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Equatorward evolution of auroras from the poleward auroral boundary

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ABSTRACT

An all-sky imager installed at the midnight sector in Dawson City (66.0° in geomagnetic latitude) recorded the equatorward evolution of auroras from the auroral poleward boundary. The auroras evolved as shear layers expanding southeastward with velocities of 1–4 km/s, referred to as N-S auroras, and occurred during the transient intensification of the convection electric fields in the nighttime magnetosphere, as inferred from an electron spectrogram at geosynchronous altitudes. A continuous increase in the inclination angle of the field lines and magnetic field perturbations associated with propagating ionospheric loop currents were observed in the auroral zone during the N-S auroras. Simultaneously, Pc4 pulsations were observed at low latitudes from night to day sectors. We conclude the following: (1) the N-S auroras are an auroral manifestation of the earthward drift of plasma sheet electrons in the equatorial plane associated with transient and localized convection electric fields; (2) the Pc4 pulsations are produced in the magnetosphere by plasma sheet ions in the plasmasphere. The localized convection fields produce a vortical motion of plasmas in the equatorial plane, which may initiate the N-S auroras and ionospheric loop currents in the auroral zone.

1. Introduction

The equatorward drifts of auroras (referred to as north-south aligned auroral structures or “N-S auroras”), auroral streamers, and north-south arcs (N-S arcs) have all been tentatively identified as auroral manifestations of the earthward transport of plasmas from the plasma sheet (Nakamura et al., 1993; Henderson et al., 1998; Sergeev et al., 1999; Nishimura et al., 2010). The N-S aurora is preceded by an intensification of the arc at the poleward auroral boundary and thus directly indicates plasma flows across the boundary between open and closed magnetic field lines (de la Beaujardlere et al., 1994; Lyons et al., 1999).

As a leading edge of the flow burst in the midnight magnetosphere, the dipolarization front transported plasmas from the tail (Runov et al., 2009). The dipolarization front propagating earthward was interpreted in terms of bubble theory (Birn et al., 2004). The plasma tube (bubble) enters into the inner magnetosphere and stops when its entropy equals that of the surrounding flux tubes (Dubyagin et al., 2010). The ionospheric flow observations by SuperDARN radar of the N-S auroras suggest that the streamer is an auroral manifestation of the plasma bubble (Gallardo-Lacourt et al., 2014). The dipolarization front, in turn, is accompanied by transient, localized electric fields, which can accelerate and transport plasmas toward the inner magnetosphere in a manner consistent with the injection's inward penetration (Gabrielse et al., 2012).

In the inner magnetosphere, the inward plasma transport can be interpreted in terms of the inward motion of the separatrix between the open and closed drift trajectories of the particles. The inner boundaries of the open trajectories approached the earthward direction as the convection electric fields increased in association with the geomagnetic activity level. Thus, the convection electric fields transport the plasma sheet plasmas into the inner magnetosphere as a function of the particle species, energy, local time and geomagnetic activity level. The drift trajectory model confirms the electron and ion observations along the geosynchronous orbit (Korth et al., 1999). The earthward transport of the plasma sheet plasmas was more or less transient, lasting no more than a fraction of an hour, and was observed by the sharp increase of the upper cutoff energies of the plasma sheet electrons (Thomsen et al., 2002). Assuming that the transient convections are more or less localized in narrow ranges of local time, the earthward propagating dipolarization front, activation of auroras at the poleward auroral boundary, and transient convection in the magnetosphere are all correlated with the N-S aurora. In this report, we present a case study of a N-S aurora that demonstrates the above-mentioned relationship. The MI coupling (magnetosphere and ionosphere coupling) associated with the N-S aurora is discussed by using ground magnetometer data from the auroral

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1364-6826/

Table 1
Geographic and geomagnetic coordinates of ground stations.

Station name	Geographic		Geomagnetic	
	Latitudes	Longitudes	Latitudes	Longitudes
BRW (Barrow)	71.3	203.4	69.2	245.0
CMO (College)	64.9	212.1	65.1	260.3
DWS (Dawson City)	64.1	220.7	66.0	269.3
SIT (Sitka)	57.1	224.7	60.2	279.2
FSI (Fort Simpson)	61.8	238.8	67.2	290.7
CNX (Chiangmai)	18.8	99.0	8.1	170.0
GUA (Guam)	13.3	144.5	4.5	214.9
ANC (Ancon)	−12.1	289.0	−1.3	0.4
TER (Teresina)	−5.0	317.2	4.5	28.5
MOK (Mokolo)	10.4	13.5	11.1	86.9

zone stations. We also studied the ground magnetometer data of low latitudes to infer possible responses of the plasmasphere to the transient convection.

2. Observations

2.1. 09 January 1994 event

In this study, we used fluxgate magnetometer data from the high-latitude ground stations of Barrow (BRW), College (CMO), Dawson City (DWS), Fort Simpson (FSI), and Sitka (SIT) in the Alaskan sector, as well as the very low latitude stations of Chiangmai (CNX) in Thailand, Guam (GUA) in the western pacific, Ancon (ANC) in Peru, Teresina (TER) in Brazil and Mokolo (MOK) in Cameroon, as well as electron and ion spectrograms from the magnetospheric plasma analyzer (MPA) on board the geosynchronous satellite (1989-046). The geosynchronous satellite was located at 195° in geographic longitude, 1.7-h west of Dawson City in local time. In one 10-s spin repeating roughly every 3-min, the MPA instrument measures hot plasma moments of from 100 eV to 40 keV for ions and from 30 eV to 40 keV for electrons (Birn et al., 1997). The auroras were observed by the all-sky imager using a panchromatic CCD imager installed at hilltop locations at an altitude of 1070 m near Dawson City. The MLT difference between the optical station and the magnetometer station in Dawson City can be ignored. The geographic and geomagnetic coordinates of the ground magnetometer stations are listed in Table 1.

Fig. 1 depicts the N-S aurora in the midnight sector (01:01 MLT) occurring at 11:40 UT January 09. The figure includes, from top to bottom, an ion and electron spectrogram from geosynchronous orbit, the angle of field line inclinations (90° for vertical) measured at the auroral zone stations, and a keogram from 500 km south to 800 km north of Dawson City. The energy-time spectrogram in the first through third panels shows an increase in the ion and electron energies in the range of 10^3 to 10^4 eV, correlating to the onset of the N-S aurora. A sharp increase of the keV electron fluxes observed at 11:37 UT for the southward-looking quadrant (e^-S) is

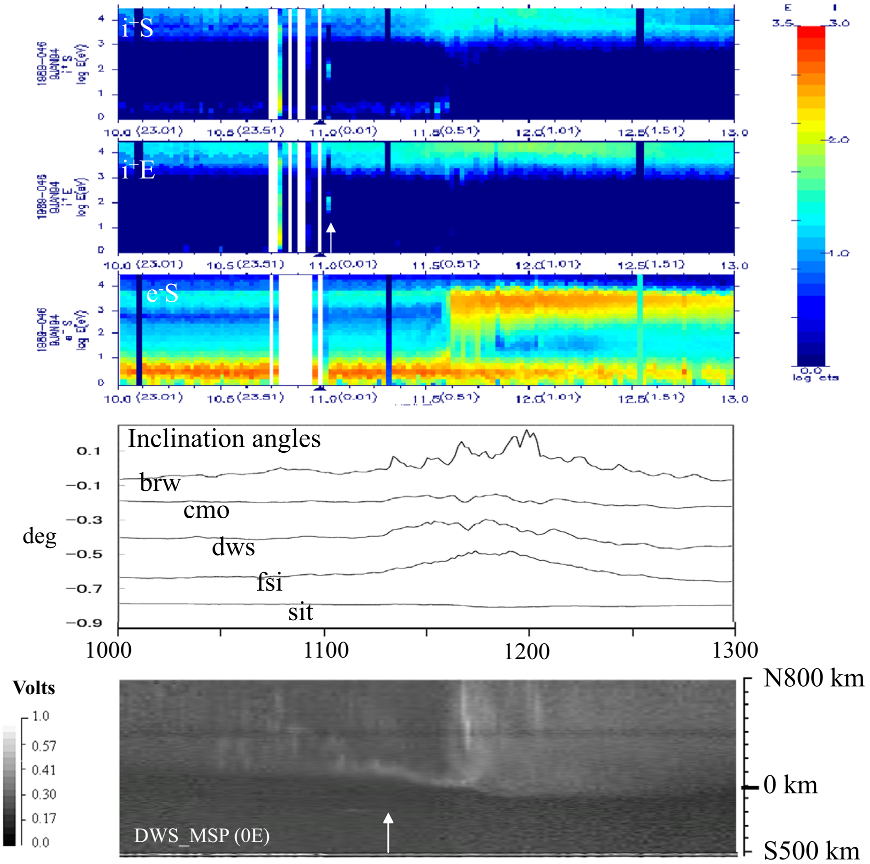

Fig. 1. From top to bottom: 3-h plots from 10:00 to 13:00 UT for 09 January 1994, showing the ion spectrogram from the southward-looking quadrant (i^+S), ion spectrogram from the eastward-looking quadrant (i^+E), electron spectrogram from southward-looking quadrant (e^-S) of 1989-046 at geosynchronous altitudes, field line inclinations of five stations in the auroral zone (BRW, CMO, DWS, FSI, and SIT), and a keogram along the geomagnetic meridians over the optical station (DWS) from 500 km south to 800 km north. The N-S aurora (fourth panel) occurred at 11:40 UT (01:06 MLT). Inclination angles relative to 80.6° for BRW, 77.1° for CMO, 77.4° for DWS, 80.3° for FSI, and 73.8° for SIT were plotted in the second panel. The auroral gray level is plotted to the left in volts, where three pieces of polygonal line conversion were used to suppress high and low voltages. The arrows in the spectrogram (i^+E) and keogram indicate an initial increase of the ion flux (11:02 UT) and the start of the equatorward drift of the proton aurora (11:20 UT), respectively.