A method for muon flux intensity modulations recognition using the indicator matrices for the URAGAN hodoscope matrix data

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Muon flux intensity modulation (MFIM) recognition is a relevant solar-terrestrial physics problem. The MFIM discussed are due to geoeffective solar coronal mass ejections.

The necessary observations are carried out using a computerized muon hodoscope (MH) URAGAN developed by NRNU MEPhI, registering muon fluxes intensity. In the MH, the number of muons falling on its aperture per unit time is counted. MH matrix data time series are formed, in which angular and temporal modulations take place due to MH design features, atmospheric disturbances and noises, the values of which significantly exceed the MFIM values.

The MFIM recognition method based on the mathematical apparatus of indicator matrices (IM) and spatial-temporal filtering is proposed.

The time series of MH matrix data, consisting of a set of Poisson processes corresponding to azimuthal and zenithal elements of MH matrices, are considered.

A reference time span is assigned where MFIM are known to be missing. For it, matrices of estimates of mathematical expectations are calculated and, taking into account the Poisson property, the matrices of reference confidence intervals are calculated. Next, the current time sections are formed, on which the matrices of the current confidence intervals are calculated. Based on the comparison of the matrices of the reference and current confidence intervals, the current matrices of anomalies are formed, which are compared with the specified threshold matrix. Thresholds exceedings correspond to anomalous events. Binary IM are formed: ones correspond to anomalous events, zeros correspond to the absence of anomalies. Recognition is to analyze IM sequence and identify areas of non-zero elements condensation that lead to the conclusion that there are significant MFIM. To reduce the recognition errors, the space-time IM filtering has been developed.

MFIM recognition technique, based on the use of IM time series with spatial-temporal filtering has been tested on model and experimental MH data.
Testing on the generated time series of model Poisson MH matrix data with model MFIM confirmed the conclusion about the possibility of MFIM recognition by the proposed method with a decrease level of 3-4%. Application of spatial-temporal filtering made it possible to recognize MFIM with decreases with a level half as much.

Testing on the formed experimental matrix MH data time series with model MFIM led to a conclusion that it is possible to recognize MFIM with the magnitudes of decreases almost commensurate with the decreases for the case of model MH data.

The proposed MFIM recognition method based on indicator matrices for MH observation data allows optimization of parameters and can be successfully applied to solve problems of MFIM recognition and early diagnostics of geomagnetic storms.

This work was funded by the Russian Science Foundation (project No.17-17-01215).