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PENETRATION OF THE MAGNETOSPHERIC CONVECTION ELECTRIC FIELD TO SUBAURORAL LATITUDES BY OBSERVATIONS OF THE DIFFUSE AURORA, SAR ARC AND IONOSPHERIC DRIFT

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Abstract. The first results of the comparison of subauroral luminosity dynamics in emission 557,7 and 630,0 nm with simultaneous measurements of the ionospheric drift in the F2 region with a digisonde DPS-4 at the Yakutsk meridian (CGMC: 55-60° N, 200° E) at Kp =2-6 are presented. It is shown from the analysis of individual events that during magnetospheric convection intensification after turning of the IMF B_z to the south the equatorward extension of diffuse aurora takes place. At the same time, the westward ionospheric drift velocity increases both in the diffuse aurora region and much equatorward of it because of the occurrence of the northward polarization electric field.

1. Introduction

Until recently in the literature the attention has been focused on the phenomenon termed as a polarization jet [Galperin et al., 1974] or SAID (subauroral ion drifts) [Spiro et al., 1979]. These are polar orbiting satellite observations of a narrow strip of westward plasma drift at a height of F2 layer with a velocity up to 2 km/s and more in the vicinity of plasmapause projection during substorms. Based on the last classification of data from the Millstone Hill incoherent scatter radar [Foster and Vo, 2002], it has been found that during geomagnetic disturbances at Kp ≥ 4, a region of the westward plasma drift equatorward of auroral precipitations in the MLT night sector has a latitudinal extent which is much larger than in SAID. Therein this phenomenon, earlier considered in [Yeh et al., 1991], is termed as a subauroral polarization stream (SAPS). The basic penetration regularities of convection electric field to plasmasphere latitudes at Kp=1-6 have been shown earlier as well as by the data from the Millstone Hill incoherent scatter radar by Wand and Evans [1981]. Lyatskaya and Kuznetsov [1990] found the relation of the height dynamics of regular ionization layer F2 (azimuth component of the electric field) at middle latitudes to an increase of the IMF southward component. The authors [Ievenko et al., 2001] revealed the recurring features of penetration of the convection electric field to the plasmasphere latitudes in the dynamics of F2 layer ionization in the region of diffuse aurora (DA) and SAR arc during substorms. The detail analysis of DA and SAR arc dynamics during substorms is presented in [Ievenko, 1994, 1999]. In the present paper we report on the preliminary results of the comparison of subauroral luminosity dynamics in 557,7 and 630,0 nm emissions with simultaneous measurements of the ionospheric drift in the region F2 at the Yakutsk meridian during the intensification of the magnetospheric convection and substorms at Kp=2-6.

2. Methods and Results of Complex Observations

Observations of the diffuse aurora (DA) and SAR arcs in 557,7 and 630,0 nm emission are performed with a digital meridian-scanning photometer at the Maimaga optical station (CGMC: 57°N; 200°E). Ionospheric parameters and plasma drifts in the region F2 are measured with a digital ionosonde DPS-4 at the Yakutsk station (CGMC: 56°N; 200°E). 15.40 UT corresponds to the midnight MLT at the Yakutsk meridian. To determine the time intervals when the magnetospheric convection is enhanced, the measurements of the IMF and solar wind (SW) velocity from ACE spacecraft are used (*http://www.srl.caltech.edu/ACE/ASC/level2/index.html*). For this purpose, the optical and ionospheric data were related to the Ey-component of the SW electric field ($V_x \times B_z$) in the GSM coordinate system. The identification of time intervals for a substorm expansion phase was made by magnetograms at the Kanoya low-latitude station (CGMC: 24,6°N; 203°E) (*http://swdcwww.kugi.kyoto-u.ac.jp/index.html*). The Doppler-technique of ionospheric drift measurements with the digisonde DPS-4 is described in [Reinisch et al., 1998]. DPS-4 in the regular regime determines the drift direction and velocity for all reflections (sources) received by the antenna system with a circular diagram at zenith angles 0-50°. To obtain information about the ionospheric plasma drift at different latitudes, we used the program, which allows us to select the sources both in the zenith region of the sounding station and in the northern or southern parts of the sky. We have carried out the analysis of spectrophotometric and ionospheric observations on March 3, 4, 6, 28, 30 and 31, 2003 under conditions of weak and moderate magnetic activity (Kp =2-6). Two examples of complex observations at the Yakutsk meridian are presented below.

Figures 1-2 (from top to bottom) demonstrates: (**a**) the variation of the Ey-component of the SW electric field with due account of the transport time ΔT from the ACE spacecraft up to X_{GSM} = 0. The region of positive (westward) Ey is shown grey; (**b**) the meridian-scanning photometer data in the form of isophotos of the surface brightness of 557,7 and 630,0 nm emissions in projection on the Earth's surface for the luminosity heights of 110 and 450 km, respectively (keograms). The vertical lines show the latitudinal ranges (1) and (2), for which the longitudinal component of the drift was determined by Doppler measurements at the Yakutsk station. The scales of emission intensities in grey gradations are on the right. Z-is the zenith of observation station; **(c)** the graphs of the longitudinal component of ionospheric drift velocity for the latitudinal ranges of 55-57° (1) and of 57-60° (2). The heavy arrows at the bottom mark the onset time of substorm expansion phase.

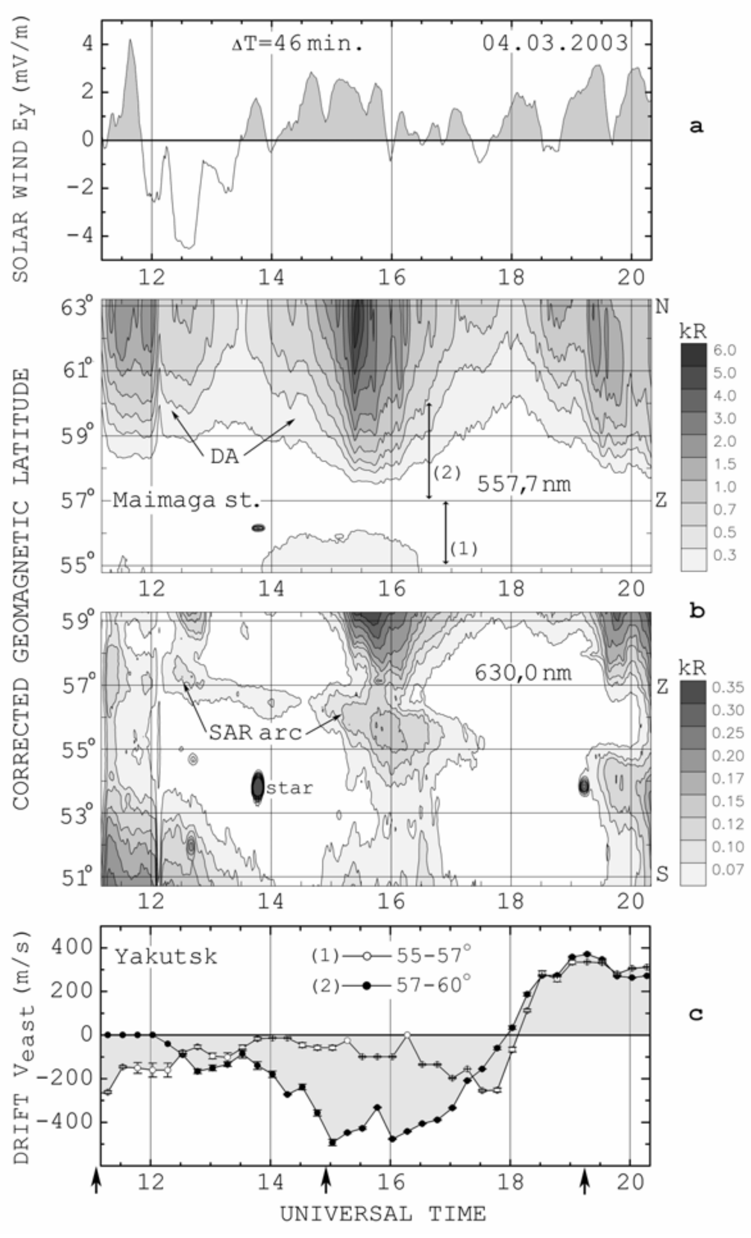

Fig. 1. The example of observations of the DA dynamics and ionospheric drift on March 4, 2003 when the weak SAR arc is observed in the vicinity of the Yakutsk zenith from evening hours MLT (Kp =4-3, Dst =-20-10 nT). (Designations see in the text.)

An example of observations of DA dynamics, SAR arc and ionospheric drift on March 4, 2003 under the moderate geomagnetic activity is presented in Fig. 1. The beginning of optical observations coincided with the onset of a substorm expansion at 11.10 UT by magnetograms of the Kanoya station (the first arrow at the bottom of Fig. 1c). At this time, the scanning photometer registered the brightness of DA in the northern part of the sky and the occurrence or increase of a SAR arc intensity in the vicinity of the observation station zenith (see the keograms in emissions of 557,7 and 630,0 nm in Fig. 1b). It is seen from Fig. 1c that in the vicinity of the Yakutsk zenith there was no increase of ionospheric drift velocity during the substorm expansion phase (see graph 1). At that time at latitudes 57-60° (in the DA region) there were no reflections that the drift velocity might be determined. Further, after 12 UT, the IMF Bz- component is positive and the activity in DA subsides. From 13.35 UT the brightening of DA and its equatorward extension begin again after Bz IMF southturn (Ey is westward) at 13.30 UT. At the same time, an increase of westward drift velocity of the ionospheric plasma begins at latitudes 57-60° in the equatorial region of DA. By the time of second substorm expansion phase onset at 14.54 UT, the DA equatorial boundary in the 5577 nm emission reaches the latitude of ~58°. During substorm expansion phase, the DA and SAR arc intensity increases. At this time the SAR arc is observed in the vicinity of the Yakutsk zenith (Fig. 1b). The plasma westward drift velocity at latitudes 57-60° reaches ~ 500 km/s at ~ 15 UT and changes slightly during the substorm expansion phase (graph. 2 in Fig. 1c). In the vicinity of the Yakutsk zenith (latitudes 55-57°), starting from 13.45 UT the digisonde does not register the regular layer F2, which suggests the formation of the ionization trough in the SAR arc region. According to Doppler measurements with a small number of sources, during the substorm expansion phase, the ionospheric drift velocity at these latitudes does not change either, being not in excess of 100 m/s (graph.1 in Fig.1c). After ~ 16 UT the westward Ey in the SW sharply decreases. Starting from this moment, the DA intensity decreases, and the ionospheric drift velocity in the equatorial region of DA decreases too. From ~ 18 UT under the next increase of SW Ey, the DA again extends to the equator and the ionospheric plasma drift velocity increases up to ~ 400m/s but in the eastward direction. In this case, the digisonde

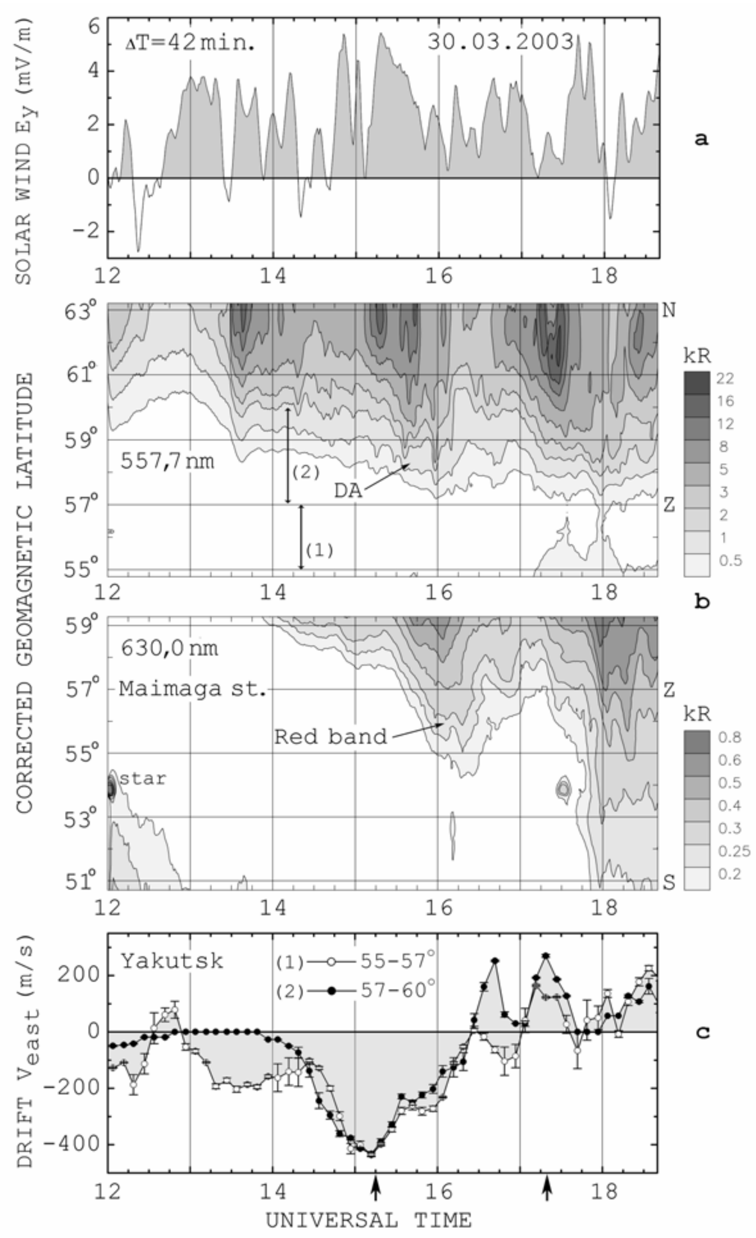

Fig. 2. Dynamics of the DA and ionospheric drift at the Yakutsk meridian in the period of magnetospheric convection intensification and during a substorm on March 30, 2003 (Kp = 4-5, Dst =-15-30 nT).

registers a wide drift band at the latitudes of 55-60°. An increase in DA and SAR arc intensity starts from ~ 19.15 UT, being coincident with the expansion phase of the next substorm.

The second example of complex observations on March 30, 2003 with higher level of the westward SW Ey is presented in Fig. 2. In the period of westward Ey enhancement, starting from 12.40 UT, the DA extends to the equator, with the westward ionospheric drift velocity increased up to ~ 200 m/s in the vicinity of the Yakutsk zenith. At latitudes 57-60° at ~ 12-14 UT the digisonde does not measure the drift velocity, because there are no reflections at the corresponding zenith angles. During the following increase of Ey from ~ 14.40 UT, the drift velocity increases up to ~ 400 m/s in a wide band at latitudes 55-60°. After substorm onset at 15.15 UT, the equatorward extension of 630,0 nm luminosity band is observed (smearing SAR arc) through the Yakutsk zenith. At that time, the ionospheric westward drift velocity subsides to zero and starting from ~ 16.30 UT has, mainly, the eastward direction. A small increase in the average Ey at ~ 16.35-17.05 UT causes further equatorward extension of DA but without regular increase of the westward drift velocity, as indicated by the measurements at the Yakutsk station. After substorm expansion phase onset at 17.20 UT, a band of red luminosity equatorward of DA arises again.

3. Conclusions

The subauroral phenomena considered in two above examples are typical for all cases of complex observations in March, 2003. The preliminary results of complex researches at the Yakutsk meridian can be formulated as follows:

1). Magnetospheric convection intensification after southward turn of IMF Bz is well pronounced in the DA extension toward the equator. At the time, both in the DA region and much more equatorward from DA the ionospheric westward drift velocity increases at F2 layer altitudes, reaching 600 m/s (E=30 mV /m) at maximum convection activity level.

2). During substorm expansion, in the vicinity of DA boundary, the SAR arc (or the red luminosity band) forms, which then moves (extends) equatorward [Ievenko, 1994, 1999]. A decrease in the westward ionospheric drift velocity is observed in majority of cases. There is a tendency for changing ionospheric drift direction from westward to eastward after 02-03 MLT.

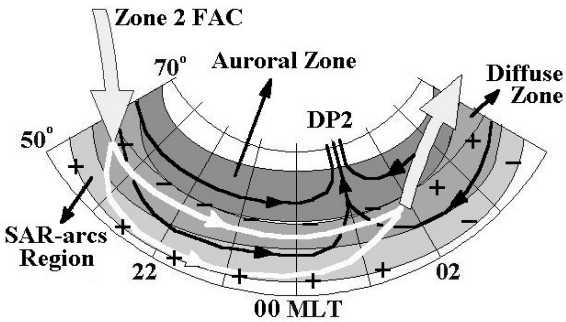

Fig. 3. A scheme for the distribution of ionospheric and field-aligned currents in the MLT night sector during the magnetospheric convection intensification after the turn of IMF Bz-component to the South.

3). We suppose that the ionospheric drift observed at the latitudes of DA and SAR arc can be caused by a polarization electric field. Fig. 3 illustrates a possible explanation of polarization electric field occurrence at subauroral latitudes. The Pedersen current in the evening-to-midnight MLT sector closes the Region 2 field-aligned currents in the ionosphere. The eastward current flows at latitudes of diffuse aurora and significantly equatorward of it, i.e. in the region of the outer plasmasphere projection, which is mapped by a SAR-arc or a red luminosity band during substorms. If the ionospheric conductivity is non-uniform along the meridian, the eastward current can be a source of the northward polarization field. The currents of DP2 system spreading to subauroral latitudes can also contribute to generation of the polarization electric field. In this case, the change of ionospheric drift direction from westward to eastward in the postmidnight MLT sector can be reasonably explained.

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