Estimating the Livetime of Optical Measurements of Air Showers at the South Pole

Segev BenZvi and Stephen Drury
University of Rochester – Rochester, NY, USA

The observation of PeV neutrinos at the IceCube Neutrino Observatory has revived interest in deploying large-exposure optical air shower detectors at the South Pole for use as an air shower veto and as an independent detector. Deploying and operating optical detectors in the harsh Antarctic environment is a major challenge. We have investigated the clarity of the atmosphere at the Pole using archival radiosonde and lidar data from the Atmospheric Research Observatory next to the South Pole Station. We estimate that an optical detector at this location would achieve 45%-50% uptime during the dark period from April to August.

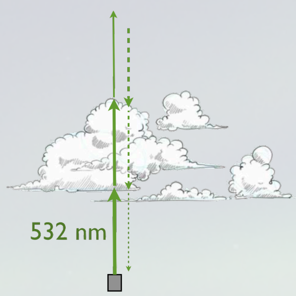
Optical Detection of Air Showers at the South Pole

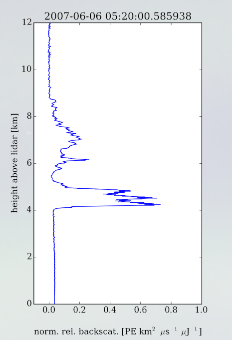
In the IceCube Neutrino Observatory at the South Pole, the detection of air shower particles in time coincidence with a neutrino event provides an excellent veto of the downgoing atmospheric neutrinos produced by cosmic rays. Therefore, the extension of a high-efficiency air shower detector above IceCube is well-motivated.

Air Cherenkov telescopes are under consideration as one of the technologies to use for air shower detection at the South Pole [1]. Unfortunately the livetime of optical detectors could be severely impacted by harsh conditions at the Pole. To evaluate the feasibility of operating such detectors at the Pole, we have studied archival weather data to estimate the atmospheric clarity during the dark period of austral winter. We focus in particular on cloud coverage.

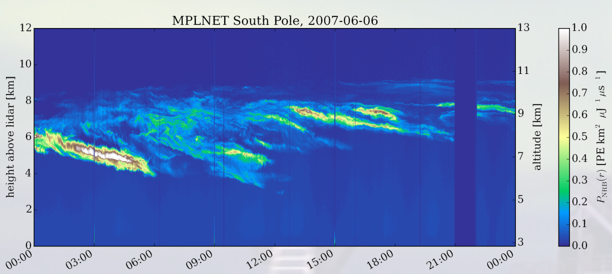
MPLNET Weather Data

Cloud and aerosol data from the South Pole are available through the Micro-Pulse Lidar Network, or MPLNET [2]. A 10 μJ laser (532 nm wavelength) has operated at the site since 2001.





The lidar station operates autonomously, providing vertical profiles of backscattered laser light with 1-minute time resolution. For public download, the MPLNET project provides the normalized relative backscatter P_{NRB}, a noise-subtracted, range-corrected laser profile.

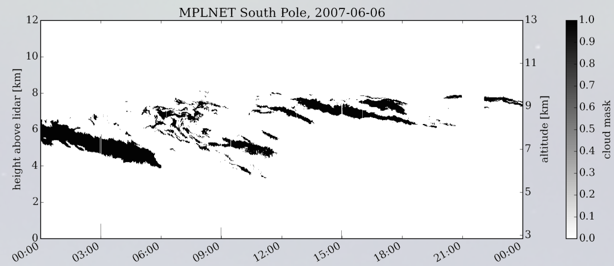


Clouds and aerosols produce bright echoes in the laser signal. An example of a cloudy 24-hour period is shown above. In this image, a series of clouds have moved across the field of view of the lidar station, producing clear echoes in the time series of vertical profiles.

We have scanned several years of data to estimate the coverage and altitude of clouds at the South Pole, with particular attention to low-altitude clouds which could affect air Cherenkov observations.

Cloud Detection Analysis

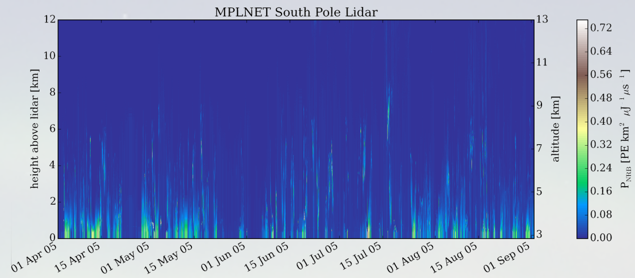
To detect clouds we apply a threshold to P_{NRB}, and then identify the bounding boxes for spatial and temporally contiguous regions within the mask. The threshold was optimized on MPLNET data from 2004.



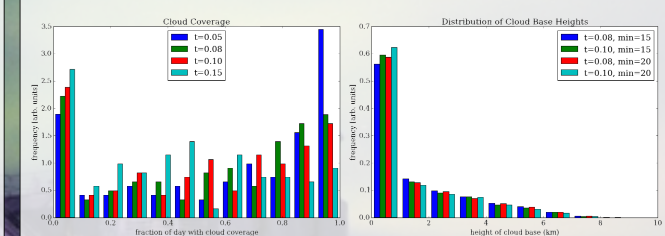
To provide a conservative estimate of the cloud base height, we report the lower edge of the bounding box as the base height.

Cloud Coverage and Base Height Distribution

Daily vertical profiles from the South Pole during winter 2005 are shown below. Clouds and aerosols are present ~55% of the time, with a significant number of clouds occurring at ground level.



During 2005-2006, sky coverage was <30% roughly 45% of the time.



Since the dark period lasts 40% of the year, the total annual livetime of an optical detector at the Pole is expected to be 20% to 25%.

References

1. J. Schumacher and J. Auffenberg, *Design Study of an Air Cherenkov Telescope at the South Pole*, ICRC15
2. J. Campbell et al., *Full-Time, Eye-Safe Cloud and Aerosol Lidar Observation at Atmospheric Radiation Measurement Program Sites: Instruments and Data Processing.* J. Atmos. Oceanic Technol. **19** (2002) 431-442.

Contact

S. BenZvi: sybenzvi@pas.rochester.edu,
S. Drury: sdrury@u.rochester.edu

Acknowledgments

This work was supported in part by a grant from the REACH program at the University of Rochester. The NASA Micro-Pulse Lidar Network is funded by the NASA Earth Observing System and Radiation Science Program. We thank the MPLNET PI E.J. Welton (NASA GSFC) and MPLNET staff T. Berkoff, J. Campbell, and J. Spinhirne (NASA GSFC) for their efforts in establishing and maintaining the South Pole site.