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SOME ANTARCTIC SITE TESTING RESULTS

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Abstract. Observing conditions at the South Pole have probably been better characterised than at any other site on earth. The benefits are now well established, and include greatly reduced near- and mid-infrared sky brightness, improved atmospheric transmission, and a unique atmospheric turbulence profile with almost zero turbulence above the lowest 200 metres of the atmosphere. The site testing work is still in progress, with a view to better understanding the residual infrared sky emission and the nature of the atmospheric turbulence. Autonomous experiments are now also currently operating at Dome C. Plans are well advanced to extend these experiments, and to study even higher altitude sites such as Vostok and Dome A. In this paper, we report the recent results from UNSW. More comprehensive reviews can be found in the literature.

1 Introduction

The Antarctic plateau offers unique observing conditions. The continent is high (up to 4000m). The temperature averages $-50°C$ and can go as low as $-90°C$ in the highest parts of the continent, which is favourable to observations in the thermal infrared. Antarctica is also the driest place on earth with a typical water vapour content of $250\mu m$, opening new windows in the sub-millimetre and infrared range. A further advantage of Antarctica is the half-year-long night and day allowing the continuous observation of stellar objects.

In order to quantify the atmospheric conditions of the Antarctic continent, we have deployed a series of experiments at both the South Pole and the future Dome Concordia station. The conditions at the South Pole are now fairly well known, with measurements of the seeing, turbulence profile, and sky brightness at a range of wavelengths. Our site testing at Dome C (started in 2000) has so far gathered information about the winter cloud cover and the summer sub-millimetre sky conditions

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2 South Pole Results

At the South Pole station, most of our experiments were located on the Automated Astrophysical Site Testing Observatory, the AASTO (Storey et al, 1996). The AASTO supplies power to the experiments, keeping their electronics at room temperature. We can remotely connect to the AASTO to collect the data from each instrument via satellite.

2.1 Sub-millimetre sky opacity

The sub-millimetre sky brightness is measured at $350\mu m$ with the SUMMIT. A sub-millimetre tipper optically identical to the radiometers jointly developed by NRAO (National Radio Astronomy Observatory) and CMU (Cargenie Mellon University). The mirror can rotate through 360° measuring the sky radiation as well as the temperature of two black bodies used for calibration.

Data were gathered in the winter 2001 at the South Pole base (Calisse et al, 2002) and a median zenith opacity of 1.85 was measured at $350\mu m$ (best 25%: 1.60, best 75%: 2.15). The SUMMIT has since almost continuously recorded data which is sent daily to a web-site available to the public at the following address:

`http://newt.phys.unsw.edu.au/~pcalisse/summit/summit_data.html`

2.2 Infrared transparency

The sky conditions in the infrared have been determined using two instruments, the NISM (Near Infrared Sky Monitor) and its analogue in the mid-infrared (MISM). The two instruments work similarly to the SUMMIT, scanning different airmasses after passing through a filter. The low temperature of the atmosphere of Antarctica explains the low emission in the near infrared. The NISM data showed that the sky emission at $2.38\mu m$ (K_{dark}) is on average equal to $220\mu Jy.arcsec^{-2}$ which is 20 times lower than the Maunea Kea site, giving the South Pole the lowest sky emission ever recorded for a ground-based site (Lawrence et al, 2002). The low level of dust, aerosol and water vapor is also an advantage present in Antarctica. This effect can be seen in the mid-infrared. The average flux between 8.78 and $9.09\mu m$ was $20 Jy.arcsec^{-2}$ as recorded in a 140 day period in 1998. The average flux profile measured between 5 and 14 microns shows that the sky background is an order of magnitude lower than at Mauna Kea (Chamberlain et al, 2000).

2.3 Turbulence and seeing

The measurement of the low altitude turbulence profile throughout the winter has been measured using a SODAR (Sound Detection And Ranging) between 20m and 890m. Previous measurements of the turbulence at the South Pole using balloon borne microthermal sondes has shown that the majority of the turbulence is located near the ground (the jet stream is absent at this latitude). The SODAR results (Travouillon et al, 2002) spanning March to November 2000 are as follows:

- The average boundary layer height was found to be 270m, being maximum near summer and constantly dropping towards winter. This low altitude distribution affects in an advantageous sense the isoplanatic angle ($\theta_{AO} = 60'', \theta_{SI} = 130''$) and the coherence time ($\tau_{AO} = 150ms, \tau_{SI} = 100ms$)
- The average seeing is rather poor from the ground (1.73″) but can quickly improve if the telescope is placed on a high tower (0.61″ above 300m)
- Strong correlation has been found between the turbulence level and the horizontal wind speed
- The turbulence profile oscillates between a one peak component and a two peak component

The seeing was optically measured using the ADIMM (Autonomous Differential Image Motion Monitor). The differential motion is measured from the 24 images produced by the Shack-Hartmann micro-lens array, giving 215 simultaneous and separate seeing measurements (Dopita et al, 1996). An average seeing of 1.90″ was found between the 28 May 2001 and the 10 September 2001.

3 Dome C Results

The full deployment of our instruments will start at Dome C in the summer of 2002/2003 with the installation of the AASTINO, a module that can be disassembled and transported around the continent for further site testing. It will be able to house the same experiments as the AASTO, being totally independent from the rest of the station. However, some preliminary site testing results have already been gathered from the Dome C site.

3.1 Sub-millimetre sky opacity

The SUMMIT experiment was sent to Dome C during the summer of 2000. The first day-time measurements of the sub-millimetre sky opacity were taken. The SUMMIT recorded data between 21 december 2000 and 26 January 2001. The median zenith opacity was 1.60 during this period (Best 25%: 1.45, best 75% 1.75)

A long winter site testing campaign will positively establish the quality of the site. Results from the 2001 summer campaign are encouraging and potentially qualify Dome C as one of the best available site worldwide, if not the best, for sub-millimetre astronomy.

3.2 Cloud cover

One of the most important characteristic of site for astronomy is the cloud coverage. We have implemented an automated CCD camera (Icecam) that is able to run continuously on batteries for a whole winter (no station power is yet available in winter). The instrument wakes up from an idle mode every two hours to record, compress and store a direct averaged image of the sky, giving an unambiguous picture of the sky condition. Data taken between February and November 2001 consist of 2095 images which have been preliminary analysed by visual inspection (Ashley, 20002). Although 22% of the data were unusable due to frost or image corruption, the images showed that for the remainder of the time the sky was clear for 74% of the time while the remaining 26% showed some clouds. The Icecam will continue to record data for a few years to obtain a statistically meaningful sample.

4 Conclusion

The South Pole site testing results show that it is the best ground-based site so far available in the infrared and the sub-millimetre range, giving it a unique scientific potential that is already being exploited. While the site testing has only recently commenced at Dome C, the higher altitude makes us believe that the site is expected to match or exceed the South Pole qualities in overall sky background. The wind speed being also far lower at Dome C, the boundary layer turbulence causing the major part of the seeing is expected to be significantly improved.

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