Estimation of vector velocity field using an array of closely-spaced ISR measurements

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The Poker Flat Incoherent Scatter Radar (PFISR) is the first dedicated ISR to employ an electronically steerable array. By repointing the beam on a pulse-by-pulse basis, the instrument can gather observations in multiple directions in rapid succession, effectively generating a regional "snapshot" of the ionospheric state at a given moment. The state parameters include both electron density patterns and Doppler velocity estimates.

In this paper, we use this "imaging" capability to develop a method of estimating the time-evolution of a vector velocity field in the upper atmosphere. Since a single radar measurement can only provide line-of-sight (LOS) velocity, the velocity vector is usually resolved by making three independent observations and performing a least-squares fit to a model determined by the geometry of the measurements. In place of this strictly geometric approach, the present technique is guided by fundamental physical principles relating the array of LOS measurements generated by PFISR to an underlying scalar potential pattern. This potential field is used along with the magnetic field to compute the $\vec{E} \times \vec{B}$ drift velocity over the domain of the measurements.

A time-sequence of such flow fields can be used to characterize when and how local velocity shears occur. This information can be brought to bear against theoretical predictions about the phasing between variations in the electric field (manifested in the velocity field) and particle precipitation (manifested in the ionization patterns) during ionospheric substorms.