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Seasonal and solar-cycle variations of propagating polar wind jets

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Abstract

Polar cap patches are regions of enhanced ionospheric density that form in or equatorward of the dayside cusp. The ion density within a patch can be from a few percent to a factor of 100 greater than that in the surrounding ionosphere. These often circular or cigar-shaped regions vary from about 200–1000 km across in the horizontal direction. Plasma density within a patch varies with altitude in a manner that is qualitatively similar to that exhibited by the ionosphere generally. Once a patch forms, it moves in the antisunward direction across the polar cap at the prevailing convection speed. A time-dependent, three-dimensional model of the coupled ionosphere and polar wind system has been used to simulate the passage of a "representative" plasma patch across the polar region. It is found that the enhanced O^+ densities within the patch region lead to enhanced H^+ densities as well. The enhanced H^+ densities result in an enhanced H^+ flux to the magnetosphere within the horizontally convecting patch region, a situation that can be described as a propagating polar wind jet. Such propagating jets of plasma have been simulated for both solar maximum and minimum conditions, for both summer and winter, and for a range of geomagnetic activity levels. It is found that polar wind jets can remain a cohesive and prominent feature of the polar wind outflow for several hours. However, the relative importance of jets to the overall polar wind outflow depends strongly on the assumed geophysical conditions.

Keywords: Polar wind; High-latitude; Plasma patch; Simulation

1. Introduction

During periods of southward interplanetary magnetic field (IMF), it is common for localized regions of enhanced O^+ density, called plasma patches, to appear in the dayside auroral region near local noon or just equatorward of this region (Buchau et al., 1983; Weber et al., 1984; Valladares et al., 1994; Crowley, 1996; Schunk and Nagy, 2000; and references therein). Once formed the plasma patches convect in the antisunward direction across the polar region at the same speed as the ionosphere generally (~100 m/s to 2 km/s). Plasma patches occur for all seasonal, solar cycle, and geomagnetic conditions, but they appear most often during times of elevated geomagnetic activity. The degree of plasma density enhancement in a patch varies over a wide range, from a few percent up to a factor of 100 greater than the background ionospheric density. Horizontally, plasma patches range from about 200 to 1000 km across and are often roughly circular or

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cigar-shaped. The vertical distribution of plasma within a patch is similar to that which normally occurs along a high-latitude field line, with a density peak occurring in the 300–400 km range.

The formation of plasma patches has been attributed to a number of different physical processes. Kelley et al. (1982) presented evidence for the direct production of plasma patches by structured soft electron fluxes, while other authors (Quegan et al., 1982; Foster, 1984; Buchau et al., 1985) have proposed that patches are produced by solar ultraviolet radiation in the sunlit region equatorward of the cusp. Anderson et al. (1988) have demonstrated that a sudden expansion of the convection pattern can transport high-density plasma from the sunlit ionosphere into the polar cap. Subsequent contraction of the convection pattern isolates the high-density blob. Lockwood and Carlson (1992) proposed that enhanced flows due to flux transfer event (FTE) signatures in the cusp could transport high-density plasma into the polar cap. Tsunoda (1988) attributed plasma patch formation to sudden changes in the IMF *By* and *Bz* components. In a computer simulation study, Sojka et al. (1993) were able to create plasma patches by temporally varying the magnetospheric electric field (ionospheric convection) inputs to their computer models. The convection variations imposed by Sojka et al. (1993) on their models were similar to naturally occurring convection variations that result from changes in the IMF *By* component for southward IMF. Valladares et al. (1994) proposed that plasma patches can be produced by the sudden occurrence of a fast convection stream on the dayside near noon.

Recently, Schunk et al. (2005) have used a time-dependent three-dimensional model of the coupled ionosphere–polar wind system to simulate the passage of a representative plasma patch across the polar region and its effect on the polar wind

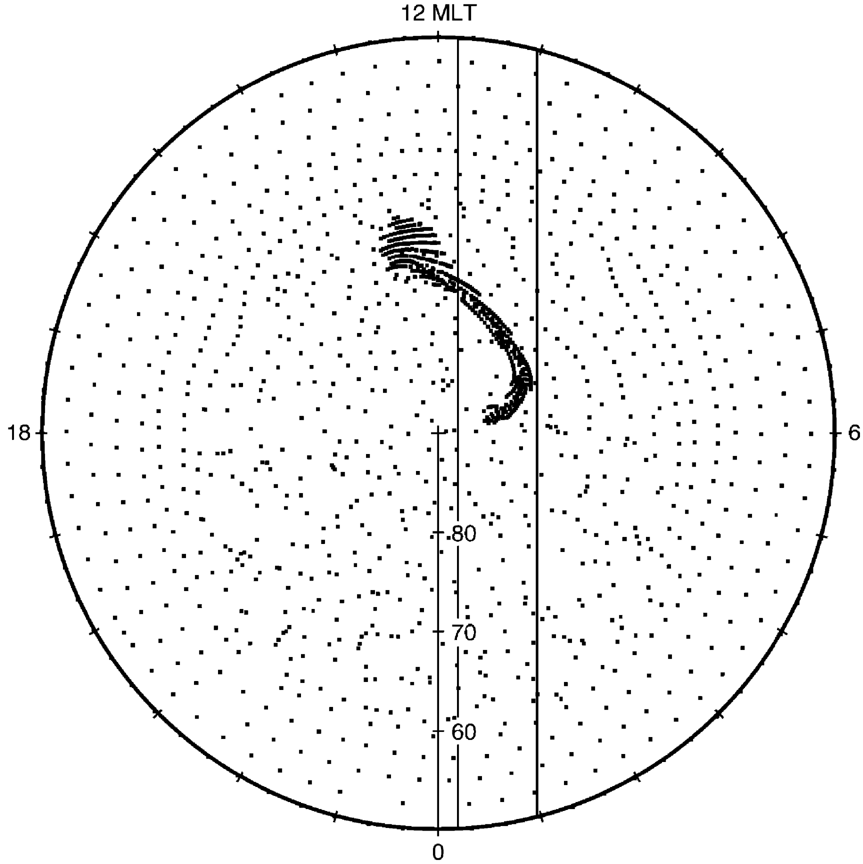

Fig. 1. Location (magnetic latitude and longitude) at 0500 UT of the approximately 1500 flux tubes simulated in each case considered in this study. The region of densely packed dots represents the location of the plasma patch at 0500 UT, which is 1 h after the plasma patch was imposed.