SAPS: A New Characterization for Sub-Auroral Electric Fields

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Subauroral electric fields play critical roles in energizing and transporting ring current ions as well as convecting thermal plasma in the inner magnetosphere and in the mid to low latitude ionosphere. A number of terms have been employed to describe the subauroral electric fields and many of these have specific associations with processes established through their prior use in the literature. The continued use of descriptive terms such as penetration electric fields, polarization jets, or sub-auroral ion drifts, has the potential for generating misunderstanding, especially when comparing the broad/narrow, persistent/transient regions of sub-auroral electric field and plasma flow. An inclusive name for these phenomena is Sub-Auroral Polarization Streams (SAPS).

Electric fields often appear in regions of low ionospheric conductivity equatorward of auroral electron precipitation associated with increased coupling of the interplanetary medium to the terrestrial magnetosphere-ionosphere system. *Galperin et al.* [1974] was the first to report strong, poleward-directed electric fields driving sunward plasma convection at sub-auroral latitudes in the evening local time sector and called them polarization jets (PJ). Similar intense, latitudinally narrow structures are usually referred to as sub-auroral ion drifts (SAID) [*Spiro et al.*, 1979]) in the US literature. Broader regions of sunward plasma drift, equatorward of and separated from the evening auroral convection cell, have been described by *Yeh et al.* [1991]. Although those sub-auroral disturbance electric fields have features similar to those of SAID/PJ structures, their large latitudinal extents and long durations are distinctive characteristics.

In March 2002 an informal workshop convened at MIT's Haystack Observatory to discuss characteristics, causes and effects of sub-auroral electric fields. The two-dozen participants included specialists in particle and field observations, space plasma imaging, M-I coupling and magnetospheric modeling. It was agreed that a single, well defined term is needed to describe regions of electric field and sunward plasma convection in the sub-auroral ionosphere. Spatially narrow (SAID/PJ) electric field structures may or may not be apparent within such regions. A new name, Sub-Auroral Polarization Streams (SAPS), was agreed upon to encompass these phenomena, the SAID/PJ structures and the broader regions described by *Yeh et al.* [1991].

The phenomena discussed in this article are illustrated in Figure 1. These data were acquired during a dusk sector pass of the Defense Meteorological Satellite Program Flight 13 (DMSP F13) satellite to the west of the Millstone Hill incoherent scatter radar near 01:00 UT on April 12, 2001 during disturbed (Kp = 7+) geomagnetic conditions. The top two panels of the figure show radar measurements of the westward component of plasma drift and the ionospheric plasma density at ~500 km, respectively. (Westward **E**x**B** plasma drift is driven by a northward electric field.) The middle panels show directional differential fluxes of downcoming auroral electrons and ions with energies between 30 eV and 30 keV (these delineate the auroral precipitation region). The bottom panel gives the westward component of plasma velocity measured by the ion drift meter on F13. All data are plotted as functions of invariant magnetic latitude. For convenience we have marked different regions mentioned in this note.

The radar velocity measurements show two broad regions of strong sunward convection. The more equatorward of these is coincident with a deep ionospheric density trough and a region of low overall ionospheric conductivity. Attention is drawn to the vertical line near 58^o marking the equatorward boundary of auroral electron precipitation. Measurable westward drifts extend from the auroral boundary to <45^o, delineating the broad extent of the SAPS. Strong (> 1 km/s) drifts centered near 53^o, collocated with the deepest plasma density trough, have the characteristics of a SAID/PJ structure. (Note that features observed near the dusk meridian by F13 are displaced poleward by ~2^o from counterparts detected by the radar. This shift in latitude is a local time effect that was previously noted in radar measurements [*Yeh et al.*, 1991] and is required to maintain current continuity across conductivity gradients near the dusk meridian [*Nopper and Carovillano*, 1978].)

Large potential drops imposed on the magnetosphere and polar ionospheres by the solar wind-driven convection electric fields are the ultimate drivers of the SAPS. Region 1 field-aligned currents (FACs) drawn from the interplanetary generator flow near the poleward boundary of the auroral oval; into the ionosphere on the dawn side and out of the ionosphere on the dusk side [*Iijima and Potemra*, 1976]. The potential distribution required to satisfy Ohm's Law spans the global ionosphere, is adjusted to reflect ionospheric conditions, and maps back into the magnetosphere along magnetic field lines [*Nopper and Carovillano*, 1978].

The electric fields associated with SAPS energize ring-current particles and transport them into the inner magnetosphere. Large pressure maxima develop in the nightside magnetosphere. Misalignments between gradients in plasma pressure and magnetic flux tube volume cause Region 2 FACs to flow into/out of the ionosphere evening/morning sector [*Harel et al*., 1981]. A fraction of Region 2 FACs flow into regions of low ionospheric conductivity at sub-auroral latitudes where large polarization electric fields, needed to maintain current continuity, drive rapidly drifting plasma polarization streams. Within the region of strong plasma drifts frictional heating enhances ionospheric recombination rates [*Schunk et al.,* 1976], accelerating the reduction of ionospheric conductivity in the channel. In turn, the intensity of polarization electric fields increases, leading to still deeper ionospheric troughs. Although Region 2 FACs at sub-auroral latitudes are usually small, low ambient plasma densities result in feedback which increases the polarization electric fields and decreases ionospheric conductances, enhancing the strength of the SAPS.

SAPS events may continue well into the recovery phase of a geomagnetic disturbance, after Region 1 currents subside. This reflects the long time required for the ring current pressure gradients to come into alignment with gradients in flux tube volume. As long as such misalignments persist, they drive Region 2 currents that require large polarization electric fields across the deep conductivity troughs developed during periods of maximum activity.

Measurements from Millstone Hill and from four the DMSP satellites operating during the April 2001 event indicate that sub-auroral plasma drift features, similar to that shown in Figure 1, extended from dusk across the night sector to at least 03 local time and appeared at conjugate locations in both hemispheres. Both the radar and DMSP satellites observed this SAPS event continuously for more than eight hours. The distribution in latitudes of plasma drifts indicates that about 35% of the –87 kV potential in the evening convection cell was equatorward of the auroral oval. For such disturbed events, the SAPS electrodynamic structures involve a significant fraction of the available potential, cover a large area in the global ionosphere, and persist for many hours.

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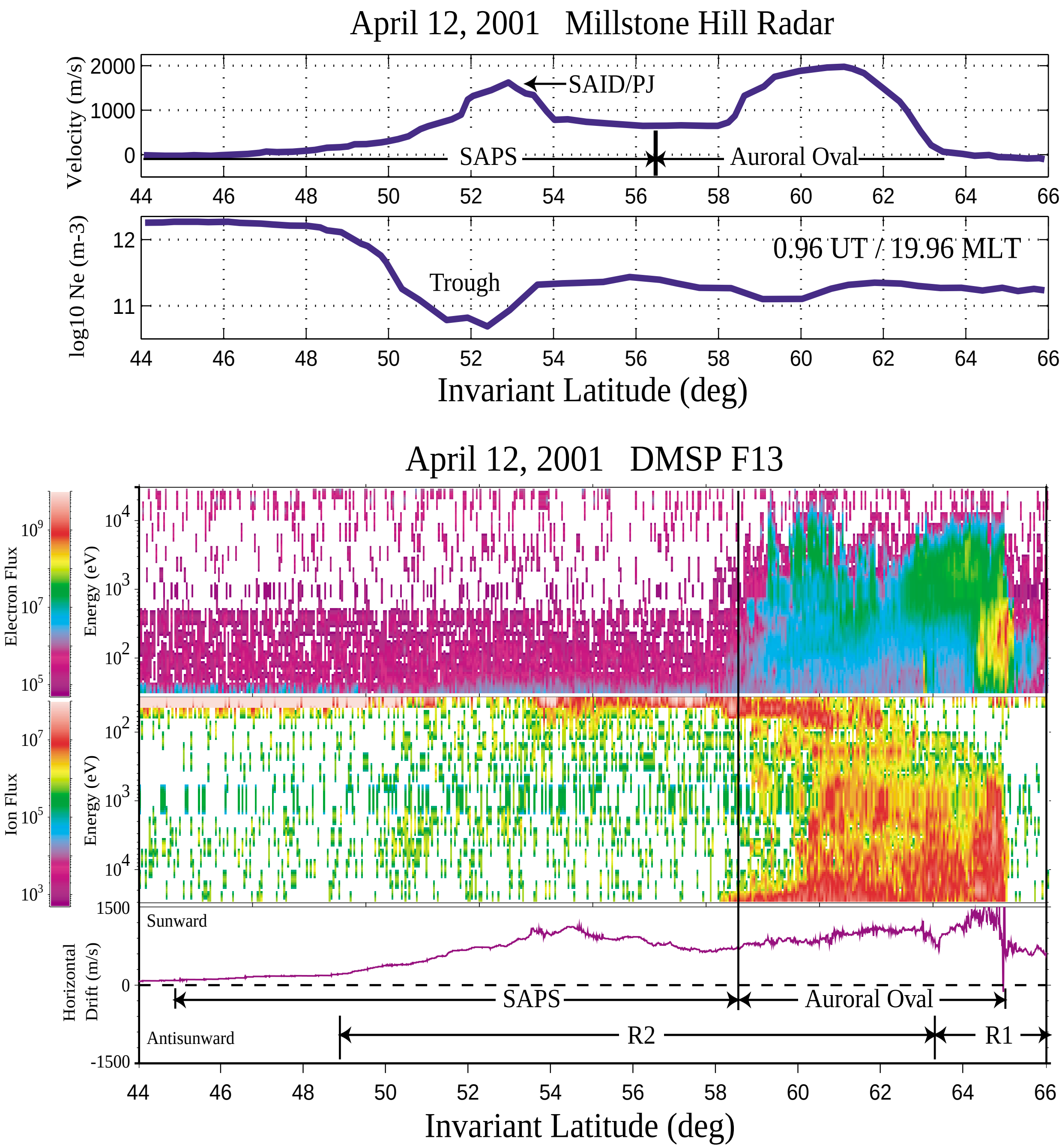

Figure 1. Simultaneous radar and *in situ* measurements of auroral and SAPS plasma characteristics acquired during a dusk overflight of the Millstone Hill incoherent scatter radar by the DMSP F13 satellite near 01:00 UT on April 12, 2001. The sub-auroral polarization stream (SAPS) is seen as a broad region of sunward plasma convection centered at 53˚Λ.