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Published Version

GEOPHYSICAL RESEARCH LETTERS, VOL 17, NO. 11, PAGES 1877-1880, OCTOBER 1990

PERIODIC AURORAL EVENTS AT THE HIGH-LATITUDE CONVECTION REVERSAL IN THE 16 MLT REGION

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Abstract. Combined optical and radar observations of two breakup-like auroral events near the polar cap boundary, within 74-76° MLAT and 1210 - 1240 UT (roughly 1540 - 1610 MLT) on 9 Jan. 1989 are reported. A two-component structure of the auroral phenomenon is indicated, with a local intensification of the pre-existing arc as well as a separate, tailward moving discrete auroral event on the poleward side of the background aurora, close to the reversal between well-defined zones of sunward and tailward ion flows. The all-sky TV observations do not indicate a connection between the two components, which also show different optical spectral composition. The 16 MLT background arc is located on sunward convecting field lines, as opposed to the 12-14 MLT auroral emission observed on this day. Although the magnetospheric plasma source(s) of the 16 MLT events are not easily identified from these ground-based data alone, it is suggested that the lower and higher latitude components, may map to the plasma sheet boundary layer and along open field lines to the magnetopause boundary, respectively. The events occur at the time of enhancements of westward ionospheric ion flow and corresponding eastward electrojet current south of 74° MLAT. Thus, they seem to be very significant events, involving periodic (10 min period), tailward moving filaments of field-aligned current/discrete auroral emission at the 16 MLT polar cap boundary.

Introduction

The identification of the ionospheric signatures of the different magnetospheric boundary layer phenomena, including pressure pulses, Kelvin-Helmholtz waves and transient magnetic reconnection, is a major objective, since good information on the spatial and temporal evolution of the ionospheric "footprints" is essential for the understanding of the respective boundary layer processes and the associated magnetosphere-ionosphere coupling.

Combined satellite and ground-based observations can be used to identify the different plasma populations and the corresponding signatures in the auroral ionosphere (e.g. Sandholt et al. 1989-b,c). It is pointed out that the different discrete auroral structures/activities on the dayside, separated in latitude and longitude, may map to different magnetospheric flow shear zones such as the cusp/mantle boundary, the interface between the low-latitude boundary layer (LLBL) and the central plasma sheet (CPS), and the plasma sheet boundary layer (PSBL).

It has been suggested that the LLBL/PS boundary on the dusk flank can be Kelvin-Helmholtz unstable and the source of field-aligned currents/auroral activity in the evening sector during substorms (Rostoker and Eastman, 1987) and that auroral bright "spots" closer to magnetic noon may also be caused by such a mechanism (Lui et al., 1989).

In this paper EISCAT ion drift observations are combined with optical observations from Svalbard of certain auroral events near the polar cap boundary at 16 MLT that are in some respects similar to the dayside breakup event phenomenon reported earlier (Sandholt et al., 1989a; Sandholt et al., 1990a), although they may well belong to a separate category of phenomenon. The near 16 MLT events reported here are part of a long sequence of events within 0830-1300 UT (1200-1630 MLT) on 9 Jan. 1989 (see Lockwood et al. 1990b and Sandholt et al. 1990b concerning observations before 1210 UT).

Observation techniques

The optical observations were obtained by a 4-channel meridian scanning photometer system and two all-sky TV cameras, one ISIT (intensifier-silicon-intensifier target) camera with maximum sensitivity between 400 and 500 nm and a CCD (charge-coupled device) camera with 630.0 nm filter, operated at Ny Alesund, Svalbard (cf. fig. 1). The meridian scanned by the photometers (approximately the magnetic meridian) every 18 seconds as well as the useful field of view of the cameras (a circle of radius 500 km) are marked in figure 1.

The ion drift observations were obtained by operating the EISCAT UHF radar in the beam-swinging mode "Polar" (version SP-UK-POLH) that permitted drift vectors to be derived at 25 gates within 71-78°

Paper number 90GL01321
0094-8276/90/90GL-01321$03.00

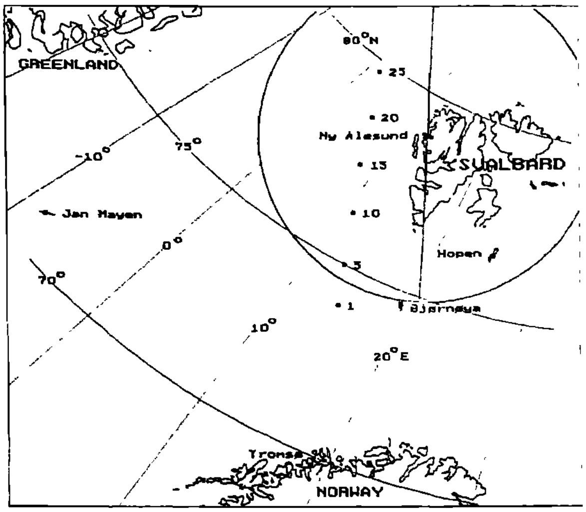

Fig. 1. Map including Svalbard and North Norway with the sites of the EISCAT radar (near Tromsø) and the optical installations in Ny Alesund (see text).

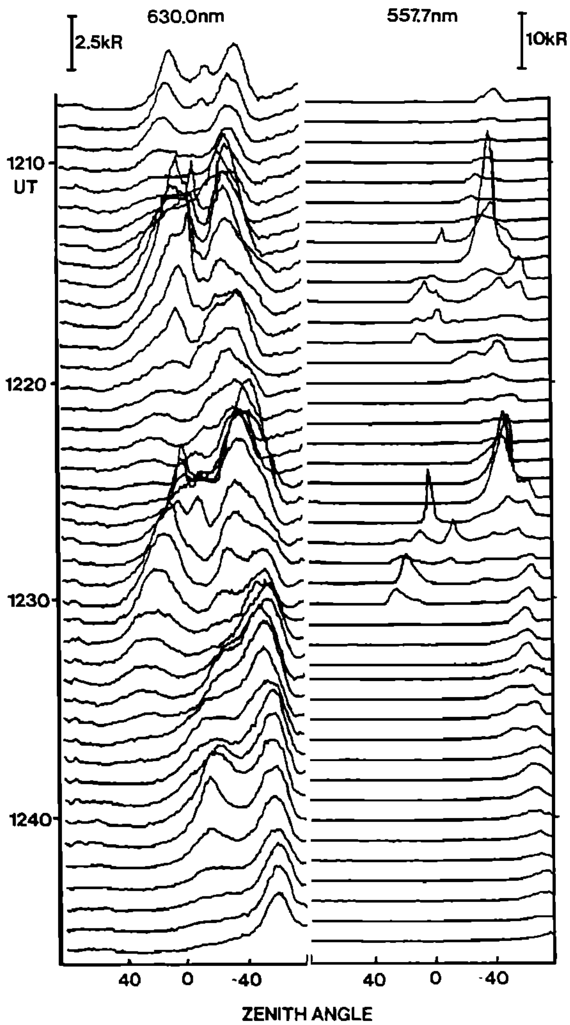

Fig. 2. Stacked auroral scanning photometer traces for the wavelength channels 630.0 and 557.7 nm.

invariant latitude every 2.5 min. The locations of drift vector gates 1, 5, 10, 15, 20, and 25 are marked in figure 1; i.e. midway between the two azimuths on the same L-shell. The longitudinal separation of the corresponding gates at the two azimuths increases from 220 km for gate 1, up to 565 km for gate 25.

The EISCAT flow data are derived using the beam-swinging technique which makes assumptions about the temporal and spatial variability of the flow in the radar field-of-view (Willis et al., 1986). Specifically, it is assumed that the flow is uniform between the two beam directions employed and that it varies linearly with time over each 5-minute beam-swinging cycle. Field-perpendicular flow vectors are derived every 2.5 minutes from the post-integrated line-of-sight velocities for each 130 seconds dwell at each azimuth, i.e. data are three-point running means of 2.5 min. resolution observations. Both the above assumptions on temporal and spatial variability may be locally invalid during transient, localised auroral events like those described in this paper (cf. Lockwood et al., 1990b). However, gross features, like the convection reversal boundary, should be accurately reproduced.

Data presentation

Figure 2 shows stacked photometer traces of auroral emissions at 630.0 and 557.7 nm, respectively, for the time period 1205-1240 UT (~ 1535-1610 MLT) on 9 Jan. 1989. We concentrate on two auroral events that are separated by approximately 10 minutes, each consisting of two components at different latitudes. The most equatorward intensification in each case (near 1214 and 1225 UT) occurs within the persistent background aurora. The other component is well separated from the background emission, on the poleward side. As seen by the ISIT camera (sensitive to discrete emissions including that at 557.7 nm) the latter consists of an east-west elongated sheet-like entity with rays in it which expands rapidly eastward (tailward). In both these cases the most equatorward intensification started a few minutes before the brightening at higher latitude.

Figure 3 shows a sequence of 2-second averaged ISIT all-sky TV images of discrete auroral forms within 122300-123000 UT covering the second of the two major cases in figure 2. Notice the intensification of the background emission in the south at 1225 UT and the narrow, elongated structure that appeared in the west at 122600 and expanded rapidly eastward until 122700 UT. Another eastward expanding rayed form is seen within 122800 - 122900 UT.

The ion drift vectors obtained by the EISCAT radar during 1205 - 1245 UT are shown in figure 4. The boundary between

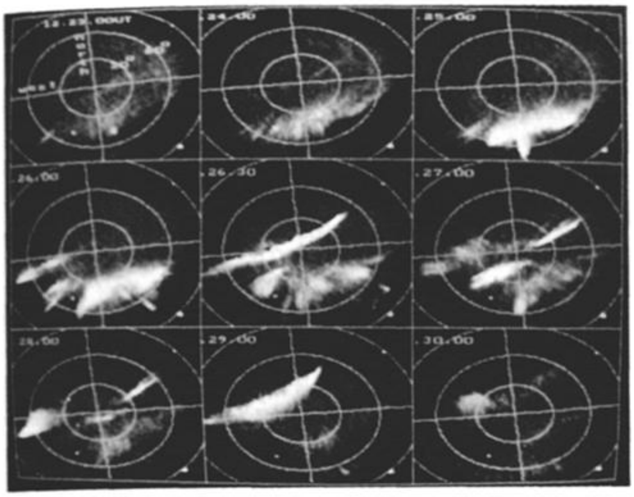

Fig. 3. 2 s integrated all-sky TV picture sequence of discrete auroral forms within 122300 - 123000 UT in zenith angle geographic azimuth coordinates.

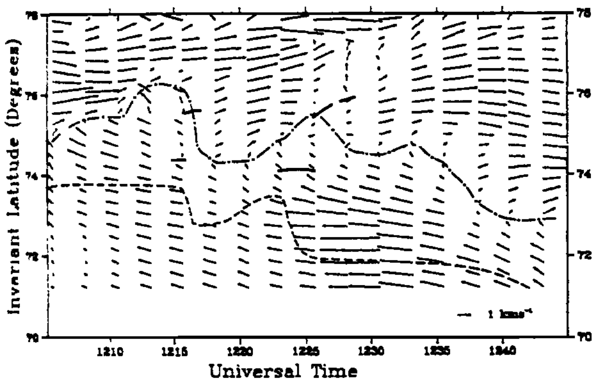

Fig. 4. Ion drift vectors at 25 range gates within 71 -78° invariant latitude (cf. figure 1) and relationship with auroral observations (see text).

predominantly eastward flow in the northern part of the radar field of view and the westward flow to the south has been marked by a dot-dash line. The dashed line at lower latitudes mark the equatorward boundary of the persistent 630.0 nm aurora displayed in figure 2. The transformation from zenith angle to invariant latitude is based on an assumed emission altitude of 250 km of the 630.0 nm aurora. The transient auroral events within 1215 - 1220 and 1224 - 1230 UT are indicated by solid lines, assuming an altitude of 150 km of the lower border of the discrete forms.

The poleward boundary of the persistent aurora (not marked in the figure) is found to be located close to the convection reversal during large parts of the interval. This indicates that the main part of the persistent auroral arc is associated with sunward convecting magnetospheric plasma.

The initial, equatorward component of the transient events is located south of the convection reversal whereas the higher latitude structure appears close to the convection boundary.

Discussion

It has been suggested that large-scale waves on the LLBL/PS boundary may modulate precipitating electrons that are already present from the LLBL . Such modulations may give rise to periodic auroral events, preferentially in the ~ 13-15 MLT sector (cf. Potemra et al., 1990; Sandholt et al., 1990b). Rostoker and Eastman (1987) suggested that episodes of enhanced momentum density produced by bursts of magnetotail reconnection is adequate to produce Kelvin-Helmholtz waves over an azimuthally limited portion of the dusk sector CPS/LLBL interface.

One problem with the Kelvin-Helmholtz and pressure pulse theories (cf. Southwood and Kivelson, 1990) in relation to the present cases is that they both predict vortical ion flow patterns which are not resolved in the radar data, possibly due to the limited temporal and spatial resolution of the beam-swinging technique. In addition, the local magnetograms does not show evidence of vortical ionospheric convection structures.

The observed discrete auroral activity near the 16 MLT polar cap boundary may map to the plasma sheet boundary layer (PSBL) instead of the LLBL/PS boundary (cf. Vasyliunas, 1979; Heelis et al., 1980). Notice from figure 2 that the background arc, containing a significant green line intensity in addition to the red line, is located on sunward convecting field lines. This is different from the 12-14 MLT events observed this same day when the background 630.0 nm aurora was associated with eastward (tailward) ion flow (Lockwood et al., 1990b).

The two spatially separated components of the auroral events, located at different sides of the convection reversal, with different optical spectral composition (cf. figure 2), may indicate that two different plasma sources are involved. It is recognized that the higher latitude events appear and move poleward and duskward along the polar cap boundary, while the lower latitude event is more stationary, i.e. a local intensification of the background aurora. The all-sky pictures do not indicate a direct connection between the two components.

The enhanced westward flow and eastward electrojet activity that are observed to accompany the events are taken to be signatures of enhanced momentum transfer from the magnetosphere. Because of the uncertainties in the possible location of a reconnection X-line at the magnetopause and in field line mapping it is not clear whether the flow enhancement at 16 MLT is driven by reconnection at the dayside magnetopause or in the geomagnetic tail (Lockwood et al., 1990b). It is noted, however, that optical structures similar to the poleward component of the present events are observed near midday and in the post- and prenoon sectors during negative IMF B_z (Sandholt et al., 1990a). The dayside breakup sequence consists of transient auroral structures which form near the equatorward edge of the background stable cusp or cleft aurora, propagate poleward and fade away after 2 to 10 minutes. In general they don't show the two-component structure that is indicated in the 16 MLT events, although similar structure has been observed also near midday. They were found to strongly resemble the expected ionospheric signatures of time-dependent dayside reconnection. IMF data are not available for the present case (R. Lepping, personal communication, 1990).

Although the plasma sources of these auroral events are not easily identified, they seem to be very significant events, i.e. ionospheric signatures of plasma dynamics in the corresponding magnetospheric boundary region (boundary waves or reconnection process); the coupling with the ionosphere giving rise to periodic (10 min period) filaments of tailward moving field-aligned current/discrete auroral emission at the 16 MLT polar cap boundary.

Acknowledgments. The authors are grateful to B. Holmeslet and A. Brekke, University of Tromsø for provision of the magnetometer data. We also thank A.D. Farmer and V.N. Davda for radar controling and plotting software, respectively, for the EISCAT data, A. Egeland for organizing the optical observation program on Svalbard, B. Lybekk for processing the optical data and T. Oguti, Nagoya University, for cooperation on TV camera observations in Ny Alesund. We thank the Director and staff of EISCAT for their assistance: EISCAT is supported by research councils of France (CNRS), West-Germany (MPG), Norway (NAVF), Sweden (NFR), Finland (SA), and the UK (SERC). Thanks are also due to the Norwegian Polar Research Institute and NAVF for the support to the optical observation campaign at Ny Alesund.

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(Received February 20, 1990;
revised June 4, 1990;
accepted June 8, 1990.)