

CONSTRUCTION OF A CATALOG OF THE MAGNETIC VARIATIONS BY DATA OF THE BULGARIAN STATION PANAGJURISHTE

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Abstract: Substorms represent one of the very important factors of the space weather. The substorms are observed at auroral latitudes as negative bay-like magnetic disturbances and displayed as positive bays (MPB) at midlatitudes. Recently, the special MPB index was introduced, which could demonstrate the substorm occurrence. This index was evaluated by the applying of the computed average values of the horizontal magnetic field power for a number of midlatitude stations.

Here we present the creation of the new catalog of the magnetic variations including the MPB data from the Bulgarian station Panagjurishte (~37° GMLat, ~97° GMLon). This catalog is being developed for the first time and consists of two main sections. The first section presents the computed values of the X and Y magnetic components and the full horizontal power. For this, we have developed special processing tools. The second section comprises some MPB characteristics, associated with substorms, identified by data of the IMAGE meridional magnetometer chain, the IL index and the obtained horizontal power at Panagjurishte with 1-min sampling. Now the first section of the catalog is completed for some time intervals. The second section is under construction.

The catalog will be on the website of the Space Research and Technology Institute of the Bulgarian Academy of Sciences.

РАЗРАБОТКА КАТАЛОГА МАГНИТНЫХ ВАРИАЦИЙ ПО ДАННЫМ БОЛГАРСКОЙ СТАНЦИИ ПАНАГЮРИШТЕ

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Абстракт: Важным аспектом при изучении космической погоды являются исследования суббурь. Известно, что магнитные суббури регистрируются на наземных магнитометрах как отрицательные бухты в авроральных широтах и как положительные бухты (mid-latitude bays- MPB) в средних широтах. Недавно был разработан индекс среднеширотной активности – MPB-индекс. Для расчета этого индекса применялись вычисленные средние значения мощности горизонтального наземного магнитного поля для ряда станций на средних широтах.

В нашем докладе мы представляем разработку нового каталога магнитных вариаций на болгарской станции Панагюриште (~ 37 ° GMLat, ~ 97 ° GMLon). Подобный каталог разрабатывается впервые, он будет состоять из двух основных разделов. В первом разделе будут представлены

вычисленные значения X- и Y- компонент магнитного поля и полная горизонтальная мощность МРВ, определенная по данным станции Панагюриште. Для этого нами были созданы специальные программы обработки магнитных данных. Второй раздел содержит некоторые характеристики положительных магнитных бухт (МРВ), которые наблюдались во время суббурь, развивающихся одновременно в авроральных широтах. Суббури определялись по данным меридиональной цепочки наземных магнитометров IMAGE, а именно по IL индексу и горизонтальной мощности МРВ в Панагюриште, использовались данные с 1-минутной выборкой. На данном этапе заполняется первый раздел нашего каталога. Второй раздел обсуждается и разрабатывается.

Планируется разместить каталог на сайте Института Космических исследований и Технологий Болгарской Академии Наук.

Introduction

The explosive release of a large amount of energy from the magnetosphere into the upper polar atmosphere is known as magnetospheric substorm [1]. Magnetospheric substorms are manifested in a number of various phenomena and are an important element of the space weather. They are related to the substorm current wedge (SCW), a current system, that originates in the Earth's magnetotail and flows along the magnetic field lines to the ionosphere [2,3]. SCW causes the auroral onset and further expansion [4]. At auroral latitudes, large disturbances in the ground magnetic field are generated. Negative bays in the X component of the magnetic field are observed. At the same time, at midlatitudes weaker disturbances occur, expressed as positive bays in the X component, known as midlatitude positive bays (MPB), and a systematic variation of the Y component. The locations of X and Y extrema can be used to determine the characteristics of the SCW and to find a relationship between other phenomena and SCW. Quantitative models of SCW have been developed, e.g. [5], in which, founded on ground based midlatitude magnetic variations determined parameters, a model of the field aligned currents is presented. The MPB can serve as a proxy for the substorm expansion onset. Recently, a new index, MPB index, was introduced [6, 7]. Lists of MPB onsets have been composed by different authors e.g. [6, 7].

The study the MPB behavior could be one of the important tools of the investigation of the solar-magnetosphere coupling during the substorm progress. The development of an original catalog of the midlatitude positive bays (MPB) registered at the Bulgarian station Panagjurishte (~37° GMLat, ~97° GMLon) is one of the basic tasks of the project "Investigation of the geomagnetic disturbances propagation to midlatitudes and their interplanetary driver identification for the development of midlatitude space weather forecast" - a bilateral project Bulgaria – Russia 2019 – 2020. In this work, the process of creation for the first time of a new catalog of the magnetic variations and the magnetic positive bays, registered at Panagjurishte (PAG), intended to work out of the tasks of the joint project, is described.

Structure and content of the catalog

The structure and content of the catalog were thought out. The catalog is ftp positioned. A scheme of the catalog is presented in fig.1. The main part of the catalog consists of two sections. The first section "Magnetic field data" contains processed every day magnetic data. In the second section, "MPB data", information for the registered midlatitude positive bays at the Panagjurishte station is included.

A complimentary part is also envisaged in the catalog, comprising concomitant data about every substorm day, as sign conversion latitude of the X negative bays to positive ones, some geomagnetic indices, the presence or no of a geomagnetic storm and so on.

Section "Magnetic field data" of the catalog

To construct the catalog, first the magnetic field data have to be processed. Section "Magnetic field data" contains the results of the processed every day one-minute measurements of the X and Y magnetic components. To carry out the processing, special processing tools following the algorithm of McPherron [6] including some new elements have been developed. The processing consists of the following procedures:

- Construction of long arrays of 36000 one-minute sampled X and Y magnetic components data for an interval of 25 days, centered on the day under consideration;
- Preprocessing, including gaps and peaks detection and removal;
- Estimation and subtraction of the main field under quiet conditions;
- Removing of the very disturbed days (outliers);
- Determination and subtraction of the solar quiet day variations (Sq);

- High-pass filtration of the obtained X and Y component variations;
- Computing of the horizontal power.

This processing has been performed for all one-minute sampled measurements of the Panagjurishte station, from 2007 to 2020 and some results have been uploaded in the catalog.

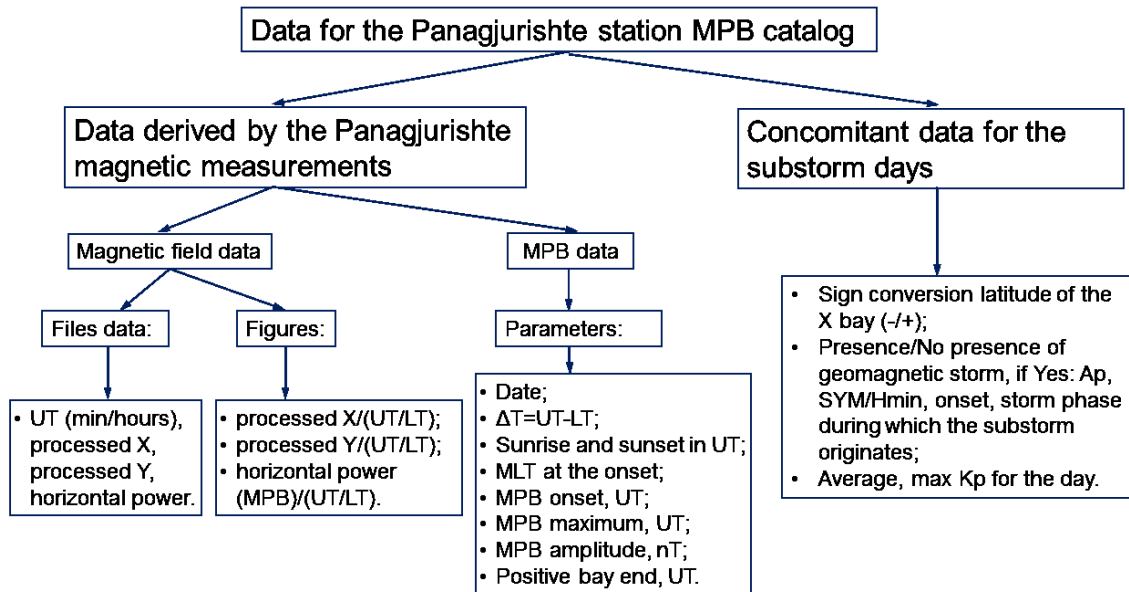


Fig. 1. Scheme of the structure of the Panagjurishte MPB catalog

The results included in the catalog, are data files and graphics for every day. The every-day files comprise:

- the time in min and hours;
- one minute data for the processed X and Y magnetic components, main field and solar quiet day variations removed;
- the horizontal power of the magnetic field (main field and solar quiet day variations (Sq) removed).

The appearance of a data file is presented in fig.2. The example is for 3 September 2013.

Magnetic field processed X and Y components and the resulting horizontal power
Calculated at Space Research and Technology Institute, Sofia, Bulgaria

Station: PAG
Date of observation: 03.09.2013

Time in UT		delta X-comp.	delta Y-comp.	Power
min	hours	nT	nT	nT
1	0.017	0.47	-3.35	11.46
2	0.033	0.43	-2.99	9.09
3	0.050	0.29	-2.72	7.47
4	0.067	0.26	-2.55	6.56
5	0.083	0.12	-2.38	5.67
6	0.100	-0.01	-2.41	5.80
7	0.117	-0.04	-2.44	5.94
8	0.133	0.03	-2.47	6.08
9	0.150	0.20	-2.69	7.30
10	0.167	0.27	-2.92	8.61
11	0.183	0.35	-2.85	8.23
12	0.200	0.42	-2.87	8.44
13	0.217	0.40	-2.50	6.41
14	0.233	0.57	-2.22	5.28

Fig. 2. Look of a magnetic field data file. The example is for 03.09.2013. The file contains 1 minute sampled data for the whole day (1440 values).

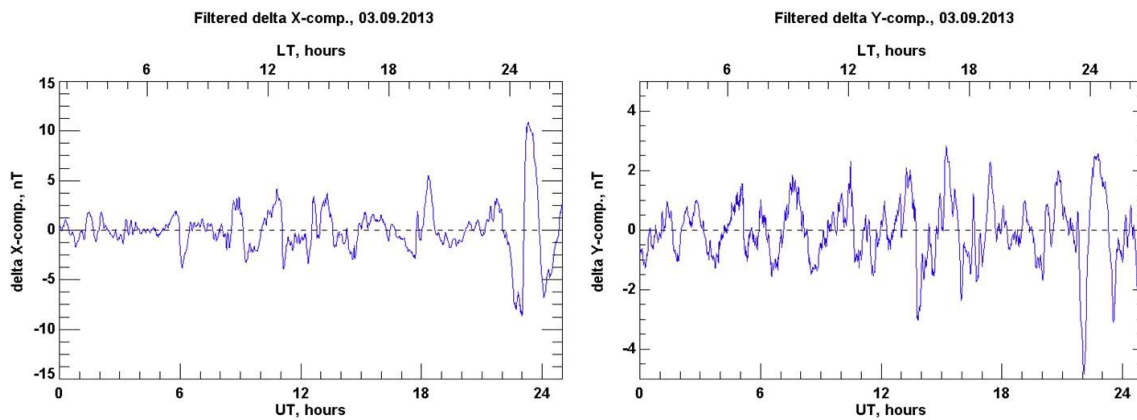


Fig. 3. Processed X (left panel) and Y (right panel) components of the magnetic field, measured on 03 September 2013 at the Panagjurishte station

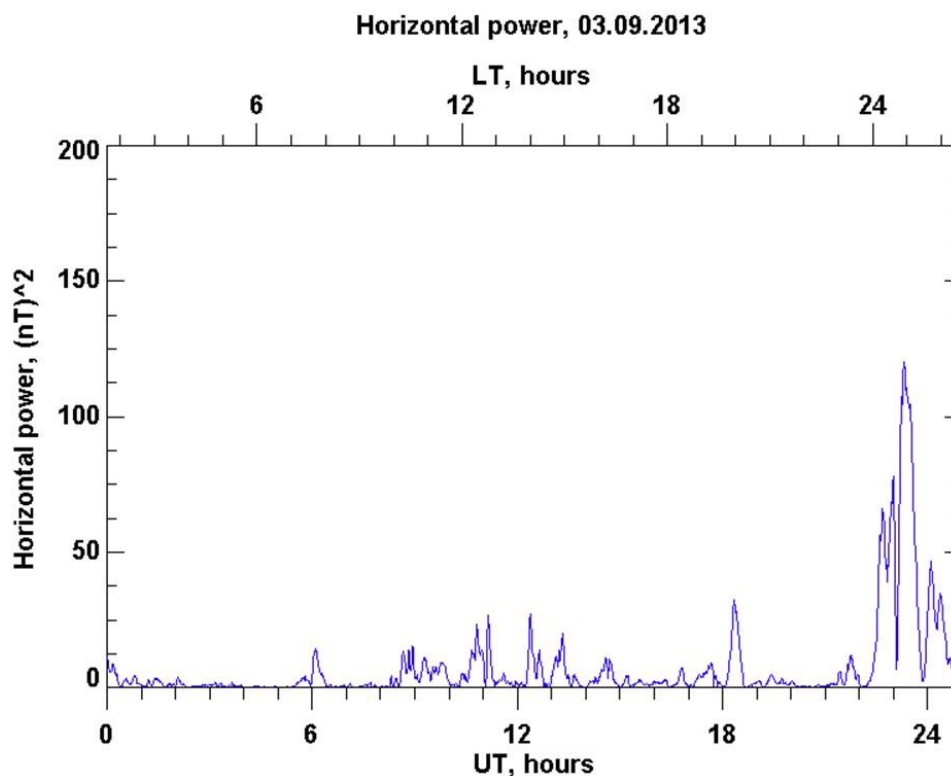


Fig. 4. Horizontal power of the magnetic field perturbations on 03 September 2013 at Panagjurishte

The graphics present:

- the processed X component;
- the processed Y component;
- the horizontal power of the magnetic field.

The processed X and Y components for 3 September 2013 are shown in fig.3, and the horizontal power computed from them is presented in fig.4.

Section “MPB data” in the catalog

The second basic section of the catalog, “MPB data”, is envisaged to provide information about all midlatitude positive bays registered at the Panagjurishte station (PAG). First, the substorms are to be identified. The substorms are being detected by the inspection of the magnetic data of the IMAGE meridional chain including the IL IMAGE index and the obtained horizontal power at Panagjurishte together. Data of INTERMAGNET and SuperMAG stations in the longitudinal band 90° - 104° GMLon (near the longitude of the PAG station ($\sim 97^{\circ}$ GMLon)), are also used to follow the substorms development.

For each substorm its midlatitude display – positive bay – at the station PAG (Bulgaria) was examined and a file with chosen parameters was created.

In the beginning of every file the date and the difference between local and universal time (LT-UT) for Panagjurishte are written, the UT for the sunrise and sunset at Panagjurishte for the substorm day, and the MLT at the positive bay onset. After that, some parameters of the relevant MPB are included, namely the time of the positive bay onset, the time of the MPB maximum, the MPB amplitude and the time of the MPB end. These parameters are being determined by the X component of the magnetic field, obtained after the main field subtraction, estimated by a smoothed spline through the midnight points of 25 consecutive days, centered on the considered day, and the following removal of the mean field caused by solar quiet day variations, obtained by superposed epoch analysis, and high-pass filtration. In fig.5 (a), the original X component from 20 UT to 24 UT on 03.09.2013 and the computed smoothed spline are presented, in fig.5 (b) – the resulting X after the main field subtracted this way, in fig.5 (c) – the obtained X after the processing, and in fig.5 (d) – the original X data, the average of the day subtracted, for comparison with the got result. The way of determination of the MPB parameters is shown by the red lines, as follows:

- time of the positive bay onset – vertical line (1);
- time of the positive bay maximum – vertical line (2);
- amplitude of the X-component – arrowed line (3);
- time of the positive bay end – vertical line (4).

The parameter values are obtained from the computed numerical X data. It is seen, that the midlatitude positive bay on 03.09.2013, obtained after our processing procedure (fig.5 (c)) and the MPB after subtracting the average value of the day (fig.5 (d)), are practically identical. The times of the MPB onset, maximum and end coincide. The amplitudes are 19.5 nT and 19.1 nT by our result (fig.5 (c)) and the average value subtraction (fig.5 (d)), respectively.

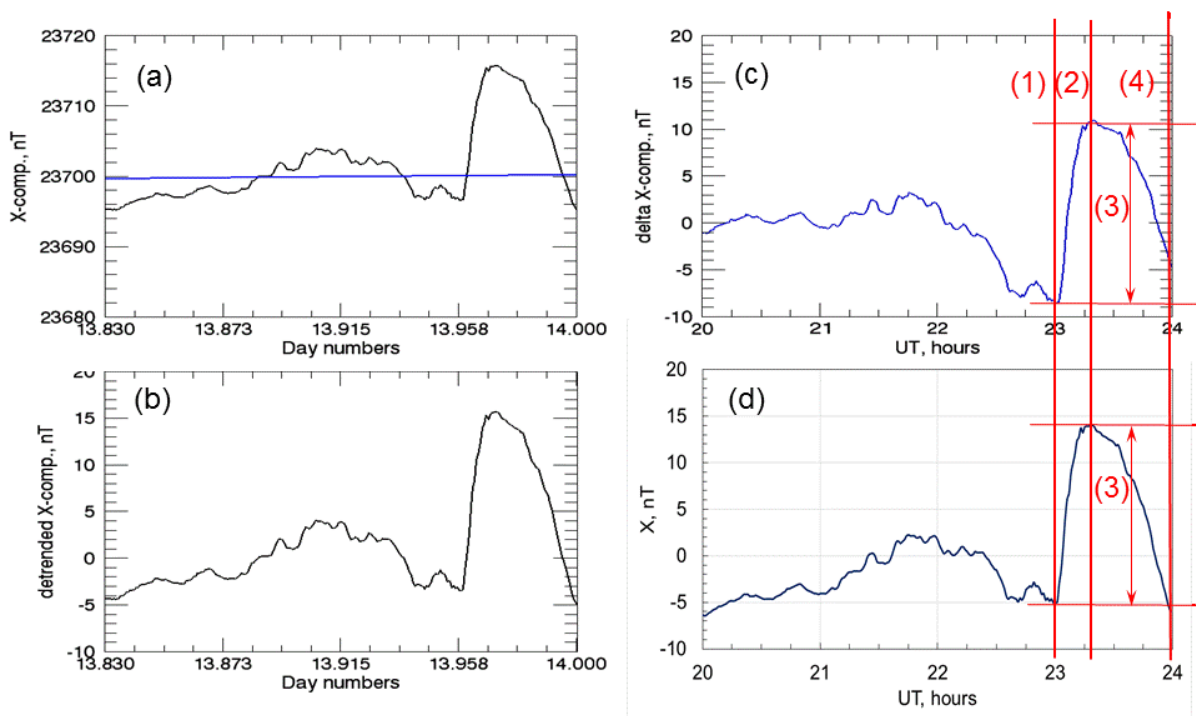


Fig. 5. An example of the determination of the MPB parameters. We have chosen an isolated substorm, namely the one at 23 UT on 03 September 2013.

- (a) Original X data from 20 UT to 24 UT on 03.09.2013 and the smoothed spline by the midnight points, computed from 25 days long series, centered on the considered day;
- (b) X component obtained after the subtraction of the main field estimated by the way mentioned above.
- (c) X component, main field under quiet conditions and mean field caused by solar quiet day variations removed. The manner to determine the MPB parameters is presented by straight lines, enumerated as follows: (1) time of the positive bay onset; (2) time of the positive bay maximum; (3) amplitude of the X-component; (4) time of the positive bay end;
- (d) The estimation of the MPB parameters, when the average day value was subtracted from the original data (as it is done by the INTERMAGNET data base). The meaning of the lines is the same as in (c).

Summary

A substorms catalog including the X and Y components variations and the horizontal power of the magnetic field, the main field under quiet conditions and the mean solar quiet day removed, and the positive bays characteristics by data of the midlatitude Bulgarian station Panagjurishte (PAG) is being created for the first time. The catalog is FTP positioned with preliminary address https://magnetic.nuclearmodels.net/Catalog_MPB/Stations/Panagjurishte/ . Later this catalog will be located in the website of the Space Research and Technology Institute (SRTI) of the Bulgarian Academy of Sciences. Section "Magnetic field data" is completed. Tools for data preprocessing and processing have been developed. The Panagjurishte (PAG) one minute magnetic data since 2007 have been processed and the results uploaded in the catalog. Section "Substorm data" is under construction. The substorms during January and February 2013 have been identified. The characteristics of the positive bays were determined.

The work on the development of the catalog of positive magnetic bays during substorms will be continued. The catalog will be used to work out the tasks of a joint bilateral project Bulgaria-Russia.

We plan also to implement permanent processing of the newly registered data and thus to keep the catalog up to date.

This work could be useful for further studies. The processing tools could be applied for other European stations data to form a dataset and to obtain the midlatitude positive bay (MPB) index. This will allow to implement a complex analysis of the space-temporal characteristics of the magnetic substorms at midlatitudes and auroral latitudes in order to reveal the peculiarities of the spreading of the geomagnetic disturbances to midlatitudes depending on the conditions of the near-Earth space weather.

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References:

1. Akasofu, S.-I., Polar and magnetospheric substorms, D. Reidel, Norwell, Mass., 1968
2. McPherron, R. L., C. T. Russel, M. P. Aubry, Satellite studies of magnetospheric substorms on August 15, 1968. 9. Phenomenological model for substorms, *Journal of Geophysical Research*, 78(16), pp. 3131–3149, 1973
3. Sergeev, V. A., L. I. Vagina, R. D. Elphinstone, J. S. Murphree, D. J. Hearn, L. L. Cogger, and M. L. Johnson (1996), Comparison of UV optical signatures with the substorm current wedge predicted by an inversion algorithm, *J. Geophys. Res.*, 101(A2), 2615–2627
4. Ritter, P., and H. Lühr (2008), Near-Earth magnetic signature of magnetospheric substorms and an improved substorm current model, *Ann. Geophys.*, 26, 2781–2793, doi:10.5194/angeo-26-2781-2008.
5. Sergeev, V. A., N. A. Tsyganenko, M. V. Smirnov, A. V. Nikolaev, H. J. Singer, and W. Baumjohann, Magnetic effects of the substorm current wedge in a "spread-out wire" model and their comparison with ground, geosynchronous, and tail lobe data, *J. Geophys. Res.*, 116, A07218, 2011
6. Chu, X., Configuration and generation of substorm current wedge, Los Angeles: University of California Los Angeles, 2015
7. McPherron, R. L., X. Chu, The midlatitude positive bay and the MPB index of substorm activity, *Space Science Reviews*, 206, pp. 91–122, 2017