

Siple Station auroral radar results: Yearly averaged doppler velocity and echo occurrence patterns

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From 29 December 1976 until late March 1978, we continuously monitored backscattered echoes from E-region electron density irregularities using two 50-megahertz doppler auroral radars installed at Siple Station (75°55'S/83°55'W). The purpose of this program was to study irregularity characteristics as well as characteristics of the associated auroral electrojet currents and of the electric fields that drive them (Balsley, Ecklund, and Carter, 1977).

Figure 1 shows the antenna configuration at Siple Station. We fixed the south antenna beam at an azimuth of 163° from geographic north and selected three sequential azimuths for the west antenna beam. We performed tentative runs at 251° (A) and 265° (B), and then we fixed the beam at an azimuth of 260° (C). The data presented here are based only on the south antenna beam and the west antenna beam directed at C. Also shown in figure 1 is the aspect angle α at an 110-kilometer altitude.

We recorded received echo power and mean doppler velocity as a function of range on magnetic tape using an online minicomputer. These magnetic tapes have been reprocessed in order to obtain echo occurrence and doppler velocity profiles averaged over the total period from 17 February to 15 November 1977. The results are shown for the south and west echoes in figures 2 and 3, respectively. We insisted that data used in these figures have an echo power exceeding the receiver noise level by at least 1 decibel dB and be an echo event lasting at least 10 minutes. Echoes that met these criteria were averaged over 20-minute periods (± 10 minutes from 0, 20, and 40 minutes following each hour of universal time) for each 60-kilometer range on the south and for each 30-kilometer range on the west. These 20-minute averaged data were subsequently averaged over the complete period 17 February to 15 November. The upper half of figures 2 and 3 shows radial velocity contours of the irregularity motion; the lower half of the same figures ("number of samples") represents the number of echoes that satisfied the above two conditions at each time and range interval.

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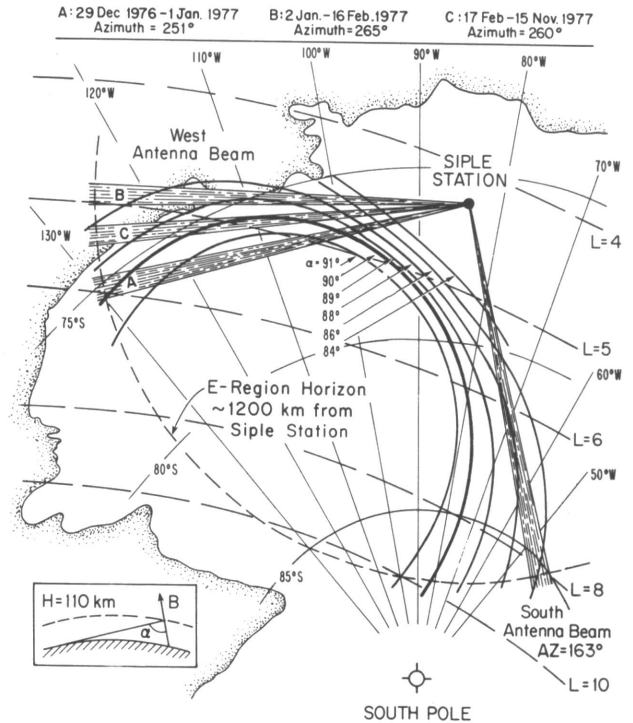


Figure 1. Configurations of two auroral radar beams at Siple Station, with associated aspect angle contours. Key: Aspect angle α = angle between radar beam and undisturbed geomagnetic field vector B at 110 kilometers altitude.

We deduced three basic sets of general characteristics from the results shown in figures 2 and 3:

1. We discerned on both systems two separate times at which echoes occur at maximum rates. Maxima can be seen at about 0700 and 2300 universal time (UT) on the south (magnetic local time [MLT] \approx UT minus 4.5 hours at 700-kilometer range), and 0000 and 0600 UT on the west (MLT \approx UT minus 6 hours at 400-kilometer range). Note that at Siple Station, MLT \approx UT minus 5.3 hours.

2. Generally, the echoes occur over more extended ranges in the morning sector than in the evening sector. At times the south radar detects echoes up to the E-region horizon (about 1,200 kilometers). The maximum occurrence range for the west appears to lie around 480 kilometers. The aspect angle α at this range is 89°, which suggests that the 50-megahertz radar wave is refracted by about 1° on account of high E-region electron density.

3. The radial velocity of the irregularities (mean doppler velocity along the radar beam) generally changes sign around 0200 to 0300 UT. The south system changes from plus to minus (radially inward to radially outward), while the west system changes from minus to plus. While the mean velocity generally tends to increase with increasing range, particularly on the south system, a tendency toward a velocity decrease can be noted at the extreme ranges.

Because the backscattered irregularities move at nearly the velocity of E/B in the direction of $E \times B$ (E = the electric field, Ecklund, Balsley, and Carter, 1977), the

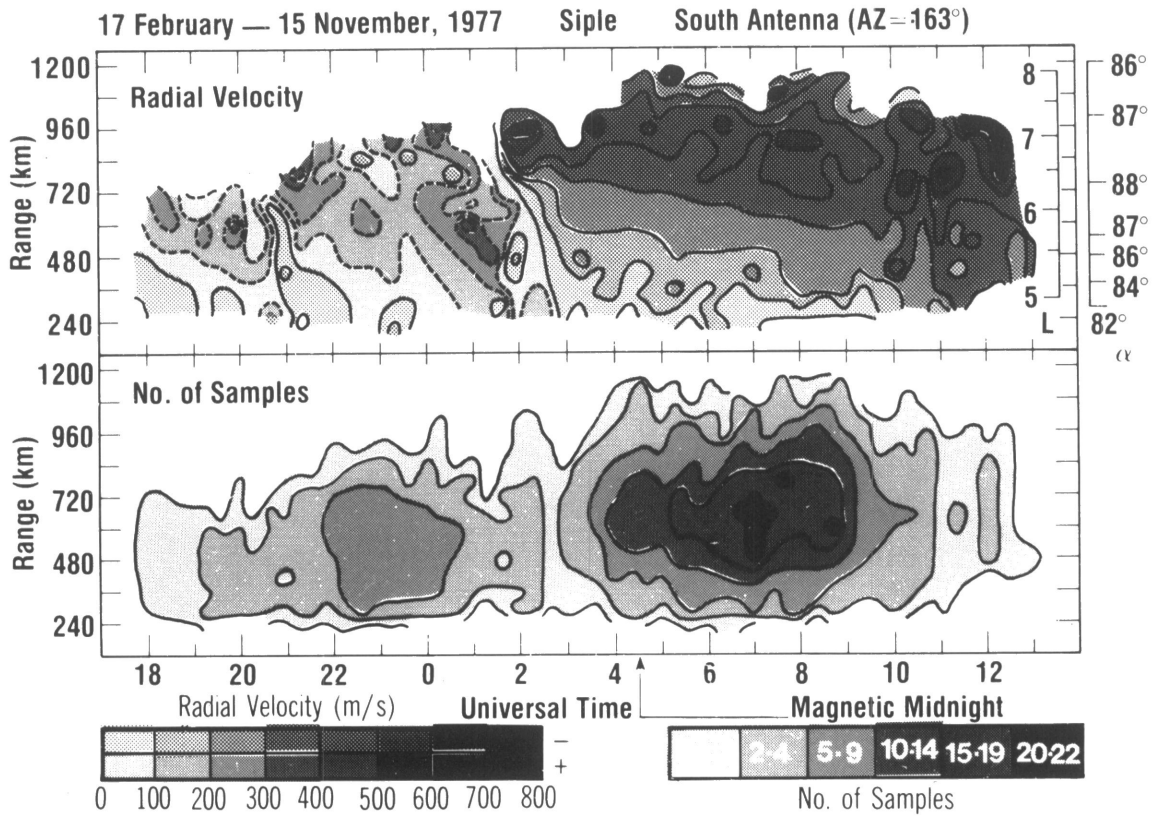


Figure 2. Contour maps for south beam of mean radial velocity and echo occurrence, averaged over the complete period 17 February to 15 November 1977.

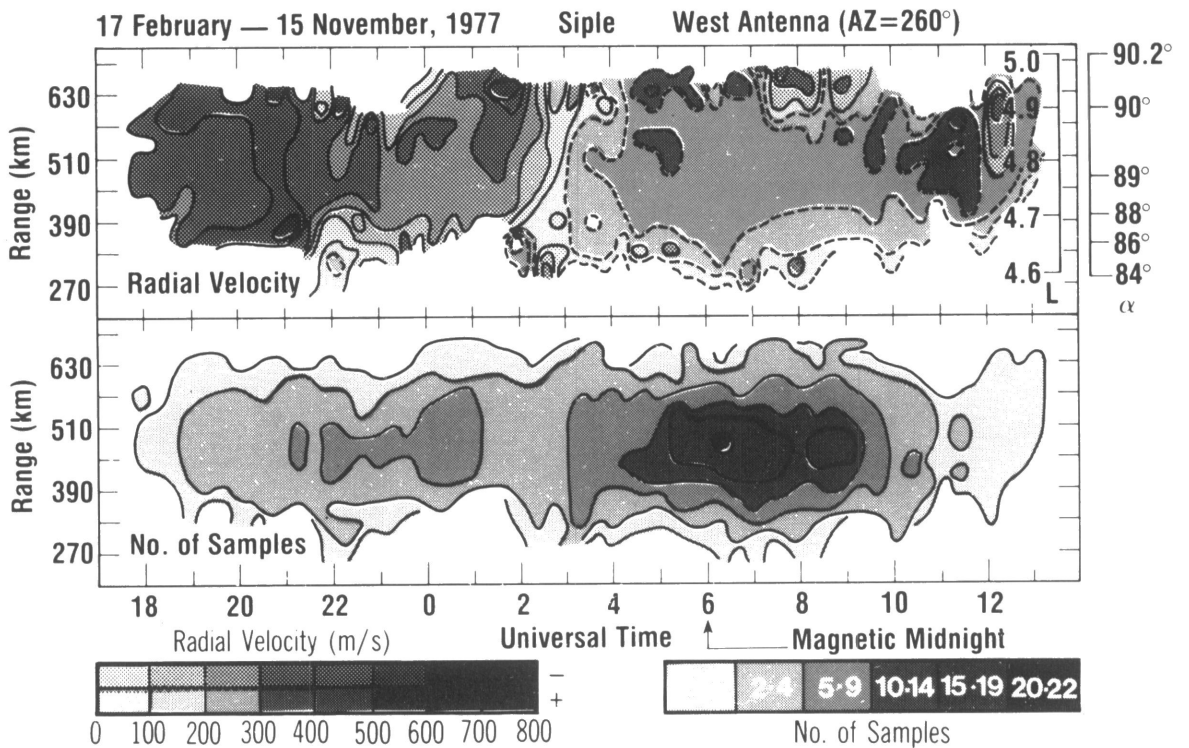


Figure 3. Contour maps for west beam of mean radial velocity and echo occurrence, averaged over the complete period 17 February to 15 November 1977.

results in figures 2 and 3 indicate that E is directed approximately poleward in the evening and equatorward in the morning, following the electric field reversal in the region of the Harang discontinuity (i.e., Maynard, 1974).

These preliminary results show the capabilities of doppler auroral radars for continuously monitoring irregularity morphology as well as electric fields in the polar ionosphere. Utilization of this technique will contribute significantly to ionospheric and magnetospheric physics. Detailed analysis of the Siple Station data is in progress.

Cold plasma diagnostics using ISEE-1 satellite measurements of nonducted VLF waves from Siple Station transmitter

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Signals from the Siple Station very-low-frequency (VLF) transmitter are being measured on satellites to study the physics of the nonlinear cyclotron resonance interaction that occurs between coherent VLF whistler mode waves and energetic electrons in the magnetosphere. In this interaction, the perturbing waves can be amplified by as much as 30 decibels, VLF emissions can be produced, and the resonant energetic electrons can be scattered into the atmospheric loss cone, eventually precipitating into the lower ionosphere to produce X-rays, optical emissions, and plasma density enhancements (Helliwell and Katsurfakis, 1974).

An understanding of the nonlinear whistler mode cyclotron interaction is essential to achieve a full understanding of the mechanisms that control the lifetimes of energetic particles in our own magnetosphere as well as that of other planets such as Jupiter, in our solar system, which possess a significant planetary magnetic field.

It has been confirmed by experiment that the energetic electrons involved in the nonlinear cyclotron interaction are two to three orders of magnitude less dense than the electrons of the relatively cold background plasma that pervades all regions of the magnetosphere. Thus, a number of the interacting coherent wave's characteristics, such as dispersion and group velocity, are controlled to a large extent by the cold plasma rather than the energetic component. In most cases, therefore, it is necessary to determine the cold plasma distribution in the interaction region to isolate the controlling factors in the wave-particle interaction.

This program has been supported by the National Science Foundation under grant DPP 77-21827.

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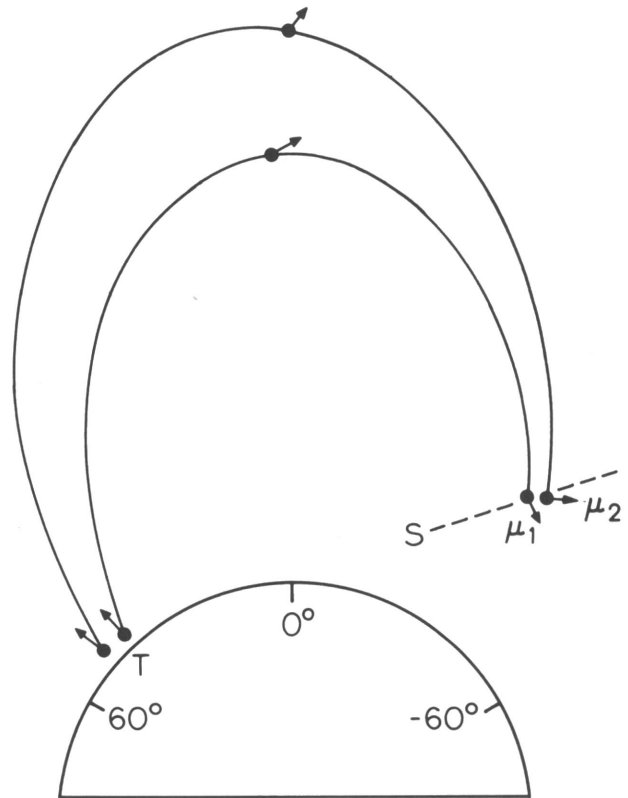


Figure 1. Example of simplified case in which transmitter pulses can reach satellite position along two separate ray paths. Waves are injected with vertical wave normals (arrows) near transmitter (T) location. Innermost ray lies in region of moderate cold plasma density gradients; outermost ray lies in region of negligible cold plasma density gradients. Local refractive index (μ_1) for waves on innermost path is much smaller than that (μ_2) for outermost path on account of dependence of μ upon normal wave direction.

One well-known method for determining the cold plasma distribution in the interaction region is the measurement of the dispersion of ducted signals, such as whistlers and Siple pulses, over their field-aligned paths. This powerful technique has yielded much of the knowledge we presently possess concerning the cold plasma