Comparison of ground-based and satellite measurements of plasma densities in space

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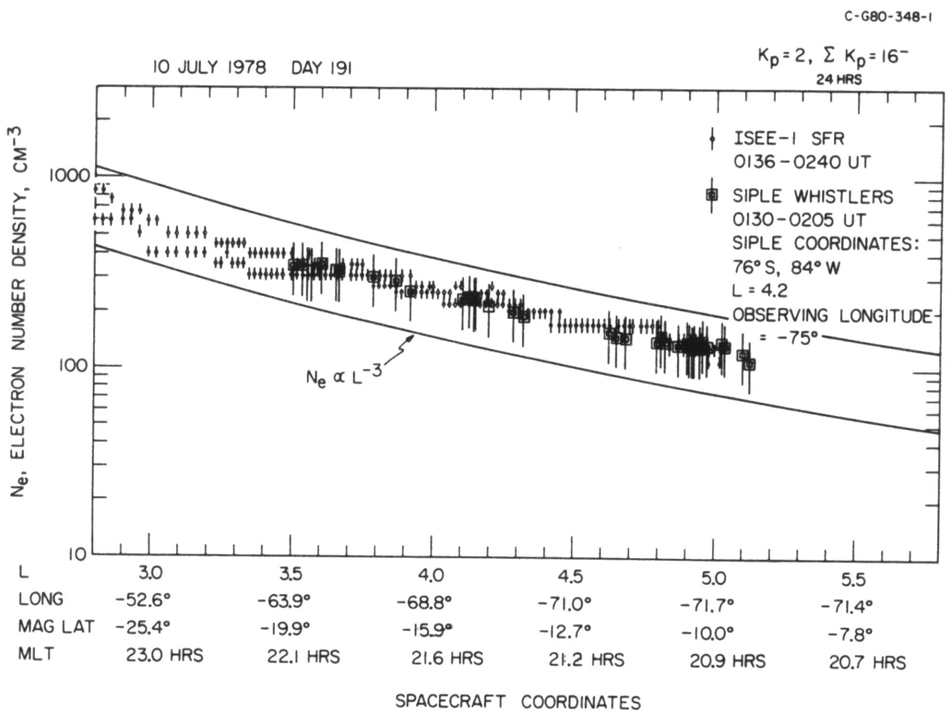
The whistler method has been used for nearly 30 years as a means of estimating the electron density near the magnetic equator (or Neq) at several earth radii geocentric distances (or L). The method depends on measurements of the frequency-time properties of lightning-induced very-low-frequency (VLF) signals that propagate from hemisphere to hemisphere along field-alined ducts of enhanced ionization. A lightning flash may excite many ducts extending to many different earth radii. As a result, a corresponding number of data points on an equatorial profile of electron density may be estimated.

The whistler method might be applied with still greater effect if certain questions of interpretation could be resolved through detailed comparisons with reliable data from spacecraft. Such comparisons are now being made for the first time, based on occasions when the high-altitude (apogee of approximately 21 earth radii) ISEE-1 satellite is in the region threaded by whistlers propagating to Siple and Palmer Stations, Antarctica. The cases studied thus far involve geocentric equatorial radii of approximately 3 to 5.5 R_E; the satellite was within approximately 20° of the magnetic equator and at longitudes within approximately ±15° of the magnetic meridian of the ground station.

A sweep frequency receiver (SFR), fed from a long dipole antenna, is operated by the University of Iowa to survey radio noise activity from 100 hertz to 400 kilohertz. A narrow electrostatic noise band centered on the so-called upper hybrid frequency is regularly present in the records. This noiseband closely approximates the plasma frequency, which in turn provides a measure of electron density at the satellite position.

The figure shows a comparison of SFR and whistler data recorded on 10 July 1978 as the satellite moved inbound near 21 hours magnetic local time. The small fixed circles represent the SFR data, while the open squares represent measurements on several whistlers recorded over a period of about 30 minutes. The profile represents the outer plasmasphere (inside the plasmapause) under relatively calm magnetic conditions. Multivalued SFR data represent upper and lower limiting density values and correspond to regions of noiseband appearance in several adjacent narrowband detectors. The error bars on the whistler data reflect uncertainty in the parameters of a model of the field-line distribution of electrons used in the calculations. There is excellent agreement between the two sets of results and hence a new kind of experimental support for the interpretation of the two measurement techniques.

Prior to these comparisons, it was not possible to compare the density within whistler ducts to the average



Equatorial electron density profiles in the magnetosphere determined from a sweep frequency receiver on the ISEE-1 spacecraft and from whistlers recorded at Siple Station, Antarctica.

density in the surrounding medium. From this example and others it is estimated that the density enhancements in the whistler ducts are no more than 20 to 30 percent above the background, in agreement with earlier theoretical predictions (Smith 1961). The excellent agreement of the profiles over a range of approximately ±15° longitude around the ground station meridian suggests that in the magnetically calm conditions of the time, there were no significant longitudinal or east-west gradients in plasma density. Studies are continuing in which densities will be compared under various conditions of magnetospheric disturbances.

The research at Stanford was supported by National Science Foundation grants DPP 76-82646 and DPP 78-05746.

References

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Cosmic ray intensity variations

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The antarctic cosmic ray stations, located at McMurdo and South Pole, provide crucial observations for investigating a wide range of dynamic features of the "weather" in the heliomagnetosphere which dominates interplanetary space. There have been significant changes recently in our understanding of the processes that occur in the far-reaching extension of the solar corona out to its boundary at about 50 to 100 astronomical units (AU).

The unusual behavior of the galactic cosmic ray flux in the current solar activity cycle has demonstrated the importance of long-term monitoring of the cosmic ray intensity over many solar cycles (each about 12 years). It is a well-established fact that data from antarctic stations have been found to be crucial in almost all of the major discoveries of new modulation phenomena that have been made in recent years.

Last year was no exception; three new types of phenomena were brought to light.

First, a large cosmic ray intensity wave was noted in the data recorded at McMurdo and South Pole Stations several years ago. The period of this strange single oscillation, which was not associated with a classical Forbush decrease, was about 27 hours. Harmonic analysis in universal time (UT) (rather than in local solar time) reveals that the diurnal vector on 27 October 1977, differs significantly from those on other days before and after the event (figure 1). Figure 1 also shows that this oscillation was associated with a geomagnetic storm on 27 to 28 October, as revealed by the abnormally high magnitude of the equatorial ring current (Dst). Subsequent analysis of data from a global network of stations revealed that this oscillation represented an anisotropy in free space, with the apparent source in the direction 80°S 70°W. The largest amplitudes by far were recorded at McMurdo and South Pole Stations. In fact, without the observations at these strategically located sites, this unprecedented event would not have been detected.

Secondly, a power spectrum analysis of the intensity difference between McMurdo and its northern conjugate, Thule, has revealed the presence of a wave with a period of 27 days, as well as its higher harmonics (figure 2). This is the first evidence for an effect of solar rotation upon the anisotropy in a direction perpendicular to the plane of the

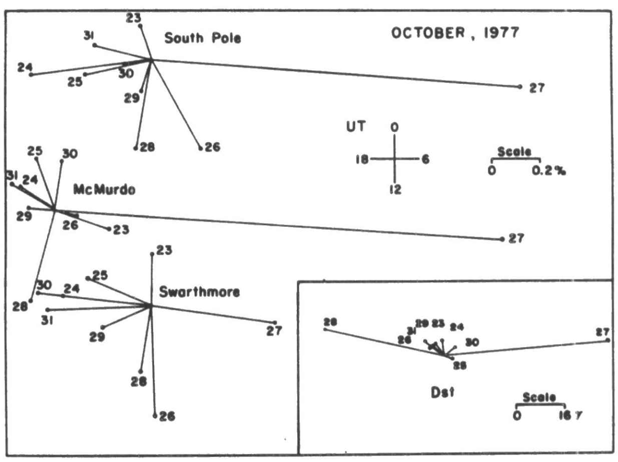

Figure 1. Harmonic dials in universal time, showing the diurnal vectors determined from cosmic ray data recorded at three Bartol stations, two of which are poles and one of which scans the ecliptic planes. A similar clock diagram representing the equatorial ring current (Dst) is shown for comparison.