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FIRST ATMOSPHERIC ELECTROSTATIC MONITORING NETWORK IN SICHUAN

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Atmospheric electric field anomalies during the pre-earthquake period have garnered significant interest among researchers. First atmospheric electrostatic monitoring network in Sichuan have been established in 2021 that include 30 stations whose inter-distance is about 30 km each other and a new method to estimate earthquake magnitude has been proposed. Notably On September 5th, 2022, a significant earthquake with a magnitude of Ms=6.8 struck Luding, Sichuan, China (102.08°E, 29.59°N). This study focuses on the atmospheric electric field data collected from three stations — Garze, Guzan, and Swallow-Gully — strategically located in the Xianshui River Active Fracture Zone, proximate to the Luding epicenter. The research involves a meticulous exclusion analysis of the impact of meteorological and space weather conditions on atmospheric electric field. Each of the three stations recorded potential negative anomalous precursor signals of the atmospheric electric field approximately 30 hours prior to the earthquake. Correlation and time delays of their anomaly segments are also analyzed in the paper, and the distribution of earthquake magnitude with respect to the variation in epicenter locations has been estimated based on the positions of the anomalous stations. The spatial distribution of these stations, spanning approximately 390 km along the Xianshui River Active Fracture Zone, provided a unique opportunity to utilize these signals for estimating the magnitude of the impending earthquake, suggesting the likelihood of a strong earthquake. Two alarms have been send respectively for warning middle magnitude imminent earthquakes in the first atmospheric network observation system all over the world.

INFLUENCE OF SEISMIC AND SOLAR ACTIVITY ON THE ELECTRIC FIELD OF FAIR WEATHER

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In fair weather conditions, the daily variation of the electric field potential gradient (PG) of the atmospheric surface layer has a morning maximum. The experiment confirmed that this maximum is due to the operation of the morning convective generator.

On the eve of earthquakes, negative anomalies are observed in PG variations. Statistical analysis of the appearance of negative anomalies before earthquakes in fair weather conditions was made.

A seismic event was considered to be a situation when in the time interval 24 hours after the anomaly, one or several EQs of Ms > 4.7 occurred with epicenters in the area with the coordinates $(45\text{-}55)^0$ N, $(155\text{-}165)^0$ E, including PG registration point. For the period from January 1, 1997 to December 31, 2002 (i.e. for 2189 days), 103 cases of anomalous behavior of the PG component were detected. In 37 (36%) cases, earthquakes occurred after the anomaly in 24 hours. The mechanism of occurrence of negative field variations has the following explanation. Under the influence of radiation, friction and absorption of ions to atmospheric aerosols at the Earth's surface, particles gain an electric charge. Due to the different mobility of ions of different polarity, an uncompensated charge is formed at the surface under the influence of an external electric field. Under the influence of the Earth's electric field, positive ions move toward the Earth's surface, and negative ions move upward. Thus, a ground "electrode layer" is formed with a local field, which compensates for the main field of the Ionosphere-Earth capacitor.

On the days of earthquakes and 3 days earlier, an increase in the amplitude in the PG power spectra is observed in fair weather conditions in the range of atmospheric gravity waves periods (0.5 - 4 hours). This may be an important factor in the transfer of energy from the lithosphere to the ionosphere.

During magnetic storms, large oscillations of the electric field caused by large ionospheric currents are observed. A few hours before the onset of a magnetic storm, a decrease in the level of air conductivity is observed. This may be the manifestation of the Forbush effect. A few hours after the beginning of a magnetic storm, an increase in the level of the unipolarity coefficient is observed ($\lambda+/\lambda-$).

During solar flares, periods of ~48 hours are observed in the flow of solar cosmic rays. These rays reflect the flow of galactic cosmic rays and modulate waves with the same period. Galactic cosmic rays have great penetrating power. They ionize the ground air. Accordingly, they transmit oscillations with the same period of air electrical conductivity. Moreover, the air electrical conductivity affects the PG. This is the mechanism of generation of planetary-scale waves in electric fields.

GEOMAGNETIC MONITORING NETWORK IN CHINA MERIDIAN PROJECT

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Space weather directly affects the safety of spacecraft, communication and navigation, as well as power transmission cable and oil pipelines. Space environmental monitoring is not only the need to protect human security, but also the focus of scientific research. The Chinese Meridian Project is currently the largest space environment monitoring project with the most monitoring elements in the world.

As part of the Chinese Meridian Project, the geomagnetic monitoring network composed of 34 observations and nearly 113 pieces of monitoring equipment arranged in a "井"(well) pattern along 100°E, 120°E, 40°N, and 30°N. The instrument includes Flux-Gate Magnetometer, Overhauser Magnetometer, Automatic Magnetic Fluxgate, Search Coil Magnetometer, Wideband Magnetic Field Wave Monitor, Low Frequency Magnetic Field Wave Receiver, Geoelectric Field Monitor, Atmospheric Electric Field Monitor and so on. It can obtain direct current geomagnetic field (DC) and alternating magnetic field (AC) signal with very wide frequency band and very high observation accuracy.

After the completion of the Chinese Meridian Project, by treating the geospace, the atmosphere, as well as the cycles and spheres of the Earth surface as an integral system, it will conduct comprehensive global observations of multiple parameters to systematically study the kinetic properties of matter in the Earth system driven by solar activities and terrestrial activities, so as to reveal the relationship of space weather and global changes, and provide scientific grounding for tackling Earth disasters and informing space security decisions. The major scientific issue studied in this program is global in nature, which demands in-depth and large-scale international cooperation in terms of scientific study and joint solutions.

MAGNETIC OBSERVATORIES OF IKIR FEB RAS AS THE FAR EAST SEGMENT OF THE RUSSIAN NETWORK OF MONITORING OF THE EARTH'S MAGNETIC FIELD: TASKS, STATE AND PROSPECTS

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Magnetic observatories are an important element of the system of experimental studies of the Earth's magnetic field. Integration them into networks operating according to common standards, for example, INTERMAGNET, significantly increases the efficiency of measurements. The magnetic observatories "Magadan", "Paratunka", "Khabarovsk" and "Cape Schmidt" of IKIR FEB RAS are integrated into a network that provides rapid data exchange, processing of measurement results, using uniform methods and using unified software developed at IKIR FEB RAS, and availability. This makes it possible to set and solve various scientific and applied tasks that take into account and focus on the unique features of the region. The article considers the equipment of observatories with magnetometers and supplied equipment, the existing infrastructure, opportunities and prospects for scientific cooperation.

GEOACOUSTIC EMISSION AS A TOOL FOR DIAGNOSTICS OF NATURAL ENVIRONMENTS

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The work of the Laboratory of Acoustic Research considers the urgent problem of interaction of geophysical fields during the impact of the lithosphere on the atmosphere. This impact is determined by the dynamics of lithospheric processes. It intensively occurs at the boundary of these geospheres. The lithosphere-atmospheric impact is the most pronounced in seismically active regions at the final stage of earthquake preparation, when rock deformation increases. The resulting radiation of elastic waves, called geoacoustic emission, can be considered as an indicator of activation of rock deformation. The report presents the main fields of the laboratory's work.

The observation technique, geoacoustic emission signal recording systems and their installation points are presented. Data processing and analysis methods are proposed.

The recorded geoacoustic emission signal is pulsed. A scheme with an adaptive threshold is used to extract a pulse flow from the geoacoustic signal. The direction to the source of geoacoustic emission pulses is analyzed. Methods of structural-linguistic processing and matching pursuit are used to identify and further analyze the pulses.

To confirm the deformation nature of geoacoustic emission anomalies, measurements of deformation of near-surface rocks are carried out at the Karymshina observation point. Mathematical modeling of geoacoustic emission zones is also carried out.

To study various properties of rocks during deformation of their samples, experiments are realized in laboratory conditions.

To identify hidden patterns in the dynamics of various parameters of the studied geophysical fields under seismic activity, neural networks are used in the laboratory.

USING A SPATIAL ANALYSIS METHOD TO STUDY THE SEISMO-IONOSPHERIC DISTURBANCES OF ELECTRON DENSITY OBSERVED BY CHINA SEISMO-ELECTROMAGNETIC SATELLITE

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Due to the complex processes of earthquake preparation, the observations and studies associated with earthquakes have attracted the attention of geophysicists for many years. The CSES was successfully launched on 2 February 2018. This satellite can provide global data of the electromagnetic field, plasma, and energetic particles in the ionosphere to monitor and study the ionospheric perturbations associated with earthquakes. Focusing on the characteristics of CSES, a spatial analysis method was proposed to extract the disturbances of electron density prior to earthquakes. Taking Indonesia Mw6.9 earthquake that occurred on 5 August 2018 as an example, the spatial method was illustrated and verified by another analysis method also using the data of electron density and GPS TEC data with the same analysis method. Based on the electron density of CSES for more than 2 years, this method was applied to carry out the statistical study prior to $M_w \geq 6.0$ global earthquakes using the superposed epoch and space approach (SESA) method. It was found that 1) relative to the epicenters, seismo-ionospheric disturbances are more obvious in the equator direction than those in the polar direction; 2) the anomalies within 300 km distance from the epicenter are significant 11, 3, and 2 days prior to $M_w \geq 6.0$ earthquakes; 3) the influence region of perturbances associated with earthquakes enlarges with the magnitude increase, and the stronger magnitude is the earlier disturbance appears. These statistical characteristics were not detected for the random earthquakes. Comparing the statistical result with the simulation output, the electric field pathway could be considered as the main channel of lithosphere–atmosphere–ionosphere coupling.

ESTIMATION OF THE PROGNOSTIC EFFICIENCY OF IONOSPHERIC ANOMALIES PRECEDING EARTHQUAKES IN KAMCHATKA REGION

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The study of the possibility of predicting earthquakes is an urgent and important scientific task. One of the approaches to its solution is the search for earthquake precursors in the atmosphere and ionosphere, which can be useful for short-term (hours-days) forecasts of powerful earthquakes. The report presents two methods used to monitor the parameters of the ionospheric *E* and *F* regions to identify periods of increasing seismic activity in Kamchatka region and the results of retrospective estimation of their predictive efficiency. The estimation of the predictive efficiency was carried out for the earthquakes with the magnitude ranges $M \geq 5.0$, $M \geq 5.5$, $M \geq 6.0$ and hypocenter depths up to 100 km.

The first prognostic method is based on the analysis of hourly values of five ionospheric parameters *h'Es*, *foEs*, *fbEs*, *foF2, hmF2* obtained during vertical radio sounding of the ionosphere for the time interval 2016–2023 at the ionospheric station located in Paratunka (φ=52,97°N, λ=158,24°E). Exceedance the values of a given combination of these parameters above the upper limit of the range of background values during a daily interval under conditions of low geomagnetic activity was considered as a possible ionospheric precursor of earthquakes. The greatest forecast efficiency was obtained when forecasted earthquakes had the magnitude of $M \geq 5.5$ and epicentral distances of up to 400 km. The forecast efficiency according to the method of A.A. Gusev was J_G =1.57, the Hansen-Kuiper score was R_{score} =0.18, while the relative number of predicted earthquakes was 45%, and the relative number of anomalies followed by earthquakes was 30%.

In the second prognostic method, a joint analysis of the following ionospheric anomalies recorded over the time interval 2013–2023 was carried out: precipitation of charged particles from the radiation belts into the ionosphere (formation of the *K*-layer), formation of a sporadic *Es* layer of type *r*, excess of the critical frequency *foF2* values over the median values during a magnetic storm, branching of the trace on ionogram near the critical frequency *foF2*. Registration of at least three out of four ionospheric anomalies in a sliding time window of five days with a step of one day was considered as a possible ionospheric precursor of earthquakes. The forecast efficiency according to the method of A. A. Gusev is greater than one for all considered ranges of earthquake magnitudes with epicentral distances up to 500 km. The forecast points are near or below the boundary of 99% confidence interval boundary in the error diagrams. The highest relative number of predicted earthquakes was obtained for the magnitude range $M \geq 6.0$ and was equal to 78%. The highest relative number of anomalies followed by earthquakes was obtained for the magnitude range $M \geq 5.0$ and was equal to 50%.

The obtained efficiency estimations allow us to conclude that the forecast using these prognostic methods differs from random guessing and indicates the presence of the relation between the ionospheric anomalies under consideration and the earthquakes that have occurred. Application these prognostic methods based on the analysis of ionospheric anomalies will be useful for identifying periods of increasing seismic activity in Kamchatka region.

EARTHQUAKE PREDICTION UTILIZING THE LITHOSPHERE-ATMOSPHERE-IONOSPHERE COUPLING OF THE DOUBLE RESONANCE MODEL

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A novel instrumental array was established near the county of Leshan in Sichuan, China. The array is comprised of 15 distinct instruments and routinely monitors changes in more than 20 different geophysical parameters from the subsurface to the ionosphere. Before the occurrence of the 2021 M6 Luxian earthquake, anomalous phenomena were found in data retrieved from seismometers, barometers, a magnetometer, and ground-based GNSS receivers. The ground vibrations from seismometers, air pressure from barometers, the geomagnetic field from magnetometers, and TEC from the ground-based GNSS receivers share frequencies, suggesting that changes in multiple parameters are dominated by the same source. The shared frequency of ~0.005 Hz is related to the resonance of the volume of atmospheric air from the Earth's surface to an altitude of ~500 km. Note that earthquake occurrences are a failure of strata. Resonance with natural frequencies can often be found in materials approaching failure. The resonance before the failure of the strata generally covers a wide area and persists for a few months. The large-scale and persistent resonance of the strata in the lithosphere triggers resonance in the atmosphere, referred to as “double resonance” before an earthquake. We collected seismic, magnetic, and TEC data in China to study the spatial distribution of resonant signals before earthquakes. A great circle with a radius of several hundred kilometers was obtained from the observed distinct parameters. The center of the circle is located very close to the epicenter of the forthcoming earthquake. We further collected data for predicting earthquakes in advance and achieved good results.

LIDAR IONOSONDE: DEVELOPMENT AND APPLICATIONS

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The idea of lidar observations in the thermosphere arose back at the end of the last century, but their implementation began in recent years. In the paper [Geomagn. Aerono. 2004], the appearance of light-scattering layers in the stratosphere during strong magnetic storms over Tomsk was shown. In order to study this optical phenomenon more in detail, it was decided to create a chain of lidar stations at Tomsk, Irkutsk, Yakutsk and Kamchatka. In Kamchatka, a lidar station was created in 2006.

At first, it was an incoherent scattering lidar at a wavelength of 532 nm, which was used to study aerosol in the stratosphere. In the paper [Geomagn. Aeron. 2009], it was shown that in the D layer of the ionosphere, the lidar signal deviates from Rayleigh scattering.

Analysis of lidar data obtained from 2008 to 2014 showed that scattering of the lidar signal in the ionosphere is caused by resonant scattering of photons on atomic transitions 532 nm of nitrogen atomic ions N^+ [EPS 2014].

To verify this result, a second channel of lidar observations of resonant scattering on atomic transitions 561 nm of atomic oxygen ions O^+ was created during the following years [Proc. SPIE 2018]. As a result of the work in 2008-2017, a two-channel thermospheric lidar ionosonde O^+ 561 nm and N^+ 532 nm was realized.

The resonant lidar provides more detailed information about the state of the thermosphere than the radio ionosonde. Resonant scattering on atomic transitions 532 nm of N^+ realizes the simplest and the most effective scheme of a thermospheric lidar.

Development of the lidar systems opens up new possibilities for studying the impact of solar activity on the atmosphere.

Their application will allow us to understand many optical phenomena in the atmosphere, climate changes and the evolution of living systems.

MULTI-SATELLITE DETECTION OF LONG-RANGE TRANSPORT AND TRANSFORMATION OF ATMOSPHERIC EMISSIONS FROM THE HUNGA TONGA-HUNGA HA'APAI VOLCANO

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Large volumes of atmospheric pollutants injected into the troposphere and stratosphere from volcanic eruptions can exert significant influence on global climate. Through utilizing multisatellite observations, we present a large-scale insight into the long-range transport and transformation of sulfur dioxide (SO_2) emissions from the Hunga Tonga-Hunga Ha'apai eruption on 15 January 2022. We found that the transport of volcanic emissions, along with the transformation from SO_2 to sulfate aerosols, lasted for two months after the Tongan eruption. The emitted volume of SO_2 from the volcano eruption was approximately 183 kilotons (kt). Both satellite observation and numerical simulation results show that the SO_2 and volcanic ash plumes moved westward at a rate of one thousand kilometers per day across the Pacific and Atlantic Ocean regions and that SO_2 transformation in the atmosphere lasted for half a month. The transport and enhancement of aerosols is related to the conversion of SO_2 to sulfate. CALIPSO lidar observations show that SO_2 reached an altitude of 25–30 km and transformed into sulfate in the stratosphere after 29 January. Sulfate aerosols in the stratosphere deceased gradually with transport and fell back to the background level after two months. Our study shows that satellite observations give a good characterization of volcanic emissions, transport, and SO_2-sulfate conversion, which can provide an essential constraint for climate modeling.

SIMULATION OF GEOSPHERIC PROCESSES

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Fractional Model of the Deformation Process

Seismic events are the markers of the crustal deformation process. Correlations between events lead to the appearance of the properties of hereditarity (memory) and spatial non-locality. Our description of the deformation process is based on the fractional Poisson process. The critical level of elastic stresses is sustained by the work of external forces. The result of their actions is a deformation process with a change of the deformation modes:

1. the background mode (background or normal pulsations);
2. the decaying mode (deceleration pulsations);
3. the activation mode in the phase of foreshocks;
4. the activation mode in the phase of the mainshock;
5. the relaxation mode in the phase of aftershocks.

This process is characterized by the rate of random changes of dislocations, which are determined by the spatial scale and the value of the displacement vector. This approach describes discontinuities, movements along existing faults, and repackaging of grains or blocks in a wide range of scales using the theory of dislocation changes.

Simulation of dynamo-systems

A technology for constructing low-mode spectral models of dynamo systems based on the use of computer algebra methods has been developed. A geodynamo model driven by 6-cell convection in the Earth's core has been constructed. Such a structure of large-scale convection in the model is taken from the data of splitting functions of free oscillations of the Earth. A two-mode hereditar model of the alpha-omega dynamo has also been developed. The fractal properties of geomagnetic polarity time scale (GMPTS) are reproduced in this model.

Simulation of radon mass transfer

A model of radon mass transfer in the "ground-atmosphere" system has been developed, including diffusion, advection and convection mechanisms. For the initial boundary value problem, an analytical solution is obtained using the Laplace transform with respect to the spatial variable. The model was generalized to the case of a fractal structure of pores in the ground. This required a transition to the description of the process by fractional differential equations. The main results of the modeling are:

1. it is shown that radon transfer in the model can be carried out in anomalous diffusion regimes (both subdiffusion and superdiffusion);

2. it is shown that the superdiffusion regime is consistent with the experimental data;

3. the features of the change in the regimes of abnormal diffusion and advection depending on the fractal properties of the porous ground are investigated.

INTRODUCTION AND APPLICATION OF VLF/LF LIGHTNING DETECTION NETWORK IN CHINA

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China Academy of Sciences has more than 40 years of research foundation in lightning detection, and has established a lightning detection network covering China and neighboring countries. At present, it has developed to the third generation detection network, and lightning data and lightning early warning and forecasting products are widely used in meteorology, civil aviation, petroleum and petrochemical, forest fire prevention, electric power and other industries in China and neighboring countries. The latest generation of lightning detection network based on full waveform developed by Institute of Electrical Engineering, Chinese Academy of Sciences includes a three-dimensional lightning detection network with a baseline distance of 100km (Detecting cloud-to-ground lightning, cloud-to-lightning and atmospheric discharge in the middle and upper layers, positioning accuracy is less than 300 meters, CG lightning detection efficiency is greater than 99%, and IC lightning detection efficiency is greater than 80%), a long baseline lightning detection network with a baseline distance of 1,000 km (Positioning accuracy is less than 5 km, and CG lightning detection efficiency is greater than 17%). Full-wave of lightning discharge waveforms and other VLF signal in nature is completely detected, based on the physical characteristics of the radiation source are mastered through high-precision lightning location network, combined with the original waveform data reflected and propagated through different paths, it can be applied to the research of ionosphere, middle and upper atmospheric discharge and so on. At the same time, it can be networked with neighboring countries to realize data sharing, and can carry out multinational cooperation in civil aviation safety flight support, lightning strikes and fires.

SIGNS OF GEOMAGNETIC-INDUCED CURRENTS IN THE ELECTRICAL NETWORKS OF KAMCHATKA DURING A MAGNETIC STORM ON MAY 10-11, 2024

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Strong geomagnetic field variations cause *geomagnetically induced currents (GIC)* in power lines. GIC magnetizates transformers cores. That leads to 1) voltage drops, 2) overheating of power transformers, 3) variation of reactive power in high-voltage power lines, 4) even harmonics generation, 5) fail automation triggering. We use the 4th property to register GIC in the 220 kV power line at Kamchatka (Mutnovskaya geothermal electric plant – Avacha electrical substation). Electromagnetic radiation of the power line is recorded at Karymshina station. The harmonics levels are calculated by the means of spectra analysis. During data processing for extremal geomagnetical storm (10-11 May 2024), the harmonic level variations with a period of about 20 seconds were detected. We suggest that the reason of this variation is the Pc 3 pulsation effect.

The recordings revealed sharp changes in the harmonic level, most likely due to the change in the mode of the Mutnovskaya geothermal power plant generator. The number of such changes increases during a magnetic storm, which may indicate the possibility of destructive manifestations of GIC due to false triggering of automation.

GIC simulation for 220 kV power line have been carried out. The initial data for the simulation are the Paratunka magnetic observatory 1 second data of the geomagnetic variations: eastern $B_x(t)$, northern $B_y(t)$ geomagnetical field components. The calculation shows that GIC in 220 kV power line exceeds 2 A value during strong geomagnetic storm on 10-11 May, 2024.

Core magnetization coefficient *CMC* is the ratio of GIC magnetic field strength H to no-load current one in transformer core H_x. It is proportional to the asymmetry coefficient *KA* and the ratio of GIC I_0 to no-load current I_x for W-shaped transformers. It is shown that CMC does not exceed the value of 0.15 during the strong geomagnetic storm on 10-11 May, 2024. Thus, the GIC effect for the 220 kV power line was noticeable but not fatal.

ORBIT OVERVIEW OF EARTHQUAKE MONITORING SATELLITE

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At present, the main method for monitoring earthquakes is ground station observation. However, there are many blank areas in ground-based observatories due to geographical and political factors. Earth observation satellites in space have advantages such as all-weather and all-time coverage, which can achieve global coverage, real-time monitoring of earthquake activity, and obtain high-precision data. Therefore, using satellites to monitor earthquakes and establishing a space-based platform as part of the earthquake three-dimensional observation system to obtain precursory information is a necessary method for achieving short-term earthquake forecasting.

Electromagnetic change monitoring has become popular of earthquake prediction. The former Soviet Union was the first country in the world to use satellites to monitor electromagnetic anomalies. In the early 1990s, Soviet scientists proposed the idea of establishing a global monitoring satellite system for earthquake precursors. Subsequently, the United States, France, Ukraine, and the European Space Agency also launched seismic monitoring satellites. Satellite Zhangheng1 is an electromagnetic monitoring test satellite independently developed by China. Since its launch on February 2, 2018, it has successfully completed 5 years of in orbit design tasks and achieved a lot of research results.

In the past, seismic satellites usually adopted sun synchronous low Earth orbits. A single satellite platform has low ground coverage and can only obtain limited earthquake precursor information, which affects the timeliness of earthquake prediction. The future development trend of earthquake satellites is establishing a satellites constellation with uninterrupted full coverage to the ground, including various types of satellites (such as monitoring electromagnetic, gravity and thermal infrared radiation, etc.), and adopting multi-national earthquake monitoring cooperation.

SYSTEMATIC ANALYSIS OF GEOPHYSICAL PARAMETERS IN SPACE WEATHER PROBLEMS AND ITS RESULTS IN THE INTERACTIVE AURORA SYSTEM

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Development of methods and specialized software tools for the analysis of geophysical monitoring data aimed at the study of the processes in the magnetosphere-ionosphere system and identification of space weather manifestations is carried out at the System Analysis Laboratory of IKIR FEB RAS. An integrated approach to data analysis includes:

- Modeling and analysis of the time course of ionospheric parameters, studying its spatial and temporal features;
- Modeling of cosmic ray regularity and investigation of its dynamic features during periods of increased solar activity, as well as during interactions between the magnetosphere and the interplanetary medium;
- Investigation of the temporal variations of the geomagnetic field and detection of anomalous changes during disturbances and magnetic storms.
- Creation of technologies and specialized software tools for the implementation of the developed methods.

The methods developed by the scientific team are implemented in the complex interactive system "Aurora" (lsaoperanalysis.ikir.ru:9180/lsaoperanalysis.html), which analyses geophysical monitoring data and assesses the state of space weather in the Northeast region of Russia (regional forecast). Using data on geomagnetic field variations, parameters of the critical frequency of the ionosphere foF2 and data on cosmic ray variations in the "Aurora" system, the magnetospheric and ionospheric activities are monitored on-line and the state of variations of galactic cosmic ray fluxes is assessed. The system analyses magnetic and ionospheric data from the IKIR observatories of the Far Eastern Branch of the Russian Academy of Sciences and data from ground-based neutron monitoring stations (www.nmdb.eu). The parameters of the interplanetary medium (omniweb.gsfc.nasa.gov/form/dx1.html) and the magnetosphere (wdc.kugi.kyoto-u.ac.jp) are used in the analyses. The system was implemented in 2018, and the accumulation of observational material and data processing results is underway.

RESULTS OF VLF OBSERVATIONS IN KAMCHATKA

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To study the powerful electromagnetic radiation of thunderstorms, the Institute of Cosmophysical Research and Radio Wave Propagation has created a VLF direction finder capable of recording signals of the electric and magnetic components of the electromagnetic field and determining the direction of arrival of the radiation in real time. To determine the azimuth of the electromagnetic wave source, two different approaches are used:

1) Determining the Umov-Poynting vector, for high accuracy.

2) The amplitude method with the elimination of ambiguity by the E component.

Along with ordinary lightnings, high-altitude discharges occur during thunderstorms. According to a number of works, a sprite indicator is a positive cloud-to-ground discharge (+CG). To verify this statement, a comparative analysis of WWLLN and VLF direction finder data was conducted. Over the entire comparison period, 27.511 paired discharges were selected, ~82% (22519) of which were the pairs of positive discharges (+CG, +CG), paired negative discharges (-CG, -CG) were observed in 7%, pairs of negative discharge — positive discharge (-CG, +CG) in 9%, 2% were the misses. Based on the analysis of the spectral characteristics of atmospherics, a method for determining the discharge height was developed. Owing to this method, in 15651 (69%) out of the 22519 selected cases, a height of more than 40 km was confirmed.

Thunderstorm activity is observed not only in meteorological clouds, but also in gas and dust clouds formed during volcanic eruptions. On April 7 and 10, 2023, two catastrophic eruptions of the Shiveluch and Bezymyanny volcanoes occurred. According to WWLLN remote observations, at 13:06 UTC on April 10, 2023, the first warning about the beginning of an explosive eruption of the Shiveluch volcano was received.

In addition to electromagnetic lightning signals, whistling atmospherics were recorded in the VLF direction finder data. Whistlers with a large dispersion coefficient have an initiating atmospheric, which is explained by the location of the initiating discharge. This is true for both eruptions. The initiating atmospherics have an azimuth that coincides with the azimuth of the volcanoes. The height calculation showed that all initiating discharges have the altitude of more than 40 km.

Based on the assumption that these are high-altitude discharges that cause whistling atmospherics, a retrospective analysis of the WWLLN and AWDANet databases was conducted. The result showed that for the magnetically conjugated region, high-altitude discharges that cause whistling atmospherics. The verification was also carried out for two other magnetically conjugate points, one of which is Dunedin (New Zealand). That confirmed the previous result. Namely, high-altitude discharges cause whistling atmospherics.