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DAYSIDE POLAR SUBSTORM BEHAVIOR: CASE STUDY

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Abstract. In our previous studies we have identified the specific polar-latitude (>70°) negative bay-like magnetic disturbances which are observed near the local noon under the northward IMF *Bz*. These disturbances occur on the contracted auroral oval similarly to the evening polar substorm. According to that, we call them "*dayside polar substorms"* and consider the polar-latitude *NBZ* field-aligned currents (FACs) as their plausible source. To confirm this hypothesis, we continued comprehensive detailed studies the dayside negative polar magnetic bays and present here the results of such analysis of the data collected from the IMAGE magnetometer chain including the Svalbard during the initial phase of the magnetic storm on January 22, 2012. The discussed daytime substorm (09-11 UT) was observed under the northward IMF *Bz* and very strong negative IMF *By* (about -30 nT) with the ratio of |*By*|/|*Bz*| ~3. In the considered time interval, there were no magnetic disturbances in the night side of the Earth as well as at the auroral latitudes (*AL*-index < 150 nT). The SUPERDARN radar data showed the significant change in the high-latitude ionosphere convection. Before and after the discussed dayside substorm, there was two-vortex convection distribution. When the IMF *Bz* became large positive, and the IMF *By* became large negative, the convection vortices weakened. However, some small additional vortices appeared near noon which could be interpreted as the *NBZ* type of FAC occurrence. The AMPERE data, based on the magnetic measurements on 66 globally distributed low-altitude satellites, demonstrated the counter-clockwise magnetic vortex above Svalbard stations and very intensive upward FACs which were surrounded by two layers of the downward currents, located to the north and south. These FACs could provide the necessary energy for the dayside polar magnetic bay generation. But, the source of these FACs is still unknown.

Introduction

In our previous papers [*Kleimenova et al.,* 2015*; Levitin et al.,* 2015*; Gromova et al.,* 2016] we have identified the specific polar-latitude (>70°) negative bay-like magnetic disturbances which are observed near the local magnetic noon under the northward IMF *Bz*. Similar disturbances have been previously reported by [*Iwasaki*, 1971*; Friis-Christensen and Wilhjem,* 1975*; Feldstein*, 1976]. The bay sign was mainly controlled by IMF *By* and was termed by [*Friis-Christensen and Wilhjem,* 1975] as DPY currents. These magnetic disturbances occur on the contracted auroral oval as well as the evening "polar substorms" discussed in [*Kleimenva et al.*, 2012]. Due to that we call these daytime polar disturbances "dayside polar substorms". An example of such very strong substorm with the amplitude in order of 1000 nT is shown in Fig. 1.

The aim of this study is comprehensive analysis of the dayside negative polar magnetic bay observed during the initial phase of the moderate magnetic storm on January 22, 2012.

Data and observations

Ground-based data. Our analysis was based on the 10 s sampled Scandinavian magnetometer chain (IMAGE) data. The moderate "dayside polar substorm" was observed on January 22, 2012 at 09-11 UT (12-14 MLT) under the northward IMF *Bz* (+10 nT) and very strong negative IMF *By* (-30 nT) with the ratio of |*By*|/|*Bz*|~3 (Fig. 2). The solar wind speed was ~500 km/s, however, the solar wind dynamic pressure before this substorm, i.e. during the initial phase of the magnetic storm, was very strong (>20 nPa) as it was discussed in [*Rout et al.*, 2016]. There were no significant geomagnetic disturbances in the night side of the auroral zone (*AL*-index < -150 nT, Fig. 2).

The AMPERE data. The AMPERE (Active Magnetosphere and Planetary Electrodynamics Response Experiment, the website *http://ampere.jhuapl.edu*) facility consists of 66 Iridium commercial satellites at 780 km altitude with the polar circular orbits distributed over six orbital planes to provide global satellite data. Each satellite carries an engineering magnetometer. The spherical harmonic fitting technique is applied [*Anderson et al.*, 2000] to estimate the global distribution of radial currents which in the polar regions correspond to the Birkeland currents or field-aligned currents (FACs) commonly associated with the region 1 (*R1*) and region 2 (*R2*) current system [*Iijima and Potemra*, 1976].

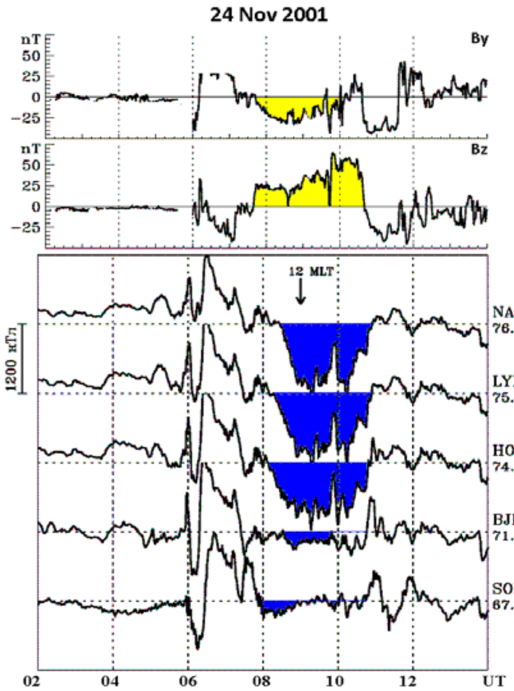

Figure 1. An example of the dayside polar substorm observed on November 24, 2001. The upper panel demonstrates the IMF conditions: strong negative IMF *By* (-25 nT) and positive IMF *Bz* (+50 nT) values. The bottom panel shows the magnetograms from high-latitude IMAGE stations. Strong daytime negative bay-like magnetic disturbances ("dayside polar substorms") are seen at three stations (NAL, LYR, HOR) at geomagnetic latitudes > 70°.

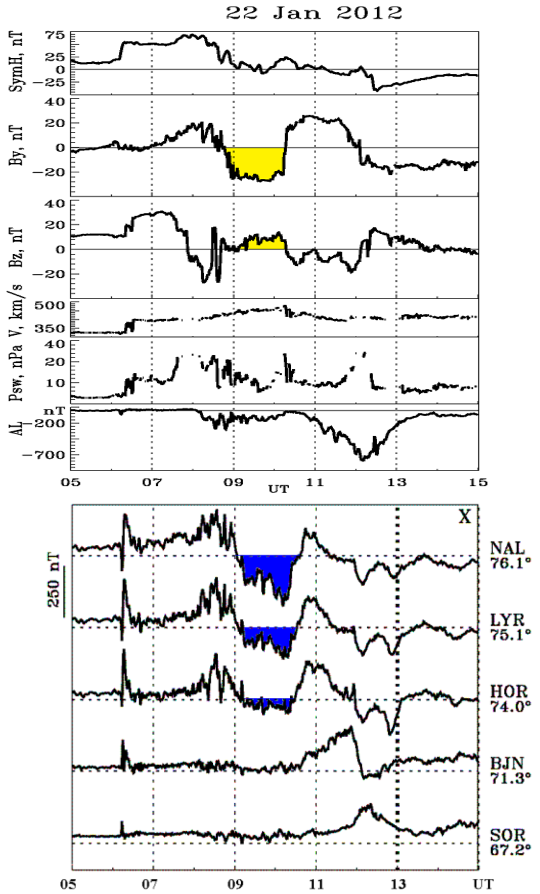

Figure 2. IMF data and IMAGE magnetometer data.

The AMPERE data during the considered dayside polar substorm is presented in Fig. 3. It is seen the magnetic vortex above Svalbard stations (marked by the green ellipse) and intense upward FACs which were surrounded by two sheets of the downward currents, located to the north and south.

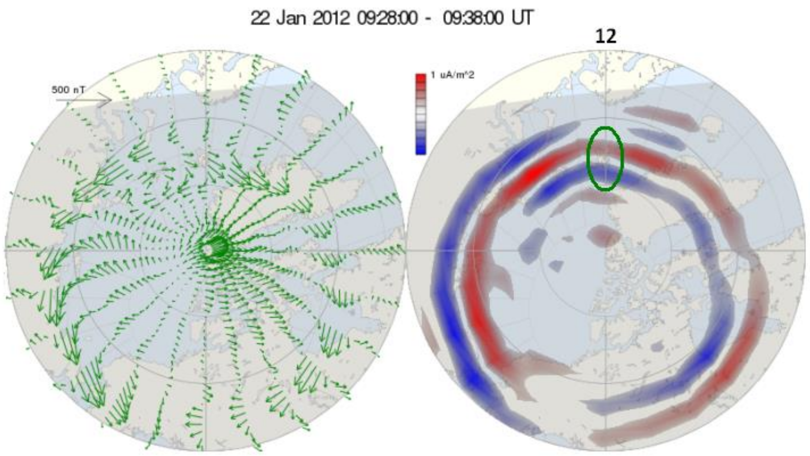

Figure 3. AMPERE data (*left panel*) shows the magnetic disturbances, and *right* one – FAC distribution.

The SUPERDARN radar data. Fig. 4 shows three high-latitude ionospheric convection maps generated by the Super Dual Auroral Radar Network (SuperDARN) HF radar network corresponding to the representative intervals of 08.40–08.42 UT, 09.30–09.32 UT, and 10.40–10.42 UT, i.e. before, during and after the considered dayside substorm. It is seen the significant change in the high-latitude ionosphere convection structure. Before and after the discussed dayside substorm, there was the two-vortex convection distribution. When the IMF *Bz* became large positive, and the IMF *By* became large negative, the convection vortices weakened. However, some small additional vortices appeared near noon and demonstrated a complicated spatial structure of the correspondent field aligned currents (FACs) enhancements.

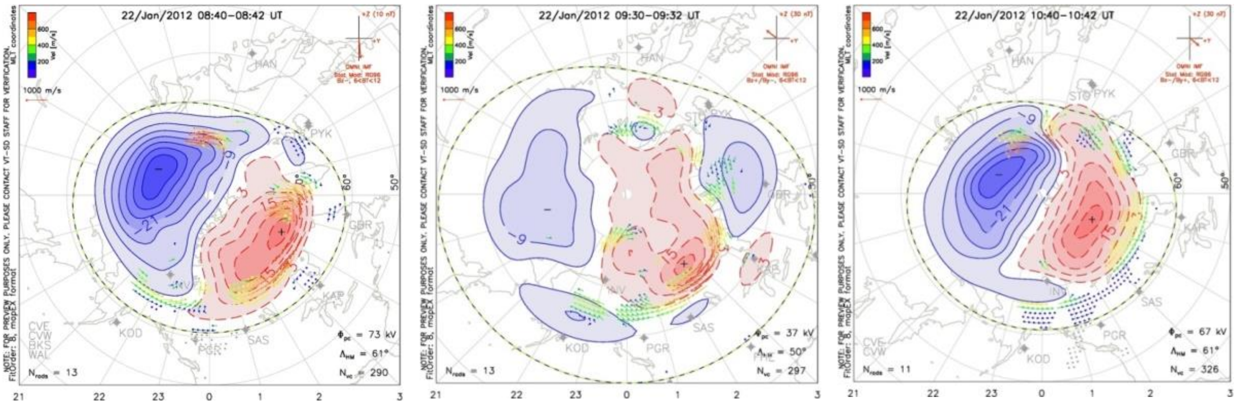

Figure 4. SUPERDARN radar data (before, during and after the "dayside polar substorm").

The auroral oval location according to the OVATION model [*http://www.jhuapl.edu/Aurora/ovation*] is presented in Fig. 5. This map shows that the high-latitude IMAGE station at Svalbard (NAL and LYR) which recorded the strongest amplitude of the "dayside polar substorm" (Fig. 2) were located in vicinity of the poleward boundary of the auroral oval.

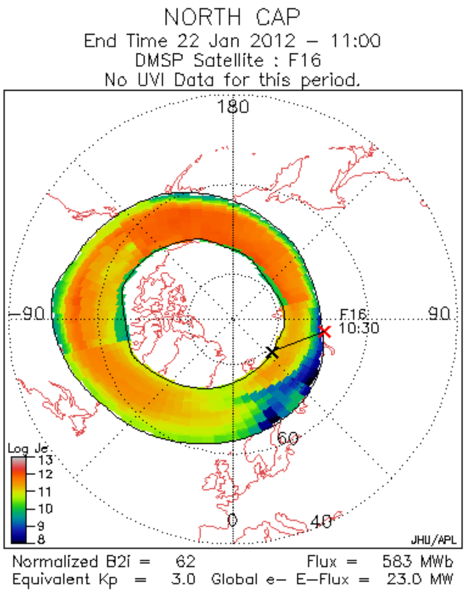

Figure 5. The auroral oval location according to the OVATION model.

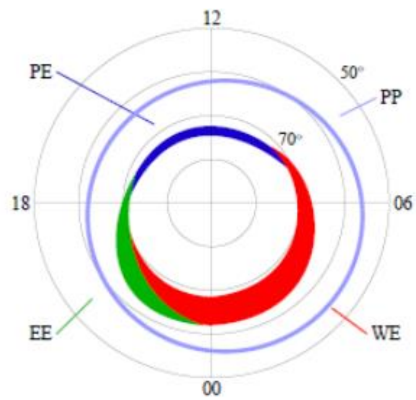

Figure 6. Schema of the electrojets space-time distribution during a substorm with *AL*~ -800 nT (after *Feldstein et al*., 2006).

Discussion

We suppose that the source of the considered "dayside polar substorm" recorded during the initial phase of the magnetic storm on January 2012 could be the intensification of high-latitude field aligned currents (FACs) which were seen in the AMPERE and SUPERDARN data. These FACs could be interpreted as the polar-latitude *NBZ* current system developing [*Iijima et al.*, 1984]. However, we have to note the *NBZ* system has been mapped into the polar cap, but the considered daytime magnetic bay was observed near the poleward boundary of aurora oval, probably, inside the closed magnetosphere.

The intensification of FACs of the magnetospheric Region 1 *(R1)* [*Iijima and Potemra*, 1976] could be another plausible source of a dayside polar substorm. Such currents have be mapped into the closed magnetosphere in the morning and into the LLBL area near noon [*Wing S. et al*., 2010].

Note, *Feldstein et al.* [2006] showed that the daytime polar electrojet (*PE*) can be interpreted as ionospheric currents linking the westward (*WE*) and eastward (*EE*) current systems (see Fig. 6). Really, sometimes during daytime polar substorms, there were small magnetic disturbances in the morning sector and in the evening one as it is seen in Fig. 3.

Summary

The turn of the IMF *Bz* to the positive values under strong solar wind dynamic pressure can provide the conditions for developing a specific dayside high-latitude bay-like magnetic disturbances which we call "*dayside polar substorms*". This substorm is developed in the vicinity of the poleward boundary of aurora oval, probably, inside the closed magnetosphere.

The daytime polar substorms are accompanied by the high-latitude field aligned currents enhancement and the change of the high-latitude ionospheric convection distribution. However, a source of these FACs is still unknown.

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