"Physics of Auroral Phenomena", Proc. XXXIX Annual Seminar, Apatity, pp. 15-18, 2016

Polar Geophysical Institute

DAYTIME POLAR MAGNETIC DISTURBANCES UNDER EXTREMELY STRONG IMF *Bz*

A.E. Levitin[1], N.G. Kleimenova[2,3], L.I. Gromova[1], L.A. Dremukhina[1], E.E. Antonova[3,4], N.R. Zelinsky[2], S.V. Gromov[1], L.M. Malysheva[2]

[1]*Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation, Moscow, Russia*
[2]*Schmidt Institute of Physics of the Earth, Moscow, Russia*
[3]*Space Research Institute, Moscow, Russia*
[4]*Skobeltsyn Institute of Nuclear Physics Lomonosov Moscow State University, Moscow, Russia*

Abstract. Daytime polar-latitude electrojet, usually termed as *PE*, has been studied very poorly. We present the results of the detailed analysis of two *PE* events recorded in the dayside sector of the Earth at the polar geomagnetic latitudes under positive IMF *Bz* during main phase of the storm on Nov 24, 2001 and recovery phase of the storm of May 30, 2003 Our study was based on the ground high-latitude IMAGE normalyzed magnetogram data. According to model calculations, a sharp intensification of the field aligned currents (*FAC*) of the *NBZ* system was noted in that region. The wave structure of this magnetic bay was represented by the (2–7) mHz geomagnetic pulsations which demonstrated the spectral properties different from resonant Pc5 waves. The possible source of high-latitude pulsations could be related with fluctuations in the turbulent magnetosheet. The space distribution of the *FAC* which can be attributed to *NBZ* system has been obtained in the polar latitudes by the low-altitude CHAMP satellite. This result has been compared with the auroral oval location (model *OVATION*) and spectra of the ion and electron fluxes measured by the low-altitude DMSP satellite. We suppose that the daytime polar electrojet under consideration could be mapped inside the closed magnetosphere at poleward part of the plasma ring surrounding the Earth.

Introduction. The dayside magnetic bays observed at polar latitudes and controlled by the IMF *By* sign, are called polar electrojet (*PE*). Daytime polar-latitude electrojet, usually termed as *PE*, has been studied very poorly

Solar wind-magnetosphere interaction manifests in a magnetic storms occurrence. Solar wind energy storages in the magnetosphere under negative IMF *Bz* and disappears under positive IMF *Bz*. It is supposed that development of these dayside substorms, (*PE* event) that observed in the polar region where the specific system (*NBZ*) of field-aligned currents, caused by the positive IMF *Bz,* may be enhanced.

Here we study two *PE* events observed during main phase of the storm on Nov 24, 2001 and recovery phase of the storm of May 30, 2003 as a response of the magnetosphere to high positive values of the IMF *Bz* occurrence. The observations at the IMAGE Scandinavian magnetometer profile and on the CHAMP and DMSP low orbiting satellites were used for the analysis.

This work continues the studies of the high-latitude effects of magnetic storms [*Kleimenova et al.,* 2015; *Levitin et al.*, 2015], during which considerable positive IMF *Bz* values are registered.

Observations. IMF *Bz* and *By* components from high resolution OMNI database) and magnetograms high-latitude of stations for storms of 24 Nov 2001 and for 30 May 2003 are presented in Fig. 1 and Fig. 2 correspondingly.

The first *PE* event was observed during the main phase of the strong magnetic storm on Nov 24, 2001 with *Dst min* ~ –220 nT (Fig. 1). In this interval the IMF *Bz* turned northward up to extremely high positive values (~ +60 nT) and the IMF *By* changed from +40 to –40 nT under a high solar wind dynamic pressure up to 50–70 nPa. In the dayside sector of the polar latitudes, the very strong magnetic bay occurred with the amplitude of about 2000 nT.

The second *PE* event was observed in the intensive storm recovery phase on May 30, 2003 with *Dst min* ~ -144

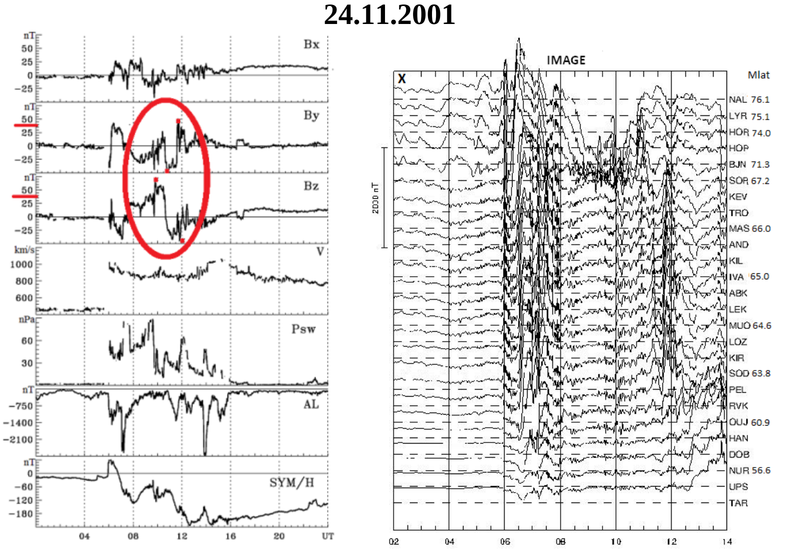

Figure 1. The OMNI data (*http://omniweb.gsfc.nasa.gov/*) and IMAGE magnetograms (*http://www.ava.fmi.fi/MIRACLE/*) for the storm of Nov 24, 2001.

nT (Fig. 1b) under the positive IMF *Bz* (up to +25 nT), and the IMF *By* changed from -15 nT to +20 nT). The solar wind density was strong (up to ~40 1/cm^3), and velocity remained at ~ 700 km/s. The intense (~400 nT) magnetic bay was recorded in the daytime sector of the polar latitudes (Fig. 2).

Discussion

The ionospheric currents, which are observed on the Earth's surface as geomagnetic variations, are closely related to the field-aligned electric currents in the magnetosphere. There are several statistical models of the global distribution of high-latitude field-aligned electric currents, e.g., [*Mishin et al*., 1978; *Dremukhina et al*., 1998; *Papitashvili et al*.,2002; *Lukianova and Christiansen*, 2006].

The Fig. 3 present the field aligned currents (*FAC*) distribution calculated by the IZMIRAN model [*Feldstain and Levitin*, 1986] in coordinates: geomagnetic latitude – MLT: red - downward currents, blue – upward ones.

29 – 30.05.2003

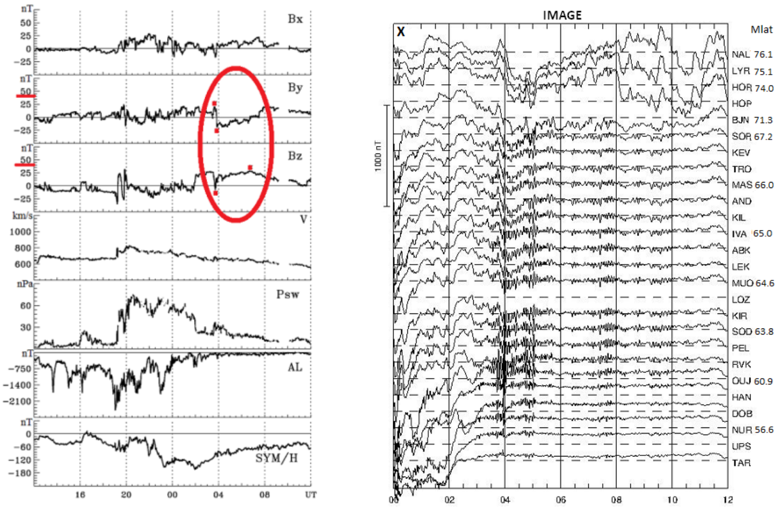

Figure 2. The OMNI data (May 29-30, 2003) and IMAGE magnetograms (May 30, 2003).

24.11.2001

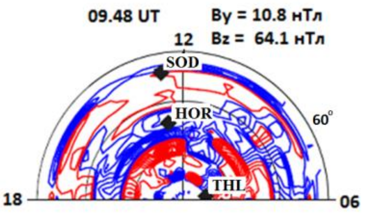

Figure 3. The field aligned currents (*FAC*) distribution according to IZMIRAN model for Nov 24, 2001.

The magnetic variation vectors of high-latitude IMAGE stations (NAL – LUR) were constructed using difference magnetograms based on magneto-quiet 2009 level [*Levitin et al*., 2014]. They are shown in Fig. 4 (left) for 02-14 UT on 24 Nov 2001 and Fig. 4 (right) for 00 – 12 UT on 30 May 2003.

The magnetospheric configuration changes substantially when IMF is northward and the corresponding NBZ system of field aligned currents are formed in this case [*Antonova and Ovchinnikov*, 1999, 2001].

One can be seen that the vortex with clockwise rotation direction are seen which corresponded downward *FAC.* The *FAC* intensification in the dayside polar region (the *NBZ* system) is seen. For event of 30 May 2003 the vortices with opposite rotation direction are seen which corresponded upward and downward FAC.

24.11.2001 **30.05.2003**

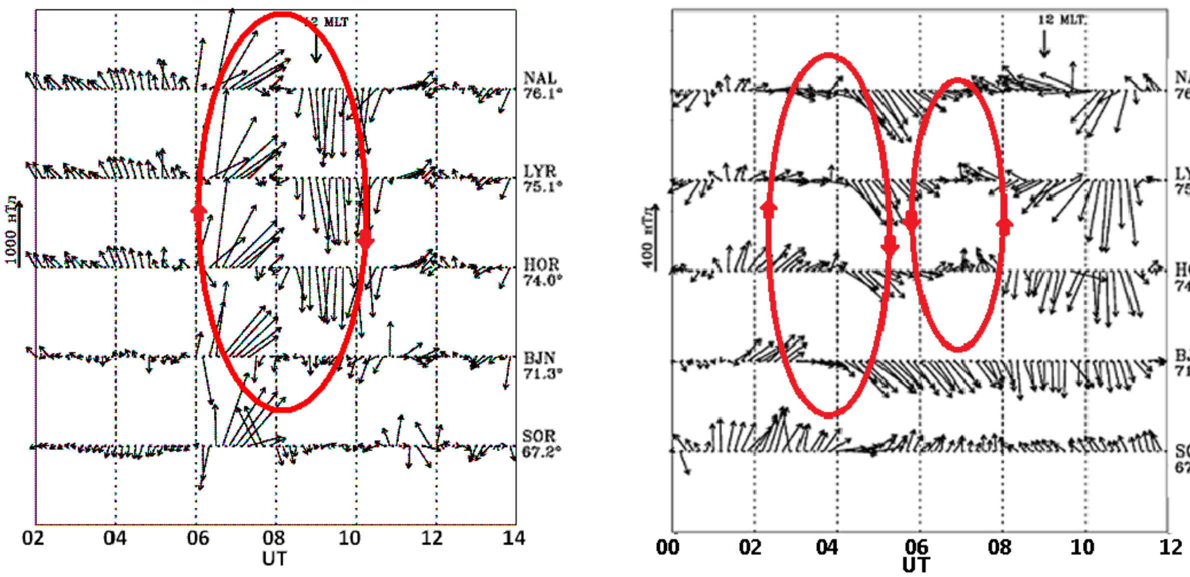

Figure 4. The magnetic variation vectors during *PE* events of 24 Nov 2001(left), and 30 May 2003(right).

As it is seen in Fig. 5 according to analyzing the DMSP F13 precipitating particle data during the CHAMP passage (at ~06.50 UT, and ~ 08.30 UT) the precipitating particle enhancement is seen in the area of the *PE* development. Fig. 6 shows the CHAMP magnetic field data *(http://op.gfz-potsdam.de/champ)*, and auroral oval location according to OVATION model (*http://sd_www.jhuapl.edu/Aurora/ovation/*) for 30 May 2003. It is seen that IMAGE high-latitude sector is located into the dayside auroral oval.

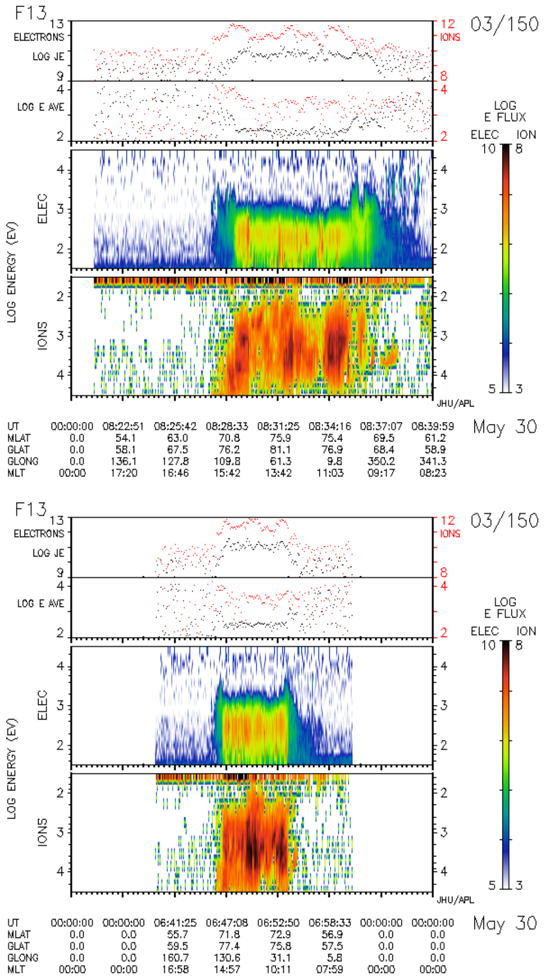

Figure 5. The DMSP F13 precipitating particle data during the CHAMP passage: (top) 06.50 UT, (upper) 08.30 UT.

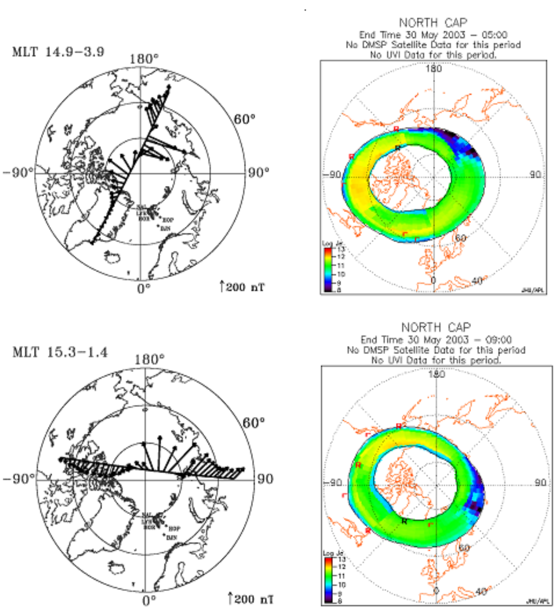

Figure 6. The CHAMP magnetic field data and the auroral oval location *(OVATION*).

The geomagnetic pulsations and solar wind and IMF fluctuations have been studied by applying a new approach to data processing based on fuzzy logic methods of discrete mathematical analysis (DMA) [*Zelinsky et al*., 2014].
Fig. 7 and Fig. 8, the wave structure of considered day-side magnetic bays was represented by the 2–7 mHz geomagnetic pulsations which do not observed in the solar wind and IMF, and demonstrated the spectral properties different from the resonant Pc5 waves.

The direct penetration of fluctuating solar wind electric fields in the polar cap was of low probability, since the bursts of geomagnetic pulsations on the Earth's surface and IMF parameters fluctuations were incoherent. Final conclusion about a physical mechanism of excitation of the daytime polar substorm (*PE* events) and accompanying geomagnetic pulsations requires further detailed experimental and theoretical studies.

Summary

1. We presented two events of the polar electrojet *(PE),* i.e. dayside polar latitude magnetic bay, which sign is controlled by the IMF By.
2. We found that the *PE* development is the magnetosphere respond to the high positive values of the IMF *Bz* occurrence during the magnetic storms.
3. The *PE* were observed at the same polar region where the NBZ system of the field aligned current (FAC) may be enhanced (according the IZMIRAN model [Feldstein and Levitin, 1986]). The sequences of two geomagnetic vortices with opposing rotation directions (upward and downward FAC) observed during the second event and one vortex with the clockwise rotation in the first one support this proposal as well as the CHAMP spacecraft data.
4. The dayside polar magnetic bays *(PE)* were accompanied by the (2-7) mHz geomagnetic pulsations with the spectral properties different from the resonant Pc5 waves.

5. We suppose that the daytime polar electrojet *(PE)* under consideration could be mapped inside the closed magnetosphere at poleward part of the plasma ring surrounding the Earth.

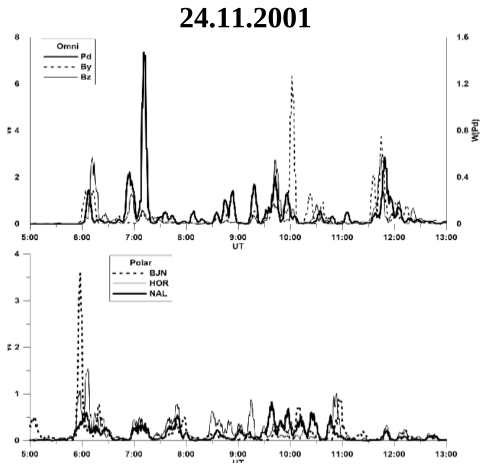

Figure 7. The 2–7_mHz geomagnetic pulsations at polar stations BJN, HOR, NAL and similar fluctuations in the solar wind and IMF (top panel), calculated as a "survey fragment energy" rectifying functional, the relative units are used [*Zelinsky et al*., 2014].

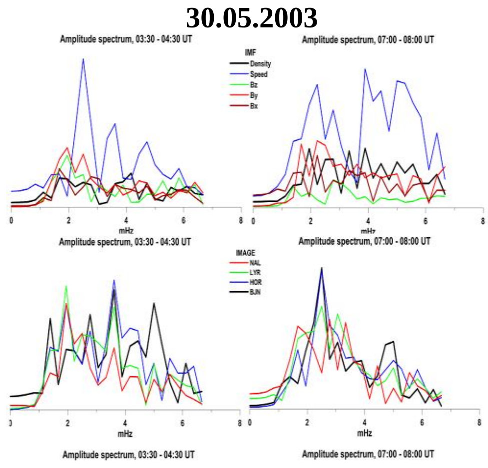

Figure 8. The amplitude spectra of 2–7 mHz fluctuations in the solar wind and IMF (top panels), and of the geomagnetic pulsations at BJN–NAL (at the bottom) during two time intervals: 04–05 and 07–08 UT; relative units are used.

Acknowledgements. The paper was partly supported by the Program No 7 of the Presidium f RAS (NK and LM) and by the RFBR Grant № 16-35-00069 (N.Z.).

References

Antonova, E.E. and Ovchinnikov, I.L., Magnetostatically equilibrated plasma sheet with developed medium scale turbulence: Structure and implications for substorm dynamics, J. Geophys. Res., 104(A8), 17292-17297, 1999.

Antonova, E.E. and Ovchinnikov, I.L., The model of turbulent plasma sheet during IMF Bz > 0, Adv. Space Res., 28(12), 1747–1752, 2001.

Dremukhina, L.A., Levitin, A.E., and Papitashvili, V.O., Analytical representation of IZMEM model for near_real time prediction of electromagnetic weather, J. Atmos. Sol.–Terr. Phys., vol. 60, 1517–1529, 1998.

Feldstein Ya.I., and Levitin A.E. Solar wind control of electric fields and currents in the ionosphere J. Geomag.Geoelectr., 38, 1143–1182, 1986.

Kleimenova, N.G., Gromova, L.I., Dremukhina, L.A., Levitin, A.E., Zelinskii, N.R., and Gromov, S.V. High_latitude geomagnetic effects of the main phase of the geomagnetic storm of November 24, 2001 with the northern direction of IMF, Geomagn. Aeron. (Engl. Transl.), 55, (2), 174–184, 2015.

Levitin, A.E., N.G. Kleimenova, L.I. Gromova, E.E. Antonova, L.A. Dremukhina, N.R. Zelinsky, S.V. Gromov, and L.M. Malysheva, Geomagnetic disturbances and pulsations as a high_latitude response to considerable alternating IMF variations during the magnetic storm recovery phase (Case Study: May 30, 2003), Geomagn. Aeron. (Engl. Transl), 55(6), 755–768, 2015.

Levitin, A.E., Gromova, L.I., Gromov, S.V., and Dremukhina, L.A., Quantitative estimation of local geomagnetic activity relative to the level of the magnetically quiet period in 2009, Geomagn. Aeron. (Engl.Transl.), 54(3), 292–299, 2014.

Lukianova, R. and Christiansen, F., Modeling of the global distribution of ionospheric electric fields based on realistic maps of field_aligned currents, J. Geophys. Res., 111(A03213). doi 10.1029/2006JA011950, 2006.

Mishin, V.M., Bazarzhapov, A.D., Anistratenko, A.A., and Aksenova, L.V., Electric currents and magnetospheric convection produced by nonmagnetized solar wind, Geomagn. Aeron., vol. 18(4) ,751–753, 1978.

Papitashvili, V.O., Christiansen, F., and Neubert, T., A new model of field_aligned currents derived from high precision satellite magnetic field data, Geophys. Res. Lett., 2002, vol. 29, no. 14, pp. 1683–1686.

Zelinsky, N.R., Kleimenova, N.G., and Malysheva, L.M.,Studies on the latitudinal distribution of ground_based geomagnetic pulsations and fluctuations in the interplanetary medium using discrete mathematical analysis methods, Geomagn. Aeron. (Engl. Transl.), 54(4), 449–455. 2014