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SUBSTORM EFFECTS IN THE POLAR LATITUDE ATMOSPHERIC ELECTRIC FIELD DISTURBANCES

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Abstract. The variations of the vertical component of the near-Earth atmospheric electric field (Ez), observed at the polar latitude obs. Hornsund (Spitsbergen, HOR, Φ=74º) in 2004-2006, caused by substorms have been performed. To avoid local meteorological influences we used Ez data, obtained only under so called "fair weather" conditions, it means the absence of snow, fog, lower cloudiness, strong wind, negative Ez values. These limitations are of special importance at polar latitudes. The long lasting "fair weather" periods occur seldom in the polar latitudes. To avoid season effects we analyzed the equinox data, when near-Earth exchange layer is absent and turbulent convection currents are insignificant.
For the analysis we selected 12 morning and 10 evening substorms observed at obs. Hornsund. We found that the substorm development both at the auroral latitudes as well as at the polar ones can cause strong perturbations in the atmospheric electric field. These Ez disturbances, measured at Hornsund, were positive (Ez values increased) in the local morning and negative (Ez values decreased) in the local evening. The sign of Ez deviations depended on the observatory location relative to the position of the positive or negative plasma convection cells in the polar ionosphere. It is well known that the two cell pattern is most clear during the substorm. In terms of electric fields the evening Ez negative deviations associated with an increasing of the northward directed electric field in the ionosphere and the morning positive Ez variations – with ionosphere electric field directed southward. The observed effects are the result from the penetration of electric fields of an enhanced polar convection to the Earth surface.

1. Introduction
The substorm effects in the atmospheric electric field (Ez) variations at auroral latitudes were reported in many previous papers [e.g., Sao, 1967; Olson, 1971; Bandilet et al., 1986; Michnowski et al., 1998, Kleimenova et al., 1998; Belova et al., 2001, Kozyreva et al., 2007]. It was shown that at auroral latitudes the bay-like Ez negative deviations are often observed simultaneously with night-time substorm development.
Contrary to that, Michnowski et al., (1991) reported the event observed at the polar latitudes (obs. Hornsund) in which there was the positive atmospheric electric field (Ez) variation during the night-time substorm onset.
The aim of the present work was to continue the studying the possible effects of the evening/night and morning substorms in the Ez variations at the polar latitudes. We based our analysis on the ground Ez observations at Hornsund observatory at Spitsbergen archipelago (HOR, Φ' = 74.0°, Λ' = 110.5°).

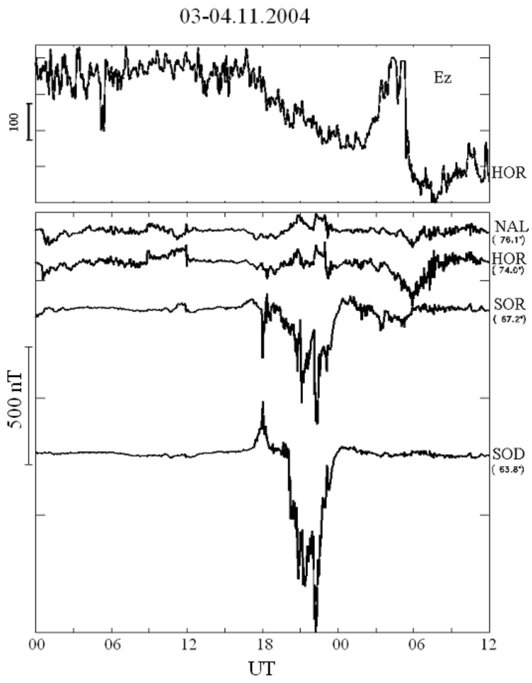
2. Observations
Under magnetically quiet conditions, the observatory Hornsund is projected into the polar cap region in the night-time and into the region of the polar cusp in the daytime. Under magnetically disturbed conditions, the auroral oval moves toward lower latitudes, and this observatory appears under the polar cap region projection independently of the local time.
In our analysis we used only the Ez data obtained under the so called "fair weather" conditions. This means the absence of a strong wind (the wind velocity is higher than 6 m/s), low cloudiness, precipitation (snow or rain), snowdrift, fog, etc. These limitations are of special importance at the polar latitudes, where motion of snow and ice particles, suspended in an air flow, results in the generation of considerable electric fluctuations, which significantly exceed the effects of the magnetospheric and ionospheric sources [Guglielmi et al., 1994; Burns et al., 1995; Frank-Kamenetsky et al., 2001]. Not more than 10–15% of the Ez registration satisfies the "fair weather" conditions at Hornsund.
An electrostatic fluxmeter, i.e., a rotating dipole (field mill), is used to register Ez variations at Hornsund. The equipment was described in detail by Kubicki, (2001).
We analyzed the Ez data in 2004–2006 for the near equinoxes (March, October, and November) in order to eliminate the seasonal effects. During these months, in the polar latitudes, the near-Earth exchange layer is absent and turbulent convection currents are insignificant [Park, 1976].
For the detail analysis we selected 12 morning and 10 evening substorms. We found that the substorm development at the auroral latitudes as well as at the polar ones can cause the strong perturbations in the atmospheric electric field at HOR. These Ez disturbances were positive (Ez values increased) in the local morning and negative (Ez values decreased) in the local evening.
Two events (03-04.11.2004 and 03-04.09.2006) of morning and evening sustorms are shown in Fig. 1. There are also presented the magnetograms from several stations, located approximately along the same meridian: two polar observatories (NAL, Φ =76°, and HOR, Φ = 74°) and two auroral observatories (SOR, Φ

= 67°; and SOD, Φ = 64°). The geomagnetic midnight at this meridian is near 21 UT. The Ez variations are given in the relative units.
One can see that on November 3, 2004 (Fig. 1a), the intense magnetic substorm developing at the auroral zone (SOD, SOR), was accompanied by the considerable negative Ez anomaly (decreases) at Hornsund at ~20–22 UT. At ~04–08 UT on the following day (November 4, 2004), the polar substorm, was observed at polar latitudes (NAL, HOR) and it was absent in the auroral zone. The preliminary phase of this substorm was accompanied by the considerable positive Ez deviations at Hornsund.
The similar positive Ez variations were observed on September 4, 2006 (Fig. 1b) during the morning substorm. The late evening substorm was observed on this day at ~ 19-20 UT and it was accompanied by the negative Ez deviations.
Such Ez variations, associated with the morning and evening substorms, were typical for all considered events. The morning substorms were accompanied by the positive Ez deviations and the evening and night-time substorms - by the negative ones.

3. Discussion

It is well known that the coupling between the solar wind and the magnetosphere creates the large scale ionosphere electric field convection. The large-scale pattern of plasma circulation most often conforms to a two-cell configuration with antisunward flow across the pole returning to the dayside via the dawn and dusk flanks. The centers of the convection cells usually locate poleward of 70 º latitude with the positive cell at the morning side and the negative cell – at the evening side. A convective motion of plasma in the geomagnetic field is equivalent to the existence of a horizontal electric field, directed from the morning side to the evening side, in the polar cap. At the poleward boundary of the auroral oval, the field direction reverses. Thus, the auroral electric field is directed toward and from the pole in the evening and morning sectors, respectively.
The processing of the data obtained by the system of the northern SuperDARN radars provides to get the maps of the global convection pattern (available at http://superdarn.jhuapl.edu/). These maps represent the distribution of the ionosphere electrostatic potential.
The polar cap potential variations can produce significant vertical electric fields (Ez) disturbances at the ground level.
The global maps of the polar ionospheric convection distribution during two considered above events (Fig. 1) are shown in Fig.2.
One can see that on November 3, 2004 at 19.00 UT, HOR was projected inside of the negative convection sell (Fig. 2a, upper panel). However, in the morning on November 4, 2004 (04.40 UT), HOR was projected inside of the positive convection sell (Fig 2a, bottom panel). The same is seen in the second event on September 4, 2006. During the morning substorm (04.10 UT) obs. Hornsund was located in the positive convection sell projection (Fig. 2b, upper panel), but in the evening – in the negative one (Fig 2b, bottom panel).

a



b

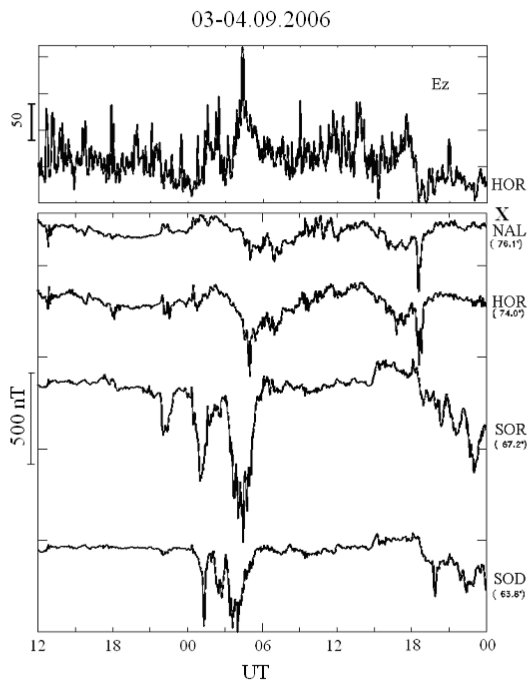


Fig. 1. Two examples of negative Ez variations during the night substorms and positive Ez variations during the morning substorms: *a* – Nov. 03-04, 2004; *b* – Sep. 03-04, 2006.

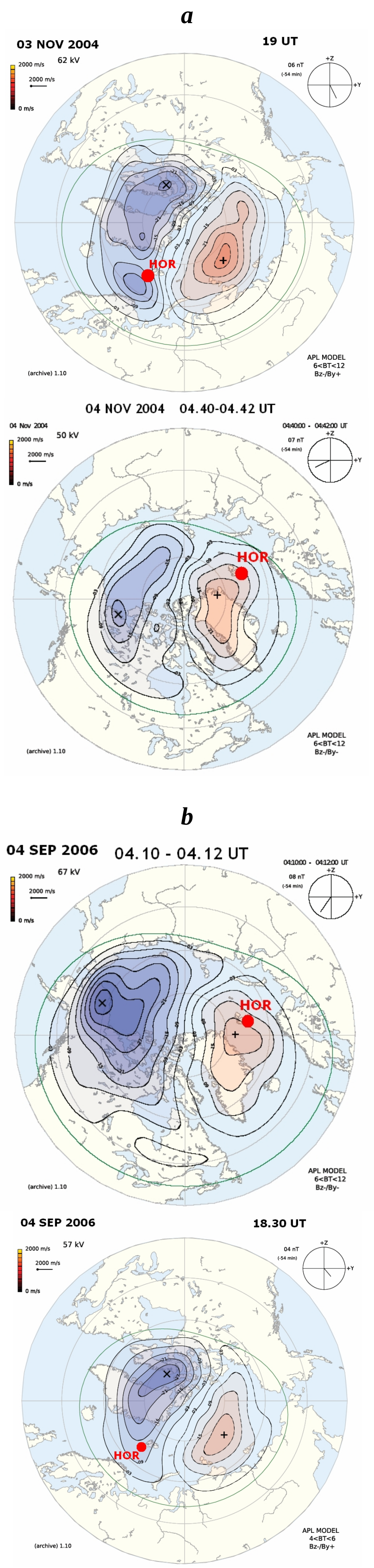


Fig. 2. The global maps of the high latitude plasma convection during considered morning and evening substorms, presented in Fig.1: *a* – Nov. 03-04, 2004; *b* – Sep. 03-04, 2006.

One more morning substorm (October 27, 2005) at 00-01 UT was developed at Scandinavian meridian with the magnitude of ~300 nT at the auroral zone. At the polar latitudes (HOR) the magnitude of this substorm reached ~60 nT. Several bay-like geomagnetic disturbances were observed at HOR during the following three hours (Fig. 3).

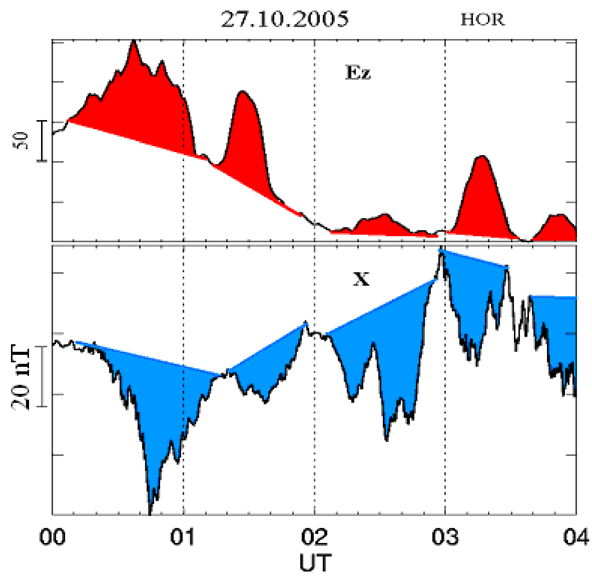


Fig. 3. The Ez variations and the magnetogram (X-component) at obs. Hornsund on October 27, 2005.

It is clearly seen (Fig. 3) that each negative magnetic deviation, observed at HOR, was accompanied by the simultaneous positive deviations in the atmospheric electric field (Ez) variations at this station. But there was no linear relationship between the Ez values and the geomagnetic disturbance magnitudes.

The global map of polar ionosphere convection during the first substorm (00-01 UT) is presented in Fig. 4. As in the previous cases, HOR was located near the center of the morning convection vortex.

The model of the analytical and numerical estimations of the effects of disturbances in the atmospheric electric field, produced by the magnetospheric or ionospheric origin, demonstrated that the variations in Ez can reach about 30% of the undisturbed Ez level [e.g., Volland, 1972; Park, 1976; Zhdanov et al., 1984; Roble, 1985; Morozov and Troshichev, 2008].

We speculate that the significant variations in the atmospheric electric field (Ez) at Hornsund observatory, observed during the development of magnetospheric substorms, are a result of the penetration of the electric fields of polar ionospheric convection (which are intensified during a substorm) to the Earth's surface. In terms of electric fields the evening Ez negative deviations associated with an increasing of the northward directed electric field in the ionosphere and the morning positive Ez variations – with ionosphere electric field directed southward.

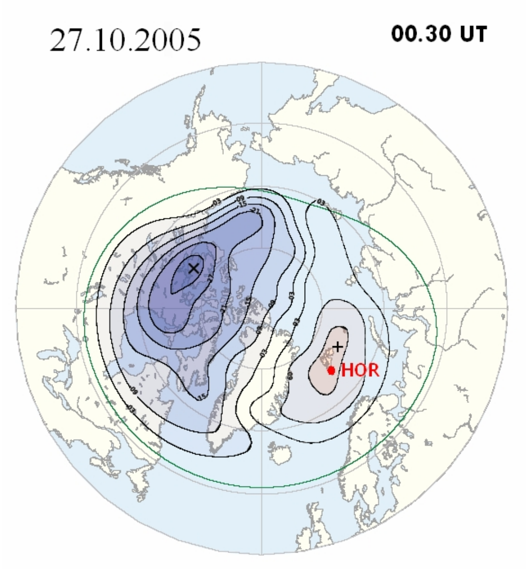


Fig. 4. The global map of the high latitude plasma convection during the first morning substorm on October 27, 2005.

4. Conclusions

An analysis of the data from ground-based observations of the atmospheric electric field (Ez) variations at the polar observatory Horsund showed that the substorm development at the auroral latitudes as well as at the polar ones can cause the strong perturbations in the Ez level. The substorm related Ez disturbances were positive (the Ez values increased) in the local morning and negative (the Ez values decreased) in the local evening. The sign of the Ez deviations depends on the observatory location relative to the position of the positive or negative plasma convection cells in the polar ionosphere.

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