[3], Matthew Riley[3], Jyothi Lingala[4]

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Abstract

The NARCliM2.0 ensemble of two regional climate model (RCM) simulations driven by five CMIP6 global climate models (GCMs) and contributing to the World Climate Research Coordinated Regional Downscaling Experiment CORDEX-CMIP6 Australasia framework have recently completed simulation for SSP1-2.6 and SSP3-7.0 for 1951-2100 at two spatial scales: i) Australia at 20 km resolution; ii) convection-permitting scale over south-eastern Australia at 4 km. Future climate projections under both emissions scenarios are examined for mid- and end-of-century changes in means and extremes of precipitation and temperature, as well as changes in future storm environments and fire weather. Under SSP3-7.0 projected temperature changes by 2030-50 exceed ~1.6K over several socio-economically important regions such as parts of eastern Australia. Although the NARCliM2.0 ensemble members show variation in the sign of projected mean precipitation, overall, far future changes are towards drying, particularly over the most populated areas of southeastern Australia. Projections of convective available potential energy (CAPE) show increases over the eastern coastline and particularly over heavily populated regions of the New South Wales coastline. These results and the NARCliM2.0 CORDEX-CMIP6 ensemble enable future assessments of regional climate changes, climate change impacts, and adaptation pathways for Australia.

Session 21C (Thursday 8 Feb, 16:30-18:00), Talk 3

Community vulnerabilities to heatwaves – An analysis of Ambulance Victoria callouts

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Heatwaves are natural hazards that impact the Australian community in a number of ways including through adverse health outcomes. Ambulance callouts can be used as a proxy for such adverse health outcomes. There are many categorisations of callouts, some of which are related to heatwave. An investigation of Ambulance Victoria callout database entries over the period 2014-2022 reveals the variability of the callouts, and a number of expected, surprising, direct, indirect ways in which extended high temperature periods affect the health of the community. The data, which was available at Victorian Local Government Area (LGA) scale, provides a good degree of granularity for analysis and results. By looking at the types of callouts that are the most related to high temperatures, we were able to classify the broad regions across the state with the most propensity to have increased callouts, or higher relative impacts to their current service levels during heatwaves and the likely reasons for them. The results from this simple analysis can be a reference point for discussion and communication and to help to set up strategies that will facilitate resilient services in the future.

Session 21C (Thursday 8 Feb, 16:30-18:00), Talk 4

A methodology for Australia's first National Climate Risk Assessment

Andrew B Watkins[1], Judith Landsberg[1], Britt Spyrou[1], Eric Lede[1], Alison Oke[2], Stephanie Jacobs[2], Guy Barnett[3], Brenda Lin[3], Angela Maharaj[4]

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

In 2023, Australia launched its National Climate Adaptation and Risk Program, including Australia's first National Climate Risk Assessment and National Adaptation Plan to inform and support decision-making for protecting Australians from increasing and more devastating climate events.

The National Climate Risk Assessment will examine and prioritise nationally significant climate-related risks for Australia by drawing on the latest science and data, building on the work already done by Commonwealth, state, territory, and local governments over many years, and by engaging with the stakeholders across all levels of government, the private sector and non-government organisations.

During scoping of the Risk Assessment, stakeholders from all levels of government, private sector, academics, non-governmental organisations, and First Nations communities were consulted to understand the things of value to Australians that could be impacted, negatively or positively, by climate change, and hence what should be included in a Risk Assessment.

This presentation will outline the methodology developed in this scoping stage of the Risk Assessment. This includes the elements, systems and sectors at greatest risk, and the set of constructs to define the future scenarios, geographic regions, time horizons and baselines to be used. It will also cover the 10 Key Climate Hazards and the 8 Systems at Risk that will be used to inform Stage 1 of the Risk Assessment – a rapid qualitative assessment of Australia's Key Climate Risks – and Stage 2 - an in-depth quantitative assessment of these Key Risks.

Session 21C (Thursday 8 Feb, 16:30-18:00), Talk 5

Developing an effective adaptation management framework for the Australian cultural heritage landscape

Eliza A Arias

UNSW, Canberra, Australia

Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

As a natural environment, the cultural heritage landscape - on the coastline and inland - is shifting in its formation - constantly changing as a result of natural environmental forces. Anthropogenic climate change, influenced by prolonged and ongoing human induced activities, is rapidly exacerbating these natural rates of change, and creating long-term shifts to weather and temperature patterns impacting upon these sites of significant heritage value.

Currently, case studies of selected Victorian and Tasmanian cultural landscapes are being examined, including Cape Duquesne in south-west Victoria and Maria Island located off the east coast of Tasmania, both recognised as coastal landscapes of heritage significance. Coastal modelling, including risk and vulnerability assessments, will subsequently be conducted to determine risks, risk ratings, adaptation strategies and ability of each locality to build resilience against the impacts of climate change and the increasing frequency of extreme temperatures, rising sea levels, marine heatwaves, storms and heavy rainfalls.

The management framework that will be developed in this research project is a tool that will provide a consistent approach and construct for the effective planning, management, protection and conservation of these landscapes in accordance with State and local government legislative obligations.

This research project will seek to address the gap that there is limited existing research on the climate resiliency of cultural heritage places that is specific to the Australian context, along with the inadequacies of current management mechanisms to effectively address the underlying meanings and values imposed by the individual and society upon these cultural heritage sites.

Session 21C (Thursday 8 Feb, 16:30-18:00), Talk 6

Understanding Marine Heatwaves in Vanuatu - what can we learn for Australia?

Jessica Bhardwaj

Bureau of Meteorology, Melbourne, Australia

Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

In this study, we applied a Marine Heatwave (MHW) framework to define and categorise MHW events in the waters around Vanuatu. Comparative analysis of events between 1982-2000 and 2000-2018 indicate that MHWs have become longer in the north of Vanuatu’s EEZ and more frequent everywhere in Vanuatu’s EEZ. From the events that met our definition, we investigated the longest and most intense, as well a recent notable impactful event from February 2016. Interestingly, this event was neither in the five most longest, nor the five most intense, highlighting how impacts in marine ecosystems are often non-linear and dependent on other factors such as a region's exposure and vulnerability. The 2016 event affected predominantly northern and central Vanuatu. An assessment of the region’s exposure and vulnerability, found these provinces to have moderate to high exposure and vulnerability values. We also accompanied this analysis with an investigation of seasonal forecast performance using hindcasts from the ACCESS-S2 model. From this study we were able to form recommendations in how risk assessments and sub seasonal to seasonal forecasts can be used for improved decision making and early action. We also reflect on key takeaways from this research that would be applicable to Australian fisheries and marine sectors. As climate change intensifies, MHWs will onset against a backdrop of other climate extremes, making the use and uptake of risk assessments and dynamical forecasts critical to the long-term resilience of vulnerable communities and sectors.

22. Understanding drought processes and impacts

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 1

Towards understanding the drivers of rapid onset droughts

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Session
22. Understanding drought processes and impacts

Abstract
Rapid onset droughts or flash droughts are events characterised by rapid intensification of dry conditions, unfolding on timescales of a few weeks. Recent studies show that flash droughts have become more common over much of the world. They have been projected to expand globally in the future and would possibly be made worse due to continued anthropogenic climate change in many parts of the world. Moreover, due to their sudden onset and the inability of the exiting models to predict them accurately, flash droughts pose multiple challenges in their understanding, predictability and monitoring. Thus, to better understand their sudden onset and to improve the predictability of these events, it is important to identify the mechanisms driving flash droughts. For this, flash drought events occurring across Australia were studied for the period 1990-2018. These events were identified using the rate of change of root zone soil moisture percentiles with time. We examined the role played by several meteo-climatological variables during and prior to the rapid onset period using a random forest model. The study also explored the co-occurrences of bushfires and heatwave events with flash droughts to understand the compounded threat associated with flash droughts. Flash drought processes were found to vary across the region. Changes in vapour pressure deficits, in addition to lack of rainfall were found to play an important role in the lead up to flash droughts for these catchments.

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 2

Reduced Moisture Sources associated with the onset and development of 2017-19 southeast Australian drought

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Session

22. Understanding drought processes and impacts

Abstract

The Murray-Darling Basin experienced its worst multi-year drought in 2017-2019. For three consecutive cool seasons, the basin experienced consistently below-average rainfall, which was an unprecedented event on record. Conditions worsened in 2019 due to a positive Indian Ocean Dipole that preconditioned the Black Summer bushfires. It is unclear, however, how the drought started and developed. In this study, we investigate the drought focusing on regional and local processes instead of remote climate modes of variability. Using a Lagrangian model to backtrack moisture sources to the Murray Darling Basin, we have found that local processes played a crucial role in explaining the onset and development of the drought. We identify the sources of moisture to the cool season precipitation over the Murray-Darling Basin and show a significant decline in moisture supply from the Tasman Sea in 2017 and 2018. We further show that anomalous atmospheric circulation diverted moisture to the northern areas of the drought region, depriving the Murray-Darling Basin of its normal moisture quota. Our results provide an explanation for the moisture and rainfall deficit that caused the MDB 2017-19 drought.

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 3

Towards Indicators for Landscape Drought Vulnerability, Resistance and Resilience

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Session

22. Understanding drought processes and impacts

Abstract

Vulnerability, resistance and resilience to drought are poorly defined at the landscape level. In rainfed agricultural systems, susceptibility to and capacity for recovery from drought are critical considerations for informed drought management. This study aims to assess these concepts for New South Wales, using long-term climate and agricultural survey data. Drought vulnerability was quantified through sensitivity of the wheat yield index and fodder spending per head of cattle to the Standardised Precipitation Index (SPI) and Standardised Precipitation Evapotranspiration Index (SPEI). Climatic vulnerability to drought was assessed by analysing patterns of exposure between regions and drought resistance was explored via changes in the wheat yield index and fodder spending in drought years compared to non-drought years. Recovery of agricultural productivity in years following drought, along with long-term changes in fraction of photosynthetically active vegetation were then used to assess drought resilience. Wheat yield index was found to be sensitive to drought identified using 3-month SPI and SPEI ($r = 0.78$ and 0.79) records during the sowing and growing seasons, while fodder spending was more sensitive to the 12-month indices all-year round ($r = -0.67$ and -0.65). All regions showed equivalent climatic vulnerability to drought, experiencing a similar number of droughts with little differences in severity or duration. Statistically, the regions could not be separated in terms of drought resistance or resilience, but no long-term impacts were found. This highlights a need for industry specific and temporally responsive metrics for understanding environmental drought vulnerability, resistance and resilience.

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 4

Investigating the occurrence of simultaneous drought events in the world's major food bowls

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Session

22. Understanding drought processes and impacts

Abstract

Ninety percent of the global food energy consumption is derived from a narrow selection of just 15 crop plants, with rice, maize, and wheat constituting two-thirds of this productivity. However, the dominance of these crops leaves global food systems vulnerable to potential pests, diseases, and environmental changes - with drought being a key concern. Drought-related crop failures can have serious consequences for food security, especially in regions heavily reliant on these staple crops for sustenance, and this can be amplified if more than one food bowl is impacted at the same time. In this study we look at trends in drought statistics across major food bowls of the world and identify historical occurrences of simultaneous drought. During the instrumental period we note two significant periods of synchronous drought - 1933-36 and 1958-1962. During the 1930's the regions that were affected were predominantly wheat growing which included northern and southern hemisphere regions. While the 1958-62 period effected maize-growing regions in Iran, Argentina and Chile, and southern Brazil as well as wheat and rice growing regions in north and north-west China. We also delve into the palaeoclimate record to show synchronous droughts are not unusual and are related to large-scale climate drivers. This research highlights the potential vulnerability of our global food supply chain and underscores the urgent need for proactive measures to enhance the resilience of agricultural systems.

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 5 | Poster Session 2, Poster 30

Australia's Tinderbox Drought: characteristics, causes and implications

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Session

22. Understanding drought processes and impacts

Abstract

Southeast Australia experienced an intense drought in 2017-2019 with sustained meteorological, hydrological, ecological, and agricultural impacts, culminating in the unprecedented 2019/20 Black Summer fires. We evaluate the characteristics and causes of this "Tinderbox Drought", whether the event was exceptional, and the potential role of climate change in this event. The Tinderbox Drought was characterised by cool season rainfall deficits of around -50% in three consecutive years, as well as high surface air temperatures and high vapour pressure deficits. These record-breaking deficits depleted water storages, affected vegetation, agriculture, and amplified heatwaves, preconditioning the land for the bushfires. The key climatic factors that caused the precipitation deficits varied through the event. The precipitation deficits were initiated and sustained by an anomalous atmospheric circulation that diverted oceanic moisture away from the region. These regional anomalies occurred in the absence of traditional drought indicators in large-scale modes of climate variability. The rainfall contributions from heavy rainfall days in winter declined, driven by a lack of rain producing weather systems over the region. Subsequently, local land-atmosphere feedbacks, and influences from remote large-scale drivers in the Indian Ocean contributed to the intensification of the drought. Observations and model datasets indicate that the precipitation deficits are extremely unlikely to have occurred from natural variability alone. We estimate, albeit with high uncertainty, that anthropogenic forcing may have intensified these precipitation deficits by around 18%. Machine learning approaches utilising multiple remote and local predictors demonstrate capacity for skilful prediction of drought impact during such events.

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 6 | Poster Session 2, Poster 29

Impacts of multi-year drought on streamflow regime shifts in south-eastern Australia

Ulrike Bende-Michl[1], Katy Bahramian[2], Steven Thomas[2], Wendy Sharples[2], Irina Rudeva[2], Elisabetta Carrara[2]

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Session

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Abstract

Prolonged droughts have led to impacts on streamflow by strongly reducing flows, and in some cases gives rise to permanent shifts in streamflow regimes, despite rainfall recovery. Understanding changes from perennial to non-perennial regimes is crucial for water management, such as the allocation of available water for crop irrigation to environmental flows. Furthermore, given the prospect of a dryer and warmer future, to combat increasing water scarcity and environmental degradation, understanding regime changes will help decision makers develop water-related mitigation and adaptation strategies.

In this study we investigate streamflow regime change from perennial to non-perennial flow, combining well established metrics using both climatic and hydrologic indices. A case study of the Victorian region in south-eastern Australia will be presented applying our analysis to pre-, during and post Millennium drought conditions. We analysed streamflow from 116 Hydrological Reference Sites in Victoria and period from 1970-2018 with respect to changes in the magnitude, duration, frequency, and timing of flow conditions. In this region, we identified rivers which remained in the non-perennial regime despite rainfall totals returning to pre drought levels. Additionally, we explored reasons for the permanent streamflow regime shift and implications for water management.

Session 22A (Wednesday 7 Feb, 14:00-15:30), Talk 7 | Poster Session 2, Poster 36

Identification and assessment of climate events that impact the viability of farming in dryland grain regions in Australia

Carly Tozer

CSIRO

Session

22. Understanding drought processes and impacts

Abstract

The dryland grains sector in Australia has experienced multiyear variability in yields over time, including runs of poor seasons, which negatively impact farming communities and Australia's economy more broadly. Using modelled grain yields, we explore the 'anatomy' of past periods to identify why yield was low, including examining within-year variability, to identify how rainfall sequencing within a year impacts yield outcomes. These insights help us define 'events' that pose challenges to the viability of marginal grain farming. We are then able to explore the climate processes associated with such events. This work is being undertaken via a co-learning approach where low rainfall farmers are engaged to provide direction and feedback around choices made to identify the events and to assist with the interpretation of results.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 1

Heavy rainfall events as predictors of drought development and recovery

Ailie J. E. Gallant[1,2], Tess Parker[1,2], Chenhui Jin[1,2]

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Session

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Abstract

Drought, and its life cycle from onset to termination, is typically identified using concepts of moisture deficits on monthly or longer time scales. However, for meteorological drought, there is utility for prediction by examining precipitation at the daily time scale. Using global daily rainfall products, we show that drought-prone locations often receive a significant proportion (~>= 50%) of their seasonal rainfall totals from the equivalent of a week or so of rain days. At many of these locations, the most significant changes to seasonal rainfall totals during meteorological droughts stem from reductions to the upper tails of daily rainfall distributions. This is, meteorological droughts can be related to the absence of relatively few heavy rainfall days per season. Likewise, recovery from meteorological drought is often marked by the return of these heavy rainfall events. Thus, the absence or presence of heavy rainfall days could a useful predictor of meteorological drought at these locations. We show that these definitions are particularly useful for multi-year droughts where rainfall may return to normal for periods of time, but the impacts of drought do not abate. Relating meteorological drought to the absence of a relatively small number of heavy rainfall days has the potential to make drought prediction a more tractable problem for short and long-term climate prediction if the mechanisms causing the heavy rainfall are known.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 2

Pairing monitoring datasets with probabilistic forecasts to provide early warning of drought in Australia.

Jessica Bhardwaj

Bureau of Meteorology, Melbourne, Australia. RMIT University, Melbourne, Australia

Session

22. Understanding drought processes and impacts

Abstract

Droughts are a cyclical feature of Australia's climate and have compounding effects on agricultural productivity and wellbeing. Understanding future conditions in context of antecedent observations is critical to providing informed early warning of drought. In this study we pair probabilistic seasonal forecasts with monitoring datasets to provide categorical early warning of drought. Hindcasts from the Bureau of Meteorology's sub seasonal to seasonal forecast model, ACCESS-S2, are paired with MSWEP satellite blended precipitation data and AWRA-L water balance modelled soil moisture and evapotranspiration. Principal Component Analysis (PCA) is used to derive objective weightings to combine precipitation, soil moisture and evapotranspiration percentiles in a multivariate manner similar to the U.S. Drought Monitor. The final DEWS maps overlay forecasting information with PCA-weighted antecedent conditions. We produce 1-, 3- and 6-month maps and analyse drought concern over the common period of overlap between our datasets (1981-2018) and conduct case studies for the 1982-1983 Ash Wednesday tinder drought and the 1997-2001 Millennium drought. We validate PCA-weighted maps with satellite vegetation data and agricultural commodity data from ABARES. Our findings indicate that early warning of drought can be categorised by concern – wherein dry antecedent conditions and dry forecasted conditions are of highest concern. Our proof-of-concept drought early warning system contributes to the growing body of proactive drought research. In a drought vulnerable future, operationalising and communicating drought early warnings will be critical to reducing the harmful impacts of drought on economies, environments, and people.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 3

A drought early warning system for Australia: translating seasonal weather forecasts into agricultural impacts

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Session

22. Understanding drought processes and impacts

Abstract

The Australian agriculture sector is uniquely exposed to climate variability particularly drought. The experience of the 2018-19 to 2019-20 droughts demonstrated that timely and accurate information on agricultural outcomes remains in high demand within both industry and government. In 2022, the Australian Government established the Drought Early Warning System (DEWS) project, a partnership between ABARES and CSIRO linking weather data and forecasts with agricultural models to produce national outcome-based drought indicators for Australia.

The DEWS makes use of seasonal weather forecasts from the Bureau of Meteorology ACCESS-S2 model downscaled and calibrated to a 5km resolution. Historical and forecast weather data are used to force a suite of agricultural simulation models including APSIM, GrassGro, AussieGRASS and FarmPredict. This joint modeling system produces a range of agricultural drought indicators measuring winter and summer crop yields, pasture growth, and farm business profits, each defined as percentiles against an historical reference period. An automated operational prototype of the DEWS has been developed within the Senaps cloud-computing environment, with monthly updates being pushed to an online interactive user interface via the Climate Services for Agriculture (CSA) platform.

While the DEWS has been developed primarily to inform government drought response, the underlying data products have a range of other potential applications including agricultural production forecasting, drought and climate financial risk assessment, index-based drought insurance, and farm business performance benchmarking and decision support.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 4

Assessing future droughts in Australia from multiple projections

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Session

22. Understanding drought processes and impacts

Abstract

Australia suffers from frequent droughts but future projections of drought have remained stubbornly uncertain over the continent. Here we explore future changes in drought over Australia using a hierarchy of projections from coupled global and regional climate models and several offline hydrological models that are widely employed in Australia. We analyse changes in hydrological (runoff) and agricultural (soil moisture) droughts across the different modelling methods using a consistent definition of drought. Our study aims to better quantify uncertainties in future hydrological projections over Australia and explore the causes behind the uncertainties arising from different modelling methods.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 5

Parched: Exploring Victoria's droughts with a truly multidisciplinary team

Linden Ashcroft[1], Karen Twigg[2], Lawrie Zion[2], Tom Ford[2], Katie Holmes[2], Susan Martin[2], Jacqueline Millner[2], Rochelle Schoff[3]

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Session

22. Understanding drought processes and impacts

Abstract

An art expert, two literary scholars, three environmental historians, a climate scientist and a media professor walk into a room. No, it's not a joke; it's Parched — a three-year, ARC-funded project exploring the cultures of the four big droughts in Victoria from the past 130 years.

But what do we mean by 'cultures of drought'? How can such a diverse team work together? And how will the outcomes of Parched inform our understanding of drought to prepare for future events?

In this presentation, we address these questions by sharing the first major output of the project, an examination of the coverage of the Federation Drought in Bendigo newspapers. The Federation Drought desiccated much of Australia between 1895 and 1903 and remains one of the most significant periods of rainfall deficiency since European colonisation. The Federation Drought also coincided with, and fuelled, a substantial increase in press coverage of the weather.

Through our examination of reportage from The Bendigo Advertiser and The Bendigo Independent, we identify themes that have persisted in drought coverage to today, and what has changed (or not changed) with the evolution of drought science. We highlight the role the press has played in shaping how communities and policy makers understand and manage the extremities of Australia's climate. Finally, we offer insights into the evolution of current drought reportage, the perspectives it enables or silences, and what this case study can teach us about drought impact communication.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 6 | Poster Session 2, Poster 32

Operational forecasting for improved early warning of drought for policy and farm decision makers in New South Wales, Australia

Jennifer B Wurtzel[1], Anthony Clark[1], Kim Broadfoot[1], Ian Marang[2], Kel Langfield[3]

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Session

22. Understanding drought processes and impacts

Abstract

The Enhanced Drought Information System (EDIS), developed by the NSW Department of Primary Industries (DPI) Climate Branch, monitors and raises awareness of drought risk. Launched in 2018, EDIS has evolved to Version 3, now featuring the capability to use dynamic seasonal climate forecasts (ACCESS-S2) to anticipate features of future drought events. A real-time seasonal drought forecast was identified as a major priority for development in recent stakeholder engagement and will be added to the current suite of EDIS outreach products like NSW DPI's interactive drought map, the NSW State Seasonal Update, the FarmTracker farm diary app, and DPI's free public data services.

The forecasting service uses the Bureau of Meteorology's 5km2 calibrated ACCESS-S2 probabilistic seasonal forecast product, interpolated to the 1km2 ANUClimate historical gridded climate dataset. The 99-member ACCESS-S2 ensemble runs through EDIS's climate-soil water balance model (DPI AgriMod) and drought indicator framework, the NSW Combined Drought Indicator (CDI), calculating CDI drought category probabilities and forecast skill at 1km2 resolution across NSW.

ACCESS-S2 hindcast data (1981 – 2018) enables a detailed evaluation of 40 years of drought forecast accuracy, excluding the most recent drought. The operational forecast is generated at 1-3 month lead times (aligned with current BoM ACCESS-S2 outlooks). Examples of past and recent drought forecasts and skill output are provided, demonstrating the system's value for policymakers and decision-makers to anticipate regional drought patterns.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 7 | Poster Session 2, Poster 35

Developing a drought outlook product for Australia

Thong Nguyen-Huy, David Cobon

Centre for Applied Climate Sciences, University of Southern Queensland, Toowoomba, Australia

Session

22. Understanding drought processes and impacts

Abstract

Drought is an extreme climate event, characterised by below-normal precipitation over a period of months or years. It is often described as one of the least understood natural hazards that threaten the agricultural systems, due to its slow and gradual onset. It also has the potential to have far reaching and long-term ramifications, such as reduced agricultural production, wellbeing and livelihood security and, in developing regions, increased risk of food insecurity and famine. Drought monitoring and early warning systems are therefore critical for effective drought mitigation planning. This study looks at the drought forecasting tools available globally and examines the early development of a simple drought forecast (outlook) tool for Australia where no such tool currently exists. It is produced by combining the recently developed Australian Combined Drought Indicator (CDI) with a 1- or 3-month precipitation forecasts from ACCESS-S. These two sources of data are used to develop an assessment on whether an existing drought is likely to be 'broken', improve but remain or worsen over the next 1 or 3 months. Verification of the Drought Outlook (the 'Outlook') against the later observed CDI are performed to show the consistency over most of Australia for all months of the 1- and 3-month Drought Outlook. This simplified drought forecasting approach is the first step toward a fully developed, verified and operationalised Drought Outlook product for Australia.

Session 22B (Wednesday 7 Feb, 16:30-18:00), Talk 8 | Poster Session 2, Poster 33

Communicating drought in Pacific Island countries

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Session

22. Understanding drought processes and impacts

Abstract

Drought and prolonged wet periods present significant challenges for communities and disaster management responses, particularly in Pacific Island countries (PICs). "Too little" or "too much" rain over several months can affect livelihoods, water security, food security and health - particularly in remote islands far from centralised support services.

Early warning – accessible and understandable to all – is fundamental to effective preparation and response. In this presentation, we outline the development of communication products for the 'Early Action Rainfall Watch' (EAR Watch) service. The EAR Watch service is a collaboration with 10 National Meteorological and Hydrological Services (NMHS) in the Pacific. Key disaster management stakeholders in each country can access information via monthly detailed bulletins released by the NMHS on a website or sent by email; also, via local briefings.

Recent work focussed on working with national and subnational stakeholders to develop products to reach the last mile. Social media via Facebook is a popular channel, but internet access can still be costly and difficult to access (because of connection issues, power outages etc.), and may not reach older age groups. Traditional methods of disseminating messages through newspapers and radio remain useful tools. A new 'Droughts in the Pacific' animation video has also been developed for awareness and education. Tailored approaches to communicating drought information are favoured depending on the country and capability.

Communication challenges can include multiple languages, poor internet coverage, also reduced literacy and education levels, particularly associated with the older generations. On-going capability development for NMHSs about drought continues.

24. Advances in remote sensing and modelling for land surface processes

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 1

The Australasian carbon budget and future research needs

Yohanna Villalobos[1], Pep Canadell[1], Elizabeth D Keller[2], Peter Briggs[3], Beata Bukosa[4], Donna Giltrap[5], Ian Harman[1], Timothy W Hilton[6], Miko WF Kirschbaum[5], Ronny Lauerwald[7], Liyin L Liang[8], Taylor Maavara[9], Sara E Mikaloff-Fletcher[10], Peter J Rayner[11], Laure Resplandy[12], Judith Rosentreter[13], Eva-Marie Metz[14], Oscar Serrano[15], Benjamin Smith[16]

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

We constructed a full carbon budget (excluding methane) for Australasia (Australia and New Zealand) for 2010-2019 with all major natural and anthropogenic sources and sinks. We used two approaches. First, we used a bottom-up method consisting of land-surface models (e.g., CABLE-POP, Biome-BGCMuso, CenW, TRENDY), observations (e.g., satellite-based fire emissions: GFED, GFAS, QFED), upscaled observation products (e.g., freshwater exchanges), and anthropogenic greenhouse gas inventories (e.g., Australian National Greenhouse Gas Inventory, FAO-Agriculture) to construct a detailed carbon budget with all major fluxes in and out of the region. Second, we used a top-down method based on atmospheric observations (in situ and satellite-based column CO2 observations from OCO-2 and GOSAT instruments) to constrain the net carbon balance of the region and estimate its year-to-year variability. We found that Australasia was close to carbon neutrality, albeit with large uncertainties associated with some of the largest natural fluxes. We showed the key uncertainties and future research development needed in observations and land surface modeling to better constrain Australasia's future carbon budget.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 2

Projection of Dryland Vegetation Productivity Under Future Climate Scenarios

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

According to the Aridity Index (AI), approximately 41% of terrestrial area is classified as drylands. Comparing with non-drylands, the low biological productivity of drylands makes it fragile and can be impacted by human activities. Any negative trend in dryland condition is considered desertification. Trends in the AI over several decades indicate increasing aridity in the drylands, which has been linked to increasing occurrence of desertification. In contrast, satellite observation of vegetation shows a general greening of the drylands. Further, future projections of the AI indicate continued increases in aridity due to climate change, suggesting that drylands will expand. However, the contradictory trends between AI changes and observed vegetation changes in the past remains an open question about future evolution of vegetation productivity within drylands. Therefore, we estimate the state of vegetation in the drylands and result shows an increase in vegetation productivity on most drylands due to climate change through to 2050. However, several regions are projected to desertify in all climate scenarios, including parts of north-east Brazil, Namibia, western Sahel, Horn of Africa and central Asia. The general increases in projected vegetation are in-line with recent trends and continue the past inconsistency with changes in the AI. Dryland vegetation productivity broadly boosts due to CO2 fertilization effects, while climate change negates the changes in at least 6.87% of global drylands to produce desertification. It also shows that while AI provides a reasonably good differentiator of vegetation state in past climates, it is not a good indicator in future climates.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 3

Seasonal to subdaily patterns of dryland ecosystem functioning from the Advanced Himawari Imager over OzFlux sites

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

Satellite remote sensing can help parameterise and/or constrain models, and with extrapolated climatic data, estimate ecosystem carbon and water exchange under conditions not yet encountered. The Advanced Himawari Imager (AHI) onboard the Himawari-8 geostationary satellite provides high-temporal imagery, every 10 minutes, that can be used to better understand terrestrial ecosystem functioning at sub-daily to seasonal scales and over multiple years that encompass inter-annual variability. This can inform better retrievals of landscape phenology and vegetation structure/ function parameters related to carbon and water cycling.

Through a Terrestrial Ecosystem Research Network (TERN) project, we evaluated the use of AHI data to track productivity and characterise land surface phenology across a network of eddy covariance flux tower sites in Australia. We assessed subdaily to seasonal and inter-annual dynamics of vegetation measures with flux tower derivations of gross primary productivity (GPP) across a gradient of dryland savanna, grassland, and shrub and forest biomes. We found strong diurnal vegetation profiles that were related to canopy structure and soil and sun-shade influences. Multi-layer grass- woody canopies were better resolved with daily resolution data that enabled more precise retrievals of vegetation growth metrics. The daily resolution was shown to advanced the utility of satellite phenology as a bio-indicator of climate change, and in combination with land surface models can improve predictions of how ecosystems will respond to climate change.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 4

JULES in Australia – future seamless land surface modelling at the Bureau of Meteorology

Christoph Rüdiger[1], Siyuan Tian[2], Valentina Marchionni[1], Luigi Renzullo[2], Fitsum Woldemeskel[1], Martin Best[3], Elisabetta Carrara[1], Andrew Frost[4], Mathew Lipson[2], Wendy Sharples[1]

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

Under its R&D Plan 2020-2030 the Bureau of Meteorology's had begun to develop a seamless hydrology framework for Australia. While current hydrology-related products are based on the Australian Water Resources Assessment (AWRA) model, the aim of this work is to consolidate the models and base them on the same physics. As UM partner, the Bureau already runs JULES in its operational numerical weather prediction models, however, to date has been using AWRA to provide higher resolution land surface states. As AWRA cannot be run within the numerical weather prediction model suite, work has started to adapt JULES to better represent Australia's hydrological and plant-physiological conditions and to utilise its output in a full production chain to deliver high-resolution customer-facing products.

Here, the overall challenges to model Australia's particular landscape dynamics will be discussed. Recent developments and insights into the impact of different soil physics, locally derived soil and vegetation ancillaries, and urban hydrology will also be presented. as well as the results from implementing a continuous streamflow routing scheme for the entire continent. While the current results are based on offline runs, future fully coupled simulations will be undertaken to study the impact of the proposed changes on the atmosphere.

The presentation will close with the future model development strategy that will be strongly driven by and based on the use of Earth Observation and in situ data, and later use of those data sets to further constrain the model trajectory through data assimilation.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 5

The influence of lateral flow on land surface fluxes varies with model resolution

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

Land surface models (LSMs) used in climate models typically represent the vertical exchange of water and energy at the surface. They operate under the assumption that the lateral movement of water between model grids have negligible impact on surface fluxes at climate modelling resolutions of 10s to 100s of km. However, emerging understanding indicates that this process may be significant in high resolution simulations. The impact of lateral flow has not been modelled in Australia, but satellite observations suggest that hydrologic connectivity has an influence on vegetation productivity in semi-arid regions of the country. To quantify the influence of this process in southeast Australia, we perform standalone LSM experiments with and without lateral flow at model resolutions of 1 to 10 km. We utilise the WRF-Hydro modelling system with the NoahMP LSM, which includes representation of overland and shallow sub-surface flows. We find that lateral flow has the largest impact on latent heat fluxes (LHF) in spring, followed by summer. The domain average changes are typically less than 6 W/m^2 (less than 10%), but some locations experience larger changes. In some downstream areas of the Murrumbidgee and Murray Riverina basins, the increases in spring LHF are about 30 W/m^2 (~50%). At a resolution of 1-km, there are reductions in LHF at upstream ridge locations, which are not apparent at coarser resolutions. Our results indicate that lateral flow has the potential to influence land-atmosphere interactions and vegetation responses to hydrologic extremes in southeast Australia, which need to be explored.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 6

Monitoring ecosystem stress of an extreme drought associated with Australia's 2019-2020 Black Summer wildfires using Himawari land surface temperature retrievals

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

From 2017 to early 2020, southeast Australia experienced the extreme "Tinderbox Drought" that contributed to the 2019-2020 Black Summer wildfire disaster with unprecedented spatial extent, intensity and impacts. By surface energy balance principles, difference between land surface temperature (Ts) and air temperature (Ta) provides a direct proxy for sensible heat fluxes that helps monitor evapotranspiration dynamics and diagnose ecosystem stress (eco-stress) conditions. Here, we proposed a novel eco-stress metric for drought assessment by computing sub-daily integral of Ts – Ta differences using Himawari geostationary Ts retrievals and gridded hourly Ta products. Exploring the optimal sub-daily window to calculate Ts – Ta differences revealed that the period around solar noon provided the maximum discrimination of eco-stress. Examining spatio-temporal patterns of the proposed eco-stress metric revealed a progressive build-up of vegetation stress since 2017 that culminated in extreme eco-stress values occurring during the Black Summer fire months. Analysis of eco-stress time series in forest areas further captured different recovery time to pre-fire normal states across different ecosystems after drought-breaking rains occurred in mid-2020, with Eucalypt forests in eastern Victoria showing one additional year of recovery compared to forests at lower latitudes. Our results highlighted the promising utility of proposed Himawari eco-stress metric to track the spatio-temporal patterns of drought and discriminate different ecological recovery trajectories from compound drought and wildfire events. The follow-up research will assess spatio-temporal dynamics of eco-stress over entire Australia and extract new understanding of sub-diurnal ecophysiological processes from high-frequency Himawari satellite observations.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 7

Surface and air temperature interactions are influenced by urban form and seasonality

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

Urban heat is a local scale warming effect associated with urban areas where most of the world's population live. Due to the scarcity of air temperature (Ta) data, urban heat studies have been mostly focused on Land Surface Temperature (LST) extracted from satellite imagery and a quantitative understanding of how LST interacts with Ta within a city is still lacking. Using crowdsourced weather station data in Sydney, Australia, combined with high resolution satellite images and urban datasets (such as Local Climate Zones (LCZ) and building-level urban data), we explore the interaction between Ta and LST, and their intra-urban variabilities during different seasons. We found that LST and Ta have different characteristics and their dependency varies by season and LCZ. When exploring the relationship between Ta, LST, and variables describing the urban structure, such as building fraction, the correlation between LST and urban structure was stronger and more seasonal dependent than the Ta-urban form relationship. Moreover, stronger correlations between LST and Ta were observed in the less built-up areas within the city. We also found that the determinants of LST variability are different from the contributing factors of Ta. These findings provide new insight for quantitatively investigating surface and canopy urban heat and their relationship with land cover, providing fit-for-purpose information to mitigate the adverse effects of urban overheating at local and global scales.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 8 | Poster Session 1, Poster 37

Water driven leaf phenology comparisons in Australia and Brazil dryland ecosystems

Andeise Cerqueira Dutra[1,2], Bruna Alberton[3,4], Desiree Ramos[3], Magna Moura[5], Shielo Muta[2], Mohammad Mahdi Taghadosi[2], Leonor Patricia Morellato[3], Yosio Edemir Shimabukuro[1], Alfredo Huete[2]

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

Understanding leaf phenology (LP) patterns and their main drivers is crucial for climate change studies. In dryland ecosystems of the Southern Hemisphere, the spatiotemporal dynamics of LP from local to regional scales remain poorly understood. In this manner, integrating different remote sensors, from orbital to near-surface, can achieve better spatial and temporal coverage to provide a better understanding of ecological processes. This study aims to analyse (I) short-term LP patterns based on multiple remote sensors in dryland forests and shrublands in Brazil and Australia, and (II) long-term patterns and drivers associated with the impacts of extreme climate events. We obtained 3-years of PhenoCam and MODIS satellite data as proxies for LP, and also acquired 20-years of LP data from MODIS and environmental variables including rainfall, air temperature, evapotranspiration, soil moisture, and fire activity. We carry out statistical correlations, and standardized anomalies for LP metrics such as the start and end of the season (SOS, EOS), and the amplitude of the growing season (AGS). Our findings indicated that (I) LP detection can significantly vary among different land cover types and cross-continental sites, exhibiting better correlations within forested areas ($r=0.34 – 0.85$, $p<0.001$) than shrublands ($r=0.15 – 0.27$, $p<0.001$). (II) LP anomalies indicated that during the driest years, the AGS exhibited more pronounced impacts than SOS and EOS, showing a stronger correlation with hydrologic drivers. Upscaling remote sensing approaches hold promise for LP studies, especially in challenging dryland environments.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 9 | Poster Session 1, Poster 35

Assimilation of satellite-derived fPAR into JULES for Australia

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

The representation of vegetation cover in land surface models, including structure, type, condition, and fraction, has profound influence on the accuracy of estimates of water, carbon and energy fluxes. This influence increases in importance as regional land surface modelling capability trends towards finer spatial scales, aiming for a prediction accuracy and relevance suited to natural resource management decision making. The Bureau of Meteorology, for example, has the near-term ambition of replacing the existing Australian Water Resources and Assessment (AWRA) system with the Joint UK Land Environment Simulator (JULES), to produce kilometre-resolution water balance estimates continentally. Our first step in adapting JULES for Australian water resources management is an assessment of a variety of vegetation information products used as ancillaries, especially those derived from earth observations (EO), to improve JULES prediction of key water variables through either parameterisation, calibration, or data assimilation.

This paper provides an exposition of how Australian-derived vegetation information products will improve JULES water balance estimation. First, we examine the impact of replacing existing (namely IGBP- or CCI-derived) fractions of plant functional type (PFT) with those derived from domestic sources (i.e., CSIRO, GA and DCCEEW) on estimates of soil moisture, latent and sensible heat fluxes. Next, we detail our approach of assimilation, via a simple observation model, of EO-derived fraction of absorbed photosynthetically active radiation (fPAR) into JULES. We show that the dynamic updating of vegetation states leads to vastly improved JULES predictions for Australia, especially compared with default model configurations, particularly in grassland regions of the continent.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 10 | Poster Session 1, Poster 34

A one-dimensional urban flow model with Eddy-diffusivity Mass-flux (EDMF) scheme and refined turbulent transport characterization (MLUCM v3.0)

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UNSW Sydney, Sydney, Australia

Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

The well-established 1.5-order k-l turbulence closure formulation provides a simple yet effective approach to parameterizing the contribution of the spatially averaged turbulent flux of momentum and scalars in urban flow models. However, this approach assumes the flow is fully turbulent and intrinsically homogeneous, which limits its applicability to relatively simple urban forms. In addition to simplifications such as unified transport efficiency for different flow properties, forbids further improvements to the model until these factors are closely examined. In this study, we conducted 49 large-eddy simulations over urban arrays reflecting both real-world building height distributions and comprehensive urban densities ($\lambda p \in [0.0625,0.64]$). The strength of turbulent transport was found roughly similar between scalar and momentum, but four times more efficient for turbulent kinetic energy, which indicates an extensive underestimation of TKE within the canopy. The dispersive momentum flux, previously lumped together with its turbulent counterpart for parameterization, was found to scale well with the external pressure gradient and the urban morphological parameters. In response to these findings, we propose two major changes to Multi-Layer Urban Canopy Model i.e., a) separate characterization for turbulent viscosity for momentum and TKE, and b) introduce an explicit physics-based "mass flux" term to represent the non-Gaussian part of the dispersive momentum transport as an amendment to the existing "eddy diffusivity" framework. The updated 1D model, after being tuned for building height variability, is further compared against the original LES results and demonstrates superior performance to the previous model.

Session 24 (Tuesday 6 Feb, 11:00-13:00), Talk 11 | Poster Session 1, Poster 36

Satellite-Derived Bathymetry with Sediment Classification Using ICESat-2 and Multispectral Imagery: Case Studiesin the South China Sea and Australia

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Session

24. Advances in remote sensing and modelling for land surface processes

Abstract

Achieving coastal and shallow-water bathymetry is essential for understanding the marine environment and for coastal management. Bathymetric data in shallow sea areas can currently be obtained using SDB (satellite-derived bathymetry) with multispectral satellites based on depth inversion models. In situ bathymetric data are crucial for validating empirical models but are currently limited in remote and unapproachable areas. In this study, instead of using the measured water depth data, ICESat-2 (Ice, Cloud, and Land Elevation Satellite-2) ATL03 bathymetric points at different acquisition dates and multispectral imagery from Sentinel-2/GeoEye-1 were used to train and evaluate water depth inversion empirical models in two study regions: Shanhu Island in the South China Sea, and Heron Island in the Great Barrier Reef (GBR) in Australia. However, different sediment types also influenced the SDB results. Therefore, three types of sediments (sand, reef, and coral/algae) were analyzed for Heron Island, and four types of sediments (sand, reef, rubble, and coral/algae) were analyzed for Shanhu Island. The results show that accuracy generally improved when sediment classification information was considered in both study areas.

25. Advancing understanding of the atmosphere and ocean through data science

Session 25 (Thursday 8 Feb, 14:00-15:30), Talk 1

Tracking and classifying clusters of ocean eddies using graph theory

Shane R Keating, Greta Paget

UNSW, Sydney, Australia

Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

Ocean eddies are “storms of the ocean” whose ability to trap ocean water and transport it between ocean basins impacts large-scale ocean circulation, thus affecting global climate and driving extreme weather events. Whilst ocean eddies can travel alone, they may also group together to form clusters that remain coherent as their component eddies cross ocean basins. In this talk I will present novel graph theoretic methods for identifying, classifying, and tracking eddy clusters in the North Pacific using satellite data collected daily from 1993 to 2014. The typical shape and size of identified eddy clusters is analysed, and a census of eddy clusters is conducted based on their underlying graph structure. Clusters are also analysed over time to determine the typical evolution and lifetime of a given cluster. This work provides a basis for future investigation into how the size of an eddy cluster impacts its trapping and transport abilities.

Session 25 (Thursday 8 Feb, 14:00-15:30), Talk 2

Optimal parameters for the ocean's nutrient, carbon, and oxygen cycles compensate for circulation biases but replumb the biological pump

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Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

Modeling the ocean's carbon and oxygen cycles accurately is challenging because of uncertainties in both biogeochemistry and ocean circulation. One solution to reduce the mismatch between observed and modelled biogeochemical tracer fields is biogeochemical parameter optimization. I will present recent work where we show that parameter optimization may compensate for biases of the embedding circulation model by altering the inner workings of the biological pump, with implications for estimating the future response of the ocean system to environmental change. To this end we embedded a mechanistic model of the ocean's coupled nutrient, carbon, and oxygen cycles into two circulation models: OCIM2, which is data-assimilated, and ACCESS-M, which is built from the ACCESS1.3 climate model. We find that parameter optimization reduces mismatch with tracer observations and reproduces the global biological pump strength and regenerated inventories for both circulations, but ACCESS-M export production optimizes to twice that of OCIM2 to compensate for ACCESS-M having lower sequestration efficiencies driven by less efficient particle transfer and shorter residence times. Idealized simulations forcing complete Southern Ocean nutrient utilization show that the response of the optimized system is strongly sensitive to the embedding circulation. In ACCESS-M, Southern Ocean nutrient and carbon trapping is partially short circuited by unrealistically deep mixed layers. For both circulations, intense Southern Ocean production deoxygenates Southern-Ocean-sourced deep waters, muting the imprint of circulation biases on oxygen. Our findings highlight that the biological pump's plumbing needs careful assessment to predict the biogeochemical response to ecological changes, even when optimally matching observations.

Session 25 (Thursday 8 Feb, 14:00-15:30), Talk 3

Data-driven prediction of the El Niño-Southern Oscillation using entropy-optimal Scalable Probabilistic Approximations

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Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

This paper applies a novel data-driven approach to the prediction of El Niño events for lead times up to 24 months. By formulating the problem as a classification task, where the Nino3.4 index is coarse-grained to take a value of 1 if it exceeds 0.5°C and 0 otherwise, a classifier is trained to predict the labelled data based on a set of features taken from observational and resimulated datasets over the period of 1950 to 2007. Specifically, the features used are the first 100 principal components (PCs) from an empirical orthogonal function (EOF) analysis of global sea surface temperatures (SST), along with the first 100 PCs from an EOF analysis of the vertical derivative of water temperature at the equator (dT/dz) as a proxy for thermocline variability.

This classification task represents an example of supervised machine learning in the small data regime, since the number of features (200) is of similar size to the number of data instances for training (667). The recently proposed entropy-optimal Scalable Probabilistic Approximation (eSPA) method has been shown to avoid overfitting in this regime. eSPA simultaneously performs clustering, feature selection and classification and is physically interpretable. Application of eSPA to an in-sample prediction of El Niño events shows that it substantially outperforms other methods, especially at longer lead times. Furthermore, composite images of SST and dT/dz from the cluster centroids allow for deeper insight into the types of patterns that have historically led to El Niño events for a given lead time.

Session 25 (Thursday 8 Feb, 14:00-15:30), Talk 4

Bayesian Variable Selection for Spatial Quantile Regression: A case study for NSW in Australia using global climate indices

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Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

The impact of large-scale climate phenomena on eastern Australian rainfall on interannual timescales is a well-researched area. However, the vast majority of this research has focused on the impact of these external influences on average rainfall. The goal of this research is to develop a statistical model which captures the dependency between, not only the average, but all quantiles of rainfall and large-scale climate phenomena, such as El Nĩno-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), and the Southern Annular Mode (SAM). Additionally, this research models how this dependency between rainfall quantiles and large-scale climate indices varies across different geographic locations. We use quantile regression as the underlying framework and take a Bayesian approach to inference regarding the impact of large-scale climate modes on rainfall quantiles, by placing a prior on the regression coefficients for each quantile that allows for the possibility that these coefficients are identically zero. Spatial dependence is incorporated by modeling the probability that the regression coefficients are identically zero as a function of geographic location. The technique is then applied to model monthly rainfall at 700 locations in the state of New South Wales (NSW) to identify which large-scale climate phenomena influence the various quantiles of rainfall at different locations and during different months of the year. Our results show a detailed picture of the dependence of rainfall across NSW on climate modes and that wet extremes are more responsive to ENSO in inland NSW compared to the coast.

Session 25 (Thursday 8 Feb, 14:00-15:30), Talk 5

Upstream Large-Scale Control of Subtropical Low-Clouds

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Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

The atmospheric boundary layer (ABL) adjusts to large-scale meteorological conditions on time scales from a few hours to a few days. Along the trade winds, the ABL air can travel thousands of kilometers during that time span. As a result, the ABL state depends on the large-scale meteorological conditions upstream (upstream controls). Previous work using back-trajectories and machine-learning statistical models with feature selection capabilities found upstream controls are systematic enough to dominate the climatological signal of low-cloud coverage, with a unique interplay of upstream and local controls found for Stratocumulus (Sc) deck, Sc-to-cumulus transition, and trade-cumulus regimes.

Here we extend this analysis to examine the sensitivity of a range of low-cloud properties to upstream controls over an extended marine domain, with unique upstream and local controls being found for different low-cloud properties. This analysis is then repeated for 11 present-climate GCM simulations. Upstream controls are poorly represented by the majority of the GCMs in this analysis, with some exceptions. These results indicate a promising avenue to improve climate model low-cloud fields through the inclusion of upstream controls or advecting more information on boundary-layer properties.

26. Atmospheric Modelling in Weather and Climate Science

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 1

ACCESS-AE: a national, km-scale numerical weather prediction ensemble system

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

The Bureau of Meteorology is developing a km-scale numerical weather prediction system for a domain that encompasses the entire nation. The system consists of a deterministic model ACCESS-A, and an ensemble system ACCESS-AE.

ACCESS-A is a 90 vertical level model with a horizontal grid spacing of 1.5 km and will provide rapid update, short-range forecasts. ACCESS-AE is a 12-member ensemble with 90 vertical levels and a horizontal grid spacing of 2.2 km and will provide end users with forecast uncertainty information.

Both ACCESS-A and ACCESS-AE use the UK Met Office Unified Model (UM) and have improved surface characteristics, especially for urban areas, due to the use of local high-resolution datasets to define land cover. The development of ACCESS-A and ACCESS-AE was made possible because of the Regional Atmosphere and Land Version 3.2 (RAL3.2) model physics configuration, which unified the previously separate mid-latitude and tropical RAL configurations. The RAL3.2 configuration has been shown to have more realistic precipitation distributions, an improved representation of convection and a reduction in 10m windspeeds resulting in improved nocturnal winds. Results from ACCESS-AE case studies for some high-impact weather events will be presented.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 2

ACCESS High-resolution Regional Modelling Project (AUS2200): A Community-based Platform for Weather and Climate Research

Yi Huang[1,2], Todd Lane[1,2], Hooman Ayat[1,2], Chun-Hsu Su[3], Scott Wales[3], Dale Roberts[1,2], Holger Wolff[4,2], Claire Vincent[1,2], Charmaine Franklin[3], Martin Dix[5], Christian Jakob[4]

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Advances in High Performance Computing in the past decades have been vital to improve our ability to predict high-impact weather events and the effects of climate change. High-resolution atmospheric modelling, which is enabled through increased computational efficiency, has led to significantly improved representation of topographic complexity and small-scale processes, many of which are associated with extreme weather.

AUS2200 is a community-based, pioneering project that aims to develop large-domain regional modelling capacity at kilometre grid-scale using the state-of-the-art ACCESS model. The project is intended to provide the Australian regional modelling community with a common platform that helps facilitate collaborations to advance scientific understanding of atmospheric processes across a wide range of scales, from continent-wide to kilometre. This project represents a flagship collaboration between the ARC Centre of Excellence for Climate Extremes (CLEX), Australian Bureau of Meteorology, National Computational Infrastructure and Australian Earth-System Simulator National Research Infrastructure (ACCESS-NRI).

In this presentation, we will provide an overview/update on the AUS2200 project, including its overarching goals, recent progress and vision for future development. In particular, we will introduce the modelling frameworks and configurations, technical innovation and advances, along with discussions around recent scientific activities and longer-term plans. We will also showcase some fresh results from several pilot science projects investigating a range of high-impact weather events across Australia, including the 2019/2020 drought and resulting fire weather, 2022 northern NSW flooding events, and local precipitation response to the Madden Julian Oscillation over NE Australia.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 3

Understanding the drying mechanisms contributing to the major bushfire events in Australia

Hooman Ayat

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Fire weather days are very much ‘weather events’ superimposed on longer-time scale phenomena (like drought) and are usually preceded by some heatwaves. Typical conditions leading to severe fire weather over eastern Australia comprises the passage of a synoptic-scale cold front, with the northwesterly prefrontal air being warm and dry. This study focuses on understanding the dynamics and processes behind surface drying conditions associated with frontal systems during significant bushfire events in Australia, including the black summer, black saturday, ash wednesday, and canberra 2003 fires. The investigation employs both Eulerian and Lagrangian approaches, utilizing the Unified Model with 2.2 km resolution to simulate the Australian atmosphere. Back trajectory analysis aids in tracking the origin of dry near-surface air and comprehending the involved large- and small-scale processes. Building upon a similar approach used in the study of black summer, this research aims to compare the identified drying processes in that event with the other three. The insights gained not only shed light on the mechanisms contributing to surface drying during bushfire events but also hold potential applications for improved fire weather prediction and management strategies, leading to more effective preparedness and response measures.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 4

Simulating the atmospheric impacts of transitioning to a hydrogen economy

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Transitioning away from a carbon-based economy will alter the emissions entering the atmosphere. Molecular hydrogen (H_2) and other hydrogen carrying gases may have a role to play in this transition.

Recent studies indicate that molecular hydrogen has an indirect but significant global warming potential, meaning that unintended release of hydrogen may reduce the benefit of lowering carbon emissions. Thus an understanding of the full impacts of molecular hydrogen is highly desirable.

Other hydrogen carrying gases, e.g. ammonia (NH_3) have known implications for air quality. When combined with changes in other atmospheric constituents, there is a strong motivation to simulate the effect of hydrogen (and related specied) on air quality.

This study provides the first look at the global and Australian implications of transitioning to a hydrogen economy, both in terms of climate and air quality impacts. Global simulations are conducted in the ACCESS-CM2-Chem model (Dennison & Woodhouse, 2023). Regional simulations are conducted in the CSIRO CCAM-CTM model. The tools and data will be invaluable for prudent and informed decision making.

Modelling scenarios are valuable, but there is an absolute requirement for determining baseline concentrations of the relevant gases, and continued monitoring throughout any transition.

References

Dennison & Woodhouse, 2023. ACCESS-CM2-Chem: evaluation of southern hemisphere ozone and its effect on the Southern Annular Mode. Journal of Southern Hemisphere Earth Systems Science 73: 17-29

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 5

A parameterisation for sea-breeze enhancement of convective rainfall in a global model

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Global models with coarse horizontal resolution cannot explicitly simulate small-scale circulations such as sea-breezes. This leads to systematic model errors in coastal convection and rainfall, particularly in island regions with complex topography.

We address this by developing a new parameterisation of sea-breeze driven coastal convection. Our parameterisation consists of two parts: i) identifying coastal points affected by sea-breezes, using large scale prognostic fields to calculate the thermal heating contrast between land and ocean, and ii) modifying the convection scheme when sea-breeze conditions are diagnosed. We implement a sea breeze parameter, defined at coastal grid points from the land-sea thermal contrast, and couple the calculation of the sea-breeze parameter to the convection scheme by increasing initial surface parcel buoyancy (increasing parcel temperature while maintaining its relative humidity) where the sea-breeze parameter is positive.

We initially test the parameterisation in single column model (SCM) runs, using prescribed initial conditions from Tropical Warm Pool International Cloud Experiment (TWP-ICE) during a period of sea-breeze convection. Having shown that the parameterisation behaves sensibly in SCM runs, we implement the parameterisation in a global atmosphere-only model (which allows for the development of dynamical and thermodynamic feedbacks). Initial experiments indicate i) that the parameterisation works as intended, ii) the model shows a corresponding increase of convective rainfall under diagnosed sea breeze conditions, and iii) that it affects the diurnal cycle of precipitation near coasts, with feedback then affecting the large-scale circulation. The parameterisation is currently being evaluated using high resolution models and observations of sea breeze convection.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 6

A machine learning approach for evaluating Southern Ocean cloud-radiative biases in ACCESS

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

The Southern Ocean radiative bias continues to impact climate and weather models, including the Australian Community Climate and Earth System Simulator (ACCESS). The radiative bias, characterised by too much shortwave radiation reaching the surface, is attributed to the incorrect simulation of cloud properties.

We use k-means cloud histogram clustering, applied to a satellite product and then fitted to nudged simulations of ACCESS atmosphere model to identify cloud types. We then identify instances when the model correctly or incorrectly simulates the same cloud type as the satellite product for any point in time or space.

We find that when the ACCESS model correctly simulates the cloud type, cloud property and radiation biases of equivalent, or in some cases greater, magnitude remain compared to when cloud types are incorrectly simulated.

To explore the cloud-radiative bias further we present a new method of model evaluation. We use an XGBoost model to predict the radiative bias of ACCESS, using cloud property biases as predictive features. The XGBoost model can explain up to 55% of the radiative bias from these cloud properties alone.

We then apply SHapley Additive exPlanations feature importance analysis to quantify the role each cloud property bias plays in predicting the radiative bias. We find that biases in liquid water path is the largest contributor to the cloud radiative bias over the Southern Ocean, though important regional and cloud-type dependencies exist. We then test the usefulness of this method in evaluating model perturbations and find that it can clearly identify complex responses.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 7

Assessing glaciogenic seeding impacts in Australia's Snowy Mountains: an ensemble modeling approach

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Australia's Snowy Mountains serve as a crucial watershed, supplying water for hydroelectric power, irrigation, and winter recreation. Wintertime glaciogenic seeding is undertaken in this region to enhance snowfall and increase water storage. To better quantify how seeding impacts on clouds and precipitation, we employed the WRF-WxMod® cloud seeding model to facilitate realistic simulations of cloud and precipitation in natural and seeded conditions over complex terrains.

Our recent numerical investigations demonstrated variable model sensitivities across different seeding cases, suggesting no one-size-fits-all model configuration. Therefore, this study aims to identify ensemble configurations that quantify the range of uncertainties for better estimating the overall seeding impacts, with the ultimate goal of assessing long-term seeding impacts over the past decades.

Nine distinct seeding cases from 2016 to 2019 were simulated. A nested domain setup was used, with a 4-km outer domain covering the major portion of eastern Australia and a 1-km inner domain enclosing the Snowy Mountains catchment. The ensemble configurations comprises 12 members, each differing in initialization datasets, ice nucleation schemes, aerosol conditions, and boundary layer schemes. For each member, we conducted both SEED and NO SEED (control) simulations, allowing for direct comparison and quantification of seeding impacts on cloud structure, cloud/precipitation process rates, and the distribution and amount of precipitation at the surface. The nine cases were clustered into four categories, featuring different meteorological regimes and varying levels of seeding potential. This presentation will show the seeding impact within these clusters and assess their uncertainties due to different factors.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 8 | Poster Session 2, Poster 44

Experimental Design of the Australian Climate Service convective-scale regional climate projections

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Convection-permitting atmospheric models (CPMs) have been used by the Bureau of Meteorology to generate short-range weather forecasts since 2017. By explicitly simulating convection and removing propagating errors that originate in convection schemes, CPMs are widely regarded to produce substantially more skilful forecasts of weather hazards than coarser resolution convection parametrised models.

CPM use in the climate modelling community has lagged behind weather forecasting. However, the improvements in forecasted weather allow convection-permitting climate projections to simulate the frequencies and intensities of hazardous weather more accurately and to project these hazard characteristics into the future. Hence, CPMs have the potential to provide substantial improvements to projections of future natural hazards.

The Australian Climate Service (ACS) is investigating the value-add that CPMs provide to climate hazard projections through generation and analysis of a targeted set of downscaled climate projections utilising a 4-km grid-spacing over Australia. These simulations will complement the larger ACS 12-17km grid-spacing regional climate ensemble by selectively downscaling a subset of the ACS ensemble. A multi-model approach will be taken, using CSIRO's CCAM and the Bureau of Meteorology's BARPA regional climate models and coordinating to ensure compatibility with other modelling approaches such as NARCliM and future CORDEX-Australasia flagship pilot studies.

This presentation will describe the experimental design of the ACS CPM ensemble. It will cover the goals of the ACS CPM experiments, advice received through consultation with hazard and CPM experts, host model selection, and consideration of the balance between resolution, ensemble size and simulation length within computational constraints.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 9 | Poster Session 2, Poster 42

Interactions between warm cloud and local forcings over the Great Barrier Reef: A case study using convection-permitting simulations

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

The important role of clouds, especially low-level clouds, in modulating the regional energy budget across the Great Barrier Reef (GBR) has garnered increasing attention, with the anomalies of cloud fractions directly linked to the thermal coral bleaching events. These shallow clouds, however, are by their nature sensitive to perturbations in both their thermodynamic environment and microphysical background.

In this study, we employ the Weather Research and Forecasting (WRF) model with a convection-permitting configuration at 1-km resolution to conduct a case study, where the sensitivities of warm clouds over the GBR to a range of local forcings, including orographic forcing, local sea surface temperature (SST) variation, and boundary layer aerosol loading, are examined. Our simulations show that orographic lifting and low-level convergence are crucial in explaining the cloud and precipitation features over the coastal mountains downwind of the GBR. However, clouds over the upwind ocean are more strongly constrained by the trade wind inversion, whose properties are strongly regulated by the coastal topography. On the scales considered in our study, the warm cloud fraction and the ensuant precipitation over the GBR show only a small response to the local SST forcing, with this response being tied to the simulated cloud-type. Finally, the cloud properties, including macro- and micro-physical properties, and precipitation appear to be agnostic to the boundary layer aerosol number concentration perturbations over the GBR. While a few isolated changes are noted throughout the simulations, these insignificant responses can largely be explained by the chaotic effects of cumulus convection.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 10 | Poster Session 2, Poster 40

Sensitivity of driving SST's resolution in simulating rainfall with high-resolution atmospheric models

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

This study unveils the substantial sensitivity of El Niño-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD)-related springtime rainfall patterns in Australia to input sea surface temperatures (SSTs) in the context of fine-resolution model simulations. Employing the Conformal Cubic Atmospheric Model (CCAM), an atmospheric General Circulation Model, we conducted SST-driven simulations forced by the 0.25° Optimum Interpolation Sea Surface Temperature (CCAM_OISST) and the 2° Extended Reconstructed Sea Surface Temperature version 5 (CCAM_ERSST5) respectively. Results indicate that both simulations meet the minimum benchmark standards for Regional Climate Model rainfall performance, with CCAM_ERSST5 obtaining higher scores in numerous metrics. However, CCAM_ERSST5 performs notably worse than CCAM_OISST in capturing ENSO/IOD-rainfall teleconnections, particularly concerning IOD. To understand this deficiency, we perform an additional experiment with CCAM driven by OISST with the SST surrounding the Australian region masked by ERSST5. This shows that CCAM_ERSST5's inability to replicate IOD-related rainfall may stem from filled values near land when imposing coarse-resolution SSTs onto a relatively high-resolution model. This emphasizes the need to soundly interpret benchmarking frameworks for model simulations and striking a balance between high-resolution and long-period SST data.

Session 26 (Thursday 8 Feb, 11:00-13:00), Talk 11 | Poster Session 2, Poster 46

Is global high-resolution simulations of the atmosphere in climate models feasible?

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

The need for high-resolution global climate model simulations has been widely recognised by the atmospheric science community for decades. One major roadblock for developing this capability is the lack of adequate computational resources. Here, we present an approach that allows us to run kilometre-scale simulations globally in climate models at adequate computational costs. The aim is to determine if global climate model simulations can be run for a short time period, typically spanning a few months, with reasonable confidence in the model errors. For this purpose, we aim to run the Australian Community Climate and Earth System Simulator Coupled Model (ACCESS-CM2) in the AMIP (Atmospheric Model Intercomparison Project) configuration for 4-8 months. As a first step, we run the model at N96 horizontal resolution (i.e., 1.875° × 1.25°) for 4 months in order to answer the question:

How much can we learn about the climatology in a climate model simulation run in the AMIP configuration for 35-years from short duration runs?

Preliminary analysis shows that a simulation of a single season reasonably reproduces the model errors as seen in the 35-year AMIP runs. There is also evidence that creating an ensemble of 4 years (randomly selected) of the same 4-month simulation is sufficient to replicate climatological model errors in AMIP simulations. Thus, it is reasonable to run high-resolution (eg. 10km × 10km) global simulations in climate models for just a few months, which allows us to investigate finer atmospheric processes that would otherwise be impossible to resolve in a climate model simulation.

27. High-resolution modelling

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 1

Evaluation of BARPA-C Convective-Scale Regional Climate Model over Australia

Emma Howard[1], Harvey Ye[1], Chun-Hsu Su[1], Christian Stassen[1], Acacia Pepler[1], Andrew Brown[2], Mitchell Black[1], Andrew Dowdy[1,2], Charmaine Franklin[1]

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Session
27. High-resolution modelling

Abstract
Natural hazards are changing across Australia and globally in response to anthropogenic climate change. Accurate projections of Australian climate hazards, such as intense rainfall, extreme winds, bushfires, and cyclones, depend to varying degrees on the representation of atmospheric convection in climate models and its upscale effects on synoptic weather systems. Furthermore, the locations of exposed populations such as urban centres and coastlines are often poorly resolved in low resolution climate models.

The Bureau of Meteorology is developing BARPA-C, a convection-permitting regional climate model, for the Australian Climate Service (ACS). BARPA-C uses the latest regional atmosphere and land- configuration of the Met Office Unified Model (MetUM) coupled to the JULES land surface model RAL3.2. BARPA-C builds on BARPA-R, the Bureau's core set of downscaled projections, which relies on a parametrisation scheme to provide atmospheric convection. Following regional climate modelling protocols, BARPA-C has been evaluated by downscaling reanalysis data and comparing modelled to observed climatologies. 10 years of ERA5 have been downscaled to 4-km grid-spacing using BARPA-C, from 2013 to 2022, via the regional-scale 17-km BARPA-R nest.

This presentation will evaluate BARPA-C against high-resolution observational datasets, including radar data, Himawari8 and BARRA-C2. This assessment will also evaluate the ability of BARPA-C to improve the representation of climate hazards, such as intense rainfall and extreme winds, compared to BARPA-R. Our results will help determine whether BARPA-C will be used to generate convection-permitting projections of Australia's future climate.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 2

Development of BARRA-C2 convective-scale regional reanalysis over Australia

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Session

27. High-resolution modelling

Abstract

Atmospheric reanalysis has been invaluable for a wide spectrum of applications, ranging from weather event studies, through trend and climatology analyses, to driving/training other physical or statistical models. Many applications depend on how well a reanalysis models influences of local surface heterogeneity in topography and surface types on the local meteorology and atmospheric convection processes that lead to wind gusts, extreme rainfall and hail.

Australian Climate Service (ACS) has a focus on providing local information on the present climatology and future changes in key natural hazards. While global reanalyses have continued to improve with horizontal resolution and quality, convection-permitting global reanalyses are still some years away. Higher-resolution, limited-area reanalyses with a regional focus can fill this gap.

For the ACS, the Bureau of Meteorology is developing a kilometre-scale downscaled reanalysis spanning 1979 to the present day over Australia. This replaces the first version of BARRA-C to provide a national coverage over a longer time period. Aligning with the development of the next numerical weather prediction system ACCESS-A and the regional climate projection modelling system BARPA-C, BARRA-C2 uses the latest regional atmosphere/land configuration (RAL3.2) of the Met Office Unified Model coupled to the JULES land surface model. It is nested in BARRA-R2 0.11-degree regional reanalysis, which assimilates more local observations than global reanalyses to provide better analyses for initialising and driving BARRA-C2.

In this presentation, we will present results from assessing BARRA-R2, BARRA-C2 and ERA5, to demonstrate where BARRA-C2 can provided additional information in capturing natural hazards.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 3

Phase-change simulations of the ice shelf/ocean boundary: examining double-diffusive layer and meltwater plume effects

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Session
27. High-resolution modelling

Abstract
The melting of Antarctic ice shelves is influenced by stratification and turbulence in the ocean boundary layer, which act to modulate the mixing of warmer and saltier water towards the ice base. Here, we consider the case of a vertical ice face melting into the stratified ocean using high-resolution phase-change numerical simulations. The simulations are first validated against a series of classic laboratory experiments that were conducted at room temperature by Huppert and Turner (J. Fluid Mech., 1980). Once validated, we move to lower temperatures that are more representative of the geophysical ocean system. The ocean dynamics show a complicated interplay between a turbulent buoyant meltwater plume and double-diffusive layers, and their influence on ice face scalloping. The double-diffusive layering height in the turbulent region matches reasonably well with the scaling prediction from the past study. The application of these results to the real ocean system is also discussed, with implications for ice shelf melt rates and future high-resolution phase-change simulations.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 4

Impact of absorption and scattering of phytoplankton, CDOM and suspended sediments on ocean heat and circulation in the Great Barrier Reef region.

Anna Maggiorano

CSIRO

Session

27. High-resolution modelling

Abstract

Phytoplankton, coloured-dissolved organic matter (CDOM) and suspended sediment in the ocean absorb and scatter solar radiation, affecting the vertical distribution of heating in the water column and its stratification. These processes are especially important where a large gradient in water clarity is present.

The Great Barrier Reef (GBR) region is characterised by highly seasonal variable freshwater input from several rivers, which can lead to large sediment and nutrient discharge near the coast, strongly affecting the water optical properties. In this study, we use a coupled hydrodynamical-optical-biogeochemical ocean model (eReefs 4 km configuration) to investigate the feedback between phytoplankton heat absorption and the ocean dynamics in the GBR region. The optical model calculates heat absorption based on the absorption and scattering of 4 phytoplankton types, CDOM and 6 sediment fractions, and as a function of solar zenith angle.

Results show that heat absorption due to phytoplankton, CDOM and sediment distribution is stronger near the coastal region, especially during the wet season. Considering the spatial variability of heat absorption can improve modelling the vertical distribution of heat compared to a constant heat absorption coefficient. Higher SST and lower subsurface temperature can develop in presence of a large concentration of optically absorbing material at surface. The modelled ocean heat content decreases on the shelf region and increases offshore when a variable heat absorption coefficient is considered. This study highlights the importance of considering water clarity and its spatial variability as an important process that drives hydrodynamic conditions, especially during extreme heating events.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 5

Air-sea coupling feedbacks over Tropical Instability Waves in a high-resolution regional coupled model of the Equatorial Pacific Cold Tongue

Ryan M Holmes[1], Lionel Renault[2], Julien Boucharel[2], Lisa Maillard[2]

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Session

27. High-resolution modelling

Abstract

Tropical Instability Waves (TIWs) play important roles in the energy and tracer budgets of the Eastern Pacific cold tongue and thereby influence El Nino, including its asymmetry and irregularity. While climate models with a 1/4-degree ocean resolution can capture some TIW variability, many associated processes such as TIW-driven modulation of air-sea fluxes and turbulent mixing are not well represented. This study investigates local-scale air-sea thermal (sea surface temperature, or SST, -driven) and current (surface current-driven) feedbacks over TIWs within a high-resolution regional atmosphere-ocean coupled model. Using manipulative process experiments where the signature of TIWs in air-sea coupling fields are removed in otherwise fully coupled simulations, we robustly quantify the rectified impact of these processes on TIW variability and the mean state of the Eastern Pacific coupled system. The thermal feedback is found to damp TIW temperature variance by a factor of 2, associated both with the direct dependence of air-sea heat fluxes on SST and indirect impacts on atmospheric boundary layer properties including surface winds, air temperature and humidity. These changes lead to a small 0.02C warming of the cold tongue SST through enhanced TIW-driven meridional heat fluxes. Current feedbacks are decomposed into TIW and mean current components using separate experiments, with both having distinct impacts on the TIWs and the mean state. Improved understanding of small-scale processes in the tropical Pacific are critical to address biases in low-resolution climate models that impact their predictions and projections of Pacific climate variability and change.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 6

Comparisons of high and low resolution GOSI9 models

Xiaobing Zhou[1], Frank Colberg[1], Gary Brassington[1], Christopher Bladwell[1], Debra Hudson[1], David Storkey[2], Catherine Guiavarch[2]

[1]Australian Bureau of Meteorology, Melbourne, Australia. [2]UK Met Office, Exeter, United Kingdom

Session

27. High-resolution modelling

Abstract

The GOSI9 model developed by UK Met Office is comprised of NEMO4-based ocean components and SI3 sea ice model. The ORCA025 (1/4 degree horizontal resolution) and ORCA012 (1/12 degree horizontal resolution) GOSI9 models have the same vertical resolution and similar physics configurations. They have been forced with the same interannually varying COREv2 forcings and intialised with the same initial conditions for 30 years from 1976 to 2005. Our results suggest that the ORCA012 model is cooler in the tropical subsurface, and this induces a larger cold bias and too strong interannual variabilities when compared with the ORCA025 model. Both models have large differences from observations in mixed layer depth and subsurface temperature in the Northern Atlantic in DJF (December to February) and MAM (March to May) seasons, and in the Southern Ocean in JJA (June to August) and SON (September to November) seasons. The ORCA012 model produces stronger sea surface kinetic energy in the regions of western boundary currents compared with the ORCA025 model. The 1/12 degree resolution allows the model to resolve the complex topography in the Indonesian Throughflow (ITF) regions and generate a more realistic ITF. The ITF volume transport in ORCA025 model is much stronger than the observations. The bias of sea level anomaly in ORCA012 model has a significant improvement in the Northern Atlantic and Southern Ocean. The model horizontal resolution has little impact on the sea ice performance in polar regions.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 7

The next-generation ACCESS-OM3 ocean - sea ice - wave model

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Australian National University, Canberra, Australia

Session

27. High-resolution modelling

Abstract

I will present an overview of ACCESS-OM3, its development progress and initial results, and our plans for the future. Since its release in 2019, the ACCESS-OM2 multi-resolution global ocean and sea ice model suite has been widely adopted in Australia, underpinning over 60 published papers and forming part of ACCESS-CM2, ACCESS-CM2-025 and OceanMAPS (Bluelink). However, it is built on now-obsolescent code (MOM5 and CICE5), so COSIMA and ACCESS-NRI are building its successor, ACCESS-OM3, which will update Australia's modelling systems to keep abreast of the leading edge of international model development. ACCESS-OM3 couples the WaveWatch 3 surface wave model with the latest MOM6 and CICE6, enabling representation of ice-wave and ice-ocean interaction, floe size distribution, landfast ice and ice shelf cavity circulation, and providing more efficient biogeochemistry and reduced numerical diffusion. Global configurations at resolutions up to 1/25° are planned, together with much higher-resolution regional configurations. Lower-resolution global configurations will be coupled with UM-CABLE via NUOPC to form ACCESS-CM3 and ACCESS-ESM3 intended for Australia's CMIP7 submission.

Session 27 (Wednesday 7 Feb, 11:00-13:00), Talk 8

A standardized benchmarking framework to assess downscaled precipitation simulations

Rachael Nichole Isphording[1,2,3], Lisa V Alexander[1,4,3], Margot Bador[5,6], Donna Green[3], Jason P Evans[1,7,8], Scott Wales[9]

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Session

27. High-resolution modelling

Abstract

Presently, there is no standardized framework or metrics identified to assess regional climate model precipitation output. Because of this, it can be difficult to make a one-to-one comparison of their performance between regions, studies, or against coarser resolution global climate models. To address this, we introduce the first steps towards establishing a dynamic, yet standardized, benchmarking framework that can be used to assess model skill in simulating various characteristics of rainfall. Benchmarking differs from typical model evaluation in that it requires that performance expectations are set a priori. This framework has innumerable applications to underpin scientific studies that assess model performance, inform model development priorities, and aid stakeholder decision-making by providing a structured methodology to identify fit-for-purpose model simulations for climate risk assessments and adaptation strategies. While this framework can be applied to regional climate model simulations at any spatial domain, we demonstrate its effectiveness over Australia using high-resolution, 0.5° x 0.5° simulations from the CORDEX-Australasia ensemble. We provide recommendations for selecting metrics and pragmatic benchmarking thresholds depending on the application of the framework. This includes a top tier of Minimum Standard Metrics to establish a minimum benchmarking standard for ongoing climate model assessment. We present multiple applications of the framework using feedback received from potential user communities and encourage the scientific and stakeholder user communities to build on this framework by tailoring benchmarks and incorporating additional metrics specific to their application.

30. Advances in verification methods, tools and technology

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 1

Toward best practice in operational forecast verification

Elizabeth Ebert[1], Brendan Dimech[2], Simon Allen[1], Samhita Barman[1], Nick Bright[1], Maree Carroll[1], George Cheng[1], Peter Edbrooke[1], Aidan Griffiths[1], Mahadi Hasan[1], Andrew Hicks[3], Mohammadreza Khanarmuei[4], Tennessee Leeuwenburg[1], Nicholas Loveday[1], Anand Nagaraj[1], Isha Nagpal[1], Thomas Pagano[1], Kevin Plastow[4], Tracy Rowland[1], John Sharples[1], Robert Taggart[5], Jez Templeton[1], Daria Wickramasinghe[1], Xiaoxi Wu[1]

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Session

30. Advances in verification methods, tools and technology

Abstract

For a national weather service to thrive and best serve the needs of its customers, it needs to routinely measure the accuracy and timeliness of its forecasts and communicate that information in an easily accessible, user-relevant manner. Forecast verification supports a process of continuous improvement within the organisation. It also provides critical information about forecast uncertainty to users so that they can make well informed weather-related decisions.

Since 2015 the Bureau of Meteorology has been actively developing its verification capability through

- new and improved operational verification systems,
- new user-focused metrics publicly available through the python ‘scores’ open source package,
- greater use of verification results to inform operational forecasting,
- interactive online displays that invite the user to explore the forecast performance, and
- creation of a vibrant Verification Community of Practice with international links.

This talk will give an overview of progress in all of these areas, and briefly describe plans to continue improving operational forecast verification in the Bureau of Meteorology.

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 2

The Use of the METplus Verification and Diagnostic Capability Across Multiple Scales and Applications

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Session

30. Advances in verification methods, tools and technology

Abstract

Verification and diagnostic activities are critical for the success of both numerical weather prediction and weather forecasting efforts at organizations around the world. Having reproducible results via a consistent framework is equally important for model developers and users alike. The enhanced Model Evaluation Tools (METplus) system is an umbrella verification, validation and diagnostic tool for use by thousands of users from both US and international organizations. Recently, several organizations within the National Oceanic and Atmospheric Administration (NOAA), the United States Department of Defense (DOD), and international partnerships such as Unified Model (UM) Partnership, led by the Met Office and including the Australian Bureau of Meteorology, have adopted the tools for their use both operationally and for research purposes. Many of these organizations are also now contributing to METplus development, leading to a more robust and dynamic framework for the entire earth system modeling community to use.

This presentation will provide an update on the rapidly expanding capabilities of METplus and how it is being used in across multiple scales and applications. It will highlight examples of the flexible configurability of METplus may be used in model and climate evaluation spanning both temporal (hourly forecasts to subseasonal-to-seasonal) and spatial scales (convection allowing to mesoscale, regional to global, tropical to cryosphere to space).

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 3

Using the METplus TC tools to verify tropical cyclones in real time

Molly B Smith[1,2,3], Kathryn Newman[3], George McCabe[3], John Halley Gotway[3], Jeff Hamilton[1,2], Randy Pierce[4,2], Ian McGinnis[4,2], Gopakumar Padmanabhan[1,2], Bonny Strong[4,2], Matthew Wandishin[2]

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Session

30. Advances in verification methods, tools and technology

Abstract

Part of the Unified Forecast System (UFS) project is unified verification for community model development, to support empirical decisions when transitioning to operations. UFS selected the Model Evaluation Tools (METplus) for this role, including its tools for verifying tropical cyclones (TCs). These were initially designed for postseason analysis, but can be used for realtime verification. We will examine two realtime implementations: the Global Systems Laboratory (GSL)'s live hurricane season verification, and METplus's inclusion into the Hurricane Analysis and Forecast System (HAFS) workflow.

As most Northern Hemisphere TCs occur over just a few months, GSL's model developers need realtime verification to show which of their developmental models are superior and which need improvements. GSL thus runs two parallel workflows with METplus. The first verifies all the points in TC forecasts as they become available, which provides the fastest feedback but can be somewhat limited. The second workflow runs at a week's lag, and verifies the last seven days of all valid forecast tracks. This feedback is slower to become accessible, but can calculate retrospective statistics such as rapid intensification.

The UFS Hurricane Application, HAFS, became operational in June 2023 with a focus on transitioning TC modeling research into operations. To facilitate both rapid performance and large sample evaluations, METplus is being implemented into the HAFS workflow.

METplus is open source, and our hope is that its use continues to expand amongst the UFS community, and to other public/private sector entities, aiding the development of new models.

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 4

Verification of Bureau's Ensemble-based NWP Rainfall against Various Observation Sources Using METplus

Mohammadreza Khanarmuei[1], Brendan Dimech[2], Beth Ebert[3], Mohammad Mahdi Hasan[3], Anand Nagaraj[3], John Sharples[3], Xiaoxi Wu[3]

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Session

30. Advances in verification methods, tools and technology

Abstract

A team of research scientists and software developers within the Science and Innovation Group of the Bureau of Meteorology is working collaboratively to enhance the Bureau's verification capabilities through the adoption of METplus, a verification system developed by the National Center for Atmospheric Research (NCAR). While the Bureau currently employs Jive, a Python-based verification system, to assess the quality of its official weather forecasts, the implementation of METplus aims to reinforce verification processes for the Bureau's NWP models.

During the initial phase of our work, a series of scientific tests were conducted to assess whether and how METplus can meet the needs of our research and operational teams. Concluding this phase, we developed a Python program that facilitates the preprocessing of the Bureau's specific forecast and observation data. Additionally, we formulated a set of recommendations on how best to utilise METplus to verify various variables of the Bureau NWP models and different aspects of verification process, such as selecting suitable metrics and interpolation techniques.

Continuing from these initial steps, one of our primary objectives was to verify rainfall forecasts generated by the Australian Community Climate and Earth-System Simulator Global Ensemble (ACCESS-GE) model against gauge and gridded daily rainfall data. In this study, we provide an overview of our end-to-end verification process of ACCESS-GE rainfall, from the preprocessing of the input data to post-processing and visualisation steps. We also discuss outcomes of our verification for multiple events of heavy rainfall during 2022-2023.

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 5

Assessing multivariate forecast skill and reliability

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[1]CSIRO, Brisbane, Australia. [2]CSIRO, Melbourne, Australia

Session

30. Advances in verification methods, tools and technology

Abstract

In the coupling of forecasts from numerical weather prediction or global climate models with downstream models such as hydrological or crop models, it is important that the input variables are jointly calibrated and have realistic spatial, temporal and intervariable patterns. It is usually the case that raw forecasts do not have appropriate characteristics at the scales of interest and therefore forecast post-processing is required. In this study, we examine the joint calibration of rainfall and temperature forecasts from seasonal GCMS for raw forecasts and forecasts that have been post-processed using statistical techniques such as quantile mapping and the Bayesian joint probability modelling approach. Several metrics to evaluate multivariate skill and reliability are employed, including the Energy Score, which is a multivariate generalisation of the Continuous Ranked Probability Score. It is found that the Energy Score summarises the forecast skill and accuracy of the variables well but is rather insensitive to misspecification of the multivariate dependencies. Another score, the Variogram Score is found to place more importance on achieving the correct multivariate dependencies in evaluating skill. Furthermore, we explore multivariate reliability through PIT and rank histograms to understand whether post-processed forecasts remain reliabile when aggregated to higher spatial and temporal scales, which is important when weather or climate forecasts are to be filtered through integrative models.

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 6

Effective estimation of the continuous ranked probability score using limited information from the predictive distribution

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[1]Bureau of Meteorology, Sydney, Australia. [2]Bureau of Meteorology, Melbourne, Australia

Session

30. Advances in verification methods, tools and technology

Abstract

The continuous ranked probability score (CRPS) is a commonly used strictly proper scoring rule for measuring the accuracy of predictive distributions. One of the advantages of the CRPS is that the results can be interpreted as the average relative economic regret of using the forecast within a simple binary decision framework. While the CRPS gives equal weighting to each possible user decision threshold, the threshold weighted CRPS permits flexible weighting on decision thresholds. For example, the threshold weight function can be chosen to emphasise predictive performance of extremes.

There are several common ways to compute the CRPS, but these usually require extensive knowledge of the predictive distribution or a large representative sample from it. In this talk, we will demonstrate that, for a range of operational forecast systems, the CRPS can be estimated to a high degree of accuracy with knowledge of only a handful of quantile values from the distribution. Similar results apply to the threshold weighted CRPS. These estimates, being weighted sums of (threshold weighted) quantile scores, are themselves proper scores and so can be legitimately used for verification. The theoretical justification for this approach is that the threshold weighted CRPS is expressible as an integral of threshold weighted quantile scores.

This estimation method will be illustrated using Bureau precipitation, temperature and streamflow forecasts. Computational time and volume advantages of using this method will also be discussed.

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 7

Using Murphy diagrams and the FIRM score to understand forecast performance at key decision thresholds.

Nicholas Loveday[1], Mohammadreza Khanarmuei[2], Robert Taggart[3], Robert A Warren[1]

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Session

30. Advances in verification methods, tools and technology

Abstract

The Bureau issues daily probability of thunderstorm forecasts as well as categorical thunderstorm outlooks. The categories are determined by whether the chance of a thunderstorm is greater than 10% or 30%. We show how Murphy diagrams (Ehm et al., 2016) and the FIxed Risk Multicategorical (FIRM) score (Taggart et al., 2022) can measure performance at these key decision thresholds.

Murphy diagrams can be used to measure performance of expectile forecasts, quantile forecasts, and probability forecasts of a binary event. They display the mean elementary score (or economic regret) across a range of user decision thresholds. The FIRM score is a verification score that can be used to verify multicategorical forecasts that have a specified risk threshold.

In this talk we illustrate graphically how the FIRM score relates to Murphy Diagrams using thunderstorm forecast verification results. We also show how the FIRM score can be used to directly compare probabilistic thunderstorm forecasts to categorical thunderstorm forecasts. This has the benefit of allowing fair comparison of continuous and categorical probabilistic forecasts in a consistent scoring framework for key decision thresholds.

References:

Ehm, W., Gneiting, T., Jordan, A. and Krüger, F., 2016. Of quantiles and expectiles: consistent scoring functions, Choquet representations and forecast rankings. Journal of the Royal Statistical Society Series B: Statistical Methodology, 78(3), pp.505-562.

Taggart, R., Loveday, N. and Griffiths, D., 2022. A scoring framework for tiered warnings and multicategorical forecasts based on fixed risk measures. Quarterly Journal of the Royal Meteorological Society, 148(744), pp.1389-1406.

Session 30 (Thursday 8 Feb, 11:00-13:00), Talk 8

Challenges and Opportunities in Operational Weather Forecast Verification

Thomas C Pagano, Elizabeth E Ebert, Robert Taggart, Nicholas Loveday, Mohammadreza Khanarmuei

Bureau of Meteorology, Melbourne, Australia

Session

30. Advances in verification methods, tools and technology

Abstract

Operational weather forecast agencies encounter significant challenges in the verification and evaluation of forecasts. To address these issues, a series of online workshops were organised, engaging operational personnel from six countries, including model developers, observations managers, operational meteorologists, and verification system developers. Through discussions and polls, five prominent themes emerged: inadequate verification approaches, incomplete and uncertain observations, challenges in assessing performance aligned with users' real-world experiences, miscommunication and misinterpretation of forecasts and complex verification information, and various institutional factors. Additionally, nearly fifty urgent scientific questions relevant to operational practices were identified, accompanied by calls to action. These include the design of forecast systems with verification in mind, better availability of observations, creation and adoption of community software systems and the fostering of an interdisciplinary community inclusive of operational agencies, users, and researchers.

32. Machine Learning for Earth System Sciences

Session 32 (Friday 9 Feb, 14:00-15:30), Talk 1

Application of Machine Learning Techniques to Detect and Respond to the Impacts of Global Warming on Southeast Australia.

Milton S Speer, Lance M Leslie

University of Technology Sydney, Sydney, Australia

Session

32. Machine Learning for Earth System Sciences

Abstract

Australia is severely affected by global warming (GW), which increasingly amplifies the well-known cycles of droughts, floods, and extreme weather events. This work focuses on the impacts of GW on populous southeast Australia. This study applies machine learning (ML) techniques to identify the main drivers of these impacts and presents examples of the relevant drivers responsible for the observed trends in precipitation and temperature, therefore illustrating that ML techniques can provide valuable guidance to policy makers in framing their responses to GW impacts.

Session 32 (Friday 9 Feb, 14:00-15:30), Talk 2

Can deep-learning models downscale rainfall extremes in future climates?

Neelesh Rampal[1,2,3], Peter Gibson[4], Sanaa Hobeichi[2,5], Steven Sherwood[2,3], Gab Abramowitz[2,3]

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Session

32. Machine Learning for Earth System Sciences

Abstract

Downscaling with deep learning can be orders of magnitude more computationally efficient than regional climate models (RCMs) and has outperformed traditional empirical downscaling techniques, particularly in resolving climate extremes in a historical context. However, there is still a lack of understanding on whether learned relationships from deep learning models trained on observations can extrapolate to future climates. Our study aims to address this issue of "extrapolation" in deep learning techniques in the context of downscaling extreme rainfall. We train a Convolutional Neural Network (CNN) that maps large-scale circulation fields from ERA5 reanalysis to high-resolution rainfall observations () over New Zealand. We then apply the trained CNN offline to historical and future projections from three different General Circulation Models (GCMs). To alleviate the issue of extrapolation, we introduce a novel two-stage training approach. First, we pre-train a CNN as an unsupervised variational autoencoder on large-scale circulation fields. Then, we fine-tune it to downscale high-resolution rainfall, thereby "sharing" knowledge from two separate tasks. We show that through training CNN in two stages, we can better reproduce trends in extreme rainfall compared to GCMs/RCMs. This contrasts with traditional training methods, which typically result in poor extrapolation to future climates and underestimating future trends in extreme rainfall. We also showcase a new method to emulate RCMs with Generative Adversarial Networks (GANs), which are able to generate an ensemble of outcomes for a specific boundary condition.

Session 32 (Friday 9 Feb, 14:00-15:30), Talk 3

Application of XGBoost in site-specific weather forecasts for Australia

Mengmeng Han[1], Tennessee Leeuwenburg[2], Brad Murphy[2]

[1]Bureau of Meteorology. [2]Bureau of Meteorology, Australia

Session

32. Machine Learning for Earth System Sciences

Abstract

Site-specific weather forecasts are essential to the accurate prediction of power demand, and consequently are of great interest to energy operators. However, current numerical weather prediction (NWP) models lack the fine resolution needed for localised weather forecasts, and instead provide the averaged weather information within each model gridbox (usually of order km in size). Even after post-processing and bias correction, area-averaged information is usually not optimal for sites. Prior work on site optimisation has focused on linear methods, weighted consensus averaging, time-series methods and others.

In this study, we are investigating the feasibility of optimising forecasts at sites using the popular machine learning model: gradient boosting decision trees. Regression trees were trained with historical NWP and site observation data to predict temperature and dew point at multiple site locations. A working ML framework, named 'Multi-SiteBoost' has been established and initial results show a significant improvement compared with gridded values from bias-corrected NWP models. A partial comparison against some alternative methods will also be presented.

Session 32 (Friday 9 Feb, 14:00-15:30), Talk 4

Increased hydroclimatic extremes in southeastern Australia over the period 2010–2022

Joshua Hartigan[1], Milton Speer[2], Lance Leslie[2]

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Session

32. Machine Learning for Earth System Sciences

Abstract

A major consequence of recent accelerated global warming is the sudden worldwide increase in hydroclimate extremes, including droughts and flood events, affecting water availability in many countries. In particular, the period 2010–2022 saw much of eastern and southern Australia experiencing flood events from the double La Niña of 2010–2012, which produced record rainfall totals. Then followed a drought from 2013–2019 that saw record lowest rainfall in Australia's food bowl, the Murray-Darling Basin. In late winter and spring 2016 a strong negative Indian Ocean Dipole resulted in record rainfall for parts of inland southeast Australia. Finally, from 2020–2023 a triple La Niña generated widespread record rainfall and extensive flooding in the four southeastern Australian states of Queensland, NSW, Victoria and Tasmania. Each of the three flooding events and the drought period between them affected eastern Australia's hydroclimate through extremes in precipitation, river levels, soil moisture and evapotranspiration. Massive impacts resulting from an extended period of reduced environmental water include loss of life and property from the catastrophic bushfires of 2019–2020, and destruction of wetlands and wildlife from ecosystem collapse. There was significant further loss of property from both riverine and coastal erosion. These extremes have occurred in the context of accelerated global warming since the early 1990s, leading up to and including 2010–2022. Machine learning attribution is applied to show the contributions of climate drivers and changes in the tropospheric circulation, on observed hydroclimate extremes over southeastern Australia focusing on 2010–2022.

Session 32 (Friday 9 Feb, 14:00-15:30), Talk 5

Pretraining AI surrogates for hybrid climate simulations

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Session

32. Machine Learning for Earth System Sciences

Abstract

Machine Learning (ML) approaches are becoming increasingly popular in weather and climate modelling, especially for learning and replacing physical parameterizations within a climate model using surrogates. Emulating physical processes are often limited by the need for large and accurate training dataset. Current datasets from global cloud-resolving models have biases in representing subgrid processes, while observations have limited variables and geographical coverage. On the other hand, higher-resolution simulations provide precise information at local scales but lack adequate sampling. In this study, we propose and test a pretraining and finetuning strategy for combining the benefits of different types of training data to obtain better physics emulators using the concept of transfer learning. We investigate model generalizations with two experiments, firstly by testing how a model trained on one dataset performs when tested on another and secondly by measuring model disagreement on a specific dataset. We also investigate the benefits of finetuning surrogates on models pretrained on lower fidelity data. Results for architectural sensitivity and network performance using hyperparameter comparisons will also be presented.

Session 32 (Friday 9 Feb, 14:00-15:30), Talk 6

Nearshore wave prediction using Graph Neural Network at Darwin Harbour, Australia

Nazeat Ameen Iqra[1], Jun Li[2], Xiao Hua Wang[1]

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Session

32. Machine Learning for Earth System Sciences

Abstract

Darwin Harbour (DH), Australia, is a flood-dominated estuary where the wave substantially influences sediment resuspension and transportation, especially in the outer harbour. Hence, the prediction of waves is crucial for coastal activities and management in DH. This paper presents a graph neural network (GNN) model to forecast wave characteristics in the nearshore zone of DH. The model was assigned for next-frame prediction of wave parameters such as significant wave height, peak period, wavelength, velocity, and wave period. This implies that the model had been configured to project future features by assessing parameters at a specific domain and timeframes. The GNN framework is intended to identify graph dependence via message passing between the nodes. Input of the model is the wave findings from 62-days simulation of the SWAN model. The study was carried out among 7194 nodes, and each node was linked to 5 neighbour nodes to forecast dependencies accurately. The data has been split into 80% and 20% for training and testing purposes. Furthermore, the significance of the number of hours as an input on anticipated outcomes was investigated. The results reveal that GNN model can replicate wave variables from physics-based model with mean-squared errors less than 0.14% and coefficients of r-squared more than 71%. Moreover, it demonstrates that increasing the number of hours for input and time steps for forecasting reduces the model's performance. As such, the proposed GNN model can be useful for wave prediction and can be integrated with traditional coastal modelling to examine coastal phenomena.

33. Renewable Energy

Session 33 (Tuesday 6 Feb, 16:30-18:00), Talk 1

A high-resolution wave energy assessment of south-east Australia based on a 40-year hindcast

Jin Liu[1,2], Ian Young[2]

[1]Department of Energy, Environment and Climate Action, Melbourne, Australia. [2]University of Melbourne, Melbourne, Australia

Session

33. Renewable Energy

Abstract

In this study, a third-generation ocean wave model (WAVEWATCH III; WW3) implemented on a high-resolution unstructured grid was developed to investigate wave energy in the south-east of Australia over the 40-year period from 1981 to 2020. The simulated wave power shows good agreement with values estimated from multiplatform satellite data. Thus, the modeled data were used to study statistics (mean conditions, seasonality, extremes, and long-term trends) of wave power in the domain, which show impacts of Southern Ocean swell and protection provided by the land mass of Tasmania. The results indicate increasing wave power trends, with the largest values in the southeastern part of the domain over the 40-year period. These positive trends are mainly a result of an increase in significant wave height rather than peak wave period. By utilizing the simulated wave properties, we estimated regional annual electric power at 14 coastal locations using 9 typical wave energy converters (WECs). To do so, we conducted a comprehensive analysis (seasonal variations, wave power roses, probability distributions, and bivariate probability distributions) at these locations. The results demonstrate that the western and southwestern coasts of the domain are promising generation sites but with large seasonal variability. The central and eastern coasts are protected by Tasmania, and exhibit more stable conditions but are far less energetic for electricity production. This study has critical implications for the region, which provides a benchmark for coastal WEC deployment.

Session 33 (Tuesday 6 Feb, 16:30-18:00), Talk 2

An assessment of atmospheric reanalyses for wind power simulation for energy system modelling

Graham D Palmer, Roger Dargaville, Changlong Wang

Monash University, Clayton, Australia

Session

33. Renewable Energy

Abstract

Atmospheric reanalyses are commonly used for wind power simulation in energy system models. Hourly wind power ‘traces’ can be produced for any location in Australia by combing reanalysis wind speed with wind turbine power curves. This presentation discusses the Australia BARRA reanalyses suites, and compares them to the global ERA5 and MERRA-2 reanalyses. When assessing the suitability of reanalyses for energy system modelling, key statistical indicators are bias, bias spread, correlation and reproduction of power frequency distribution. The performance of the reanalyses are discussed, including the role of bias correction and simulation uncertainties.

Session 33 (Tuesday 6 Feb, 16:30-18:00), Talk 3

Climate influence on compound wind and solar droughts in Australia.

Doug Richardson

ARC Centre of Excellence for Climate Extremes, Sydney, Australia

Session

33. Renewable Energy

Abstract

Solar photovoltaics and wind power are central to Australia's renewable energy future, which implies an energy sector vulnerable to weather and climate variability. Alignment of weather systems and the influence of large-scale climate modes of variability risks widespread reductions in solar and wind resources, and could induce grid-wide impacts. This talk will describe the weather patterns associated with widespread, compounding reductions in solar and wind power across the National Electricity Market. We will also explore the role of large-scale climate modes of variability, such as the El Nino Southern Oscillation and the Southern Annular Mode, in modulating renewable energy resources and energy demand. This research could have implications for management decisions on monthly and seasonal time scales.

Session 33 (Tuesday 6 Feb, 16:30-18:00), Talk 4

Quantifying variability and sky condition for PV across multiple timescales

Shukla Poddar[1], Merlinde Kay[1], John Boland[2]

[1]School of Photovoltaic and Renewable Energy Engineering, UNSW. [2]Industrial AI Research Centre, University of South Australia

Session

33. Renewable Energy

Abstract

Deployment of photovoltaic (PV) systems has increased globally to meet the renewable energy targets. However, PV power production is sensitive to climatological factors like intensity of radiation, presence of cloud cover, temperature changes, etc. Intermittent PV power generated due to cloud-induced variability introduces reliability and grid stability issues at higher penetration levels. It is essential to quantify resource variability to mitigate intermittent power supply. To date, there have been several metrics proposed to quantify variability and classify sky-conditions that perform extremely well for high-temporal resolution (minute-to-seconds) data. However, with the lower-temporal resolution datasets like 1-hourly, the classification scheme is not applicable since variability smoothens out. Climate model projections usually provide hourly data due to high-computational requirements. Thus, making it difficult to classify the sky-conditions in the absence of additional cloud data[JB1] . In this study, we propose a new scheme to classify the sky-conditions that is based on the two common variability metrices: clear-sky index and normalized aggregate ramp rates. The normalized aggregate ramp rates can be calculated using global horizontal irradiance or power output. This classification scheme can identify clear-sky, highly-variable, intermittent and overcast days. We use Bureau of Meteorology (BOM) weather station data to identify and validate our scheme for different climate regions across Australia. We use the regional climate projections from the the Coordinated Regional Downscaling Experiment (CORDEX) for Australasia to classify the sky-conditions for historical and future periods under high-emission scenario. This proposed classification scheme can be homogenously applied to any dataset despite their temporal resolution.

Session 33 (Tuesday 6 Feb, 16:30-18:00), Talk 5

Addressing the challenges of sub-seasonal forecasting for wind generation

Rachael Quill, Evgenia Titova-Shankar

Weatherzone, Sydney, Australia

Session

33. Renewable Energy

Abstract

Occupying the space between short-term weather dynamics and long-term climatology, forecasting at sub-seasonal to seasonal scales can present unique challenges. Yet, critical operational decisions across various industries must be made weeks or months ahead of time to enable the required planning and scheduling to take place, with renewable energy and wind generation no exception.

In this project, forecasting tools are developed to support decision making in wind energy operations by providing data out to 4-weeks ahead. Sub-seasonal generation forecasts are produced in a hybrid modelling environment using global sub-seasonal meteorological forecasts blended with local wind generation observations. Multiple modelling approaches are compared to analyse the most informative, yet robust, mechanism for predicting wind generation over the 28-day horizon. Two specific pathways are investigated in detail; the first targeting hub-height wind speeds prior to power conversion, and the second improving power curve calibration to directly target wind generation.

A significant challenge in sub-seasonal forecasting is to provide useful information. Often decision makers require deterministic forecasts like those provided in the first 14 days, yet these can be meaningless considering high uncertainty at 3-4 weeks ahead. Alternatively, typical seasonal forecasts provide regional probabilities of, say, above or below average, which can be too general to support operational decision making. In this project, various derivations and representations of forecast data are explored to relate the sub-seasonal wind speed outlook to variability in the local long-term generation averages, as well as the uncertainty around that relationship.

Session 33 (Tuesday 6 Feb, 16:30-18:00), Talk 6

Photovoltaic soiling from particulate matter across Australia

Abhnil Prasad[1,2,3], John Rodriguez[2], Brendan Wright[2], Ziv Hameiri[2], Merlinde Kay[2]

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Session

33. Renewable Energy

Abstract

The impact of particulate matter on both human health and air quality in Australia is widely acknowledged, however, its effects on solar energy remain unclear. $PM_{2.5}$ and PM_{10} are types of particulate matter that can affect the production of photovoltaic power by decreasing transmission through soiling panels. This matter is produced in Australia through direct emissions or gaseous conversions from both natural (dust storms, bushfires, vegetation, and sea spray) and anthropogenic (combustions, erosions, and abrasions) sources. Thus, our goal is to investigate PM characteristics in Australia by comparing the Modern-Era Retrospective Analysis for Research and Applications version 2 (MERRA-2) with ground stations to validate and assess $PM_{2.5}$ and PM_{10} climatology and trends in Australia. Our study will illustrate the energy reductions caused by PM-related soil accumulations, as well as the effect of removing them through precipitation bursts over Australia, including some operational solar farms. Additionally, we will examine the transmission loss due to soiling on panels from PM concentrations and its sensitivity to rainfall thresholds for natural cleaning.

34. Equity and justice in climate services + education and outreach

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 1

An agenda for justice and equity in Australian climate services

Svenja Keele

Monash University, Melbourne, Australia

Session

34. Equity and justice in climate services + education and outreach

Abstract

Although climate services have a social ambition to reduce vulnerabilities, it is becoming increasingly evident that their provision and distribution of benefits can produce social, economic and spatial inequalities. In this presentation, we synthesise current academic literature from diverse geographies to identify the social and spatial dimensions of inequalities and injustices associated with climate services. In light of the significant growth in climate services in Australia and our Indo-Pacific region, and the intense climate risk and adaptation policy work currently underway by the Federal Government, we also propose an agenda for equity and justice in Australian climate services.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 2

Challenging inequity through responsible design and delivery of climate services in Australian agriculture

Yuwan Malakar[1], Rebecca Darbyshire[2], Aysha Fleming[3], Emma Jakku[1], Stephen Snow[1], Simon Fielke[1], Tammy Hunter[4], Stephanie Dickson[4]

[1]CSIRO, Brisbane, Australia. [2]CSIRO, Canberra, Australia. [3]CSIRO, Hobart, Australia. [4]Bureau of Meteorology, Australia

Session

34. Equity and justice in climate services + education and outreach

Abstract

Climate services are key to build a climate resilient agriculture system. Their benefits, however, may be contingent on access to technology and resources (economic equity), the scale of investment, and farming commodity and community (sectoral equity) as well as other diversity characteristics (e.g., cultural and equity). We demonstrate how unintended inequities throughout the design of climate services can be challenged by embedding a more responsible inclusive approach in the design process. Our case study is My Climate View, a product of the Climate Services for Agriculture (CSA) program. CSA uses four critical elements to achieve inclusive and equitable design of My Climate View: (1) focus on national scale of climate projections; (2) iterative development responsive to user feedback; (3) engagement with existing extension institutions for sustainable adoption; and (4) training of advisors for skill support and facilitation. The interdisciplinary collaboration among engineers, scientists (social science, climate science, agricultural science, and data science), and government bodies played an important role to identify and act on these four elements. Consequently, My Climate View offers climate services to a wide range of farmers (small holdings to corporate) across various commodities and has plans for including bush foods. We learned that the consideration of equity needs to be a part of the design process not an afterthought. Further, achieving equity in climate services is not about any one activity or milestone, but is a process that continues from the conception stage to delivery and beyond. It requires a system perspective and a partnership approach.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 3

Evaluating the state of play: Country Hydromet Diagnostics results for the SW Pacific and implications for climate and weather warnings equity

Andrew Tupper

Natural Hazards Consulting, Melbourne, Australia

Session

34. Equity and justice in climate services + education and outreach

Abstract

Over the past several years, a global tool and approach, the Country Hydromet Diagnostics, has been developed to give a peer-evaluated maturity-based assessment of National Meteorological and Hydrological Services. The process considers ten elements, including governance, partnerships, observational infrastructure, data and product sharing, numerical weather prediction application, warning and advisory services, climate services, contribution to hydrological services, product dissemination and outreach, and the use and national value of products and services. During 2023, this tool and approach was rolled out for many least developed countries, including in the Pacific as well as elsewhere, in support of the Systematic Observations Financing Facility and the Early Warnings for All initiative, both important global initiatives. The results reinforce the multiple areas in which the peoples of small-island developing states are disadvantaged, but also show us the great potential for service improvements, with benefits for the entire region.

Using this systematic approach will help us gain a synoptic view of climate and weather services, and also track the evolution of these services in time. This is important in the interests of tackling equity issues, particularly as many capacity development initiatives effectively fail. The systematic approach will help encourage investment in 'non-sexy' areas such as governance and infrastructure, whilst also considering the impact of improved services.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 4

Does sea-level rise amplify the inequity in urban spatial accessibility to public facilities? Evidence from a case study of Ningbo, China

Zhi LIU

The University of Melbourne, Melbourne, Australia

Session

34. Equity and justice in climate services + education and outreach

Abstract

Sea level rise induced by climate change can increase the extent of coastal flood events, which consequently has posed great challenges to different dimensions of social development. Particularly, these challenges might amplify inequity issues due to varied impacts across different areas and demographic groups. Beyond direct impacts, when transportation facilities and roads are flooded, the spatial accessibility of residents to key facilities is also affected, which may exacerbate social inequity by leaving disadvantaged group with difficulties in evacuating from disaster areas and access opportunities. Therefore, we explored the potential spatial and social inequity issues under sea level rise scenarios in Ningbo, China, with a focus on the spatial accessibility to public facilities (shelters, health institutes, supermarkets and green spaces). We simulated inundation maps under different sea level rise scenarios, along with the distribution of social and economic attributes to investigate who are exposed to future inundation risks. Further, we calculated the spatial accessibility to key facilities under different sea level rise scenarios to examine how this impacts social inequity. Results reveal that sea level rise causes a disproportionate impact on the transportation network, which translates into unequal accessibility to services among communities. Some marginalized areas (peri-urban areas, old-built residential communities, etc.) and disadvantaged groups (migrant workers, low-income groups, etc.) experience less accessibility and loss of opportunity to services. Given these increasing inequity issues related to sea level rise, disadvantaged groups should be prioritized to mitigate existing inequities, and more effective and inclusive adaptation actions are needed to benefit all groups.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 5

WA case study for identifying and monitoring user needs for informing stakeholder engagement and designing and evaluating the effectiveness of the Climate Science Initiative knowledge products and web portal.

Sharna t Nolan[1], Tamara Pinkerton[2]

[1]DWER, Perth, Australia. [2]DWER, Perth

Session

34. Equity and justice in climate services + education and outreach

Abstract

This presentation will provide an overview of how Western Australia's Climate Science Initiative (CSI WA) has targeted priority needs identified by users of climate science information. The CSI will produce and present climate science information to support governments, business and communities to understand and adapt to the impacts of climate change. A stakeholder engagement strategy and end user needs assessment supports the program's communication strategy and production of accessible climate projections and knowledge products. Here, we will describe the process and benefits from consultation and collaboration with counterpart roles in interjurisdictional and national agencies to determine the approach, lessons and resource requirements learned from different engagement approaches when producing climate information and knowledge products for similar audiences. We will also describe the process and results of our state end user consultation process, including use of a stakeholder analysis and mapping exercise, targeted surveys and focus group testing to characterise stakeholder groups and tailor climate science narratives, preferences and communication modalities to inform web portal and knowledge product development. This work highlights the importance of aligning the climate science program with the Climate Adaptation Strategy, Risk Assessment Framework, state Adaptation Research planning, planned Monitoring and Evaluation Framework and relevant national initiatives.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 6

Meeting the climate information needs of environmental decision makers

Brad Murphy[1], John Clarke[2], David Hoffmann[1]

[1]Bureau of Meteorology, Melbourne, Australia. [2]CSIRO

Session

34. Equity and justice in climate services + education and outreach

Abstract

The National Environmental Science Program Climate Systems Hub undertakes research to advance the understanding of Australia's climate, its extremes and associated drivers, that will directly inform climate adaptation solutions for Australia. A hub project has been focussing on how to best deliver accessible and useable climate information to enable the widest possible uptake and increased impact by stakeholders making decisions on environmental management. Wide stakeholder engagement provided vital insight on the greatly varying needs of users depending on their level of technical expertise and intended applications. The most universally identified requirement was for a single location guiding users to the most appropriate, and sector-specific information, as well as to data at the appropriate level for their expertise and application. Calls for guidance, training, and support on how best to use information also emerged as pressing needs.

The gateway aims to overcome barriers in finding and applying climate information in decision-making by using the best available science and following good practice that fills a gap in the existing information landscape, and meets the specific needs of NESP stakeholders. We present progress on how to best meet user needs, and on co-designing a gateway to deliver integrated training, guidance, and regional projection summaries, including how user-centred design principles are guiding gateway design and user testing.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 7

Doorway to Northern Queensland – Delivering Baseline Climate Briefings

Jessie L Gray[1,2], Eliza Glasson[1,2], Jake Hammelswang[1,2], Bradley Bleeker[1,2], Luke Shelley[1,2]

[1]Bureau of Meteorology, Townsville, Australia. [2]Australian Climate Service, Townsville, Australia

Session

34. Equity and justice in climate services + education and outreach

Abstract

Uptake and understanding of baseline climate knowledge were identified as critical challenges for Northern Queensland councillors in preparing and making decisions about future adaptation measures. The Northern Queensland team – a hybrid office for the Bureau of Meteorology and the Australian Climate Service – has embarked on an educational uplift to councillors with the intention to provide awareness and understanding of future climate trends into the next 60 years. Key messaging utilises information from the State of the Climate Report 2022 and the My Climate View tool communicated in a way that highlights the local impact on the councillor's region of responsibility (i.e., the so what factor). Between October 2022 and November 2023, over 70% of councils accepted our invitation to present, with 63% requesting an in-person presentation. These engagements taught us about local insights into natural disaster patterns, risk mitigation and key climate concerns regarding heat, flooding, tropical cyclones, rainfall, and sea level rise. Further insights and relationships built through this engagement have been paramount in bridging the gap between Northern Queensland councils and decision-makers in the Bureau of Meteorology and Australian Climate Service – making the concerns of these communities known and heard.

Session 34 (Wednesday 7 Feb, 11:00-13:00), Talk 8

INVESTIGATE: Converting an old shipping container into an immersive marine science cinema

Ben Arthur, Matt Marrison, Zoe Burton, Matt Kimber

CSIRO Marine National Facility, Hobart, Australia

Session

34. Equity and justice in climate services + education and outreach

Abstract

The CSIRO Marine National Facility is committed to deepening the public's understanding of marine and atmospheric research and its contribution to solving key challenges for Australia. We seek to make research accessible through appealing and creative storytelling showcasing our contribution, impact and value. Enter *INVESTIGATE.*

INVESTIGATE is a travelling outreach tool housed in a repurposed shipping container. Designed to inspire, engage and educate, *INVESTIGATE* is a dynamic, immersive experience encouraging users to explore Australia's vast marine estate and the key role that marine research plays within it. As an avenue for the Australian public and students to engage in a contemporary way, *INVESTIGATE* tells the story of Australian marine research and its impact. It is an invitation to dive a little deeper.

With at-sea operations taking RV *Investigator t*o ports around Australia, *INVESTIGATE* is used alongside the vessel to create a hub for community engagement by capitalising on the invaluable tool that the vessel offers to capture people's interest. *INVESTIGATE* also tours museums, educational facilities and events across the country.

Here we explore the rationale behind *INVESTIGATE*, detail the project's lifecycle, and provide advice to others on the development of similar creative science outreach projects.

35. History of AMOS sciences in Australia and their impact on our society

Session 35 (Tuesday 6 Feb, 14:00-15:30), Talk 1

Braak, de Boer, Berlage, and the El Niño - Southern Oscillation

Neville Nicholls

Monash University, Melbourne, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

In the early to mid decades of the 20th century Dutch meteorologists conducted a great deal of research into the nature and predictability of interannual variations in Indonesian rainfall. They related these variations to the phenomenon we now call the El Niño - Southern Oscillation. Much of their ground-breaking research is poorly known because it was published in reports in Indonesia rather than in journals. I will summarise their major breakthroughs, and demonstrate the remarkable success their methods have produced for many decades, on independent data unavailable to them when they did their work.

Session 35 (Tuesday 6 Feb, 14:00-15:30), Talk 2

Enabling digital access to historic records.

Mac Benoy

Australian Meteorological Association, Adelaide, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

Instrumental climate observations in Australia started with the first European footfall in the late 18th century and by the 1840's, most of the colonies were creating Government sponsored, standardised records. Some of this paper-based data is discoverable and accessible by researchers while other logs and diaries are anonymously held in formal and informal archives making discovery and accessibility a time-consuming task.

The ACRE project, run from the UK Met Office was established 15 years ago to encourage and support "data rescue" projects across the globe to discover and digitise key paper-based data for use by climate researchers. For fifteen years the South Australian office of the Bureau of Meteorology has hosted a local team of ACRE citizen scientists who have imaged folios of observations stored on thirteen pallets covering Australia and its proximate neighbours. 115,000 images are now electronically accessible over the web. On the images are an estimated 100 million data items, of which one million have been digitised and lodged with international global climate databases, making a valuable contribution to climate reanalysis in the data sparse Australian and Southern Ocean region from 1843-1957. The presentation includes an overview of accessible global climate databases stretching back to the 19th century.

This citizen science project began under the auspices of the Australian Meteorological Association in 2008. Led by retired professionals, it is self-managing and self-funded and is a useful model for accessing professional resources to create quality controlled historic data.

*ACRE – Atmospheric Circulation Reconstructions over the Earth

Session 35 (Tuesday 6 Feb, 14:00-15:30), Talk 3

Consolidating historical instrumental observations in southern Australia for assessing pre-industrial weather and climate variability

Joëlle Gergis[1], Zak Baillie[1], Linden Ashcroft[2], Blair Trewin[3], Robert J Allan[4]

[1]Australian National University, Canberra, Australia. [2]University of Melbourne, Melbourne, Australia. [3]Bureau of Meteorology, Melbourne, Australia. [4]Met Office, Exeter, United Kingdom

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

Human-induced climate change has resulted in long-term drying trends across southern Australia, particularly during the cool season, with the most pronounced impacts observed in the southwest since the 1970s. Although these trends have been linked to changes in large-scale atmospheric circulation features, the limited number of daily weather datasets that extend into the pre-industrial period have so far prevented an assessment of the long-term context of synoptic-level changes associated with global warming. To address this need, we present the development of the longest sub-daily atmospheric pressure, temperature and rainfall records for Australia beginning in 1830. We first consolidate a range of historical observations from the two southern Australian cities of Perth and Adelaide. After assessing the quality and homogeneity of these records, we verify their ability to capture the weather and climate features produced by the Southern Hemisphere's key climate modes of variability. Our analysis shows the historical observations are sensitive to the influence of large-scale dynamical drivers of Australian climate, as well as the relationship between southwestern and southeastern Australia. Finally, we demonstrate the ability of the dataset to resolve daily weather extremes by examining three severe storms that occurred in the nineteenth century associated with westerly storm tracks that influence southern Australia. The historical dataset introduced here provides a foundation for investigating pre-industrial weather and climate variability in southern Australia, extending the potential for attribution studies of anthropogenically-influenced weather and climate extremes.

Session 35 (Tuesday 6 Feb, 14:00-15:30), Talk 4

A brief history of CSIRO's contribution to global climate modelling.

Ian N Smith

University of Southern Queensland, Toowoomba, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

This talk provides a brief overview of the achievements and success of the CSIRO climate modelling team over the period 1981 to 2007. This came about despite the relatively small size of the team in comparison to major international groups at the time and can be attributed to the sustained effort and dedication of many team members - most notably Hal Gordon and the team leader Barrie Hunt. In particular, it is important to note that many of the research findings informed concerted global efforts to better understand the consequences of enhanced greenhouse gases in the atmosphere. Undoubtedly, the climate modelling work conducted back then helped underpin the development of present day mitigation and adaptation policies.

Session 35 (Tuesday 6 Feb, 14:00-15:30), Talk 5

20 years of cloud seeding science in the Snowy Mountains, Australia

Andrew Peace, Suzanne Kenyon, Johanna Speirs, Thomas Chubb

Snowy Hydro Ltd., Sydney, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

As the 20th anniversary of the start of cloud seeding operations in the Snowy Mountains approaches, we look back on the achievements and benefits of the project and its off-shoots to Snowy Hydro, the wider research community, ski fields, agricultural sector and the general public. Although cloud seeding is a tool best used in average and wetter years to build up storages in preparation for the dry years, it is dry years that spur action. This was the case early in the Millenium Drought in 2003 when old plans for cloud seeding in the Snowy Mountains were dusted off, reviewed and the required legislative changes were proposed and passed. The nine year scientific trial that followed forged many research partnerships, both in Australia and abroad, that have continued through the eleven years of operational cloud seeding since the trial. These research partnerships have covered many topics relating to weather, climate and hydrology in Australia and the Southern Ocean and have resulted in 9 PhDs and several dozen journal papers. The program is still innovating, with new instrumentation being deployed and new research on state of the art NWP modelling. The science team at Snowy Hydro, initially formed for the cloud seeding program, now also provides various other internal forecasting and data science services and collaborates externally on climate and renewable energy research.

Session 35 (Tuesday 6 Feb, 14:00-15:30), Talk 6

Community-wide learning about climate in Australia from the First Fleet forward – evidence from poetry, film and art

Mary E Voice

University of Melbourne, Cumulus Consulting, Ivanhoe, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

The so-called creative/cultural sector (as if science isn't creative!) includes various forms of written and visual outputs. Authors/workers in this sector often pick up on contemporaneous debates in society (eg droughts, floods, bushfires) and sometimes provide helpful mechanisms for transmitting information to wide sectors of society. Generally speaking such information is approximately meteorologically correct – at least for their time. For example, from the First Fleet forward, writers and artists have given recipients hints at far-flung influences on our climate, the hardship of our highly variable climate, warnings about the climate of the continental interior and the mateship which some people considered was a consequence. Even Antarctica gets a poetic touch, along with the country-city divide and understanding and managing in the tropical wet season. Modern artists have recognized and expressed the challenges for Australia of El Niño and also the Greenhouse Effect.

Poets and artists pick up on some of the concerns of scientists and can therefore assist in getting messages through to different sections of the community. We can discuss if their messages are reasonably /sufficiently accurate, even when overlain with artistic license.

This presentation will provide examples (from the past 100+ years) of works that reference Australian weather and climate in creative ways. A point to ponder is whether more use could be made of artists and artistic materials in the communication game.

36. Value chains for Early Warnings Systems

Session 36 (Thursday 8 Feb, 16:30-18:00), Talk 1

Evaluation of the Warning Value Chain as an Educational Approach for University Students

David Hoffmann[1], Beth Ebert[1], Carla Mooney[1], Sharan Majumdar[2], Martin Goeber[3]

[1]Bureau of Meteorology, Melbourne, Australia. [2]University of Miami, Miami, USA. [3]DWD, Berlin, Germany

Session

36. Value chains for Early Warnings Systems

Abstract

The Weather Information Value Chain offers a way to understand how information about severe weather is created, shared, and used within a complete warning system. An international WMO project led by the Bureau has been using this approach to explore and evaluate systems that warn about such events. This involves bringing together insights from both scientific and social perspectives.

A major result of this effort is a questionnaire designed for gathering and analysing real case studies to learn from past events. The questionnaire, originally intended for experts, has proven to be an effective educational instrument, particularly among university students.

For instance, interns at the Bureau of Meteorology used the questionnaire to examine warning value chains related to the Black Summer Bushfires (2019/2020), Hurricane Isaias (2020), and the 2022 Lismore floods. Similarly, students from the University of Miami employed the questionnaire to deconstruct the warning value chain of Hurricanes Ida (2021) and Ian (2022) as part of their tropical meteorology curriculum. Moreover, master's students at the Free University Berlin routinely conducted value chain analyses, comparing those of significant forest fires in 2018 and 2022.

Leveraging accessible online resources, these students filled in the questionnaire and teamed up to share their findings. This kind of cross-disciplinary exploration boosted their ability to think critically about forecasting, the impacts of hazards, how warnings are communicated, and how people respond.

Here, we introduce the questionnaire database and explain how it can be an excellent tool for learning, both in universities and in research settings.

Session 36 (Thursday 8 Feb, 16:30-18:00), Talk 2

A framework and guide for using value chain approaches to understand, measure, improve, and design early warning systems

Elizabeth Ebert[1], David Hoffmann[1], Jeff Da Costa[2], Xudong Liang[3], Brian Mills[4], Carla Mooney[1], Hellen Msemo[5], Jacob Pastor-Paz[6], Adriaan Perrels[7], Andrew Tupper[8]

[1]Bureau of Meteorology, Melbourne, Australia. [2]University of Reading, Reading, United Kingdom. [3]China Meteorological Administration, Beijing, China. [4]Environment and Climate Change Canada, Toronto, Canada. [5]World Meteorological Organization, Geneva, Switzerland. [6]GNS Science, Wellington, New Zealand. [7]Finnish Meteorological Institute, Helsinki, Finland. [8]Natural Hazards Consulting, Melbourne, Australia

Session

36. Value chains for Early Warnings Systems

Abstract

Value chain studies can provide useful insights for organisations involved in early warnings. National weather services and their partners wish to understand and improve the warning value chain because it directly affects their activities and their stakeholders. Authorities and funding bodies need to ensure that the warning services are operated according to agreed regulations and represent good value for money. User communities in all parts of the chain receive and transmit warning information that assists them to take appropriate action at the right time; they also provide important feedback on warning effectiveness, contributing to their improvement.

The WMO WWRP Value Chain project is developing a framework and guide for using value chain approaches to understand, measure, evaluate, improve, and design early warning systems. It draws on expertise from practitioners in the broader warning community and natural and social science researchers. It brings together process-oriented "top-down" perspectives and people-oriented "bottom-up" perspectives, offering a variety of approaches for value chain studies. Relative to many benefit-cost studies, value chain analyses place greater emphasis on the process and means of getting to the benefits.

The framework begins with a basic model of the information value chain, namely, describing an existing service chain, then progresses to describe value chain approaches for guiding service improvements, assessing the social and economic value of service improvements using quantitative and qualitative methods, and designing a new service. It includes tools and workshop ideas as well as examples of how value chain approaches are being successfully applied in hydrometeorology.

Session 36 (Thursday 8 Feb, 16:30-18:00), Talk 3

Where's the impact? Predicting damage from TCs in sparsely populated areas

William C Arthur, Nicole Allen

Geoscience Australia, Canberra, Australia

Session

36. Value chains for Early Warnings Systems

Abstract

Severe TC Ilsa crossed the Western Australian coastline approximately 120 km east of Port Hedland on Thursday 13 April 2023. Observations at Bedout Island were the highest wind speeds recorded on standard Bureau of Meteorology instruments (gust wind speed of 289 km/h). In anticipation of the TC, residents in the mining township of Telfer were evacuated, along with a small number of evacuees in other townships (Marble Bar, South Hedland and Nullagine). As a category 5 TC, the threat of widespread destruction was front of mind for emergency managers in Western Australia.

Geoscience Australia (GA) has established the National Hazard Impact and Risk Service (NHIRS), which provides quantitative modelled impact forecast information for tropical cyclones, large-scale wind events and earthquakes in Australia. NHIRS has been used by the Department of Fire and Emergency Services (DFES) Intelligence Unit to support operational resource planning for TC events.

In TC Ilsa, DFES Intelligence (and GA) officers reviewed the impact predictions in the days leading up to landfall. Genuine questions were asked about the level of predicted damage, which was almost negligible across northern WA in spite of the predicted landfall intensity. Why was that the case? Was the service operating as expected? This paper highlights the challenge of educating users on the utility of impact forecasting products and communicating the components that are integrated in the impact forecast.

Session 36 (Thursday 8 Feb, 16:30-18:00), Talk 4

Communicating uncertainty in flash flood events

David Wilke, Carla Mooney, Karen Hudson, Brenda Mackie

Bureau of Meteorology, Melbourne, Australia

Session

36. Value chains for Early Warnings Systems

Abstract

Flash flooding presents a significant and increasing risk to public safety across many regions of Australia. This type of flooding, which typically occurs over small spatial scales within 6 hours of the onset of rainfall, is often classed as "high-impact, low probability" and is generally difficult to predict. This is because of the uncertainties in forecasting the intensity and spatial-temporal distribution of rainfall and the resulting landscape response. The short timescales associated with flash flooding also mean that there is limited opportunity to trigger protective action during an event.

The current predictive capability constrains the confidence with which the threat can be messaged, meaning that the communication of uncertainty becomes highly important to the successful mitigation of risk. Increasingly, probabilistic and ensemble-based data are expected to be utilised to quantify this uncertainty. However, there remain questions about how best to communicate this information to the public to ensure it is understood and acted on.

The aim of this study is to define the baseline of current practice and develop strategies to improve the communication of flash flood risk. This is achieved through case studies of recent high-impact flash flood events and a survey designed to gauge public comprehension of flash flooding and uncertainty terminology. In particular, the project considers how information flows through the warning value chain and how forecast uncertainty is communicated by the Bureau of Meteorology, local councils, emergency services and the police.

Session 36 (Thursday 8 Feb, 16:30-18:00), Talk 5

Addressing barriers and barnacles at multiple levels to improve continuity of care in a comprehensive multi-hazard early warning system

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Session

36. Value chains for Early Warnings Systems

Abstract

A complex multi-hazard early warning system has much in common with health system concepts of continuity of care – we are providing holistic, people-centred outcomes within a complex, multi-disciplinary and multi-institutional environment. In a value-chain approach, we must understand and improve individual warning processes whilst having regard for the whole outcome – both the local and strategic levels are important.

In this context, we can consider the ‘barriers’ (things that stop us progressing) and ‘barnacles’ (things that slow us down) within a value chain and generalise from those to the whole system where needed. For example, there is a long-standing gap in volcanic monitoring arrangements for the purposes of the aviation industry, but this cannot be properly addressed without also improving arrangements for volcanic tsunami and volcanic ground hazards, suggesting a coordinated, UN level approach. Similarly, warning systems for compounding and cascading hazards should consider specific combinations of events, but to work in all cases must attain overarching relationships of trust and communication between agencies, across borders, across disciplines, and at community level. At the other extreme, warning systems within a failed state must effectively work locally around breakdowns in governance to protect vulnerable communities, whilst seeking to rebuild the principal warning pathways.

A value-chain approach should therefore be scalable and multi-dimensional, applied with unlimited ambition to accelerate address warning system gaps at whatever levels they occur. This is potentially daunting for warning practitioners. Our presentation will give further examples of the potential application of multi-dimensional approaches for warning system improvement.

Session 36 (Thursday 8 Feb, 16:30-18:00), Talk 6

Risk-based alerting on enhanced noise propagation

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Session

36. Value chains for Early Warnings Systems

Abstract

Vertical gradients of temperature and wind speed are known to have a strong impact on the variations in the sound levels. Particularly favorable to the sound wave propagation are conditions accompanying temperature inversions and wind calms. The latter have an impact on mining industries which are expected to put on hold certain operations such as blasting at quarries to mitigate impact of noise and pollutant dispersal in the surrounding neighborhoods.

Here we propose a metric for risk-based alerting on meteorological conditions favorable to enhanced noise propagation. We apply this metric to the vertical profiles of temperature and wind speeds derived from ACCESSC APS3 model to evaluate its skill in predicting low level temperature inversions and calm conditions against sounding data. We then validate it against noise observations made of sound pressure by sensors at Australian airports. The alerting scheme is demonstrated to be successful in capturing meteodependent component in the noise variations and potentially useful for noise abatement purposes.

37. Dynamics and Prediction of High Impact Weather

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 1

Sudden Rainfall Change following Landfalling Tropical Cyclones over Australia

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Tropical cyclones (TCs) and their remnants are significant contributors to heavy rainfall over continental regions. Subsequent to a TC's landfall, TC usually tends to weaken, leading to dissipation of rainfall events because of lack of heat and moist energy supplied from landmass. However, in some cases a TC or its remnant may reinvigorate, consequently it may then produce even heavier rainfall than it did at landfall and pose great challenge to operational forecasting and various communities residing in the affected regions.

Using ERA5, TRMM and IMERGE datasets, the sudden rainfall changes of landfalling tropical cyclone are examined in Australia. The statistical results show that, although the composite large-scale conditions exhibit minor differences between the instances of rainfall enhancement events (referred to as "RE" events) and rainfall decrease events ("nonRE" event), the major distinctions lie in the mid-level vertical velocity and boundary-layer recovery process. Specifically, RE events are intrinsically linked to the size growth of mid-level vertical velocity and the maintenance of high-equivalent air within the boundary layer, while the non-RE events are tied to the size contraction of mid-level vertical velocity and a reduction of boundary-layer high-equivalent air. These changes can be observed in the atmospheric conditions approximately 6 to 12 hours prior to the onset of the rainfall shift. In this presentation, we will continue to present the detailed processes that control these rainfall events across the Australian continental regions. The study may help us to better identify and predict the TC-related rainfall over the land in Australia.

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 2

Tropical cyclone contributions to heavy rainfall climatology

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

The Australian Cyclone Reinsurance Pool covers losses that occur during a named tropical cyclone (TC) and up to 48 hours after. Yet significant flood related risks can extend prior to a TC being named and long after its demise. We also don't have adequate understanding of what controls TC related flooding as the storms track inland. These twin scientific and risk management needs provide motivation for this study of TC contributions to heavy rainfall climatology.

Using historical data we present an approach to quantify TC rainfall contributions across Australia. Here we use heavy rainfall as a proxy for flood. This assumes that the heaviest rainfall has more of a one-to-one correspondence with flood than more moderate rainfall.

Heavy rainfall is attributed to TCs by filtering according to storm proximity. A time-step of 6 hours is chosen as a balance of the hydrologic response times of most watersheds of interest and the credible scales in the rainfall datasets. We quantify uncertainty in the heavy rainfall by comparing across satellite-based, surface station-based, and atmospheric reanalysis-based rainfall datasets.

Initial findings will be presented on the fraction of heavy rainfall occurring within the time window determined by the cyclone pool event definition and how this varies by region and TC and environment characteristics. This study is a first step that will be followed by exploring TC rainfall variability in the larger event sets provided by climate model large ensemble simulations.

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 3

TC intensification feedback from oceanic responses during air-sea coupling processes

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Predicting tropical cyclone (TC) intensity change is one of the biggest challenges in operational forecasting of TCs. In particular, the mechanisms for TC rapid intensification are not well understood. The environment, ocean and inner-core processes are three factors that have been shown to govern tropical cyclone intensification. The majority of previous research on rapid intensification has mainly focused on atmospheric processes including environment and inner-core processes.

Sea surface temperature typically decreases after the passage of tropical cyclones due to shear-induced vertical mixing and deep upwelling. This decreased SST may weaken the TC by reducing or limiting air-sea heat and moisture fluxes into the boundary layer. However, the extent of ocean changes due to the TC passage depend on a number of factors including the pre-TC ocean structure, the intensity of the TC and the speed of motion of the TC. Thus it is important to understand how the feedback of the TC-induced ocean response to TC passage affects future intensification of the TC. In this presentation, two intense North Atlantic TCs Irma (2017) and Lorenzo (2019) are chosen to examine the effects of the air-sea interaction on their intensification and steady state maintenance by coupling the atmosphere WRF model with the ocean ROMs model. Both Irma and Lorenzo occurred in an environment with moderate vertical wind shear. However the SST changes during their passage differ. The TC intensity change due to the variation of enthalpy and momentum fluxes and TC structure will be analysed.

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 4

Is there a universal scaling of the Hurricane Boundary Layer?

Shefali Verma[1], Jeff Kepert[2], Peter May[3], Marco Giometto[4], Basudev Biswal[5], Marc Parlange[6]

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Universal scaling in turbulent flows is crucial as it provides a framework to describe and predict turbulent behavior across different systems. It allows researchers to identify common patterns and characteristics, enabling the development of generalized models and insights into turbulence that can be applied across various engineering and scientific disciplines. This research examines different scales employed in the analysis of atmospheric flows with reference to scales from the literature. This paper provides an overview of various methods for obtaining normalization scales for Hurricane Boundary Layer flows using Large-Eddy Simulation (LES) data. The research utilizes LES, a computationally intensive method that accurately represents the dynamic and turbulent nature of hurricanes. The parameters of the LES model consist of spatial and temporal resolutions, subgrid-scale closures, and boundary conditions that are adjusted to accurately replicate the dynamics of hurricanes. A total of 96 simulations were conducted to generate datasets of horizontal boundary layer (HBL) flow. These simulations involved variations in the following parameters: radial distances, the Coriolis factor, geostrophic wind velocity, aerodynamic surface roughness, thermal winds, and the strength of the tangential velocity gradient. A comprehensive survey of the various scales employed for normalization in atmospheric flows has been undertaken in this paper. Subsequently, a conclusive discussion is presented to identify a scale that could universally normalize hurricane flows.

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 5

Primary atmospheric and oceanic environments associated with tropical cyclone size changes

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Tropical cyclones (TCs) are observed to change size under a variety of environmental conditions. Operationally, TC size expansion is critical because the extent of the wind field impacts sea state, storm surge and the warning area of damaging winds upon landfall. Numerical studies suggest that high relative humidity and surface energy fluxes favour TC size expansion. Variables that negatively impact TC size and structure include high vertical wind shear and dry-air intrusion.

This study examines 30 years of TC cases in the North Atlantic basin where the wind field made a significant expansion or contraction while maintaining an intensity of at least 50 kt during its lifetime using the European Centre for Medium-range Weather Forecasting (ECMWF) reanalysis v5 (ERA5) and the HYbrid Coordinate Ocean Model (HYCOM) global reanalysis datasets. An empirical orthogonal function (EOF) analysis technique is performed separately on the size increase and size decrease cases to identify the dominant circulation patterns in the datasets associated with each set. In this presentation we will analyze and discuss the distinguishing composited atmospheric and oceanic patterns associated with size change from 48 hours prior to the size change through the size change time.

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 6

Simulation of Landfalling Tropical Cyclone Future Impacts along the Bangladesh Coast

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[1]UNSW, Canberra, Australia. [2]Monash University, Clayton, Australia

Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Tropical cyclones (TCs) are highly influential and impactful weather phenomena, greatly affecting both the environment and society. It is well recognized that their activity and physical impacts are likely to be influenced by anthropogenic climate change. In the Bay of Bengal region of the North Indian Ocean, TCs have caused human casualties, sometimes extreme, in densely populated communities in Bangladesh, India, and Myanmar over the past few decades. It is very important to explore in what manner TCs might be expected to behave in the North Indian Ocean under projected climate change scenarios, particularly with regard to their landfalls in the Bay of Bengal region and their impact on the coast of Bangladesh.

This study evaluates the future climatology of TCs that make landfall in the upper North region of the Bay of Bengal, specifically along the Bangladesh coast. The research focuses on simulations conducted with the high-resolution Weather Research and Forecasting (WRF) model for 21 TCs that impacted the coastal areas between 1990 and 2020 and aims to investigate the activity of landfalling TCs in the future. The study involves utilizing climate perturbations from the CMIP6 ACCESS-CM2 model. Two scenarios, SSP245 and SSP370, are examined for three projected time periods: 2050s, 2070s, and 2090s. The changes in TC landfall impacts climatology are then compared to the historical TC climatology for the same 21 TCs. This comparison allows for an assessment of the potential changes in TC activity in the future under different scenarios.

Session 37A (Wednesday 7 Feb, 11:00-13:00), Talk 7

Tropical cyclone wind adjustment at landfall – the mysterious case of Tropical Cyclone Veronica.

Jeffrey D. Kepert

Bureau of Meteorology, Melbourne, Australia

Session

37. Dynamics and Prediction of High Impact Weather

Abstract

The surface wind maximum in a Southern Hemisphere tropical cyclone is normally in the left forward quadrant, relative to the cyclone motion. In March 2019, TC Veronica stalled about 40 km offshore of the Pilbara coast before slipping away to the west. A remarkable sequence of synthetic aperture radar wind retrievals show that the wind maximum shifted from the usual left forward position to the right of track during the 36 hours as Veronica approached land. An idealised model of the tropical cyclone boundary layer will be used to show that the shift in the wind asymmetry was caused by asymmetric friction due to the proximity to land. The dynamical mechanisms by which the friction asymmetry causes the wind asymmetry will be elucidated with the aid of a further-simplified model which possesses analytical solutions. The talk will close by briefly presenting other observations of near-landfall winds that appear to be reflect the same processes and discussing the operational implications of this wind adjustment.

Session 37B (Wednesday 7 Feb, 14:00-15:30), Talk 1

Observations of Severe-Wind Driven and other Wildfires with Doppler On Wheels (DOW) mobile radars

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Doppler On Wheels (DOW) mobile / targetable truck-borne radars have deployed to collect fine-scale observations in several wildfires, one, recently, causing widespread destruction in an urban area. DOW measurements in wildfires permit the mapping of the windfields, hydrometeors, and airborne particles in the fire plumes, and characterization of the near-fire environment. DOWs can collect windfield and other data below the observing horizon of more distant radars, and at much finer-scale spatial resolution, revealing otherwise unmappable aspects of low-level and small scale structure and evolution.

Observations of three wildfires will be discussed:

- In 2020, two DOWs deployed in the mountains of Colorado and collected dual-Doppler vector wind data primarily in the fire environment.
- During another fire in 2020, the DOWs were deployed close to wildfires which destroyed many homes. Small-scale vortices and other features are resolvable due to the close proximity of the deployed radars to the wildfires. Dual-Doppler DOW analysis, the first fine-scale dual-Doppler analysis of this type, will be presented.
- In 2021, a DOW deployed in South Boulder, Colorado in the metropolitan Boulder wildfire / extreme wind event where winds exceeding 45 m/s enhanced fires which destroyed many homes and businesses in the south Boulder area. The evolution of the wind field was mapped.

Session 37B (Wednesday 7 Feb, 14:00-15:30), Talk 2

Destructive fire-driven winds in Australia bushfires

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

In addition to widespread destruction by fire, post-event reviews of Australia's most devastating bushfires describe the impact of destructive fire-driven winds. While the significance of these winds may be overshadowed by the direct effects of the fires themselves, their impact can be disastrous. Damage to houses caused by destructive winds ahead of the fire can make them more susceptible to ignition, and the force of the winds can contribute to mass spotting of flames well in advance of the main fire front.

In a least two of the fires (Canberra, 2003 and Black Summer, 2019/20) the extreme wind damage was caused by fire generated tornadic strength vortices (FGTV) with winds speeds estimated be 250 km/h or greater. In the other major fires, the cause of the destructive winds is less clear but is likely due to a combination of both fire-generated straight line winds and tornadic strength vortices.

In this paper, we highlight the devastating impact of destructive winds in several major Australian bushfires, beginning with the Black Friday 1939 Victorian fires, through until the 2019/20 Black Summer fires. We discuss mechanisms that are the likely cause of the winds and use case study output from ACCESS-Fire to illustrate aspects of these during the Black Summer fires. Given the consequences of the destructive winds, we highlight the importance of increased awareness of their potential occurrence near high-end bushfires.

Session 37B (Wednesday 7 Feb, 14:00-15:30), Talk 3

Black Summer New Year's Eve fire weather in southeast NSW

Paul Fox-Hughes

Bureau of Meteorology, Hobart, Australia

Session

37. Dynamics and Prediction of High Impact Weather

Abstract

The Black Summer fires of 2019-20 devastated a record fraction of the forest estate of eastern Australia as well as burning extensive areas of other vegetation. In New South Wales alone they caused 26 fatalities and destroyed 2476 homes. A number of studies have investigated antecedent climate conditions and impacts of the fires. There have been relatively few publications, however, examining synoptic and mesoscale weather conditions at critical periods during Black Summer. One such period occurred around New Year's Eve in southeast New South Wales and far eastern Victoria, when widespread extreme fire weather occurred. Large areas of vegetation suffered unusually severe damage and a globally significant outbreak of fire-generated thunderstorms occurred, including pyrotornadogenesis. Fires also spread rapidly overnight when normally they would be expected to be quiescent.

Exceptionally dry conditions and successive heatwaves preconditioned the landscape for fire occurrence. Then, the passage of a surface cold front and associated upper tropospheric circulations on New Year's Eve contributed to the severity of the fire weather. An overnight low-level jet and downslope winds followed by horizontal boundary layer rolls during the afternoon added to the complexity and difficulty of the weather conditions confronted by meteorologists and fire managers during the event.

Following a request from the NSW Rural Fire Service, this study examines weather conditions leading up to and during New Year's Eve in southeast NSW, aimed at contributing to improved understanding and forecasting of such extreme fire weather events.

Session 37B (Wednesday 7 Feb, 14:00-15:30), Talk 4

Performance of a firebrand transport parameterisation within a fire spread model.

Jeffrey D Kepert[1], James Hilton[2]

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Spotfires are a major challenge in bushfire management, and in extreme circumstances have been observed to ignite new fires over 30 km ahead of the parent fire. Spotfires result from firebrands transported from the fire igniting fuel well ahead of the front and greatly complicate suppression efforts, contribute to fires breaking control lines, and are implicated in structure loss. Spotfire ignition is a fundamentally stochastic process, and contributes to uncertainty in fire prediction, yet existing predictive techniques provide insufficient guidance on the problem of extreme-range spotting.

We have incorporated a simple model, or parameterisation, of long-range firebrand transport into CSIRO's Spark fire spread model. The model system is run in ensemble mode, in recognition of the stochastic nature of spotting. This paper presents the results of simulations of three Australian fires with well documented instances of long-range spotting, including the Kilmore East fire of 7 Feb 2009 ("Black Saturday"). We obtain good agreement between observed maximum spotting distances and those from the model. Final fire perimeters are in better agreement with those observed than when spotting is omitted – for instance, the total fire run for Kilmore East is about half that observed when spotting is omitted, but much closer when it is included. In other cases, parameterised spotting causes the simulated fire to break natural containment lines.

The parameterisation presently represents only ember transport and does not include any information about the finite burn time of embers. This, and other areas for future development, will be discussed.

Session 37B (Wednesday 7 Feb, 14:00-15:30), Talk 5

Satellite-microwave-sounder-based characteristics of strong convective clouds at the pre-convection stage

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

The advanced new-generation geostationary (GEO) meteorological satellite infrared measurements are consistently utilized to capture and predict distinctive characteristics at the cloud top of rapidly developing strong convective clouds during the pre-convection or convection initiation (CI) stage. However, the complex and unpredictable trigger factors make it challenging to avoid the high false alarm rate of GEO satellite CI nowcasting. Although the microwave measurement technique can observe thick clouds and even the precipitation within clouds, observation data of microwave sensors from polar-orbiting satellites on the CI cloud systems is limited by their relatively low temporal resolution. Here, we analyze several unknown CI characteristics over the East Asia region from 2016 to 2019, based on spatially and temporally matched Advanced Technology Microwave Sounder (ATMS) data. These typical CI samples are initially identified by utilizing continuous and high-resolution infrared images from the Himawari-8 geostationary satellite. The results reveal a distinct CI cloud optical depth in the western (deep) and eastern (shallow) Tibetan Plateau (TP). The shallow precipitating cloud clusters of the CI over the eastern TP are possibly attributed to the favorable local dynamic and thermal conditions stemming from the Asian monsoon. Another notable finding demonstrates that the fast-developing CI over the ocean exhibits significantly thicker clouds compared to the samples observed over land. Overall, the unique and intriguing CI characteristics discovered through microwave observations in this study indicate that future advancements in geostationary microwave sounder technologies will undoubtedly yield novel insights and greatly enhance early warning capabilities regarding convection.

39. General oceans

Session 39A (Wednesday 7 Feb, 14:00-15:30), Talk 1

The response of oceanic meridional heat transport to varying surface forcing

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Session

39. General oceans

Abstract

The ocean gains thermal energy in the tropics and loses energy by radiation at polar latitudes. Radiative equilibrium necessitates a net transport of heat from lower to higher latitudes. To achieve this balance, the large-scale ocean circulation, fuelled by a combination of winds and surface buoyancy fluxes, carries a peak of 1.5-2 PW of poleward heat. However, the relative influence of winds and surface buoyancy fluxes in maintaining the local meridional heat transport is not well understood. Moreover, both of these surface forcings and, consequently, the meridional heat transport are expected to readjust in the wake of climate change. Through a series of eddy-permitting global ocean model simulations, we aspire to quantify better the relative contribution of wind stress and surface buoyancy fluxes in carrying the meridional heat transport through anomalies in the ocean circulation. We perturb the atmospheric forcing by varying wind stresses and/or surface buoyancy fluxes and attempt to decompose the meridional heat transport due to the large-scale ocean circulation into meridional overturning circulation and gyres. We find that the meridional heat transport, dominated by the strength and the near-surface temperature of the Gulf Stream, responds to varying surface forcing on different timescales.

Session 39A (Wednesday 7 Feb, 14:00-15:30), Talk 2

Investigating the wind effect on bluebottle's drift: insights from a lab-based experiment

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Session

39. General oceans

Abstract

Despite causing numerous stings amongst Australian swimmers, little is known about the bluebottle's origin, distribution, and pathways. To explore its drifting behaviour, which relies on external factors (wind, waves, currents), our investigation focuses on wind-induced effects. Wind is believed to play a crucial role in directing bluebottle's movements, though a comprehensive study has been lacking since the 1960s.

Bluebottles display a body dimorphism, with left and right-handed forms, appearing as mirror images and assumed to exhibit symmetrical trajectories relative to the wind. We investigate these behaviours using 3D-printed replicas of bluebottles at the Large Air-Sea Interaction Facility in Marseille (France). We focus on three key questions: How does the bluebottle velocity and direction relate to the wind speed? Are trajectories symmetric between left and right-handed individuals? How do the bluebottle's size and morphology influence their trajectories?

The 3D-printed models replicate realistic buoyancy and waterline. Guided by beach surveys and scans of real bluebottles, we built various shapes subjected to varying wind speeds. Preliminary results show consistent trajectories for the handedness types, especially at lower wind speeds. At higher wind speeds, drifting angles decrease, driving bluebottles downwind with variability from wind-driven waves. Further experiments will analyse the combined effect of wind and currents on the trajectories. Our findings will provide a basis to parametrize Lagrangian numerical tracking for bluebottles, and gain insights into their origins and pathways. This research enhances our understanding of bluebottle drift, helping to build predictive systems and management of bluebottle's influence on coasts.

Session 39A (Wednesday 7 Feb, 14:00-15:30), Talk 3

Topographically generated internal waves as a response to surface winds

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Session

39. General oceans

Abstract

Internal waves (IWs) propagate on the ocean stratification and carry energy and momentum through the interior ocean. Two of the most significant sources of these waves in the ocean are the creation of IWs by surface winds and oscillatory flow across topography due to the tides. We propose a hybrid of these two mechanisms, in which wind induced oscillations of sea surface and isopycnal heights are rapidly communicated to the seafloor via hydrostatic pressure. In the presence of topography, the resulting oscillatory bottom velocity may then generate internal waves in a similar manner to the barotropic tide. We investigate this mechanism in an idealised numerical isopycnal model of a storm passing over a mid ocean ridge, and performe several perturbation experiments in which ocean and wind properties are varied. Bottom generated internal waves were identified propagating zonally from the ridge in the wake of the storm. Estimates of the total wave energy suggest that in the right circumstances these waves could pose a significant source of internal wave energy with up to a 1% conversion rate of the incident wind work.

Session 39A (Wednesday 7 Feb, 14:00-15:30), Talk 4

Does cabbeling shape the thermohaline structure of high-latitude oceans?

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Session

39. General oceans

Abstract

The vertical exchange of heat is a key aspect of how the ocean helps regulate the global climate. Convection, an important driver of near surface mixing, occurs when profiles become gravitationally unstable due to denser waters overlying lighter waters. Fofonoff (1957) pointed out that warm-saline deep waters in the Southern Ocean become denser as they mix with relatively cold-fresh near surface water and hypothesised that this is due to the nonlinear dependence of density on temperature and salinity, via an effect known as cabbeling. Here, we propose that an instability due to cabbeling can occur prior to gravitational instability in temperature inverted profiles. Further, the mixing triggered as a result of this cabbeling instability may be shaping the nature of profiles in the high-latitude oceans. A one-dimensional model demonstrates that convective mixing can occur in temperature inverted profiles that are unstable to cabbeling but gravitationally stable. Analysis of data constrained global circulation model output and high quality in-situ observational data reveals that the probability a temperature inverted profile is stable to cabbeling, given a temperature difference of -0.5°C, is approximately 1 and 0.88 respectively. Increasing the magnitude of the temperature difference, we find the probability a temperature inverted profile is stable to cabbeling increases suggesting that weakening temperature stratification increases density stratification. Our results suggest that cabbeling limits how unstable temperature inverted profiles can become prior to convection occurring and may shape the thermohaline structure of the high-latitude ocean where cold-fresh overlays warm-saline water.

Session 39A (Wednesday 7 Feb, 14:00-15:30), Talk 5

Eddy-induced water subduction in the Southern Ocean

Felipe Vilela-Silva[1,2,3], Helen E Phillips[1,2,4], Nathan L Bindoff[1,2,3,4], Steve R Rintoul[5,6,2,4], Max Nikurashin[1,2,4]

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Session

39. General oceans

Abstract

Transfer of fluid from the mixed layer to the upper thermocline (i.e., subduction) determines the ventilation of the ocean interior. The propagation of eddies changes the subduction within the density layer surrounding the base of the mixed layer. The eddy-induced subduction is obtained by estimating the eddy bolus velocity instead of solely decomposing the subduction equation in Reynolds terms for the mean and eddy fields (Marshall, 1997). The eddy-induced subduction plays an order one role in the Southern Ocean subduction (Sallee et al., 2010) and most of the Antarctic Intermediate Water formation occurs by the eddy-induced term (Li et al., 2022). Previous studies have parameterized the impact of eddy mixing in 1/2° ARGO products. In this study, we use the 1/10° ACCESS-OM2 global ocean model, forced by the JRA-55 atmospheric reanalysis, to estimate the subduction in the Southern Ocean. We also work with the vertical velocity (w) at the mixed layer base instead of vertical Ekman velocity because recent work shows that w in the Southern Ocean is bottom forced instead of Ekman driven (Liang et al., 2017). Moreover, we compute each subduction term using the definition per se (i.e., without any parametrization). In this case, we evaluate the Eulerian and eddy-induced subduction between two isopycnals bounding the density at the MLD. Here, the results show that the eddy-induced subduction does not correlate with the Eulerian subduction. The implications of this for the Southern Ocean subduction will be discussed.

Session 39B (Thursday 8 Feb, 09:30-10:30), Talk 1

Water-mass transformation in the Indonesian Seas: the interplay of wind, air-sea fluxes, and tides

Chengyuan Pang[1,2], Maxim Nikurashin[1,2,3], Beatriz Pena-Molino[4,3], Bernadette Sloyan[4]

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Session

39. General oceans

Abstract

The Indonesian Seas are the only connection between the Pacific and Indian Oceans and play a vital role in regulating the overturning circulation and climate. The Indonesian Seas are also a region where strong monsoons, air-sea interactions, and diapycnal mixing result in the transformation of the Pacific water masses as they transit through the region. Previous studies have shown that the thermocline water is formed by consuming the surface and deep waters within the region and suggested that the transformation is accomplished primarily by tide-driven mixing. Here, we use a high-resolution (2km) regional model of the Indonesian Seas with and without explicit tides to explore the transformation mechanisms and the role also played by wind and air-sea fluxes. We show that the water-mass transformation results from an interaction between wind, air-sea fluxes, and tides, with all components playing an important role. Together these processes result in an annual mean formation of 4Sv of thermocline water from the net transformation of 1Sv from deep water and 3Sv from the surface water. However, the tidal mixing doesn't drive the thermocline water formation directly. The tides act to increase the outcropping area of the thermocline water leading to 3Sv destruction of thermocline water by air-sea fluxes. This is compensated by interior mixing driven by both winds and tides forming 7Sv thermocline water. As winds and air-sea fluxes change with climate, our results have implications for the variability of water-mass properties locally across the Maritime Continent, but also more broadly throughout the global ocean.

Session 39B (Thursday 8 Feb, 09:30-10:30), Talk 2

A decade of IMOS HF ocean Radar surface current data

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Session

39. General oceans

Abstract

Observations of coastal ocean surface currents with high spatial and temporal resolution provide a critical tool for understanding physical and ecological processes, and for validating ocean circulation models. Despite this, few observation techniques can provide the necessary data.

High-Frequency Radar (HFR) are one of the few systems that can provide both high temporal and spatial resolution of surface currents. HFR relies on Doppler backscatter observations in the HF (radio wave) portion of the electromagnetic spectrum (3-50 MHz) to map near-surface currents on hourly timescales up to several hundred kilometres offshore.

The Integrated Marine Observing System (IMOS) Ocean Radar facility has deployed and managed HFR systems around the coastline of Australia since 2010, resulting in more than a decade of freely available real-time and quality-controlled data around Australia.

The long-term gridded hourly HFR data compliment more traditional observations such as moorings as the dataset enables investigations of event scale processes (order of kilometres / hours) all the way to longer and wider scales spanning from shallow water to beyond the continental shelf, over more than a decade.

This talk will use the dataset to illustrate such processes as the influence of the sea breeze on surface currents, passage of a tropical cyclone, the generation and persistence of sub-mesoscale eddies, and the cross-shelf migration of boundary currents. Examples will be shown for East Australian Current, Bonney coast upwelling, Leeuwin and Capes Current structures from the southwest and Ningaloo regions of Western Australia.

Session 39B (Thursday 8 Feb, 09:30-10:30), Talk 3

Lagrangian diagnostics for verification of forecast ocean currents in global ocean systems

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Session

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Abstract

Lagrangian drifters are the primary source of observations for verification of Eulerian ocean currents in global ocean systems. In this study, we have complemented the verification of Eulerian versus Lagrangian currents by employing Lagrangian diagnostics. We compare the Lagrangian trajectories of simulated particles released over the global domain with those of the drifters from the Global Drifter Program (GDP) using Eulerian currents from OceanMAPS, the Bureau of Meteorology's operational ocean forecast system. We further evaluate the simulated trajectories in the Western Central Pacific region with the trajectories of fish aggregating devices (FADS). Although the FADS are not designed to function as controlled ocean observation instruments, the currents computed from FADs are highly correlated with the GDP observation currents. Moreover, a significant advantage of using FADS as a verification tool is the availability of high frequency FADS observations in regions where GDP data are sparse. Results from this study demonstrate that the average separation distance between the simulated trajectories using OceanMAPS currents and the GDP trajectories in the global domain over a period of 100 days is 295 km while the median separation distance is 77 km.

Session 39B (Thursday 8 Feb, 09:30-10:30), Talk 4

Observations of mixing and stirring in the Antarctic Circumpolar Current

Helen E Phillips

IMAS, University of Tasmania, Hobart, Australia

Session

39. General oceans

Abstract

The Antarctic Circumpolar Current (ACC) presents a barrier to the poleward movement of heat, allowing waters around Antarctica to remain close to freezing. In locations where the ACC interacts with steep sea floor bathymetry, the barrier becomes leaky. Satellite measurements, sparse in situ observations and models all indicate that these locations are hotspots for the poleward transport of heat and other tracers. The small-scale processes that are responsible for the cross-frontal transport are not well understood but are parameterised in eddy-permitting models. High-resolution EM-APEX profiling float observations in two ACC hotspots at the northern Kerguelen Plateau and south of Tasmania allow us to quantify both diapycnal and isopycnal processes there. Thermohaline variability is consistent with strong isopycnal stirring and cross-frontal exchange south of Tasmania. In contrast, isopycnal stirring is suppressed at the northern Kerguelen Platueau. The characteristics of these two locations that may contribute to the contrast will be discussed.

41. General climate variability and change

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 1

Recent trends in extratropical lows and their rainfall over Australia

Acacia Pepler

Bureau of Meteorology, Australia

Session

41. General climate variability and change

Abstract

Low pressure systems are an important cause of rainfall in southern Australia, particularly deep lows that extend from the surface to 500hPa. While their frequency and associated rainfall is projected to decline by the end of the 21st century, large interannual variability has made the detection of trends over the well-observed satellite era challenging. The ERA5 reanalysis now allows the detection of trends in both lows and their associated rainfall over the longer period 1959-2022, and has statistically significant declines in the frequency of cool season lows despite high frequencies during recent wet years. We also assess how robust changes in rainfall from low pressure system are to the period used for calculating trends, as well as how observed trends compare to those in the most recent generation of climate models (CMIP6).

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 2

Historical and future changes in tropical cyclones over Australia and the SW Pacific region

Cindy L Bruyère[1], James M Done[2], Bruce Buckley[3], Abigail Jaye[2], Mark Leplastrier[3], Peter Chan[3], Joanna Aldridge[4]

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Session

41. General climate variability and change

Abstract

The short historical tropical cyclone (TC) record for Australia combined with the rarity of occurrence makes it challenging to evaluate past TC impacts and predict future changes. Despite the short record, significant changes to TCs have already been observed. The number of strong TCs per decade has increased, the location of storm lifetime peak intensity has migrated southward, and TC rainfall totals and wind speeds have increased. If these trends continue, particularly the southward shift, cities in marginal regions could experience TCs more often than in the past, with extratropical transitioning storms also extending their impacts to higher latitudes. Stochastic modeling can be used as a tool to partially compensate for the rarity of occurrence. Still, these models are commonly based on past storm tracks and, therefore, largely ignore recent and near-term future changes in storm tracks.

The large number of simulated years provided by the Community Earth System Model Decadal Prediction Large Ensemble Project (DPLE) and Large Ensemble (LENS) datasets are useful to explore how TC activity has changed in the recent climate and how it may change in the future. In this study, we investigate how cyclone characteristics may have changed in recent decades and are expected to change along the Australian coastlines as well as in the New Zealand area. We will compare three regions – Eastern and Western Australia and New Zealand – to understand differences and similarities among these regions. This study specifically examines storm intensity, precipitation rates/storm total rainfall, and over land impacts.

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 3

Global projections of hail frequency change and effects on crop production

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Session

41. General climate variability and change

Abstract

Hailstorms ruin crops, damage assets, and harm people, yet expected changes to hailstorms in a warming climate remain highly uncertain. Here, we show global projections for changes to hailstorm frequency in a warming world, and examine the effects of the changes on crop production zones. The projections are based on a hail proxy that uses large-scale environment information to estimate hail hazard frequency; this proxy was applied to a selection of global models from the CMIP6 ensemble for 1980—2000 and for projections of future 20 year periods with additional global warming. Global climatologies for the present climate match known hail-prone areas. Changes in hail hazard under warming scenarios show non-spatially-homogeneous changes in hail frequency with large geographical variability. Using a high-resolution dataset of global crop areas and growing periods by crop type, we investigate potential changes to hail threat over crop regions worldwide. We analyse changes in the crops at risk both spatially and in terms of whether crop growing periods are likely to become more or less hail-prone in future. Our projections shed light on changes to an important hazard that affects food security and agricultural risk assessment.

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 4

South-east Australian rainfall: the latest VicWaCI2 findings by the Bureau of Meteorology

Irina Rudeva[1], Surendra Rauniyar[2], Ghyslaine Boschat[2], Ulrike Bende-Michl[2], Acacia Pepler[2], Chiara Holgate[3], Chris Lucas[1], Eun-Pa Lim[1], Gen Tolhurst Tolhurst[1], Katayoon Bahramian[1], Roseanna McKay[1], Sur Shamila[1], Steven Thomas[1]

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Session

41. General climate variability and change

Abstract

Victoria's rainfall is highly variable and has experienced a significant decline over recent decades in the cool season. The Victorian Water and Climate Initiative (VicWaCI) is a research program coordinated by DEECA to inform water resource managers on water availability and future planning. This presentation summarises the findings of the second phase of VicWaCI (2021-2024). We show that Victorian annual and cool season rainfall has experienced two regime shifts since 1900. A comprehensive review of atmospheric drivers of rainfall variability in southeast Australia highlighted the importance of extratropical processes and informed research into the role of the subtropical jet. The project further addresses the role of asymmetric components of the Southern Annular mode and the importance of stratospheric ozone in predicting circulation anomalies in the Southern Hemisphere and their impact on rainfall in southeast Australia. We also analyse large- and synoptic-scale processes that lead to extreme dry and wet events and explore components of the hydrological balance at Hydrological Reference Sites across Victoria to show how they changed during and after the Millennium Drought. Finally, to support long-term water resource planning, we analyse Victorian rainfall in CMIP simulations. An evaluation of historical model outputs shows that CMIP6 models are generally able to simulate the teleconnection between Victorian rainfall and the key large-scale drivers, which helps increase our confidence in future projections. During the twenty-first century, Victorian rainfall is projected to decline under high and moderate emission scenarios with the magnitude of the decline being outside the natural variability.

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 5

South-east Australian hydroclimate: the latest VicWaCI2 findings by CSIRO and Bureau of Meteorology

Francis Chiew, Steve Charles, Guobin Fu, Zitian Gao, Zaved Khan, Julien Lerat, Seline Ng, David Post, Nick Potter, David Robertson, Jin Teng, Hongxing Zheng

CSIRO Environment

Session

41. General climate variability and change

Abstract

Streamflow in south-east Australia is highly variable and has experienced a significant decline in recent decades. Projections also indicate that the region will be hotter and drier under climate change. This will significantly exacerbate existing water resources management challenges. This presentation will summarise the findings of hydroclimate and hydrological modelling science after almost three years of research in the second phase of the Victorian Water and Climate Initiative. VicWaCI is a research program coordinated by Victoria's Department of Energy, Environment and Climate Action to inform water resource managers on water availability and risks under hydroclimate variability and climate change.

There are two core research areas. The first research area is characterising and modelling hydrological non-stationarity. Key research outcomes have: developed the requirements for modelling hydrological non-stationarity to enable robust prediction of future runoff; improved the conceptualisation of dominant hydrological processes during long dry spells; developed a Data Assimilation guided Model Structure Improvement (DAMSI) method to reduce systematic modelling bias in dry periods; and improved the understanding of catchment recovery after very long dry periods in western Victoria.

The second research area is evolving methods for next generation hydroclimate projections. Key research outcomes have: assessed streamflow projections informed by multiple climate projection products and hydrological impact modelling methods; developed runoff projections informed by CMIP6 GCMs; quantified realised added value from dynamical downscaling in reproducing rainfall characteristics important for runoff generation; and improved bias correction of daily rainfall from dynamical downscaled outputs for robust runoff simulation.

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 6 | Poster Session 1, Poster 55

Attributions of rainfall anomaly to weather systems in Victoria of the southeast Australia

Guobin Fu[1], Francis Chiew[2], David Post[2], Acacia Pepler[3], Irina Rudeva[3]

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Session

41. General climate variability and change

Abstract

It is well known that rainfall characteristics are related to weather systems. Therefore, the contributions of changing synoptic types to rainfall anomaly have been widely investigated in the literature. This study attributes the rainfall anomaly to weather systems in Victoria of the southeast Australia with a multi-method weather type dataset and two popularly-used gridded daily rainfall datasets for the period 1979–2015. The rainfall anomaly before, during and after the Millennium Drought (1997–2009) is compared to quantify the temporal variability of rainfall responses to weather type changes. The results show: 1) Three weather systems (Front, Cyclone and Thunderstorm) and their combinations contribute 89% of total rainfall in the study region; 2) Contributions of weather types to rainfall vary from month to month with winter season rainfall coming from more diverse weather types than summer rainfall; 3) A seasonal shift in the post-drought period is found with higher rainfall in February and March and lower rainfall in September and October. The increased rainfall in February mainly results from Front–Thunderstorm (FT) and Thunderstorm-only (TO), while rainfall declines in September from all-weather types; 4) The impacts of climate system on rainfall characteristics show spatial heterogeneous patterns. The outcomes of this study can not only provide additional information on the non-stationary rainfall-streamflow relationship under climate change scenario for a better water resource management, but also have implications for other regions to investigate the attributions of rainfall characteristic changes to weather systems.

Session 41 (Tuesday 6 Feb, 16:30-18:00), Talk 7 | Poster Session 1, Poster 54

Change in precipitation mean and variability impacting water resource security

Hongxing Zheng[1], Francis Chiew[1], Steve Charles[2], David Robertson[3], David Post[1]

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Session

41. General climate variability and change

Abstract

Climate change is expected to alter precipitation patterns, increase temperature and enhance potential evaporation in the future. The percentage change in precipitation will be amplified in the percentage change in streamflow, impacting regional water resource security. The negative impact will be accentuated by the increase in potential evaporation where precipitation is projected to decrease, and moderated by the increase in potential evaporation where precipitation is projected to increase. Climate models, particularly the CMIP6 GCMs, also project an increase in interannual precipitation variability. The increase in interannual precipitation variability will have little additional impact on the change in mean streamflow. However, the consequential increase in interannual and multi-year variability in streamflow and reservoir inflow will reduce the reliability of water supply.

This paper will present the projected changes in mean annual precipitation and interannual precipitation variability globally from CMIP6 GCMs, as well as the modelled impact on mean annual streamflow and interannual streamflow variability. The presentation will then focus on south-east Australia and assess the influence of changes in mean annual precipitation, mean annual potential evaporation and interannual precipitation variability on mean annual streamflow, inter-annual variability of streamflow and water security or reliability of supply. The latter will be estimated using the Gould-Dincer storage yield and reliability method. The paper will explore the sensitivity of streamflow to different changes in dominant climate variables as well as present the impact on water security informed by changed signals from the CMIP6 GCMs.

42. General extreme events

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 1

Heavy rainfall in the Maritime Continent and mesoscale convective systems

Clemente Lopez-Bravo[1,2,3], Claire L. Vincent[4,5], Yi Huang[4,5], Todd F. Lane[4,5]

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Session

42. General extreme events

Abstract

The general description of the diurnal cycle of rainfall and cloud in the Maritime Continent (MC) is that mesoscale convective systems (MCSs) develop over land during the afternoon and evening and tend to propagate offshore at night. However, there is considerable variability in the diurnal precipitation and cloud populations during heavy rainfall events in the MC. We present an analysis of satellite-derived measurements of daily and hourly accumulated precipitation from the Integrated Multi-satellitE Retrievals for GPM and the characteristics of convective systems over the major islands of the MC to investigate the relationship between the organization of MCSs and heavy rainfall in the MC. Geostationary measurements from the Himawari-8 Advanced Himawari Imager instrument and satellite infrared techniques are used to investigate convective features during heavy rainfall events. Our results suggest that the heavy rainfall days over land are associated with well-organized MCSs and the diurnally forced convection in the MC. Those systems show tropical convective clouds with a significant increment of cold cloud area during heavy rainfall events and diurnal variations over land between events. We also found that heavy rainfall events represent, on average, 5% of total rainfall over land. However, this percentage represents the most hazardous MCSs over the MC. We conclude that a particular subgroup of mesoscale convective systems has a significant contribution to heavy rainfall over the MC region. This study is relevant for our comprehension of heavy precipitation and presents a comprehensive view of MCSs for evaluating numerical simulations of the MC.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 2

Increasing Large-Scale Degree of Organization of Convection: Implications for Tropical Precipitation Extremes and Equilibrium Climate Sensitivity

Philip C.O. Blackberg

Monash University, Melbourne, Australia

Session

42. General extreme events

Abstract

The spatial organization of deep convection in tropical regions is posited to play an important role in determining characteristics of the tropical climate such as the humidity distribution, cloudiness, and intensity of precipitation extremes. Changes to the Degree of Organization of Convection (DOC) under warming may therefore be an important control on Equilibrium Climate Sensitivity (ECS), as well as having impacts on future precipitation extremes. Here we investigate relationships between the large-scale clustering of convection and radiative feedbacks and precipitation extremes in climate models. We present evidence that the tropical scene, with convective regions defined from surface precipitation rates, exhibits increased DOC in a warmer climate scenario in 17 of 19 GCMs analyzed from CMIP5 and all 19 GCMs analyzed from CMIP6. While the cross-model correlation between tropical-mean measures of daily precipitation extremes and DOC is not significant, a strong daily correlation between these quantities is found in most models ($R^2~0.2-0.3). In addition, we show that increases in DOC is associated with a trend of domain mean drying, increased outgoing longwave radiation, and increased dry static stability from monthly anomalies ($R^2~0.1-0.3). These results contribute to advancing our knowledge about critical climate variables such as ECS and tropical precipitation extremes by elucidating the interaction between climate change and tropical large-scale circulation and deep convection.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 3

The dynamics of rapid southward displacements of monsoon troughs over Australia

Matthew R Heislers[1,2], Michael J Reeder[1,2], Christian Jakob[1,3], Sugata Narsey[4]

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Session

42. General extreme events

Abstract

The Australian summer monsoon brings substantial rainfall to northern Australia with many regions receiving more than 80% of their annual rainfall within the "wet season", this consequently has important social, economic, and ecological ramifications. The monsoon and its impacts are more pronounced in the north; however, monsoon troughs can be identified far south of the peak monsoon region and even occur over the arid, desert climates of central Australia. It's not understood how monsoon troughs form or get displaced to these regions. Using an objective method for identifying time averaged low-level convergence lines as a proxy for the location of the monsoon trough the dynamics of these events is investigated. We propose that the mechanism driving these events is an increase in moisture supply to dry, semi-permanent continental heat troughs. Given sufficient moistening, the stability decreases, and deeper convection is permitted. Once a threshold is crossed, troughs can transition from thermally to convectively driven and substantial rainfall can occur. We also propose that similar processes can be involved in rapid southward monsoon trough displacements more broadly including monsoon onset. Analysis of the 1979 Australian monsoon onset which occurred during Winter MONEX, suggests that an existing heat trough over northern Australia underwent rapid moistening leading up to onset and by the time of onset had become the monsoon trough and a region of high convective activity, shifting the centre of convective activity and ITCZ to inland Australia from where it was over the Maritime Continent only three days prior.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 4

Skilful subseasonal-to-seasonal (S2S) prediction of extreme Australian summer rainfall using the QBO and MJO

Xiaoxuan Jiang[1,2,3], Neil Holbrook[1,2], Andrew Marshall[3], Peter Love[4]

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Session

28. Prospects for predicting hydroclimate beyond a season

Abstract

Climate extremes, including heatwaves and extreme rainfall, can have substantial impacts on human health, energy, water supplies, and agriculture. Accurate forecasts can be beneficial for strategic responses and vulnerability to climate hazards. This study assessed the accuracy of the Bureau of Meteorology's Australian Community Climate and Earth-System Simulator – Seasonal2 (ACCESS-S2) dynamical forecast system to simulate and predict Australian summer high rainfall extremes with lead time of 2-3 weeks, especially focusing on the combined role of the Quasi-Biennial Oscillation and Madden-Julian Oscillation (MJO). The predictability of the MJO improves in the easterly phase of the QBO (EQBO) compared to the westerly phase of the QBO (WQBO). In MJO phases 6 to 8, the EQBO contributes to better predictive skill over central Australia, which is likely related to the development of the Australian Southwest Cloudband. In southwestern Australia, the EQBO contributes to more accurate predictive skill in MJO phases 2-5, while forecasts associated with the WQBO show higher skill in MJO phases 8+1 and 6+7. The areas with high predictability in the EQBO and the WQBO are consistent with higher extreme rainfall probabilities and wet lands. In the Murray-Darling Basin, forecasts in the EQBO show higher skills in MJO phases 4+5 and 6+7, which is likely to be linked to higher rainfall over the east coast. This study provides insights for evaluation of the ACCESS-S2 model. Increased understanding of extremes' predictability from this study will be beneficial to development of regional applications and warning systems for agriculture, livestock and water security.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 5

What made the 2022 austral spring so wet over south-eastern Australia?

Linjing Zhou, Eun-Pa Lim, Pandora Hope, Griffith Young

Bureau of Meteorology

Session

42. General extreme events

Abstract

In September-November 2022, south-eastern Australia (SEA) experienced its wettest spring on record, causing widespread and long-lasting flooding in the region. During this season, the tropical oceans showed a strong negative Indian Ocean Dipole (IOD) event and a moderate La Niña. This was the third consecutive year of La Niña following 2020 and 2021. Consistent with the phases of IOD and ENSO, the sea surface temperatures to the North of Australia were above average. The Antarctic polar vortex was stronger than normal, pushing the Southern Annular Mode towards its positive phase. Due to the continuous wet conditions, the soil moisture in the region was much higher than normal. Additionally, the Australian region has warmed by 1.4°C since 1900 due to increasing greenhouse gases (GHGs), which has been altering both mean climate and how natural climate modes impact Australia. All of the above may have contributed to the extremity of this rainfall event.

In this study, we explore the event with the Bureau of Meteorology's sub-seasonal to seasonal forecast system, ACCESS-S2, which successfully predicted the high rainfall over SEA in real-time. By re-forecasting the event with modified initial conditions, we assess the forecast sensitivity to the atmosphere, ocean and land initial conditions and GHGs, and investigate 1) the role of tropical ocean conditions relative to that of atmosphere conditions, 2) the importance of pre-conditioned wet soil and its association with the tropical ocean conditions, and 3) the role of the underlying climate change trend relative to the weather condition.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 6

Examining Prolonged Recent Flooding Events in Eastern Australia

Mohammad Mahadi Hasan[1], Jannatun Nahar[1], Shishutosh Barua[2], Blair Trewin[2], Simon Grainger[1], David John Martin[2], Lynette Bettio[2]

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Session

42. General extreme events

Abstract

Since 2010, there have been three periods of increased rainfall in Australia: 2010–11 to 2011–12, 2016–17, and 2020–21 to 2022–23. These wetter than average periods were closely linked to widespread riverine flooding, particularly in eastern regions of the country.

This study investigates the spatial distribution, severity, and duration of flooding events that occurred in mid-to-late spring 2022. The extent and severity varied over the period between August 2022 and January 2023 affecting New South Wales, Victoria, and Tasmania. Most impacted regions covered upper and lower catchments of the Murray–Darling Basin (MDB), reaching South Australia by late December2022 to January2023.

Extensive flooding was observed along major rivers in New South Wales. Many flood forecasting sites exceeded major flooding thresholds. In Victoria, major flooding extended to both MDB and non-MDB catchments, including the Murray Riverina reach, Goulburn and Broken rivers, Campaspe, and Maribyrnong and Werribee rivers. In the southern MDB, the flooding during the latter half of 2022 was the most severe and prolonged in decades. The impact, extending to multiple flood forecasting sites in Victoria, was a phenomenon not previously observed within the flood observation network.

The duration of flooding along the many rivers was significantly longer than those in recent decades. While heavy rainfall remains the primary contributor to flooding, the presence of a saturated landscape with water storage at or near full capacity, coupled with consistently high streamflow, emerged as a significant factor in reshaping the flood's severity, extent, duration, and subsequent impacts.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 7

Modelling Escalating Landslide Risks in Changing Climate

Sanjaykumar Patil[1], Ned Haughton[2], Joshua Hartigan[2], Nikki Epema[3], Karl Mallon[2], Max McKinlay[4]

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Session

42. General extreme events

Abstract

Landslides are natural downhill ground movements driven by gravity, causing widespread devastation including loss of life and infrastructure destruction costing billions of dollars annually. As these events become more frequent, understanding and predicting their occurrence is crucial. This research outlines a predictive framework that combines static factors (e.g., slope, geology) and shifting rainfall patterns driven by climate change to estimate landslide probability.

This methodology builds on previous works by Stanley et al, which uses a decision tree model. It calculates annual landslide likelihood by integrating susceptibility mapping, the number of days exceeding baseline rainfall thresholds, and an event trigger coefficient. The latter accounts for the rare nature of actual landslides even when all the conditions are favorable.

Calibration of the method involves using NASA global landslide catalog. In order to mitigate the selection bias we only consider landslide events between 2006 and 2020. The approach is then applied globally, revealing a startling increase of up to 350% in landslide likelihood by 2100 in some parts of the world, underlining the urgent need for climate adaptation strategies.

Session 42 (Thursday 8 Feb, 11:00-13:00), Talk 8

Categorising the strength of Indian Ocean Dipole and El Niño Southern Oscillation events and their relationship to temperature and rainfall patterns

Caitlin Minney

Bureau of Meteorology, Melbourne, Australia

Session

42. General extreme events

Abstract

The typical impacts on rainfall and temperature of the El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) are well understood and aid in the predictability of long-range forecasting and hazard preparation.

We have worked on refining the criteria used to categorise of the strength of historical IOD and ENSO events. These criteria incorporate both sea surface temperature and atmospheric indicators. The refined criteria were applied to historical data to form an updated list of IOD and ENSO years.

Using these updated categorisations, rainfall and temperature patterns of typical events, as well as for events of varying strength were determined. The relationship between changes in rainfall and temperature, and event strength was also investigated quantitatively.

The impact of ENSO and IOD on other Bureau products, such as their relationship to the Northern Rainfall Onset (NRO) was also explored.

This work builds upon previous work in historical ENSO and IOD event analysis. Updating our understanding of historical events allows for better preparation for future ENSO and IOD events and assists in the communication of their expected impacts.

44. General monitoring, modelling and other services

Session 44A (Thursday 8 Feb, 14:00-15:30), Talk 1

Real-time nowcasting of low-level winds (10m and 100m) from weather radar observations

Valentin Louf, Alain Protat

Bureau Of Meteorology, MELBOURNE, Australia

Session
44. General monitoring, modelling and other services

Abstract
SWIRL (Synthetic Wind Information from Radar and Lidar) is an operational 3D wind retrieval technique that produces 3D grids (1km horizontally and 500m vertically) of the three wind components in severe weather using radar data from the Australian operational radar network. The 3D wind is retrieved for all Doppler radars in the network in situation of dual-Doppler (meaning an overlap between radars) but also in single-Doppler using the optical flow computed directly from the reflectivity field in precipitation and clear-air. We found that SWIRL results are within 1 m/s and 5 degrees for the wind magnitude and direction, respectively, compared to the wind profilers. Moreover, using the NWP (Numerical Weather Predication) models as guide for SWIRL, we present an assessment of the feasibility of extrapolating SWIRL winds close to the surface using NWP low-level wind profiles for wind farm application. The study used four key data sources to conduct verifications: ACCESS-C Sydney, AWS station data, wind-profiler data, and SWIRL radar winds data in the Sydney domain. We used low-level winds from NWP with SWIRL winds for precipitation, clear air, and boundary layer index separately into a Regression model to assess the possibility of extrapolating the wind information to the wind farm level of interest using the radar observations.

Session 44A (Thursday 8 Feb, 14:00-15:30), Talk 2

Projections for future drought in Australia using CMIP6 downscaled projections

Rohan Eccles[1], Ralph Trancoso[1,2], Jozef Syktus[2], Sarah Chapman[1], Hong Zhang[1], Nathan Toombs[1]

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Session

44. General monitoring, modelling and other services

Abstract

Droughts are recurring natural hazards throughout the Australian continent, with their impacts affecting society and the environment. Under climate change, there is potential for more frequent and severe drought events. However, the ability of global climate models to generate regionally relevant insights into future droughts is limited. As such, regional projections of droughts are required to inform decision makers on the likelihood of these hazards across the different regions of the continent.

In this study we employ the 12-month standardised precipitation index (SPI; including only precipitation) and the 12-month standardised precipitation-evapotranspiration index (SPEI; including precipitation and temperature/evaporation) to investigate changes to future meteorological droughts.

We used an ensemble of 15 CMIP6 simulations downscaled using the Conformal Cubic Atmospheric Model (CCAM) to a 10 km resolution for the whole of Australia. Simulations of precipitation and potential evapotranspiration were bias corrected against observational and reanalysed data using the MBCr bias correction approach developed by Cannon. We assess the changes to 12-month SPI and SPEI in two future periods (2041-2060 and 2081-2100) and compare them with the historical baseline (1995-2014) for three Shared Socioeconomic Pathways (SSP1-2.6, SSP2-4.5, and SSP3-7.0, representing low, moderate, and high-emissions pathways, respectively). Three metrics (frequency of occurrence, duration, and percent time in drought) are used to evaluate the impacts of climate change across different drought severity categories. The insights generated from these results are of importance to a range of stakeholders across Australia and may be adopted to help inform future adaptation strategies.

Session 44A (Thursday 8 Feb, 14:00-15:30), Talk 3

The future of water services in Australia

Wendy Sharples, Ulrike Bende-Michl, Sharmila Sur, Jiawei Hou, Navid Ghajarnia, Christopher Pickett-Heaps, Katayoon Bahramian, Christoph Rudiger, Andrew Frost, Elisabetta Carrara

Bureau of Meteorology, Melbourne, Australia

Session

44. General monitoring, modelling and other services

Abstract

One of hydrology's grand challenges in Australia is simulating accurate, high-resolution hydrological fields such as streamflow on a continental-scale, seamlessly, from a few hours to decades. Seamless hydrology is a critical input for numerous applications, including water management, hazard prediction, infrastructure planning, renewable energy and emergency response. Due to climate change and a non-stationary climate, past observations and localized modelling are no longer reliable. However, the path to seamless, more impactful water services could be seen as a long and winding road.

This presentation will describe the journey from the current state of the Bureau of Meteorology's water services to a future state-of-the-art service. Detailing the underpinning science leading to future improvements in continental-scale water services, and the potential for their use in numerous applications. We show that although the road is long, the path is well trodden, and that the potential benefits justify the investment. The Bureau's future water services will support Australia to plan and prepare for the days, weeks, seasons, years, and decades ahead.

Session 44A (Thursday 8 Feb, 14:00-15:30), Talk 4

An overview of the Queensland Future Climate Science Program in 2024: advances in climate modelling, analysis, and services

Ralph Trancoso[1,2], Jozef Syktus[2], Sarah Chapman[1], Nathan Toombs[1], David Ahrens[1], David Owens[1], Hong Zhang[1], David Putland[1], Ryan McGloin[1], Rohan Eccles[1], Celine Roux[1], Ove Hoegh-Guldberg[2]

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Session

44. General monitoring, modelling and other services

Abstract

The Queensland Future Climate Science Program (QFCSP) is a collaborative program between Queensland's Department of Environment and Science and the University of Queensland undertaking downscaling of global climate models, analysis of climate extremes and translation of knowledge into climate services. The first phase of the program was based on CMIP5 downscaled simulations and delivered several products to underpin adaptation and disaster preparedness. The second phase of the QFCSP has produced the largest ensemble of CMIP6 downscaled projections for the Australasian region at a 10 km spatial resolution with 15 CMIP6 simulations forced under three emissions scenarios (SSP1-2.6, SSP2-4.5 and SSP3-7.0). The downscaling aligns with the Climate Projections Roadmap for Australia. Projections have been evaluated and show substantial added value, especially over urban regions with complex topography. The CORDEX compliant projections data are published via the Australasian CORDEX archive hosted by the NCI. Projections were bias-corrected and a range of hydroclimate, climate hazards and extremes metrics are being computed to generate sector-specific knowledge. An updated version of QFCSP website was launched, including fire weather on the Queensland Future Climate Dashboard and the Regional Reports, a new web application for visualization of customized climate change interactive time-series and summary tables across Queensland's regions. The QFCSP web resources will be updated with CMIP6 data and additional resources later in 2024. The QFCSP has been instrumental for the Queensland Climate Action Plan, fostering assessments of future climate risk, underpinning adaptation across multiple sectors and ensuring a more sustainable future for Queenslanders.

Session 44A (Thursday 8 Feb, 14:00-15:30), Talk 5 | Poster Session 2, Poster 60

Stormy subtropics and stratiform south: A radar-based classification of Australian rainfall events

Annabel J Bowden

Monash University, Clayton, Australia

Session

44. General monitoring, modelling and other services

Abstract

Weather radar is an essential data source that allows for analysis of rainfall at a high temporal and spatial resolution. Despite this fact and the presence of an extensive operational network spanning a variety of climatic regions, Australian weather radar data is not commonly used to identify and characterize rainfall events. For this work, a threshold-based rainfall event identification algorithm is used on Level 2 radar data from the Australian Unified Radar Archive (AURA) to cluster rainfall events into distinct classes. Two different types of heavy rainfall events are extracted and investigated: high accumulation events, which are the 100 events with the highest total rainfall accumulations for each location, and high intensity events, the 100 events with the highest average intensities for each location. It is found that rainfall events in tropical/subtropical Australia are more convective in nature and generally more common in the warm season, while events in the midlatitudes have more stratiform attributes and tend to be more frequent in winter. High accumulation events are long-lived and spatially extensive, and high intensity events are localized, intense, and strongly convective. Overall, radar data displays great utility in studying the characteristics and morphology of rainfall events and heavy rainfall events in Australia. But improvements in data quality, record lengths, and coverage of remote areas are needed for this utility to be fully realized.

Session 44A (Thursday 8 Feb, 14:00-15:30), Talk 6 | Poster Session 2, Poster 62

Can your smartwatch measure ambient air temperature?

Mahya Parchami, Negin Nazarian, Melissa Hart, Sijie Liu

University of New South Wales, Sydney, Australia

Session

44. General monitoring, modelling and other services

Abstract

Urban overheating, exacerbated by rapid urbanization and global climate change, is one of the key environmental challenges facing our cities. While there are widespread efforts for collecting highresolution datasets, there is still a lack of human-centric monitoring of urban heat focusing on the immediate environment of individuals as they go about their lives in cities. Project Coolbit aims to address this limitation by utilizing wrist-mounted wearable devices, such as smartwatches, to measure and crowdsource ambient air temperature. The wearable monitoring method (introduced in Nazarian et al. 2021) combines environmental and physiological responses to provide a more holistic understanding of the human experience in urban areas. Sensors placed on smartwatches are used to measure air temperature and relative humidity at the wrist, as well as the skin temperature and heart rate of individuals. These measurements are then compared with data captured by a highly-accurate mobile weather station - the MaRTy cart capturing 6- directional radiation and wind speed in addition to ambient temperature and relative humidity – and a prediction model for ambient air temperature is proposed based on the wearable datasets. The mobile weather station also allows us to quantify the biases in air temperature prediction, particularly as mean radiant temperature and wind speed are not captured by wearable devices. The ability to predict air temperature using wearable devices offers a new, more comprehensive, and personalized way of measuring urban heat impacts in cities. This information can further be used to better understand the thermal environment and design urban spaces to mitigate the effects of urban overheating. Ultimately, the data collected through Project Coolbit will help to understand the spatial variability of air temperature in urban environments and provide valuable information to create more livable, sustainable cities.

Session 44B (Thursday 8 Feb, 16:30-18:00), Talk 1

On the use of mobile weather radar for bushfire nowcasting

Peter T May[1], Mika Peace[2], Alain Protat[3], Mark Curtis[3], Adrien Guyot[3], Agnes Kristina[4]

[1]Monash University, Clayton, Australia. [2]Bureau of Meteorology, Adelaide, Australia. [3]Bureau of Meteorology, Melbourne, Australia. [4]Western Australia Department of Fire and Emergency Services, Cockburn Central, Australia

Session

44. General monitoring, modelling and other services

Abstract

Mobile radars deployed at fires can capture high resolution data that detects wind shifts, and changes in intensity and vertical plume growth can indicate dynamic and dangerous fire behaviour. Radar data from fires therefore presents an opportunity to assist decision making, as well as providing a rigorous data set that can be used to test the performance of fire simulation models.

Building on previous work by the University of Queensland, we deployed a sensitive X-band dual polarization radar to environmental burns conducted in southwest WA. The proof-of-concept experiment involved operational fire teams in the planning and deployment of the mobile radar.

The radar data shows the ability to detect wind shifts in the vicinity of the fires and demonstrates that even relatively low intensity fires can produce significant perturbations on the local wind fields. Project outcomes included the development of Standard Operating procedures for radar deployment, with a view to sampling bushfires. The project team ran a workshop which was attended by operational fire agencies from around the country.

This presentation will include examples showing the interaction of the fire with an approaching wind shift, fire induced circulations, and the separation of ash cloud and precipitation. The talk will conclude with insights from the workshop and next steps towards nowcasting capabilities and model testing.

Session 44B (Thursday 8 Feb, 16:30-18:00), Talk 2

Recent advances in radar-based 3D wind retrievals

Jordan Brook, Alain Protat, Joshua Soderholm

Bureau of Meteorology

Session

44. General monitoring, modelling and other services

Abstract

Weather radars play a crucial role in identifying and nowcasting hazards associated with severe thunderstorms, including hail, extreme rainfall, wind, and tornadoes. While radar-based hail detection and quantitative precipitation estimates are widely employed in operational contexts, the adoption of radar-based wind retrievals has been hindered by the complications involved with computing these products. The difficulties predominantly arise due to the fact that Doppler radars measure only the radial component of the wind, rendering the retrieval of the full 3D wind field a challenging task. In this presentation, we will highlight our recent methodological advancements in this domain and demonstrate the attainable accuracy using high-resolution simulations and real case studies from Australia. Reliable, real-time 3D wind retrievals offer considerable potential for diagnosing storm severity, nowcasting severe weather hazards, and deepening our understanding of storm dynamics. Our aim, through these advancements, is to contribute to the creation of more effective early warning systems and strategies to reduce the impacts of severe thunderstorms.

Session 44B (Thursday 8 Feb, 16:30-18:00), Talk 3

Improved gridded analysis of daily rainfall for Australia

Alexander D Evans

Bureau of Meteorology, Melbourne, Australia

Session

44. General monitoring, modelling and other services

Abstract

The Bureau of Meteorology is committed to improving the services it provides to the Australian community and industry, including enhancing its public products. The Bureau of Meteorology published the Australian Gridded Climate Data set (AGCD version 2) in September 2020 as its operational national, real-time monthly gridded rainfall dataset, replacing the previous monthly gridded rainfall analysis, known as the Australian Water Availability Project (AWAP). AGCD version 2 incorporates enhanced analysis and scientific methods, as well as state of the art geostatistical computer modelling.

Here we show the performance of the AGCDv2, daily rainfall analysis, in terms of cross-validation statistics and compare error metrics against AWAP. With this, we also show how the analysis scheme deals with areas where station observations are sparse and the network density is low. To deal with discontinuities and extrapolation errors in sparsely observed areas, we generate additional pseudo-observations with regular spacing determined from the observation network density. The general irregularity and sparseness of the observation network presents a significant challenge in generating a consistent spatial analysis of historical data across Australia. It is well known that the statistical interpolation technique, and indeed other existing spatial analysis approaches, are adversely influenced by network inconsistencies. We formally addressed this issue by generating a regular spaced coverage of pseudo-observations in the very data-sparse areas.

Session 44B (Thursday 8 Feb, 16:30-18:00), Talk 4

A new analysis scheme for the gridded temperature in Australia

Wahid Zaman[1], Alex Evans[1], Andrew Frost[2], Blair Trewin[1]

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Session

44. General monitoring, modelling and other services

Abstract

The Bureau of Meteorology provides a range of gridded national, daily climate data series based including precipitation, maximum and minimum temperature and vapour pressure, with data available from 1900 (precipitation)/1910(temperature) until the present – see www.bom.gov.au/climate/maps. This dataset, the Australian Gridded Climate Data (AGCD v1) dataset, is currently provided at 0.05° resolution (approx. 5 x 5 km). The data is used for a range of applications including supporting historical analysis, inputs to modelling and for downscaling/calibration/verification purposes for climate change studies.

The Bureau is in process of updating the methods supporting this service including increasing the resolution of the product to 0.01° resolution (approx. 1 x 1 km), to produce the next version of product AGCD v2, for which monthly rainfall is already operational. This work presents the updated gridded analyses of maximum and minimum daily temperature. The new technique is presented, validation results are compared with the existing analysis, and several extreme temperature events are presented in detail to show the improved performance of the new approach.

Session 44B (Thursday 8 Feb, 16:30-18:00), Talk 5

The Flexible Array of Radars and Mesonets (FARM)

Joshua Wurman[1], Karen Kosiba[2]

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Session

44. General monitoring, modelling and other services

Abstract

The Flexible Array of Radars and Mesonets (FARM) Facility is an extensive mobile multiple-Doppler radar and in-situ instrumentation network.

The FARM comprises four mobile / quickly-deployable radars: two X-band Doppler On Wheels DOW6/DOW7, the Rapid-Scan DOW (RSDOW), the C-band On Wheels (COW), and mini-COW.

The FARM includes 3 mobile mesonets (MM) with 3.5-m masts, an array of rugged weather stations (PODNET), weather stations deployed on infrastructure including light/power poles (POLENET), and other instrumentation.

The FARM's integration of radar, in situ, and sounding systems provides robust kinematic, thermodynamic, and microphysical observations. FARM has deployed to >30 projects, obtaining pioneering observations of a myriad of small spatial scale and short temporal scale phenomena including tornadoes, hurricanes, lake-effect snow storms, aircraft-affecting turbulence, convection initiation, microbursts, intense precipitation systems, boundary layer structures and evolution, airborne hazardous substances, coastal storms, wildfires, weather modification, and mountain/alpine weather.

Proposed major upgrades to the FARM targeted observing network, including the S-Band On Wheels NETWORK (SOW-NET) replacing large stationary S-band research radars, and the Bistatic Adaptable Radar Network (BARN) will be summarized.

A next-generation long wavelength adaptable/targetable research radar network, comprising an array of truck-borne scanning 10-cm radars, S-band On Wheels (SOW), incorporating a Bistatic Adaptable Radar Network (BARN), can provide fine-scale S-band observations of the atmospheric boundary layer, convective, and other precipitating systems, simultaneously measuring dynamically meaningful fine-scale vector wind fields.

SOW/BARN will fill critical gaps in current observing systems, providing broadly and inexpensively available long wavelength, dual-polarimetric, near-ground, fine-scale, vector wind observations.

Posters

Poster Session 1

Poster Session 1, Poster 01

Applying action mechanics to the thermodynamics of the troposphere

Ivan R Kennedy[1], Migdat Hodzic[2]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Practical advances in applied mechanics regarding better understanding of the recycling of heat and work in the troposphere are now possible. Four testable proposals we advance solve problems including (i) the phenomena of decreasing temperature and molecular entropy but increasing Gibbs energy with altitude in the troposphere (ii) a reversible system storing thermal energy to drive vortical wind flow in anticyclones while frictionally warming the Earth's surface by heat release from turbulence (iii) vortical generation of electrical power from translational momentum in airflow in wind farms and (iv) vortical energy in the destructive power of tropical cyclones. The scalar property of molecular action ($@_t \equiv \int mvds$, J-sec) is used to show how equilibrium temperatures are achieved from statistical equality of mechanical torques (mv^2 or $mr^2\omega^2$); these are exerted by Gibbs field quanta for each kind of gas phase molecule as rates of translational action ($d@_t/dt \equiv \int mr^2\omega d\phi/dt \equiv mv^2$). A better understanding of these vortical Gibbs energy fields as thermodynamically reversible reservoirs for heat can help optimize work processes on Earth, delaying the achievement of maximum entropy production from short wave solar radiation being converted to outgoing long wave radiation to space. This understanding may improve strategies for management of global changes in climate.

Kennedy, I.R. and Hodzic, M. Applying the action principle of classical mechanics to the thermodynamics of the troposphere. *Applied Mechanics* 4, 729-751

Poster Session 1, Poster 02

Estimating maximum power from wind turbines: A need to minimize environmental impacts of predicted vortical energy released from downstream turbulent air

Ivan R Kennedy[1], Migdat Hodzic[2], Angus N Crossan[3], Nikolas Crossan[3], Niranjan Acharige[1], John W Runcie[4]

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Session

33. Renewable Energy

Abstract

Newton's third law has provided us [1] with a novel mechanism for estimating maximum wind power from deflection of its momentum by twice its angle of incidence (ϑ) on rotor blades as airfoils. The lateral reaction in response ($Mv\sin 2\vartheta$) to the deflection provides the turning moment for the turbine's rotors. Action mechanics integrates the rates of impulsive wind action on turbine blades as torques ($\int mrvd\vartheta/dt \equiv Mv^2$) on rotor surfaces at decreasing radii. Windward torque (T_w) is estimated from rotor dimensions, the angle of wind incidence and radial action of wind impulses on the blade surfaces ($\int mrvd\vartheta/dt \equiv mv^2$). A leeward torque ($T_b$) for back reaction of turbine blades on air mimics drag exerted parallel to the plane of rotation of the blade. Net torque is then converted to potential power $(T_w - T_b)\Omega$ by the angular velocity (Ω) of the turbine rotors, a function of tip speed ratio to wind speed. A mechanism for release of warming vortical field energy [2] from laminar flow of air in anticyclones is predicted in turbulent downstream wakes, affecting maximum power output by wind farms. Significant vortical heat release from downwind turbulence will require care for their location. Diligence demands that use of windfarms as major sources of renewable energy minimize any environmental impacts from drying of landscapes. Such action mechanics introduces new frontiers for climate science and its variations with time.

1. Kennedy, I.R. et al., 2023, *Arch.Adv.Eng.Sci.* XX, 1-21. doi:10.47852/bonviewAAES32021330.
2. Kennedy, I.R. Hodzic, M. *Appl.Mech.* 4, 724-751.

Poster Session 1, Poster 03

Horizontal and vertical influences on the thermal structure of the tropical troposphere

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Our conceptual understanding of the tropical thermal structure is based on two complementary idealisations: convective quasi-equilibrium (QE) and the weak-temperature gradient (WTG) approximation. Through QE, moist convection provides a local vertical control on the thermal structure, while under WTG, wave dynamics are assumed to provide a non-local horizontal control. While it is clear that moist convection plays an important role in setting the tropical mean stability through QE, the extent to which it applies locally in different regions or whether the WTG effectively inhibits the influence of local conditions on stability remains debated.

Here we hypothesise that a strong local vertical control of the thermal structure would imply a relationship between humidity and stability in the troposphere, as convection within moister regions would be less affected by entrainment of surrounding air. We utilise a combination of ERA5 reanalysis and observational data to examine the relationship between stability and local humidity across the tropics. The results are compared to a prediction based upon the theory of QE under a simple entraining-plume model of convection.

We discover that, in convective regions, moist convection is most influential and that the resulting relationship between stability and humidity can be well approximated by the entraining plume model. However, in non-convective regions, the WTG effectively inhibits the influence of local humidity and instead sets a convective threshold based on the stability of surrounding convective regions. These results may help us understand the controls on horizontal density gradients in the tropical troposphere and the associated overturning circulations.

Poster Session 1, Poster 04

Atmospheric Heat Waves in New Caledonia: A Study of Spatiotemporal Variability and Teleconnections

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

New Caledonia's climate is atypical in the South Pacific, combining tropical and temperate influences with orographic effects. In the context of global warming, with record-breaking temperatures in 2022 and health authorities questioning the potential impact on the population's health, the study of atmospheric heat waves in New Caledonia is a key priority for local meteorologists. We focus on events that have affected New Caledonia over the past 40 years and use EHF (Excess Heat Factor) index to define and measure heat waves. Referenced data were collected from a network of climate monitoring stations and compared to ERA5-Land reanalysis, the latter providing insight on heatwave spatial variability. Yearly climatologies reveal an average of 4 to 5 heat waves over the country, lasting 4.5 to 5 days on average. They are more frequent on the south-east coast of Grande Terre and on the Loyalty Islands, but more intense along the west coast of Grande Terre. Heatwaves are also more intense and last longer during the cool season. Trends computed by Sen's Kendall slope estimator show a significant increase in the number of heat waves over most of the territory ; trends for average intensities and durations are not significant. Archetipal Analysis is applied to examine the spatiotemporal variability of heatwaves and identify teleconnections that lead to extremes over New Caledonia. Results show that ENSO significantly modulates the number of heatwaves in summer. Using a set of pre-defined circulation types and supervised classification we highlight the synoptic-scale weather conditions prone to extreme heatwaves.

Poster Session 1, Poster 05

Exploring the Impact of Northeast Pacific Feedback on recent ENSO Variability in a conceptual model."

Arnold Sullivan[1,2], Geng Tao[3,4], Wenxiu Zhong[5,6], Anyi Huang[7,8]

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Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

The Northeast Pacific (NEP) feedback refers to the interaction between NEP low clouds and sea surface temperatures (SSTa), in which Pacific subtropical cyclones interact with the Pacific Parametric Mode (PMM), providing feedback to the tropical Pacific through the wind-evaporation-SST (WES) mechanism. This highlights the pivotal role of the extra-tropics in altering ENSO variation. In the context of the recent 2020-2022 triple-dip La Niña and an upcoming (potentially strong) 2023 El Niño, we explore whether the current El Niño-like warming SSTa is accurate or is merely a residual effect of negative PMM accumulation caused by remote effects from other oceanic areas. This study employs a conceptual model to simulate the impact of extratropical influences on the tropical Pacific's climate. It reveals the intricate dynamics of the tropical Pacific climate system by untangling the complex interactions among NEP feedback, extratropical impacts, and ENSO variability. These insights provide novel perspectives that contribute to our understanding of tropical-extratropical interactions and ENSO prediction.

Poster Session 1, Poster 06

The Dynamics of Extratropical Cyclones and Their Role in Extreme Multi-Day Rainfall

Martin Jucker, Greta Paget, Caleb Burke

University of New South Wales, Sydney, Australia

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

Extratropical cyclones play a significant role in extreme multi-day rainfall events in the extratropics. These events, which often lead to extended flooding, are characterized by large amounts of cumulative rainfall over several days. Multi-day rainfall extremes can result from various factors such as stationary precipitating cyclones, large cyclones that cover a region for an extended period, or multiple less extreme cyclones occurring in quick succession. To better understand the dynamics behind extreme multi-day rainfall and assess the relative importance of different drivers, this study uses cyclone tracking information from reanalysis and climate models combined with Rossby wave theory. This approach aims to test existing ideas regarding the drivers of extreme multi-day rainfall and to examine both historical trends and projected future changes.

Poster Session 1, Poster 07

Linking ENSO to Synoptic Weather Systems in Eastern Australia

Zoe Gillett[1,2], Andrea Taschetto[1,2], Chiara Holgate[3,2], Agus Santoso[1,2]

[1]University of New South Wales. [2]ARC Centre of Excellence for Climate Extremes. [3]Australian National University

Session

4. Atmospheric Dynamics of Climate and Extreme Weather

Abstract

The El Niño-Southern Oscillation (ENSO) is the main driver of interannual rainfall variability in eastern Australian, but its link with rain-producing synoptic weather systems in this region is unclear. By tracking low pressure systems in ERA5 over 1979 to 2021, we find that springtime cyclones are linked to variations in the large-scale atmospheric circulation during ENSO events. On spring days with a cyclone over southeastern Australia during La Niña years, a pressure dipole occurs with a strong anticyclonic anomaly southeast of Australia and a cyclonic anomaly over eastern Australia. The northeasterly circulation directs tropical moisture toward eastern Australia, and coupled with induced ascent, promotes rainfall in this region. Both dynamical and thermodynamical changes are important for the rainfall response. An almost opposite circulation response occurs on cyclone days during El Niño events: high-pressure over the Australian continent reduces rainfall in eastern Australia. These synoptic setups resemble the seasonal-mean Rossby wave teleconnections, indicating a link between weather systems and ENSO.

Poster Session 1, Poster 08

Compounding impacts of hydroclimatic events in the Pacific Islands

Liz Dovey

ANU (Fenner School of Environment and Society),,Canberra,, Australia

Session

8. Compound events - characteristics, drivers, and impacts

Abstract

In and around the small islands of the Pacific, what might have been small changes elsewhere can readily compound across ecosystems to make major impacts on both land and/or in the surrounding sea. This presentation considers and illustrates this effect by examining a few examples, such as:

- Effects of global warming including sea level rise, ocean acidification and oxygen depletion and increasing frequency of extreme events including floods, cyclones, droughts, fires and heatwaves (most of which can impact all parts of a small country at once)
- Impacts vary with the context such as different physical characteristics, location and environmental dynamics of the islands
- Both slow moving and sudden global warming impacts have ecological responses, which in turn interact with each other and with other more direct human impacts, such as land-use change, invasive species, or pollution
- In turn these changes can interact further on the species mix, causing mismatches in seasonality, spatial ranges, reproduction and life cycles, and even body size of organisms
- Changes pressure species to move to the extent this is possible: poleward, upwards in altitude and downwards in the canopy and the ocean – but movement is limited within and between small islands and even movement between ocean areas can be difficult
- Species left behind can be subject to systematic (and often irreversible) changes such as death of corals with replacement by algal blooms.

Such a mosaic of stresses also has major implications for the human populations of small islands.…

Poster Session 1, Poster 10

Evaluation of seasonal teleconnections to remote drivers of Australian rainfall in CMIP5 and CMIP6 models

Christine Chung[1], Ghyslaine Boschat[1], Andréa Taschetto[2], Sugata Narsey[1], Shayne McGregor[3], Agus Santoso[2], Francois Delage[1]

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Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

This study describes how coupled climate models participating in the sixth phase of the Coupled Model Intercomparison Project (CMIP6) simulate the primary climate drivers that impact Australian climate, and their seasonal relationship to Australian rainfall, namely the El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), and the Southern Annular Mode (SAM). As regional downscaling efforts draw on CMIP models, it is important to evaluate these teleconnections across Australia. As results from the earlier generation of models (CMIP phase 5) are still in use, the CMIP6 multi-model mean teleconnections between climate drivers and seasonal Australian rainfall are compared to CMIP5. Collectively, an improvement is found in CMIP6 relative to CMIP5 in the representation of the relationship between ENSO and IOD events and Australia's springtime rainfall. Overall, CMIP6 models are also able to reproduce the asymmetric relationship between ENSO and eastern Australian rainfall, i.e. a more robust signal during La Niña than during El Niño years. CMIP5 and CMIP6 models are also generally able to capture the stronger relationship between Central Pacific La Niñas, compared with Eastern Pacific La Niñas. However, the large spread in model-to-model behaviour, and amongst ensemble members, remains a source of uncertainty. While CMIP6 models have improved in their representation of SAM variability, the simulated relationship between SAM and Australian rainfall has not materially improved.

Poster Session 1, Poster 14

The importance of North Atlantic regional aerosol forcing in historical evolution of global-mean surface temperatures

Harun A Rashid

CSIRO, Melbourne, Australia

Session

10. Modelling, prediction and projections of climate variability and past and future climate change

Abstract

Understanding the historical evolutions of surface temperatures in observations and model simulations is important for making reliable climate projections. However, a full understanding of this topic has proven to be challenging, partly due to the complexity of the climate processes and feedbacks that affect surface temperature evolutions. Here, we investigate the forced component of global-mean surface air temperature (GMST), estimated as the multi-model mean of CMIP6 historical simulations, to determine the relative contributions of different forcing agents to the GMST evolution. We find that the forced GMST evolution is not fully explained by the well-known global anthropogenic forcing, from combined greenhouse gas (GHG) and aerosol forcings, and natural forcing, from volcanic aerosols and total solar irradiance (TSI); an aerosol-induced North Atlantic regional forcing is also needed to this end. This regional forcing significantly modulates the forced GMST evolutions in vast majority of CMIP6 models and observations, especially during the second half of the 20th century. Individual models with a high North Atlantic forcing tend to underestimate the effect of anthropogenic GHG forcing. Consequently, the strength of this regional forcing in a model, not the model's climate sensitivity, significantly influences the magnitude of its simulated historical warming. This highlights the importance of reducing the aerosol forcing uncertainty in models for a realistic simulation of the historical climate and for reliable climate projections.

Poster Session 1, Poster 17

Assessment of future fire weather hazard in Australia using downscaled CMIP6 projections

Ryan McGloin[1], Ralph Trancoso[1,2], Jozef Syktus[1,2], Sarah Chapman[1], David Putland[1], David Ahrens[1], Nathan Toombs[1], Hong Zhang[1], David Owens[1]

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Session

12. Regional climate projections and applications

Abstract

Australian landscapes are fire prone and have been severely damaged by bushfires in the recent past. Understanding how the climate conditions conducive to bushfires are projected to change in the future is essential for building preparedness. Here, we assess the impact of climate change on fire weather using high-resolution climate simulations from downscaled global climate models (GCMs) from the latest phase of the Coupled Model Intercomparison Project (CMIP6). We selected 12 CMIP6 GCMs to downscale to a spatial resolution of 10 km. The downscaling was performed using the Conformal Cubic Atmospheric Model (CCAM) forced with multivariate bias-corrected sea surface temperatures under three emission scenarios (SSP1-2.6, SSP2-4.5 and SSP3-7.0). Downscaling was performed continuously over the 1960-2100 period for the entire Australian continent. We used the McArthur Forest Fire Danger Index (FFDI) as our underlying metric for the assessment. The FFDI uses rainfall, wind speed, temperature and humidity to quantify fire weather hazard. These variables were bias corrected against observations and reanalysis using a multivariate approach. The future impacts on FFDI are presented across severity categories (ranging from low to severe) for mid-term (2050) and long-term (2090) future scenarios. Preliminary results for Queensland suggest that the frequency of severe and very high fire risk days is likely to substantially increase by 2050 except for areas near the coast (where the increase will mainly be in moderate to high fire risk days). The increase in severe fire risk days is projected to be particularly apparent in the southwest portion of the state.

Poster Session 1, Poster 18

Selecting CMIP6 GCMs for CORDEX dynamical downscaling over Southeast Asia using a standardised benchmarking framework

Phuong Loan Nguyen[1,2], Lisa V. Alexander[1,2], Marcus Thatcher[3], Son C. H. Truong[3], Rachael N. Isphording[1,2], John McGregor[3]

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Session

12. Regional climate projections and applications

Abstract

Downscaling global climate models (GCMs) provides the crucial higher-resolution data needed for informed decision-making at regional scales. However, there is no uniform approach to selecting which GCMs would be most suitable. In some regions like Southeast Asia (SEA), observations are sparse with large uncertainties, particularly for rainfall which makes GCM selection more complicated. We apply a standardized benchmarking framework to select a subset of CMIP6 GCMs for dynamical downscaling over SEA, addressing current limitations with observational networks. Benchmarking differs from typical model evaluation in that it requires model expectations to be set a priori. This framework identifies fit-for-purpose models through a two-step process: (a) selecting models that meet minimum performance requirements in simulating the fundamental characteristics of rainfall and surface temperature (e.g., spatial pattern, annual cycle, and trend) and (b) selecting models from (a) to further assess performance in simulating precipitation drivers (monsoon) and modes of variability (El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) teleconnection). GCMs generally exhibit wet biases, particularly over the complex terrain of the Maritime Continent. Meanwhile, CMIP6 shows biases of variable sign for average temperature, with a greater number of GCMs exhibiting cold biases rather than warm biases. Overall, models are better at simulating temperature than precipitation over SEA. The framework identifies five GCMs from three independent modelling groups (i.e., differences in atmospheric, land, and ocean models) that align with our purpose of downscaling over CORDEX-SEA.

Poster Session 1, Poster 19

Assessing bias correction approaches for analysis of climate extremes and hazards

Sarah Chapman[1], Ralph Trancoso[1,2], Jozef Syktus[2], Nathan Toombs[1], Hong Zhang[1], Rohan Eccles[1]

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Session

12. Regional climate projections and applications

Abstract

Evaluations of downscaled climate projections have shown they generally add value over host models, especially over coastal and mountainous regions. However, downscaled simulations also carry systematic biases inherited from global models and generated by regional models that must be adjusted otherwise they are propagated into the calculations of climate extremes and hazards. Here, we performed a series of numerical experiments assessing different bias correction approaches with the goal of defining the methodology for the CMIP6 cycle of downscaled simulations of the Queensland Future Climate Science Program. We used our previous CMIP5 downscaled projections under RCP8.5 over Queensland with the Conformal Cubic Atmospheric Model (CCAM). The bias correction was applied to two downscaled simulations with ACCESS1-0 and ACCESS1-3 and three variables: precipitation, minimum and maximum temperatures. After a preliminary assessment of a broader list, we selected the two best performing methods (quantile delta mapping and non-parametric transfer function) with and without seasonal calibrations (seasonal and monthly) and wet/dry day frequency correction. We also assessed the performance of the three Cannon's multivariate bias correction approaches: MBCn, MBCp and MBCr. We used the periods 1980-2000 and 2001-2020 as calibration and validation, respectively. The assessment criteria were bias in climatological spatial patters, impact on the future climate change signal (2079-2099) and impacts on climate extremes – assessed using an adaptation of the Perkins skill score applied to the lower and upper tails of the distributions. The results revealed important insights to inform bias correction strategies of climate modelling programs and impact assessments.

Poster Session 1, Poster 20

Climate change impacts on evapotranspiration using CMIP6 downscaled simulations

Hong Zhang[1], Ralph Trancoso[1], Jozef Syktus[2], Sarah Chapman[1], Nathan Toombs[1], Rohan Eccles[1], Ryan McGloin[1]

[1]Department of Environment and Science, Brisbane, Australia. [2]The University of Queensland, Brisbane, Australia

Session

12. Regional climate projections and applications

Abstract

Evapotranspiration is the second most important water cycle component, accounting for water losses through surface evaporation and vegetation transpiration. Here, we estimated future evapotranspiration at a daily time step using 15 CMIP6 downscaled climate simulations under three emissions scenarios (SSP1-2.6, SSP2-4.5 and SSP3-7.0) for Australia. The downscaling was performed using the Conformal Cubic Atmospheric Model (CCAM). We estimated seven evapotranspiration models: the Penman–Monteith for reference evapotranspiration (short and tall crops), Morton's actual evapotranspiration, point potential evapotranspiration and wet environment areal average potential evapotranspiration. We also estimated synthetical pan evaporation and Morton's shallow lake evaporation.

We assessed the historical mean climatology (1981-2010) and the climate change signal for the seven evapotranspiration variables. Results show small biases in climatology for most evapotranspiration variables except for actual evapotranspiration. The Kling-Gupta Efficiency (KGE) score (combining bias, correlation and variability) showed higher skills for Morton's point potential evapotranspiration and synthetical pan evaporation and lower skills for Morton's actual evapotranspiration. The future projected changes are generally consistent across CCAM ensemble runs. The annual average increases by the end of this century in Australia are 10.23%-12.25% (SSP3-7.0); 7.45%-9.21% (SSP2-4.5); and 4.77%-6.05% (SSP1-2.6) for six variables other than actual evapotranspiration. The projected changes in actual evapotranspiration are relatively small. The annual average changes at the end of this century in Australia are 1.04%, -5.25% and -5.90% for the three SSPs. The evapotranspiration projections dataset is a useful resource for impact assessments on water and agricultural sectors and will be released in 2024.

Poster Session 1, Poster 21

Updates to the Conformal Cubic Atmospheric Model for CORDEX-CMIP6 regional projections

Marcus Thatcher, Sonny Truong, Benjamin Ng

CSIRO Environment

Session

12. Regional climate projections and applications

Abstract

This poster describes various updates to the Conformal Cubic Atmospheric Model (CCAM) for CMIP6 regional climate projections. These changes are to improve aspects of the simulated regional projections for the CORDEX-CMIP6 experiment, based on a C384 grid that provides 12.5km resolution for most of the CORDEX Australasia domain and an average global resolution of 25km. Our configuration of CCAM relies on spectral nudging of air temperature, winds, and surface pressure at length-scales above 3,000km, as well as sea-surface temperatures at length-scales above 1,000km. The CCAM simulation also includes prognostic aerosols for direct and indirect effects, as well as an in-line Boussinesq ocean model that is implicitly coupled to the atmosphere through a combined turbulent mixing parameterisation. Several model enhancements have been made based on early results after downscaling CMIP6 GCMs. These model changes include: i) the refinement of category 4-5 cyclone representation, ii) improvements of cloud microphysics to better capture extreme rainfall and ice cloud formation, iii) better representation of ocean eddies, and iv) integration with the COSP cloud satellite simulator and ILAMB for evaluation, as well as general optimisation for parallel code on modern supercomputers. The original and updated configurations of the model will be published as different model versions using CORDEX conventions for data publishing, although both datasets will be available for regional projections.

Poster Session 1, Poster 22

A collaborative web – the evolution of an interjurisdictional knowledge broker network to help users apply climate science research

Ramona I Dalla Pozza[1,2], Sarah Bassett[3], Helen Bloustein[4], David Putland[5], Graham Green[6], Susan Sweeney[6], Sharna Nolan[7], Tamara Pinkerton[7], Matthew Riley[3]

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Session

12. Regional climate projections and applications

Abstract

Knowledge brokers form a key link in Australia's climate service delivery chain, forming a bridge between climate scientists and users. Working alongside climate scientists, policy and decision makers, on-ground practitioners and, others, we are helping translate climate information into meaningful decision-ready content.

Before 2019, there was a lack of collaboration and alignment between state, territory and Australian governments and science agencies producing future climate science information. This created confusion for users and hindered the development of Australia's climate science capability. Users demand nationally comparable, robust, decision-ready information. Over the last 4 years there has been an important shift towards government collaboration through the Cross-Jurisdictional Community of Practice for Climate Science (CJ COP CS). The success of this collaboration has led to the first-ever interjurisdictional knowledge brokering team within the National Environmental Science Program (NESP) Climate Systems Hub, as well as the formation of the National Partnership for Climate Projections.

These collaborations are bringing together the Australian Climate Science Community (including state and territory governments, CSIRO, Bureau of Meteorology, Australian government initiatives NESP Climate Systems Hub and the Australian Climate Service, as well as key universities) to develop consistent approaches to providing comparable, robust, authoritative and fit-for-purpose future climate information. Knowledge brokers are at the centre of this collaborative web, involving stakeholders in co-design and co-production. We are helping users apply climate science information for climate risk assessments and adaptation planning and are ensuring researchers understand how these user perspectives can enhance the impact of their work.

Poster Session 1, Poster 23

Shaping national climate science research - Building a national picture of state and territory user requirements

Susan Sweeney[1], Sarah Bassett[2], Helen Bloustein[3], David Putland[4], Graham Green[1], Sharna Nolan[5], Tamara Pinkerton[5], Ramona Dalla Pozza[6,7]

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Session

12. Regional climate projections and applications

Abstract

Decision-makers in Australian states and territories have their own distinct needs for climate change risk assessment, mitigation, planning and adaptation. States and territories own and are responsible for critical infrastructure and essential services and have data and expertise that can assist to manage the risks to these services and assets from climate change.

The National Environmental Science Program (NESP) Climate Systems Hub Knowledge Brokers, representing the states and territories, are strengthening the impact of the hub. Acting as interpreters between the climate scientists and decision-makers, we are building partnerships and facilitating knowledge transfer to ensure research is co-designed and co-produced with the people that need it to inform their organisations' planning and operations.

The NESP Knowledge broker team are consulting within their states and territories across multiple sectors including emergency management, utilities, health, infrastructure, local government, primary production and natural resources to understand their climate change information requirements. The potential use of climate change information is broad, and sector and state/territory needs can be quite specific reflecting regional differences and/or regulatory requirements. This presentation will provide a summary of these consultations to illustrate how a greater understanding of specific climate science requirements is helping build opportunities for collaboration and inform climate adaptation needs across Australia.

Poster Session 1, Poster 24

Statistical Assessment of Busfires over Australia under different warming scenarios.

Rashmi Mittal[1], Nidhi Nishant[2]

[1]Freelance, Australia. [2]University of New South Wales, Australia

Session

12. Regional climate projections and applications

Abstract

Bushfires are one of the most frequent and catastrophic natural hazards experienced in Australia. Bushfire characteristics are influenced by a number of factors such as climate change, fuels, terrain, and land management. In this study, we examine bushfire characteristics i.e., its intensity, frequency and duration and their projected changes in future using New South Wales (NSW) / Australian Capital Territory (ACT) Regional Climate Modelling (NARCliM) data.

We use Forest Fire Danger Index (FFDI) as an indicator of the fire weather and examine three research questions. First, how well does NARCliM simulate the historical FFDI (from 1990 to 2009), when compared with data from the Australian Bureau of Meteorology (BOM)? Second, how do the projections from NARCliM predict future (2060-2079) changes in future bushfire characteristics? And third, how do factors like wind, temperature, and humidity contribute to the changes in the FFDI? This study has strong implications on understanding the usability of downscaled RCMS for bushfire impact assessment and understanding the future bushfire hot-spot regions over Australia.

Poster Session 1, Poster 25

Sensitivity analysis of Planetary Boundary Layer parameterisation schemes in CORDEX-CMIP6 regional climate model simulations over Australia

Yue Li[1], Giovanni Di Virgilio[1,2], Fei Ji[1], Eugene Tam[1], Jatin Kala[3], Julia Andrys[3], Jason P. Evans[2], Stephen White[1], Dipayan Choudhury[1], Carlos Vieira Rocha[1]

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Session

12. Regional climate projections and applications

Abstract

The turbulent mixing in the planetary boundary layer (PBL) plays an important role in the vertical transport of moisture, heat and momentum, thus influencing how thermodynamic and kinematic profiles evolve. The turbulent mixing mostly occurs at the spatiotemporal scales that cannot be explicitly resolved in regional climate models (RCMs), such that PBL parameterisation schemes are needed. An ensemble of Weather Forecasting and Research RCMs driven by ERA5 reanalyses and CMIP6 global climate models over Australia at 20 km resolution as part of CORDEX-CMIP6 use different physical parameterisations. RCM performances in simulating mean and extreme maximum, minimum temperature and precipitation show markedly different profiles for two RCMs, such as biases of opposite sign for the simulation of temperature and precipitation. However, the only difference between these RCMs is their PBL parameterisations, namely the Mellor-Yamada Nakanishi Niino (MYNN2) and Asymmetric Convection Model 2 (ACM2) schemes. In this study, the impacts of these two PBL schemes on RCM performances are investigated. A set of comprehensive diagnostics on vertical thermodynamical and dynamical structures will be presented, which offer explanation of the mechanisms underlying the different performances of these two RCMs caused by the selection of PBL schemes. These insights can assist the interpretation of the varying climate hindcasts and projections simulated by the different RCM configurations assessed here and may also inform future model design and development activities undertaken as part of CORDEX.

Poster Session 1, Poster 33

Data Preparation and Machine learning (ML) for Predicting Marine Heatwaves (MHWs)

Madhuri Angel Baxla[1], Olga Lyashevska[2], JoseMaria Farinas-Franco[1]

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Session

18. Applications of Machine Learning Techniques to Severe, Impact-Producing Climate Extremes

Abstract

This project focuses on harnessing machine learning techniques to predict sea surface temperature (SST) and analyse marine heatwaves around the region of Ireland. Due to a lack of comprehensive time series data on factors like ocean currents, wind conditions, cloud cover, heat influx, SST is the primary variable used. Historical data from sources like NOAA and IFREMER, spanning from 1982 to 2021, reveal significant marine heatwaves in the vicinity of Ireland. These events exhibit consistent patterns in terms of their duration, intensity, and frequency. The training dataset for the machine learning model is constructed from diverse sources, including the Marine Institute, ICES, NOAA, and Copernicus SST data. This interdisciplinary project aims to bridge marine sciences and data engineering to create actionable tools, potentially serving as early warning systems for aquaculture sectors, aiding in predictions of harmful algal blooms, and facilitating rapid decision-making in the marine industry.

Poster Session 1, Poster 38

Two-tier nested Southwest Pacific ocean model suite using MOM6

John Anthony Reilly[1,2], John Reilly[2]

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Session

27. High-resolution modelling

Abstract

We describe the development and evaluate performance of a two-tier nested modelling suite focused on the Southeast Australian coastal region using the latest release (version 6) of GFDLs Modular Ocean Model (MOM6). The larger regional model (SOUTHPAC-01) is forced by the global 1/10th degree Ocean-Sea ice model from the ACCESS-OM2 model suite at the boundaries and has the same resolution as the parent model. The small regional model (EAC-003) is forced by SOUTHPAC-01 at the open ocean boundaries, whilst the resolution is increased to 1/30th degree horizontally, and from 75 to 100 vertical levels. This study lays the groundwork for future analysis of the large-scale influence on coastal and shelf sea variability, with particular focus on temperature extremes and marine heatwaves in the nearshore environment of Southeast Australia.

Poster Session 1, Poster 39

Influence of current and future climates in PV module degradation

Shukla Poddar[1], Houston Warren[2], Phillip Hamer[1], Merlinde Kay[1], Mark Nuttal[3], Jakub Tomczyk[3], Bram Hoex[1]

[1]University of New South Wales. [2]University of Sydney. [3]Sun Cable

Session

33. Renewable Energy

Abstract

Photovoltaic (PV) systems are the fastest growing renewable technologies and are projected to supply ~23% of the world's electricity by 2027. However, the long-term exposure to outdoor weather conditions can induce severe stress on the PV modules resulting in module degradation over time. Degradation of the PV modules can reduce the lifetime and performance of the modules, therefore leading to reliability issues. At present, failures resulting in module degradation are generally not considered individually because of the difficulty in measuring the power of a single module in a PV system and the lack of feedback on the various degradation modes of PV modules. Given that the PV deployment rate is likely to increase to well over 1 terawatt per year, a detailed analysis of the degradation rates in PV modules is required. In this study, we present a modelling framework that considers the weather parameters responsible for module degradation and their non-linear interactions. Our framework proposes modelling degradation as an aggregate of the component degradation and failure modes for a given system. We use weather station data from Alice Springs and ERA5 reanalysis data to validate our model, along with climate projections from the CMIP6 models to understand the historical and future degradation rates. Results indicate that globally, module degradation due to moisture ingress and high temperature are highest in the tropical regions (~1.2-1.5%). These rates are projected to increase by 0.5% in the future. This study will help in improving system yield calculations and developments in module technology.

Poster Session 1, Poster 40

Which climate modes control Australian wind variability and long-range predictability?

Andrew Dowdy[1,2], Claire Vincent[1,2]

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Session

33. Renewable Energy

Abstract

Very little is known about how winds are influence by large-scale modes of climate variability (such as El Niño-Southern Oscillation and others). Here we examine the main modes of climate variability for the Australian region and quantify their influence on wind variability using reanalysis data. Results are presented for land regions as well as offshore regions relevant to wind electricity generation. The analysis covers a range of different wind metrics averaged over different time periods and at different height. Extreme winds, as well as 'wind droughts', are also examined. Lagged correlations are calculated between the wind metrics and different modes of variability, providing new insight relating to long-range predictability and reliability of wind electricity generation at specific times of the year.

Poster Session 1, Poster 41

Joint Modulation of Peak Power Consumption and Wind Energy Resource across Southeast Australia

Adam Nahar[1], Claire Vincent[1,2], Kelvin Say[1,3]

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Session

33. Renewable Energy

Abstract

Wind farms account for ~10% of energy production in Australia, a share expected to rise in the coming years. Offshore sites are planned by the end of the decade, tapping into increased wind energy potential that parts of the coastline offer, placing heightened dependence on this sector. The El Niño–Southern Oscillation (ENSO) correlates with different aspects of Australian weather, but connections with regional winds are largely unexplored.

In this work, average capacity factors (CF) across southeast Australia and their variability based on ENSO conditions are analyzed. CFs on days in which a high electricity demand was likely in Victoria (differentiated based on heating or cooling demand) are also compared with their climatological values to see which locations feature increased or decreased efficiency. We particularly focus on the Gippsland declared offshore wind zone, examining CFs on days with high electricity demand under different ENSO phases.

Results indicate that highest CFs are offshore, with a maximum between King Island and northwestern Tasmania. Much of western Victoria sees increased CFs on high cooling demand days, and notably higher efficiency off Cape Howe. More neutral anomalies appear on high heating demand days, which are found to often occur under windy cold front or calm high pressure conditions, with windy conditions being observed more often under El Niño.

These results examine the first joint modulation of both electricity demand and wind power supply over southeast Australia through inter-annual climate variability, which has implications for long-term electricity system planning.

Poster Session 1, Poster 42

A new illustrated history of the Bureau of Meteorology

John W Zillman[1], Richard N Whitaker[2], Terry L Hart[3]

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Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

The history of meteorology in Australia is a wonderful saga of science, technology and constant progress, sometimes in hostile environments and at others during sympathetic periods when progress accelerated. European meteorology in Australia is only a recent endeavour with the early settlers knowing little of the weather and climate of the strange new land in which they had arrived. The story of how they learned is a fascinating one that is encapsulated in the story of Australia's National Weather Service - the Bureau of Meteorology. A history of the Bureau covering the period 1939 to 2003 has been written recently by Prof. John Zillman and illustrated by Dick Whitaker. This talk will outline the major achievements, developments, challenges and occasional obstacles faced by the Bureau during this period.

Poster Session 1, Poster 43

Applying the concept of the "front" to synoptic analysis in Australasia

Terry L Hart

Formerly Bureau of Meteorology, Melbourne, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

During the 1920s the Bureau of Meteorology's then new head of research, Edward Kidson, was proactive in introducing the Polar Front model of cyclone development to southern hemisphere synoptic meteorology. Despite some scepticism, by the outbreak of World War II, there was a general acceptance of the usefulness of frontal analysis and forecaster recruits were schooled in the intricacies of air mass recognition, frontal identification and the use of the frontal model for weather forecasting.

The frontal theory was put to a stern test as forecasters attached to the Australian and New Zealand Air Forces in the tropics struggled to reconcile the theory of fronts with their experience. In the years following the War there was a period of robust debate and the development of a new understanding of tropical weather patterns.

This paper describes these debates and the identification of other complexities associated with fronts. The key Cold Fronts Research Programme in the early 1980s provided a major impetus to understanding. It was followed by many significant field experiments accompanied by developments in numerical modelling of idealised fronts, aimed at understanding the mesoscale features of these synoptic systems and modifications as they progressed over land.

Field experiments, understanding of fronts and operational forecasting of fronts and other discontinuities have been facilitated by major improvements in observations and numerical weather prediction.

Poster Session 1, Poster 44

Retelling the story of climate through a century of cluey climate quotes

Mary E Voice

University of Melbourne, Cumulus Consulting, ivanhoe, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

Over the course of the past century, scientists working in the climate space have published useful and/or profound comments about the climate system, about developments in understanding the climate sciences and about the ability to predict climate states for the Earth, for regions, for locations. This poster presents a century of cluey climate quotes to help track the history of our understanding of the climate system over the past century and beyond.

Poster Session 1, Poster 45

Experiential and science-investigated learning about Australian climate from the “Age of Exploration” forward.

Mary E Voice

University of Melbourne, Ivanhoe, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

Whilst long-timescale climate variations (including that of the last Milankovitch-cycle ice age) and continent-wide geographical climate patterns have clearly influenced the Australian continent and its inhabitants for millennia, this presentation focuses on understanding of the climate of Australia from the “Age of Exploration” or colonial times forward. It will discuss some of the circumstances leading to exploration of the Australian coastline: for example, a climate discovery pertinent to the story of Australia occurred as early as 1611 during the “Age of Exploration”. It will also discuss some of the documented experiences that contributed to the early grasping for climate knowledge by European settlers. And how those experiences led to scientific investigation of Australian climate patterns by pioneer researchers.

Selected sources (abbreviated):

Museum.wa.gov.au – longitude; southern oceans

Mystery of the La Perouse expedition (TheConversation)

Neumann, J. 1977. Great Historical Events That Were Significantly Affected by the Weather

Joseph Banks in Australia

Nicholls, McBride and Nicholls, Gergis and Fowler

www.bom.gov.au

Jevons, Todd, Goyder, Wragge, Warren, Hunt.

Poster Session 1, Poster 46

Charles Todd, data, communications, meteorology – an Australian pioneer

Mac Benoy[1], Beth Walton[2]

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Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

Charles Todd was a true pioneer in the fields of data, communications and meteorology, for South Australia, for Australia and for Australian links with the wider world. The data story starts at the Royal Observatory Greenwich from 1841 where he was employed in part to analyse and publish backlogs of data. The communications story began at the Cambridge Observatory and Greenwich where he worked on telegraphy and undersea cables. The meteorology story probably began in February 1855, when he accepted the position of Astronomical and Meteorological Observer, and Head of Electric Telegraph Department in South Australia. Thus began his pioneering work on meteorological observing systems and related communications networks in Australia. This poster will highlight his achievements and also the work of dedicated volunteers who have "rescued" some of the early observations through digitisation.

Poster Session 1, Poster 47

A brief history of stratospheric ozone observations in Australia

David J Karoly

University of Melbourne, Melbourne, Australia

Session

35. History of AMOS sciences in Australia and their impact on our society

Abstract

The stratospheric ozone layer is crucial for protecting life on Earth from dangerous solar UV radiation. Concerns were raised about depletion of stratospheric ozone due to increasing concentrations of oxone-depleting substances, such as chloroflurocarbons, well before significant reductions were observed.

To obtain observations of the vertical profile of ozone in the troposphere and stratosphere, an ozonesonde is generally used. An ozonesonde is a chemical cell and radio transmitter attached to a hydrogen-filled balloon, which transmits ozone concentrations to a ground site as it rises to a height of about 35km.

The first ozonesonde flights in Australia were undertaken by researchers at CSIRO Meteorological Physics at Aspendale from 1965. These ozonesonde operations were transferred to the Bureau of Meteorology in the late 1960s at a site in Melbourne. that moved several times. At present,the Bureau conducts weekly ozonesonde flights from Laverton, near Melbourne. A pilot weekly program of ozonesonde flights in late winter, spring and early summer was initiated in 1996 at Macquarie Island by the Cooperative Research Centre for Southern Hemisphere Meteorology and operated by the Bureau of Meteorology. This program has been maintained by the Bureau of after the CRC closed in 2000.

The Bureau of Meteorology and the Australian Antarctic Division established a program of ozonesonde releases from Davis station in Antarctica (in 2003 and it has continued to date, close to the edge of the Antarctic ozone hole in spring.

These ozonesonde data are vital in the data-sparse Southern Hemisphere middle and high latitudes.

Poster Session 1, Poster 48

Minute-scale and Mesoscale Atmospheric Motion Vectors tracked from FY4B Geo High-speed Imager (GHI) visible and infrared imagery

PAN XIA

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Geostationary satellite-tracked atmospheric motion vectors have been used over half century in a wide variety of meteorological applications. The increasing horizontal and vertical resolution of numerical weather prediction models puts a greater demand on satellite-derived wind products to monitor flow accurately at smaller spatial scales and higher temporal resolution. The Geo High-speed Imager of FY4B allow for scanning rates as high as 1min and provide 500m, 250m visible and 2000m infrared imagery. The mAMV tracking processing greatly increases the vector density that be derived from FY4A Imager throughout the troposphere and lower stratosphere. Vectors in the VIS channel are even tracked up to the 50-hPa level, providing high-density flow information from cirrus clouds and convective storm outflow.

Poster Session 1, Poster 49

Deep Learning approach to sub-seasonal tropical cyclone prediction

Jesse Greenslade

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Tropical Cyclone (TC) projections for up to four weeks are produced by the Bureau of Meteorology using ACCESS-S2 numerical weather prediction. Weather forecasts are fed through a tropical cyclone track model. The proportion of model ensembles that predict TCs in spatial bins provides a TC probability output.

Predicting TC occurrence probability could instead be done through Deep Learning (DL), providing a research opportunity in the extreme weather forecasting space. DL has been used to detect TCs and to predict extreme US weather systems. There is hope that this new solution space could provide longer TC forecast lead times, more accurate forecasts, and even improved TC formation understanding.

My work involves training Convolutional Neural Networks (CNN) using ACCESS-S2 hindcast data (1980 to 2018) targeting historical TC tracks (from the Joint Typhoon Warning Centre). Hindcasts are subset into rectangular regions, and three metrics produce 2D images with three colour bands. The historical tracks are used to label the images as TC coincident (or not) at the forecast date. This set of labelled images is the basis for training a CNN image classification model, and testing is performed on a separate subset of the hindcasts.

The goal is to produce TC probabilities up to 42 days ahead, with comparable or greater skill than current approaches. Skill is examined for several CNN, region definitions, and forecast durations. Additionally, mini-case-studies are performed to assess performances on specific TCs, using a well forecast event and one that was not well forecast.

Poster Session 1, Poster 50

Simple forest-fire-weather indices incorporating dewpoint depression and windspeed

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

Projections of future fire weather using empirical fire potential models could vary substantially depending on the model used, due to differences in the thermodynamic functions incorporated in these models. This, and recent renewed interest in simple fire-weather indices (FWIs), highlights a need to reassess FWIs and the fire-weather concept itself. FWIs use empirical functions of wind speed (V) and thermodynamic quantities, such as temperature (T) and relative humidity (RH), to provide a measure of fire behaviour potential associated purely with meteorological conditions. Two simple FWIs are reviewed, and a new class of FWI for Eucalypt forest application is introduced. The thermodynamic components of the two simple FWIs differ substantially from one-another, and both differ further from the thermodynamic component of the Vesta fire spread-rate model (designed for Eucalypt forests). The new FWIs introduced incorporate dewpoint depression (DPD) as a thermodynamic function, which varies with RH and T in a manner very similar to the Vesta thermodynamic function. These FWIs, termed Dry Windy Indices (DWIs), are linear functions of wind and DPD (both of which are quantities easily obtained from standard weather observations). Tuned to match the weather components of the Vesta models, these simple-to-calculate DWIs represent forward rates of fire spread that are potentially verifiable. For climate applications the DWIs' are computationally cheap to calculate, and the projection results simple to interpret, being attributable to changes in just two simple quantities, DPD and windspeed.

Poster Session 1, Poster 51

Ocean heat uptake via tropical cyclones

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Session

37. Dynamics and Prediction of High Impact Weather

Abstract

The passage of a tropical cyclone over the ocean results in the formation of an area of anomalously cold water, most commonly referred to as a cold wake. The mixing responsible for the wake formation also entrains warmer surface water into the colder thermocline. The strength of the ocean response is dependent on the intensity of the wind forcing due to the tropical cyclone and also on the tropical cyclone speed of motion. Air-sea fluxes warm the cold wake and sea surface temperatures returns to a climate norm within approximately 20 days. The warm thermocline anomaly may remain for a much longer time period in the ocean to create overall net warming of the ocean.

Previous studies examining the heat uptake by the ocean due to tropical cyclones have been limited to individual case studies using model simulations or ocean observations, or use of longer-term reanalysis datasets. All have their limitations in providing a generalisation of the impact of TCs on the ocean. In particular, reanalysis datasets under-represent the wind-induced forcing on the ocean by category 4 and 5 tropical cyclones limiting the effective results to category 3 or lower intensity tropical cyclones. In this study, we combine results using HYCOM reanalysis data to explore 22 years of Atlantic Hurricanes along with six simulations of category 4 and 5 tropical cyclones in the North Atlantic to better define the ocean energy uptake due to intense tropical cyclones.

Poster Session 1, Poster 52

Consistent treatment of saturation in mixed-phase cloud conditions

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Session

40. General atmosphere

Abstract

Mixed-phase cloud conditions are common in the real atmosphere. However, in atmospheric thermodynamics, saturation with respect to liquid water and saturation with respect to ice are typically treated separately. For example, analytical equations exist for the saturation vapour pressure (SVP) over liquid and over ice; for the dewpoint and frost-point temperatures; and for the lifting condensation level (LCL) and lifting deposition level (LDL). In parcel-based calculations (e.g., of convective available potential energy), freezing is typically either neglected entirely or assumed to occur isobarically, resulting in a discontinuity in parcel buoyancy at the freezing level. In this presentation, a simple parameterisation of mixed-phase saturation will be introduced. This parameterisation allows for the derivation of analytical equations for (i) mixed-phase SVP, (ii) the saturation temperature (a mixed-phase equivalent of the dewpoint and frost-point temperatures), (iii) the lifting saturation level (a mixed-phase equivalent of the LCL and LDL), and (iv) mixed-phase reversible and pseudoadabatic saturated lapse rates. Possible applications of these equations will be discussed.

Poster Session 1, Poster 53

Human survivability during future hot and humid conditions

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Session

41. General climate variability and change

Abstract

It is well documented that heatwaves have historically increased in their intensity, frequency and duration, and will continue to do so as climate change intensifies. Moreover, there is a growing body of evidence that the combined effects of heat and humidity will render parts of the world uninhabitable by the end of the 21st Century. However, the vast majority of studies assessing changes of heat coupled with humidity employ understudied or only theorised thresholds in the context of human survivability, for example a wet-bulb threshold of 35oC (Tw35oC). Contemporary research by human physiologists strongly suggests that the true threshold which influences human survivability is more likely lower than Tw35oC, and different for various demographics, for example based on age or gender. Moreover a challenge resides in how different combinations of humidity and heat that all reach Tw35oC affect the capacity of a person to survive the adverse conditions.

These presentation will discuss how more realistic assessments of human survivability – which are designed by physiologists – change both historically and under future climate change. This will be explored over Australia using fully-coupled global climate models, with an onus on how climate mitigation may influence the likelihood of adverse hot and humid conditions, as well as when such events emerge from both background climate variability and tolerable conditions in terms of human health.

Poster Session 1, Poster 56

A historical upper-air humidity dataset for Australia

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Session

41. General climate variability and change

Abstract

Direct measurements of upper-air humidity are made by radiosondes and were historically subject to reporting and measurement biases. It is important to remove these biases with the aim of gaining greater confidence in the results of the data analysis.

To improve the homogeneity of sampling, part of the daily humidity data (represented as dew point temperature) from the latest period of record were removed in accordance with accepted criteria. This was done based on the formula proposed for the WMO Hygrometer Intercomparison. Data series obtained in this way were further homogenised by removing discontinuities caused by the introduction of new radiosonde/sensor types.

Analysis of the resultant dew-point temperature data indicates that over the 1965-2017 period linear trends are mostly positive. The all-Australian time-series show positive trends at the 850 to 400 hPa levels. The total increase in dew point temperature since 1965 at 850, 700, 500 and 400 hPa levels are about 0.5°C, 1.2°C, 1.3°C and 0.8°C respectively. For the 850 hPa level, data show that that the amount of moisture at this level increased about 8.8%°C-1 between 1965 and 2015.

Trend maps for the 1965-2017 period show a general increase of humidity at the 850 to 400 hPa levels. Decreasing trends were found at the 850 hPa level over the south-west, south-east and north-east of the Australia, consistent with the decrease of rainfall observed over these areas, particularly during the winter.

Poster Session 1, Poster 57

Australian rainfall associated with multi-year ENSO events

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Session

42. General extreme events

Abstract

The recent 2020-23 La Niña event was marked by record-breaking rainfall and flooding across eastern Australia. The continuous wet conditions during the triple La Niña motivated us to explore the rainfall impacts during multi-year El Niño-Southern Oscillation (ENSO) events. In this study, we investigate the impacts of single-year and multi-year ENSO events on Australian rainfall using observational datasets from 1900 to 2023. We find that, while there is no difference in the rainfall impacts during single or double El Niño events, Australian rainfall tends to increase in the third year of triple La Niña events compared to the first and second years. This occurs despite the tropical Pacific sea surface temperatures in the second and third years of multi-year La Niña events generally being weaker than the first year's value. Although analysis is limited to five triple-dip La Niña events observed in historical record, the amplified rainfall response in multi-year ENSO events is a consistent and significant result that warrants further investigation. While the associated mechanisms is under examination, we suggest that land-atmosphere coupling plays a role in prolonging the effects of La Niña in Australia by enhancing rainfall in the third year of the event.

Poster Session 1, Poster 58

An examination of extreme rainfall representation in Australian Gridded Climate Data

Alexander D Evans

Bureau of Meteorology, Melbourne, Australia

Session

42. General extreme events

Abstract

The Bureau of Meteorology is committed to improving the services it provides to the Australian community and industry, including enhancing its public products. The Bureau of Meteorology published the Australian Gridded Climate Data set (AGCD version 2) in September 2020 as its operational national, real-time monthly gridded rainfall dataset, replacing the previous monthly gridded rainfall analysis, known as the Australian Water Availability Project (AWAP). AGCD version 2 incorporates enhanced analysis and scientific methods, bringing into operations a new high resolution gridded analysis of daily rainfall.

Here, we present a case study of an extreme heavy rainfall event which occurred in the area around Crohamhurst in southeast Queensland in early February 1893. In particular we look at the performance on the AGCD to resolve the event and make direct comparison to station observations from the area. The event saw ~907 mm of rainfall recorded in 24 hours to 9am on 3 February 1893. This record rainfall led to disastrous flooding in the Brisbane and Mary Rivers. Heavy rainfall continued in the 2-week period following the record rainfall at Crohamhurst on the 3rd with the passage of two more cyclones crossing the Curtis Coastline Rainfall totals for the month of February 1893 were in excess of 800 mm which included Brisbane Regional Office having its highest monthly total on record of 1025.9 mm.

Poster Session 1, Poster 59

The extremely wet 2022 in eastern Australia

Blair Trewin[1], Shishutosh Barua[1], Simon Grainger[1], Mahadi Hasan[2], David Martin[1], Jannatun Nahar[1], Alison Oke[1], Robert Smalley[1], Skie Tobin[1]

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Session

42. General extreme events

Abstract

2022 was an exceptionally wet year in much of eastern Australia. Many locations had their wettest year on record, especially around Sydney and in southeast Queensland and northeast New South Wales. New South Wales as a whole had its second-wettest year on record, and Victoria its fifth-wettest (and wettest since 1974).

There were numerous extreme rainfall events with severe, and in some cases ongoing, impacts, including in late February and early March in southeast Queensland and much of coastal New South Wales. Some of the most extreme rainfalls were in the Lismore area in northern New South Wales, where catchment-averaged rainfall for the Wilsons River catchment was more than 200 mm above previous records at 1- and 2-day timescales. There were further heavy rainfalls in coastal New South Wales in July. Spring saw persistent heavy rainfall, with the season being the wettest on record for New South Wales, Victoria and the Murray-Darling Basin (all by large margins), and October the wettest month on record for Victoria. Locally intense rainfall during this period drove flash flooding at various locations.

The rains of 2022 drove major flooding in many catchments, particularly in coastal catchments during the February/March event, and in the Murray-Darling Basin later in the year. Inland flooding was exceptionally persistent, with flood warnings in place for the Lachlan River continuously for more than eight months. The lower Murray had its highest flood since the 1970s.

Poster Session 1, Poster 60

A machine learning tool for determining the required sample size for GEV fitting in climate applications

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Session

42. General extreme events

Abstract

Extreme climate events (ECEs) like fires, floods, and heatwaves significantly impact people, communities and the environment and climate change is modifying their occurrence. Generalised Extreme Value (GEV) distributions are used to quantify the magnitude and occurrence of ECEs and guide human system design (e.g. the return value of extreme wind gust sets construction codes at a given location). We train a Machine Learning (ML) model utilising a suite of GEV distributions to determine the sample size required to estimate return values to an arbitrary uncertainty. For the typical GEV parameters for heat and rainfall extremes, accurate estimates of the return values can require a large sample size. If regional climate model projections aim to characterise the magnitude and occurrence of ECEs, a large sample size places substantial computational requirements on the regional climate simulations.

Poster Session 1, Poster 61

Communicating complex climate change messages on extreme rainfall

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Session

42. General extreme events

Abstract

Whenever extreme weather events of any kind occur there is public discussion about the role climate change may be playing. For heatwaves and other hot extremes, the message is always clear that human-caused climate change is increasing the occurrence and intensity of these events. While it is easier to identify the signal of climate change on large-scale extreme heat than on short and smaller scales, it is still widely accepted that the human influence on the climate is worsening such events.

In contrast, discussion about the climate change effect on extreme rainfall is more varied with apparent disagreement between experts. This is because extreme rainfall is considerably more complicated as the sign and magnitude of the climate change signal differs greatly by location, spatial scale, and temporal scale. In this presentation, we discuss the climate change effect on different aspects of extreme rainfall and how we can use multiple lines of evidence to make more robust and defensible statements about climate change and extreme rainfall.

Poster Session 1, Poster 62

Ecosystem-based adaptation in the Pacific Islands

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Session

43. General impacts and risks

Abstract

Small Island Developing States are widely recognised as among the most vulnerable to the deleterious impacts of both the climate change and biodiversity loss crises. One nature-based solution, Ecosystem-Based Adaptation (EBA), offers the ability to simultaneously address both these threats and to address several global Sustainable Development Goals, with primary benefits of EBA including water and food security, and coastal protection. This paper examines the application of such measures in the Pacific Islands and their role in reducing the undesirable outcomes of these threats. It focusses on the application of EBA in four regionally widespread ecosystem types: coral reefs, mangroves, subsistence gardens, and rainforests, and at a landscape level in water catchments. The chapter examines the ecosystem services each provides and examples of EBA measures that can sustain these services, particularly at the community (village) level. The most effective approaches build on the knowledge systems held by island communities, combining traditional environmental knowledge with western science to develop and implement locally relevant solutions, encouraged and facilitated by governments and other agencies. EBA measures in the Pacific may have significant adaptive benefits for food and water security and for coastal and biodiversity protection. However, given that most EBA measures involve incremental change rather than transformation, their ability to meet the more severe challenges of long-term climate change may be limited.

Poster Session 1, Poster 63

Assessing Historical Heatwave Trends for New South Wales, Australia: Implications for Adaptation and Community Safety

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University of Newcastle, Callaghan, Australia

Session

43. General impacts and risks

Abstract

Heatwaves have claimed more lives than any other natural hazard in Australia; yet are often overshadowed by the devastation of other climate related disasters. This is particularly concerning given that heatwaves are expected to increase because of anthropogenic climate change. In this study we identify historical trends in heatwave statistics across New South Wales (NSW)concerning and assess regions that have become more in recent decades. We use the Australian gridded temperature data from SILO to calculate heatwave duration, amplitude and frequency on a 5km grid across NSW over the period 1910-2020. A Mann Kendal Trend test was used to identify spatiotemporal trends and associated 'hot spots' of increased heatwave activity. We show for most of NSW, the heatwave amplitude has been increasing, while the far west and east coast have also experienced a significant increase in heatwave duration and frequency. This shift in climate patterns becomes particularly concerning when considering the vulnerabilities of certain populations. Notably, research underscores that elderly residents who reside at home emerge as one of the most vulnerable groups within the community. Therefore we also apply a spatially weighted overlay with NSW Census data to identify Local Government Areas (LGAs) with a high population of elderly residents (>65) at increasing risk of extreme heatwaves. The outcomes of this assessment can be used to inform management strategies for adapting to heatwaves, and keeping our vulnerable community members safe during these extreme events.

Poster Session 1, Poster 64

Scientist and activist: How you can help shape humanity's future.

Karin C Xuereb

Karin Xuereb, Montrose, Australia

Session
46. Other

Abstract
As members of the climate and oceans scientific community, we come once again to hear findings from colleagues about worsening atmospheric and ocean conditions. In 2023, we are seeing the worst realisations of the climate projections made many years ago.

As scientists, we detach ourselves from emotions that might arise when we report on the state of the biosphere. Yet, when we have time to ponder about governments and populations sleepwalking into a future that looks bleak at best, and catastrophic at worst, despite numerous warnings by scientists, a sense of fear and dread of what the Age of the Anthropocene might bring to us, and our families may set in.

Individually, we can feel helpless in dealing with the climate crisis, and this can have an adverse effect on our mental health. However, by joining together with other like-minded people, we can send a strong message to other people and government and demand change to safeguard a liveable future.

Scientist Rebellion Australia is part of a world-wide movement of scientists, students, academics, and professors taking part in non-violent direct action. The urgency of the situation requires the equivalent of shouting out the message from the rooftops to prevent the worst climate scenarios from taking place. Things will get worse, but we must do what we can so they will not get as bad as they could if we did nothing. So come and join us – together we may change the world.

Poster Session 2

Poster Session 2, Poster 01

Marine heatwave prediction from weeks to months to seasons

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

Above average ocean temperatures leading to marine heatwaves have implications for many marine ecosystems and industries. The impacts felt include mass coral bleaching and mortality, altered aquaculture yields and changes in wild fish migration patterns. Impacts are related to marine heatwave severity, duration, and also onset and decline rates. Seasonal forecasts of marine heatwave risk covering timescales from weeks to seasons from dynamical ocean-atmosphere models can be very useful tools for marine managers, businesses and researchers. The Australian Bureau of Meteorology's seasonal forecast model ACCESS-S2 currently produces operational real-time forecasts of sea surface and subsurface temperatures. Experimental products based on marine heatwave metrics using subseasonal to seasonal forecasts and probabilities of exceeding the 90th percentile have been developed and assessed. These new products will complement existing operational accumulated thermal stress forecast products developed for coral bleaching to improve both the understanding and the management of these events.

Poster Session 2, Poster 02

An analysis of Marine Heatwaves and their associated sea level variations over the Australian region since 1981

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

Marine heatwaves (MHWs) have recently been recognized as extreme climate events considering their devastating impacts on marine ecosystems. Identifying and quantifying both common and distinctive characteristics of historical events may contribute to future studies and predictions of regional MHWs. We analyzed the main spatial and temporal features of MHW metrics on a pixel-wise (~5km) scale over the Australian region using the gap-free Climate Change Initiative and Copernicus Climate Change Service (C3S) Level 4 Sea Surface Temperature (SST) analyses from 1981 to 2020. Relatively short-term events (<10 days) account for over half of the identified MHWs over the domain, among which nearly 90% are classified as having moderate intensity. Natural variability of the local climate system possibly contributes to most of these short events rather than the remote modulation of climate modes and/or the ocean warming. Excluding these short events using the updated 10-day definition will highlight the impacts of ocean warming on longer and more intense events especially over the GBR region. Sea Level Anomaly (SLA) metrics are applied to analyze MHWs and explore the relationship between SST metrics over the northwest and southeast coast of Australian. We found that longer MHWs that are driven by a similar combination of forcing factors may exhibit similar SLA variation trend or pattern. Therefore, SLA over the 90th percentile, as a recommended SLA metric, has the potential to help classify MHWs or identify subsurface MHWs in regions free of strong eddy activities, which could help improve the understanding and predictability of MHWs.

Poster Session 2, Poster 03

Conducting a tailored and localised Marine Heat Wave risk assessment for Vanuatu fisheries

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

Increased frequency and severity of Marine heat wave (MHW) events, resultant of climate change, is concerning for vulnerable communities. In Vanuatu, communities are predicted to be at high risk to MHW impacts in the future. A critical sector at risk in Vanuatu is fisheries, which vitally supports food security and livelihoods. To sustain local communities, MHW risk to Vanuatu fisheries must be extensively explored. Tailored risk assessment is recognised as a key method for informing on MHW risk. In this study, three critical steps in a tailored MHW risk assessment methodology are addressed: indicator selection, indicator weighting, and risk calculation/mapping. A combined process, utilising both a literature review and participatory research survey, was implemented to select indicators appropriate for examining MHW risk to Vanuatu fisheries. A user-informed weighting scheme was developed based on survey results. Following this, an integrated Geographic Information System (GIS) method was employed to conduct a retrospective MHW risk assessment in Vanuatu. Sea Surface Temperature, Coral bleaching, and Chlorophyll-a concentration were selected as appropriate hazard indicators. Terrestrial-based food/income generation, fishing skills/technology, fishery diversity and production of commercial fisheries were selected for the vulnerability index. Seagrass population, crown of thorns prevalence, crab stock health and fish stock health were the selected exposure indicators. The risk assessment displayed MHW events throughout a period in 2015-2017 and again in 2020-2022. Such an assessment is likely critical for informing local decision-makers of future high-risk areas and can aid in increasing the resilience of the fisheries sector in Vanuatu.

Poster Session 2, Poster 04

Identification of persistent thermal refugia : how ocean circulation can mitigate warming and heat-driven bleaching

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Session

1. Beyond Temperature Extremes: Exploring the dynamics and impacts of marine heatwaves

Abstract

The Great Barrier Reef (GBR) is the largest living structure on Earth, providing critically important ecological, social, cultural and economic services. Over the last decade, coral cover has declined to an historic low, questioning the long-term resilience of the reef ecosystems. In recent years, the reef capacity to adapt has been overwhelmingly challenged by one particular stressor: severe heat-stress resulting in heat-driven mass bleaching events.

After four mass bleaching events in the last 8 years, all GBR regions have been threatened by large-scale marine heatwaves. Only local weather events and ocean processes may lead to sustained temperature reductions strong enough to locally counteract the effect of warming. The identification of the remaining thermal refugia is key for coral reef conservation.

Here, we use the 1km eReefs ocean model to track any remaining cold-water persistence that may protect reefs from extreme heat conditions, heat-stress and bleaching. We show that wind-induced upwelling and current-induced thermocline uplift have been consistently acting as a barrier to heat-stress during the past mass bleaching events in the Southern and far Northern GBR. The mapping of these persistent thermal refugia at the surface and at depth is critical to support and inform reef restoration and adaptation programs.

Poster Session 2, Poster 08

Development of a Stochastic Hailstorm Model for Australia

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Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Modelling hailstorm frequency and intensity require proper choice of predictors that explain the favourable environments leading to a hailstorm event. What are the best predictors that can explain the possible dependencies between the occurrences and their magnitudes, be able to derive hailstorm tracks or footprints, and ensure that the explained environments are closest to the actual occurrence of the events? The overall aim is to use this model to study the varying patterns of hailstorms in changing climate in Australia and their impacts by constructing hail footprints.

A stochastic hailstorm model has been developed for Australia using radar-based hail database and ERA5 datasets. Starting with a small region such as Adelaide in South Australia, Convective Available Potential Energy (CAPE) and bulk wind shear have been chosen as predictors to assign probabilities to each favourable environment using Generalized Linear Models. Further investigation has been performed to establish seasonal and spatial dependencies through additional predictors and hailstorm simulation criteria. Hailstorm tracks have thus been constructed, and each hailstorm event is associated with a hail size estimated using Generalized Pareto Distribution. Translational velocity and direction have been derived for each of these events. The preliminary model has then been extended to all regions in Australia covered by the radar network, and rather than using a single threshold for discriminating all environments, the model has been improved to reflect the region-specific influences and changes in the environments. Possible errors in explaining regional environments introduced by the chosen predictors and their combinations have been explored.

Poster Session 2, Poster 09

The effects of large-scale climate drivers on hail environments across Australia.

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[1]UNSW Climate Change Research Centre, Sydney, Australia. [2]ARC Centre of Excellence for Climate Extremes, Sydney, Australia

Session

6. Severe thunderstorms: processes, prediction, impacts, and changes

Abstract

Hailstorms are destructive phenomena that can cause large insured losses. Consequently, there is heightened motivation for better understanding hail occurrence and investigating hail trends, especially in regions with company assets and a significant population. With climate change, hailstorms are generally expected become less frequent and more severe, but high uncertainty remains.

Predicting extreme events is a challenging task. As climate modes of variability can influence temperature, precipitation, and humidity, they may offer predictive skills. The modes that largely govern Australia's climate are the El Niño Southern Oscillation (ENSO), Indian Ocean Dipole (IOD), and Southern Annular Mode (SAM).

Here, we examine relationships between these modes and days that are susceptible to hailstorms (hail-prone days) across Australia. These days have been identified using a hail proxy applied to reanalysis data between 1979-2022.

By correlating hail-prone day anomalies with the strength of each mode's index at each hail-susceptible grid point, we highlight significant hail-prone regions across Australia that were influenced by certain modes. Similar regions across all modes could be identified, with some regions affected more by certain modes. We investigated meteorological and confounding influences on the observed correlations and explained the driving factors behind some effects by examining the proxy "ingredient" variables & what is known about precipitation trends under different modes.

This work comprehensively examines links between hail-prone days and climate drivers across the whole Australian continent. Our work sheds light on connections that could aid with seasonal prediction and understanding inter-annual variability of this important extreme weather hazard.

Poster Session 2, Poster 12

Land Management for Carbon Neutrality in Australia's Grazing Lands

Abraham J Gibson, Terry J Rose

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Session

11. Realisation of Paris Agreement pledges

Abstract

Increasing soil organic carbon (SOC) in grazing soils is a key strategy for achieving carbon neutrality within the meat and livestock industry and fulfilling Australia's commitment to the Paris Agreement. To understand the distribution of SOC and relationships with soil fertility under grazing management regimes, 116 paddocks were sampled to 10 cm depth, across the Northern Rivers region of New South Wales. SOC stocks across the region ranged from 33.91 to 118.76 t.ha-1, with a mean of 55 t.ha-1. SOC stocks were highest (mean of 63.96 t.ha-1) where improved management had been implemented for more than fifteen years. Improved management encompassed rotational grazing, sown subtropical pastures with winter feed and soil amendment application. In contrast, mean SOC stocks across continuously grazed, naturalised or unimproved sites were 42.64 t.ha-1. Carbon to nitrogen ratios ranged from 11 to 22 (mean of 14) across the region, while boron ($r = 0.58$), zinc ($r = 0.50$) and copper ($r = 0.33$) were significantly correlated with SOC. These results indicate that grazing and soil management have the potential to increase SOC in this region. Increasing SOC from the lower end of this range to higher levels represents a significant opportunity to mitigate carbon emissions across the industry. Developing this information is pivotal to better informing land managers to sequester SOC in their soils to mitigate emissions and climate change.

Poster Session 2, Poster 13

Tracking the world's movement towards 1.5 °C

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Session

11. Realisation of Paris Agreement pledges

Abstract

A threshold of global mean temperatures 1.5 °C above the pre-industrial period is a key indicator in the Paris Agreement. While individual months above the 1.5 °C threshold have already occurred, during the peak of the 2015-16 El Niño, temperatures over a threshold in a single month or a single year do not indicate sustained crossing of the threshold. IPCC define the crossing time of a threshold as the midpoint of the first 20-year period whose mean exceeds that threshold.

Whether the IPCC definition has been met can only be definitively determined in retrospect. Global mean surface temperature for 2013-2022 was 1.15 °C above the 1850-1900 average (an instrumental-era approximation of the pre-industrial baseline); assessment of variability of observed historical data applied to this result implies a very likely range for 2013-2032 (and hence a current multi-year value centred on 2022-2023) of 1.20 to 1.25 °C. IPCC projects the most likely timing of crossing of the 1.5 °C threshold in the early 2030s under most emission scenarios.

Individual years above the 1.5 °C threshold will become increasingly possible as the multi-year value continues to warm. Reaching the 1.5 °C threshold in 2024 will require 2024 to be more than 0.2 °C above the estimated 2024-centred baseline, a difference between a year and the relevant current baseline greater than has been observed in any individual year in the last 100 years, and somewhat greater than the 0.16-0.17 °C differences observed during the strong 1997-98 and 2015-16 El Niño events.

Poster Session 2, Poster 14

Using palaeoclimate data to inform resource management - a case study from eastern Australia

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Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

Recent extreme flood and drought events across much of Australia have raised questions about their recurrence intervals. Because the Australian hydroclimate is highly variable, short instrumental records are inadequate for understanding the full magnitude and frequency of extreme events. Here, we investigate the 600-year spatial drought record for eastern Australia contained in the Australian and New Zealand Drought Atlas (ANZDA). We examine how extreme drought or wet recurrence events have changed over time for individual Natural Resource Management regions (NRMs). We then use the gridded drought record to identify neighbouring areas prone to extreme drought and, perhaps more importantly, other areas that appear to be less vulnerable – potential drought refugia. There has been a tendency towards wetter conditions and/or shorter recurrence intervals for wet conditions over the past ~50 years in northern Australia. In general, neither the severity nor duration of recent droughts have been particularly unusual in the 600-year context. However, the trend towards drier conditions in the Southern Slopes is notable. We find that relying only on short instrumental data for identifying refugia locations/regions is likely flawed because regions may have experienced frequent drought prior to a wetter instrumental period.

Poster Session 2, Poster 16

Unveiling Holocene Climate Dynamics in the South Pacific through Speleothem Stable Isotopes and Trace Elements – a review of available proxy data

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[1]University of Newcastle, Newcastle, Australia. [2]University of Quebec, Montreal, Canada

Session

14. The changing climate and the risk of extremes: from the Holocene to the Anthropocene

Abstract

During the Holocene epoch, spanning approximately the last 11,700 years, the South Pacific region has experienced diverse environmental changes. The climatic impacts of these changes can be studied using paleoclimate archives such as stalagmites and flowstones (speleothems) retrieved from caves cut in carbonate rocks. Oxygen and stable carbon isotope ratios incorporated into speleothem crystals are sensitive recorders (proxies) of temperature, rainfall, and vegetation dynamics. Trace elements series also record past climate, soil conditions, and other environmental conditions. Analysing the stable isotope ratios and trace elements preserved in speleothems enables a better understanding of the interplay between the South Pacific Convergence Zone (SPCZ), El Nino Southern Oscillation (ENSO), and Holocene climate dynamics in the region. Here we present a review of available stable isotope and selected trace element data (where Sr is a marker of dry periods and Y is a marker of wet periods) from the region spanning [40; -40] latitude and [116; -70] longitude with a focus on long (several hundred years), high resolution Holocene records. The purpose of this review is to develop a network of proxy data to test changes in the SPZC and ENSO as well as compare to Palaeoclimate GCM output. We also present some initial investigations into broadscale patterns preserved in the records associated with the SPCZ and ENSO. This multidisciplinary approach, which incorporates stable isotopes ratios and trace elements, enhances our comprehension of long-term climate variability and aids in predicting future climatic trends in the South Pacific and beyond.

Poster Session 2, Poster 18

Changing ENSO and impacts in a warming climate

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Under greenhouse warming, majority of latest climate models project a weakening in the Walker Circulation and an increase in sea surface temperature (SST) variability associated with extreme of El Niño-Southern Oscillation (ENSO), amid warming background SSTs. Model simulation of the 20th century suggests that ENSO has increased by greenhouse warming. The projected changes have important implications. In this presentation I will discuss the impacts on tropical-extratropical interactions, variability of tropical North Atlantic SST, extreme subtropical high events, and Southern Ocean warming, Antarctic ice shelf, and global economic growth.

Poster Session 2, Poster 19

The global sea level experiences a decline during La Niña years

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

The 2010-2011 La Niña event had a distinct impact on extreme precipitation in Australia and a sharp decline in global mean sea level. Our curiosity extends to whether analogous effects are observed in other La Niña occurrences regarding global mean sea level and terrestrial precipitation. Here we investigate four La Niña events spanning 2003 to 2022 (when sea level data is available) aiming to discern a possible recurring pattern of global sea level variations during La Niña years. Our findings reveal that declines in global mean sea level are consistently linked to a cooling of the sea surface temperatures in the Niño 3.4 region, a reliable indicator of La Niña events. Notably, three out of the four La Niña events display similar trends encompassing increased terrestrial precipitation, expanded global land mass, and decreased global sea level. Intriguingly, our analysis reveals a robust negative correlation coefficient of up to -0.77 between terrestrial precipitation and global sea level fluctuations, suggesting that increased land precipitation during the early stages of a La Niña events leads to declines in global mean sea level.

Poster Session 2, Poster 20

Tropical Pacific Trends: Does it matter how warm it is or how much is warm?

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Warming trends in the tropical Pacific are often obfuscated by internal variability, in large part due to El Nino- Southern Oscillation (ENSO): during ENSO's El Nino phase, warm waters are spread over a larger fraction of the Pacific and during its La Nina phase, cooler waters are exposed at the surface and the area of warm water temperatures is diminished. Understanding how ENSO and other modes of variability influence seasonal and long-term trends are of particular importance in the tropics as this region drives large-scale atmospheric and oceanic processes.

Modern climate models do not robustly capture recent observed warming trends, casting doubt on their ability to predict future changes. Past literature has often quantified these trends by comparing SSTs in eastern and western regions using fixed geographical boxes. We present an alternative perspective, which considers the temperature of warmest patches of the Pacific versus the coldest patches, even as those patches are rearranged by ocean dynamics.

To do so we consider probability density functions of tropical Pacific SST data, from which we partition the surface area into percentiles—organised from the warmest 1% to the coldest 1%—thereby constructing quasi-Lagrangian coordinates. Using these new area percentile coordinates, we investigate SST trends of both observational (NOAA) and CMIP6 tropical Pacific data. We examine quasi-Lagrangian analogs of other known metrics such as east-west SST gradients and warm-pool expansion. We've found that by averaging over the tropical Pacific, the area-percentile metrics show reduced variability compared to a Eulerian, longitude-averaged counterpart.

Poster Session 2, Poster 21

Pathways of ENSO-MJO teleconnections and their seasonality in the SH

Raina Roy[1,2], Julie M Arblaster[1,2,3], Matthew C Wheeler[4,5], Eun-Pa Lim[4,5]

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Madden Julian Oscillation (MJO) and the El Niño Southern Oscillation (ENSO) are two of the major contributors to the intraseasonal and interannual variability in the tropics and extratropics. Previously, there have been studies that have tried to understand the role played individually by these processes in developing different weather patterns in the extratropics; however, not many studies have analysed their combined effect and the possible pathways that drive them. In addition to this, most of this understanding remains confined to the Northern Hemisphere (NH). In our study, we investigate the pathways of ENSO-modulated MJO teleconnections in the Southern Hemisphere (SH) and their seasonality. There is a clear asymmetry in the interactions of ENSO and MJO and their impacts on the extratropics for different MJO phases. We observed that during the austral summer, El Niño-MJO impacts are mostly through tropospheric pathways (Rossby Wave-like); however, La Niña-MJO interactions are more through stratospheric pathways. Certain phases of MJO during the La Niña background state show a more positive SAM-like pattern. This SAM-like pattern can have an impact on the extratropical weather directly or indirectly by making the extratropics more conducive to the impact of the MJO teleconnections. During the austral spring and winter periods, this dynamic changes, and both El Niño-MJO and La Niña-MJO adapt the tropospheric pathway. An understanding of these pathways is important for improving extratropical weather predictability.

Poster Session 2, Poster 22

Future changes of iron supply to the Equatorial Undercurrent

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Session

16. Tropical climate variability: dynamics, teleconnections, and change

Abstract

Tropical Pacific circulation plays a pivotal role in delivering essential nutrients to the eastern equatorial Pacific, underpinning its high primary productivity. This study explores the impacts of future tropical Pacific biogeochemistry, circulation, and temperature changes on the transport of dissolved iron to the Equatorial Undercurrent (EUC). Using a Lagrangian iron model combined with an eddy-permitting ocean biogeochemistry model, we find a projected strengthening of EUC iron flux in the western Pacific as a result of increased iron-rich waters from the New Ireland Coastal Undercurrent (NICU) and New Guinea Coastal Undercurrent (NGCU). However, the iron boost is progressively diluted as the EUC flows eastward and the overall iron flux of the EUC ultimately weakens in the eastern Pacific. We find that the dFe concentration in the EUC is typically more sensitive to changes in transport contribution than changes in the initial iron concentration of sources, phytoplankton uptake, remineralisation and scavenging. The increase in iron-rich NICU and NGCU water in the EUC may not necessarily drive an increased iron supply available for primary producers in the euphotic zone of the eastern equatorial Pacific, especially considering the projected decrease of equatorial upwelling.

Poster Session 2, Poster 23

An attribution atlas for Aotearoa New Zealand

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

We present a product that summarises the current understanding of the human role in recent extreme weather over New Zealand. The basic format is of national maps, with various layers running from very basic regional summaries, to more detailed descriptions, to full lists of evidence, to relevant maps of vulnerability. We describe how this product has been developed, how it is intended to be used, and experience in using it as a communication tool.

Poster Session 2, Poster 24

ACCESS-MICAS: a forecast-based tool for event attribution

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

The Australian Community Climate and Earth-System Simulator – Modified Initial Condition Attribution System, ACCESS-MICAS, is a forecast-based tool for event attribution. Using the operational global coupled sub-seasonal to seasonal forecast version of ACCESS, ACCESS-S2 with modified initial conditions, we can re-forecast an event with counterfactual conditions and assess various contributors to the extremity of the event. The choice of modification at initialisation depends on the research question. For example, to assess the effect of climate change, we reduce the greenhouse gas concentrations and remove the associated mean state changes in the atmosphere, ocean and land. In this way, we alter the background thermal state but retain the dynamics information, so the event can be well-represented in the past climate after a short spin-up. By comparing what the event was (factual forecast) to what it might have been in the past climate (counterfactual forecast), we can make attribution statements on the magnitude, spatial extent and dynamic changes, which provides dynamically consistent perspectives beyond what existing statistical methods can offer. In this study we demonstrate 1) the methodology of forecast-based event attribution, 2) a case study of the Black Summer heatwave event, 3) examples of attribution statements based on the experiment results.

Poster Session 2, Poster 25

Toward a simple temperature attribution service

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

Heat and cold temperature extremes on month to seasonal time-scales have major economic and societal impacts, leading to a need to understand what drives them. However, temperature events can be driven by many factors (including large-scale drivers, climate change) making it difficult to understand and communicate which of those factors contributed. Multi-linear regression (MLR) is a simple but powerful tool for estimating the factors behind temperature events. As regression coefficients are calculated in advance, MLR allows for rapid attribution both leading into events, with the ACCESS-S2 seasonal forecasts, and for post event analysis from observations. As such, with careful selection of the factors going into MLR (appropriate climate modes of variability, impact of climate change), MLR forms the base of a simple attribution and communication tool. The effectiveness of this tool is demonstrated with case studies from most recent conditions, such as the anomalous high temperatures observed in Tasmania during July 2023. While MLR has several caveats, its simplicity makes it ideal for rapid temperature attribution and communication.

Poster Session 2, Poster 26

Attribution of an extreme heat event in northern Australia

Pandora Hope[1], Francine Machin[2], Hanna Heidemann[3], Eric Lede[1], Kate Saunders[2], Linjing Zhou[1], Roseanna McKay[1], Surendra Rauniyar[1], Andrew King[4], Tim Cowan[1]

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Session

19. Extreme weather and climate events: contextualisation and attribution

Abstract

No studies have ever attributed the influence of climate change on extreme events in northern Australia, and data availability is generally poor. The background climate is hot, and people are already impacted by the heat, particularly in the build-up before the onset of the monsoon season. In this period, heat impacts quickly amplify when events are hotter than normal. For central northern parts of the region, there is a cooling trend in mean temperature, hence a simplistic approach of examining a shift in the observed temperature distribution will give results at odds with many other event attribution studies. Other factors also need to be considered, for example: anthropogenic aerosols, the role of seasonal timing, and the role of rainfall trends in influencing temperature trends. This presentation will describe a recent extreme heat event in northern tropical Australia, the underlying trends and how different attribution approaches can be used to assess the attributable anthropogenic influence.

Poster Session 2, Poster 27

Translating climate science into climate risk for the public sector

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Let there be no allusions that major impacts associated with the rapidly changing climate are here now. The situation varies across the world but in Australia the last five years have been a succession of climate-related disasters hurting communities and the environment with costs to the economy emerging. But what does it mean when it gets hotter or when the rain won't stop? Climate risk includes both physical hazards and transition drivers and how they intersect with exposures and vulnerabilities. How we proactively manage, or reactively respond, when risks eventuate is also an important determinant of climate risk. Climate risk is often split between the physical climate changes while transition risks are associated with multiple socioeconomic changes required to limit further warming. Climate change may also unlock opportunities, particularly through initiatives that will support the transition.

Climate risk management is not just required of big business, governments are critical for reducing barriers to change through appropriate policies aimed at shifting incentives away from emissions intensive activities. Our team at Deloitte has conducted dozens of climate risk and opportunity assessments for multiple public sector organisations, ASX10 and Fortune 500 companies across all continents and sectors. We will present Deloitte's approach to all aspects of climate risk management, from identification through to public disclosure. We will highlight some of the critical nuances between different sectors and the importance of translating climate science into decision-ready insights to advise governments and businesses on the necessary steps to respond to the challenges of climate change.

Poster Session 2, Poster 28

Gallagher Re detailed climate risk assessment tool

Valentina Koschatzky, Krystelle Ho, Esther David

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Session

21. Assessing Australia's Climate Risk – from climate change, to impacts, to adaptation.

Abstract

Gallagher Re Australia has decades-long experience in natural hazards. Our models are highly regarded and widely used by the insurance industry. We believe that our high-resolution models, enhanced to reflect a range of climate change scenarios can play an important role in identifying regions at risk and inform adaptation and mitigation measures.

We combine our hazard models with several climate change scenarios to create climate change conditioned views of natural peril risk in Australia. This type of modelling, albeit uncertain, is immensely powerful for considering what potential changes we may have to contemplate and adapt to. By using the high-quality baseline of our proprietary hazard models, we can draw meaningful and decision-useful conclusions.

We pair our modelling with data on income, community resilience and the local industry to consider the impacts of climate change on insurance affordability at a granular level. We also consider the expected population growth and the associated need for new homes. We have an opportunity to build them in a smarter way, in better locations and with better design.

The challenges posed by the changing climate must be tackled by collaborating across different sectors and the wider community. The insurance industry already plays a pivotal role in protecting our communities by encouraging mitigation behaviour, through education and financial incentives, and by continuously investing in modelling capabilities and enhanced data collection to improve our understanding of natural peril risk. We show here how our framework and data can directly contribute to the assessment of climate change risk.

Poster Session 2, Poster 31

Vegetation Drought Prediction Tool for Sustainable Cattle Farming in New Caledonia

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Session

22. Understanding drought processes and impacts

Abstract

In New Caledonia, cattle farming plays a key role in the rural economy. Between 1990 and 2010, the cattle herd has shrunk by 30% which led authorities to set up incentive programs. The rainfall deficits recorded in 2014, 2015, 2017 and 2019 have put the brakes on recovery. To reduce the sector's vulnerability to drought, Météo France and INSIGHT have developed a tool for monitoring and predicting vegetation drought using satellite images, meteorological data and tailored seasonal climate forecasts. Measurements from various satellite sensors are combined to estimate the health of vegetation cover on surfaces likely to be used by livestock., across the entire territory and at different decision-making scales (plots, municipality, etc.). Statistical analysis of the vegetation drought index highlights the spatial and temporal variability of drought episodes since 2000, as well as the recurrence of key events. Given the strong correlation with cumulative rainfall over 3 months and the predictability of this parameter at monthly to seasonal time-scales, we develop a tool for categorial vegetation drought prediction at municipality scale. It uses ordinal logistic regression (OLR) and the extreme forecast index provided by Global Drought Observatory (GDO) as one predictor. Cross-validation is implemented using stratified sampling to ensure no drought category is mis-represented in the training and test sets, which gives a more accurate estimate of OLR performance. Scores show that vegetation drought predictions are reliable and well-calibrated for most communes with high agricultural stakes.

Poster Session 2, Poster 34

Using ACCESS-S calibrated rainfall forecasts and observed rainfall deficiencies to produce a probabilistic rainfall deficiency forecast

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Session

22. Understanding drought processes and impacts

Abstract

The current drought monitoring product at the Bureau of Meteorology (BOM) evaluates changes in meteorological drought based on tracking serious rainfall deficiencies (defined as rainfall in the bottom 10% of the historical record) over a period. There is useful context to be gained from including forecast information, but most existing systems rely on combining observed and forecast rainfall subjectively and indirectly.

The product developed in this study uses calibrated ensemble forecasts of rainfall totals from the ACCESS-S climate model and observed rainfall deficiencies from the Australian Gridded Climate Dataset (AGCD) rainfall analysis (AGCD) to generate probabilistic rainfall deficiency forecast products with lead times of a month (monthly forecast) and three months (seasonal forecast). Existing deficiency areas are included to facilitate analysis of how these areas are forecast to change.

The product was verified from June 2022 to May 2023, using Percent Correct (PC), Brier Score (BS) and Relative Operating Characteristic (ROC) statistics. Analysis of the forecast plots visually was also completed. Forecast performance for areas with existing deficiencies as well as for non-deficiency areas was good. Although PC rates for observed deficiencies were low across most months, the mean forecast probability for these areas was 36%, indicating the system still had value and outperformed climatology.

Overall, the product demonstrated value but the short study period limited the generality of the results, especially since most of the study period only contained a small proportion of deficiency areas.

Poster Session 2, Poster 37

Applying the FAIR principles to the Drought Monitor to improve accessibility of data

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Session

22. Understanding drought processes and impacts

Abstract

Despite the growing requirements to make research datasets Findable, Accessible, Interoperable and Reusable (FAIR) there is scarcity in the literature describing how this can be achieved in the climate sciences. The benefits of making research datasets FAIR are well documented and commitment to FAIR principles by funding agencies and research institutions is increasing. In this paper we describe the process of retrospectively making a drought monitor dataset FAIR. We highlight the challenges faced and the approach undertaken to make the dataset FAIR. The Australian Drought Monitor (ADM) dataset was developed as part of the Northern Australia Climate Program (NACP), a joint project funded by Meat and Livestock Australia, the Queensland Drought and Climate Adaptation Program and the University of Southern Queensland (UniSQ). The aim of the NACP drought monitor dataset was to primarily generate maps to assist in decision making by farmers, policy makers and other stakeholders. Making the ADM dataset FAIR involved information management aspects in the creation of accompanying metadata, assignment of persistent identifiers and standardisation of vocabulary to improve findability, accessibility and interoperability. Contractual, legal and social aspects were necessary for securing ownership rights, attribution and licencing to enable reusability. We describe how we made the drought monitor dataset FAIR to agricultural researchers, policy makers and farm managers. These users now have better drought status information for decision making. In this paper we focus on the scientific, organisational and social processes undertaken to make a dataset reusable and subsequently increase its' utility, citation footprint and impact.

Poster Session 2, Poster 38

Anthropogenic aerosols offsetting ocean warming less efficiently since the 1980s

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Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

The composition of the atmosphere has a major impact on our climate. Greenhouse gases warm the planet, while aerosols (i.e., suspensions of particles in the atmosphere) cool the planet, and most of this change is absorbed by the oceans. Since 1980, the rate of cooling of the planet due to aerosols has plateaued. In the past few decades, the ocean has begun to equilibrate to this change, and this work explores where and when this equilibration has occurred in the ocean based on global climate models.

To understand this change, we use novel percentile-based methods to calculate a layer-wise 'ocean heat uptake efficiency' metric which describes how much additional heat builds up in the ocean for a given degree of surface temperature gain (or loss). We find that the ocean is cooling more slowly given a degree of surface cooling due to aerosols compared to the pre-1980s. This change is largely occurring in percentile layers corresponding to the tropics and sub-tropics, where the ocean has stopped cooling in response to aerosol-driven negative surface temperatures. Polar and sub-polar regions, however, continue to cool due to aerosols. These changes are occurring alongside accelerating greenhouse gas-driven warming, suggesting that the relative role of aerosols in cooling our climate is weakening.

Poster Session 2, Poster 39

Using a Gaussian Mixture Model to Map Sparse Ocean Observations.

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Session

25. Advancing understanding of the atmosphere and ocean through data science

Abstract

Ocean data is, on the one hand, heterogeneous and complex geographically, and on the other hand, simple thermodynamically. Specifically, when data from the world ocean is projected onto a temperature-salinity-pressure (T-S-p) diagram, it forms a 'thin' structure filling a remarkably small fraction of that space. Locally, there is a tight relationship between the three variables, suggesting that knowledge of two variables (e.g. temperature and pressure) could be used to predict the third (e.g. salinity). However, a global one-to-one mapping does not exist, and non-parametric methods are needed to describe the T-S-p relationship. We use Gaussian Mixture Modelling (GMM), a form of unsupervised machine learning, to piece together the T-S-p structure. The emergent mixtures map into connected geographical regions and describe oceanographic features such as gyres and fronts. We propose a method to infill sparse salinity observations based on knowledge of the geographical distribution of the Gaussian mixtures and knowledge of ocean temperature and pressure. Using synthetic data from a numerical climate model of the South Atlantic, we find that the sparse ship-based observations, combined with our GMM-based method, are sufficient to map salinity observations in 3D. At a depth of 500m, the root mean square error (RMSE) in the mapped salinity is less than 0.05g/kg while the RMSE of the linear trend is less than 0.002g/kg/yr. The method is extendable to other tracers, especially those for which only ship-based measurements exist. The nature of the Gaussian mixtures likely holds clues to the underlying physics of the ocean.

Poster Session 2, Poster 41

Seamless Day 1 to Multiweek Precipitation and Temperature Forecasts

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

The Bureau of Meteorology's Day 1 to 7 forecasts are published to the Australian Digital Forecast Database (ADFD) and are based on a statistically post-processed blend of numerical weather prediction model forecasts curated by operational meteorologists. On the other hand, the Bureau's multiweek to seasonal forecasts are produced by an ensemble from a coupled ocean atmosphere model known as ACCESS-S. ADFD and ACCESS-S forecasts are independent of each other and often produce inconsistent forecasts for overlapping lead times.

This talk will discuss statistical techniques developed to alter the values of ACCESS-S ensemble members so that ACCESS-S is consistent with ADFD forecasts. For precipitation forecasts, this involves fitting the ADFD and ACCESS-S forecasts to gamma distributions. Quantile-quantile matching is then used to remap ACCESS-S values so that they are a plausible sample from the ADFD distribution. For daily temperature forecasts, ACCESS-S ensemble values are remapped using linear transformations so that the ensemble mean matches the single-valued ADFD forecast whilst avoiding unrealistic extremes.

Verification shows that these methods increase the predictive skill and reliability of ACCESS-S Week 1 forecasts. Moreover, for daily temperature forecasts, the blending of the single-valued ADFD forecast with the ACCESS-S ensemble results in greater predictive skill than either forecast alone. The techniques are also selected to be computationally efficient so that they can be implemented on operational systems.

Poster Session 2, Poster 43

WRF simulation of winter orographic clouds and precipitation in Snowy Mountain of Australia: Using BARRA reanalysis as the driving dataset

Sisi Chen[1], Lulin Xue[1], Sarah Tessendorf[1], Thomas Chubb[2], Andrew Peace[2], Suzanne Kenyon[2], Johanna Speirs[2], Jamie Wolff[1]

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

Bureau's Atmospheric high-resolution Regional Reanalysis for Australia (BARRA) offers a comprehensive suite of gridded meteorological datasets covering Australia, New Zealand, and a significant expanse of SE Asian countries. The BARRA version 1 reanalysis dataset is publicly available and boasts a higher spatial resolution (12 km) over the area compared to the commonly used global reanalysis dataset such as ERA-5 (~31 km) and CFSv2 (~38 km). Such enhanced spatial resolution allows BARRA to provide more detailed initial and boundary conditions for numerical simulation.

In this study, we employ the 6-hourly BARRA version 1 reanalysis as the initialization dataset to drive WRF simulations. Our primary objective is to demonstrate whether BARRA can serve as a reliable initialization dataset for simulating the winter orographic clouds and precipitation over the Snowy Mountains of Australia. Comparisons between simulations driven by ERA-5, CFSv2, and BARRA-R will be conducted to evaluate the performance of each dataset. This first attempt to initialize WRF with BARRA will aid future opportunities for retrospective numerical simulations over Australia and New Zealand driven by a higher-resolution dataset.

Poster Session 2, Poster 45

Simulating atmospheric composition in ACCESS

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Session

26. Atmospheric Modelling in Weather and Climate Science

Abstract

The Australian Community Climate Earth System Simulator (ACCESS) can simulate various aspects of the chemical state of the atmosphere. Specifically, ACCESS can simulate gas-phase climate chemistry (e.g. tropospheric and stratospheric ozone, methane), and aerosol number, size and composition (plus interactions with cloud, precipitation, and radiation).

The framework in which atmospheric composition is handled is known as UKCA (United Kingdom Chemistry and Aerosol). UKCA currently handles emission, advection, processing, and removal of atmospheric constituents. UKCA includes both tropospheric and stratospheric chemistry (Archibald et al., 2020). Aerosol microphysics is handled by GLOMAP-mode (Mann et al., 2010, 2012).

A full global configuration (ACCESS-CM2-Chem, Dennison & Woodhouse, 2023), with optional coupled ocean, is now available and mature. Regional configurations (enabling higher resolution studies) are also now available.

This submission serves as an overview and guide to the various configurations, what they can do, and the scientific questions that can be addressed.

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Poster Session 2, Poster 47

Atmospheric Water Vapour Transport in ACCESS-S2 and the Potential for Enhancing Skill of Subseasonal Forecasting of Precipitation

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Session

30. Advances in verification methods, tools and technology

Abstract

Extended warning of above average and extreme precipitation is valuable to a wide range of stakeholders. However, the sporadic nature of precipitation makes it difficult to forecast skilfully beyond one week. Subseasonal forecasting is a growing area of science that aims to predict average weather conditions multiple weeks in advance using dynamical models. Building on recent work in this area, we test the hypothesis that using large-scale horizontal moisture transport as a predictor for precipitation may increase the forecast skill of above median and high precipitation weeks on subseasonal timescales. We analysed retrospective forecast (hindcast) sets from the Australian Bureau of Meteorology's latest operational subseasonal-to-seasonal forecasting model, ACCESS-S2, to compare the forecast skill of precipitation using integrated water vapour transport (IVT) as a proxy, compared to using precipitation forecasts directly. We show that ACCESS-S2 precipitation generally produces more skilful forecasts, except over some regions where IVT could be a useful additional diagnostic for warning of heavy precipitation events.

Poster Session 2, Poster 48

Comparative Analysis of Rainfall Sources forVerifying NWP Forecasts

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Session

30. Advances in verification methods, tools and technology

Abstract

Accurate rainfall data is essential for evaluating Numerical Weather Prediction Quantitative Precipitation Forecasts (NWP QPFs). While conventional gauge observations serve as a reference, the analysis of gridded data demands an optimal approximation of reality to ensure robust forecast verification using tools like METplus.

This study meticulously assesses daily rainfall data quality from diverse sources, revealing their merits and limitations, with a focus on identifying the most reliable data source for forecast verification. It critically analyses disparities in measurements from traditional gauges, gridded daily rainfall data (e.g., Australian Water Availability Project - AWAP and Australian Gridded Climate Data - AGCD), and satellite-based data GPM-IMERG.

The investigation delves into the spatiotemporal variations of rainfall patterns across the above datasets. It conducts comprehensive categorical analyses, considering diverse thresholds and evaluating the performance of each source across temporal aggregations (weekly, monthly, seasonal and annual). Additionally, the study assesses the capability of each source to capture extreme events' intensity, frequency, wet/dry day distribution, spatial distribution, and the average intensity of precipitation on days critical for potential impacts on flooding, soil saturation and water availability.

This comprehensive study explores the efficacy of data sources in detecting and estimating rainfall events of varying intensities, providing a deeper understanding of their practical utility. By advancing our comprehension of rainfall data sources and their pivotal role in NWP QPF forecast verification, this investigation equips meteorologists and researchers with the ability to discern and select better quality rainfall data, ensuring accurate forecast evaluations.

Poster Session 2, Poster 49

Added value and the verification of trends in RCM simulations

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Session

30. Advances in verification methods, tools and technology

Abstract

Added value and the verification of trends in RCM simulations

The question of whether fine scale Regional Climate Model (RCM) simulations add valued to coarser scale Global Climate Model (GCM) simulations is often answered by evaluating spatial characteristics of mean variables. This is generally performed using RCM models forced by GCMs, as this configuration is used to generate long range projections, which is the main application of RCMs. However, this approach often simply reinforces the circular reasoning that higher resolution models are capable of producing outputs at finer spatial scales. In this study, we apply an approach closer to forecast verification to assess the added value of RCMs. We assess RCMs forced by coarse-scale reanalysis, enabling us to verify any improvements in the representation of historical trends. As the projection of trends if often the fundamental application of RCMs, this verifies this key output directly. We use the well-known Theil-Sen estimator of slope to assess if RCMs add value to coarse reanalysis. We find that RCMs can add value in the representation of trends, even when improvements due to increased resolution are ignored. We discuss further prospects for the use of forecast-type verification for climate modelling.

Poster Session 2, Poster 50

Climate change projections: can a machine learning technique cut the mustard?

Roger W Bodman, Marcus Thatcher

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Session

32. Machine Learning for Earth System Sciences

Abstract

The dominant forcing of the observed increase in global average temperatures over the last hundred years has been the increase in greenhouse gases (GHG) due to human activity. Here, we test the application of a machine learning (ML) algorithm to projecting a local temperature change based on observed and projected changes in greenhouse gas concentrations and atmospheric aerosols. We tested the ML model by fitting it to Victoria (Australia) daily climate data for the period 1910 to 2012 as the training period and then predicted temperatures for 2013 to 2022, comparing the results to observations. Additional projections were then performed to extend the model out to 2050. These results were then compared to results from other climate models, including a CMIP6 general circulation model and a downscaled regional climate model. An evaluation of the ML model was then conducted. We reflect on the limitations and validity of the methodology.

Poster Session 2, Poster 51

Deep learning for detecting anthropogenic fingerprints in daily land surface temperature

Hyun-Jeong Lee, Yoo-Geun Ham, Jeong-Hwan Kim

chonnam national university, gwangju, Korea, Republic of

Session

32. Machine Learning for Earth System Sciences

Abstract

Climate change has many effects on human society and ecosystems. Detecting climate change signals is important for predicting future climate change effects and developing policies. However, detecting climate change is a challenging task due to various reasons, including natural variability, limited data, and the complexity arising from interactions among climate variables.

This study attempted to overcome limitations by using a deep learning (DL) model. The conventional analysis of climate change detection often assumes linear shifts in the environment, but DL models have the potential to solve existing challenges by being able to handle nonlinear phenomena.

In this study, to leverage/to apply the advantages of DL to climate change detection, a CNN (Convolutional Neural Network) model is being trained using global temperature data from the CESM2 (Community Earth System Model 2) Le (Large Ensemble) dataset. As a result of CNN, the global annual mean temperature shows a climate change detection ability that is approximately 11.14 times better than the existing linear model. Through sensitivity analysis, the temperature amplitude and patterns in Southeast Asia were identified as key factors in these CNN results. We confirm that as the intensity of temperature in Southeast Asia increases, the ability to detect climate change improves when the pattern of temperature is consistently maintained for more than five days.

Hence, this study shows the high potential of the CNN model in detecting climate change.

Poster Session 2, Poster 52

Global ocean pCO2 estimation using deep learning

Kang-Min Kim, Yoo-Geun Ham, Jeong-Hwan Kim

CHONNAM NATIONAL UNIVERSITY, Gwangju, Korea, Republic of

Session

32. Machine Learning for Earth System Sciences

Abstract

In the Earth system, the exchange of carbon dioxide (CO2) between the ocean and the atmosphere plays a vital role in regulating atmospheric CO2 levels. This exchange arises from fluctuations in the partial pressure of CO2 at the ocean-atmosphere boundary. Precise estimation of this partial pressure is essential for advancing our insight into forthcoming climate forecasts. However, the paucity of direct measurements concerning carbon dioxide's partial pressure presents a significant hurdle in precisely gauging the global air-sea CO2 flux.

In this study, we estimate global ocean pCO2 reanalysis data using deep learning model. Specifically, we deploy the convolution-based U-Net architecture, well-established in image analysis. The U-Net model methodically extracts pivotal features from input data during encoding, subsequently utilizing decoding to upscale these features to match the original input dimensions. Throughout this progression, skip-connections are employed to prevent potential information loss.

To validate the effectiveness of our methodology, we perform a comprehensive comparative analysis employing data from the extensively employed SOM-FFN pCO2 reanalysis dataset. This analysis serves to assess the alignment of results and to demonstrate our methodology's proficiency in addressing the limitations of the SOM-FFN approach. Moreover, to confirm inter-annual variability, we leverage ENSO and PDO composites, showcasing our model's comparable performance against alternative reanalysis sites. This provides substantial evidence for the authenticity and reliability of our simulation outcomes.

Collectively, our research enhances our understanding of the complex dynamics regulating carbon dioxide exchange at the ocean-atmosphere interface.

Poster Session 2, Poster 53

Net primary productivity forecasting system using deep learning method.

Yong-sik JOo

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Session

32. Machine Learning for Earth System Sciences

Abstract

Net primary productivity (NPP) is important factor in global carbon cycling, but it becomes more uncertain the further into the future. We study to forecast the NPP using deep learning method. We used CESM2 LE dataset to train the deep learning model. In perfect model framework, we validated the forecasted NPP by the deep learning model. The foresting skill is defined by correlation and mean square skill score (MSSS). The persistence forecasting was used to compare the forecasting by deep learning. The correlation skill in forecasting by the deep learning model is upper than 0.6 in most regions. The MSSS is upper than 0.6. Therefore, the deep learning model successfully predicted. We compared the time series in eastern europe, western Indonesia and northeastern USA, and we accidentally fined the NPP long periodicity. The deep learning model captured the NPP long periodicity, so the deep learning model successfully predicted. In sequence, we validated the performance of the deep learning model using reanalysis data and remote sensing data. The partial correlation value is upper than 0.68.

Poster Session 2, Poster 54

A random-forest approach to discriminating hail-prone atmospheric environments

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Session

32. Machine Learning for Earth System Sciences

Abstract

Hailstorms cause extensive damage to the built environment and crops, and are a driving factor in insured losses. However, hailstorms are difficult to measure and model owing to their small spatial footprint and relative rarity. A common approach to estimate the likelihood of hail is to use a "hail proxy", that takes information on the broad atmospheric environment and relates it statistically to hail probability. Hail proxies usually use derived atmospheric variables that describe the "ingredients" required for a hailstorm in broad terms. Such ingredients often include a measure of atmospheric instability and a measure of wind shear, amongst other possible variables. Here, we use a different approach in which a random forest classifier is trained using entire vertical columns of atmospheric information on humidity, temperature and wind. These columns are the input data for all hail-relevant atmospheric variables, so comprise a complete set of information which can be leveraged for prediction of hail-prone environments. We trained the random forest approach using columns from reanalysis data over Australia over the past four decades, and use observed storm reports as labelling data. The results show improved performance over existing techniques, including over a state-of-the-art proxy developed for use in Australia. In addition the random forest technique allows for detailed analysis of which variables on which parts of the vertical column were the most important for environmental discrimination, allowing for greater physical understanding of the atmospheric conditions that are most likely to lead to surface hail occurrence.

Poster Session 2, Poster 55

Deep learning for nowcasting and heavy precipitation

Kirien Whan

Session

32. Machine Learning for Earth System Sciences

Abstract

Precipitation nowcasting is essential for weather-dependent decision-making. The combination of radar data and deep learning methods has opened new avenues for research. Deep learning approaches have demonstrated equal or better performance than optical flow methods for low-intensity precipitation, but nowcasting high-intensity events remains a challenge. We use radar data from the Royal Netherlands Meteorological Institute (KNMI) and explore various extensions of deep learning architectures (i.e. loss function, additional inputs) to improve nowcasting of heavy precipitation intensities. Our model outperforms other state-of-the-art models and benchmarks and is skilful at nowcasting precipitation for high rainfall intensities, up to 60-min lead time.

Transferring research to operations is difficult for many meteorological institutes, particularly for new applications that use AI/ML methods. We discuss some of these challenges that KNMI is facing in this domain.

Poster Session 2, Poster 56

Multi-decadal changes in water mass properties of the South Indian Ocean along 110°E

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Session

39. General oceans

Abstract

Two hydrographic voyages separated by 56 years reveal significant changes in the watermass properties in the southeast Indian Ocean along 110°E. The observations from the International Indian Ocean Expedition in 1963 and the reoccupation of the line in 2019 covered the full ocean depth from 40°S to 11°S, measuring physical, chemical, and biological properties. We focus on the physical and biogeochemical properties in watermass layers of the global meridional overturning circulation and the Indian Ocean's shallow overturning cells. The subtropical high salinity water (STHW), which forms the lower branch of the shallow overturning cells, has warmer and increased salinity. Subantarctic Mode Water has cooled and freshened on density levels and Antarctic Intermediate Water (AAIW) has warmed and increased in salinity. Both the SAMW and AAIW watermasses have decreased dissolved oxygen content but increased concentrations of nitrate and phosphate. The results show that changes within watermasses follow their northward pathways, suggesting influences from their formation regions, modified by interior mixing along the overturning pathways.

Poster Session 2, Poster 57

Boundary currents, fronts and eddies : barrier or conveyors of transport ?

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Session

39. General oceans

Abstract

Boundary currents, characterized by strong velocities and dynamic interactions with continental margins, play a pivotal role in shaping global oceanic circulation patterns. This study investigates the dynamics of two different boundary current systems — the East Australian Current in the South Pacific Ocean and the Northern Current in the North Western Mediterranean Sea. We combine high-frequency radars, moorings and gliders data with 3D numerical models to analyze the dynamic of the boundary currents. Lagrangian methodologies based on forward and backward particle tracking and finite size Lyapunov exponents (FSLE) will be applied to identify the dynamical barriers and to understand the influence of boundary currents, fronts, and eddies on vertical and horizontal transport.

Our study focuses on the dual nature of these oceanic features—acting as both barriers and conveyors of transport. Comparing the East Australian Current and the Northern Current, we identify disparities and similarities in their dynamical characteristics to understand the physical processes driving such distinctions, at their temporal and spatial scales.

One crucial aspect of our study is the understanding of vertical transport associated with boundary currents and coherent structures. We investigate how these features contribute to vertical mixing, which can impact biological productivity. Furthermore, the insights gained from this research can be extrapolated to better understand the movement of passive matter like jellyfish and plastic, with implications for environmental conservation and pollution management.

Poster Session 2, Poster 58

Ocean gliders reveal impacts of Atmospheric, Terrestrial and Underwater rivers on Australian continental shelf waters

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Session

39. General oceans

Abstract

Oceanographic observations has been traditionally undertaken using ships but the emergence of autonomous ocean gliders have provided an alternative measurement platform to acquire high spatial and temporal resolution data even during periods of extreme weather conditions. These data sets enable researchers to discover physical processes as well as document the natural variability of the ocean and coastal ecosystems. The Australian Integrated Marine Observation System (IMOS) ocean glider facility has been in operation since 2017 and have completed more than 370 glider missions around Australia. The recent extended La Niña events resulted in major rainfall events, some generated through atmospheric rivers (north-west cloud bands). These rainfall events resulted in major river plumes through terrestrial rivers that were sampled using ocean gliders in Western Australia (Swan River), South Australia (Murray River) and New South Wales (Hawkesbury River). River plumes were not sampled prior to these events using ocean gliders. Each of the river plumes exhibited contrasting dynamics with vertically well mixed fronts to typical river plumes. The roll-rate of the ocean glider was used to define the different mixing processes in these plumes. Discovery of Dense Shelf Water Transport (DSWT), or underwater rivers, where higher density water is transported along the sea bed across the continental shelf around Australia is one of the major highlights.

Poster Session 2, Poster 59

Resolving ocean currents in the Great Barrier Reef with high-definition satellite altimetry

Shane R Keating[1], Matthew R Bell[1,2], Ayden Bauer[1,3], Gary Brassington[4], Madeleine Cahill[5]

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Session

39. General oceans

Abstract

Detailed observations and predictions of ocean currents are critical for hazard response, search-and-rescue, and fisheries management. The NASA-CNES Surface Water and Ocean Topography (SWOT) mission is a pioneering new satellite that uses a unique "wide-swath" altimeter to derive 2D maps of sea-surface height, including (for the first time) in coastal and estuarine zones. This presentation will describe the results of a synergistic in situ measurements of surface currents in the Great Barrier Reef in May 2023 in collaboration with the Bureau of Meteorology (BOM) and the Australian Institute of Marine Science (AIMS). The GBR study site was located under SWOT's unique 1-day repeat sample phase, providing a once-in-a-generation opportunity to measure and validate fine-scale ocean currents with unprecedented spatial and temporal resolution in a crucially important ocean region of Australia. The outcomes of this project will enhance the capability of BOM and AIMS to leverage future wide-swath radar altimetry data for ocean current prediction, contribute to validation of the SWOT mission.

Poster Session 2, Poster 61

A MAGICC Sea Ice Emulator

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Session

44. General monitoring, modelling and other services

Abstract

Global coupled climate models are the most comprehensive tools that we have for predicting how Arctic sea ice will change in the future. However, there are large uncertainties surrounding their projections. CMIP6 models tend to simulate higher levels of global warming than observations suggest, while underestimating the Arctic Amplification (Rosenblum & Eisenman, 2017; Rantanen et al, 2022). As such, too little sea ice is lost per degree of global warming than is observed (Niederdrenk and Notz, 2018; Rosenblum and Eisenman, 2017; Mahlstein and Knutti, 2012). We present an emulator that generates probabilistic projections of the Arctic temperature and sea ice cycle that capture the core physical processes of CMIP6 projections, while correcting for model biases to ensure current projections match present day trends. We show that by forcing our model with an observationally constrained global mean surface temperature and Arctic Amplification, we are able to capture the observed sensitivity of sea ice loss to global warming. When using our model to diagnose the timing of an ice-free Arctic Ocean, we find that in all months our model advances the first ice-free year when compared with CMIP6 projections. An ice-free September Ocean is 'likely' at 2 of global warming under SSP5-8.5 and SSP2-4.5, yet 'unlikely' at 1.5 of global warming, stressing the importance of preventing global temperatures rising above 1.5, as the probability of losing sea ice coverage in September rises sharply thereafter. Our model therefore suggests an ice-free summer ocean could occur 0.5 cooler than the CMIP6 multi-model ensemble mean.

Poster Session 2, Poster 63

Establishing priorities for Australia's Coastal Research Infrastructure (CoastRI)

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Session

44. General monitoring, modelling and other services

Abstract

Over 85% of Australians live within 50 km of the coast. Our cities, industries, recreation and culture are closely entwined with this environment. Climate change is altering our coastline at unprecedented rates; with sea level rise, coastal erosion, inundation and weather changes compounding the habitat loss already experienced due to human activity. These changes also impact the built environment, natural resource systems and Australia's infrastructure planning. Australia currently lacks a national, cohesive approach to monitor, understand, predict and adapt to coastal change. As a basis for enhanced understanding, planning and adaptation we propose a Coastal Research Infrastructure (CoastRI) Initiative to meet current and future needs of Australian researchers, industry and government.

Planned activities in CoastRI align with three major categories: observing coastal processes, cross-sector modelling and prediction, and data identification, management, and integration. Given the scope and breadth of issues facing our coastal systems this project is only feasible through synthesis and coordination among National Collaborative Research Infrastructure Strategy (NCRIS) capabilities and close collaboration with other related agencies such as Geoscience Australia and the Bureau of Meteorology. This integrated effort will represent a step-change for Australia in how we operate and connect essential research infrastructure in coastal regions. CoastRI will provide integrated national-scale environmental and coastal climate capabilities not currently available. The program of work will include marine, estuarine, terrestrial, subsurface, modelling and analytical elements. Threats to Australia's ocean and coasts reinforces the need for such an integrated and multidisciplinary capability to help address cumulative threats.

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