



Agricultural resilience to extreme weather events- taking stock of and reanalysing dependencies and history in climate risk management

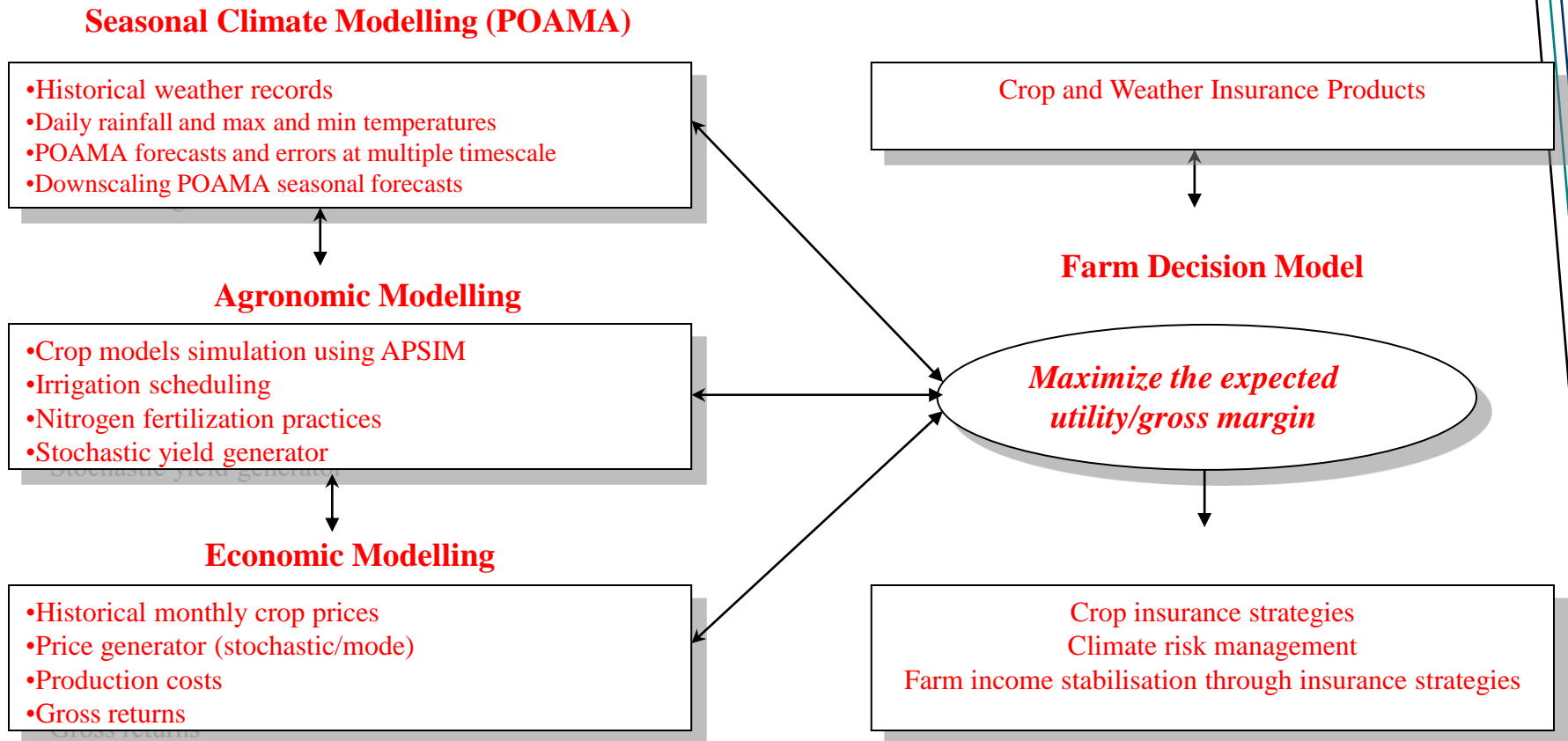
**Peter Best, Shahbaz Mushtaq &
Roger Stone**

**Presentation to the WMO Workshop,
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- **Climate forensics & predictive capabilities for extreme weather events (EWE) in agricultural, energy, water, weather and insurance markets?**
- **Assimilation of information & methodologies to make industry sectors & communities more resilient to EWEs, at various time horizons?**
- **Are interacting climate modes, reanalysis, RCM & palaeo-tempestology techniques useful for the understanding /design & popularising of Community Weather-based Alternative Risk Techniques (CWART)?**

Conceptual framework of interfacing seasonal climate forecast models with insurance strategies for farm decision-making



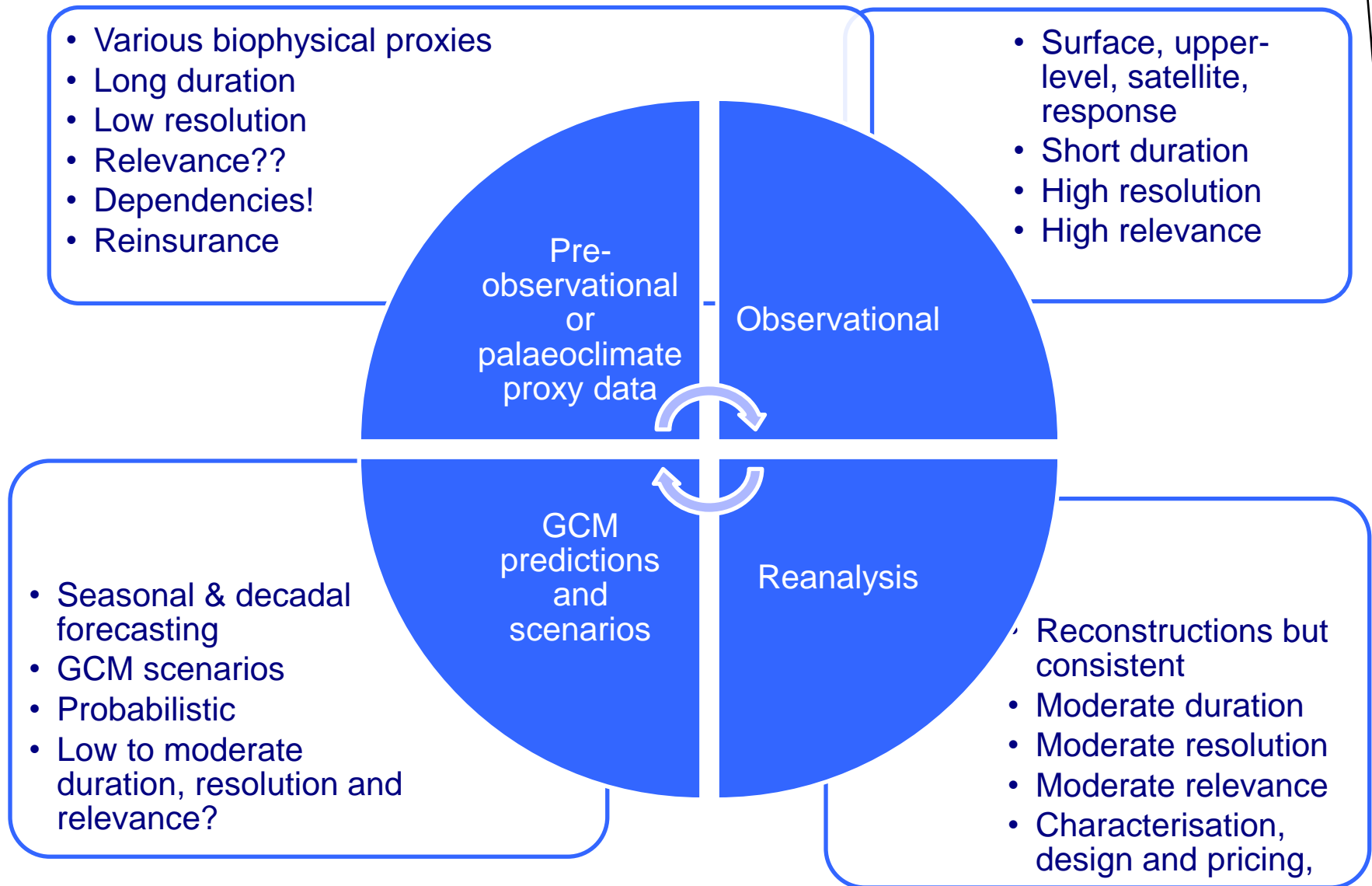
What procedures are useful in optimising farm performance measures of several types at the various timescales caused by EWE and climate change-induced impacts?

What information is essential for financial management of residual climate risk due to EWE via insurance, derivatives, bonds, microfinance and new methods of governance?

What useful overlaps in CRM are there between different industry sectors (e.g. agribusiness, water resources, power, tourism)?



- **Single farmer wishing to optimise crop management, using seasonal forecasting and alternative risk transfer (ART) such as weather derivatives.**
- **Enterprise risk management for agribusinesses operating across multiple regions and climate zones.**
- **Agricultural co-operatives (Irrigation Companies) investigating insurance for improving adaptation efforts in water demand, harvesting and energy.**
- **More efficient alternatives to “emergency assistance measures”**
- **Environmentally sustainable & GHG-friendly irrigation systems, & carbon- neutral catchments.**





Taking stock of weather history - Reanalysis 101; the Atmospheric Circulation Reconstructions over the Earth project.

- **Horizontal surface pressure fields + ensemble Numerical Weather Prediction model give 6 hourly 2 degrees 120 + years of surface + upper-level weather parameters *and* flux variables *and* errors.**
- **Virtual history of radiosonde and fluxmeter stations worldwide.**
- **Downscaling often needed for many purposes but 0.5-1 degree resolution (experimental) captures tropical cyclones and heat waves etc with reasonable weather observations.**
- **Detailed event analysis, precursors to EWE, statistical linkages and teleconnections worldwide and over 120+ years.**
- **Cross-linking with GCM testing and palaeoproxy data aids coherent view of climatic “present” and insurance viability.**
- **Will form key roles in major education programmes such as GLOBE and ACRE/Google.**



What information, space/time and duration/resolution?

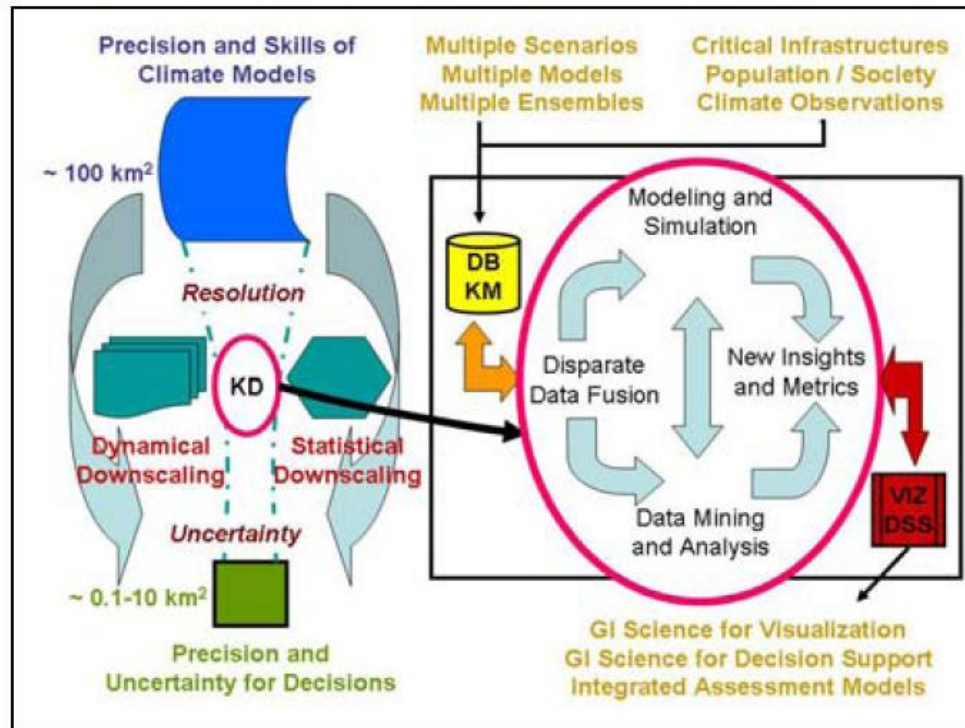
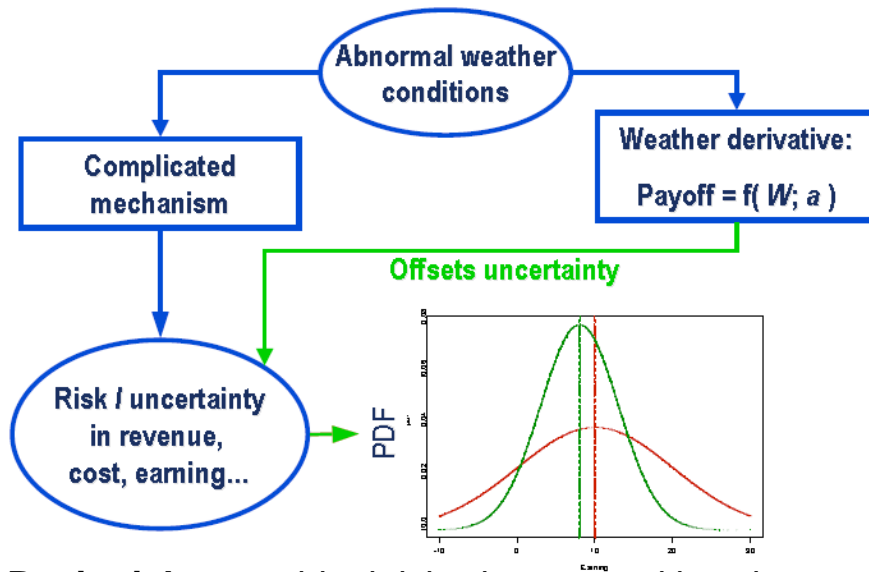


Figure 1. Knowledge Discovery in Climate
Data Mining for Climate Change and Impacts

Auroop R Ganguly and Karsten
Steinhaeuser

- Time extent > 10 x period of dominant mode
- Centennial duration (palaeo and RCM?) for estimating EWE dependencies.
- Sub-diurnal for many responses (GDD, HDD, RD)
- Coarse spatial resolution OK for U/L precursors, or downscaling responses?
- Downscale for site info, statistical has many uses.
- Site or satellite observations for detail e.g. basis risks?
- Non-stationarity &/or anthrop CC complicate answer!

Weather derivative contract design



• **Basis risks** – residual risk where actual loss is uncompensated by CRM procedures, due to inadequacies in spatio-temporal representations and contract design.

• **Alternative Risk Transfer (ART)** – product, channel or solution that transfers risk exposures between insurance and capital markets to achieve specific (Climate) Risk Management (CRM) – weather insurance, bonds and derivatives, catastrophe bonds ..

- **Reanalysis** – intelligent use of past information with modern modelling to create consistent, long-term, spatially-extended data sets (meteorology, climate, production etc).
- **Forecasting** – prediction of outcomes based on varying degrees and different approaches (deterministic, statistical, semi-empirical and artificial intelligence) of understanding of processes and history over different timescales, spatial resolution, costs and accuracy.
- **Risk Management** – actions to control, retain, reduce and/or distribute risk or expand current exposures.
- **Enterprise Risk Management** – combining disparate risks, time horizons and instruments into a single, multi-year program of action.



- **{ENSO, SAM, MJO, NAO..} – Climate “modes” or “oscillations” with CAI descriptors**
- **“Atmospheric bridges & oceanic tunnels” - teleconnections**
- **Commodity production and price depends on CAI (one or many?) + other determinants like oil price?**
- **More modes may emerge from 120+ year reanalysis – is there a minimal set for given region?**
- **Spectral peaks “above noise” but red noise (LRD) needs treating before causality testing?**
- **Simple indices such as SOI for strong modes, space-time models for weaker modes?**
- **Short-term memory (STM) – due to nearest neighbours in time or space; autoregressive descriptions, persistence types, AI techniques for weaker non-linearities.**
- **Long-range dependence (LRD) or long-memory processes – ocean heat or soil moisture storage - embedded memory of growth processes; often associated with (multi)-fractality.**
- **Intermittency or burstiness – sudden changes in volatility that can encourage clustering of extremes, phase transitions and critical point behaviour.**
- **Aggregation of low-correlation signals >> fat-tailed distributions >>enhanced univariate extremes.**



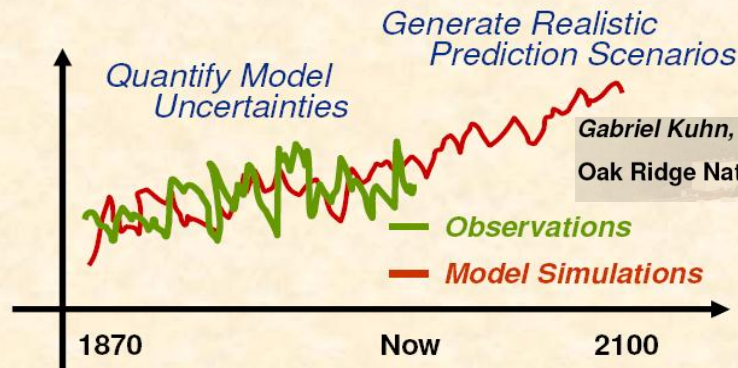
Extreme Value Theory

- *Prob. ($X > u$): Univariate Extreme Value Theory (EVT)*
- *Prob. ($Y > v | X = x$): Extremes and Multiple Covariates*
- *Prob. ($Y > v | X > u$): Multivariate Extreme Value Theory*

Gaps for real applications

- *Large-scale data: Scale up extreme value theory for automated use*
- *Geospatial-temporal extremes: Extend multivariate EVT for space and time*

- **Hydrologic Observations**
 - Grid-based Precipitation
- **Climate Model Simulations**
 - 1870 to Now: Past
 - Now to 2100: Future



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- **$F(X,Y)=C(X,Y) F(X) F(Y)$; Copula C connects two univariate pdfs to multivariate pdf, either overall or in tails. Used in insurance, hydrology etc**
- **Investigate causes, importance, estimation methods, multivariate signals .**
- **Non-stationarity important, especially in hydromet. and attribution studies.**
- **Non-linearities prevalent in geophysical processes, producing signal amplification, regime shifts and unexpected behaviour.**
- **Spatiotemporal structural methods such as “climate network analysis” characterise changing connectivity of ocean-atmosphere, with some predictive capacity.**



Key characteristics of EWE for assessment, model selection, pricing and prediction?

Characteristics	Important determinants	Insurance interactions
Return periods	Cycles, Short-Term Memory, Long-Range Dependence	Pricing, client education, business and insurance cycles
Clustering, temporal	LRD, “burstiness or intermittency”	Reinsurance layering
Spatial distributions	Process characteristics	Insurance cycles and pricing?
“Loss” measures	Maximum probable loss, expected shortfall	Risk management, all sectors
Interdependence	Multivariate copulas?	Catastrophe reinsurance
Asymptotes	Outliers, kings, swans & iceberg risks	Reinsurance viability, retrocession
Climate variability	Inter-annual and decadal cycles	Pricing
Climate change	Trends, change in system characteristics	Viability of reinsurance and adaptation measures



Index-based insurance and seasonal forecasting.

Australian Centre for Sustainable Catchments

FIGURE 1: PAYOUT STRUCTURE FOR A RAINFALL INDEX INSURANCE CONTRACT FOR DROUGHT RISK

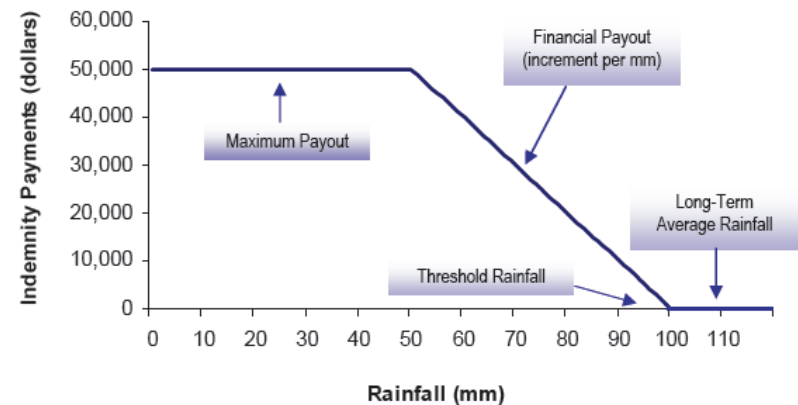
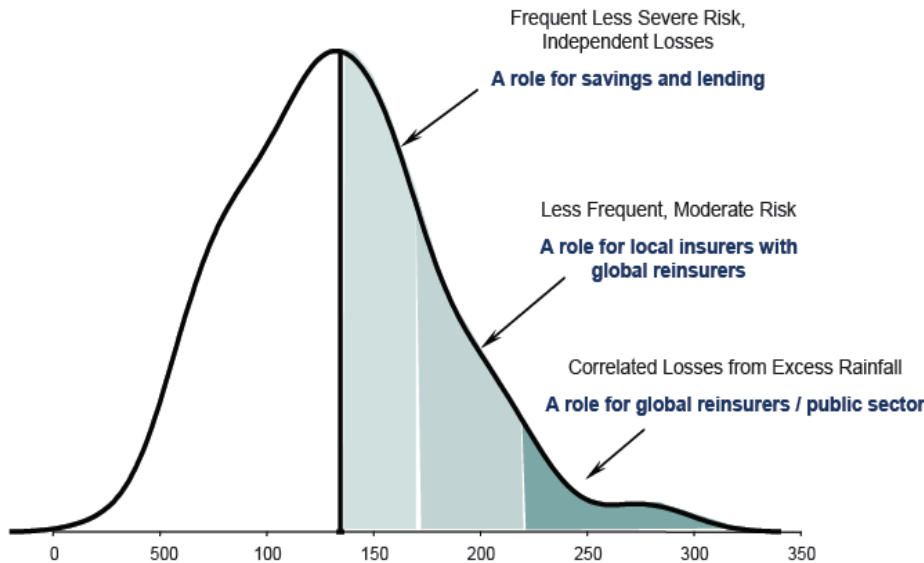
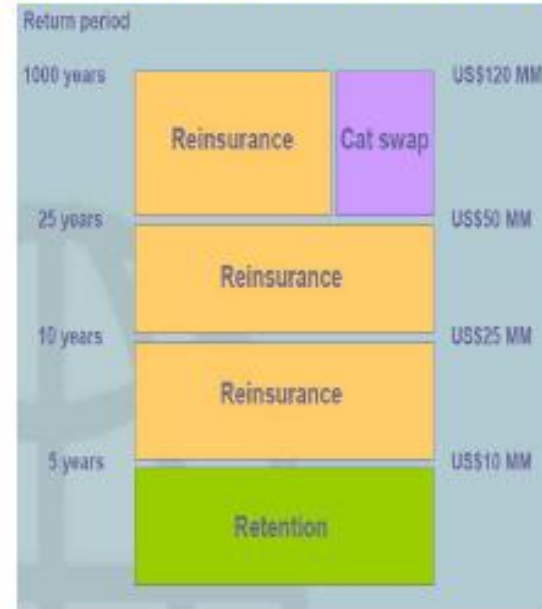


FIGURE 2: LAYERING OF EXCESS RAINFALL RISK BY RAINFALL LEVELS



Source: Skees, Barnett, & Hartell, 2005

Risk financing capacity:



Coping and risk management of Extreme Weather Events in agricultural context require a combination of insurance, forecasting, adaptive operation strategies, full use of historical information (e.g. reanalysis and palaeoclimate), and appropriate consideration of community vulnerabilities, uncertainties and communication requirements.



MCV project methodologies and expected outcomes – example of heat stress in cattle, poultry and pigs?

Characteristics	I. Heat stress in Confined Animal Feedlot Operations
Critical conditions	Multi-day “heatwaves” with poor night-time relief
Key climate & meteorology?	Synoptic blocking
Key parameters	Accumulated Temperature, Rain, Black Globe T
Key indices (illustrative)	MJO, STR.....
Current insurance	Mortality only, but major impacts on production, immune systems, reproductive capacity etc
Index products?	Some in various parts of Asia
Reanalysis for insurance/adaptation?	Strategic risk and forecast validation, new product design? Stress database available for Aust/US.



- **EWE treatment important in community education, disaster relief planning, insurance design and viability, RCM utility and industry strategy.**
- **Reanalysis widens information windows and opportunities.**
- **Stochastic properties heavily linked to adaptation cost/benefits.**
- **IBI and WART work well in sponsored, single-sector, “aid” applications. Other locations/situations may need cross-sector diversification.**

We expect that:

- **Model/observational error fields may be key consideration in ART where seasonal climate forecasting is needed.**
- **There may be some dependence measures that are relatively independent of mild/medium/severe or even abrupt climate change.**
- **Copula/CVAR approaches should be useful in many agri-finance-insurance evaluations of EWEs.**



We live in exciting times when we seek sunshine behind seemingly threatening clouds.

“When you don’t know where you’re going, it’s important to remember where you came from” – African proverb.

“Only by transmitting the past to our children can we enable them to invent their future” (Alain 1989).

“Man can believe the impossible, but man can never believe the improbable.” – Oscar Wilde.