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of earthquakes precursors”

Development of a substorms catalog including the MPB observed at Panagjurishte station, Bulgaria

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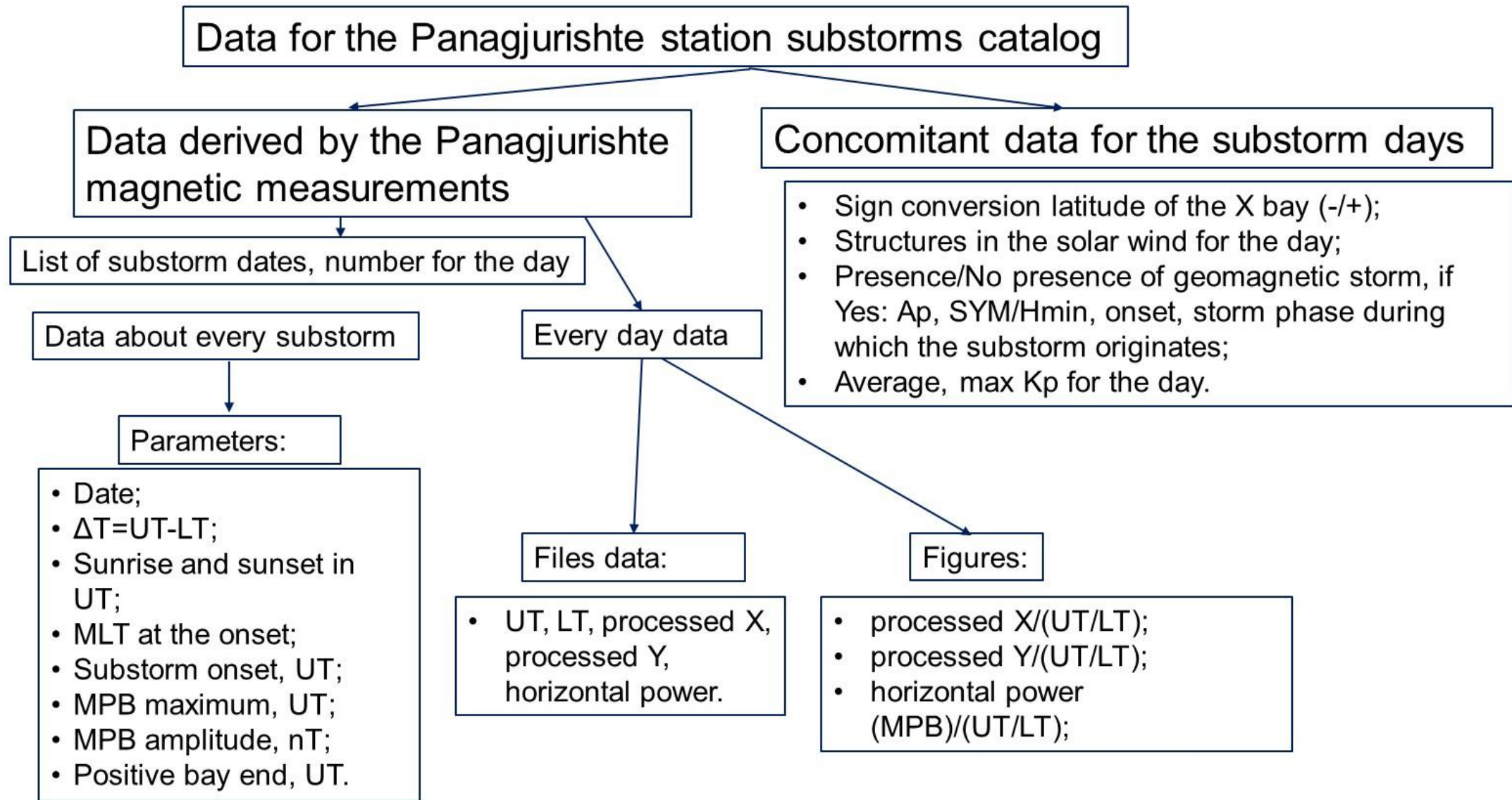
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The development of an original catalog of the midlatitude positive bays (MPB) registered at the Bulgarian station Panagjurishte ($\sim 37^\circ$ GMLat, $\sim 97^\circ$ GMLon) is one of the basic tasks of the project **“Investigation of the geomagnetic disturbances propagation to midlatitudes and their interplanetary drivers identification for the development of midlatitude space weather forecast”** - a bilateral project Bulgaria – Russia 2019 – 2020, financed by the National Science Fund (project number КП-06-Русия/15) and RFBR (project number 20-55-180003 Болг_а)

The study the MPB behavior could be one of the important tools of the investigation of the solar-magnetosphere coupling during the substorm progress because, as it is generally accepted, a MPB represents the midlatitude effect of the substorm current wedge (SCW) development and could be a proxy of the dipolarization process in the magnetotail.



Scheme of the structure of the Panagjurishte substorm catalog.

Index of /Catalog_MPB/Stations/Panagjurishte

<u>Name</u>	<u>Last modified</u>	<u>Size</u>	<u>Description</u>
Parent Directory		-	
Magnetic field data/	2021-08-05 11:44	-	
Substorm data/	2021-08-05 11:43	-	

Index of /Catalog_MPB/Stations/Panagjurishte/Magnetic field data

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Years/	2021-0		

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2013/	2021-07-24 21:43		
2014/	2021-07-24 21:36		
2015/	2021-07-24 21:36		
2016/	2021-07-24 21:36		
2017/	2021-07-25 14:23		
2018/	2021-08-03 11:11		
2019/	2021-08-03 11:11		
2020/	2021-07-25 14:05		
2021/	2021-07-20 14:11		

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02 February/	2021-08-05 23:15		
03 March/	2021-09-22 21:02		
04 April/	2021-09-23 12:00		
05 May/	2021-09-23 12:12		
06 June/	2021-09-23 11:39		
07 July/	2021-07-18 22:19		
08 August/	2021-09-23 11:39		
09 September/	2021-07-18 22:20		
10 October/	2021-07-18 22:20		
11 November/	2021-07-18 22:21		
12 December/	2021-07-18 22:21		

Index of /Catalog_MPB/Stations/Panagjurishte/Magnetic field data/Years/2013/2 February

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20130207/	2021-08-03 10:47	-	
20130208/	2021-08-03 10:47	-	
20130209/	2021-08-03 10:46	-	
20130210/	2021-07-24 21:48	-	
20130211/	2021-08-03 10:47	-	
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20130216/	2021-08-03 10:48	-	
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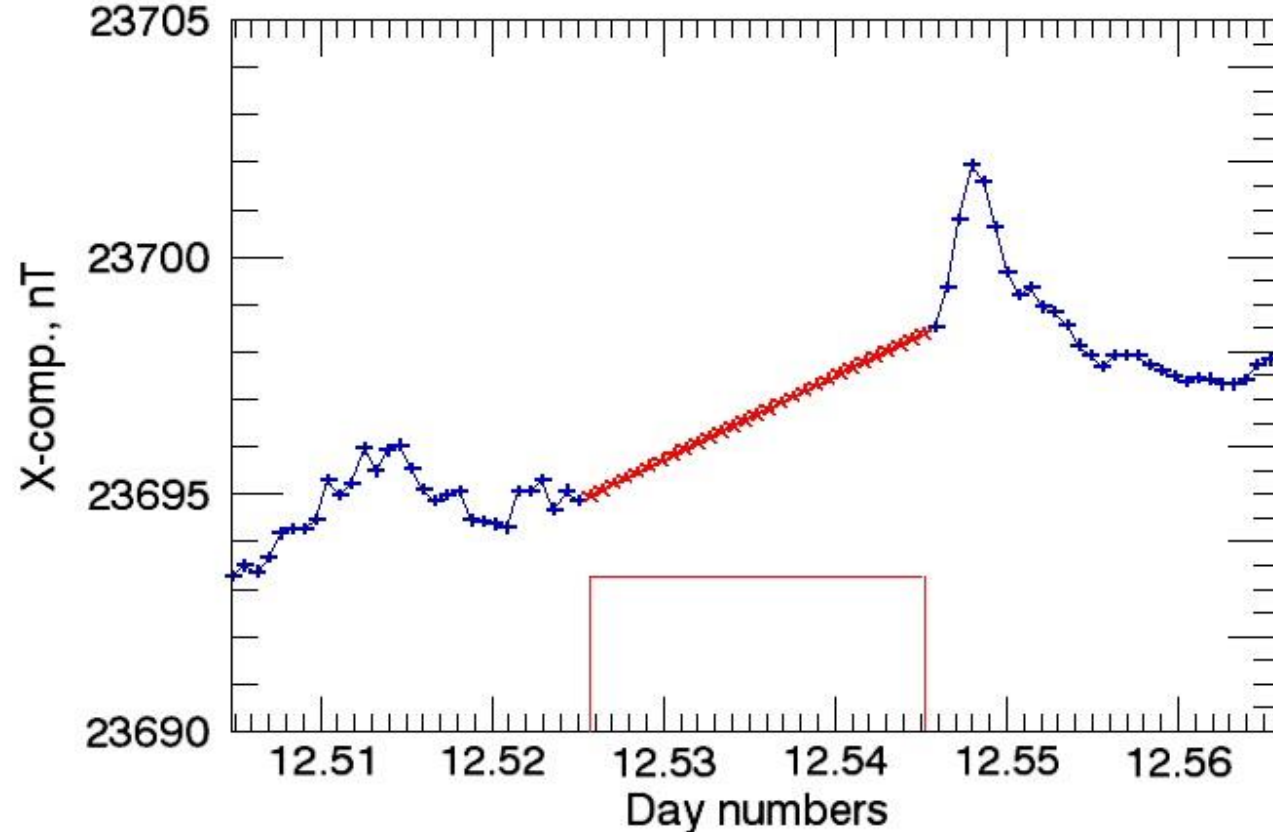
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PAG_Y-comp_2013_02_...>	2021-08-30 18:43	12K	

Consecutive windows to look at the graphs and the data file for a given day.

To construct the catalog, first the magnetic field data have to be processed. In this purpose, special processing tools were developed. The processing includes:

- Construction of a long array of 36000 data points spaced in minutes 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;
- Removing of the very disturbed days (outliers);
- Determination and subtraction of the mean field under solar quiet conditions;
- High-pass filtration of the obtained X and Y component variations;
- Computing of the horizontal power.

Preprocessing: data gaps removal

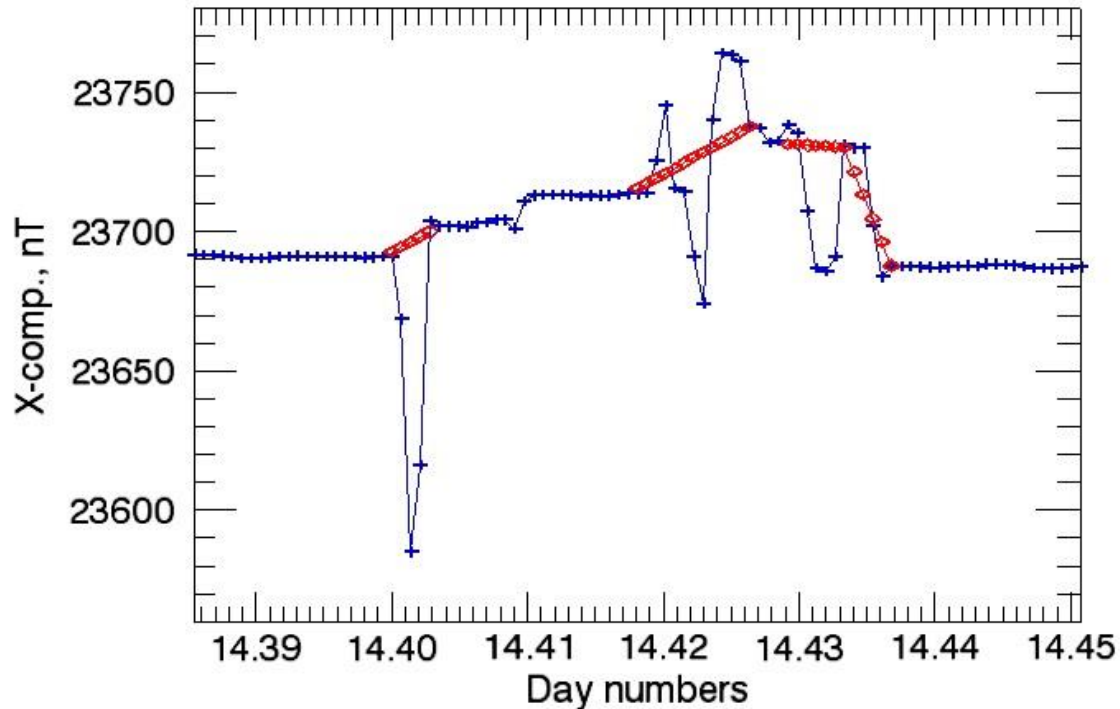


Procedure:

- Detection of the “no data” intervals
- Linear interpolation between the last and first measurements outside of the no data interval

Example: one gap, observed at the day 13 (20.02.2017) of the time interval 08.02.2017 - 04.03.2017 is marked by the bar plot. The original data are presented by plusses, connected by lines, and the interpolated data are shown by asterisks, also connected with a line.

Preprocessing: data peaks removal



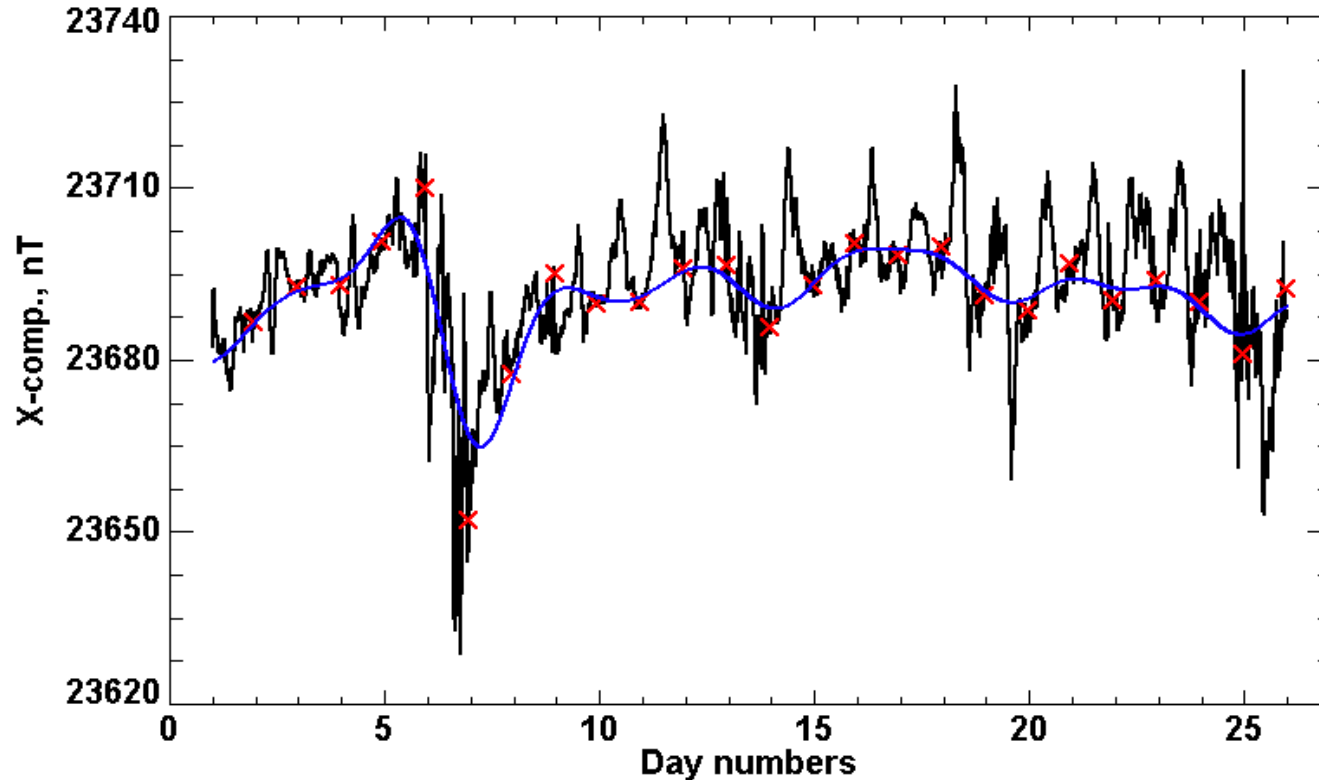
Procedure:

- Peak detection - by the absolute value of the first derivation greater than a given threshold
- Peak borders determination - by the first undercut of mean standard deviation of the first derivation at left and right of the peak
- The values between the peak borders were replaced by linear interpolation

The figure demonstrates how the peak removal is working. The original data are in blue, and the interpolated data are in red. In the left side near the day number of 14.40 (22.02.2017) a single peak, detected and removed, is presented. In the right side a sequence of peaks was found and removed by linear interpolation.

Elimination of the main magnetic field

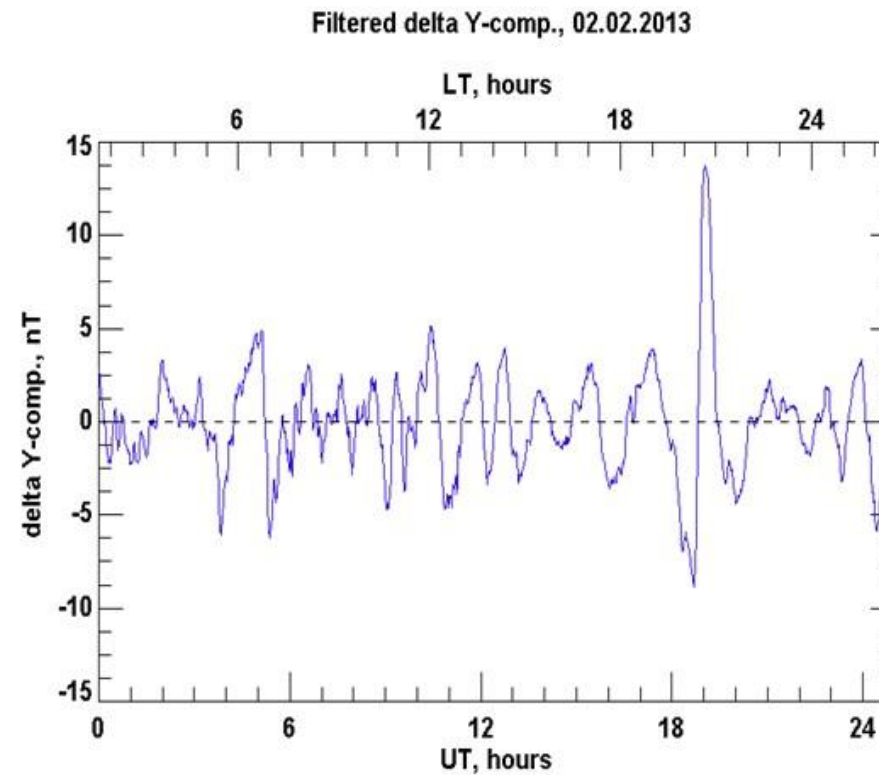
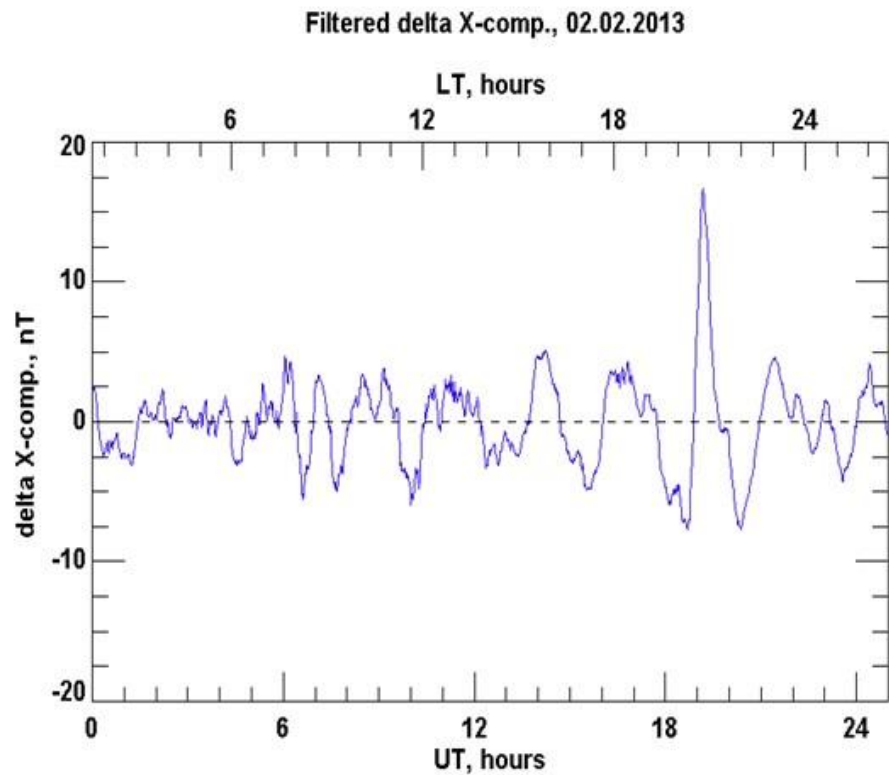
X-comp. and smoothed spline, 02.02.2013



To eliminate the main magnetic field and the slow changes due to the ring current and partial ring current a base line was constructed by a smoothed spline interpolation through the midnight points (at 24h in LT). The resulting spline was subtracted from the time series.

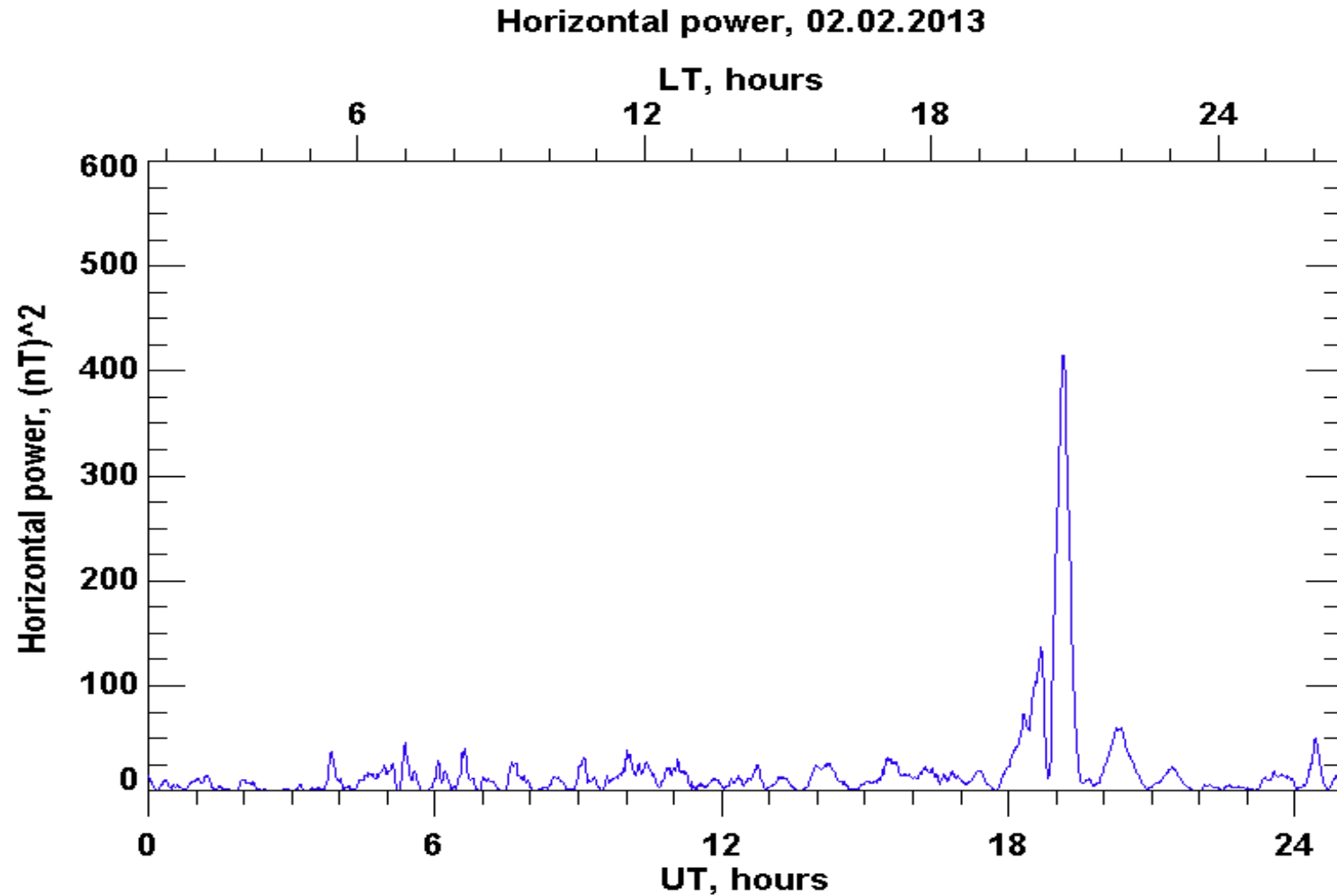
X-component series for 25 days, centered on 02 February 2013. The midnight points (24 LT) are marked by "x" sign. The computed smoothed spline through the midnight points is drawn by a continuous line.

- Subtraction of the mean Solar quiet magnetic variations S_q , determined by averaging of the daily variations of the field components (disturbed days removed)
- Filtration by a high pass filter to suppress the high frequencies and to keep



the low frequency changes. Signals with frequencies longer than about 3 hours were filtered out.

Processed X (left panel) and Y (right panel) components of the magnetic field, measured on 02 February 2013 at the Panagjurishte station.



Horizontal power of the magnetic field perturbations on 02 February 2013 at Panagjurishte. The obtained maximum at about 19:10 UT corresponds to the substorm, observed in the auroral zone, on the IMAGE meridional chain PPN-NAL.

Every day data file

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

Station: PAG

Observation Data: 02.02.2013

Time in UT		delta X-com.	delta Y-comp.	Power
min	hours	nT	nT	nT
1	0.017	2.63	2.84	14.99
2	0.033	2.50	2.45	12.25
3	0.050	2.37	1.96	9.45
4	0.067	2.44	1.77	9.09
5	0.083	2.21	1.18	6.29
6	0.100	1.99	1.09	5.14
7	0.117	1.66	0.80	3.40
8	0.133	1.24	0.61	1.91
9	0.150	0.91	0.03	0.83
10	0.167	0.49	-0.06	0.24
11	0.183	0.07	-0.04	0.01
12	0.200	-0.45	0.07	0.21
13	0.217	-0.67	-0.51	0.71
14	0.233	-1.09	-1.19	2.61
15	0.250	-1.51	-1.57	4.75
16	0.267	-1.63	-1.75	5.72
17	0.283	-1.74	-1.83	6.39

Magnetic field data file for 02.02.2013.

Substorm data

Substorm detection – in the auroral zone, on the IMAGE meridional chain PPN-NAL.

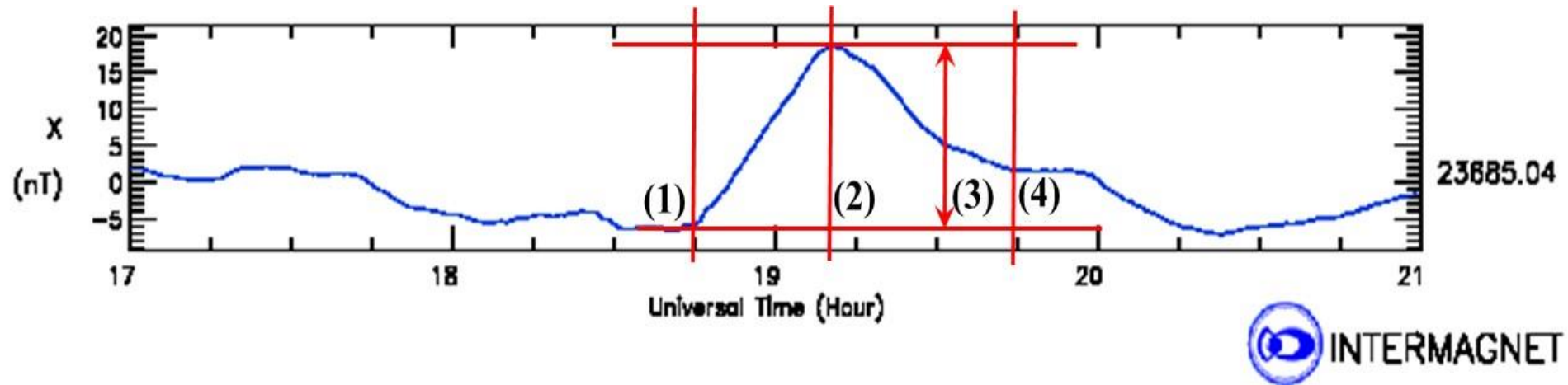
Use of INTERMAGNET and SuperMAG stations data in the longitudinal band 90° - 104° GMLon (near the longitude of the PAG station ($\sim 97^{\circ}$ GMLon), to follow the substorms development.

Time period – January and February 2013. During this time 67 substorms were identified; this number includes all observed substorms.

For each substorm in the auroral zone 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 substorm onset.

MPB parameters



An example of the determination of the MPB parameters. We have chosen an isolated substorm, namely the one at 18:43 UT on 02 February 2013. The way of estimation the MPB parameters, included in the catalog, is presented in the plot from INTERMAGNET by straight lines, enumerated as follows:

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

Summary

A substorms catalog including the X and Y components variations and the horizontal power of the magnetic field, main field and the mean field under solar quiet conditions subtracted, and the positive bays characteristics by data of the midlatitude Bulgarian station Panagjurishte (PAG) is under construction. The catalog is FTP positioned with preliminary address https://magnetic.nuclearmodels.net/Catalog_MPB/Stations/Panagjurishte/. Tools for data preprocessing and processing have been developed. The substorms during January and February 2013 have been identified. The PAG magnetic data for these two months have been processed. The characteristics of the positive bays were determined. The obtained results have been uploaded in the catalog.

In the future work we intend to process in such a way all one minute magnetic data from Panagjurishte (since 2007) and to complete the substorm catalog. We plan also to implement permanent processing of the newly registered data and thus to keep the catalog up to date.

Such catalog is being made for the first time. This work could be useful for further studies.

Thank You for your attention!

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