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Site Testing at Dome C—Cloud Statistics from the ICECAM Experiment

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Abstract. Analysis of sky images obtained from an automated experiment at Dome C, Antarctica, at 2-hourly intervals from February to November 2001 show cloud-free conditions 74% of the time. This augurs well for the prospects of future astronomical observatories at this site.

1. Introduction

Dome C on the Antarctic plateau is almost certainly one of the best astronomical observing sites on earth. Most of its characteristics are expected to be similar to or better than those of South Pole Station. However, the fraction of cloud-free skies during winter-time has been an entirely unknown quantity. We set out to measure this fraction in order to facilitate planning for a future observatory.

Determining the amount of cloud cover over an uninhabited site on the Antarctic plateau during winter time, when the sun is below the horizon for much of the time, is a surprisingly difficult problem. The current generation of earth-orbiting satellites cannot resolve the difference between cloud and ice.

Our solution was to build ICECAM, a small, low-powered, CCD camera system that can take images of the sky every two hours for a year and store them on a solid-state disk. ICECAM is completely automated, working at air temperatures down to −80°C, and is now in its third year of obtaining data from Dome C.

2. Instrumental design and challenges

Until Concordia Station at Dome C opens for winter-over operation, there is no electrical power or heating available at Dome C for the nine months beginning in February each year. Solar power cannot be used during the long dark winter, and wind power is also problematic given the low-to-zero wind speeds on the plateau for much of the year. With temperatures down to −80°C during winter, many off-the-shelf electrical and mechanical devices tend to fail.

Fortunately, ice is an excellent insulator, so that a few meters below the surface the temperature remains stable at the yearly average of about −57°C. This is sufficiently warm for many electronic devices to function, and for lithium thionyl chloride batteries to have a reasonable capacity.

To provide an unambiguous indication of cloud cover in a form that would convince a skeptic, we decided to use a CCD camera to take images of the sky. The camera, a low light level Watec 902-HS, was found to operate reliably at $-80°C$ (although it was only rated to $-10°C$). We used a lens with a 30 degree field-of-view. The images from the camera were processed by a PC/104 computer (equivalent to a 66MHz Intel 80486, and drawing only a few watts) running MS-DOS (chosen for its small memory footprint and fast boot time), and stored on a 256MB CompactFlash disk (thereby eliminating any moving parts in the computer). There is sufficient space on the disk to store a year's worth of data, with images being taken every two hours. The entire system can be powered for a year from 5 kilograms of lithium thionyl chloride batteries. 99.6% of the time ICECAM is idle and using only a few milliwatts of electricity to operate a timer. For 30 seconds every two hours, the computer is turned on, ten images are acquired, averaged, compressed and written to the CompactFlash disk, and an ARGOS transmitter is programmed to send 32 bytes of status information to the ARGOS satellite network. The total amount of energy used during this two-hour cycle is 200J, about the same as used by a person to go up one step.

The ICECAM computer and ARGOS transmitter reside in a "crypt" some 7m below the ice surface, in order to take advantage of the warmer temperatures there. The CCD camera was mounted on a pole 3m above the ice.

At the end of each year, the CompactFlash disk is retrieved for analysis, and the lithium thionyl chloride batteries are replaced. Several years of data will be required for good statistics.

3. Results

During the first year of operation a blown fuse after three days of operation halted all ARGOS transmissions from ICECAM during 2001. We were therefore pleasantly surprised to find that when we returned almost a year later ICECAM had obtained 2095 images of the sky (fewer than the expected 3800 due to occasional boot problems and corruption of part of the file system on the CompactFlash disk). The PC real-time-clock had also reset itself on occasion once the temperature had dropped below $-40C$. The image times can be reconstructed from a careful analysis of the images themselves (e.g., by noting the positions of the stars, and the presence/absence of the moon). These instrumental problems were addressed during a servicing mission in January 2002. However, a modification to the CCD camera housing inadvertently led to persistent frost which resulted in much of the 2002 data being useless. We are currently waiting on 2003 data (a web-camera in our AASTINO experiment at Dome C has already shown >97% clear skies for 100 days beginning on 2003 February 9).

Figure 1 shows typical images from ICECAM at Dome C in 2001. A calibration light-emitting diode is visible at the top left of the post towards the bottom of each image. Figure 2 summarizes the data from 2001. 22% of the images were unable to be used (due to frost on the CCD window, or in some cases a corrupt image file). Of the usable images, 74% showed evidence of clear skies, and the remaining 26% showed some cloud.

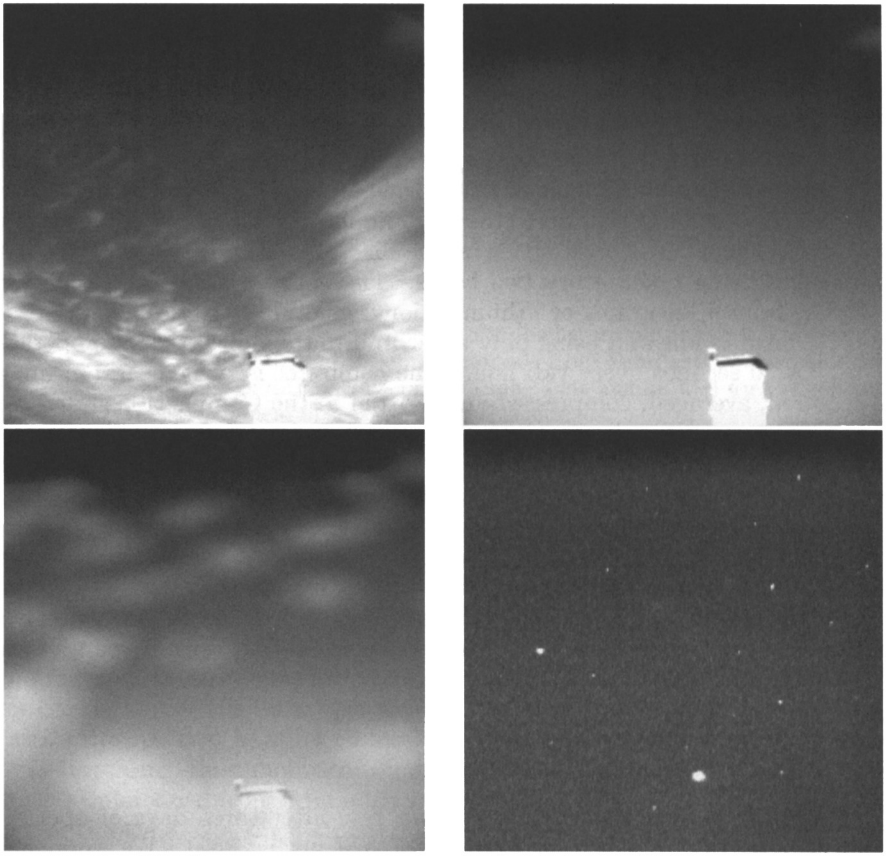

Figure 1. Sample ICECAM images from Dome C: clockwise from top left: circus cloud, clear twilight sky, patches of frost on the CCD camera window, and stars down to magnitude 6 observed during midwinter. The field-of-view is 30×30 degrees centered at a declination of −53°.

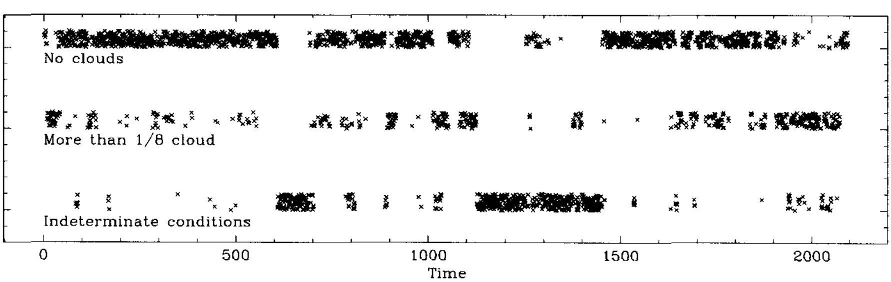

Figure 2. Summary of the 2001 ICECAM data for Dome C. Each cross represents an image, obtained at 2 hourly intervals from February to November. The X axis is image number. The images were characterized by eye as either showing clear conditions ("No clouds"), some evidence of cloud ("More than 1/8 cloud"), or ambiguous ("Indeterminate conditions"), usually due to frost on the CCD camera window.

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