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Forecast of strong geomagnetic storms in February-March 2023 based on measurements of fluctuations in the intensity of galactic cosmic rays

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In order to develop methods for space weather forecasting, the dynamics of fluctuations (variations with periods from several minutes to 2-3 hours) of the intensity of galactic cosmic rays (CR) during the events of strong geomagnetic storms on February 26 and March 23, 2023, which are characterized by the values Dst < -100 nT. To do this, we use 1-minute pressure-corrected registration data from the neutron monitors of the Yakutsk and Tixie Bay CR stations, 1-minute data from direct observations of the parameters of the interplanetary magnetic field (IMF) and solar wind (SW) onboard the ACE and DSCOVR spacecraft. To study the properties of CR fluctuations and SW turbulence, digital filtering methods and Blackman-Tukey spectral analysis with the Tukey spectral window are used. In this case, the maximum values of the coherence coefficients in the frequency range 1.23·10-4 - 1.67·10-2 Hz are used as the index of CR and SW fluctuations. Note that the coherence coefficient is a generalization of the correlation function to the frequency domain. Its use is due to the fact that, in contrast to fluctuation spectra, the level of which varies by orders of magnitude depending on the state of the interplanetary medium, coherence takes values ranging from 0 to 1, regardless of the level of solar activity.

It is shown that in the event in February, in contrast to the event in March, significant coherent CR fluctuations of large magnitude (about 0.8) are observed about 2 days before the start of the geomagnetic storm. An analysis of data from direct measurements of SW parameters shows that the geomagnetic storm on February 26 was caused by the passage of an interplanetary shock wave, and on March 23, by a coronal mass ejection with a magnetic cloud moving at a speed not exceeding the background SW velocity. A more detailed analysis leads to the conclusion that the presence of CR fluctuations in February is due to the presence in the SW of fast magnetosonic waves of noticeable amplitude, which can be generated by energetic storm particle flows in the region ahead of the interplanetary shock wave front. While in March 2023 the contribution of these waves to the observed IMF turbulence spectrum d id not exceed 50%, and before the onset of the geomagnetic storm, no coherent CR intensity fluctuations were observed. At the same time, high coherence values of CR fluctuations were observed in both events in the region of the disturbance itself, which may indicate an increased level of magnetosonic turbulence of the solar wind in the region of the SW disturbance itself. The results obtained here are in good agreement with the physical picture of the occurrence of CR intensity fluctuations that we have previously constructed, but further research is required to develop a method for predicting geomagnetic storms based on measurement data from neutron monitors.

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