Balloon measurements of energetic electron precipitation in the vicinity of South Pole Station

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The first balloon measurements of electron precipitation over the geographic south pole were made between 15 December 1985 and 16 January 1986 with launches from South Pole Station. This work was part of a University of Houston/University of Maryland campaign. The University of Houston measured electric fields on all eight payloads and bremsstrahlung X-rays on four, while the University of Maryland measured X-rays on the other four payloads.

This article emphasizes data on precipitating electrons deduced from X-ray measurements made by the University of Maryland on 2 and 3 January, 1986, a geomagnetically active period. The instrument was identical to that used in previous campaigns, consisting of a sodium-iodide scintillator, 7.6 centimeters in diameter, mounted integrally with a suitable photomultiplier. The scintillator had a 25-micron beryllium window and was otherwise unshielded. Energies from 25 to 500 kiloelectronvolts were measured in seven differential channels and an integral channel.

The observed X-rays are produced by electrons precipitating into the atmosphere at altitudes far above the balloon. As these electrons strike molecules in the atmosphere at altitudes above 70 kilometers, they lose energy by a variety of processes, some of which (photoelectric absorption, for example) produce X-rays. These X-rays, categorized as bremsstrahlung (braking radiation), are much more penetrating than the electrons and can reach the balloon altitude of about 30 kilometers, where they are detected and used to deduce the precipitating electron spectrum using thick-target bremsstrahlung theory.

We first consider correlated data during a period of intense prenoon precipitation. Figure 1 shows balloon data together with ground-based data obtained at South Pole Station. Local magnetic noon is 1530 universal time. Observed precipitation is on closed magnetic field lines and is of the type known as dayside aurora. The local-time period within a few hours of magnetic noon corresponds to the magnetospheric region known as the cusp, where the Earth's magnetic field lines curve steeply away either toward the geomagnetic pole or toward the equator. The cusp is a transition region between auroral phenomena (relatively energetic electron precipitation) and polar-cap phenomena (less energetic electron precipitation). South Pole Station is close to the average cusp latitude, but the cusp may not have been overhead at South Pole at the time of observation.

Correlation among all the data is clearly evident. This is also true of the balloon electric field data, which are not shown.

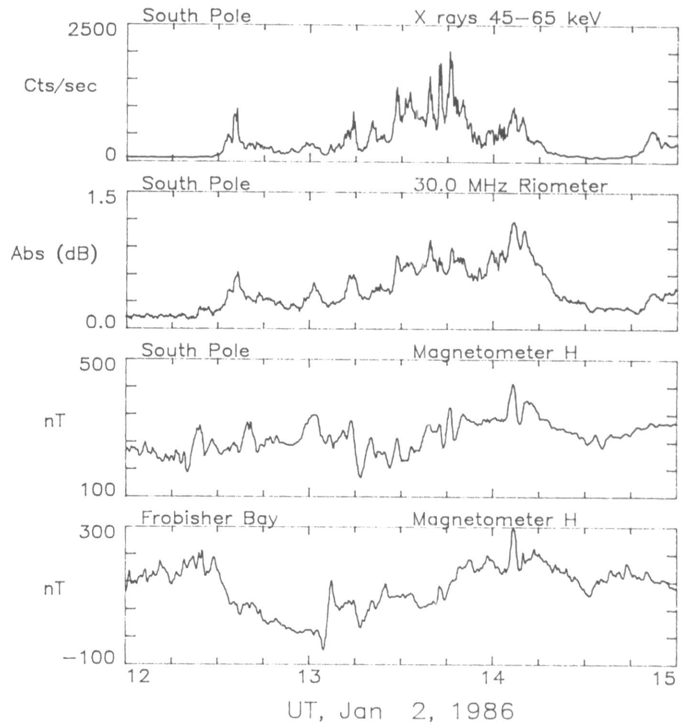

Figure 1. Some correlated data from a balloon, from South Pole Station and from the magnetically conjugate station Iqaluit (formerly Frobisher Bay). ("Cts/sec" denotes "counts per second." "Abs" denotes "absorption." "keV" denotes "kiloelectronvolt." "dB" denotes "decibel." "MHz" denotes "megahertz." "nT" denotes "nanotesla." "UT" denotes "universal time.")

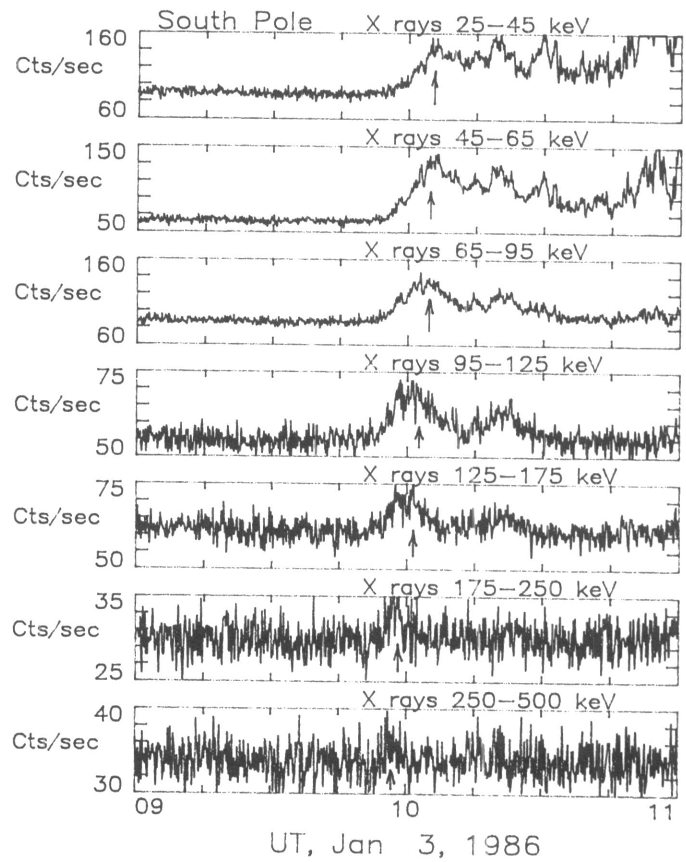

Figure 2. A hard electron precipitation event near 1000 universal time. Peaks mentioned in the text are marked with arrows. ("Cts/sec" denotes "counts per second." "keV" denotes "kiloelectronvolt." "UT" denotes "universal time.")

Power-spectrum analysis shows several well-defined periods in the range 1.4 to 16 minutes (13 to 1.0 millihertz). Such correlations have been previously reported by others, but simultaneous data on electric and magnetic fields and electron precipitation are rare and valuable since they can be used to identify the kinds of waves that are propagating in the magnetospheric plasma.

We have found several examples of very hard—relativistic—electron precipitation, one of which is shown in figure 2. Shortly before 1000 universal time the flux in all channels up to and including the 250–500 kiloelectronvolt channel is visibly above background. The maximum e-folding or characteristic energy at this time is 150 kiloelectronvolts; 200 kiloelectronvolts or more has been observed in other events. To our knowledge this is the first observation of such hard precipitation at so high a latitude, although it is not uncommon in the auroral zone at L-values below 8. Figure 2 further exhibits marked dispersion, that is, the 25–45 kiloelectronvolts electrons peak about 10 minutes later than the 250–500 ones, while intermediate energies peak at intermediate times. From the dispersion one can deduce that some of the observed electrons have drifted in longitude from an injection region, the more energetic electrons drifting faster. A rough estimate shows the injection region to have been around midnight local time, corresponding to an auroral event.

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Relationships of high-latitude geomagnetic variations to interplanetary plasma conditions

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As an extension of the United States program at South Pole Station to study in detail the southern magnetospheric cusp region, we have initiated geomagnetic studies at Iqaluit (formerly Frobisher Bay), Baffin Island, Northwest Territories, Canada. This location is approximately geomagnetically conjugate to South Pole Station under quiet geomagnetic conditions. Both sites are just inside the equatorward boundary of the dayside magnetospheric cusps in their respective hemispheres (see, for example, Wolfe et al. 1986). This research includes studies of the conjugacy of geomagnetic activity at these high latitudes, studies of the conditions under which conjugacy breaks down, and the relationship of geomagnetic variations to energy sources in the interplanetary plasma. This article outlines some recent work related to this last topic.

In both hemispheres, variations in the magnetic field are measured with fluxgate magnetometers over the range from 0.0 to approximately 0.5 hertz. The field variations are measured in three orthogonal components: geomagnetic north-south (H-component), geomagnetic east-west (D-component), and vertical (V-component). At each site the field components, together with system performance parameters, are digitized and written in computer-compatible format on magnetic tape. Instrument noise level is approximately 0.2 nanoteslas; the digitization increment is equal to 0.06 nanoteslas. The magnetic field data are analyzed using a number of statistical techniques, including power spectra analysis.

Presented here are the results of a study of hourly power spectra computed for the H-component magnetic field data acquired at both South Pole and Iqaluit for the 30-day interval 17 July to 15 August 1985. After computing the spectra, the geomagnetic power is calculated over several different bandwidths corresponding, roughly, to frequencies related to hydromagnetic waves in the Earth's magnetosphere. These power levels are then correlated with various interplanetary plasma parameters in order to ascertain possible associations of the power with interplanetary energy sources.

The figure shows that a significant linear relationship is found between ultra-low-frequency broadband power in the Pc 3–5 frequency range (approximately 0.0017–0.05 hertz) observed during local daytime hours at both Iqaluit and South Pole and the solar wind speed. The vertical axes represent hourly magnetic energy densities integrated over the broad period bands 150–600 seconds (Pc 5-left panel) and 20–30 seconds (in the Pc 3 range-right panel). These results are for H-component data acquired during local day hours 10–21 universal time (magnetic local noon is approximately 1530 universal time) for nearly 1 month of simultaneous data. Solar wind speeds were recorded by instrumentation on the IMP8 spacecraft (located in the upstream region). Hourly averages of 1-minute values of these data are plotted on the horizontal axes.

Similar predictive equations (indicated in each panel) are found for the two high-latitude conjugate stations. The linear correlation coefficient $r = 0.4$ is significant beyond the 99.9 percent confidence level for the number $N = 140$ data points used. These conjugate results further substantiate the earlier single station South Pole results using a 3-month data set from 1982 as shown in figures 4 and 7 of Wolfe et al. (1987). It is concluded that near cusp latitudes one dominant source is responsible for dayside ultra-low-frequency broadband power regardless of frequency range, unlike the conclusions reached