UDC 523.98; 551.521:523

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Evaluation of CARPET hardware and software potentialities

This article describes the ground-based cosmophysical complex CARPET/ASTANA. The Cosmophysical Complex CARPET/ASTANA was put into operation at the Physico-Technical Faculty of the L.N.Gumilyov ENU. This is software and hardware complex, which includes a CARPET detector, as well as the EFM-100 fluxmeter. The purpose of the installation of the CARPET complex is the measurement and processing of solar and geophysical parameters in the Earth's atmosphere. The CARPET detector detects soft (electron-photon) and hard (muon) components of cosmic rays. Monitoring of the electric field of the atmosphere was carried out using an electrostatic fluxmeter. The processing and analysis of the experimental data of the detector and the fluxmeter allow to carry out investigations of the radiation situation in the earth's atmosphere during flares on the Sun, to measure the maximum intensity of the flux of solar cosmic rays and their energy spectrum. From the analysis of the obtained results, it is concluded that the cosmophysical complex makes it possible to make an assessment of the radiation and meteorological situation in the terrestrial conditions of the region of Astana.

Keywords: secondary cosmic rays, CARPET detector, electrostatic fluxmeter, gas discharge counters.

1. Introduction

Cosmic rays play an important role in atmospheric processes associated with weather and climate.

The study of variations in secondary cosmic ray fluxs caused by atmospheric processes is one of the actual problems of cosmophysics, and it has been widely discussed in recent years [1-5].

Long-term measurements of cosmic rays in the atmosphere and at the Earth level are one of the most actual experiments in the world. The behavior of cosmic rays with an energy of> 100 MeV is studied in detail, depending on the atmospheric pressure or altitude, the level of solar activity and geomagnetic conditions at the observation station. Measurements of cosmic rays in the atmosphere have been and are being carried out at present by the DSS FIAN in collaboration with many institutes [6-9].

In this paper, a cosmophysical complex is used to experimentally study variations in the secondary particles of cosmic radiation during periods of changes in the characteristics of the surface electric field (the passage of thunderstorm clouds, thunderstorms, etc.) and changes in the meteorological parameters of the surface atmosphere (precipitation, etc.) which includes a CARPET/ASTANA detector and an electrostatic fluxmeter EFM-100.

In 2016, the CARPET/ASTANA ground complex was installed to measure the flux density of the general ionizing component of the secondary cosmic rays at the Physical-Technical Faculty of the ENU of L.N. Gumilyov (Astana, Kazakhstan, 71°26′45″W, 51°10′48″S, , height 358 m, rigidity of geomagnetic cut-off Rc ~ 2.5 GV). The detector was developed and created at the Physical Institute of the Academy of Sciences of P.N.Lebedev within the agreement on international cooperation between FIAN (Russia) and ENU (Kazakhstan) [10, 11].

The cosmic ray detector CARPET/ASTANA is designed for continuous monitoring of cosmic ray flux at the Earth level. The description of the cosmic ray detector CARPET/ASTANA and its characteristics are presented in [12-14].

The cosmic ray detector CARPET/ASTANA is designed for continuous monitoring of the cosmic ray flux at the Earth level. The detector consists of 120 gas-discharge counters STS-6, located on a metal platform measuring ~1.5. Each block consists of two horizontal layers of counters, separated by a 7 mm aluminum layer. In each horizontal layer of the block there are 5 STS-6 counters. The detector provides continuous recording of charged particles. The CARPET detector is an integrated registrator, the totalizer of the charged particle flow: it counts and accumulates pulses from the flow of flying charged particles over the entire area of the device. It is assembled from 2 detector vertical modules, combined with recording and summing electronics throughout the instrument. The two detector modules - the «telescope» - have upper and lower gas-discharge counters. The summing electronics of the CARPET detector captures and accumulates pulses from these telescopes in such a way that:

– all impulses from all upper counters of all CARPET telescopes are summarized in the counter of the 1st channel (data channel - CH1);

– all impulses from all lower counters of all telescopes of the device are summed up in the counter of the 2nd channel (CH2);

– all coincidences of simultaneous operations of the upper and lower counters of any telescope of the device are summed up in the counter of the 3rd channel (TEL channel).

The general view of the installation is shown in Figure 1. The first block of the CARPET detector is installed inside the building, and the second block is located outside the faculty building. In contrast to the first unit, it additionally provides the temperature stabilization.

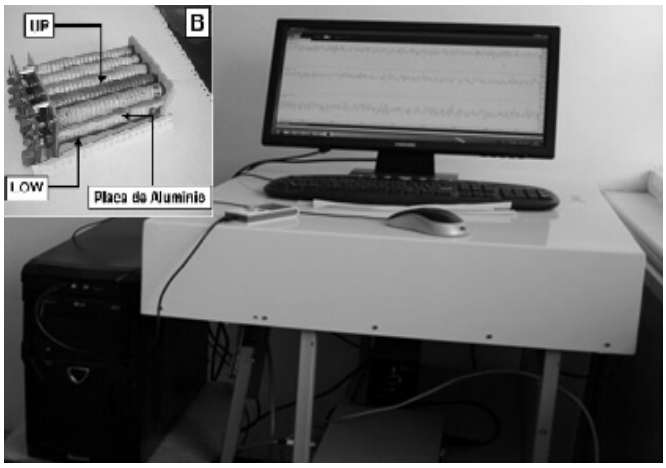

Figure 1. The cosmic ray detector CARPET/ASTANA

In order to study the meteorological situation in Astana region, the EFM-100 electrostatic fluxmeter is included in the CARPET detector, a complex installation for the measurement of cosmic rays. The electrostatic flux meter EFM-100 allows not only to detect lightning discharges, but also to determine the state of high electric field strength, preceding the first lightning discharges.

Figure 2 shows the appearance of the EFM-100 flux meter.

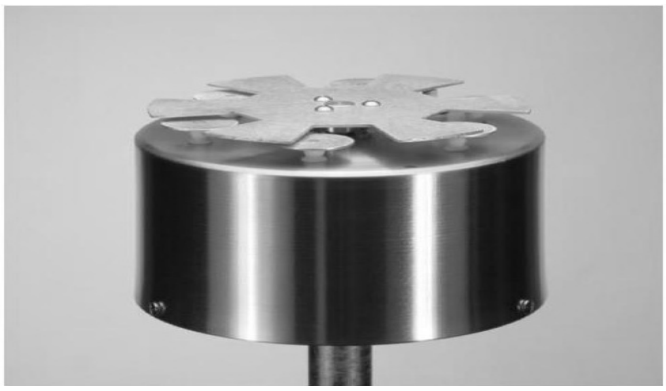

Figure 2. Appearance of the EFM-100 flux meter

EFM-100 not only measures the static electric field created by lightning formations, but also is able to recognize atmospheric conditions that precede thunderstorms. The data are displayed on a personal computer in a graphic and text forms, using standard software.

For full electrical insulation, the EFM-100 is connected to the computer with a special optical table. Figure 3 shows the measurement of the static electric field in the region of Astana using the fluxmeter.

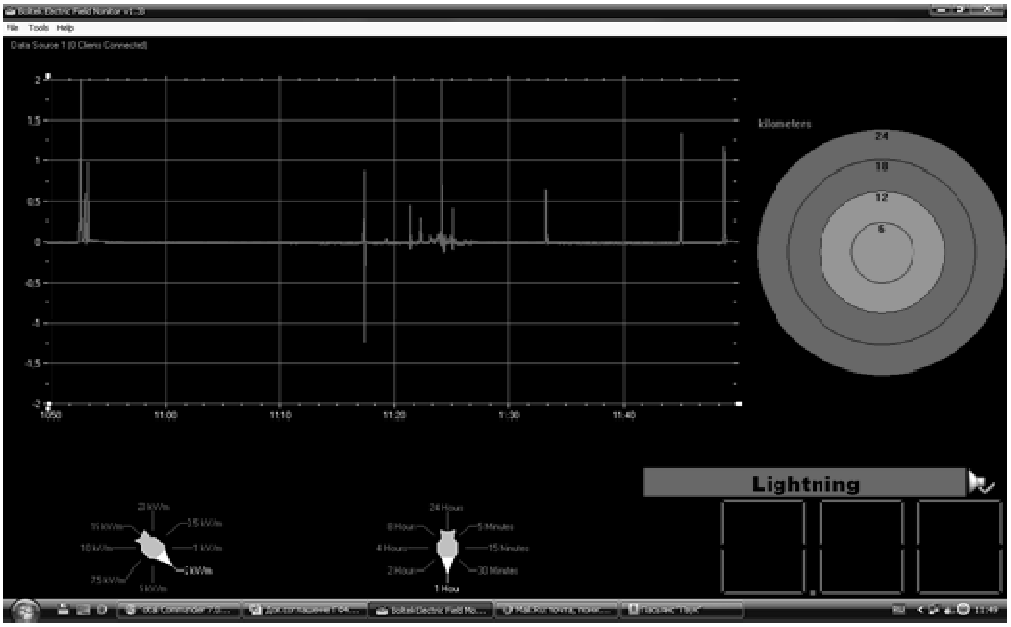

Figure 3. Measurement of the static electric field in the region of Astana (October 26, 2017)

For full electrical insulation, the EFM-100 is connected to the computer with a special optical cable.

To process experimental CARPET/ASTANA data, application packages implemented in IDL environment [15] are used.

1. Experimental data

In recent years, the problem of influencing geophysical factors on environment has attracted increasing attention. Studies of the dose and electrical characteristics of the lower part of troposphere play an important role, where the majority of human activity takes place.

In this paper, data on the dosimetric calibration of the CARPET/ASTANA detector, obtained by simultaneous measurements with a detector and a standard dosimeter SOEKS 01M Prime, are presented. The accumulated dose of radiation is measured and the level of radioactive background in Astana region is estimated.

A method for estimating the radiation background by the magnitude of power of ionizing radiation in Astana region is developed. We used a SOEKS 01M Prime dosimeter along with the CARPET/ASTANA detector.

The results of simultaneous measurements using a standard dosimeter SOEKS 01M Prime were used to carry out dosimetric calibration of the data of upper (CN1) channel of the CARPET/ASTANA detector. This dosimeter is designed to measure the accumulated dose of radiation and assess the level of radioactive background. The detector of ionizing radiation in this dosimeter is the Geiger-Muller counter. Radiation background is estimated from the amount of ionizing radiation power (mainly gamma radiation with energy above 100 keV and beta-particles flux).

In 2016-2017 years several simultaneous measurements of the charged particle count rate were conducted by the CARPET/ASTANA detector and the SOEKS 01M Prime dosimeter. The data of the measurements made on September 10th in 2016 are shown in Figure 4. The processing of the simultaneous measurements made by the CARPET/ASTANA detector and the SOEKS dosimeter has made it possible to determine the average rate of counting of the charged particles CN1 and the average dose D. These values allowed us to calculate the average normalizing transition coefficient from of the CARPET/ASTANA detector to the dose at the detector location. Its value was $k=2.1\cdot10^{-3}$ (μSv/h)/(imp/s).

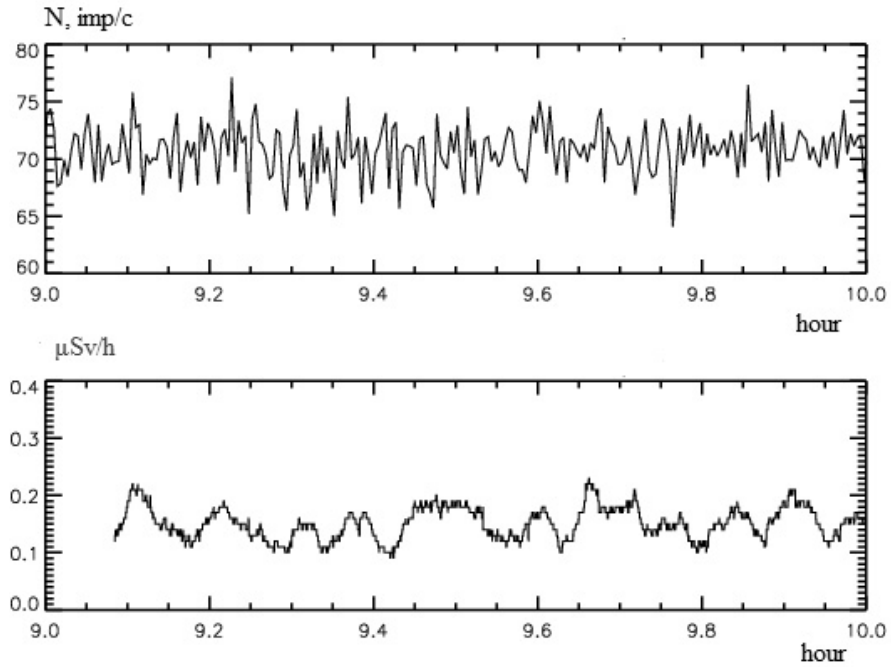

Figure 4. The charged particle count rate of the CARPET/ASTANA detector (CN 1, the count rate per second averaged over 15 points) and the dose value (radioactive background) measured by the SOEKS dosimeter (unit μSv/h). Data were received on September 10, 2016 at 9-10 a.m

Further, using the results of ground-based measurements of charged particle fluxes by the CARPET/ASTANA detector (secondary cosmic rays and surface radioactivity) in 2017, it is possible to estimate the dose value in the surface layer. The estimated results are shown in Figure 5.

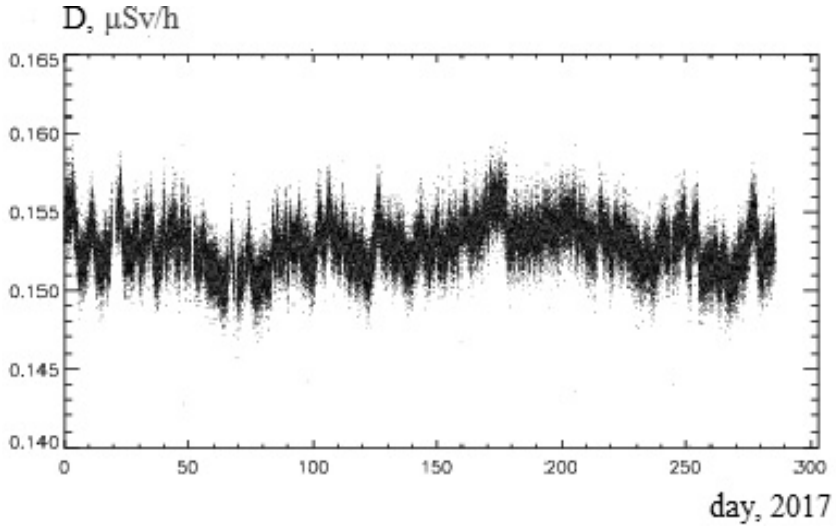

Figure 5. Time dose changes (hourly averaging), determined from the CARPET/ASTANA detector measurements in 2017

It should be noted that, as determined in this way, the dose in the surface layer did not exceed the safe level (up to 0.23 μSv/h). Thus, it is possible to use the experimental data obtained by the ground instrument CARPET/ASTANA, not only for fundamental research in the field of high energy physics and cosmic rays, but also for solving some practical problems (for example, for continuous monitoring of radioactive background in the surface layer). Importantly, unlike widely used standard dosimeters, the CARPET/ASTANA detector is sensitive to a more energetic (all-penetrating) component of charged particles. In the future, it is planned to continue simultaneous measurements to improve this technique.

Conclusion

Based on the above presented experimental data obtained at the CARPET/ASTANA ground complex, the following conclusions can be made:

- the detector data allow to investigate the nature of cosmic ray variations caused by processes on the Sun, in the interplanetary medium and in the terrestrial magnetosphere for different time intervals;
- analyze the effect of secondary cosmic rays on the parameters of the surface electric field;
- analyze the effect of secondary cosmic rays on radiation characteristics in the ground layer of the atmosphere.

Acknowledgement

This work was supported by the Ministry of Education and Science of KR, gtant№5230 GF4.

References

1 Fullecrug M. Sprites, Elves, and intense Lightning Discharges / M.Fullecrug, E.Mareev, M.Rycroft; Eds: M. Fullecrug, E. Mareev, M. Rycroft. — Dordrecht: Springer, 2006. — 398 p.

2 Merier J-F. Increased environmental gamma-ray dose rate during precipitation: a strong correlation with contributing air mass / J-F.Merier, B.L.Tracy, F.Changon, I.Hoffman, E.P. Korpach, S.Johnson, K.Ungar // Journal of Environmental Radioactivity. — 2009. — Vol. 100(7). — P. 527–533.

3 Famoso B. An educational study of the barometric effect of cosmic rays with a Geiger counter / B.Famoso, P.La Rocca, F.Riggi // Physics Education. — 2010. — Vol. 40(5). — P. 461–467.

4 Germanenko A.V. High-energy photons connected to atmospheric precipitations / A.V. Germanenko, Yu.V. Balabin, B.B. Gvozdevsky L.I. Schur, E.V.Vashenyuk // Astrophys. Space Sci. Trans. — 2011. — Vol. 7. — P. 471–475.

5 Amenomori M. Cosmic-ray energy spectrum around the knee observed with the Tibet air-shower experiment / M.Amenomori et al. // Astrophys. Space Sci. Trans. — 2011. — Vol. 7. — P. 15–20.

6 Khaerdinov N.S. Variations of the Intensity of Cosmic Ray Muons due to Thunderstorm Electric Fields / N.S. Khaerdinov, A.S. Lidvansky, V.B. Petkov // 29th Intern. Conf. onCosmicRays, Pune. — 2005. — August 3-10. — Vol. 2. — P. 389–392.

7 Свиржевская А.К., Базилевская Г.А., Крайнев М.Б., Махмутов В.С., Стожков Ю.И. Особенности минимума 24-го солнечного цикла в солнечных и гелиосферных характеристиках и в интенсивности галактических космических лучей / А.К. Свиржевская, Г.А. Базилевская, М.Б. Крайнев, В.С. Махмутов, Ю.И. Стожков // Сб. науч. тр. — М.: НИЯУ МИФИ, 2010. — Т. 4. — С. 95–98.

8 Sloan T. Ionization in the atmosphere, comparison between measurements and simulation / T. Sloan, G.A. Bazilevskaya, V.S. Makhmutov, Y.I. Stozhkov, A.K. Svirzhevskaya, N.S. Svirzhevsky // Astrophys. SpaceSci. Trans. — 2011. — Vol. 7(1). — P. 29–33.

9 Mizin S.V. Brief Communications on Physics. / S.V. Mizin, V.S. Makhmutov, O.S. Maksumov, et al. — 2011. — Vol. 2. — P. 9–17.

10 Stozhkov Y.I., Svirzhevsky N.S., Bazilevskaya G.A., Makhmutov V.S. // Proc. 32ndICRC. — Beijing, Chine, 2011. — P. 4.

11 Morzabaev A. Research of cosmic rays variations in July-August 2016 with of data of the CARPET detector / A.Morzabaev, Sh.Giniyatova, S.Sakhabayeva, V.Makhmutov et al. // International Journal of Mathematics and Physics. — 2016. — Vol. 7(2). — С. 106–112.

12 Морзабаев А.К. Детектор космических лучей CARPET / А.К. Морзабаев, В.С. Махмутов, Ш.Г. Гиниятова // Вестн. КазНИТУ. — 2017. — № 3. — С. 505–509.

13 Морзабаев А.К. Исследование вариаций космических лучей в ноябре 2016 г. по экспериментальным данным детектора CARPET (Астана) / А.К. Морзабаев, В.С. Махмутов, Ш.Г. Гиниятова, Г.А. Шаханова // Вестн. ЕНУ. — 2017. — № 2(112). — С. 142–146.

14 Морзабаев А.К. Методика учета влияния атмосферного давления на интенсивность космических лучей по данным детектора CARPET / А.К. Морзабаев, Ш.Г. Гиниятова, Г.А. Шаханова // Вестн. Караганд. ун-та. Сер. Физика. — № 4(88). — 2017. — С. 78–83.

15 Основы языка программирования IDL: учеб. пособие. — М.: ЗАО «Компания «Совзонд», 2009. — С. 191.

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CARPET бағдарламалы-аппараттық кешені мүмкіндіктерін бағалау

Мақалада CARPET/ASTANA ғарыш-физикалық кешеніне сипаттама берілген. Ғарыш-физикалық CARPET/ASTANA кешені Л.Н. Гумилев атындағы ЕҰУ-ның физика-техникалық факультетінде орналастырылған. Бағдарламалы-аппараттық кешен құрамына CARPET детектор және EFM-100 флюксметр кіреді. CARPET кешенін орнатудың мақсаты — Жер атмосферасындағы гелио- және геофизикалық параметрлерді өңдеу және өлшеу. CARPET детекторы ғарыштық сәулелердің жұмсақ

(электронды-фотонды) және қатты (мюонды) компоненттерін тіркейді. Атмосфераның электр өрісін бақылау электрстатикалық флюксметр көмегімен жүргізілген. Флюксметр мен детектордың тәжірибе деректерін талдау және өңдеу Күн жарқылы кезіндегі Жер атмосферасындағы радиациялық жағдайға зерттеу жүргізуге, сонымен қатар Күндік ғарыштық сәулелердің максималды ағыны мен олардың энергетикалық спектрін өлшеуге мүмкіндік береді. Алынған нәтижелерді талдау арқылы ғарыш-физикалық кешен Астана аумағының Жер маңындағы радиациялық және метеорологиялық жағдайын бағалауға мүмкіндік береді деген қорытынды жасалды.

Кілт сөздер: екінші реттік ғарыштық сәулелер, CARPET детекторы, электростатикалық флюксметр, газразрядты есептеуіштер.

А.К. Морзабаев, Ш.Г. Гиниятова, Г.А. Шаханова, В.С. Махмутов

Оценка возможностей программно-аппаратного комплекса CARPET

В данной статье описывается наземный космофизический комплекс CARPET/ASTANA. Космофизический комплекс CARPET/ASTANA введен в эксплуатацию на физико-техническом факультете ЕНУ им. Л.Н. Гумилева. Это программно-аппаратный комплекс, в состав которого входят детектор CARPET, а также флюксметр EFM-100. Цель установки комплекса CARPET – измерение и обработка гелио- и геофизических параметров в земной атмосфере. Детектор CARPET регистрирует мягкую (электрон-фотонную) и жесткую (мюонную) компоненты космических лучей. Мониторинг электрического поля атмосферы проведен с помощью электростатического флюксметра. Обработка и анализ экспериментальных данных детектора и флюксметра позволяют проводить исследования радиационной обстановки в земной атмосфере во время вспышек на Солнце, измерить максимальную интенсивность потока солнечных космических лучей и их энергетический спектр. Из анализа полученных результатов сделаны выводы, что космофизический комплекс позволяет сделать оценку радиационной и метеорологической обстановки в наземных условиях региона Астаны.

Ключевые слова: вторичные космические лучи, детектор CARPET, электростатический флюксметр, газоразрядные счётчики.

References

1 Fullecrug, M., Mareev, E., & Rycroft, M. (Eds.). (2006). Sprites, Elves, and intense Lightning Discharges. Dordrecht: Springer.

2 Merier, J-F., Tracy, B.L, Changon, F., Hoffman, I., Korpach, E.P., Johnson, S., & Ungar, K. (2009). Increased environmental gamma-ray dose rate during precipitation: a strong correlation with contributing air mass. *Journal of Environmental Radioactivity, Vol. 100 (7),* 527–533.

3 Famoso, B., La Rocca, P., & Riggi, F. (2010). An educational study of the barometric effect of cosmic rays with a Geiger counter. *Physics Education, Vol. 40(5),* 461–467.

4 Germanenko, A.V, Balabin, Yu.V, Gvozdevsky, B.B, Schur, L.I, & Vashenyuk, E.V. (2011). High-energy photons connected to atmospheric precipitations. *Astrophys. Space Sci. Trans., Vol. 7,* 471–475.

5 Amenomori, M. & et al. (2011). Cosmic-ray energy spectrum around the knee observed with the Tibet air-shower experiment. *Astrophys. Space Sci. Trans., Vol. 7,* 15–20.

6 Khaerdinov, N.S., Lidvansky, A.S., & Petkov, V.B. (2005). Variations of the Intensity of Cosmic Ray Muons due to Thunderstorm Electric Fields. *29th Intern. Conf. on Cosmic Rays, Pune.* (Vol. 2, pp. 389–392). (August 3-10, 2005).

7 Svirzhevskaja, A.K., Bazilevskaja, G.A., Krajnev, M.B., Mahmutov, V.S., & Stozhkov, Ju.I. (2010). Osobennosti minimuma 24-ho solnechnoho tsikla v solnechnykh i heliosfernykh harakteristikakh i v intensivnosti halakticheskikh kosmicheskikh luchei [Features of the minimum of the 24th solar cycle in the solar and heliospheric characteristics and in the intensity of galactic cosmic rays // Proceedings]. *Sbornik nauchnykh trudov – Collection of scientific papers, 4,* 95–98. Moscow: NIIaU MIFI [in Russian].

8 Sloan, T., Bazilevskaya, G.A., Makhmutov, V.S., Stozhkov, Y.I., Svirzhevskaya A.K., & Svirzhevsky N.S. (2011). Ionization in the atmosphere, comparison between measurements and simulation. *Astrophys. Space Sci. Trans., Vol. 7(1),* 29–33.

9 Mizin, S.V., Makhmutov, V.S., Maksumov, O.S., & et al. (2011). Brief Communications on Physics*, Vol.2,* 9–17.

10 Stozhkov, Y.I., Svirzhevsky, N.S., Bazilevskaya, G.A., & Makhmutov, V.S. (2011). Proc. 32nd ICRC. Beijing, Chine.

11 Morzabaev, A., Giniyatova, Sh., Sakhabayeva, S., Makhmutov, V. & et al. (2016). Research of cosmic rays variations in July-August 2016 with of data of the CARPET detector. *International Journal of Mathematics and Physics, Vol. 7(2),* 106–112.

12 Morzabaev, A.K., Makhmutov, V., & Giniyatova, Sh. (2017). Detektor kosmicheskikh luchei CARPET [The cosmic ray detector CARPET]. *Vestnik Kazakhskoho natsionalnoho issledovatelskoho tekhnicheskoho universiteta – Bulletin Kazakh National Research Technical University, 3,* 505–509 [in Russian].

13 Morzabaev, A.K., Makhmutov, V., Giniyatova, Sh, & Shakhanova, G. (2017). Issledovanie variatsii kosmicheskikh luchei v noiabre 2016 h. po eksperimentalnym dannym detektora CARPET (Astana) [The study of cosmic ray variations in November 2016 based on the experimental data of the CARPET detector (Astana)]. *Vestnik Evraziiskoho natsionalnoho universiteta – Bulletin of the Eurasian National University, 2 (112),* 142–146 [in Russian].

14 Morzabaev, A.K., Makhmutov, V., Giniyatova, Sh, Shakhanova, G. (2017). Metodika ucheta vliianiia atmosfernoho davleniia na intensivnost kosmicheskikh luchei po dannym detektora CARPET [The method of accounting for the effect of atmospheric pressure on the intensity of cosmic rays from the data of the CARPET detector]. *Vestnik Karahandinskoho universiteta. Seriia Fizika – Bulletin of Karaganda University Series of Physics, 4(88),* 78–83 [in Russian].

15 Osnovy yazyka prohrammirovaniia IDL. (2009) [Basics of the programming language IDL]. Moscow: ZAO «Kompaniia «Sovzond» [in Russian].