Calculation of the horizontal power perturbations of the Earth surface magnetic field

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Introduction

Magnetic substorms are phenomena related with release of a large amount of magnetotail energy into the Earth ionosphere and inner magnetosphere. They generate a lot of different events among which disturbances in the Earth surface magnetic field. At high latitudes in the X-component are observed negative bays and at midlatitudes - positive bays.

A number of indices were developed to identify the occurrence of substorms, the disturbance storm time (Dst) index, the upper auroral jet (AU), the lower auroral jet (AL) and their differences the auroral jet AE for example.

McPherron and Chu have introduced a new index to characterize the storm activity, the midlatitude positive bay index (MPB)

McPherron algorithm

The MPB index estimation, based on an algorithm from R.L. McPheronn and X. Chu, published in Space Sci. Rev., 206(1–4), 91–122 (2017), consists of the following main steps:

1. Removing of the main field and storm time changes in the X and Y components for 23 consecutive days, centered over the day of consideration (substorm day).
2. Determination of the mean solar quiet day variations of the horizontal components of the surface magnetic field and the resulting power.
3. Calculation of the average horizontal power of 35 midtatitude stations to form the MPB index

To prepare the determination of the MPB index we have looked in detail only the points 1 and 2

Data

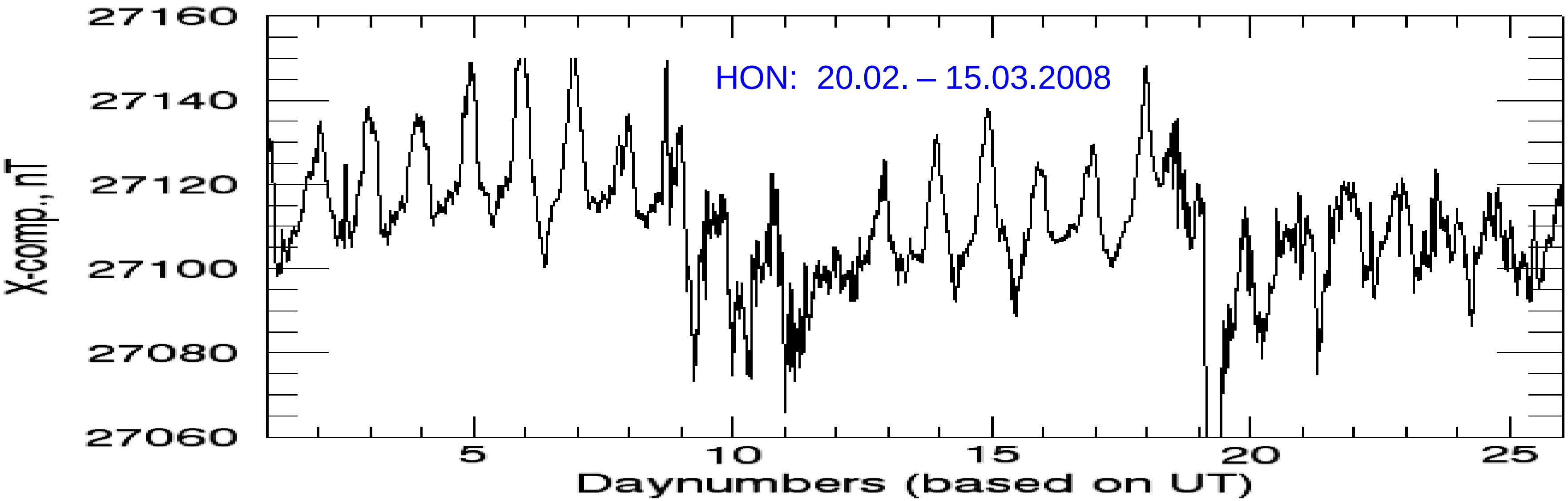
Data from Intermagnet are used for the Honolulu station from 20.02 up to 15.03.2008 and for the Panagjurishte station from 08.02 up to 04.03.2017. The Honolulu data were used to verify our calculations with the results from McPherron and Chu (2017).

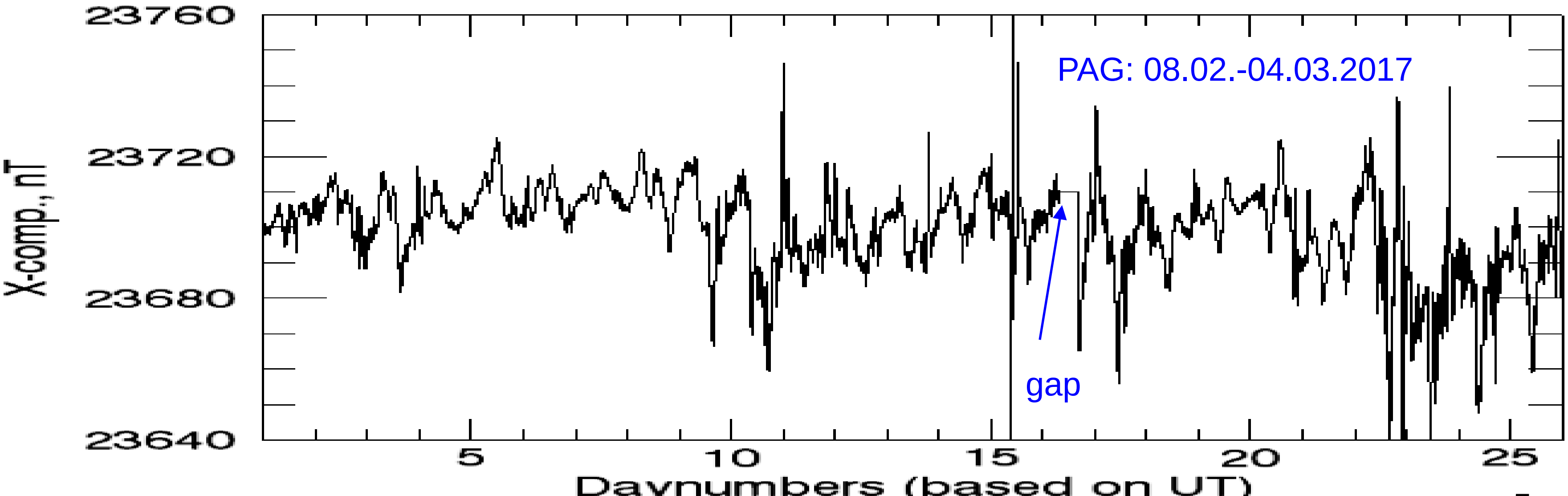
The data are given as: $\boldsymbol{X = X(month, day, min.)}$

We form a long array in UT $\boldsymbol{X = X(min.)}$

The shift by - 10.52 h for the Honolulu and +1.62 h for the Panagjurishte station gives the magnetic field components in LT, where the midnight points are easy to found.

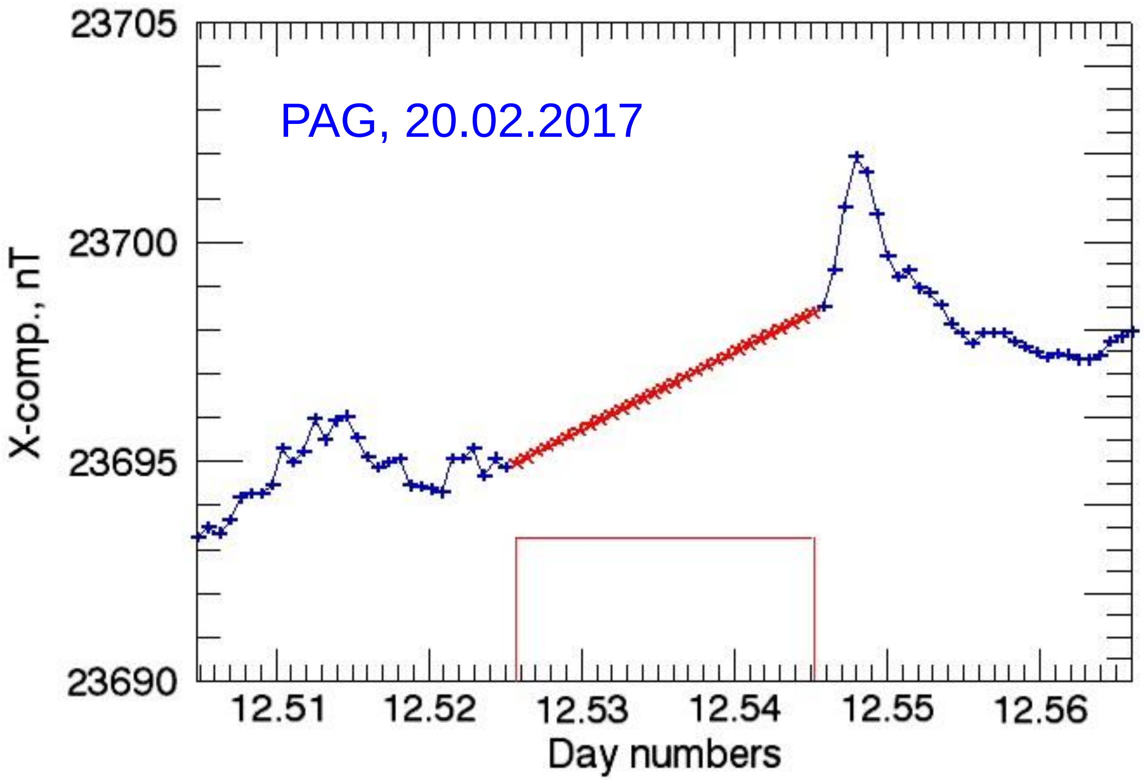
Time series


HON: 20.02. – 15.03.2008
X-comp., nT
27160
27140
27120
27100
27080
27060
5
10
15
20
25
Daynumbers (based on UT)


PAG: 08.02.-04.03.2017
gap
X-comp., nT
23760
23720
23680
23640
5
10
15
20
25
Daynumbers (based on UT)

Pre-processing

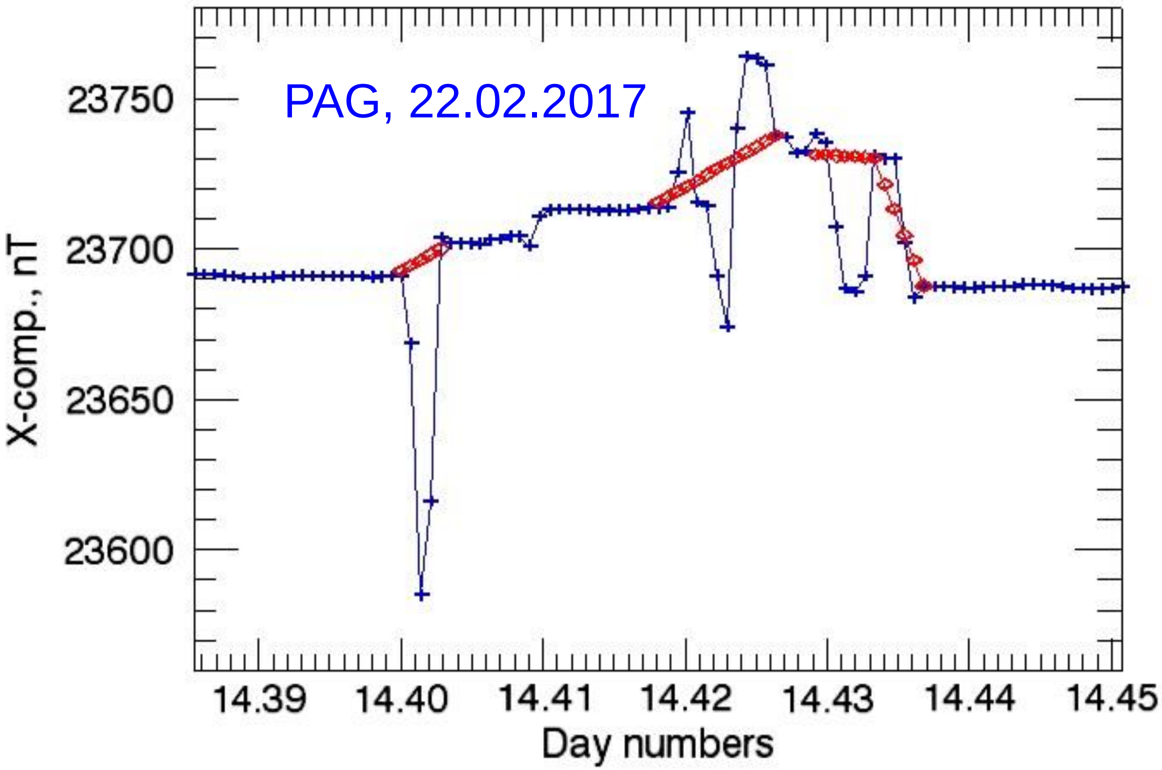
Gap detection and removal (here for the Panagjurishte station):



The interval borders of the data gaps are easy to found. The no data values were replaced by the result of the linear interpolation.

Pre-processing

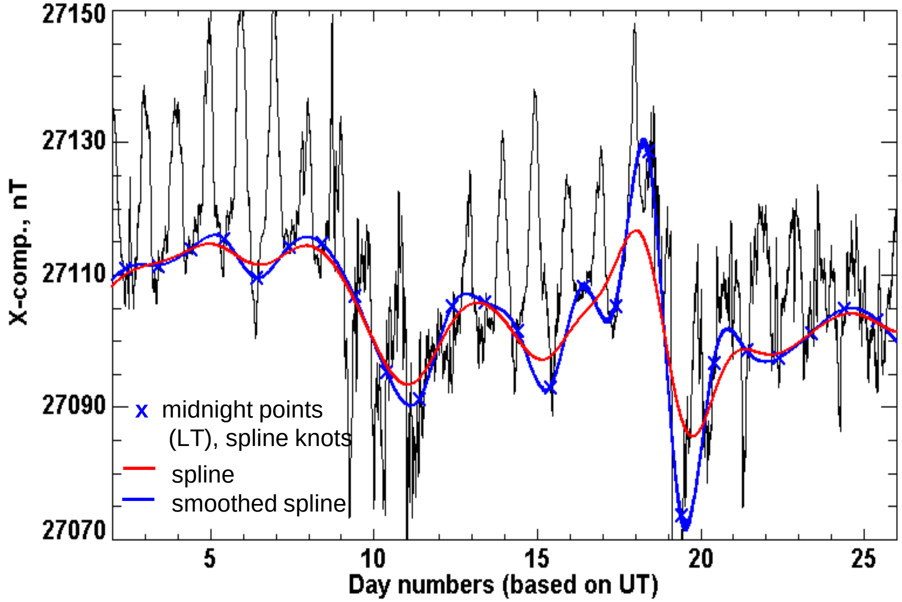
Peak detection and removal (here for the Panagjurishte station):



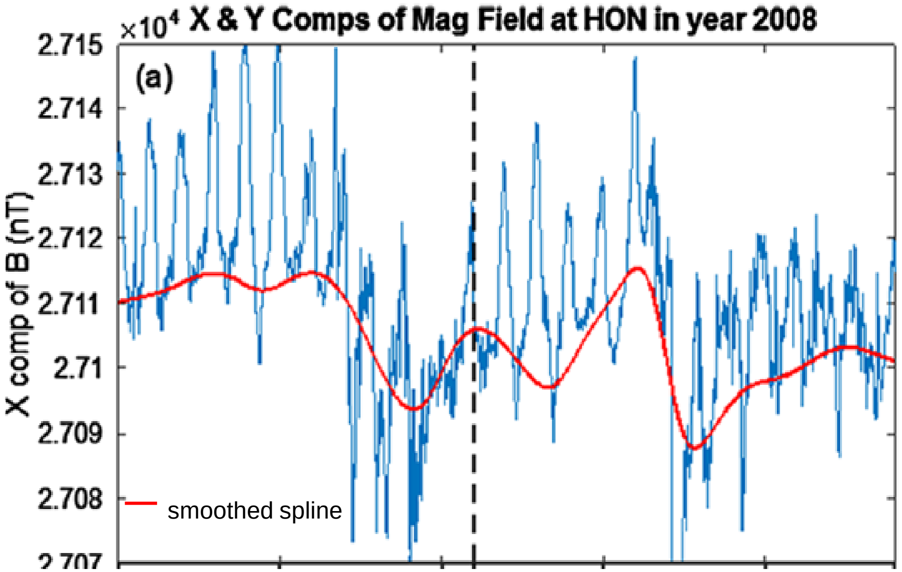
Sudden changes can be characterized by the absolute value of the first derivation greater than a given threshold. Values between the peak borders were replaced in the same manner as for the gap removal, by linear interpolation.

X-component of the horizontal magnetic field

X-component and the estimated main field by a smoothed spline



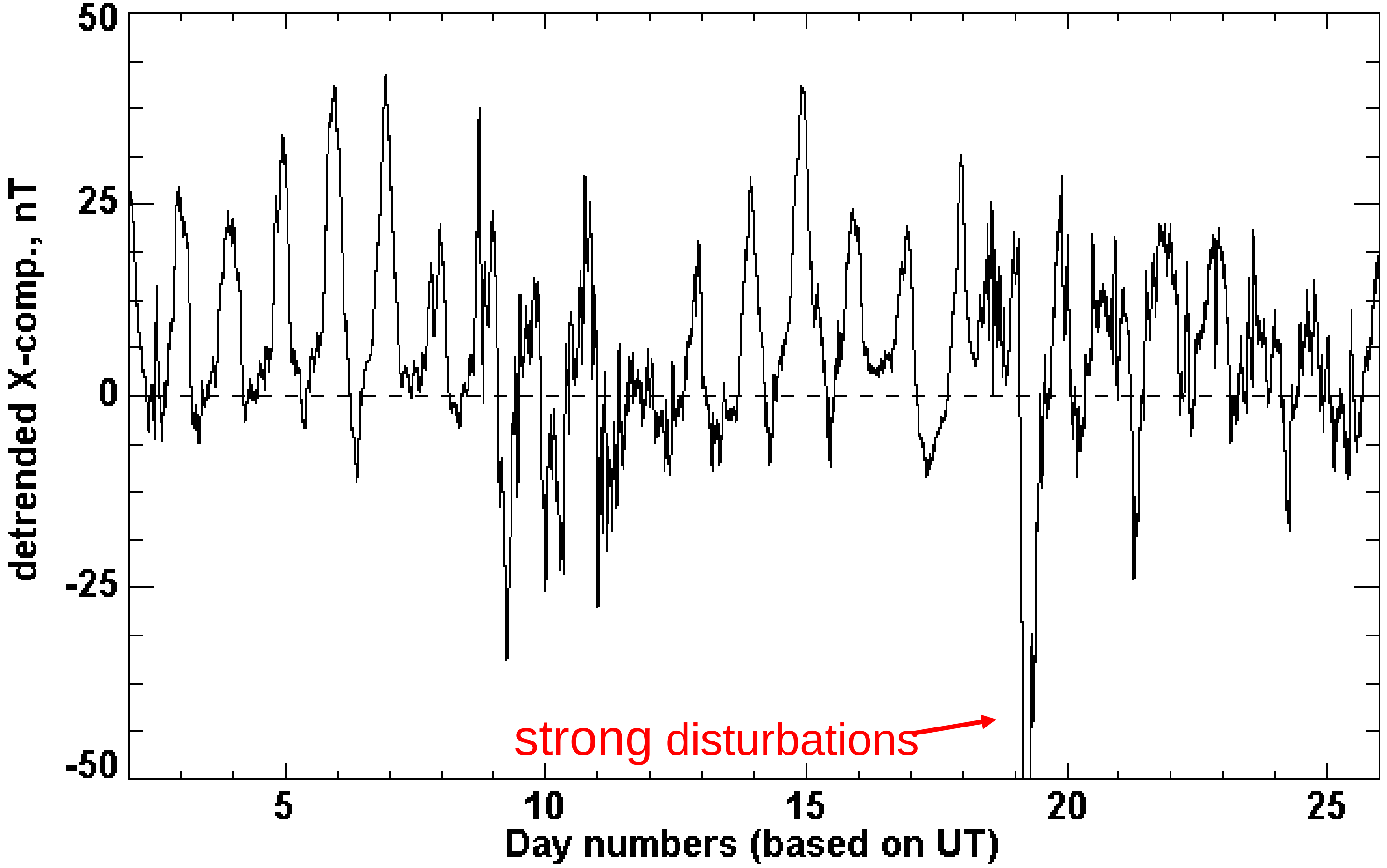
Our result



Calculated by McPherron and Chu

X-component of the horizontal magnetic field

X-component main field subtracted

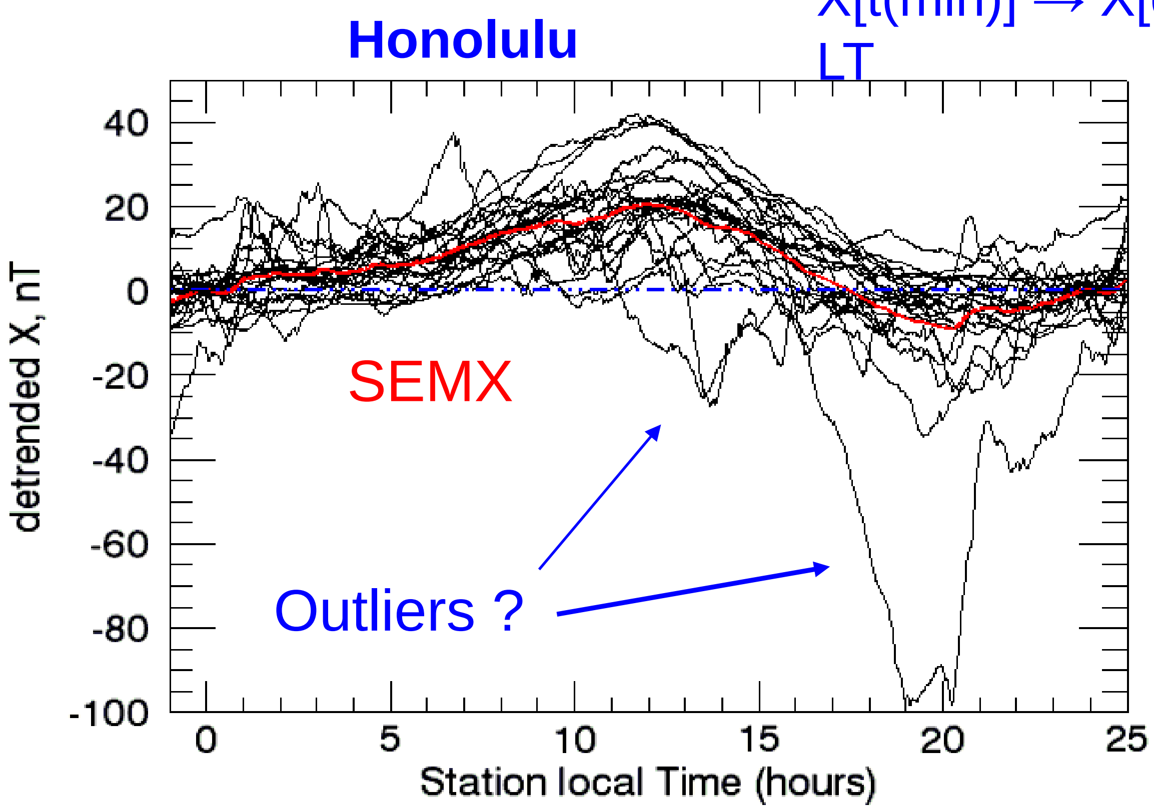


The daily variations are generated by the rotation of the station under the solar day ionospheric current system.

Superposed epoch analysis

To determine the mean magnetic field for solar quiet conditions days with strong disturbances are to be removed. The long time series X(min) is transformed back in series of X[daynumber,t(min)].

X[t(min)] → X[daynumber,t(min)] in LT



t = 1,…,1440 ± 60 min

For the PAG station is used:

t = 1,…,1440 ± 180 min

Superposed epochs for the X-component (SEMX presents the mean of X over all days for one moment t_i)

Outliers removal

To eliminate days where the magnetic field is strong disturbed, the Grubbs outlier test is applied. The mean squared errors

$$MSE_j = \frac{1}{n_i} \sum_i (x_{ij} - SEMX_i)^2$$

are considered as a normally distrubuted time series x. The hypothesis x_i is not an outlier is rejected if

$$G_i = \frac{\bar{x} - x_i}{s} > G_{n,1-\propto} ,$$

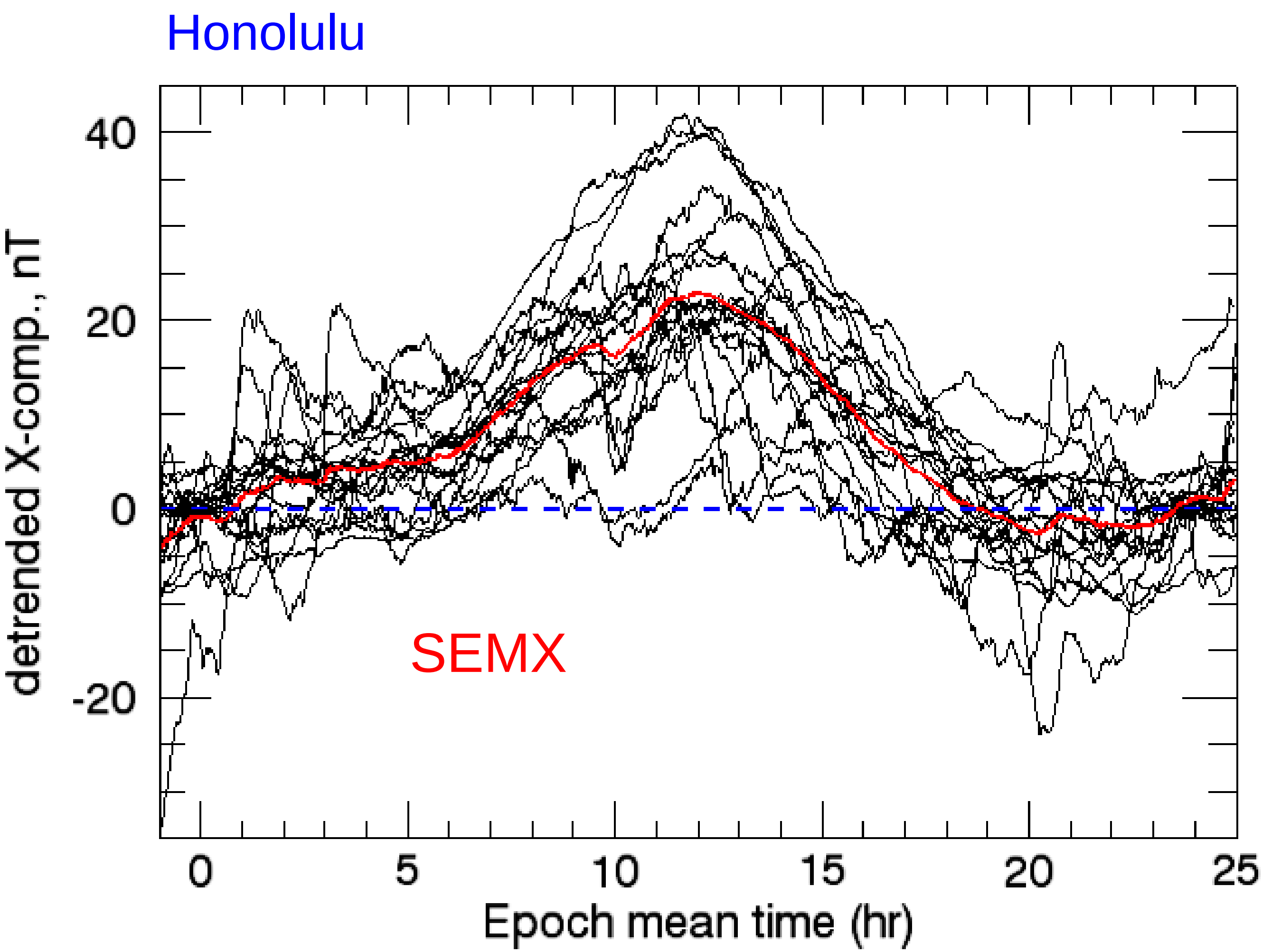
where s is the estimated standard deviation of the series.

The critical Grubb test statistic is $G_{n,1-\propto}$, which is defined by

$$G_{n,1-\propto} = \frac{n-1}{\sqrt{n}} \sqrt{\frac{t^2_{\frac{\propto}{2n},n-2}}{n-2+t^2_{\frac{\propto}{2n},n-2}}} ,$$

where $t^2_{\frac{\propto}{2n},n-2}$ denotes the critical t-distribution with n-2 degrees of freedom and a significance level of $\frac{\propto}{2n}$. (see Wikipedia, Grubbs's test). The test was conducted as one side test replacing ∝/2n by ∝/n.

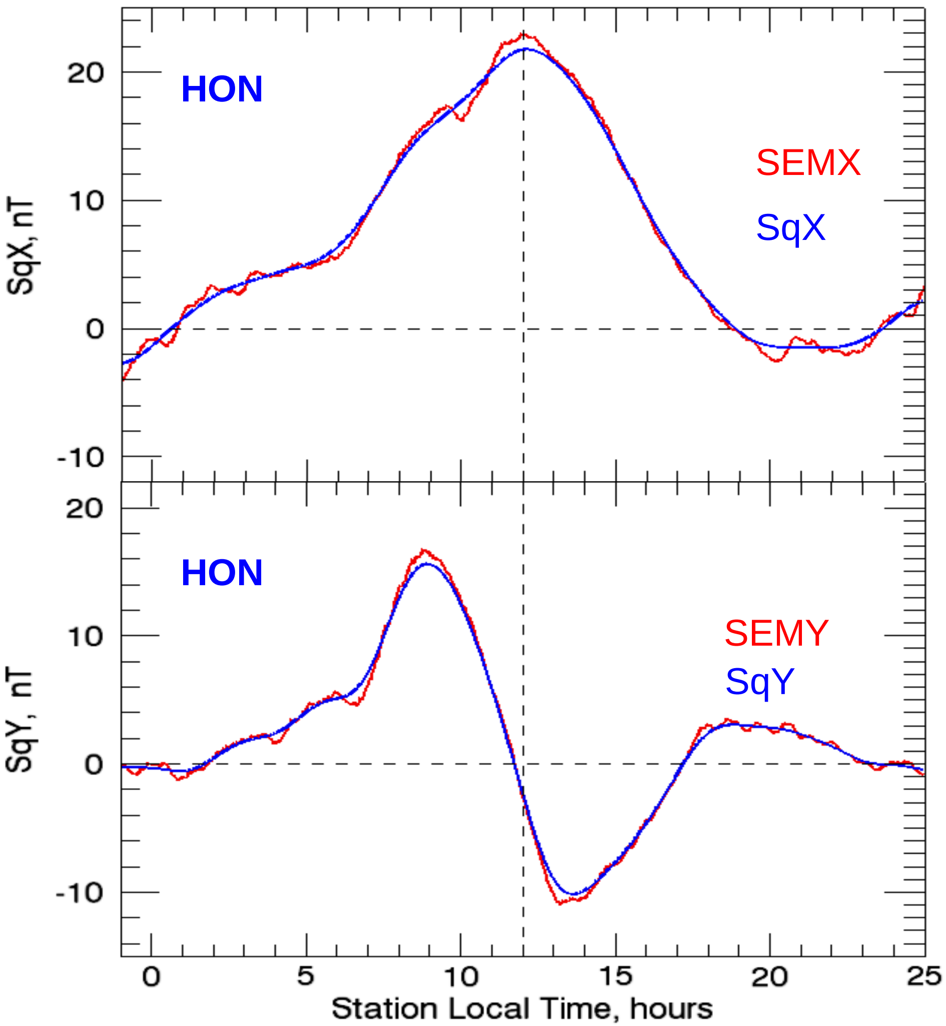
Superposed epoch analysis

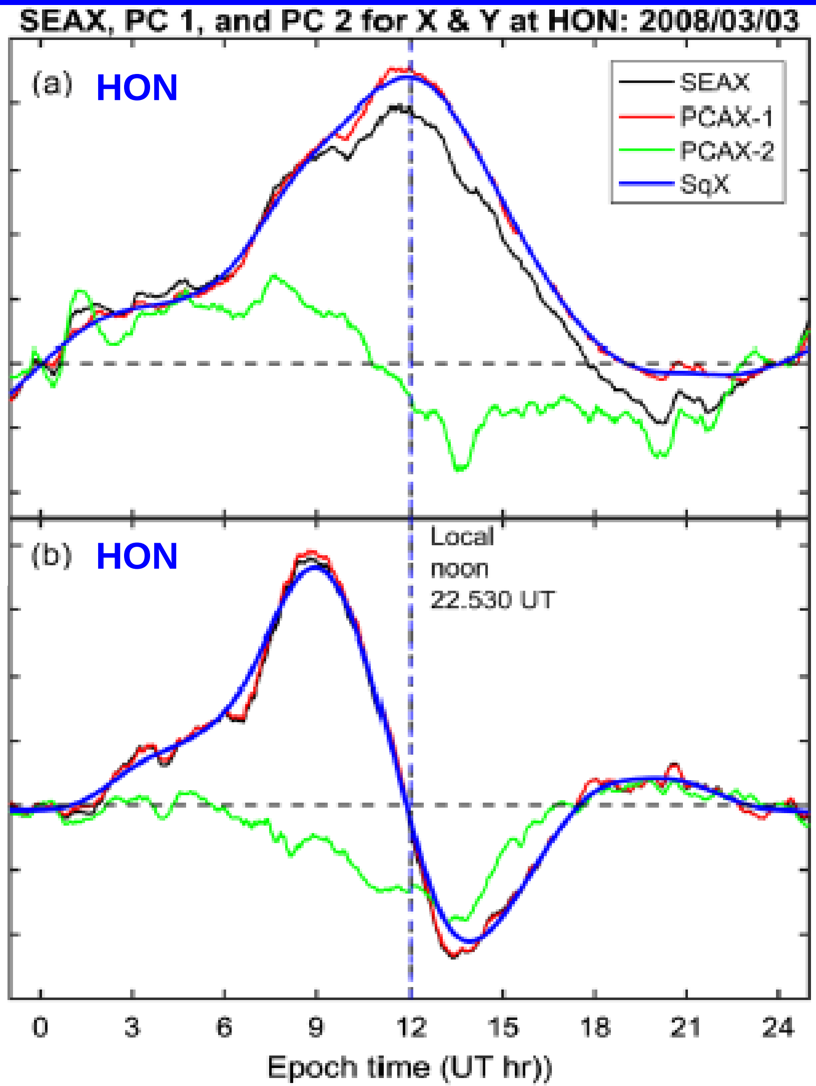


Four “disturbed days” were removed

Superposed epoch mean for the X-component (main field subtracted removed, disturbed days removed)

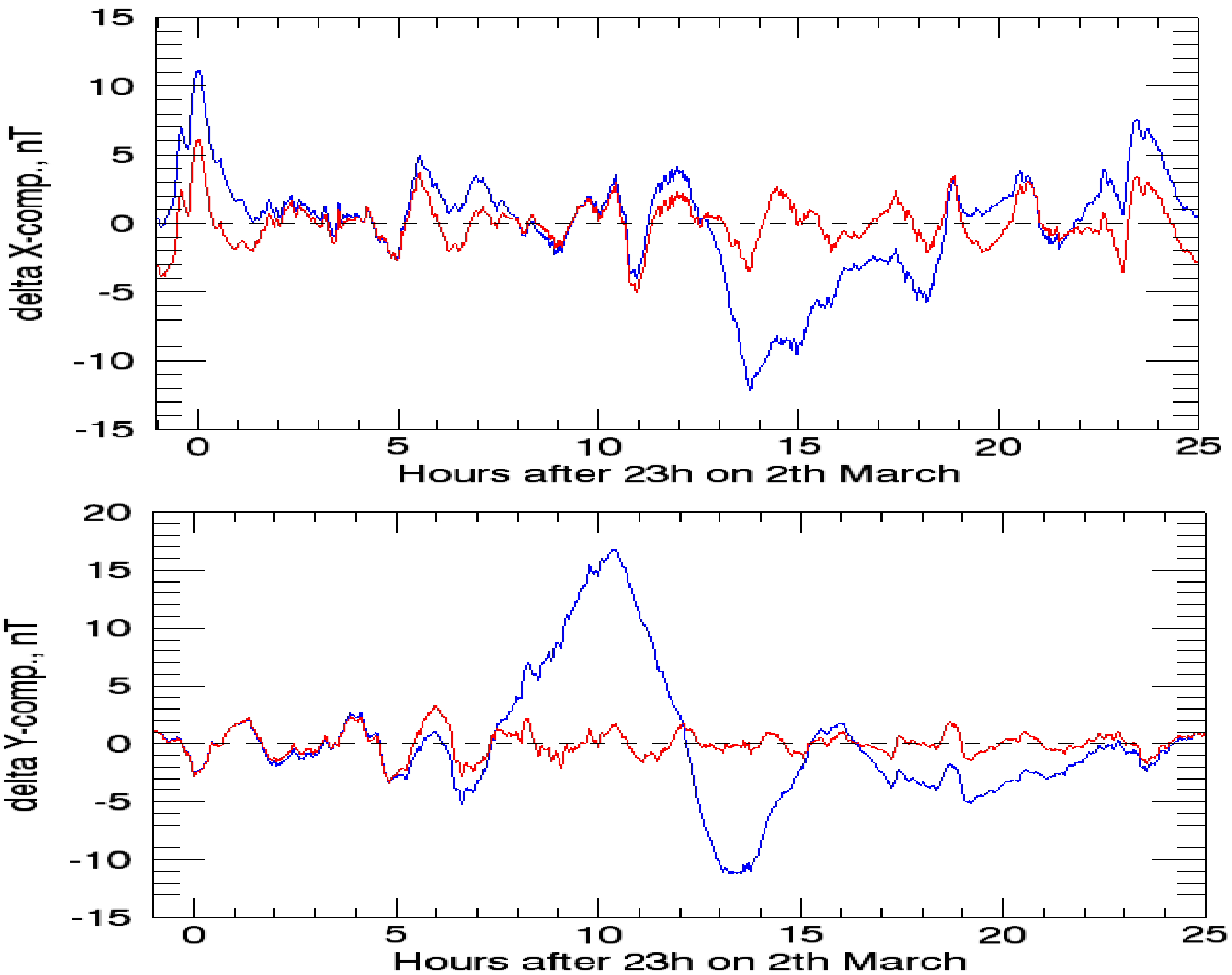
Superposed epoch analysis





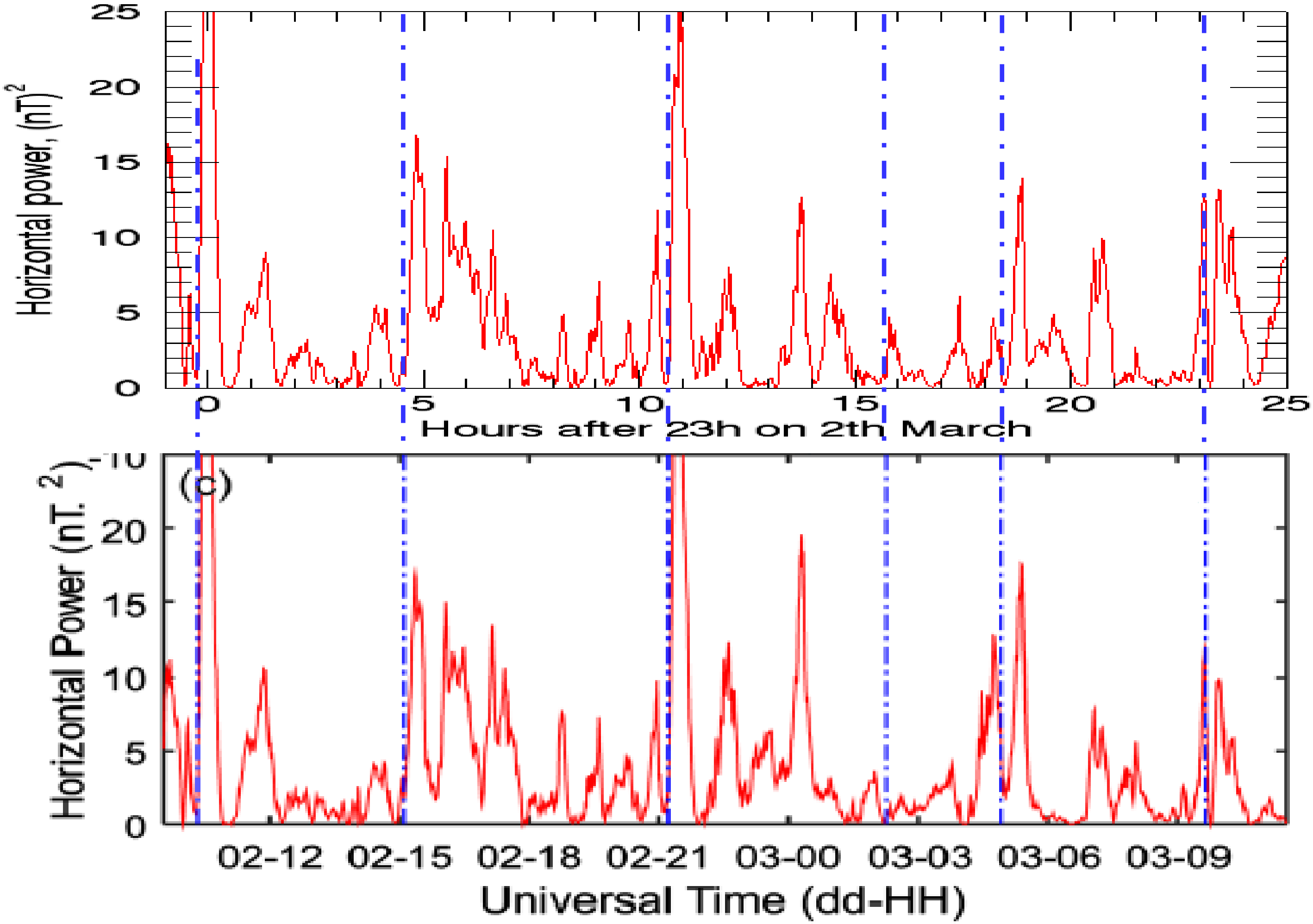
The superposed epoch means (SEM) of the quiet X and Y component and the resulting low pass filtered SEM, called solar quiet SqX and SqY component.

Magnetic variations in the horizontal components during the substorm day 2-3 of March 2008



The magnetic variations at the day in consideration (here the substorm day 2-3 march 2008) are obtained by the high pass filtered difference of the observation and Sq.

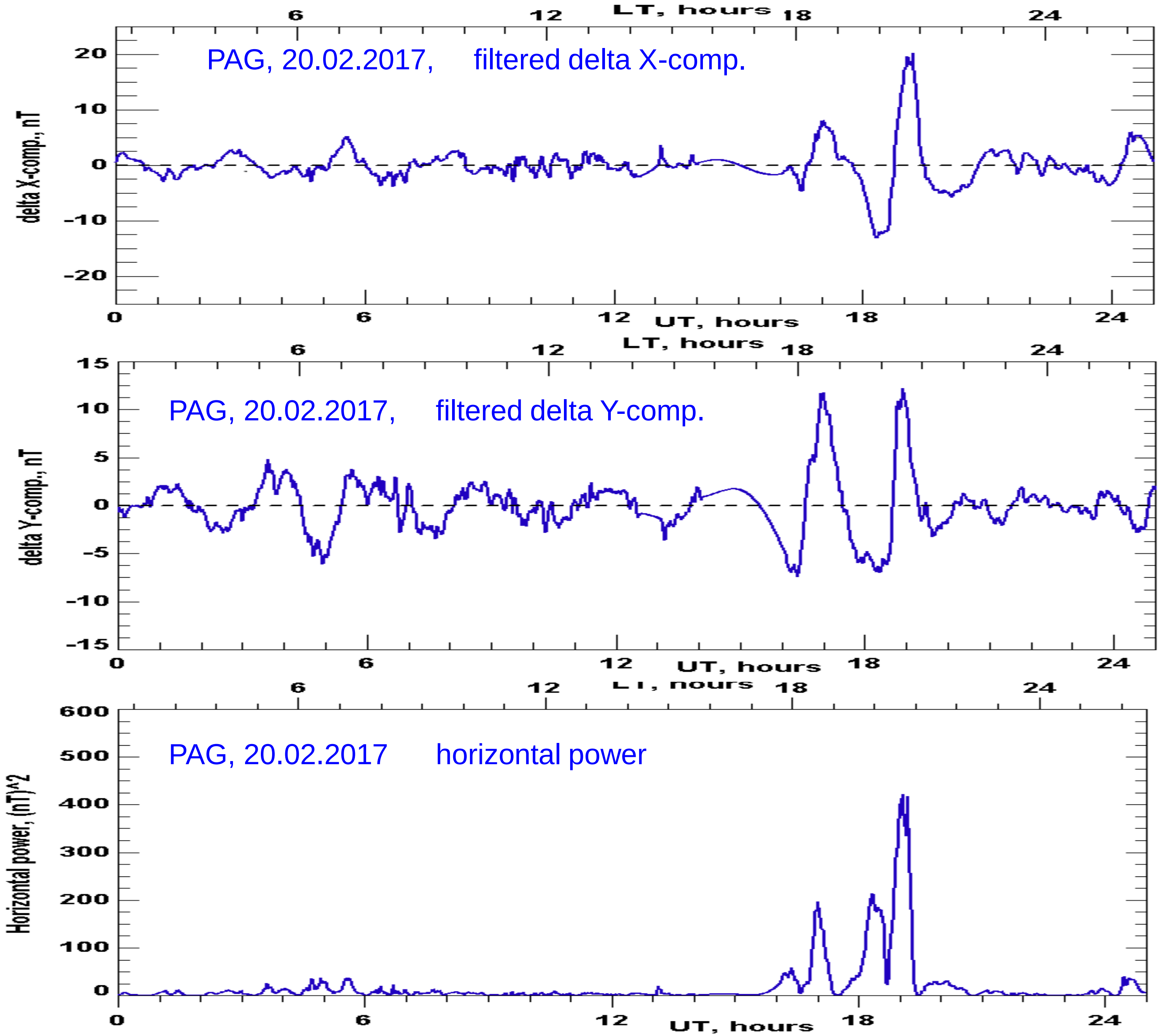
Horizontal power



McPherron and Chu

The horizontal power, called by McPherron MPB, calculated here show very like structure as the original, published by McPherron and Chu in 2016, but some differences in the power are evident. The vertical dash-dot lines present substorm onsets determined by Chu 2015.

Result for the Panagjurishte station



Summary and conclusions

1. The calculated horizontal power for the HON station for the substorm day 2.03 - 3.03.2008 has the same structure as the original, published by McPherron and Chu in 2017, but some differences in the power are evident.
2. In difference to the calculation of McPherron and Chu, the application of the Grubbs's test is used to eliminate days with strong disturbed magnetic field components and gap and peak detection and removal are implemented in the pre-processing procedure.
3. To remove the main field and the magnetic variations under quiet solar conditions here a window of 23 days centered over the substorm day are used, but secular variations have not been determined.
4. To obtain the mean field under quiet solar conditions after the subtraction of the main field components low pass filtered superposed epoch means of the components are used in agreement with the Chu's algorithm 2015.

Thank you

for

your attention

Acknowledgments:

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