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© B.T. Zhumabayev[1], A.A. Altaibek[1,2], A.T. Sarsembayeva[3], M. Nurtas[1,2]*, 2025.
[1]Institute of Ionosphere, Almaty, Kazakhstan;
[2]International Information Technology University, Almaty, Kazakhstan;
[3]Al-Farabi Kazakh National University, Almaty, Kazakhstan.
E-mail: maratnurtas@gmail.com

SPACE WEATHER INFLUENCE ON SEISMIC ACTIVITY: ANALYZING THE MAY 1, 2011, MW 5.1 EARTHQUAKE IN KAZAKHSTAN

Zhumabayev Beibit Tenelovich — Candidate of Physical and Mathematical Sciences, Chief Researcher of the Geomagnetic Research Laboratory of the Ionosphere Institute of Aerospace Committee of the Ministry of Digital Development, Innovation and Aerospace Industry of the Republic of Kazakhstan, Almaty, Kazakhstan,
E-mail: beibit.zhu@mail.ru, https://orcid.org/0000-0002-8402-7934;
Altaibek Aizhan — PhD, Leading researcher, Institute of Ionosphere and Associate professor of IITU, Almaty, Kazakhstan,
E-mail: aizhan.altaibek@yandex.ru, a.altaibek@iitu.edu.kz, https://orcid.org/0000-0001-8431-7950;
Sarsembayeva Aiganym Tnysbekovna — PhD, Senior lecturer, Department of theoretical and nuclear physics, Al-Farabi Kazakh National University, Almaty, Kazakhstan,
E-mail: sarsembaeva.a@kaznu.kz, https://orcid.org/0000-0002-3003-0038;
Nurtas Marat — PhD, leading researcher, Institute of Ionosphere and associate professor of IITU, Almaty, Kazakhstan,
E-mail: maratnurtas@gmail.com, m.nurtas@iitu.edu.kz, https://orcid.org/0000-0003-4351-0185.

Abstract. In recent years, questions about the possible influence of space weather factors on seismic activity have become increasingly relevant, especially in regions where tectonic faults are further affected by anthropogenic factors, such as the creation of artificial reservoirs and changes in hydrogeological conditions. This study focuses on the earthquake with magnitude MW = 5.1 that occurred on May 1, 2011, near the Kapchagay reservoir in Kazakhstan. The main aim of the study is to reveal a potential relationship between geophysical processes in the lithosphere and the effects of space weather, including solar wind, magnetic field parameters, and SYM/H index variations. The analysis is based on data from regional and global seismological catalogs, measurements of geomagnetic field parameters, solar wind data, and mathematical models describing electromagnetic initiation of earthquakes. It was found that 28 hours before the main seismic event, a powerful pulse of solar wind was recorded, causing notable changes in geomagnetic field parameters and accompanied by anomalies in the electrical conductivity of the fault. These observations are consistent with models predicting that solar flares may trigger earthquakes in electrically conductive faults of the Earth's crust, especially when conductivity is increased by anthropogenic factors. The results suggest that the investigated earthquake could have been triggered by a combination of space weather and local geophysical conditions. Further and more detailed studies of similar events in other regions are required to confirm this hypothesis and to expand scientific understanding of the mechanisms behind such phenomena.

Keywords: earthquake in Kazakhstan, artificial reservoir, tectonic fault, earthquake precursor, space weather

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© Б.Т. Жұмабаев[1], А.А Алтайбек[1,2], А.Т. Сарсембаева[3], М. Нұртас[1,2]*, 2025.

[1]Ионосфера Институты, Алматы, Қазақстан;
[2]Халықаралық Ақпараттық технологиялар университеті, Алматы, Қазақстан;
[3]Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан.
E-mail: maratnurtas@gmail.com

ҒАРЫШ АУА РАЙЫНЫҢ ЖЕР СІЛКІНІСІНЕ ӘСЕРІ: 2011 ЖЫЛҒЫ 1 МАМЫРДАҒЫ ҚАЗАҚСТАНДАҒЫ MW 5.1 ЖЕР СІЛКІНІСІН ТАЛДАУ

Жұмабаев Бейбіт Тенелович — физика-математика ғылымдарының кандидаты, Қазақстан Республикасы Цифрлық даму, инновациялар және аэроғарыш өнеркәсібі министрлігі Аэроғарыш комитеті Ионосфера институтының Геомагниттік зерттеулер зертханасының бас ғылыми қызметкері, Алматы, Казахстан,
E-mail: beibit.zhu@mail.ru, https://orcid.org/0000-0002-8402-7934;
Алтайбек Айжан Алтайбекқызы — PhD, бас ғылыми қызметкер, Ионосфера институты және Халықаралық ақпараттық технологиялар университетінің қауымдастырылған профессоры, Алматы, Қазақстан,
E-mail: aizhan.altaibek@yandex.ru, a.altaibek@iitu.edu.kz, https://orcid.org/0000-0001-8431-7950;
Сарсембаева Айғаным Тнысбековна — PhD, аға оқытушы, теориялық және ядролық физика кафедрасы, Әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
E-mail: sarsembaeva.a@kaznu.kz, https://orcid.org/0000-0002-3003-0038;
Нұртас Марат — PhD, бас ғылыми қызметкер, Ионосфера институты және Халықаралық ақпараттық технологиялар университетінің қауымдастырылған профессоры, Алматы, Қазақстан,
E-mail: maratnurtas@gmail.com, m.nurtas@iitu.edu.kz, https://orcid.org/0000-0003-4351-0185.

Аннотация. Соңғы жылдары ғарыштық ауа райы факторларының сейсмикалық белсенділікке ықтимал әсері мәселелері барған сайын әсіресе тектоникалық жарылымдарға жасанды су қоймаларын құру және гидрогеологиялық жағдайларды өзгерту сияқты әртүрлі антропогендік факторлар қосымша әсер ететін аймақтарда өзекті болуда. Осы ғылыми жұмыста 2011 жылғы 1 мамырда Қазақстан аумағындағы Капшағай су қоймасы маңында болған MW = 5.1 магнитудалы жер сілкінісі жан-жақты әрі терең қарастырылды. Зерттеудің негізгі мақсаты – литосферадағы күрделі геофизикалық үдерістер мен ғарыштық ауа райының, соның ішінде күн желінің, магнит өрісі параметрлерінің және SYM/H индексінің өзгерістерінің ықпалын анықтау және олардың арасындағы ықтимал байланыстарды ашу. Талдау аймақтық және жаһандық сейсмологиялық каталогтардың деректері, геомагниттік өріс параметрлерінің, күн желінің өлшеу нәтижелері және жер сілкіністерінің электромагниттік туындауын сипаттайтын заманауи математикалық модельдер негізінде жүргізілді. Негізгі сейсмикалық оқиғаға дейін 28 сағат бұрын күн желінің қуатты импульсі тіркеліп, геомагниттік өріс параметрлерінде айтарлықтай өзгерістер тудырды және жарылымның электрөткізгіштігінде бірқатар аномалиялар байқалды. Бұл бақылаулар электрөткізгіштігі жоғары жарылымдарда, әсіресе оның антропогендік факторлар әсерінен қосымша артқан жағдайында, күн жарқылдарының жер сілкіністерін триггерлеу мүмкіндігін болжайтын заманауи модельмен толықтай үйлеседі. Алынған нәтижелер қарастырылып отырған жер сілкінісінің ғарыштық және жергілікті геофизикалық факторлардың кешенді әрі күрделі әсерінен туындауы мүмкін екенін көрсетеді. Бұл ұсынылған гипотезаны түпкілікті растау үшін басқа аймақтардағы ұқсас жағдайларды одан әрі және тереңірек зерттеу қажет, бұл осындай құбылыстардың пайда болу механизмдері туралы ғылыми түсініктерді айтарлықтай кеңейтуге мүмкіндік береді.

Түйін сөздер: Қазақстандағы жер сілкінісі, жасанды су қоймасы, тектоникалық жарылым, жер сілкінісінің алдын ала белгісі, ғарыштық ауа райы

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[1]Институт Ионосферы, Алматы, Казахстан;
[2]Международный Университет Информационных Технологий, Алматы, Казахстан;
[3]Казахский Национальный Университет имени аль-Фараби, Алматы, Казахстан.
E-mail: maratnurtas@gmail.com

ВЛИЯНИЕ КОСМИЧЕСКОЙ ПОГОДЫ НА СЕЙСМИЧЕСКУЮ АКТИВНОСТЬ: АНАЛИЗ ЗЕМЛЕТРЯСЕНИЯ 1 МАЯ 2011 ГОДА В КАЗАХСТАНЕ С МАГНИТУДОЙ MW 5.1

Жумабаев Бейбит Тенелович — кандидат физико-математических наук, Главный научный сотрудник лаборатории геомагнитных исследований Института ионосферы Комитета по аэрокосмической отрасли Министерства цифрового развития, инноваций и аэрокосмической промышленности Республики Казахстан, Алматы, Казахстан,
E-mail: beibit.zhu@mail.ru, https://orcid.org/0000-0002-8402-7934;
Алтайбек Айжан Алтайбекқызы — PhD, ведущий научный сотрудник, Институт ионосферы, ассоциированный профессор Международного информационно-технологического университета, Алматы, Казахстан,
E-mail: aizhan.altaibek@yandex.ru, a.altaibek@iitu.edu.kz, https://orcid.org/0000-0001-8431-7950;
Сарсембаева Айганым Тнысбековна — PhD, старший преподаватель кафедры теоретической и ядерной физики, Казахский национальный университет имени аль-Фараби, Алматы, Казахстан,
E-mail: sarsembaeva.a@kaznu.kz, https://orcid.org/0000-0002-3003-0038;
Нуртас Марат — PhD, ведущий научный сотрудник, Институт ионосферы и ассоциированный профессор Международного информационно-технологического университета, Алматы, Казахстан,
E-mail: maratnurtas@gmail.com, m.nurtas@iitu.edu.kz, https://orcid.org/0000-0003-4351-0185.

Аннотация. В последние годы вопросы возможного влияния факторов космической погоды на сейсмическую активность приобретают всё большую актуальность, особенно в регионах, где на тектонические разломы дополнительно воздействуют антропогенные факторы, такие как создание искусственных водохранилищ и изменение гидрогеологических условий. В данной работе подробно рассматривается землетрясение магнитудой MW = 5.1, произошедшее 1 мая 2011 года вблизи Капчагайского водохранилища на территории Казахстана. Основная цель исследования – выявить возможную связь между геофизическими процессами в литосфере и воздействием космической погоды, включая солнечный ветер, параметры магнитного поля и изменения индекса SYM/H. Анализ выполнен на основе данных региональных и глобальных сейсмологических каталогов, измерений параметров геомагнитного поля и солнечного ветра, а также современных математических моделей, описывающих электромагнитное инициирование землетрясений. Установлено, что за 28 часов до основного

сейсмического события был зафиксирован мощный импульс солнечного ветра, вызвавший существенные изменения параметров геомагнитного поля и сопровождавшийся аномалиями электропроводности разлома. Эти наблюдения согласуются с моделью, предсказывающей возможность триггерного влияния солнечных вспышек на формирование землетрясений в электропроводных разломах земной коры, особенно в условиях дополнительного увеличения электропроводности вследствие техногенных факторов. Полученные результаты позволяют предположить, что рассматриваемое землетрясение могло быть спровоцировано комплексным воздействием космических и локальных геофизических факторов. Для окончательного подтверждения данной гипотезы необходимы дальнейшие и более глубокие исследования аналогичных случаев на других территориях, что позволит углубить научные представления о механизмах возникновения подобных явлений.

Ключевые слова: землетрясение в Казахстане, искусственное водохранилище, тектонический разлом, предвестник землетрясения, космическая погода

Introduction. In September 1969, the Ili River, originating on the Tien Shan in the People's Republic of China, was blocked on the territory of the Almaty region (Kazakhstan). A dam and hydroelectric power station were built in the narrow Kapchagay gorge, and since 1970 the filling of the Kapchagay reservoir in the central part of the Ili Depression began. In former times, the Ili Depression was classified as an aseismic area, so a noticeable earthquake with an energy class of K = 13 (Mw = 5.1), which happened here on May 1, 2011 at 02:31:29 UT at a depth of 23.2 km with the coordinates of the epicenter 43.58°N 77.7°E was unexpected for both seismologists and residents of the region. The epicenter of the earthquake was located south of the Kapchagay reservoir, the intensity of seismic tremors in the territory of Almaty was 4-5 points. After the main shock, which occurred in the morning local time, there were several aftershocks of lower magnitude. During May 1, 2011, Almaty residents felt the vibrations from earthquakes at least six times. The epicenter of the Kapchagay earthquake is located in the transition zone from structures of the Tien Shan orogen to Dzungaria, the features of the geological and tectonic structure and deformation regime of this zone are presented in detail in. It is shown (Figure 1) that the earthquake area is a weakly seismic zone separating the North Tien Shan and Dzungaria seismic zones of Kazakhstan. The crystalline basement of the Caledonian consolidation is overlain here by strata of Meso-Cenozoic rocks. The earthquake center was realized under conditions of regional compression stress in the submeridional direction, under the influence of which there were movements along the rupture planes consistent with the kinematics and extension of the main regional faults. The earthquake hypocenter is confined to the junction of higher-order faults, one of them is subparallel to the Kapchagai-Chilik shift, the other has a northeastern strike. The nearest seismogenerating zone to the focus of the Kapchagay earthquake is the Altyn-Emel seismogenerating zone, the potential of which in the north is Mmax = 6.5, and in the south the most possible earthquake magnitude is Mmax = 7.0.

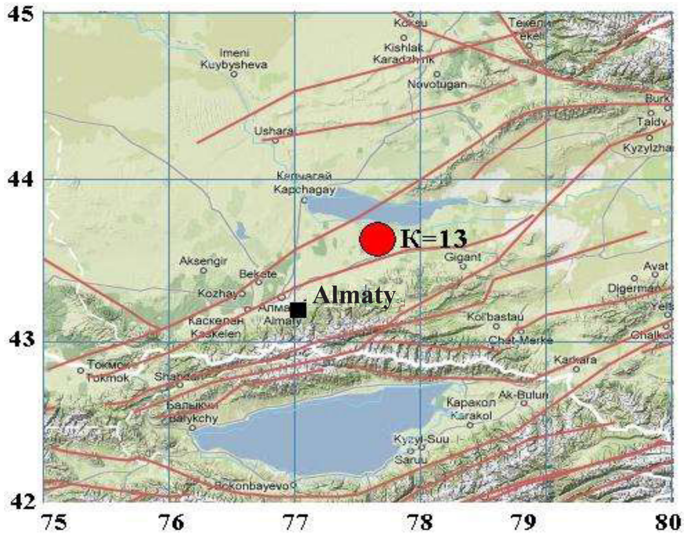

Figure 1 - Location of the epicenter of the Kapchagay earthquake with energy class K=13 (Mw=5.1), which occurred on May 1, 2011

The analysis of seismicity in the territory of the Kapchagay earthquake before 1971 and after allowed to suggest that the observed increase in seismicity may be associated with the creation of the Kapchagay reservoir, that is, the earthquake of May 1, 2011 could have been induced. Since the reservoir is located in close proximity to the Altyn-Emel tectonic fault, and since further evolution of reservoir-induced seismicity is possible, which can activate this fault, the possibility of a stronger seismic event here is not excluded, which has already been confirmed to some extent. Thus, according to the data of the American Geological Survey USGS (Nurtas, et al., 2023: 26), on August 8, 2017, in the zone of the eastern tip of the Altyn-Emel fault in China (44.302°N 82.832°E) an earthquake with a magnitude of M=6.3 occurred at 23:27:53 (UTC), and then within 17 minutes two more earthquakes with M=5.2 and M=5.3 occurred on the same fault, but already on the territory of Kazakhstan (44.325°N, 82.742°E and 44.359°N, 82.790°E) at 23:39:18 and 23:44:31 (UTC), respectively.

The analysis of the Kapchagay earthquake involved 1-minute data of the absolute values of the components of the magnetic field vector measured at 4 magnetovariation stations located at 100 and 130 km from the epicenter of the earthquake. The coefficient of the transfer function A=δZ/δH was calculated for periods of 8, 15, 22, 90, 120 and 180 minutes associated with the conductivity of rocks at the depths of field penetration in the corresponding periods of variations. At one of the stations (Kurty), an anomaly was detected in the values of A for a period of 120 minutes, corresponding to a decrease in the electrical resistance of the rock at a depth of about 20 km. When analyzing the variations of the seismic parameter Vp/Vs (the ratio of the velocities of longitudinal and transverse seismic waves), which characterizes the strength of the geological medium, it was found that about a day before the earthquake, two zones of reduced values of Vp/Vs of the northwestern direction were observed, between which the epicenter of the earthquake arose. On the eve and during the Kapchagay earthquake, changes were also observed in the intensity of the thermal neutron flux, in gamma radiation, in bursts of surface atmospheric electricity and in the spectra of micropulsations of atmospheric pressure. These results indicate that the process of preparation and implementation of the Kapchagay Mw=5.1 69 earthquake was accompanied by variations in geophysical parameters recorded at the Earth's surface.

The formulation of the problem of the possible connection of the Kapchagay earthquake with variations in the state of space weather is currently justified, since an article (Sorokin, et al., 2023: 14) has recently been published, where a mathematical model of electromagnetic generation of earthquakes has been developed due to the influence of solar flare energy on the ionosphere-atmosphere-lithosphere system and the strengthening of telluric currents in the lithosphere, including the field of tectonic faults. It should be noted that the creation of this model was preceded by more than 170 years of statistical research on the possible connection of seismic activity with variations in the number of sunspots, solar flares, high-speed streams of charged particles, for example. The results of correlation analysis often showed both a positive correlation between solar and seismic activity and a negative one, and works appeared, for example (Love et al., 2013: 40), where it was concluded that there was no significant connection between solar and seismic events. However, these investigations are only statistical in nature, where a simple (not physical) hypothesis was tested about the presence or absence of a correlation between solar activity and seismicity of the Earth. In contrast, the paper (Sorokin et al., 2023: 14) considers a physical hypothesis – the possible electromagnetic effect of a solar flare on the earthquake preparation area. The absorption of solar flare radiation in the ionosphere creates additional ionization in it, which is accompanied by the appearance of an additional electric current in the ionosphere and, consequently, an electric field. In (Sorokin et al., 2023: 14), equations were obtained that make it possible to determine the disturbance of the electric field in the ionosphere–atmosphere system and then calculate the characteristics of the electric field and telluric current for the Earth's surface due to the absorption of solar flare radiation. The results (Sorokin et al., 2023: 14) showed that after an X-class solar flare, the telluric current density in the conducting layer of the lithosphere can reach 10^{-8} – 10^{-6} A/m2, which is 2-3 orders of magnitude higher than the average telluric current density in the lithosphere 2×10^{-10} A/m2 (Lanzerotti et al., 1986). The duration of the telluric current impulse can be 100 s, and the duration of the leading edge of the impulse is 10 s. Indeed, there are works, for example, (Dunson et al., 2011:

11), where it is shown that sometimes, before earthquakes, unipolar impulses with such characteristics can be observed in the parameters of the geomagnetic field. It was also shown in (Sorokin et al., 2023: 14) that electrical conductivity and the geographical orientation of the tectonic fault, where earthquakes mainly occur, play an important role in the electromagnetic triggering of an earthquake. Stronger telluric currents will be generated when the telluric current density vector is directed parallel to the direction of the tectonic fault. Their calculations showed that at the middle and low latitudes of the northern hemisphere, the density vectors of telluric currents are oriented mainly along latitude. In Figure 1, thin brown lines show faults in the earth's crust in the vicinity of the Kapchagay earthquake. We see that their orientation is near latitude, therefore, this region meets the requirements for electromagnetic (solar) triggering of earthquakes. Another important aspect for choosing a fault where electromagnetic generation of earthquakes is potentially possible is its electrical conductivity. Usually, electrical conductivity is determined by the method of magnetotelluric sensing, which, unfortunately, is not available for this area. However, since the Kapchagay earthquake occurred on a fault where an artificial reservoir was created, it can be assumed that due to this reservoir of water, the conductivity of the fault in this place could be increased. Below are the results of the analysis of the Kapchagay earthquake in connection with the state of space weather currently.

Materials and Methods. The proposed article uses data from the regional seismological catalogue (Nurtas, et al., 2024: 231), data from the global seismological catalogue of the US National Geological Survey (USGS), available on the web page (Nurtas, et al., 2023: 26). Data on solar wind parameters and global geomagnetic activity are taken from the OMNI database presented on the NASA website (Altaibek, et al., 2024: 15), where 1-minute values of the geomagnetic SYM/H index are obtained from the Kyoto International Geomagnetic Data Center (Japan) (Chen et al., 2025: 52). Geomagnetic data from the international INTERMAGNET network (Sorokin et al., 2024: 14) and data with per second resolution from the Alma-Ata Geomagnetic Observatory (Kazakhstan), available on the website of the Ionosphere Institute (Altaibek et al., 2025: 16), were also used. The geomagnetic data with per second resolution was previously cleared of false outliers (due to technical interference) by the exclusion method according to criterion 5 σ, and then the gaps in the data were filled by interpolation values using spline interpolation. The continuous series of per second values of the geomagnetic X-, Y-, and Z–components prepared in this way for the period April 29 - May 1, 2011, each with a length of 259200 values, were used to calculate the per second values of the transfer function R=Z/H, where H = √X2 + Y2 is the horizontal component of the geomagnetic fields. To analyze the characteristics of the transfer function, an algorithm of scalogram calculation was used, which is the absolute value of the continuous wavelet transform, constructed as a function of time and frequency. This algorithm is implemented in the package (Wavelet Time-Frequency Analyzer, MatLab) (Mallat, 2009).

Results. At 106 km from the epicenter of the Kapchagay M5.1 earthquake that occurred on May 1, 2011, with the coordinates of the epicenter (43.58°N 77.7°E), the Alma-Ata Geomagnetic Observatory is located on the territory with coordinates (43.10°N, 76.57°E). The type of equipment used in the observatory: LEMI-008 ferrosonde magnetometer, LEMI-203 portable single-component magnetometer, Processor Overhauser Sensor (POS-1). Geomagnetic measurements at the observatory are carried out in accordance with the Instructions and the INTERMAGNET standard. Variational measurements of XYZ components are performed with a frequency of 1 s, measurements of the full geomagnetic field vector F are performed with a frequency of 5 s, minute files of XYZF values are formed from data of per second resolution, available on the website (Altaibek, et al., 2025: 16). Figure 2 shows, for example, variations of the full geomagnetic field vector for the period from April 29 to May 1, 2011. The black line marks the date of the earthquake on May 1 at 02:31:29 UT.

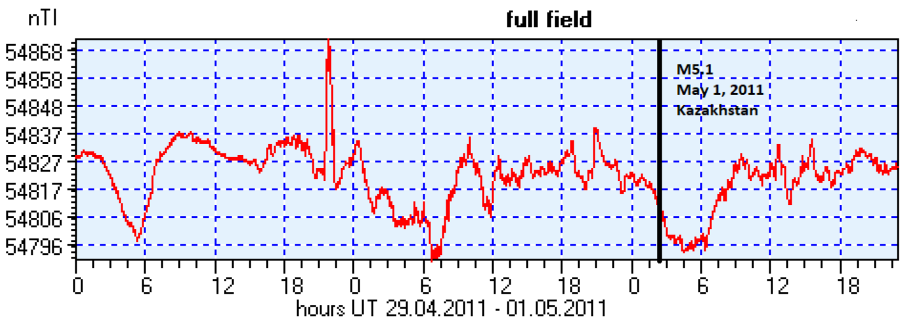

Figure 2 - Per minute values of the full geomagnetic field vector according to the Alma-Ata Geomag- netic Observatory for the period from April 29 to May 1, 2011 (Altaibek, et al., 2025: 16); the black line marks the date of the Kapchagay M5.1 earthquake that occurred at 106 km from the observatory.

As can be seen from Figure 2, a positive impulse was observed in the values of the geomagnetic field on April 29, 2011. Namely, at 21:27 UT, the values of the total field vector were F=54820.5 nT, at 21:50 UT they reached the value of F=54872.5 nT, increasing by 52 nT in 23 minutes, and then at 22:30 UT they returned to the value of F=54816.5 nT, decreasing to 56 nT in 40 minutes. That is, the impulse amplitude in the full geomagnetic field vector was 54 nT, and the duration was 63 minutes. Analysis of variations in the components of the geomagnetic field showed that the observed positive impulse manifested itself most vividly in the northern X component and had an amplitude of 82 nT. The time interval between the peak of the positive impulse in the geomagnetic field on April 29 at 21:50 UT and the earthquake on May 1 at 02:31:29 UT was 28 hours and 40 minutes.

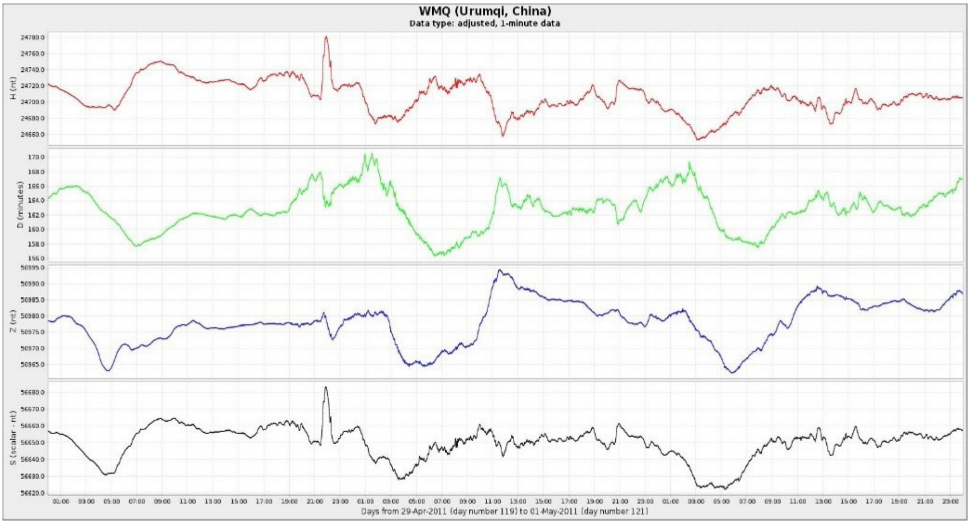

Figure 3 - (from top to bottom): Per minute values of the horizontal component of the geomagnetic field, geomagnetic declination, vertical component, and the total vector of the geomagnetic field according to the Urumqi Geomagnetic Observatory (China) for the period from April 29 to May 1, 2011 (Sorokin, et al., 2024: 14).

To find out whether the nature of the impulse in the geomagnetic field registered at the Almaty observatory was local or global, records of the nearby geomagnetic observatories Urumqi, China (43.8 N 87.7 E) and Arti, Russia (59.4 N 58.6 E), presented on the INTERMAGNET website, were analyzed. A similar impulse was detected at both stations, Figure 3 shows, for example, data from the Urumqi Geomagnetic Observatory (China).

Comparing Figures 2 and 3, it can be concluded that the positive impulse in the geomagnetic field vector registered by the Alma-Ata Geomagnetic Observatory on the eve of the Kapchagay earthquake was not local. A similar impulse was registered at the Urumqi magnetic observatory (Figure 3) and Arti (not shown), which may indicate about a global source of its generation. As shown below, its cause was the arrival of a high temperature dense stream of solar wind (protons) into the Earth's orbit, which caused an impulse pressure on the magnetopause and, consequently, an impulse in the parameters of the geomagnetic field. Figure 4 shows the 1-minute values of the vertical component of the interplanetary magnetic field in the geocentric solar magnetospheric coordinate system (GSM), the velocity, density and temperature of the solar wind flow, the dynamic pressure of the solar wind on the daytime magnetopause, and the geomagnetic SYM/H index for the period from April 29 to May 1, 2011. The data is obtained from the OMNI database presented on the NASA website (Altaibek et al., 2024: 15). Table 1 shows the observation time of the extreme value (high-lighted in bold) in each of the six parameters shown in Figure 4.

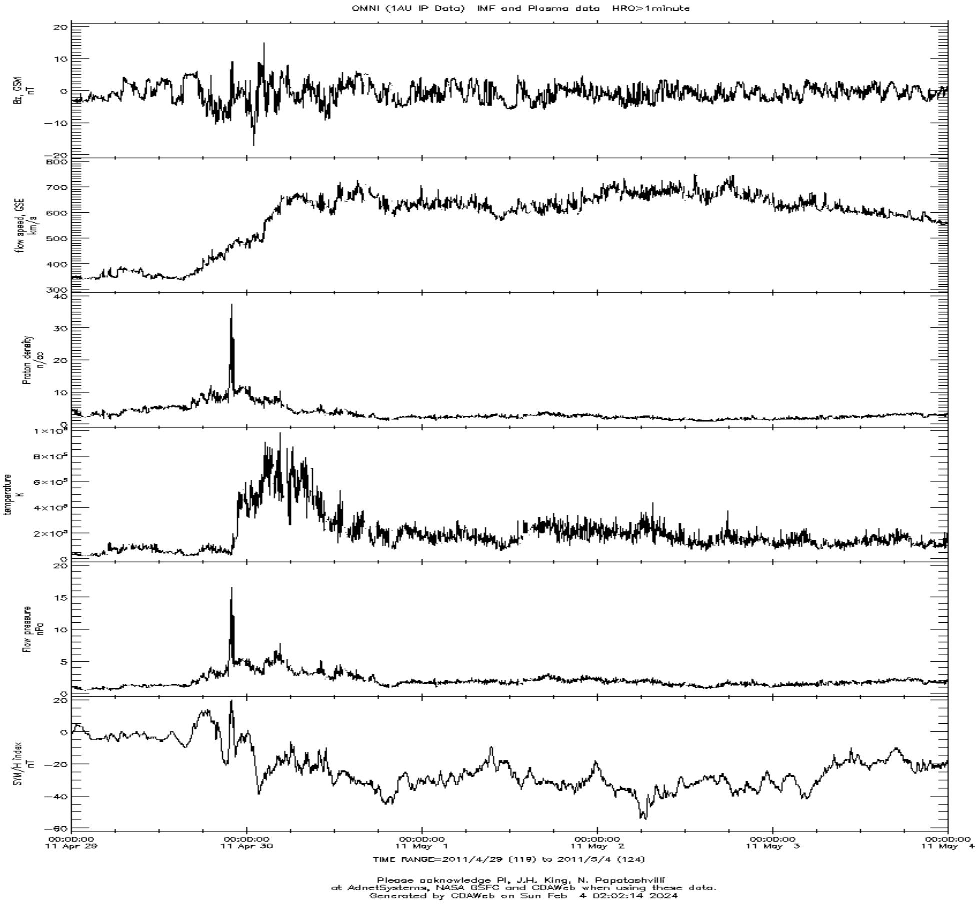

Figure 4 - ((from top to bottom) – 1-minute values of the vertical component of the interplanetary magnetic field in the geocentric solar magnetospheric coordinate system (GSM), velocity, density and temperature of the solar wind flow, dynamic pressure of the solar wind at the daytime magnetopause, and geomagnetic SYM/H index for the period from April 29 to May 4, 2011 from OMNI databases (Altaibek, et al., 2024: 15).

Table 1. Extreme values (highlighted in bold) in the parameters of the solar wind (vertical component of the interplanetary magnetic field in the GSM coordinate system, velocity, density, temperature, dynamic pressure of the solar wind flow to the magnetopause), and the geomagnetic SYM/H index observed in the period April 29 - May 1, 2011.

Date	**Time UT**	**BZ_GSM (nT)**	**Speed (km/s)**	**Density ($1/cm^3$)**	**Temperature (K)**	**Pressure (nPa)**	**SYM/H (nT)**
29 April	21:54	7.71	469.0	37.44	48934.0	16.47	17
29 April	21:58	6.63	462.5	21.02	75023.0	8.99	20
30 April	00:57	-17.25	513.5	7.39	445795.0	3.9	-10
30 April	02:54	1.49	571.2	8.05	872653.0	5.25	-23
30 April	15:12	4.85	725.3	2.24	271422.0	2.36	-31
2 May	06:34	-2.21	661.0	2.48	263121.0	2.17	-55 [1]

The data presented in Figure 4 and Table 1 show that on April 29, 2011, at 21:58 UT, there was a sharp positive jump in the values of the geomagnetic SYM/H index, which reached a value of +20 nT (bottom panel in Figure 4). The reason for this was a dense solar wind stream that abruptly approached the Earth's orbit at 21:54 UT with a density of 37.44 1/cm3 (the third panel from above in Figure 4), which caused a sharp jump in the dynamic pressure of the solar wind on the daytime magnetopause to a value of 16.47 nPa (the second panel from below in Figure 4). The temperature of the solar wind flow reached a maximum value of 8726530K on April 30 at 02:54 UT (the third panel from below in Figure 4). The speed of the solar wind also began to increase and on April 30 at 15:12 UT reached 725.3 km/s, doubling relative to the initial value of 350 km/s (the second panel from above Figure 4). The vertical component of the interplanetary magnetic field in the geocentric solar magnetospheric coordinate system (GSM) began to change its sign from positive to negative, in which the lines of the geomagnetic field are effectively reconnected with the lines of the magnetic field of the solar wind (interplanetary magnetic field) with concomitant penetration of solar wind energy into near-Earth space. The value of BZ_GSM (upper panel of Figure 4) reached a maximum negative value of -17.25 nT on April 30 at 00:57 UT, when the main phase of the geomagnetic storm began to develop. The maximum negative value of SYM/H=-55 nT was observed on May 2 at 06:34 UT (a small geomagnetic storm according to the classification (Altaibek et al., 2024: 15)).

Figure 5 shows a scalogram of the transfer function R=H/Z for April 29 - May 1, 2011, obtained from 1-second data from the Alma-Ata Geomagnetic Observatory. In this figure, the horizontal axis shows the time from 00 UT on March 29, 2011, to 24 UT on May 1, 2011, the numbers at the bottom of the axis mark the consecutive hours from 00 UT on March 29, 2011. The vertical axis indicates the oscillation frequency in the range 0.01-0.1 Hz. The amplitude of the oscillations is shown in color (red corresponds to the largest amplitudes of Kapchagay). The arrow at the bottom of the picture marks the date of the earthquake. Figure 5 shows that the amplitude of oscillations at almost all frequencies increased about a day before the earthquake, while fluctuations was characterized by the greatest amplitude in the range of 0.01 – 0.03 Hz, which corresponds to periods of 100 - 30 s. This result coincides quite closely with the predictions of the mathematical model (Sorokin et al., 2023: 14), where it is shown that the activation of space weather can generate a telluric current impulse in a seismically active region lasting 100 s.

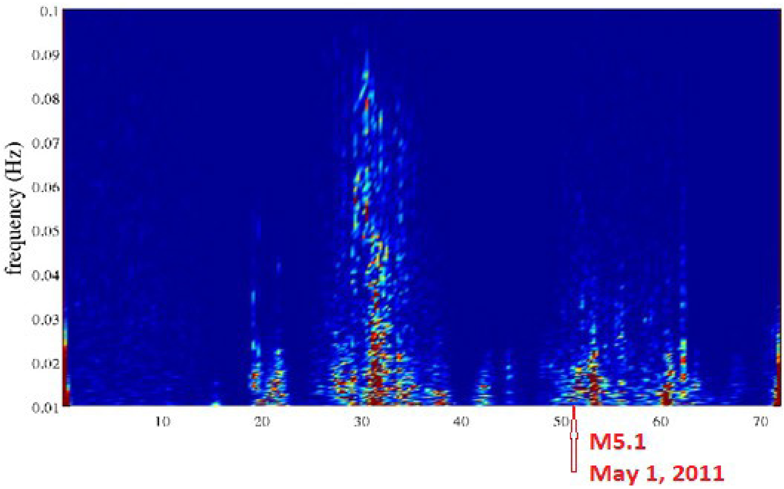

Figure 5 - Scalogram of the transfer function R=H/Z for April 29 - May 1, 2011 in the frequency range 0.01-0.1 Hz according to the Alma-Ata Geomagnetic Observatory, the arrow indicates the date of the Kapchagay earthquake.

Discussion. Before the Kapchagay M5.1 earthquake on May 1, 2011, the Alma-Ata Geomagnetic Observatory, located 106 km from the epicenter, registered a positive spike in the parameters of the geomagnetic field. A similar spike was recorded at other geomagnetic observatories. An analysis of the solar wind parameters according to the OMNI database showed that this surge had an external cause - it was caused by the pulsed arrival of a solar wind stream with high density and high temperature to the Earth's orbit, which led to the development of a small geomagnetic storm (SYM/H= -55 nT).

The mathematical model (Sorokin, et al., 2023: 14) predicts that solar flares, the most striking manifestation of which on Earth are geomagnetic storms, can cause an increase in telluric currents in tectonic faults of the Earth's crust. This model is based on field and laboratory experiments demonstrating the possibility of an earthquake due to the introduction of an electric current into a tectonic fault (Zeignarnik et al., 2022: 58). The key parameter in the model (Sorokin, et al., 2023: 14) is the electrical conductivity of the medium, which in the ionosphere is provided by ultraviolet and X-ray radiation from the Sun, the latter manifests itself most effectively during solar flares. The conductivity of the Earth's crust is determined by the material composition of the geological environment, and currently its condition is significantly influenced by manmade human activity, including the creation of artificial reservoirs (Gupta, 1992; Nurtas et al., 2024; Sarsembayeva et al., 2021: 8).

There is a general opinion that the creation of artificial reservoirs can have an impact on seismic activity, but this effect depends on many factors and conditions. At the same time, it is believed that the threat may be only in those regions of the planet where there is an increased level of natural seismic activity. Quite a lot of articles have been published (Klose, 2008; Nurtas et al., 2023), stating that the M7.9

earthquake that occurred on May 12, 2008, in the Chinese province of Sichuan, the victims of which were about 80 thousand people, could have been provoked by the creation of a reservoir near the epicenter (at about 12 km). Possible trigger causes of earthquakes that occurred near the Koina artificial reservoir (India) are also actively discussed (Gupta, 1992).

At the same time, even though the occurrence of induced earthquakes in the areas of artificial reservoirs has already been well documented, there is no complete explanation for this phenomenon yet. Thus, in (Negmatullaev, et al., 2006) it was shown that in the case of simultaneous locking of a large part of the tectonic fault extending along the reservoir, favorable conditions are created for simultaneous movement of the earth's crust along the fault over a large extent, which can cause a strong trigger (excited) earthquake. (Nurtas et al., 2023; Altaibek et al., 2024: 15) As noted above, it has already been suggested that both this earthquake and the increase in seismicity observed in this region after 1971 may be associated with the Kapchagay reservoir.

It is reasonable to assume that locking a part of a tectonic fault in the vicinity of an artificial reservoir can increase its electrical conductivity, and since the model (Sorokin, et al., 2023: 14) predicts that solar flares should activate seismicity in faults with increased conductivity, then the seismically active territory in the area of an artificial reservoir may be one of the first in the list of candidates for the connection of its seismicity with variations of cosmic weather. Therefore, it seems advisable to analyze other earthquakes in the territory of artificial reservoirs for their possible connection with variations in space weather.

One of the strongest earthquakes (M=6.3) associated with the creation of artificial reservoirs occurred on December 10, 1967, south of the Koina reservoir (India) (Gupta, 1992). The authors of these monographs noted that seismic activity was decreasing here, but after filling, located south of the reservoir, also in India, a new surge of seismic activity began. So, on December 8, 1993, at 23:45:07 UT, an earthquake with a magnitude of M =5.1 occurred at a depth of 25 km with epicenter coordinates of 17.074°N 73.634°E. In Figure 6, we have presented, for example, 1-minute values of the geomagnetic SYM/H index for the period December 7-10, 1993, where the red line marks the date of the M5.1 earthquake. This event was accompanied by a strong geomagnetic storm SYM/H= -100 nT, which began with a positive impulse in the geomagnetic field SYM/H= + 6 nT on December 7 at 12:23 UT. The time interval between the positive peak in the SYM/H index on December 7 at 12:23 UT and the earthquake on December 8, 1993, at 23:45:07 UT was 35 hours 22 minutes. As noted above, the time interval for the Kapchagay earthquake was 28 hours and 40 minutes. That is, in principle, the nature of the result in Figure 6 for the M5.1 earthquake near an artificial reservoir in India closely coincides with the nature of the result in Figure 2 for the M5.1 earthquake near an artificial reservoir in Kazakhstan, which can serve as a foundation for further deeper research in this direction.

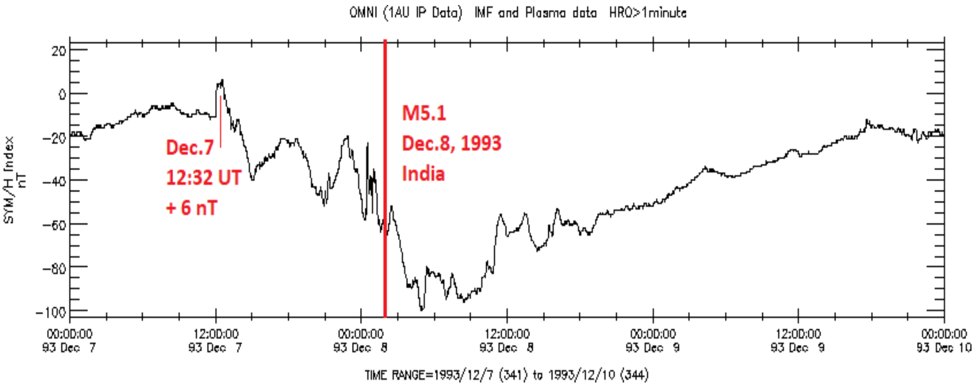

Figure 6. Per minute values of the geomagnetic SYM/H index for the period December 7-10, 1993, according to the OMNI database (Altaibek, et al., 2024: 15); the red line marks the date of the earthquake on December 8, 1993, in the area of an artificial reservoir in India.

Conclusions. The analysis of the earthquake Mw 5.1 in the area of Kapchagai reservoir on May 1, 2011 revealed a temporal and physical relationship between anomalous manifestations of space weather and seismic activity in the study region. It was found that immediately before the earthquake there was a significant geomagnetic pulse caused by the arrival of dense and high-temperature solar wind flow, which, according to modern mathematical model, can initiate an increase in telluric currents in conductive faults in the Earth's crust.

Given the presence of an artificial reservoir that can increase the electrical conductivity of tectonic faults, the results support the hypothesis of a potential electromagnetic earthquake trigger. In addition, analogies with other cases (e.g., the 1993 India earthquake) confirm the recurrence of the observed mechanism.

Thus, the conclusions emphasize the need for further research on the integrated analysis of the influence of space weather and anthropogenic factors on seismic activity, which is especially relevant for areas near large hydraulic structures. Only the accumulation and systematization of data on similar events will allow a more reliable assessment of risks and increase the effectiveness of measures to predict and reduce damage from possible earthquakes.

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