report

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Method for the identification of heliospheric anomalies based on the functions of the characteristic deviations for the observation matrices of the muon hodoscope

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Abstract

This report presents a method for identifying heliospheric anomalies using the introduced function of characteristic deviations for the muon hodoscope matrices. The estimation of the averaged hardware function is considered. Spatial filtering is proposed to eliminate fluctuations in the functions of the characteristic deviations. An example of the implementation of the developed method using the example of the storm 2015.07.13; It is shown that for this event, the identified anomaly precedes by several hours a sharp increase in the Kp index.

Statement of the Problem

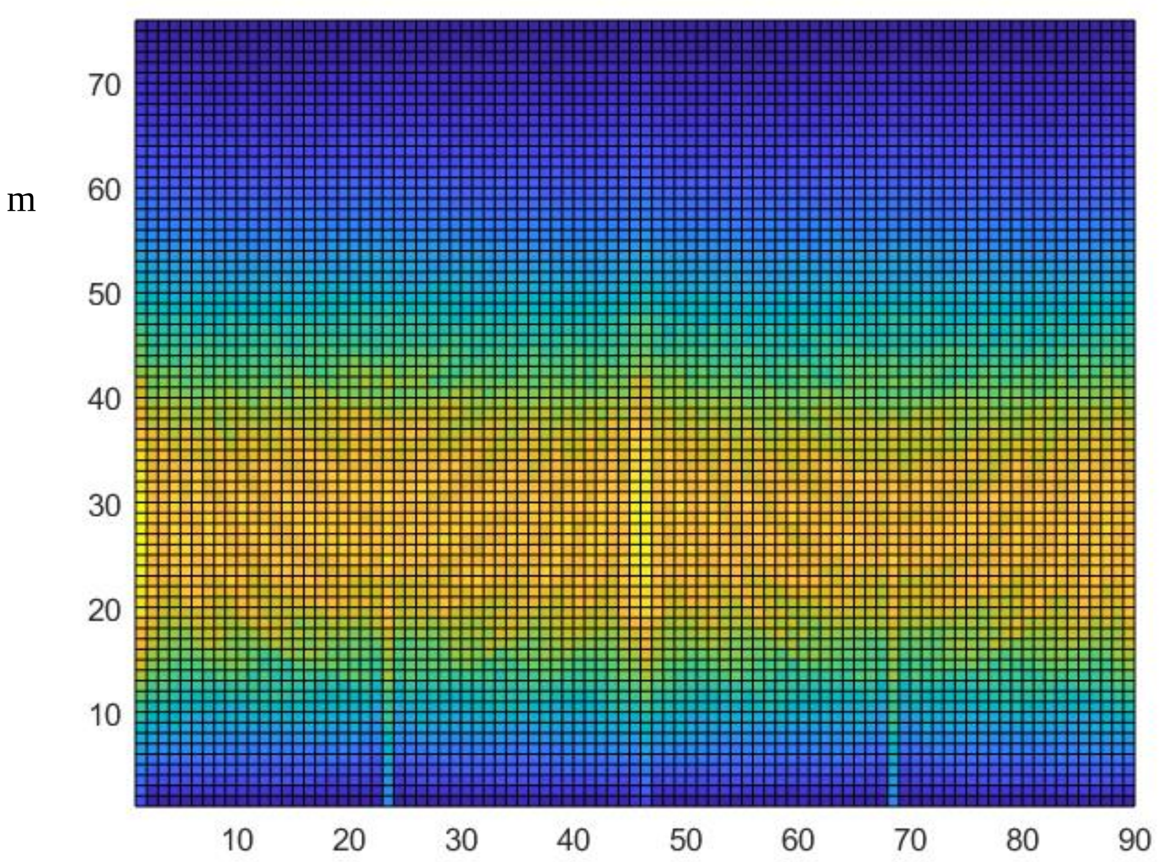
Initial matrix data:

$$Ma(i,j,kT),\ i=1,\dots,N_1,\ j=1,\dots,N_2,\ k=0,1,\dots,k_f-1,$$

T – sampling rate.

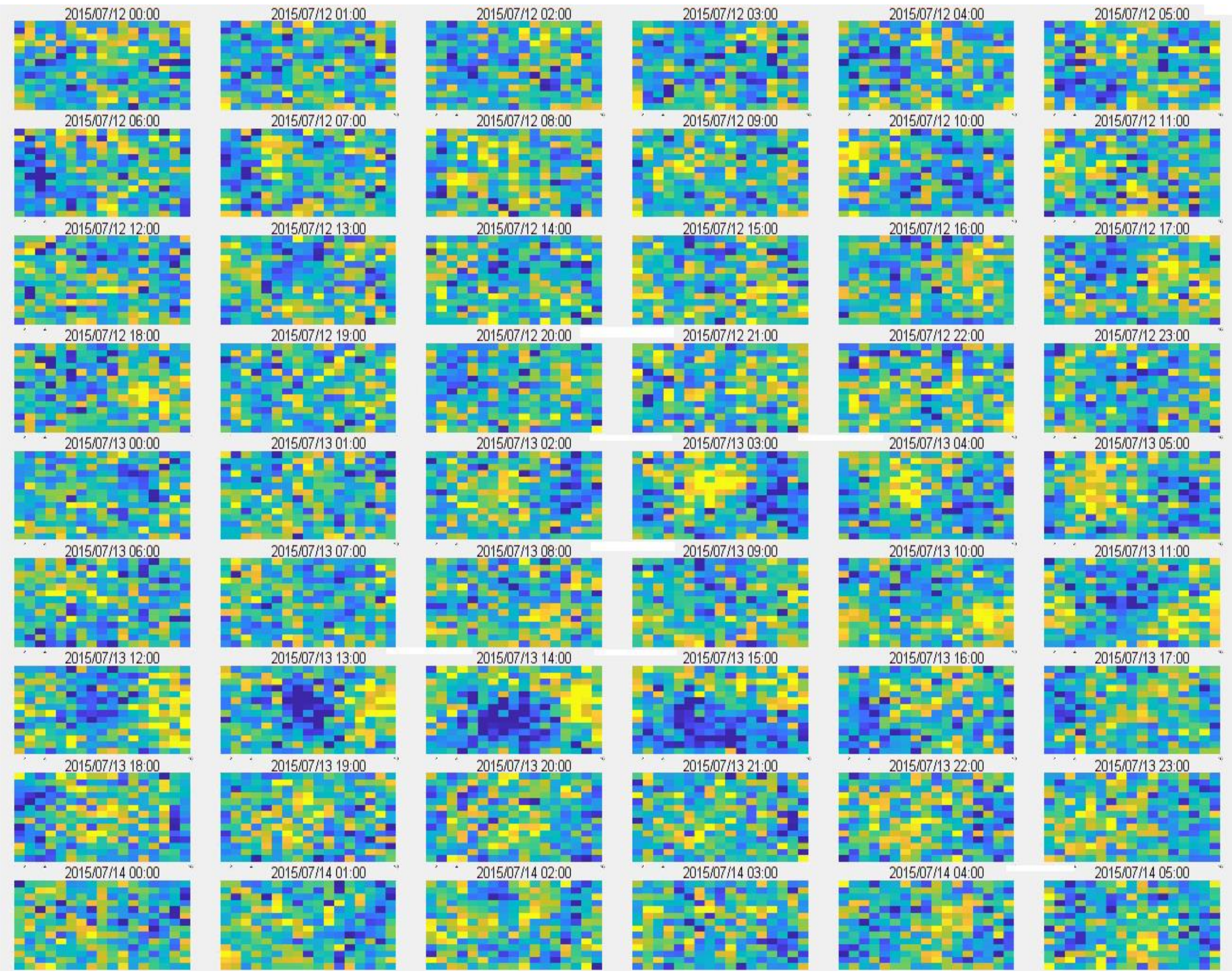
The goal is to find areas of the anomalous decrease.

Initial matrix



An example of identification of heliospheric anomalies

2015/07/12 - 2015/07/14



Maximum Kp=6 on 2015.07.13, 18:00, with an accuracy of ≈(5-10) degrees for zenithal angles and ≈(20-40) degrees for azimuthal angles, it is anomalous decrease in filtered matrix of characteristic deviations had preceded.

Estimates of normalized MH matrices

Estimation of hardware function (average chance to hit)

$$A^\circ_M(i,j) = \frac{1}{k_f}\sum_{k=1}^{k_f}\frac{M_a(i,j,Tk)}{I(Tk)},$$

where I - total number of muon hits

$$I(Tk) = \sum_{i=1}^{N_1}\sum_{j=1}^{N_2} M_a(i,j,Tk)$$

Estimates of normalized MH matrices

$$M^\circ_{a,H}(i,j,Tk) = \frac{M_a(i,j,Tk)}{A^\circ_M(i,j)}.$$

Statistical characteristics

Functions of the mean

$$\bar{M}^\circ_{a,H}(Tk) = \sum_{i=1}^{N_1}\sum_{j=1}^{N_2} M^\circ_{a,H}(i,j,Tk)$$

Mean square deviation

$$\sigma^2(i,j,Tk) = \frac{1}{k+k_f}\sum_{s=k_f+1}^{k}[M^\circ_{a,H}(i,j,Ts) - \bar{M}^\circ_{a,H}(Ts)]^2$$

Characteristic deviation function

$$\xi(i,j,Tk) = \frac{[M^\circ_{a,H}(i,j,Ts) - \bar{M}^\circ_{a,H}(Ts)]}{\sigma(i,j,kT)}$$

Averaged modulated HF lead to errors in the normalized MH matrices, which, in turn, cause random spatial fluctuations in the functions of the characteristic deviation. These fluctuations are described by spatial random functions.

Spatial filtering

In this case spatial filtering is the average pooling in rectangles with dimensions Δq=5 Δp=5, it formed the filtered matrix of characteristic deviations.

$$\xi_\Phi(i,j,Tk)\ \sum_{i=\Delta p(p-1)}^{\Delta p\cdot p}\ \sum_{j=\Delta q(q-1)}^{\Delta q\cdot q}\ \xi(i,j,Tk)$$

Conclusions

- The developed method of identification based on the functions of the characteristic deviations turned out to be workable and made it possible to realize the possibility of recognizing the resulting heliospheric anomalies in space and time.
- Due to high angular resolution of the MH and as a result of the application of the proposed identification method, it became possible to estimate the angular positions of the anomalies with an accuracy of ≈(5-10) degrees for zenithal angles, ≈(20-40) degrees for azimuthal angles.
- The developed approach allows for significant improvements. The accuracy of determining the parameters of anomalies can be improved by digital processing of the sequence of functions of characteristic deviations.

Acknowledgements

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