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Short-term forecast of space weather in real-time

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Abstract. The suggested method for the early detection of the large-scale solar wind disturbances by the registration of galactic cosmic ray (GCR) scintillation is realized in the near real-time regime since January 1999. It seems for us the test experiments carried out in 1999-2000 gave the hopeful results. In this connection, since 2001 the ground-based radiation monitoring and the forecast of the large-scale disturbances began to be carried out in the real-time regime. The monitoring and forecast results are available in Internet by address - http://teor.ysn.ru/rswi/.

1 Introduction

As it is known, the individual random trajectories uncorrelated with each other are ascribed to fast particles in diffusive approximation. At the same time, on small spatial-temporal scales, the trajectory correlation must be considerable, so that groups of particles, beeng at a close short distance in phase space are kept comparatively for a long time as compact formations with a "single" trajectory. In this connection we have studied the cosmic ray variations caused by the group behaviour of galactic cosmic rays in the interplanetary magnetic field. It is advisable to look for the corresponding variations in situations when the "dyed" groups of particles appear whose evolution is easy traced. The strongest contrast in cosmic rays are created by interplanetary shocks initiating sharp decreases of intensity. According to this, the correlated cosmic ray intensity fluctuations registered by several neutron monitors are studied.

2 Method

The example of early detection of the large-scale solar wind disturbances suggested in Kozlov et al. (1984); Tugolukov and Kozlov (1991); Kozlov and Tugolukov (1992) by the method modified with the account of results of the test experiment carried out in 1999-2000 (Kozlov , 1999; Kozlov et al. , 1999, 2001) is shown in Figure 1. In this Figure 1 the monitoring and large-scale disturbance forecast results in March-April 2001 are presented. The standardized values of the scintillation index being in the interval $-1 \leq \mu \leq 1$, have been averaged for 1 hour. Two horizontal lines show two-sided 80% significance level. The scintillation index values located inside the 80% significant interval are related to the random values (the undisturbed conditions). And vice versa, the scintillation index values being outside this interval are not random at the 80% significance level. The significant values of the scintillation index exceeding the significance level represent the high-frequency component of the signal (conditionally, it is "predictor") and is identified with "the early detection" of the event. The significant values of the scintillation index locating below lowest the significance level, i.e. the low-frequency component of the useful signal is identified with the "diagnosis" of the event. All three possible situations are illustrated in Figure 1.

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3 Results

The geoeffective event forecast in a real–time regime has aroused considerable interest. Below the Space Weather forecast results in March–April 2001 in the ASCAD system are given. The studied period refers to the final reversal stage of the total magnetic field of the Sun in the 23-rd cycle and therefore it is of considerable interest. Figure 1 shows the 1–hour registration of the cosmic ray intensity at the Tixie station (in a low part of Figure 1) and also the GCR scintillation index (upper). The analysed period is characterized by the increased activity of the Sun. In interplanetary medium at this time a series of shocks had been registered. In the GCR intensity it is manifested in the analogous series of the Forbush–effects with the amplitudes $5 - 6\%$, followed one by one with the same interval which is equal to 4 days: on March 27, March 31, April 4, April 8 and April 12 (with the amplitude $A \sim 10\%$). As a results, this series of disturbances was over by a powerful GCR flare on April 15, registered by whole neutron monitors world network. Each GCR intensity Forbush-decrease is preceded by the registration of the GCR scintillation index at the significance level $P \geq 80\%$ (see Figure 1). The significant values of the GCR scintillation index are registered at both Tixie and Yakutsk stations. Be-

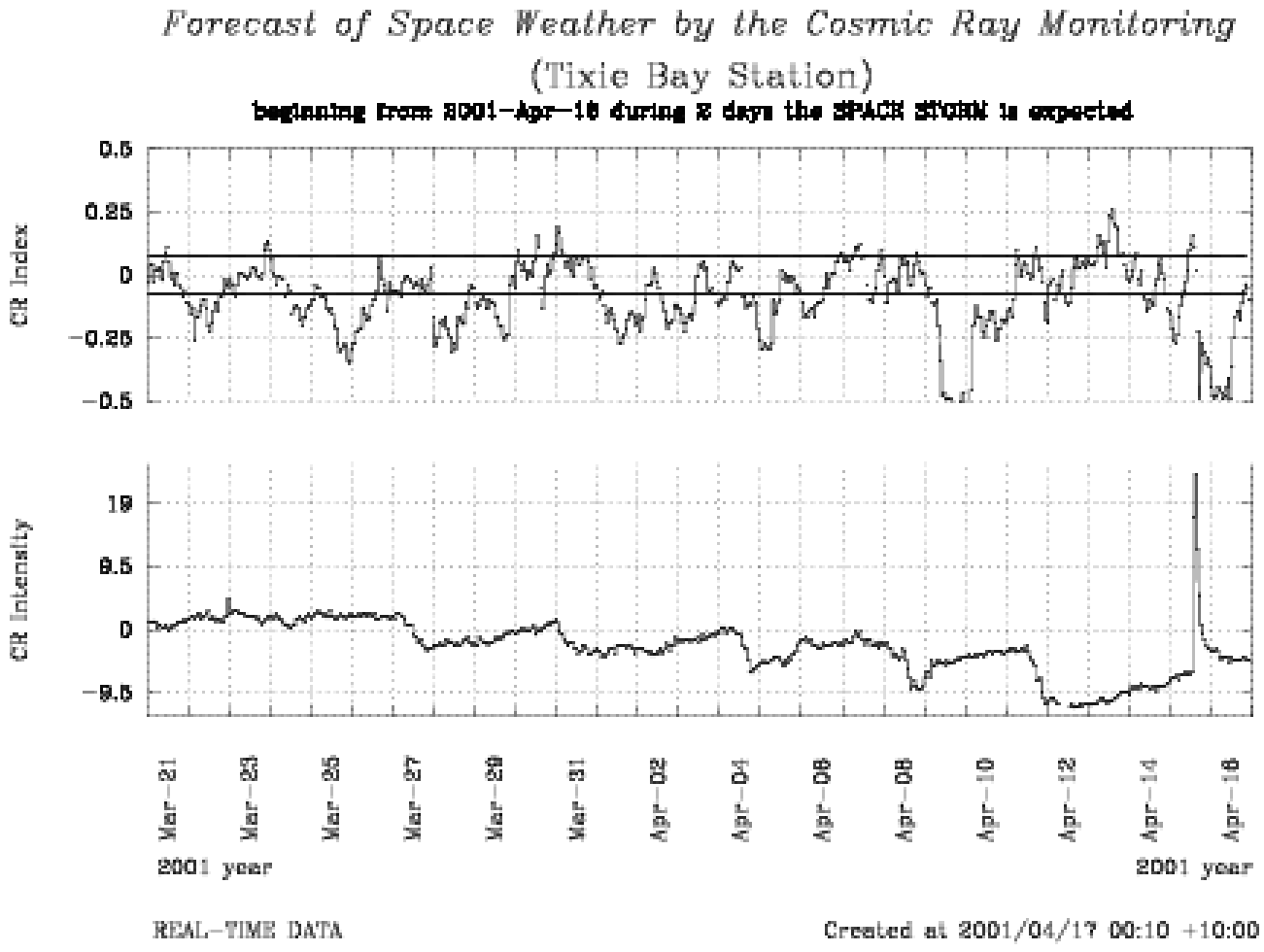

Fig. 1. Results of the forecast of space weather for March–April 2001.

fore all 5 Forbush-effects in interplanetary medium the flux increase of low-energy particles was registered: by $\sim 10^4$ from March 25-27, by $\sim 10^2$ - from April 3-4, by $\sim 10^1$ - from April 7-8 and by $\sim 10^2$ - from 10-11. Besides, the solar cosmic ray (SCR) increase was registered on April 9-11 with the energy $\varepsilon > 10$ MeV - $\sim 10^3$, with $\varepsilon > 50$ MeV - $\sim 10^2$ and with $\varepsilon > 100$ MeV - $\sim 10^1$. The repeated GCR increase $\sim 10^2$ with $\varepsilon > 50$ and with $\varepsilon > 100$ MeV was registered on April 12. The CR intensity flare on April 15 was also accompanied $\sim 10^4$ of superhigh solar protons with $\varepsilon > 50$ and with $\varepsilon > 100$ MeV $\sim 10^3$. Aboard spacecraft in every event considerable changes of the direction and value of interplanetary magnetic field and also the density and velocity enhancement of the solar wind plasma were registered. The extreme values of the solar wind plasma parameters and IMF were registered on March 31 - April 1 $B > 50$ nT, $V > 800$ km/s). All 5 Forbush-decreases were accompanied by the geomagnetic storms. The most powerful events were on March 31 - April 1 ($Kp \leq 9$) and April 11-13 ($Kp \leq 8$). The largest active region No.9393 containing the largest spot for the current 11-year cycle is responsible for the most powerful storm on March 31. Another active region No.9415 is responsible for the second magnetic storm by its power. The passage of both giant spots was accompanied by powerful X-ray flares (of X–class).

The analyzed period from March to April 2001 refers to the period of the most sporadic solar activity (see Figure 2 from our report at the 27 ICRC). This period falls on the final stage of a reversal of the general magnetic field of the Sun in the current 23–rd solar cycle. The decay of the large–scale magnetic field at the final stage of the reversal of the field has caused the high activity at the end of March – at the beginning of April of 2001. Like that what it was observed on the decline branches of the 21-st and 22-nd solar activity cycles (Kozlov and Markov , 1999a,b). It has engaged our attention the following remarkable fact: similarity of the GCR intensity profiles for the decrease branches of the 22-nd and 23-rd cycle is observed not only in the "large" (for the 27-day values) but in the "small" one, i.e. for hourly values (see Figure 2). First of all, the quasi–periodical character of the process in both cases strikes. Moreover, the interval between Forbush–decreases ≈ 4 days. In this case, the period of the found variation is wonderfully stable during the whole Sun's rotation! It is possible that the process of the decay of the large–scale magnetic field of the Sun at a final stage of its reversal manifests itself in the formation of a thin

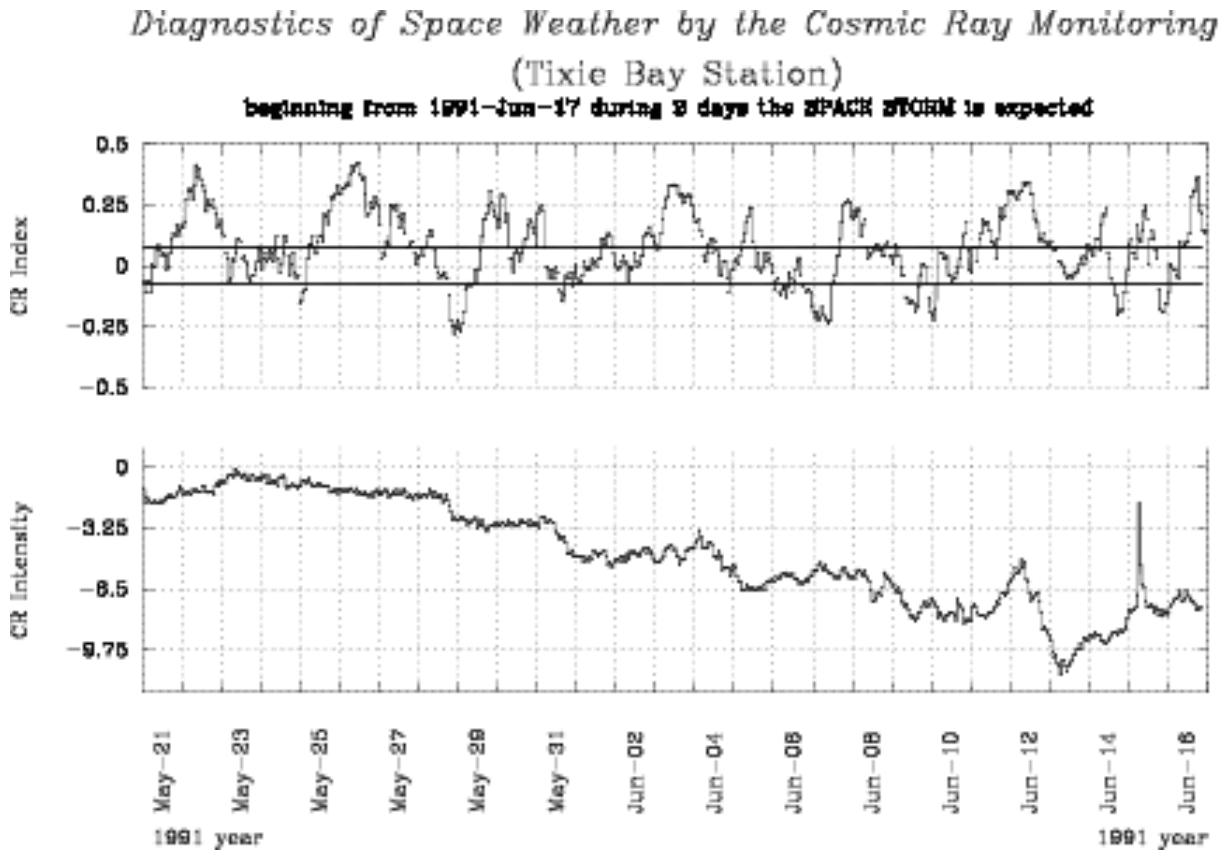

Fig. 2. Results of the forecast of space weather for May–June 1991.

quasi–periodical structure of heliospheric current sheath.

4 Conclusion

It followed from the obtained results that the introduced GCR scintillation index is a sufficiently informative index. Its separation to a high-frequency and low-frequency component is found to be useful too. The high-frequency signal is identified with the ”predictor” or ”the early diagnosis” of the event. By an event in our case is meant the large-scale magnetic IMF cork. The low-frequency signal component is identified with the diagnosis of the event.

The decay of the large–scale magnetic field at the final stage of a reversal of the general magnetic field of the Sun in the 23-rd cycle is caused by the high activity at the end of March – at the beginning of April of 2001. It is possible that the process of the decay of the large–scale magnetic field of the Sun at a final stage of its reversal manifests itself in the formation of a thin quasi–periodical structure of heliospheric current sheath.

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