32. POSSIBLE COSMIC RAY OBSERVATIONS FROM A MULTI-NATIONAL ANTARCTIC STATION ON DOME A

M.L. Duldig

Cosmic Ray Section
Antarctic Division
Kingston Tasmania 7050
Australia

ABSTRACT

The proposal that a multi-national astrophysical observatory be established on the highest area of the Antarctic ice plateau (Dome A) has centred on the opportunities for optical, infra-red and submm wave astronomy. Such a site could also be used to extend the world-wide cosmic ray observatory network. Suitable cosmic ray experiments for the site are considered. Additionally, possible geomagnetic and upper atmospheric physics measurements from such a site are briefly discussed.

32.1 INTRODUCTION

The Dome A site on the Antarctic ice plateau is located at 67°E, 82.4°S at an altitude of 4270 m. The pressure altitude is even higher, exceeding 5000 m. The location has many unique features which make it a desirable site for cosmic ray observations. A large IQSY neutron monitor at Dome A would be the highest monitor in the world and would have the lowest energy cutoff (both atmospheric and geomagnetic) of any such monitor. This would be invaluable in the study of Ground Level Enhancements (GLE) and Forbush Decreases (FD).

Another advantage of such a site is the possibility of using the ice as a material absorber, of completely determined characteristics, for shallow underground muon observations. All other underground muon observatories suffer from poorly determined overburden with varying densities and rock structures and seasonal changes in water content. A detector buried in the Antarctic ice sheet would have a fully determined absorber depth in all possible directions of view and would be comparable in this respect to previously proposed sub-surface lake and ocean systems.

32.2 NEUTRON MONITOR

The asymptotic cone of response of a neutron monitor located at Dome A is not unique but the energy coverage is significantly different to adjacent cones of view of other instruments. Furthermore, the lowest energy of response, due to atmospheric absorption, would be only several hundred MeV. This would allow the gap in spectral coverage between satellite and ground based instruments to be filled for the first time. Two important needs would be met by such an instrument. Firstly, some apparent inconsistencies between satellite and ground based detector system responses to transient events such as FD and GLE may be resolved. Secondly, access to this spectral 'hole' will help to resolve the problem of poorly determined yield functions for neutron monitors at such energies. Studies of GLE have demonstrated that the yield functions, based on theoretical calculation of high energy particle interaction in the atmosphere, are not consistent with observations made by high altitude neutron monitors at their lowest energies of response of $\gtrsim 1$ GeV (D.F. Smart, private communication 1992).

Resolution of these two problems using data which fills the spectral 'gap' will lead to deeper insights into the acceleration, scattering and propagation of high energy particles by the solar magnetic fields and associated solar wind plasma during GLE and FD. The complete spectral coverage achieved by the addition of a Dome A monitor will significantly enhance this advance.

32.3 MUON TELESCOPE SYSTEM

Galactic cosmic ray modulation in the heliomagnetosphere at energies above 50 GeV can only be studied by ground based and underground muon telescope systems. In the northern hemisphere there are a number of observatories in Japan, North America, C.I.S. and Europe which give very good latitude and energy coverage necessary for the study of anisotropies generated by solar processes. By contrast the southern hemisphere, particularly viewing southward of 15°S, is only covered by observatories in Tasmania and at Mawson to mid-latitudes, and Mawson alone further south. This coverage is reasonable up to 200 GeV but only the Poatina observatory in Tasmania, viewing to mid-southern latitudes, measures up to 500 GeV, necessary to establish the upper limiting energy of solar modulation (Duldig et al. 1985).

A novel approach to an underground system would be to place a telescope in a simple reinforced building under the ice on the polar plateau. A great advantage of such a system would be the perfectly determined overburden of absorber material.

Underground muon telescope sites suffer from poorly determined overburdens with seasonally varying water content, varying structure with depth and varying density of material including water filled or air filled gaps and fissures. As a result it is difficult to correct for seasonal variations of local origin and to accurately determine energies of response. By contrast an in-ice system would not suffer from any of these difficulties. Furthermore, muon systems could operate at the ambient in-ice temperature of $\approx$ -20°C, minimising the problem of the housing sinking into the ice and changing the depth with time. With no structure extending above the flat surface, snow drift accumulation would not affect this distribution of overburden. The only correction necessary to observational data would be for the very slow accumulation of snow over periods of years to decades which would reduce the count rate and increase the energy of response over long timescales.

Such a system has been designed for the South Pole station (Duldig et al. 1985) but could equally well be placed at the Dome A site. Furthermore, a station specifically established for astrophysical research would be expected to include solar observations throughout the austral summer which could be coordinated with the cosmic ray studies on site.

32.4 AIR SHOWER AND ULTRA-HIGH ENERGY γ-RAY ASTRONOMY

A cosmic ray air shower experiment (TeV – PeV energies) already operates at the South Pole (Finnemore et al. 1991). The atmospheric cascades of electrons produced by very high energy cosmic rays and by ultra-high energy (UHE) γ-rays can be discriminated by the shower structures and by the heavier charged particle content of the shower using muon detectors.

There is no point in reproducing the experiment already operating at the pole, however, the increased altitude at Dome A improves the efficiency of such systems and it may be useful to move the south pole system to Dome A once the station is operational.

32.5 GEOMAGNETIC OBSERVATIONS

The invariant magnetic coordinates (epoch 1988) of the Dome A site are 76.6°S, 46°E. Thus the site is just inside the *average* location of the ionospheric footpoint of the cusp location at local magnetic noon (~1345 UT). The probability of overhead aurora on any day is ~75%. Most commonly the aurorae will be low energy electron precipitation ±3 hours from magnetic noon. They will be principally red in colour, diffuse and of low intensity (500 R to 2 kR). At this latitude the aurorae are not strongly dependent on solar activity but are less likely with increasing activity.

During active substorms, the poleward edge of the auroral oval may move across the site during the auroral break-up phase. When this occurs the aurora will be very active, green-white in appearance and intensities may exceed 100 kR. These aurorae are short in duration, generally lasting less than 1 hour and rarely longer than 2 hours. Although relatively infrequent their occurrence is strongly solar cycle dependent.

Sun-aligned quiet areas of low energy and low intensity may be present at almost any time. These electron precipitations may mark the ionospheric boundaries of plasma convection regions.

The Dome A site, in conjunction with South Pole (74.4°S, 18°E magnetic) and Davis (74.6°S, 102°E), would be valuable for monitoring the passage of the cusp region, the generally accepted principal region of interaction between the solar wind and the geomagnetic field.

Conjugacy studies between Dome A and Godhaven (Greenland) would be an excellent pairing for such high latitudes and would rival the South Pole–Frobisher Bay pairing at similar latitude.

Electric field measurements at a fair weather site such as Dome A may help in setting strict limitations on models of the ionospheric dawn-dusk potential applied by the interaction of the solar wind and the geomagnetic field. Studies are underway at South Pole and Davis to see if this phenomenon gives rise to a measurable surface effect. If it does the addition of such observations at Dome A would extend the possible dawn-dusk temporal coverage of estimates of the polar cap potential magnitude.

32.6 CONCLUSION

The Dome A site would be a valuable addition to the worldwide cosmic ray station network. It would be particularly valuable for the studies of heliospheric modulation and particle interactions in the atmosphere.

Studies of galactic cosmic ray anisotropies, unaffected by the heliomagnetosphere, and UHE γ-ray sources could be improved by moving the present South Pole system to Dome A once a station is established.

Research into geomagnetic phenomena with electric field measurements, aurorae and conjugacy observations from the Dome A site will lead to advances in our understanding of the complex interactions between the solar wind and the earth's magnetic field and atmosphere.

32.7 ACKNOWLEDGMENTS

The author wishes to thank Dr Gary Burns for valuable input on the geomagnetic observations possible from the Dome A site.

REFERENCES

Duldig, M.L., Jacklyn, R.M. *and* Pomerantz, M. (1985). A medium rigidity muon experiment for the South Pole station. *Proceedings of the Astronomical Society of Australia 6:48* – 52.

Finnemore, M., Gaisser, T.K., Perrett, J.C., Petrakis, J., Pomerantz, M.A., Stanev, T.S., van Stekelenborg, J.T.P.M., Hillas, A.M., Johnson, P.A., Lloyd-Evans, J., Smith, N.J.T., Reid, R.J.O. *and* Watson, A.A. (1991). Progress report on the point-source search being made with the South Pole air shower experiment. *Proceedings of the 22nd International Cosmic Ray Conference, Dublin 1:*388 – 391.