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THE FORBUSH-DECREASES IN COSMIC RAY FLUXES AND SOLAR-PROTON EVENTS IN JULY AND SEPTEMBER 2017

The study of the nature of variations in cosmic ray fluxes, including diurnal, 27-day, annual, etc., and the question of the relationship of solar-geophysical factors on the state of the atmosphere attracts special attention of scientists. Coronal mass ejections are the result of solar winds generated on the Sun during a series of flares. At the same time, solar winds provoke variations in the intensity of cosmic rays, which include, in particular, Forbush-decreases. The article presents brief characteristics of the CARPET detector of the scientific cosmophysical complex of the L.N.Gumilyov ENU and experimental data obtained at this facility during the observation of Forbush-deacreases in July and September 2017. The results of the analysis of variations in cosmic ray fluxes are presented and their relationship with the conditions in the interplanetary medium and the Earth's magnetosphere caused by processes on the Sun is described. It was found that the decrease in cosmic ray fluxes in July and September 2017 was due to high solar activity (a series of solar flares). A comparative analysis of the time changes recorded by the CARPET detector modules of the L.N.Gumilyov ENU scientific complex with the data of the world network of neutron monitors («Apatity», «Almaty» and «Jungfraujoch IGY») is also presented. Data on the electromagnetic environment of interplanetary space during the period of heliospheric and magnetospheric disturbances were also used for the analysis. The analysis showed that the measurement data of the CARPET detector is in good agreement with the data of the above-mentioned neutron monitors of the world network, which allows us to study the physical nature of cosmic ray variations for different time intervals.

Key words: The Forbush-decrease, the variation of cosmic rays, solar activity, neutron monitor, magnetosphere, magnetic field.

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2017 жылғы шілде мен қыркүйектегі ғарыштық сәулелер ағындарының Форбуш-төмендеуі және Күн-протон оқиғалары

Ғарыштық сәулелер ағындарының, оның ішінде тәуліктік, 27 күндік, жылдық және т.б. өзгеру табиғатын зерттеу және күн-геофизикалық факторлардың атмосфераның күйіне қатынасы туралы мәселе ғалымдардың ерекше назарын аударады. Күндегі бірқатар алау кезінде пайда болатын күн желі массаның короналды шығарылымдардың нәтижесі болып табылады. Сонымен қатар, күн желдері ғарыштық сәулелердің қарқындылығының өзгеруін тудырады, оған атап айтқанда Форбуш-төмендеу жатады. Мақалада Л.Н. Гумилев атындағы Еуразия ұлттық университеттегі CARPET ғылыми космофизикалық кешеннің детекторының қысқаша сипаттамалары және осы қондырғы арқылы 2017 жылдың шілде, қыркүйек айларында форбуш-төмендеулерді бақылау кезеңінде алынған эксперименттік деректер келтірілген. Ғарыштық сәуле ағындар өзгеруінің талдау нәтижелері келтірілген және Күндегі процестерден туындаған планетааралық ортадағы және жер магнитосферадағы жағдайлармен байланысы сипатталған. 2017 жылдың шілде және қыркүйек айларда ғарыштық сәулелер ағынының азаюы жоғары күн белсенділігімен (Күн сәулесінің сериясы) байланысты екендігі анықталды. Сондай-ақ, Л.Н. Гумилев атындағы ЕҰУ CARPET ғылыми кешеніндегі детектор модульдерінде тіркелген уақытша өзгерістері әлемдік нейтрондық мониторлар («Апатиттер», «Алматы» және «Jungfraujoch IGY») желісінің деректерімен салыстырмалы талдауы ұсынылды. Талдау үшін гелиосфералық және магнитосфералық ауытқулар кезеңіндегі планетааралық кеңістіктің электромагниттік ортасы туралы мәліметтер де қолданылды. Талдау көрсеткендей, CARPET детекторының өлшеу деректері жоғарыда аталған әлемдік нейтронды мониторлар желінің мәліметтерімен жақсы сәйкес келеді, бұл әр түрлі уақыт

аралықтары үшін ғарыштық сәулелердің өзгеруінің физикалық табиғатын зерттеуге мүмкіндік береді.
Түйін сөздер: Форбуш-төмендеу, ғарыштық сәулелердің вариациясы, күн белсенділігі, нейтрондық монитор, магнитосфера, магнит өрісі.

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Форбуш-понижения потоков космических лучей и солнечно-протонные события в июле и сентябре 2017 года

Изучение природы вариации потоков космических лучей, в том числе суточных, 27-дневных, годовых и т.д., и вопроса взаимосвязи солнечно-геофизических факторов на состояние атмосферы привлекает особое внимание ученых. Корональные выбросы массы являются результатом солнечных ветров, возникших на Солнце во время серии вспышек. При этом, солнечные ветра провоцируют вариации интенсивности космических лучей, к которым относится, в частности, Форбуш-понижения. В статье представлены краткие характеристики детектора CARPET научного космофизического комплекса ЕНУ им. Л.Н. Гумилева и экспериментальные данные, полученные на данной установке в период наблюдения форбуш-понижений в июле и сентябре 2017 года. Приведены результаты анализа вариаций потоков космических лучей и описана их связь с обстановками в межпланетной среде и земной магнитосфере, вызванными процессами на Солнце. Установлено, что уменьшения потоков космических лучей в июле и сентябре 2017 года были обусловлены высокой солнечной активностью (серия вспышек на Солнце). Представлен также сравнительный анализ временных изменений, зарегистрированных модулями детектора CARPET научного комплекса ЕНУ им. Л.Н. Гумилева с данными мировой сети нейтронных мониторов («Апатиты», Алматы и «Jungfraujoch IGY»). Для анализа использовались также данные об электромагнитной обстановке межпланетного пространства в период гелиосферных и магнитосферных возмущений. Анализ показал, что данные измерений детектора CARPET хорошо согласуются с данными вышеуказанными нейтронными мониторами мировой сети, которое позволяет исследовать физическую природу вариаций космических лучей для разных временных интервалов.
Ключевые слова: Форбуш-понижение, вариация космических лучей, солнечная активность, нейтронный монитор, магнитосфера, магнитное поле.

Introduction

Cosmic rays (CR) play a significant role in atmospheric processes associated with weather and climate. Therefore, the study on different time scales (daily, 27-day, seasonal, annual, etc.) of the physical nature of variations in secondary CR fluxes caused by atmospheric processes is very important.

The issue of the impact of various manifestations of solar-geophysical factors on the state of the lower atmosphere, weather and climate of the Earth has been the focus of attention of scientists over the past several hundred years [1]. One of the first works on this topic can be attributed to work [2], which establishes an eleven-year periodicity in variations in the average air temperature in the Northern Hemisphere, correlating with eleven-year variations in Wolf numbers. This allowed the author to prove the existence of a connection between solar activity, weather and the Earth's climate.

The relationship between the parameters of the lower atmosphere (the nature of circulation, temperature, pressure) with helio-space factors was noted in a number of works [3,4,5,6].

In addition to the wave radiation of the Sun, the characteristics of the atmosphere are also affected by the fluxes of solar protons with energies of tens and hundreds of MeV [5,6]. According to [5,7], the dynamics of the solar wind affects the nature of the ionosphere and the current density in the global electric circuit.

During solar flares, solar winds are disturbed, which in turn accompany coronal mass ejections. Solar winds influence galactic CR fluxes and thereby provoke CR intensity variations [8]. Such variations include the Forbush effect (short-term and sharp decrease in the intensity of cosmic rays).

This effect is quite complex, requires study, and has not been fully investigated until now.

Materials and methods

To study cosmic rays, ground-based installations are used that register secondary particles formed during the interaction of primary CRs with the atmosphere [9].

At the same time, the creation and implementation of experimental ground-based complexes is necessary for carrying out research to study the nature of cosmic ray fluxes modulation.

For this purpose, the L.N. Gumilyov Eurasian National University (ENU), in cooperation with the P.N. Lebedev Physical Institute of the Russian Academy of Sciences, created a cosmophysical complex consisting of a CARPET detector, a neutron detector, and an EFM-100 electrostatic fluxmeter.

The scientific CR detector CARPET was installed at the end of 2015 at the Faculty of Physics and Technology of ENU in Nur-Sultan, Republic of Kazakhstan (51°10 ' 48 "s. w., 71°26' 45 " w. d., height 358 m, geomagnetic circumcision stiffness R_c~2.9 GeV) [10]. To increase the measurement accuracy, two modules are installed.

The basis of the CARPET device is gas-discharge cylindrical Geiger counters of the STS-6 type, united into 12 counting units (size ~ 1.5×1.5 m), each of which contains 10 counters [11,12, 19]. The meter block consists of two layers of meters (5 upper and 5 lower), separated by an aluminum absorber (filter) 7 mm thick

The CARPET detects particles with energies: in the channels "UP" and "LOW" – electrons and positrons with energies E> 200 keV, protons with E> 5 MeV, muons with E> 1.5 MeV and E> 20 keV photons (efficiency less 1%). Channel "TEL" (coincidence) detects more energetic particles: electrons with energy E> 5 MeV, protons with E> 30 MeV and muons with E> 15.5 MeV [13, 20].

Thus, the CARPET, unlike ground-based neutron monitors, is sensitive to all charged particles, including the low-energy charged secondary CR component formed by primary galactic and solar CRs in the Earth's atmosphere and/or other processes in the near-ground atmosphere.

Results and discussion

This paper examines the Forbush decreases observed in July and September 2017 against the background of a strong geomagnetic storm. For the analysis, we used data from the world network of neutron monitors, as well as data on the electromagnetic environment of interplanetary space during the period of heliospheric and magnetospheric disturbances [14-17].

Figures 1 and 2 show the results of a comparative analysis of temporal changes of registered modules 1 and 2 of the CARPET detector and data obtained using neutron monitors Apatity (curve 1, the Polar geophysical Institute, Russia, 67.57°N, 33.39°E, geomagnetic rigidity of circumcision R_c = 0.65 GW), Almaty (curve 2, Institute of ionosphere, Kazakhstan, 43,1°S, 76,6°E, R_c = 6,69 GW) and "Jungfraujoch IGY" (curve 3, Switzerland, 46.55°N, 7.98°E R_c =4.49 GW) in the period from 10 July to 20 July 2017 and for the period from 1 September to 15 September 2017 [14].

During these periods, a series of Forbush decreases in the CR intensity observed by the global network of ground-based neutron monitors were recorded.

Experimental data from the CARPET detector and neutron monitors in July and September 2017 showed that the CR flux in the surface atmosphere decreased, which is due to high solar activity (a series of solar flares).

Thus, a series of solar flares occurred in the active region of the Sun NOAA2665 (S06W 29) from July 14 to 16 [15, 16].

In July 2017, a significant decrease in the CR flux is observed (Fig. 3) with an onset in the second half of July 16 and a subsequent continuation of the series on July 17. The CR decreases fall on the phase of the geomagnetic storm, when the value of the geomagnetic hourly index D_{st} decreased to -72 nT on July 16 at 15 UT and -61 nT on July 17 at 16 UT, the planetary geomagnetic index K_p reached 6.0 on July 16 (18-20 UT) and 5.7 July 17 (15-17 UT). The maximum solar wind plasma velocity V_{SW} falls on the second half of July 16 and was 625 km/s. On July 16, the critical values of the magnetic field B and B_z reached 23.7 and -20.2 nT, respectively, and the magnetic field density n increased to 43.8 N/cm^3 at 7 UT.

According to the measurements of the GOES-13 satellite (Fig. 4), the arrival of fluxes of low-energy (<10 MeV) solar protons was registered from July 14 at ≈3 UT and is observed until July 16. The source of these particles is a series of M-class flares. More energetic solar protons with energies above 100 MeV have not been observed.

Forbush-decrease was also observed in September 2017. It was caused by high solar flare activity in the NOAA 12673 area (S 11W 16) from September 4 to September 10 [15, 16, 18]. A decrease in the CR intensity with an amplitude of ≈2% occurs on September 7 with the onset of interplanetary disturbances and a geomagnetic storm. Further, on September 8, there is a significant decrease in the intensity of CR flows on all ground monitors, including the CARPET detector.

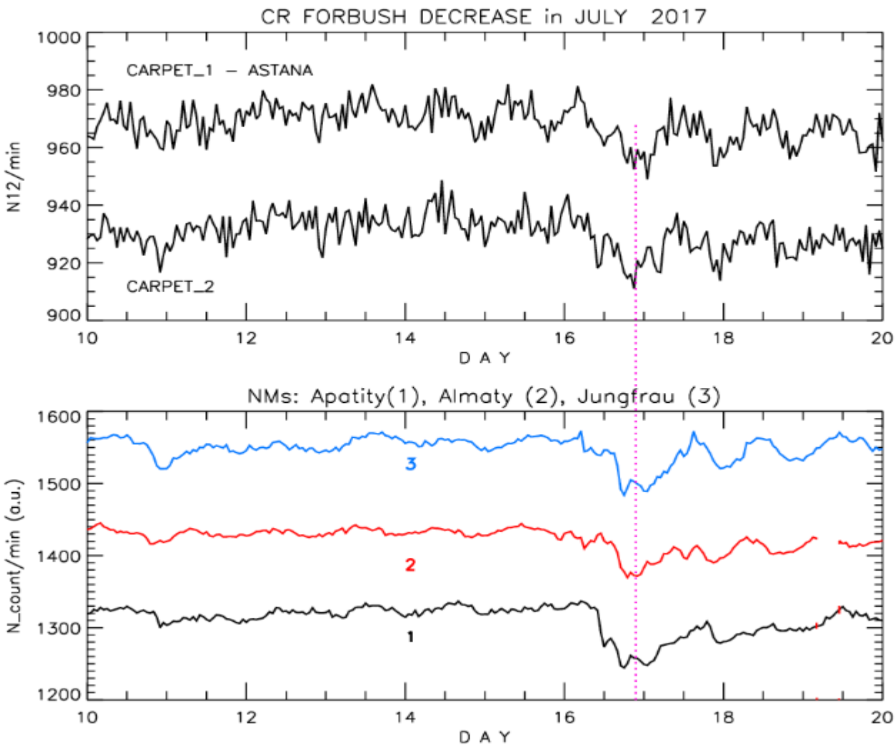

Figure 1 – Counting rate in TEL channels of two CARPET detector modules (Forbush effect, July 2017)

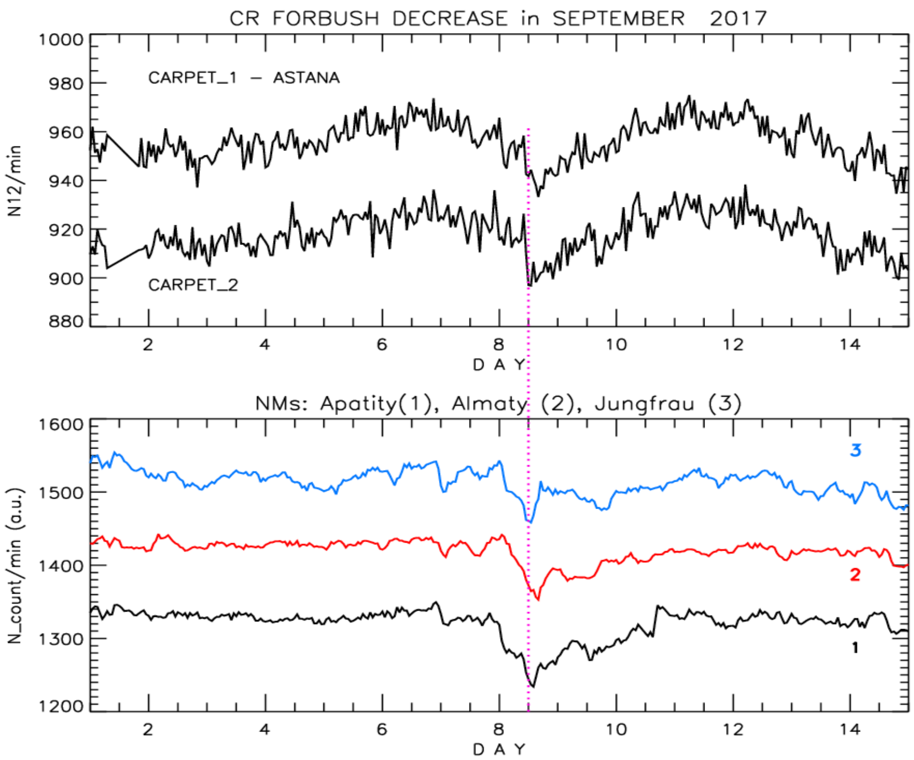

Figure 2 – Counting rate in the TEL channels of two CARPET detector modules (Forbush effect, September 2017)

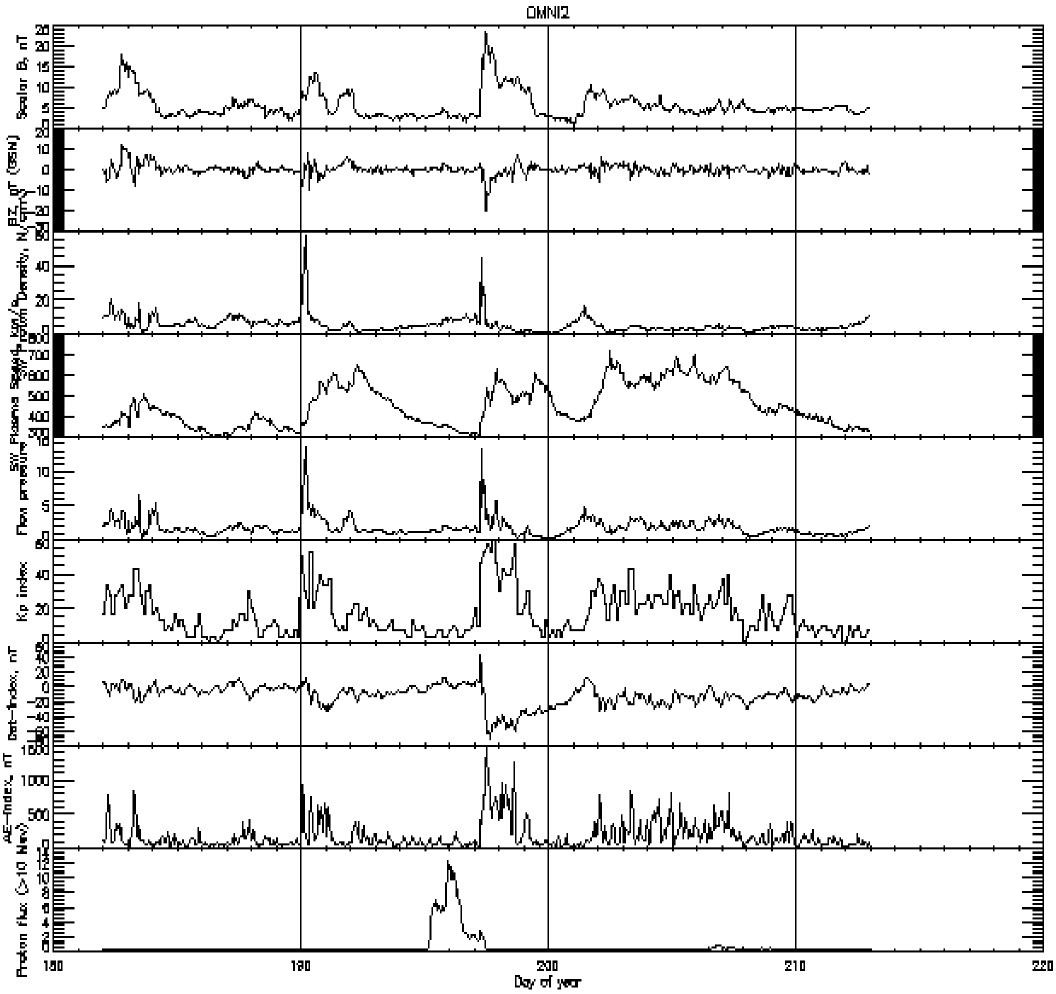

Figure 3 – Changes in the values of the interplanetary magnetic field for 01.07.2017 – 31.07.2017

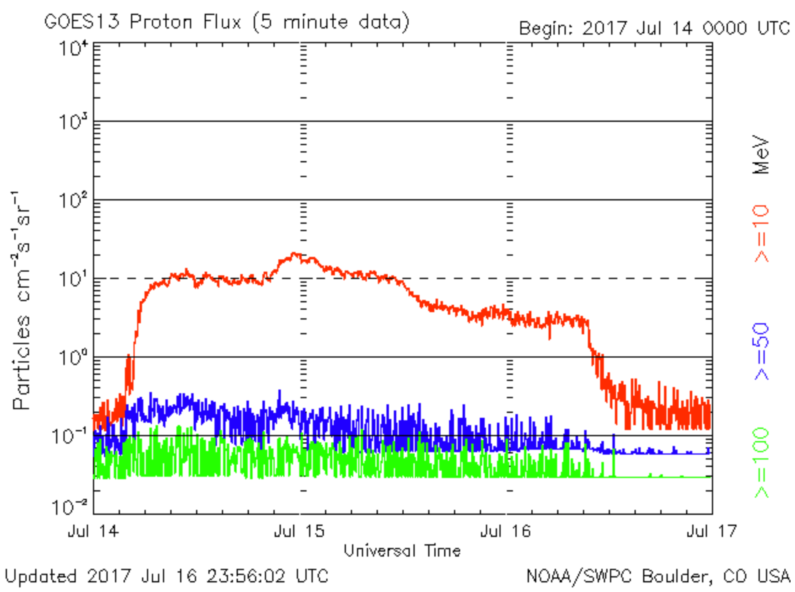

Figure 4 – Fluxes of solar protons according to the measurements of the GOES-13 satellite in the period from 14.07.2017 to 17.07.2017.

On September 8, 2017, the D_{st} value decreased to -142 nT (1 UT), and the three-hour planetary geomagnetic index K_p was high until September 9 (from 4.7 to 8.3), the maximum value (8.3) reached September 8 at 12-14 UT. The solar wind plasma velocity reached 817 km/s (September 8 at 8 UT). The critical values of the magnetic field B and B_z reached 27.3 and -24.2 nT, respectively, the magnetic field density -n on September 7 was 13.9 N/cm^3 (Fig. 5).

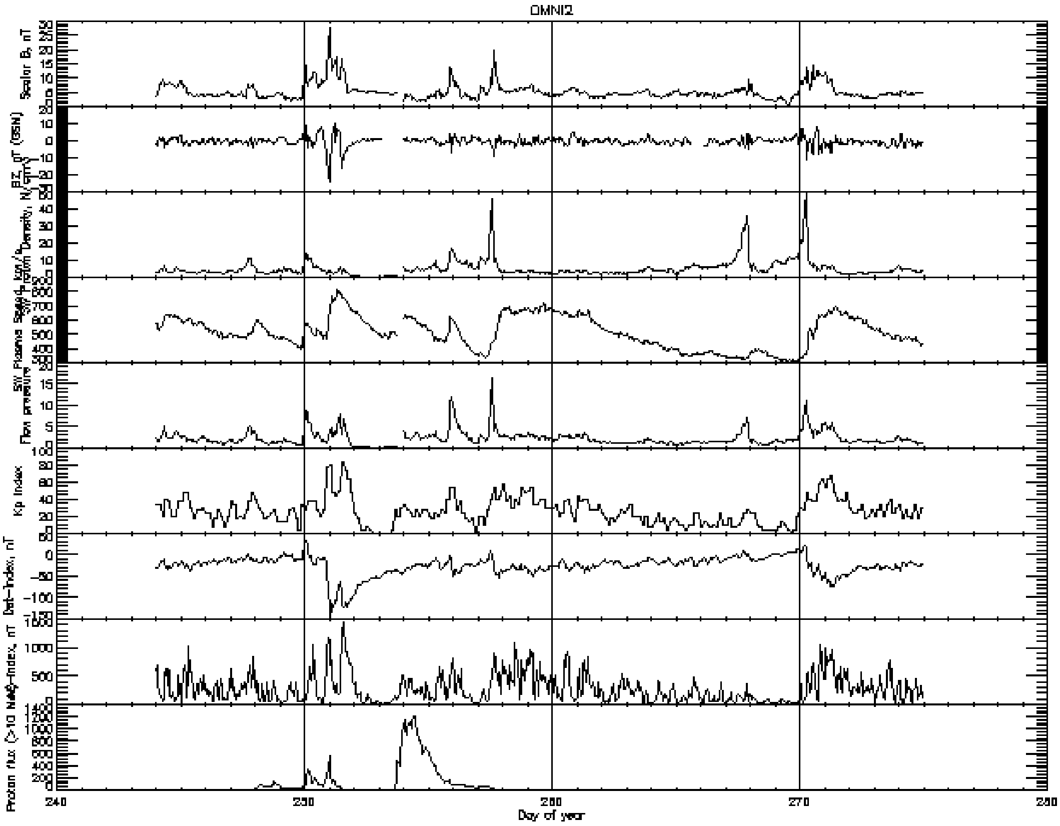

Figure 5 – Changes in the values of the interplanetary magnetic field for 01.09.2017-31.09.2017

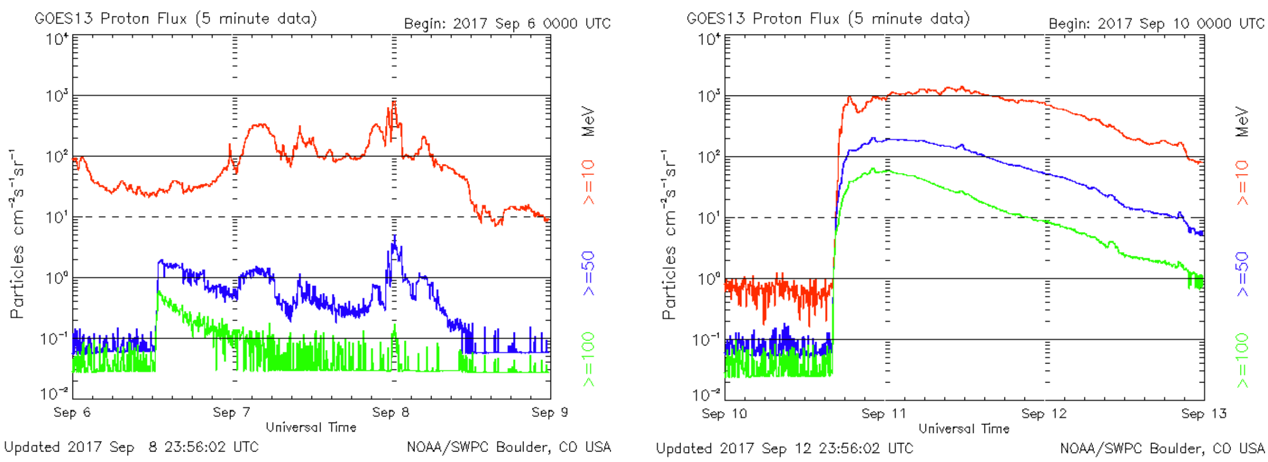

Figure 6 – Solar proton fluxes according to the data of the GOES-13 satellite measurement in the period from 06.09.2017 to 13.09.2017.

According to the GOES-13 satellite (Fig. 6), the proton flux peaks fall on September 8 and 11, 2017. On September 10, a powerful solar-proton event was observed at ≈15-16 UT, where the proton flux increased in a wide energy range (from 10 MeV to> 100 MeV) [15].

The measurement data using the CARPET detector of the scientific complex of the L.N. Gumilyov ENU agree well enough with the measurement data on neutron monitors Apatity, Jungfrau and Almaty.

Conclusions

The results obtained confirmed and showed that variations in CR intensity (Forbush-decreases) are due to previous changes in the elements of the geomagnetic field caused by perturbations on the Sun.

The analysis of the obtained experimental data of the installed and debugged CARPET detector of the scientific complex of the L.N. Gumilyov ENU and their correlation with the results of ground-based neutron monitors shows that the detector makes it possible to study the nature of CR variations for different time intervals, including for observations of Forbush-decreases.

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