First simultaneous observations of magnetospheric plasma drifts by the whistler and incoherent scatter radar methods

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A topic of major interest in solar-terrestrial physics is the bulk flow of the Earth's magnetospheric plasma in a direction transverse to the geomagnetic field lines. There are several sources of this flow, a major one being electric fields established through the interaction between the Earth's magnetospheric envelope and the impinging solar wind. Measurement of the flow patterns has proven difficult, partly because of the great size and variability of the magnetosphere. This report describes an initial comparison of results on flows from two ground-based radio probing techniques, the whistler method and the incoherent scatter radar technique (Gonzales, Kelley, Carpenter, Miller, and Wand in press).

The whistler method is based on lightning-induced very-low-frequency (VLF) whistler signals that propagate through the magnetosphere. From measurements of the frequency-time properties of successively recorded whistlers, one obtains information on the time rate-of-change of the equatorial radius of field-alined whistler "ducts" or paths. This radial motion, when projected downward along the geomagnetic field lines to ionospheric heights, corresponds to movement in the magnetically north-south direction.

The incoherent scatter radar technique measures line-of-sight Doppler shifts due to the drift of electron irregularities in the ionospheric plasma. Recently, thanks to the upgrading of facilities at Millstone Hill, Massachusetts, it has been possible to perform radar measurements of the north-south and east-west components of drift near the paths of whistlers observed at Siple Station, Antarctica. Lines in figure 1 show the two alternating directions of the radar beam during a joint experiment with Siple Station on 10 July 1978. The circle shows the estimated region within which the northern hemisphere ends of the whistler paths were located. This region is centered approximately on Roberval, Quebec, the magnetic conjugate station with respect to Siple.

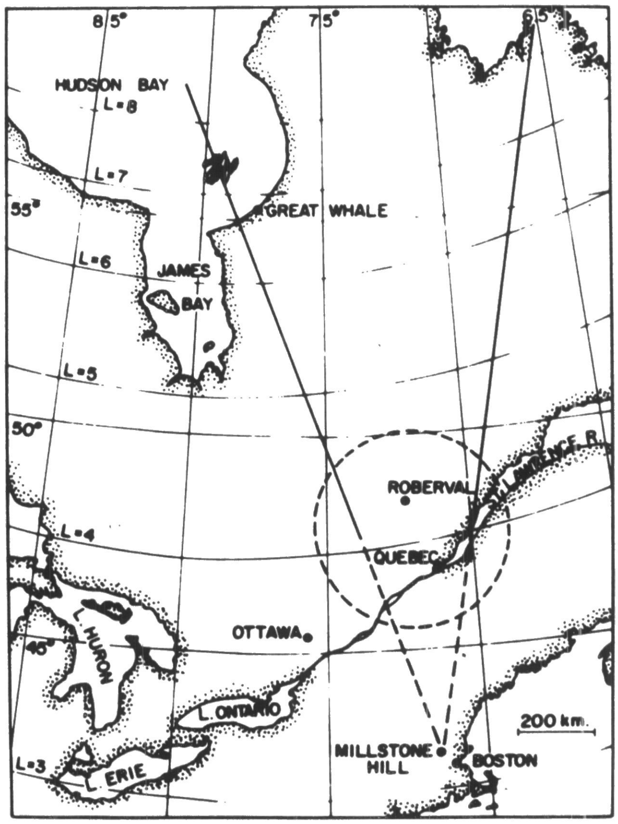

Figure 1. Radar measurements at Millstone Hill (along solid lines) and the estimated whistler viewing area (dashed circle).

The compared results of the experiment are shown in the lower two panels of figure 2. The data represent drifts near field lines extending to 4.4 earth radii geocentric distance. The numbers plotted are in units of an equivalent east-west electric field E_E. Southward flow corresponds to negative E_E. There is a factor of 10 difference in the amplitude scales; this is a mapping factor by which the equatorial data from whistlers and the ionospheric data from the radar would be expected to differ, provided that the geomagnetic field does not vary with time.

The measurements represent time averages over about 20 minutes. There is good agreement both overall and in many

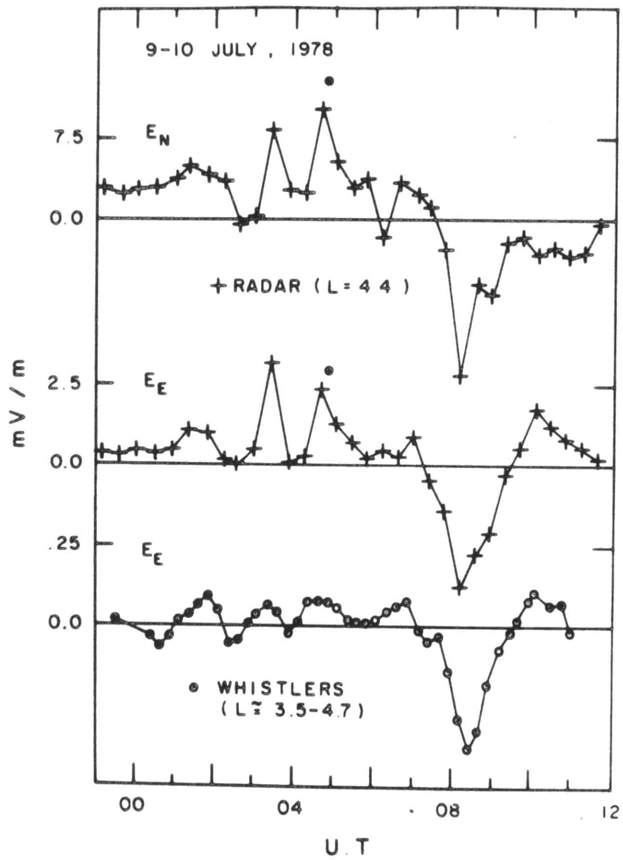

Figure 2. Comparison of radar and whistler data on plasma drifts, plotted in terms of electric fields perpendicular to the local magnetic field in the north direction (E_N) and in the east direction (E_E).

details. Particularly well defined in both data sets is a negative excursion of the fields near 0830 universal time (UT). This event coincided with a magnetospheric substorm disturbance and reveals a number of characteristic features that have been described in previous whistler-based analyses (Carpenter, Park, and Miller 1979). The lack of agreement in amplitude near 04 UT may be due to distortions of the real magnetic field that are not taken into account in mapping the whistler data to the ionospheric level.

The comparison near 0830 UT provides evidence that the compared electric fields were largely potential in nature, at least on the 20-minute time scale of the measurements. These results are providing a basis for further whistler-radar studies of the high and low altitude drift activity.

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Photometrically detected precipitation bursts at the conjugate point of Siple Station

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The precipitation of energetic electrons from the Van Allen radiation belts can result from interactions with electromagnetic waves. Very-low-frequency (VLF) waves generated by terrestrial lightning can propagate along field-alined ducts in the magnetosphere and scatter trapped electrons through cyclotron resonance. Some of the scattered electrons follow trajectories which carry them into the ionosphere where they can collide with ions or neutral constituents, causing further ionization, heat, optical emissions, and bremsstrahlung X-rays.

Observational evidence for wave-induced electron precipitation was first seen as correlations between bursts of VLF noise and X-rays occurring at balloon altitudes over Siple Station (Rosenberg, Helliwell, and Katsufrakis 1971). Precipitation has also been found to cause amplitude perturbations in subionospherically propagating VLF signals (Helliwell, Katsufrakis, and Trimpi 1973) as a result of localized enhancements in ionization.

Correlations between discrete VLF waves and ionospheric optical emissions were first observed at Siple Station in 1977 (Doolittle, Armstrong, Katsufrakis, and Carpenter 1978). The relative arrival times of the waves and precipitating electrons in those events suggested that northgoing