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Application of digital processing of muonogram time series to the analysis of extreme events in the heliosphere

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Extreme events in the heliosphere that lead to anomalous muon flux variations, registered by the URAGAN muon hodoscope (MH), developed by MEPhI, are analyzed. MH measures two-dimensional muon flux intensity distribution functions (MFIDF) for a system of solid angles with a predefined sampling step, that are concatenated into matrix data time series of muonograms – the MFIDF outpur data from the MH. It can be assumed that the corresponding input MFIDF time series fall on the MH detectors. Assuming the MH linearity, input and output MFIDF are related by the hardware function (HF).
Occurrence of extreme events leads to occurrence of spatial and temporal MFIDF anomalousness in muonograms. Here, the task of development of the necessary mathematical tools for solving the problems of the mentioned extreme events is formulated, based on digital processing of muonogram time series.
The methods and algorithms propose here are divided into two categories. The first (supplementary) category includes one- and two-dimensional filtering algorithms for reducing temporal and spatial noises in muonograms, including elimination of daily variations, and the HF estimation algorithms. The second (main) category comprises the variants of anomalousness - local anisotropy (LA) - recognition methods for input MFIDF based on time series of muonograms.
To reduce noises in muonograms, the algorithms have been developed for one-dimensional sequential and parallel temporal and two-dimensional spatial filtering. A method has been developed for estimating the normalized HF for MH based on multiparameter models. The method has been tested on model and experimental muonograms.
A method has been proposed for LA analysis by estimating normalized variations (1) of input MFIDF with respect to normalized HFs, using spatial-temporal filtering. The method has been tested on model and experimental muonograms.
A method has been proposed for LA analysis by estimating normalized variations (2) of input MFIDF with respect to averaged output MFIDF, using spatial-temporal filtering. The method has been tested on model and experimental muonograms.
A method has been proposed for LA analysis in muonograms, based on calculation of confidence intervals systems for estimates of mathematical expectations of muonograms on reference and current confidence intervals. An algorithm is designed for LA analysis (recognition), based on decision making procedures. The algorithm has been tested on model and experimental muonograms.
The proposed digital processing is a mathematical toolkit, the effectiveness of which for the analysis of extreme events in the heliosphere has been confirmed by testing.
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