VALIDATION OF IMPROVED SKY CAMERA ALGORITHM FOR MEASUREMENT OF CLOUD AROUND THE SUN

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ABSTRACT

A low cost automatic sky camera system was designed, constructed and tested for the use to study the effect of cloud on the amount of ultraviolet radiation (UV) at the ground level. This paper presents the results of a twelve-month comparison between the results obtained with the sky camera system and those of manual observation, with the major cloud type of Cumulus (36 %). The sky camera system is the first to measure cloud properties near the sun, in contrast to whole-sky assessment. images were analysed using an improved image-processing algorithm estimating the cloud amount in an angular region of 37.5 ° around the sun for local noon at Toowoomba, Australia (27.6 ^{o}C). The state of solar disk obstruction was also determined, as it would be useful for assessing the effect of cloud on the UV level. It was found that the new algorithm compared favourably with a previous evaluation of an earlier system (85.2 % for disk obstruction and 81.7 % for cloud amount). The finding suggests that the camera system is suitable for the use of long-term radiation studies.

1. Introduction

McKenzie *et al*. (1998) suggests that the complex relationship between cloud cover and ultraviolet radiation (UV) make it impractical to derive a simple expression that accurately relates the two for all conditions. They report that correlations between cloud estimates and ratios of measured/modelled clear-sky UVB are much weaker when the sun is not obscured by cloud. For cloud estimates, less than 50 % there seems to be little effect of cloud on UVB. One needs to know whether the sun is obscured and the cloud optical depth.

What appears to be missing in the literature to date is a quantification of cloud in the vicinity of the sun. For example, would the proximity to the sun of the 50

% cloud mentioned by McKenzie *et al*. (1998) above effect the measured UV? Borkowski *et al.* (1977) quantified all-sky photographs using photometric measurements and applied an empirical orthogonal function analysis to the data. The method allowed representation of the cloud pattern as a composition of basic patterns to which a definite physical meaning could be attached. It was found that the distribution of coefficients of the first eigenvector was governed by the major distribution of clouds in the sky, while those for the second related to the highly variable cloud cover of the area close to zenith, with clouds of different thickness. Although no definitive conclusions could be made, their work indicated that not only the fraction of the sky covered by clouds, but also their distribution, determined the intensity of UV. Long & DeLuisi (1998) suggest that fractional cloud cover alone, except for the extreme of an overcast sky, cannot fully characterise the cloud field. For instance, a cloud cover of 50 % could be due to many small cumulus clouds, or having half the sky covered by a stratus deck. The effects on the downwelling irradiance are often quite different for these two conditions. Additional information provided by a cloud edge to area ratio allows further assessment of the cloud field.

At the present time there has been no reported study of the measurement of cloud properties in the vicinity of the sun using an automated satellite or ground based sky camera system. Cloud images near the sun can be recorded automatically with a sun-tracking camera. In order to process a vast number of images of cloud, it is desirable to automate the image analysis process. Long & DeLuisi (1998) describes the development and Wooldridge (1993) describes the development and evaluation of automated whole-sky camera systems to estimate cloud fraction retrievals. Davis *et al*. (1992) used colour slides as a source of cloud images. McKenzie *et al*. (1998), Schafer *et al*. (1996), and Borkowski *et al*. (1977) employed ground based whole-sky cameras to study cloud effects on UV at ground level.

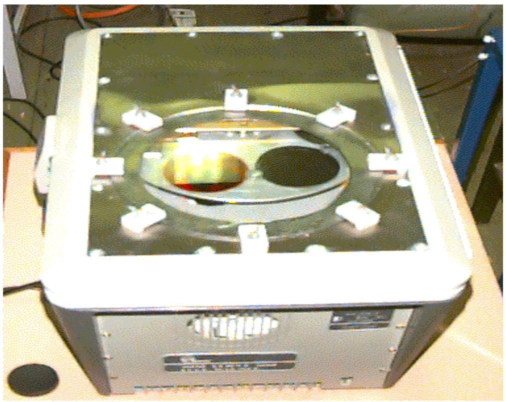

Figure 1 The Sky Camera in the laboratory, showing two of the filters used to record cloud images in the vicinity of the sun.

In these studies the degree of solar obstruction and whole-sky cloud amount (not cloud near the sun), were determined visually (not automatically) from the images by subjective methods.

McKenzie *et al*. (1998) attempted to use a commercially available video camera (Harnett, 1992), however the restrictions of lack of colour, narrow field of view, and the necessity of shading the sensor from direct sunlight limited its suitability.

2. Materials and Method

The sun centred sky camera was situated at Toowoomba, Australia (27.6 ° S, 696 m a.s.l.) at the campus of the University of Southern Queensland (Figure 1). Cloud measurements were recorded automatically by the sky camera and manually by an observer at the site over a period of 12 months (September 1997 to August 1998), at local noon each day. The sky camera system consisted of a standard video camera and a wide-angle lens. A stepper motor was used to point the camera in the direction of the sun in an east-west direction. The altitude angle of the camera was manually adjusted at the end of each week by approximately 2 ° to keep the sun in the centre of the field of view of the camera in a north-south direction. A second stepper motor was used to turn a filter wheel assembly, which was located above the camera lens. The first filter was opaque and ensured that the sun's rays did not damage the CCD chip of the camera.

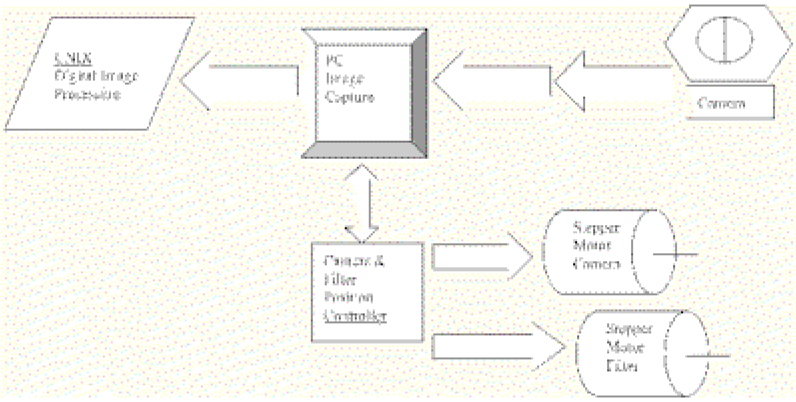

Figure 2 A Block diagram of the Sky Camera System showing the major components of camera, PC, controller, stepper motors and UNIX workstation.

A UNIX computer performed digital image processing. Figure 2 shows a block diagram of the sky camera system and the reader is referred to Sabburg & Wong (1997) for a full description.

The images had varying contrasts between the sun, sky, and clouds, and the sun was approximately in the centre of the image (Figure 3a). In the initial version of the image processing software, a non-linear approach was used and this method was evaluated by comparison to visual interpretation of the recorded sky camera images (Sabburg & Wong, 1998). The image processing software positioned the sun at the centre of the image and determined if the sun was obstructed or not. The sun was removed (subtracted), from the image and a measure of cloud cover around the sun was made (Figure 3b). The methodology of the new approach differs by using a linear algorithm that varied from the above method in the areas of filter selection, thresholding, handling bright cloud obstructing the sun and the underestimation of the area of dark cloud (Figure 3c).

Figure 3 a) A typical sky image (in this case with the sun blocked), recorded by the Sky Camera; **b)** The resulting sky image of a) after image processing with the non-linear algorithm and **c)** the resulting sky image of a) after image processing with the new linear algorithm. White is cloud and black is sky, except for the sun's disk which is subtracted from the image in case b).

A unique problem which was confronted when analysing the images of the present research, was determining the state of the sun's disk (whether it was blocked or not). In most cloud imaging to date, the sun has been blocked by a 'gooseneck' or shadow band device, thus avoiding the imaging of the bright sun. The manual observer was trained prior to the study by comparison with official meteorological whole-sky cloud cover observations for reported 9 AM and 3 PM data, and was found to be accurate to ± 1 okta. The observer wore protective sunglasses and carefully determined if the sun was blocked by cloud and then estimated the cloud cover around the sun, in a similar field of view as the sky camera.

3. Results

During the 12-month period, 231 images and 129 corresponding manual observations were collected at local noon, with a solar zenith angle (SZA) ranging from 4.2 to 51 °. Cloud type ranged from Cumulus (36 %), Stratus (9 %), Alto-Cumulus and Alto-Stratus (15 %), sky's containing Cirrus cloud (11 %) and the remainder being other cloud combinations. As in the case of the visual evaluation of the sky images produced by Sabburg & Wong (1998), the manual observer found difficulty in determining the state of the sun's disk and the amount of cloud cover in the presence of Cirrus clouds. Therefore, for the purposes of this validation, the presence of predominant Cirrus cloud cases has not been included. This left 115 cases with corresponding manual observations (Table 1). It should also be noted that for the purposes of this evaluation, partial obstruction of the sun was taken as disk obscured. The cloud amount percentage is that covered by cloud in the 75 ° field of view (FOV) of the sky camera centred on the sun.

Table 1 - Results of comparison between manual sky observation and algorithm derived cloud parameters for 115 images recorded at local noon near the sun.

PARAMETER	**Manual Observation**	**Linear Algorithm**	**% Error**
State of Sun			
Disk not obscured	28	24	14.3
Disk obscured	87	74	15
Total	**115**	**98**	**14.8**
Cloud Amount			
100 - 67 %	77	69	10.4
66 - 35 %	9	5	44.4
34 - 0 %	29	20	31
Total	**115**	**94**	**18.3**

4. Discussion & Conclusions

Compared to the non-linear algorithm there has been improvement in detection of the state of obstruction of the sun (85.2 %), with a similar accuracy in cloud amount estimation (81.7 %). There still seems difficulty in agreement in the middle cloud amounts of around 50 %, but this could be a problem with the manual observations and/or the detection of dark cloud patches by the algorithm, as there is considerable variation in contrasts for these middle cloud amounts. Both the manual observation error and the algorithm error for this cloud range compound the overall error.

The fact that the comparison is over a full year indicates the potential use of the camera system for long-term periods. The system has the potential to investigate the findings of Borkowski *et al.* (1977), who indicated that cloud distribution was a factor in determining the intensity of UV.

A new system has been developed to quantify the amount of cloud around the sun, and whether this cloud blocks the sun. This is the first sky camera system which uses image processing to evaluate the sky images automatically to extract the sun obstruction. The system has application as a research tool for evaluating the attenuation of clouds around the vicinity of the sun, to enable improvements to existing radiation models.

Acknowledgments. We would like to thank the Technical staff at both QUT and USQ for construction of mechanical components, electrical wiring and computer support.

REFERENCES

Borkowski, J., Chai, A-T., Mo, T. & Green, A.E.O. 1977, 'Cloud effects on middle ultraviolet global radiation', *Acta Geophysica Polonica*, vol.XXV, no.4, pp.287-301.

Davis, G.B., Griggs, D.J. & Sullivan, G.D. 1992, 'Automatic estimation of cloud amount using computer vision', *J. of Atmospheric and Oceanic Technology*, vol.9, pp.81-85.

Harnett, C.M. 1992, 'The effect of cloud cover on the surface radiation budget', MA thesis, Geography Department University of Canterbury, New Zealand.

Long, C.N. & DeLuisi, J.J, 1998 'Development of an Automated Hemispheric Sky imager for Cloud Fraction Retrievals', Proc. 10th Symp. on Meteorological Observations and Instrumentation, Phoenix Arizona, Jan.11-16,1998, pp.171-174.

McKenzie, R.L., Paulin, K.J., Bodeker,G.E., Lilley, J.B. & Sturman, A.P. 1998, 'Cloud cover measured by satellite and from the ground: relationship to UV radiation at the surface', *Int. J. Remote Sensing*, vol.19, no.15, pp.2969-2985.

Sabburg, J. & Wong, J. 1997, 'Development of a Sun Centred Sky Camera for use in UV Measurements'. image Analysis and Information Fusion, Heping Pan, Mike Brooks, Daniel McMichael and Garry Newsam, Editors, Proceedings of the International Workshop (IAIF'97), 6-8 November, 1997, Adelaide, Australia, pp.113-118.

Sabburg, J. & Wong, J. 1998, 'Evaluation of a Ground Based Sky Camera System for use in Surface Irradiance Measurement', (In Press, *J. of Atmospheric and Oceanic Technology*).

Schafer, J.S., Saxena, V.K. & De Luisi, J.J. 1996, 'Observed influence of clouds on ultraviolet-B radiation', *Geophysical research letters*, vol.23, no.19, pp.2625-2628.

Wooldridge, C. 1993, 'The development and evaluation of a digital whole-sky cloud monitoring system', PhD Thesis, Macquarie University.