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GEOINFORMATIC ADVANCES IN GEOMAGNETIC DATA STUDIES AND RUSSIAN INTERMAGNET SEGMENT

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Continuous and stable operation of modern complex technological systems is noticeably affected by electromagnetic processes originated from the interaction between the solar wind and the Earth's magnetosphere, which form the phenomena of "space weather". Russian geomagnetic observatories and the low orbiting satellites, carrying the high-precision magnetometers, provide complex monitoring of geomagnetic environment and detection of anomalous events of various nature. Analysis of observatory and satellite data allows modeling the structure of the internal and external parts of the Earth's magnetic field.

In the past few years considerable progress has been achieved in the ground geomagnetic observations development in Russia. A number of geomagnetic observatories, jointly maintained by the Geophysical Center of RAS and local RAS institutes, have been upgraded in order to comply with the INTERMAGNET standards. They include Arti (ARS), Saint Petersburg (SPG), Bor (POD), Kazan (KAZ) and a newly deployed observatory Klimovskaya (KLI). In June 2016 the Saint Petersburg observatory was officially assigned the status of INTERMAGNET observatory. Borok (BOX) observatory is being upgraded towards 1-second data standard jointly with Paris Institute of Physics of the Earth.

Since 2014 the Geophysical Center of RAS has been carrying out the project devoted to development of a new hardware and software system for geomagnetic data management and intellectual analysis. The system represents an innovative instrument, which integrates existing magnetic observatories and those, which are under development, in Russia. The important objective of the project is implementation of modern system analysis and data mining methods for retrieval, processing, classification and studying ground based and satellite geomagnetic observations. The system functionality includes automated data verification, recognition of anthropogenic disturbances, estimation of geomagnetic activity, online modelling calculations and more. It enables comprehensive monitoring of geomagnetic environment and provides a sophisticated classification of extreme geomagnetic phenomena and detection of extreme geomagnetic conditions. These features largely contribute to prevention and mitigation of negative effects on technological infrastructure and economic activity within the regions of Russia, caused by extreme geomagnetic events.

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CONSTRUCTION AND VALIDATION OF ULF WAVE INDICES AS INDICATORS OF TURBULENT ENERGY TRANSFER INTO THE MAGNETOSPHERE

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All existing geomagnetic indices and interplanetary parameters characterize the steady-state level of the electrodynamics of near-Earth environment. Here we describe the construction, verification and introduction into space geophysics of a new hourly ULF wave index to characterize the turbulent level of the solar wind-magnetosphere-ionosphere system. The ground ULF index in frequency range of the Pc5 band (2-7 mHz) characterizing world-wide ULF activity is derived from 1-min data from array of magnetometers in the Northern hemisphere. A similar wave index is calculated from interplanetary monitor data to quantify the short-term outer space variability. These wave indices have been calculated since 1991 up to nowadays. A wide range of the space physics studies, such as substorm physics, relativistic electron energization, solar wind-ionosphere coupling, etc. will benefit from the introduction of the wave indices. The index database is freely available via the specially designed website for all interested researchers for testing, validation, and statistical studies.

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USGS INDUCTION HAZARD SCIENCE

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Geoelectric fields induced in the Earth's electrically conducting interior can drive quasi-direct currents in bulk electric-power grids. These geomagnetically induced currents (GICs) are of sufficient strength to interfere with electric-power grid operations, sometimes causing blackouts and damaging transformers. Historically, the most dramatic realization of this natural hazard occurred in March 1989, when an intense magnetic storm caused the collapse of the entire Hydro-Québec electric-power grid in Canada. According to some scenario analyses, the future occurrence of extremely intense magnetic storms might result in national and continental-scale failure of electric-power grids with long-lasting deleterious consequence for society.

In support of a U.S. national priority for improving space-weather operations, response, and mitigation, the Geomagnetism Program of the U.S. Geological Survey is supporting data acquisition operations, assessment services, and performing research related to magnetic-storm induction hazards, including: (1) Long-term operation of magnetic observatories, data management, and real-time data dissemination to partners in government, academia, and industry; this work is coordinated on an international scale through the INTERMAGNET consortium. (2) A magnetotelluric survey of Florida; this work is complementary to survey work supported by the NSF's EarthScope Project. (3) Collaborative work with colleagues at NOAA and NASA for developing a service for real-time mapping of geomagnetic activity across the continental United States. (4) Collaborative work with colleagues at Oregon State University for inverse modeling of solid-Earth electrical conductivity structure. (5) Collaborative work with colleagues at NOAA and NASA to develop algorithms and products needed for real-time mapping of geoelectric fields, using interpolated magnetic field activity maps and measured or computed magnetotelluric impedance tensors. (6) Initiating long-term geoelectric monitoring, which will provide data needed to validate modeling projects. Taken together, these efforts represent a non-traditional application of magnetotelluric data with the emphasis on induction hazards rather than the structure of the solid Earth, and require multidisciplinary input from magnetotelluric, space weather, and engineering communities.

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AEROSOL PROCESSES IN THE IONOSPHERE

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The propagation of electromagnetic field in the lower ionosphere (D and E layers) is strongly affected by the presence of aerosol particles whose size spectrum stretches from 10 nm to several microns, with their concentration being comparable to that of the Rydberg complexes (10 – 1000 particles per c.c.). The aerosol particles are mostly highly charged. We discuss the very specific mechanism of RF waves-charged particles interactions related to the excitations of the surface plasmons in the particles. The plasma frequencies of the charge cloud surrounding the particle are shown to vary within the rf wave range which leads to the resonance effects in the elastic channel. We also consider the efficiencies of charging the particles by direct UV Sun radiation and by the electron from the carrier ionospheric plasma. The presence of the aerosol particles in the ionosphere leads also to excitation of additional branches of electromagnetic waves related to the oscillation of the self-consistent electromagnetic field in the ionospheric plasma.

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THE 2015 NEPAL EARTHQUAKE – A SIGNATURE ON THE MAGNETIC SWARM SATELLITES DATA?

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Space magnetic measurements obtained from Ørsted, CHAMP and SAC-C satellites provide a new global perspective in understanding the geomagnetic field variations. The datasets provided by these satellites, over the past decades, have given us the ability to obtain an improved description of the geomagnetic field. With the launch of Swarm constipation in 2013, for the first time, we are able to analyze the Earth's magnetic field variations and provide a truly unique window into a large number of key processes within the Earth system, many of which are difficult to fully observe in any other way. Swarm mission has provided data that are not only critically valuable on their own, but also as an excellent complement to other geophysical data.

Here, taking advantage of the measurements accuracy provided by the Swarm magnetic satellites, the possibility to detect some pre-earthquake magnetic anomalous signals, likely due to a lithosphere-atmosphere-ionosphere coupling is investigated: a case study is the 2015 Nepal earthquake occurrence.

GEOMAGNETIC MONITORING OF GAS AND OIL PIPELINES FOR PREVENTION OF TECHNOGENIC ACCIDENTS

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Safe exploitation of gas pipelines requires development of innovative physical scanning techniques. The report discusses a new application of the Overhauser magnetometer for pipeline research. Due to the high absolute precision (up to 0.2 nT) and stability (<0.05 nT per year) we propose long-term monitoring of the pipelines magnetic parameters for control of dangerous phenomena precursors: cracking, corrosion, stress-strain states etc. We discuss the development of mathematical methods and software for interpretation of the magnetic data for pipeline monitoring and scanning.

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