Characteristics of the Midlatitude Effects of Different Substorms

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Abstract.

Depending on the interplanetary conditions and the solar wind transients, different substorms can develop. By one classification they can be divided in ”usual“, ”expanded“ and ”polar“. The ”usual“ substorms begin and develop at auroral latitudes (~60°- ~ 71° GMLat). When the substorm onset is at auroral latitudes, but the substorm propagates to higher latitudes (>~70° GMLat), the substorm is ”expanded“. And in the case, when the substorm originates and develops at latitudes above ~70° GMLat, without expansion to South, it is ranked among the ”polar“ ones. The substorm effect at midlatitudes consists of the appearance of peaks in the X component of the magnetic field at ground, called midlatitude positive bays (MPB). A number of characteristics as conversion latitude of the magnetic bay sign, amplitude and duration of the MPB, horizontal power of the magnetic field etc., can be attributed to the midlatitude effects of substorms.

The characteristics of the midlatitude effects have been determined by data of the Bulgarian midlatitude station Panagjurishte (PAG) (~37° GMLat, ~97° GMLon) for 3 substorms: a polar substorm at 18:45 UT on 06.01.2013, a usual substorm at 22:30 UT on 31.01.2013 and an expanded substorm at 18:42 UT on 02.02.2013. The differences between the MPB characteristics for these different types of substorms have been analyzed.

Introduction

Substorms are a typical phenomenon in the auroral latitudes (~ 60°- ~ 71° MLAT) [*Akasofu*, 1964]. The magnetic substorms display at auroral latitudes represents negative bays in the X-component of the surface magnetic field. Depending on the solar wind and Interplanetary Magnetic Field (IMF) conditions, substorms can extend to both: very high latitudes (>70° MLAT) (e.g. [*Pudovkin* and *Troshichev*, 1972; *Nielsen et al.*, 1988; *Despirak et al.* 2008]) and middle (~ 50° MLAT) latitudes [*Feldstein and Starkov*, 1967]. Furthermore, magnetic substorms produce positive bays in the X-component of the ground-based magnetic field (midlatitude positive bays, MPB). Nowadays, the commonly adopted opinion of this phenomenon is, that the positive bays are associated with a current system, the substorm current wedge (SCW) [*McPherron et al*. 1973a].

It has to be stressed that substorms, occurred during different conditions in the solar wind can differ considerably from each other (e.g., [*Tanskanen et al*., 2002; *Guineva et al.*, 2016; *Guineva et al.*, 2018]). By reason of this, diverse categories of substorms have been introduced: “limited” and “extended” [*Lui et al*., 1976], “localized” and “normal” [*McPherron et al*. 1973b], “substorms on the contracted oval” and “normal” [*Kamide et al*., 1975], "polar" and "classical" or “usual” [*Kleimenova et al*., 2012], “high latitude” and “normal” [*Despirak et al.* 2008], “expanded” and “polar” [*Despirak et al.* 2018]. Therefore, the development of positive bays at midlatitudes during substorms should also have some various characteristics, according to the different conditions.

The goal of this work is to study the peculiarities of the midlatitude positive bays (MPB) at the Bulgarian midlatitude station Panagjurishte (PAG) (~37° GMLat, ~97° GMLon), associated with different types of substorms. Three isolated substorms were chosen, a polar substorm at 18:45 UT on 06.01.2013, a usual substorm at 22:30 UT on 31.01.2013 and an expanded substorm at 18:42 UT on 02.02.2013.

Data

To identify the substorms and to follow their development, data from the magnetometer networks IMAGE, INTERMAGNET and SuperMAG have been used. The interplanetary conditions have been verified by means of the OMNI data base and the solar wind large-scale phenomena catalog (http://www.iki.rssi.ru/omni/).

Interplanetary and geomagnetic conditions

Three cases of isolated substorms were selected. The interplanetary and geomagnetic conditions during the substorms are presented in Fig.1. From up to down the following quantities are drawn: the magnitude of the IMF vector, the IMF Bz component, the X component of the velocity Vx, the proton density PD, the temperature T, the dynamic pressure P, and the AL and SYM/H indices. The boundaries of the structures in the solar wind are marked by rectangles. The red vertical lines indicate the substorm onsets.

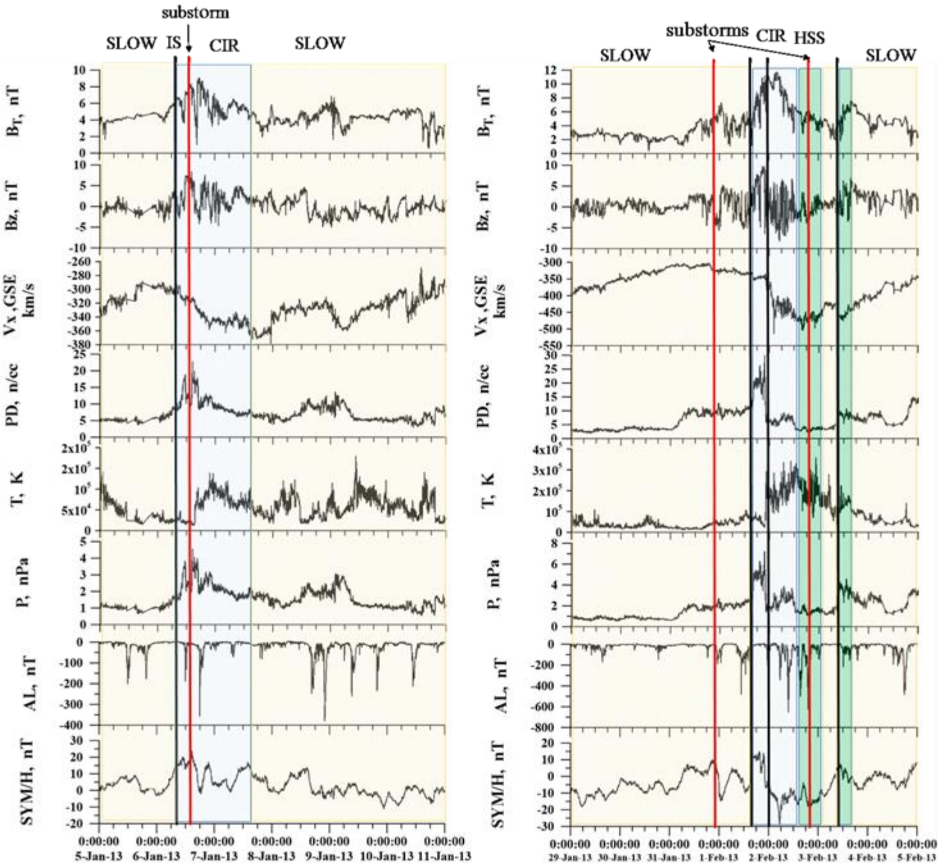

Fig.1. Interplanetary and geomagnetic conditions concerning the three examined substorms: on 06 January 2013 (left panel, time interval from 05 to 11 January 2013) and on 31 January and 02 February 2013 (right panel, time interval from 29 January to 05 February 2013).

The first substorm, on 06.01.2013, occurred during CIR in the solar wind on the background of a slow solar wind, Vx was about -310 km/s, Bz fell down from positive to negative values, jumps in PD, P and T were registered, AL was about -200 nT (Fig.1, left panel). The second substorm, on 31.01.2013 (Fig.1. right panel), happened during a slow stream in the solar wind, Vx was ~-330 km/s, a drop in Bz of ~7 nT to negative values was observed, AL=~-200 nT. These substorms developed under quiet conditions. The third substorm originated in more disturbed conditions, during a high-speed stream (HSS) in the solar wind, Vx=~-460 km/s, AL=~-600 nT. All three substorms developed in non-storm conditions.

Substorms development and midlatitude display

Substorm at 18:45 UT on 06.01.2013

The substorm development at auroral latitudes and its appearance at PAG station are given in Fig.2. This substorm can be classified as polar. The first negative disturbances in X are observed at BJN (71.45° GMLat) and development to South is not seen (left upper panel of Fig.2). This substorm is weak, which is typical for polar substorms, and its effect at PAG station is feebly seen. The horizontal power reached just about 25 nT^2.

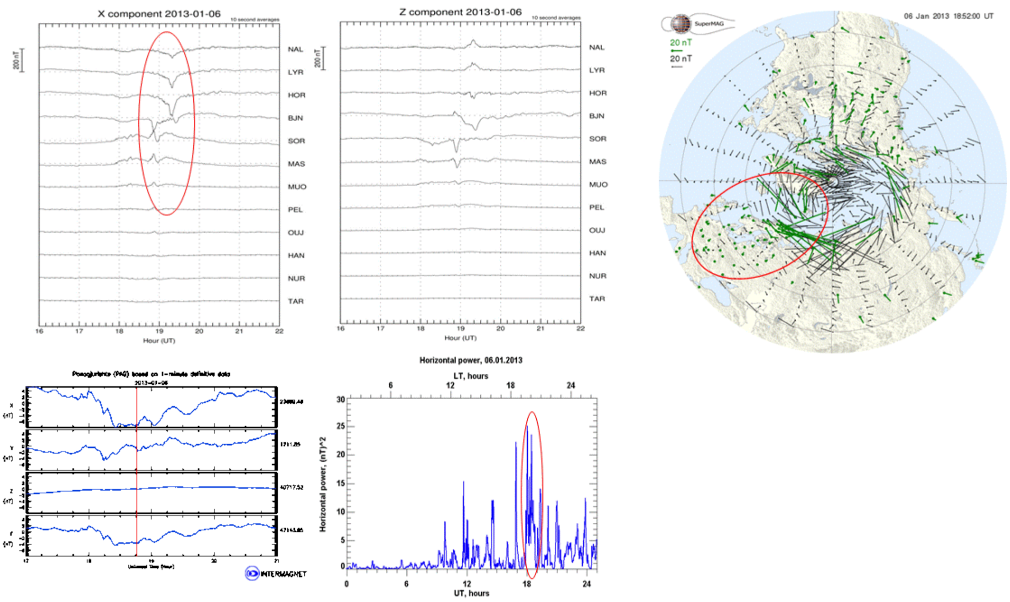

Fig.2. The substorm on 06.01.2013. Upper panels – magnetic field X (to the left) and Z (in the middle) components by the IMAGE NAL-TAR chain and magnetic field vectors by SuperMAG at the time of the MPB maximum (to the right). The substorm is indicated by red ellipse in the left panel and the substorm region is marked by a red ellipse in the right panel. Left bottom panel – the magnetic field at PAG station by INTERMAGNET. The MPB onset is marked by a red vertical line. Right bottom panel – the computed horizontal power of the magnetic field for the PAG station. The peak, associated with the substorm, is shown by a red ellipse.

Substorm at 22:30 UT on 31.01.2013

This substorm is presented in Fig.3. This is a usual substorm, which developed at auroral latitudes (~60°- ~ 71° GMLat), without higher latitudes (above ~70°GMLat) expansion (Fig.3, left upper panel). This is a weak substorm, as the one on 06.01.2013, but its display at PAG is better expressed (e.g. the horizontal power of the magnetic field reached ~34 nT^2 and the positive bay is much better manifested).

Substorm at 18:42 UT on 02.02.2013

The substorm on 02.02.2013 is presented in Fig.4. This is an expanded substorm, it began at auroral latitudes and the magnetic disturbances reached NAL (75.25°GMLat) (upper left and middle panels of Fig.4). Its effect at PAG is clearly expressed. The horizontal power of the magnetic field reached ~400 nT^2, the positive bay is higher and well seen.

Results

For the considered substorms, the sign conversion latitude, and some positive bays characteristics at PAG have been determined. The X-bay sign conversion latitude was determined by data of the magnetometer networks IMAGE, SuperMAG and

INTERMAGNET in the longitudinal band 90° - 104° GMLon, which is round the longitude of the Bulgarian station Panagjurishte (~97° GMLon). This boundary can be estimated by the map of the magnetic field vectors (upper right panels in Fig.2, Fig.3 and Fig.4). The MPB onset, MPB maximum, MPB amplitude and MPB end at PAG have been determined by the processed X-component of the magnetic field, after the subtraction of the main field and the mean field caused by solar quiet day variations [*Guineva et al*., 2021].

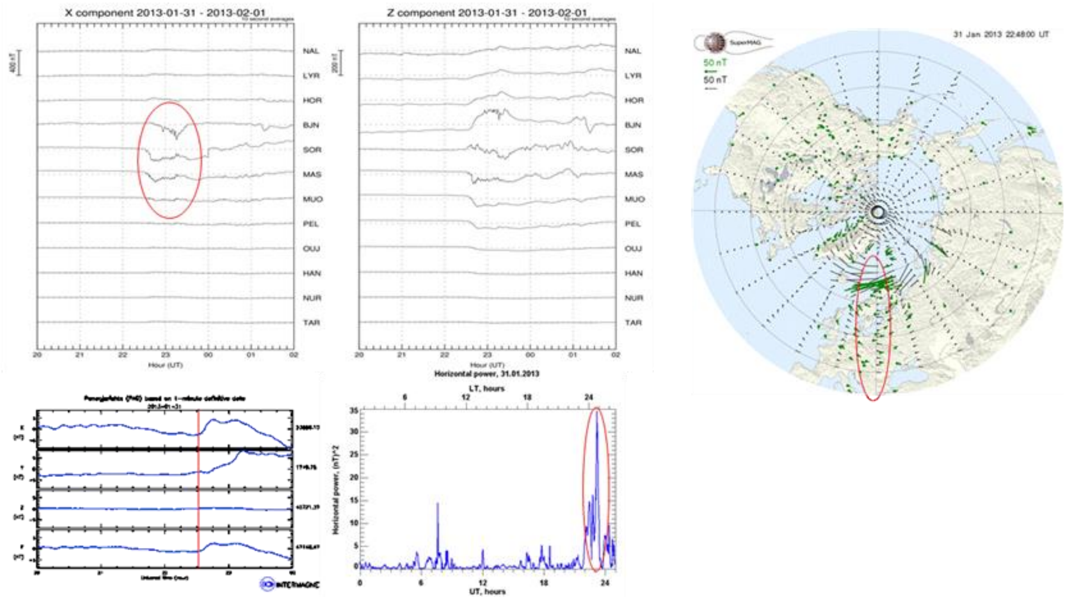

Fig.3. The substorms on 31.01.2013. The presented quantities and symbols are the same as for the substorm on 06.01.2013.

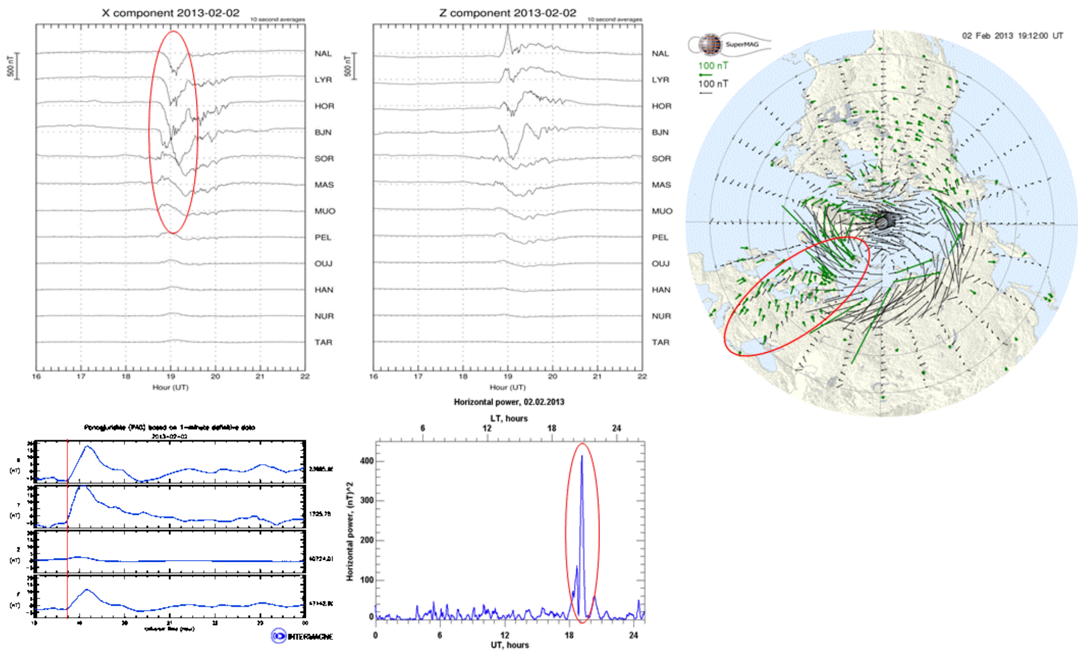

Fig.4. The substorms on 02.02.2013. The presented quantities and symbols are the same as for the substorm on 06.01.2013.

The results for the examined substorms are summarized in Table 1.

Table 1. Parameters of the midlatitude positive bays (MPB), determined at the Panagjurishte station (PAG), associated with the considered substorms. From up to down: bay sign conversion latitude, MPB onset time, MPB maximum time, MPB amplitude, MPB end time.

Parameter/date	6.01.2013	31.01.2013	02.02.2013
Conv. lat., deg.	69	61	65
MPB onset, UT	18:45	22:30	18:42
MPB max, UT	18:51	22:47	19:10
MPB ampl., nT	3	7.5	24.4
MPB end, UT	19:03	00:01	19:45

Summary

Three isolated substorms of different type have been examined, namely a polar substorm, at 18:45 UT on 06.01.2013, a usual substorm, at 22:30 UT on 31.01.2013, and an expanded substorm at 18:42 UT on 02.02.2013. It was found out, that:

- The conversion latitude is the highest for the polar substorm, and lowest for the usual one.
- The midlatitude positive bay amplitude is very small for the polar substorm, higher for the usual substorm, and greatest for the expanded substorm. The same result is obtained for the horizontal power of the magnetic field.

The effect of the weak polar and usual substorms can be detected at PAG station (~37° GMLat), but it is negligible.

These results should be verified by a wide investigation, based on a number of different types of substorms, occurred during long time intervals, and during various interplanetary conditions.

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