FIFTEENTH WORKSHOP

Solar Influences on the Magnetosphere, Ionosphere and Atmosphere

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Book of Abstracts

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Topics:

Sun and Solar Activity
Solar Wind-Magnetosphere-Ionosphere Interactions
Solar Influences on the Lower Atmosphere and Climate
Solar Effects in the Biosphere and Lithosphere
Instrumentation for Space Weather Monitoring
Data Proccessing and Modelling

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Simeon Asenovski.

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Sun and Solar Activity

Microwave Observations of the Sun in VIRAC

Bezrukovs D., Bezrukovs V.
Ventspils International Radio Astronomy Centre (VIRAC)

For last years Ventspils International Radio Astronomy Centre (VIRAC), Latvia got a sufficient experience of an implementation of microwave observations of the Sun and now has an opportunity to perform routine solar microwave spectral polarimetric observations of the whole disk of the Sun and separate active regions. The microwave emission is observed with RT-32 radio telescope equipped by multichannel (12 frequency channels) spectral polarimeter for 2.1-7.4 cm wavelength range and both circular polarizations.

Spectral observations of solar microwave polarized emission offer the possibility for direct measurements of plasma parameters and magnetic field inductions in upper chromosphere and lower corona at the range of heights. Thus current microwave observations of the Sun could be expected for studies of some tasks in the frame of the problem of the space weather creation.

The presentation concerns to some technical and methodological issues of solar observations implemented in VIRAC. Also the presentation discusses feasible problems of solar physics which could be studied on the base of microwave spectral polarimetric observations. The possibility of studies of coronal holes and coronal hole-like areas (“dark coronal corridors”, “coronal partings”, “s-web”) associated with local open magnetic fields which could be expected as sources of the slow solar wind and the analysis of microwave flux fluctuations of active regions preceding solar flares are discussed as well.

Prediction of the Solar Cycles 25 and 26 Using the Machine Learning Method (SARIMA)

Calisir M.A., Ozmen O., Kilcik A.
Department of Space Science and Technologies, Akdeniz University Faculty of Science

In this study, the amplitudes and times of maximum of the sunspot numbers during solar cycles 25 and 26 were predicted by using the SARIMA (Seasonal Autoregressive Integrated Moving Average) method. For this purpose, monthly observed sunspot numbers were taken from Solar Influences Data Analysis Center (SIDC) for the time period ranging from 1800 to 2022, and model parameters were computed. The SARIMA method was tested for the last five solar cycles (20, 21, 22, 23, and 24). In result of test analysis, the best prediction parameters were determined and used for the prediction of the 25th and 26th sunspot cycles. As a result, it was found that the predicted cycles would be approximately at the same level with the cycle 24, but slightly weaker.

Six EUV Solar Radiation Proxies: a Comparative Analysis

Elias A.G.[1], Medina F.D.[1], Duran T.[2], Zossi B.S.[1], de Haro Barbas B.F.[1]
[1]FACET, UNT & INFINOA (CONICET-UNT), Argentina;
[2]Departamento de Fisica, UNS & Instituto de Fisica del Sur (CONICET-UNS), Argentina

Six EUV solar radiation proxies (Mg II, Lyman alpha flux, F10.7, Rz, F30 and He II) are analyzed along the period 1979-2022, covering four solar activity cycles, to assess their differences and similarities along the different phases of the quasi-decadal cycle. Following a previous study based on four of these proxies, their variability is compared through the following approaches: (1) a correlation analysis, (2) superposed epoch analysis, (3) sensitivity along the solar activity cycle through its variation in terms of percentage, and (4) through their role in filtering solar activity effect from ionospheric F2 region critical frequency, foF2, which depends mainly on EUV solar radiation. The differences detected through these approaches can be used to decide which solar proxy to use according to the research purpose.

A Catalog of Intense Geomagnetic Storms and the Associated Solar Sources

Gopalswamy N.[1], Akiyama S.[1,2], Yashiro S.[1,2], Makela P.[1,2], and Xie H.[1,2]
[1]NASA/GSFC;
[2]Catholic University

Intense geomagnetic storms are characterized by the minimum value of the Dst index at or below – 100 nT. It is well known that these storms are caused by the southward magnetic fields in coronal mass ejections (CMEs) and corotating interaction regions (CIRs). While CIR storms are confined to Dst values > -150 nT, CME storms can reach Dst < -500 nT. Intense geomagnetic storms are followed by a number of space weather consequences such as energization of particles in Van Allen belts, particle precipitation in the polar atmosphere, atmospheric heating, and geomagnetically induced current. The intense storm catalog presented here provides detailed information on the solar sources of the storms, viz., CMEs from closed magnetic regions and fast solar wind originating from open magnetic field regions (coronal holes). These are observed in coronagraph and EUV images of the corona, respectively. We also provide information on the basic properties and heliographic coordinates of the coronal holes and CMEs. We also present the statistical properties of the associated CMEs and coronal holes as a function of the solar cycle.

Stellar Cycles and Exoplanets: a Search for Connections

Katsova M.[1], Obridko V.[2], Sokoloff D.[2,3]
[1]Sternberg State Astronomical Institute, Lomonosov Moscow State University;
[2]IZMIRAN, Troitsk, Moscow;
[3]Depatrmen of Physics, Lomonosov Moscow State University

Cyclic activity on the Sun and stars is primarily explained by the generation of the magnetic field by a dynamo mechanism, which converts the energy of the poloidal field into the energy of the toroidal component due to differential rotation. There is, however, an alternative point of view, which explains the field generation by the gravitational influence of the planetary system and first of all, Jupiter. This hypothesis can be verified by comparing the characteristics of exoplanets with the activity variations on their associated stars. We have performed such a comparison and have drawn a negative conclusion. No relationship between the gravitational influence of the exoplanets and cycle of the host star could be found in any of the cases considered. Moreover, there are reasons to believe that a strong gravitational influence may completely eliminate cyclic variation in stellar activity.

Helium Abundance Behavior Inside ICME at Large Spatial Scales

Khokhlachev A., Yermolaev Y., Lodkina I., Riazantseva M., Rakhmanova L.
Space Research Institute of RAS

The interplanetary coronal mass ejections (ICMEs) are one of the large-scale solar wind phenomena. They are characterized by the increased average values of the relative abundance of doubly ionized helium ions. The study is devoted to the changing of the behavior of the helium abundance for the period from 21 to 24 solar cycles inside ICMEs. Since the beginning of the 23 cycle, a decline in solar activity has been observed, which, in particular, led to a general decrease in the relative helium abundance in the solar wind.

To study the effect of helium abundance decrease on its behavior inside ICMEs, we compared the relationship between helium abundance and other solar wind parameters in two periods. In addition to the plasma and interplanetary magnetic field parameters, the distance between the observation point and the ICME axis was additionally considered.

A period of high solar activity (21-22 cycles) and a period of low activity (23-24 cycles) were identified.

The results of the statistical analysis show that the general nature of the dependences between the parameters for two periods is similar, however, some dependences became weaker in 23-24 cycles. For both periods, the increased helium abundance is observed in the central region of the ICME compared to the peripheral regions [Khokhlachev et al., Universe, 2022, https://doi.org/10.3390/universe8110557]. This fact indicates that the existence of an electric current enriched with helium ions is possible near the ICME axis.

The work is supported by Russian Science Foundation grant № 22-12-00227.

Solar Cycle Dependencies of Sunspot Umbral Dot Parameters

Kilcik A., Calisir M.
Akdeniz University , Faculty of Science, Department of Space Sciences and Technologies, Antalya, Turkey

In this study we investigated the solar cycle dependencies of sunspot umbral dot (UD) which are bright dot like fine structures observed in sunspot umbra, parameters. The selected UD parameters are average UD intensity, diameter, eccentricity, dynamic velocity and life time for each umbra. For the analysis 17 high resolution sunspot umbra time series taken from Big Bear Solar Observatory (BBSO)/Goode Solar Telescope (GST) were used. Average UD parameters compared with sunspot number (SSN) data downloaded from Solar Influences Data analysis Center (SIDC) web page. To obtain the possible relationship between above mentioned UD parameters with each other and SSN the temporal variation graphics were plotted and the correlation coefficients were calculated. In results of our analysis we found that all UD parameters, except dynamic velocity, show meaningful correlations with SSN. We also found that the relationships between selected UD parameters are not linear in general.

Prediction of Solar Activity and Geomagnetic Changes during 26th Solar Cycle from Earlier Cycles Data (9th - 25th) using Elman Recurrent Networks

Kobylinski Z.[1], *Wysokinski A.*[2]
[1]High School of National Economics, Kutno, Poland,
[2]Independent Researcher, Iganie, Poland

Solar and geomagnetic activity prediction is very important for space weather and Earth climate studies. A number of techniques have been developed to predict the amplitude of solar maximum, duration and shape of following solar cycles and geomagnetic field behavior. The review of the last literature results is presented in the paper. A relatively small number of papers are based on the artificial neural network (ANN) adoption to the forecast of the future solar and geomagnetic data sets. We use the Elman ANN because comparison with other equivalent feed-forward ANN types indicates that the Elman could be a better predictor. This paper is an extension of the posters presented on 13th and 14th Workshops. Now the period of used data is longer: from maximum of 9th cycle (Feb 1848) to May 2023. Daily data averaged by Bartels rotation of sunspot numbers, aa and C9 geomagnetic indices, cosmic ray intensity from 1939 to nowadays are used. The time relation between solar and geomagnetic activity or cosmic ray intensity is tested by means of the wavelet coherence scalograms and recurrence plots. It seems that geomagnetic activity in the cycle 26 at the begin of 27th cycle would be on the same level as in the cycle 25, solar activity would be higher than in cycle 25.

Where did the Solar Energetic Protons Observed in Mars Orbit Come from?

Koleva R.[1], *Semkova J.*[1], *Benghin V.*[2], *Krastev K.*[1], *Matviichuk Y.*[1], *Tomov B.*[1], *Bankov N.*[1], *Maltchev S.*[1], *Dachev T.*[1], *Drobyshev S.*[2], *Gopalswamy N.*[3], *Mitrofanov I.*[4], *Malakhov A.*[4], *Golovin D.*[4], *Litvak M.*[4]
[1]Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria;
[2]State Scientific Center of Russian Federation, Institute of Biomedical Problems, Russian Academy of Sciences, Moscow, Russia;
[3]NASA Goddard Space Flight Center, Greenbelt Maryland, USA;
[4]Space Research Institute, Russian Academy of Sciences, Moscow, Russia

Since July 2021 the dosimeter Liulin-MO aboard ExoMars Trace Gas Orbiter (TGO) registered 8 solar energetic particles (SEP) events. Only four of them reached Earth. We try to relate the observed SEP to solar phenomena using images from the SOHO and STEREO A coronagraphs though till April 2022 Earth and Mars are at opposite sides of the Sun. Our observations contribute to the details for the solar activity not observed from Earth.

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Non-adiabatic Coronal Seismology

Kolotkov D.
University of Warwick, United Kingdom

A powerful technique for the diagnostics of physical conditions in active regions of the Sun's corona is the method of coronal seismology, based on the use of MHD wave processes as natural probes. Traditionally, coronal seismology is focused on the diagnostics of magnetic properties of the Sun's corona, including the coronal magnetic field strength, twist, geometry, free energy, and fine cross-field structuring, which are difficult to measure otherwise. In a series of recent papers, the method of coronal seismology has been proven effective for probing not only magnetic but also fundamental thermodynamic parameters of the coronal plasma through theoretical modelling and observations of MHD waves in intrinsically non-adiabatic conditions.

This talk presents a gold standard for the application of the method of non-adiabatic coronal seismology to probe such crucial parameters of the coronal plasma as energy transport coefficients, polytropic index, and heating function, regulating the delicate energy balance. More specifically, the departure of the effective heat transfer coefficient from its classical Spitzer form due to various microinstabilities and plasma turbulence is assessed seismologically with exceptional accuracy, comparable to the resolution and sensitivity of recently commissioned instruments. The exact role of the effective polytropic index of the corona in the dynamics of non-adiabatic magnetoacoustic waves, its relationship with the effective thermal conduction coefficient, and shortcomings of the polytropic plasma approximation are discussed. A frequency-dependent damping of slow magnetoacoustic waves and a recently developed theory of wave-induced thermal misbalance are used for constraining the functional form of the enigmatic coronal heating mechanism.

Coronal Eruptive Activity in the Quiet Sun

Madjarska M.S.[1,2], Mackay D.H.[3], Galsgaard K.[3], Wiegelmann T.[2]
[1]Space Research and Technology Institute, Bulgarian Academy of Sciences, Acad. Georgy Bonchev Str., Bl. 1, 1113, Sofia, Bulgaria
[2]Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077, Göttingen, Germany,
[3]School of Mathematics and Statistics, University of St Andrews, North Haugh, St Andrews, KY16 9SS, Scotland, UK

Small-scale magnetic loops are the main magnetic skeleton of the solar atmosphere outside active regions. Some appear bright and are for historical reasons referred to as coronal bright points. Others are fainter, building up most of the background corona of the so-called quiet Sun. Thus, these small-scale loops dominate the solar corona seen in images that record the emission from plasmas heated to approximately 1 million degrees, especially during the minimum of the solar activity cycle. Their role in heating the upper solar atmosphere is still under intense debate, being a subject of numerous observational and theoretical studies. I will briefly review the morphological, magnetic, and plasma properties reported in studies that span more than five decades. I will present a series of our observational and modeling studies on eruptive activity (mini coronal mass ejections and jets) associated with these loop systems. I will discuss the possibility of whether these mini eruptions have contribution to the solar wind and could be the source of magnetic switchbacks (sudden deflections of the magnetic field) that prevail in the inner heliosphere.

Extended Cycle and Assymmetry of Large-Scale Solar Magnetic Field

Obridko V.N.[1,2], *Shibalova A.S.*[1], *Sokoloff D.D.*[1,3,4]
[1]IZMIRAN,
[2]Central Astronomical Observatory of the Russian Academy of Sciences,
[3]Lomonosov Moscow State University,
[4]Moscow Center of Fundamental and Applied Mathematics

Traditionally, the solar activity cycle is thought as an interplay of the main dipole component of the solar poloidal magnetic field and the toroidal magnetic field. However, the real picture as presented in the extended solar–cycle models is much more complicated. Here, we develop the concept of the extended solar cycle clarifying what zonal harmonics are responsible for the equatorward and polarward propagating features in the surface activity tracers. We arrive at a conclusion that the zonal harmonics with l = 5 play a crucial role in separating the phenomena of both types, which are associated with the odd zonal harmonics. Another objective of our analysis is the role of even zonal harmonics, which prove to be rather associated with the North-South asymmetry of the solar activity than with its 11-year solar periodicity.

Temporal Offsets Between Solar Flare Index and Cosmic, Geomagnetic, and Interplanetary Indicators During Solar Cycle 24

Ozguc A.[1], *Kilcik A.*[2]
[1]Kandilli Observatory and Earthquake Research Institute, Bogazici University, 34684 Istanbul, Turkey
[2]Department of Space Science and Technologies, Akdeniz University Faculty of Science, 07058 Antalya, Turkey

We analyzed modulation of cosmic-ray intensities (CRIs) during Solar Cycles 24 by using the solar flare index (FI), interplanetary magnetic field strength, and the geomagnetic Ap and Dst indices. Temporal variations, cross-correlations, and hysteresis patterns of CRI, FI, scalar B, Ap and Dst data were investigated. As a result, we concluded that the FI better describes solar modulation of the CRI as compared to the other solar indicators. We also analyze the temporal offset between the flare index and the above-mentioned cosmic, geomagnetic, and interplanetary indices. It is found that this solar activity index, analyzed jointly with cosmic, interplanetary parameters, and geomagnetic activity indices, shows a hysteresis phenomenon. It is observed that these parameters follow different paths for the ascending and descending phases of Cycle 24.

Problems Arising in Studying the Mechanism of a Solar Flare by the Way of Comparing the Results of MHD Simulations above the Real Active Region With Observations

Podgorny A.I.[1], *Podgorny I.M.*[2]
[1]Lebedev Physical Institute RAS
[2]Institute of Astronomy RAS

Primordial energy release of solar flare occurs in solar corona at altitude of 15,000-70,000 km. Slow accumulation of magnetic energy of flare in stable configuration, and then its rapid release, can be explained by mechanism of solar flare proposed by S.I. Syrovatskii, according to which accumulation of flare energy occurs in magnetic field of current sheet, which is formed in vicinity of X-type singular line. Fast release of current sheet magnetic energy leads to observed manifestations of flare, which are explained by the electrodynamic model of solar flare proposed by I. M. Podgorny. Beam X-ray emission on solar surface is explained by deceleration in the lower dense layers of the solar atmosphere of electrons accelerated in longitudinal currents caused by the Hall electric field. To study mechanism of solar flare, magnetohydrodynamic (MHD) simulations are carried out above real active region. For numerical solution of MHD equations, absolutely implicit finite-difference scheme, conservative relative to magnetic flux, has been developed. Numerical solution in real scale of time became possible due to use of parallel computing on graphics cards. Comparison showed general agreement between flare positions found from results of MHD simulations and observations, which confirms current sheet mechanism. However, detailed comparison of MHD simulation results with observations causes problems. Sometimes singular lines with significant divergent field or significant longitudinal field coincide better with regions of flare emission. There is a need for further improvement of technique for MHD simulation to obtain more accurate results of MHD simulation and compare them with observations.

Update of the Science Results from the Radiation Investigations in Mars Orbit Aboard Exomars TGO in 2018-2023

Semkova J.[1], *Koleva R.*[1], *Benghin V.*[3], *Krastev K.*[1], *Matviichuk Y.*[1], *Tomov B.*[1], *Bankov N.*[1], *Maltchev S.*[1], *Dachev T.*[1], *Mitrofanov I.*[2], *Malakhov A.*[2], *Kozyrev A.*[2], *Golovin D.*[2], *Mokrousov M.*[2], *Litvak M.*[2], *Shurshakov V.*[3], *Drobyshev S.*[3],*Gopalswamy N.*[4], *Guo J.*[5,6], *Zhang J.*[5], *Liu W.*[5,7]
[1]Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria
[2]Space Research Institute, Russian Academy of Sciences, Moscow, Russia
[3]State Scientific Center of Russian Federation, Institute of Biomedical Problems, Russian Academy of Sciences, Moscow, Russia
[4]NASA Goddard Space Flight Center, Greenbelt Maryland, USA
[5]Deep Space Exploration Laboratory/School of Earth and Space Sciences, University of Science and Technology of China, Hefei 230026, China
[6]CAS Center for Excellence in Comparative Planetology USTC, Hefei, China
[7]Department of Climate and Space Sciences and Engineering, University of Michigan, Ann Arbor, MI 48109, USA

Presented are the main results from the measurements in Mars orbit of the galactic cosmic rays (GCR) and solar energetic particle events provided by Liulin-MO dosimeter aboard ExoMars Trace Gas Orbiter (TGO) during different phases of the solar activity in the period 2018-2023. Discussed are comparisons between the measured and simulated dose rates and particle fluxes from GCR and albedo radiation in Mars orbit.

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Flare Properties at Millimeter Wavelengths

Skokić I.[1,2], Benz A.O.[3,4], Brajša R.[1], Sudar D.[1], Matković F.[1], Bárta M.[5]
[1]Hvar Observatory, Faculty of Geodesy, University of Zagreb;
[2]Zagreb Astronomical Observatory;
[3]University of Applied Sciences and Arts Northwestern Switzerland, Windisch;
[4]Institute for Particle Physics and Astrophysics, ETH Zürich;
[5]Astronomical Institute of the Czech Academy of Sciences, Ondřejov

Full-disk solar ALMA observations enabled a new look into flare properties at frequencies above 100 GHz. Results indicate that flare millimeter brightenings are associated with a variety of flare features in cool (Hα, 304 Å), intermediate (171 Å), and hot (94 Å) lines, such as activated filaments, flare footpoints, and flare loops. In one case we can compare with hard and soft X-ray measurements. We also analyze spectral properties of a flare and confirm a slope ascending with frequency, as expected for optically thick thermal emission.

Resonances in Stellar Dynamos

Sokoloff D.D.[1], Serenkova A.Yu.[2], Yushkov E.V.[3]
[1]Moscow State University, IZMIRAN,
[2]Moscow State University,
[3]Moscow State University and IKI

Stellar and in particular solar activity cycles are quasiperiodic magnetic field modulation associated with MHD process in stellar convective shell. Planets and stellar companions in binary systems affect the stellar MHD due to tidal forces and various other effects. This allows to expect various resonance effects in stellar dynamos driving activity cycles. The dynamo resonances occurs to be however quite different from resonances arising due to conventional swing excitation. Specific featrures of dynamo resonances are discussed in the talk.

Investigation of Solar Energetic Particles (SEPs) Associated with X-ray Solar Flares

Tirnakci M.[1], Asenovski S.[2], Kilcik A.[1]
[1]Akdeniz University;
[2]SRTI-BAS

In this study, we present the statistical relationship between X-ray solar flares and solar energetic particle (SEP) events. The SEP data were taken from the SINP MSU Space Weather Analysis Center, and the solar flare data were obtained from Solar Monitor, covering the last two solar cycles (1996 – 2022). The cross-correlation analysis was performed to monthly data. The results of the cross-correlation analysis showed that there was no significant correlation between C-class solar flares and SEP events ($r = 0.13 \pm 0.13$). However, low-level correlations were found between M-class and X-class solar flares and SEP events (0.21 ± 0.11 and 0.30 ± 0.1, respectively). Furthermore, to investigate the time variations of these data sets temporal variation analysis were performed. The results showed that there were significantly more SEP events during the Solar Cycle 23 (SC23) compared to Solar Cycle 24. Thus, we can conclude that the SC23 was a stronger cycle than the SC24. Investigation of the statistical relationship between SEPs and solar flares is an important topic for predicting solar activity and forecasting space weather effects.

Eclipsed Sun over Australia on 20 April 2023

Tsvetkov Ts., Petrov N., Zinkova Y.
Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences

Despite the advantages of modern ground-based and space-based instruments for observing the Sun, some parts and conditions in the corona are still only possible to be explored during total solar eclipses. That is why organized scientific research expeditions accompany every such astronomical event. The latest total solar eclipse occurred on April 20, 2023 and was observed from territories in Western Australia, East Timor and Papua. Our team completed an expedition to Australia to collect additional data to study both the structure and degree of polarization of the solar corona, as well as some phenomena accompanying the eclipses, such as shadow bands, changes in meteorological parameters, etc. We present our first results of the conducted experiments and compare them to the ones obtained during previous eclipses.

Will Solar Cycle 25 be Similar to Cycle 24 According to Solar Wind Observations?

Yermolaev Yu., Lodkina I., Khokhlachev A.
Space Research Institute of RAN

Based on the analysis of solar wind measurements in the OMNI database and our catalog of large-scale solar wind types (http://www.iki.rssi.ru/pub/omni), we study the change in plasma and magnetic field parameters at the growth phase of solar cycle 25 and compare with the behavior of these parameters on a similar period of the 24th solar cycle. The results allow us to suggest that the current cycle will be similar to the previous cycle.

Solar Wind-Magnetosphere-Ionosphere Interactions

The Analysis of Observations of Ionospheric and Geomagnetic Time Series for Detection of Precursors of Earthquakes

Adibekyan M.V.
Ministry of Emergency Situations of The Republic of Armenia -Territorial Survey for Seismic Protection State

Aiming at earthquake precursors apportionment the earthquake preparation displays of Shorzha (Armenia, 29.05.2022, M=3.5) and Vardenis (Armenia, 29.04.2008г, M=3.6), earthquakes in time-series have been studied using the geomagnetic and ionosphere tools.

There were received some results, allowing to make out the difference of seismogenic anomalies of ionosphere between the longer anomalies connected to magnetic activity of ionosphere by the method of vertical reconnaissance of ionosphere. For a research of assessment of the current seismic hazard were studied observation geomagnetic fields and vertical sounding of ionospheric time series. Results of the analysis observation have confirmed communication between earthquakes magnitude M ≥ 3.5 and absorption of a radio-emission of discrete radiation sources radio atmospheric observations and also dependence between and geomagnetic parameters. Have been used Lebed - A and Cassiopeia - A (ionospheric station of observation Saravand), geomagnetic station observation Garni.

Keywords: Earthquake, precursors, ionosphere, time-series, geomagnetic

Investigation of the Type of Radio Emissions from Sources of Radio Emissions such as: Seismo-Ionospheric Communications, Galactic Background, "Swan-A" and "Cassiopeia-A" by Vertical Ionospheric Sounding at a Wavelength of 4.2 m.

Adibekyan M.V.[1], *Gulyan A.G.*[2], *Sargsyan S.A.*[2], *Arakelyan H.S*[2]
[1]Ministry of Emergency Situations of the Republic of Armenia -Territorial Survey for Seismic Protection State
[2]Non Commercial Organization

Vertical ionosphere sounding seismic hazard assessment. The structure and system specifications of the vertical sounding of the ionosphere at a wavelength λ= 4,2 m, and opportunities to improve the sensitivity of the interference of the radio telescope with digital data observations to study the seismic hazard assessment symptoms and the nature of change of flux density of the radio sources Swan-A and Cassiopeia-A. Aiming at earthquake precursors apportionment the earthquake preparation displays of Нахичеванской (Азербайджан, 02.09.08, M = 5.1) earthquake in time-series have been studied using ionosphere tools. There were received some results, allowing to make out the difference of seismogenic anomalies of ionosphere between the longer anomalies connected to magnetic activity of ionosphere by the method of vertical reconnaissance of ionosphere. Results of the analysis observation have confirmed communication between earthquakes magnitude M ≥ 3.5 and absorption of a radio-emission of discrete radiation sources radio atmospheric observations dependence between.

Ascending Phases of Solar Activity in the Heliosphere

Asenovski S., Georgieva K., Kirov B.
Space Research and Technology Institute - Bulgarian Academy of Sciences

The study of geomagnetic activity during the last six ascending phases in the solar activity cycles has provided important insights into the complex relationship between solar activity and its impact on the Earth's magnetic field. By analyzing available data on geomagnetic indices and solar wind parameters, researchers have been able to identify patterns and trends in geomagnetic activity during the ascending phase of solar cycles. It is clear that geomagnetic activity during the ascending phase of the solar cycle can vary significantly in terms of duration, intensity, and timing. This variability is driven by a number of factors, including the level of solar activity, the strength and direction of the solar wind, and the orientation of the interplanetary magnetic field. While it is difficult to predict the exact behavior of geomagnetic activity during the next ascending phase of the solar cycle, ongoing research and monitoring can provide valuable insights into the likelihood and potential impact of future geomagnetic storms.

Analysis of the Response of the Ionospheric Storm over Europe during 26-28 February 2023

Bojilova R., Mukhtarov P.
National Institute of Geophysics, Geodesy and Geography-Bulgarian Academy of Sciences

A study of the behavior of the main characteristics of the ionosphere over Europe during 26-28 February 2023 ionospheric storm caused by the G3 (Strong) geomagnetic storm is presented. The behavior of the critical frequency of the ionosphere foF2 (characterizing the maximum electron density), the true height of the F2- layer (hmF2) and Total Electron Content (TEC) was investigated through their relative deviations from the quiet conditions. Solar wind parameters and indices of geomagnetic activity indicate that this event had a sudden onset. The behavior of the TEC over Europe shows the geographic latitudinal dependence of the response. Positive reactions caused by the additional ionization in the auroral oval and the influence of the Equatorial Ionization Anomaly (EIA) on the mid-latitude atmosphere are observed. The negative responses during the storm are due to the spread of heated in the auroral oval neutral wind to mid-latitudes. The variability of the ionospheric critical frequency is represented by the data of 10 ionospheric stations for vertical sounding located in two groups i) near the prime meridian and ii) near the 25°E meridian. Some differences are found in the response and compared to the TEC response, which is explained by the different responses of the top maximum region and bottom maximum region. The true height varies strongly during the storm, which is due to the forced drift of ionospheric plasma induced by additional electric fields. The presented detailed analysis of the storm shows that the considered storm exhibits characteristic features inherent in the winter season but with some manifestations of reactions in equinox conditions.

Median Model for Forecasting of Ionospheric Virtual Height for Sofia City

Bojilova R., Mukhtarov P.
National Institute of Geophysics, Geodesy and Geography-Bulgarian Academy of Sciences

The purpose of the present investigation is to present a methodology for determining the values of the virtual height of the ionospheric F region. The dependence of the entire ionosphere on the level of solar activity is well known, which is one of the main factors in the empirical modeling of the ionosphere. In order to analyze the dependence between the solar activity represented by F107 and h`F, a regression analysis was performed by month. The results show that the optimal dependence is close to linear. In addition, in order to study the seasonal dependence of h`F, the decomposition method was also applied. The amplitudes of the diurnal cycle and its harmonics, as well as the corresponding phases, are examined. As a result, an empirical median model for forecasting h`F for the territory of the Sofia city, depending on solar activity and season, is proposed. In its concluding part, this study also presents examples of the model's performance in selected months. The resulting errors are ME=0.000 km and RMSE=8.180 km, respectively, which is accurate enough for practical purposes such as radio path prediction.

Space Weather Conditions and non-Storm Supersubstorms Observations

Despirak I.V.[1], Lubchich A.A.[1], Kleimenova N.G.[2]
[1]Polar Geophysical Institute, Apatity, Russia;
[2]Schmidt Institute of Physics of the Earth, RAS, Moscow, Russia

It is known that very intense substorms, so-called “supersubstorms” (SSSs: SML < −2500 nT) usually occur in the main phase of the magnetic storms. At the same time, it was found that such intense events are observed not only during very strong storms (superstorm with Dst<-250 nT), but also during intense or moderate magnetic storms (-100 nT >Dst>-250 nT; -50 nT >Dst>-100 nT). The aim of this work is to study the supersubstorms observed during non-storm conditions by the OMNI data base and global magnetometer networks SuperMAG, INTERMAGNET and IMAGE. For this purpose, we selected the SSS events observed by SYM/H>-50 nT. We found 18 such SSS events in the period 1998-2017. Among them, several typical events can be distinguished: (1) – the events observed near the magnetic storm commencements or near the SC, (2) - the events in the distant recovery phase of the storm, (3) – the events out of the magnetic storm. In our work, we discussed some special conditions in the solar wind and the interplanetary magnetic field (IMF) under which such events were observed.
This study was supported by the RFBR (project number 20-55-18003) and National Science Fund of Bulgaria (NSFB) (project number КП-06-Русия/15).

Polar Substorm Disturbances on the Archipelago Svalbard

Despirak I.V.[1], Kleimenova N.G.[2], Malysheva L.M.[2], Gromova L.I.[3], Lubchich A.A.[1], Roldugin A.V.[1]
[1]Polar Geophysical Institute, Apatity, Russia;
[2]Schmidt Institute of Physics of the Earth, RAS, Moscow, Russia;
[3]IZMIRAN, RAS, Troitsk, Moscow, Russia

Polar substorms include substorms observed at geomagnetic latitudes above 70° MLAT in the absence of simultaneous negative magnetic bays at lower latitudes. On the example of individual events registered on arch. Svalbard, the general morphological features of polar substorms are considered. It is shown that polar substorms, like “classical” substorms, are characterized by the formation of a substorm current wedge (SWC), an abrupt movement to the pole after the onset; generation of Pi2 geomagnetic pulsations, an increase in the PC- index of the polar cap before the onset. At the same time, there are certain differences between polar substorms and “classical” substorms, namely, development in the region of a compressed auroral oval, appearances at earlier pre-midnight hours, generation only at low solar wind velocity and weakly disturbed geomagnetic conditions. It has been suggested that polar substorms, apparently, represent a specific type of "classical" substorms developing in the evening sector under magnetically quiet or weakly disturbed conditions, when the auroral oval is compressed. The source of polar substorms can also be associated with a local intensification of previously existing substorms in the post-midnight sector.

External Current Systems as a Driver of Oscillations in the Geomagnetic Field

Demetrescu C., Dobrica V., Stefan C.
Institute of Geodynamics, Romanian Acacdemy

Beside the sunspot number time series, going back to ~1700, reconstructed parameters directly related to solar activity (open solar flux, Fs, total solar irradiance, TSI, galactic cosmic rays flux, GCR/Φ, solar wind velocity and pressure, V and P) based on physical models plus correlations, going back to ~1700, as well as of shorter, going back to only 1868 geomagnetic indices PC and aa, or designed to proxy the strength of the magnetosphere ring current, such as Dst, show long-term variations at the well-known solar activity cycles ’11-year’ (decadal), Schwabe (8-14 years), magnetic, Hale (20-30 years), and long, Gleissberg (60-90 years) one. On the other hand, observatory geomagnetic annual means and the time series returned by long-term geomagnetic models based on them show the same kind of variations; moreover, time-longitude plots constructed from time series returned by the gufm1 model of Jackson et al. (2000), that show alternate strips of maxima and minima, slightly inclined with respect to the geographical coordinate system, point to the variable external current systems in the magnetosphere as being responsible for the inductive response of the Earth’s interior that is also recorded by geomagnetic observatories. We deployed the Hodrick and Prescott (1957) type of analysis, that separates the decadal variation from the data trend, followed by Butterworth (1930) filtering of the trend to get the inter-decadal (20-30 years) and sub-centennial (60-90 years) variations in data. Geomagnetic data returned by long-term models were calculated in a 2.5x2.5º latitude/longitude grid.

Quantifying the Causality between Solar Flares and Dst Index using rEDM's Convergent Cross Mapping: Solar Cycle 24

Gerçeker K., Kilcik A
Akdeniz University

In this study, the "Solar Flare Index" and "Dst Index" data were analyzed using the "Convergent Cross Mapping" approach, taking into account the solar cycle 24 (2009 to 2021). The Solar Flare Index data were downloaded from the Kandilli Observatory and Earthquake Research Institute at Boğaziçi University web page, while the Dst Index data were taken from the World Data Center for Geomagnetism at Kyoto University's database. To investigate the causality relationship between two datasets the CCM approach were performed. The method is useful for understanding the interaction between two parameters. CCM analysis provides information about changes in one parameter affect the other, i.e., the level of interaction between time series. Our findings indicate a causality relationship between the Solar Flare and Dst Index data sets. This study aims to demonstrate the important advantages of the CCM analysis in terms of causality and it is potential for future predictions.

Electron-Scale Current Layers Observed by MMS in the Magnetotail Plasma Sheet

Grigorenko E., Malykhin A., Leonenko M., Zelenyi L.
Space Research Institute of RAS

We report the intense electric current structures (j-spikes) observed by MMS spacecraft at electron kinetic scales during the propagation of high-velocity bulk flows in the magnetotail Plasma Sheet (PS). The electric current density in the j-spikes exceeds 30 nA/m2, which is several times larger than the typical values of electric current density observed in the undisturbed magnetotail current sheet. A thickness of the j-spike structures was about a few electron gyroradii or less, and the electric current was carried by unmagnetized electron population with energies >1 keV. The epoch analysis has shown that the majority of j-spikes were observed near the trailing edges of the bulk flows both in the earthward and tailward sides of a near-Earth X-line. In the earthward side of X-line the probability to observe j-spikes maximizes in the outer PS, while in the tailward side of the X-line the majority of j-spikes are observed in the central PS. In many j-spikes the strong nonideal electric fields (E’) with the amplitude up to tens mV/m were observed. This results in significant energy dissipation: the value j*E’ is up to ~1 nW/m3 which is larger than that observed at dipolarization fronts. Thus, the processes of energy transformation in the electron-scale current structures formed in the PS can be important element in energy transfer between electrons and fields and can provide an additional energization of the ambient electron population.

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Slow-Cloud Magnetic Storms: Case Study

Gromova L.I.[1], Gromov S.V.[1], Kleimenova N.G.[2], Malysheva L.M.[2]
[1]IZMIRAN, Moscow, Troitsk, Russia;
[2]Schmidt Institute of Physics of the Earth RAS, Moscow, Russia

Magnetic storms are often caused by magnetic cloud approach to the Earth. The most studied storms are large ones caused by high-speed magnetic clouds. But slow magnetic clouds with Vsw < 400 km/s can be geoeffective as well. According to the Catalog of CME by Richardson, there were registered 10 slow magnetic clouds causing magnetic storms (Dstmin < -50 nT) during the 24-th solar activity cycle (2009 – 2019). Two of these storms (23 April 2012 and 27 May 2017) were very intensive ones with Dstmin < -100 nT. We studied these intensive slow-cloud-storm properties in comparison with the same properties of the magnetic storms caused by high-speed clouds during the same solar activity. As it was empirically established, the intensity of a storm mainly depends on the solar wind speed and IMF Bz within the magnetic cloud. However, we did not find a linear relationship the intensity of the slow-cloud-storms with the IMF Bz. Very intensive slow-cloud-storms occurred due to a long duration (~7 hours) of the strong southward IMF Bz (≤ □16 nT) when the solar energy entered the magnetosphere, estimated by the PC-index, increased significantly. The most intensive magnetic storms (Dstmin ~ □100 nT), associated with high-speed clouds with Vsw ~ 600-700 km/s were observed under the weaker IMF Bz than during the slow-cloud-storms, but with the preceding values of the PC-index of 1, 5 times stronger than in the case of slow-cloud-storms. Thus, geoefficiency of slow magnetic clouds increases with increasing southward IMF Bz.

Determination of the Parameters of Midlatitude Positive Bays Caused by Magnetospheric Substorms

Guineva V.[1], Werner R.[1], Atanassov A.[1], Bojilova R.[2], Raykova L.[1], Valev D.[1]
[1]Space Research and Technology Institute (SRTI) – Bulgarian Academy of Sciences, Stara Zagora Department, Bulgaria;
[2]National Institute of Geophysics, Geodesy and Geography (NIGGG) - Bulgarian Academy of Sciences, Sofia, Bulgaria

Magnetospheric substorms are an important feature of the space weather. Apart of the variety of phenomena that they provoke, they influence the magnetic field at the Earth surface. Negative X-bays at auroral latitudes and positive bays in the X magnetic component at midlatitudes known as midlatitude positive bays (MPB) are observed. The study of the MPB development serves in the investigation of the solar-magnetosphere coupling during the substorm progress. At the Space Research and Technology Institute of the Bulgarian Academy of Sciences, a substorm catalog is developed, based on data by the Bulgarian magnetic station Panagjurishte (PAG). The aim of this work is to create a processing tool to determine the beginning and end of the MPB registered at PAG. The tool is based on smoothing by moving average and by inspection of the consecutive minima of the X-component before and after the MPB maximum, calculated by the first derivative of the X variations. The MPB amplitude was obtained by the difference between the MPB maximum and the X value at the MPB beginning. Criteria to choose the minima of the beginning and end of the MPB have been specified. A minima find algorithm has been worked out and applied to specific cases.

This study was supported by the National Science Fund of Bulgaria (NSFB) (project number КП-06-Русия/15) and by the RFBR (project number 20-55-18003Болг_а).

Determination of the Parameters of Midlatitude Positive Bays Caused by Magnetospheric Substorms

Kirov B., Georgieva K., Asenovski S.
Space Research and Technology Institute– Bulgarian Academy of Sciences

It is well known that the number of Sunspots R and the geomagnetic activity measured by aa indices within an 11-year solar cycle have an almost linear relationship. As Feynman has shown this dependence can be expressed by the equation aa=a + b*R. Later Kirov et al. show that the coefficients a and b are different in the various 11 year solar cycles. They have shown that these coefficients change smoothly from cycle to cycle. In the present work, we investigate the reasons for the change of the coefficient b in the different cycles.

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Role of the Varying Solar Wind in Properties of the Magnetosheath Turbulence

Kleimenova N.G.[1], Despirak I.V.[2], Malysheva L.M.[1], Gromova L.I.[3], Lubchich A.A.[2], Gromov S.V.[3]
[1]IFZ-RAS;
[2]PGI,
[3]IZMIRAN

The Harang discontinuity (HD) is a longitudinally extended ionospheric signature before the local magnetic midnight of a latitude flow reversal (from westward to eastward). The "polar" substorms are those substorms that recorded at the geomagnetic latitudes above 70° MLAT under the absence of negative magnetic bays at the lower latitudes. Like the "classical" substorms, the "polar" substorms are accompanied by aurora brightening, poleward expansion, substorm current wedge formation. Onsets of "polar" substorms are typically located near 70° MLAT at ~19-23 MLT. This MLT sector is common area of the HD development. The aim of our work is to study a possible relationship between the "polar" substorm onsets and the HD location. Our study of about 250 "polar" substorms, recorded at IMAGE magnetometer profile in 2010-2020, revealed the tendency of these substorms to occur near the HD location, detected by the AMPERE measurements at the 66 ionospheric satellites. It was found that in the case of the "polar substorm", the Harang reversal was observed at higher latitude then during the "classical" substorm. That explained why the strongest amplitudes of lower-latitude positive magnetic bays, accompanied "polar" substorms, are recorded not at middle, but at subauroral latitudes. Near the eastward edge of the HD, we found a magnetic vortex associated with FACs enhancement separated the evening "polar" substorms and after-midnight westward electrojet. Some individual events of the "polar" substorms are discussed.

Role of the Varying Solar Wind in Properties of the Magnetosheath Turbulence

Rakhmanova L., Riazantseva M., Khokhlachev A., Yermolaev Yu.
Space Research Institute of the Russian Academy of Sciences

Magnetosheath is a link between the solar wind and the magnetosphere. Properties of turbulent solar wind plasma change substantially at the bow shock. Among others, these changes include modification of the properties of the turbulent cascade. Recent experimental studies demonstrated evolution of the turbulence properties when plasma moves away from the bow shock. Moreover, some of the studies indicate differences in the turbulent cascade development for different conditions in the solar wind which are determined by different large-scale solar wind phenomena such as ICMEs or CIRs. The magnetosphere response is known to be different for the various large-scale solar wind phenomena. That is, special ways of turbulence evolution in the magnetosheath for different conditions in the solar wind may contribute to the solar-terrestrial relations and should be taken into account for development of realistic models of the space weather.

Present study considers properties of the turbulence at different locations inside the magnetosheath for different types of the solar wind. The study bases on statistics of fast (32 points per second) measurements of ion flux on board the Spektr-R spacecraft and fast (4 vectors per second) magnetic field measurements by the Themis spacecraft. The results reveal different scenarios of turbulence evolution in the magnetosheath for disturbed and undisturbed solar wind streams and peculiarities in magnetosheath turbulence features for compressed solar wind streams.

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The Optimum Solar Activity Proxy for Long-Term Studies of foF2

Lastovicka J.
Institute of Atmospheric Physics CAS

To model ionospheric climate and to study its long-term changes and trends we need solar activity proxies, because long and homogeneous data series of solar ionizing flux are not available. To identify the optimum solar activity proxies, we use yearly average foF2 data of six ionospheric stations from latitudes of four continents over 1976-2014 and six solar activity proxies, F10.7, sunspot numbers, F30, Mg II, He II and solar Lyman-α flux. For middle latitudes F30 followed by Mg II are found to be the optimum solar proxies, not the usually used F10.7 or sunspot numbers. Solar activity describes 99% of the total variance of yearly foF2 at midlatitudes; foF2 dependence on solar proxies is highly linear. Only F30 has the same relationship to foF2 in 1976-1995 and 1996-2014. Long-term trends in foF2 appear to depend on solar proxy used; various solar proxies provide somewhat different trends. The results are derived for yearly average values but probably are valid also for monthly median values.

Intense Mid-Latitude Magnetic Disturbances and Solar Wind Conditions

Lubchich A.A.[1], Despirak I.V.[1], Werner R.[2]
[1]Polar Geophysical Institute, Apatity, Russia;
[2]Space Research and Technology Institute, Bulgarian Academy of Sciences, Stara Zagora Department, Bulgaria

The purpose of this work is to find out the solar wind conditions under which high values of magnetic disturbances at the middle latitudes are observed. The intensity of magnetic disturbances was determined according Midlatitude Positive Bay (MPB) index proposed by McPherron and Chu, 2017. The list of the MPB index dating back to 1991 and can be found in the supplementary information for the online version of McPherron and Chu, 2018. Calculations of MPB index is based on data from 41 stations in the northern and southern hemispheres (from 20° to 52°). In additional, for several selected events, we analyzed the variations of horizontal component of magnetic field at the mid-latitudes stations (including the Panagurishte station in Bulgaria). The study of the magnetic disturbances was based on the data from the magnetometer networks SuperMAG, INTERMAGNET and IMAGE. The solar wind conditions before the substorms were determined using the CDAWeb OMNI database (http://cdaweb.gsfc.nasa.gov/), the solar wind structures were determined according to the catalog of large-scale solar wind phenomena (ftp://ftp.iki.rssi.ru/omni/). It was found the dependences of occurrence of high values of MPB index on solar wind parameters (components of the interplanetary magnetic field, solar wind velocity, density, dynamic pressure etc.). Several examples of very intensive events are discussed. This study was supported by the RFBR (project number 20-55-18003) and National Science Fund of Bulgaria (NSFB) (project number КП-06-Русия/15).

Short Period Variations of the Parameters of Ionospheric Scintillations on the Long-Time Obsrvations of the Cosmic Radio Sources at the Decametric Radio Waves

Panishko S.K., Lytvynenko O.A.
Institute of Radio Astronomy of NASU

On the observations of the power cosmic sources at the radio telescope URAN-4 (working frequencies 20 and 25 MHz) long-time rows of ionospheric scintillation parameters such as index, characteristic time and spectral index of the intensity fluctuations were obtained. As shown earlier yearly mean values correlate with indices of solar and geomagnetic activity, monthly mean estimations have well expressed seasonal-daily dependence. In this work the behavior of daily mean values of index and spectral index of the ionospheric scintillations during multiply solar cycles were analyzed. These values were compared with geomagnetic Ap-index and solar flux at the wavelength 10.7 cm. Daily mean estimations of the ionospheric parameters show significant variability but also they are regulated by processes in the ionosphere that caused geomagnetic activity. Investigation of the relationship between several of the cosmic weather indicators allow to clarify the mechanisms of the formation of ionosphere irregularity structure that including caused the ionospheric scintillations.

On the Variability of Dynamical Complexities of Space Environment with Solar Cycle

Rabiu A.B.[1,2], Ogunjo S. T. [3], Fuwape I. A.[3,4], Obafaye A. A.[1]
[1]United Nations African Regional Centre for Space Science and Technology Education - English;
[2]Institute of Space Science and Engineering, African University of Science and Technology, Abuja, Nigeria;
[3]Department of Physics, Federal University of Technology, Akure, Ondo State, Nigeria';
[4]Michael and Cecilia Ibru University, Ughelli, Delta State, Nigeria

We examined the variability of the dynamical complexities of the space environment using the hourly Dst values over four solar cycles (1964–2008) using nonlinear methods: sample entropy, Lyapunov exponents, correlation dimension, recurrence quantification analysis, and multifractal detrended fluctuation. The space environment was observed to be chaotic based on Lyapunov exponents obtained. The order of increasing complexity in the solar cycles based on recurrence rate (RR) values is Cycle 21 < 22 < 23 < 20. Similar patterns and trend were observed in the correlation dimension values for the different solar cycles. The peak of each solar cycle is associated with high chaoticity. In all the analysis considered, high values of sample entropy, Lyapunov exponent, correlation dimension, correspond to increasing chaoticity. However, lower value of RR signifies more chaotic activity. The solar cycle 20 with the greatest values of mean sunspot number (651.62) and standard deviation of sunspot number (1,656.90) has the greatest chaoticity. The chaoticity in the magnetosphere increases with increasing geomagnetic activity as captured by Dst index. Similar trends were not observed in BZ and solar wind dynamic pressure which showed that the observed chaoticity is due to internal variations. The multifractal spectrum of Dst at all solar cycles considered revealed that the chaotic activities in the magnetosphere are not influenced by the local fluctuations in the region

Geomagnetically Induced Currents During Different Types of Solar Wind

Setsko P.V.[1], Despirak I.V.[1], Sakharov Ya.A.[1], Bilin V.A.[1], Lubchich A.A.[1], Selivanov V.N.[2]
[1]Polar Geophysical Institute, Apatity, Russia
[2]Northern Energetics Research Centre KSC RAS, Apatity, Russia

Relationship between geomagnetic activity and increasing of geoinduced currents (GICs) were studied during an extremely active space weather period – September 2017. To analyze which magnetic disturbances led to the enhancement of GIC we considered four time interval connected with various types of the solar wind (Magnetic Clouds, CIRs, sheaths, High Speed Streams), which caused magnetic storms of different intensity (SYM/H ~ -65 – -150 nT). During these magnetic storms were registered several substorms from moderate to very intense (supersubstorms). We analyzed the grow of westward electrojet using the latitudinal profiles of the IMAGE network and the equivalent currents of the MIRACLE system data. GICs were monitored by EURISGIC data from Russian stations Vykhodnoy (VKH), Revda (RVD) and Kondopoga (KND) in the North-West of Russia (eurisgic.ru) and station Mäntsälä (MAN) in the South of Finland. The data from these stations are convenient for tracking the GIC from subauroral to high latitudes (~60° to ~69° geographical latitudes). Taking into account that substorms are the main source of magnetic disturbances in the auroral zone, such position of GIC stations makes it possible to compare them with the motion of an electrojet to the pole during the expansion phase of a substorm. It is shown that events of GICs growth on September 2017 were connected with an increasing and an expansion of the westward electrojet during substorm expansion and sometimes with Pc5 pulsations observed at the recovery phase of substorms. This study was supported by the RFBR (project number 20-55-18003 Bulg "a") and National Science Fund of Bulgaria (NSFB) (project number КП-06Русия/15).

Data Proccessing and Modelling

Possible Method for Determining Direction of Motion of Coronal Mass Ejections

Roša D.[1], Skokić I.[1,2], Hržina D.[1], Maričić D.[1], Šterc F.[1], Romštajn I.[1]
[1]Zagreb Astronomical Observatory, Zagreb, Croatia;
[2]Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia

This article presents a possible method of determining the direction of motion of a coronal mass ejection (CME) by measuring the secular (perspective) acceleration and radial velocity. The method is already used in stellar astronomy for measuring the proper motions of stars. In solar physics the direction and propagation of CMEs is one of the most discussed topics in space weather phenomena. Using the appropriate methodology is crucial for finding different approaches to estimate the direction and position of Earth directed CMEs.

Do Global-Scale MHD Modes of the Ionosphere Exist and How?

Nenovski P.[1], Shkevov R.[2]
[1]Independent researcher,
[2]Space research and technology institute - Bulgarian academy of sciences

Recently, ionospheric signatures of Ultra-Low-Frequency (ULF) waves in the Pc3–5 band (1.7–40.0 mHz) have been well established by different facilities (both ground-based and satellites). Including, Pc3-5 and Pi2 pulsation spectral, amplitude, polarization, and phase characteristics changes in latitude, longitude and associated plasma parameter variations. There are quite a few cases when i) these pulsations exist simultaneously at high-, mid- and low latitudes; ii) appear unrelated to previously alleged relationships, as solar wind parameters (Pc3, Pc4), the substorm current wedges (Pi2), etc. Close coincidences in frequency of their amplitude peaks, absence of correlations with the solar wind changes and alleged magnetospheric processes as well as other evidences however, led to an idea of global-scale MHD modes of some internal origin. We extend our recent finding of MHD modes of the ionosphere considering their characteristics (electric and magnetic field structures) above and below the ionosphere

Analysis of Possible Locations of the Relativistic Sources of Resonance Particles in the Inner Heliosphere Space

Shkevov R.[1], Zolnikova N.[2], Mikhailovskaya L.[2]
[1]Space and Research and Technology Institute, Bulgarian Academy of Sciences;
[2]Space Research Institute, Russian Academy of Sciences

The work analyzes the possible locations of time-dynamic resonance sources of relativistic particles in the inner space of the heliosphere. On the basis of theoretical calculations for resonant acceleration of charged particles in a calm plasma in the presence of a transverse weak permanent magnetic field, the initial and maximum values of the energies, reached during the acceleration process were determined. The calculations are realized through numerical experiments based on a nonlinear, nonstationary second order differential equation for the phase of the accelerating wave on the particle's trajectory under the conditions of Cherenkov resonance. The analysis is based on the comparison between the simulation results in the meridional plane of the Boston university 3D models and the Moscow model of the heliosphere for the presence of potentially suitable spaces for the realization of resonant acceleration. Conclusions are made about possible locations with calm homogeneous plasma and sources of relativistic resonance particles, placed in the inner heliosphere space were drawn.

Application of Extreme Value Theory to Describe the Statistical Distributions of the Auroral Electrojet IL Index

Werner R.[1], Guineva V.[1], Despirak I.[2], Lyubchich A.[2], Bojilova R.[3], Raykova L.[1], Atanassov A.[1], Valev D.[1]
[1]Space Research and Technology Institute (SRTI) – Bulgarian Academy of Sciences, Stara Zagora Department, Bulgaria;
[2]Polar Geophysical Institute (PGI), Apatity, Russia;
[3]National Institute of Geophysics, Geodesy and Geography (NIGGG) - Bulgarian Academy of Sciences, Sofia, Bulgaria

The occurrence of magnetic substorms and their activity have been described with the help of extreme value distributions in the last few decades using global auroral electrojet indices as AE, AL and AU. The geomagnetic substorm activity over Northern Europe is related to the westward auroral electrojet over this region. The magnetic network IMAGE provide an indicator - the auroral electrojet IL index - of the westward currents crossing the region over northern European stations of the magnetic network. Here the probability distribution function (PDF) and the cumulative distribution function (CDF) of the IL index were estimated and by help of the calculated occurrence rate the extremal value of the IL index was determined. The distributions of magnetic disturbances, based on IL, were studied separately in the morning, day, evening and night sectors. In addition, we used the values of the IL index calculated from the meridional chains in the auroral zone (PPN-SOR) and from the chain of stations at high latitudes (BJN-NAL). More over the CDF and the PDF were calculated for events with strong magnetic disturbance (IL<200 nT) in cases with and without accompanying midlatitude positive bays (MPB's), observed at the Bulgarian Panagjurishte station. It was shown that all distributions were fitted well by extreme value Weibull distributions. In the different magnetic time sectors three classes were discovered, which differ significantly by their own distribution parameters.

This study was supported by the National Science Fund of Bulgaria (NSFB) (project number КП-06-Русия/15) and by the RFBR (project number 20-55-18003Болг_а).

Long Time Trend in Total Ozone Column by MRS2 Overpass Data for Sofia for 1979-2022 Based on Ordinary and Weighted Linear Regression

Werner R.[1], Guineva V.[1], Valev D.[1], Petkov B.[2], Bojilova R.[3], Kirillov A.[4]
[1]Space Research and Technology Institute (SRTI) – Bulgarian Academy of Sciences, Stara Zagora Department, Bulgaria;
[2]Institute of Polar Sciences, National Research Council (CNR), Bologna, Italy;
[3]National Institute of Geophysics, Geodesy and Geography (NIGGG) - Bulgarian Academy of Sciences, Sofia, Bulgaria;
[4]Polar Geophysical Institute (PGI), Apatity, Russia

Trend determination of total ozone columns is an important tool to observe the ozone recovery process. Here the Multi Sensor Re-analysis version 2 (MSR-2) overpass data for Sofia from 1979 to 2022 were analyzed using monthly means. The time series was deseasonalised by consideration of the first Fourier coefficients and by the determination of epoch means. Trends were calculated using multiple regression models including explanatory variable as the ultraviolet solar flux, the volcano aerosol loading, variations caused by the Elniño-Southern Oscillations and the Quasi-biennial Oscillations. To determine the regression coefficients linear regressions were performed based on ordinary least squares (OSL) and weighted least squares (WLS) for the whole time interval and for the interval after the mid-nineties. In different studies a change of the global total ozone trend was found after the middle of the 1990-ies. Here a linear trend for the whole time period 1979-2020 was obtained by a regression based on OSL of -2.9 DU/decade and using WSL -2.3 DU/decade. However, the quadratic time terms are highly significant. For the time interval after 1995 no significant trends were found out. The obtained here results were compared with the ones resulting from measurement of total ozone at Stara Zagora for the last eight years. The Stara Zagora ozone series were homogenized using OMI-Aura satellite TO3 gridded ozone data.

Instrumentation for Space Weather Monitoring

Penetration of Energetic Electrons from Outer Radiation Belt to Lover L-Values and to Inner Radiation Belt

Dachev T.[1], Tomov B.[1], Matviichuk Y.[1], Dimitrov P.[1], Semkova J.[1], Koleva R.[1], Jordanova M.[1], Bankov N.[1], Mitev M.[1]. Krastev K.[1], Malchev S.[1], Reitz G.[3], Header D.P.[4]
[1]SRTI-BAS, Sofia, Bulgaria
[2]DLR, Köln, Germany
[3]Möhrendorf, Germany

R3DR2 instrument was situated outside the Russian segment of the International Space Station (ISS) and inside the ESA EXPOSE-R2 facility in the period November 2014 - January 2016.

We start to observe penetration of the relativistic electrons below L=2.5 in the recovery phase of the magnetic storm after 18 March 2015. In the period March 18-28 2015, the lower boundary of L=1.8 was reached. The relativistic electrons at the low L disappeared on March 28th 2015.

The magnetic storm on 25th June 2015 generated again relativistic electrons fluxes from the Outer Radiation Belt (ORB) at the L values below 2.5. The ORB enhancement on July 4th 2015 emphasised them again. In this specific case the minimal L values reached L=1.6. Almost all disturbances in the Dst from July 11th, 2015 until January 1st, 2016 generated a new portion of relativistic electrons in the L-values below 2.5. They existed for few days and disappeared until the next Dst disturbance.

LOFAR-BG - Current state

Dechev M., Kozarev K.
Institute of Astronomy and NAO, BAS

LOFAR means Low Frequency Array or a kind of radio telescope in frequencies between 10 - 240MHz. Building and maintaining a LOFAR-BG station will provide Bulgarian scientists with a number of unique scientific advantages. LOFAR-BG is part of the National Research Infrastructure Roadmap 2020. We are currently working on preparing for the station (near NAO Rozhen).

Here we present the project LOFAR-BG and its current state.

Numerical Simulation of the Liulin-Mo Device

Krastev Kr., Semkova J., Koleva R., Benghin V., Drobijshev S.
SRTI-BAS

In this work we present the results of numerical simulation of the Lyulin-MO dosimeter onboard Trace Gas Orbiter (TGO) of ExoMars-2016 mission to Mars using the Geant4 package. A comparison is made between the BO20 model and the real data. The contribution of the individual components of the spectrum of galactic cosmic rays is estimated. The specific period under consideration is the flight to Mars of the ExoMars-2016 mission.

Solar Influences on the Lower Atmosphere and Climate

Common cycles of solar activity and Antarctic Oscillations

Chapanov Ya.
Climate, Atmosphere and Water Research Institute, Bulgarian Academy of Sciences

The Antarctic Oscillations (AO) are connected with various regional and global climatic event. These oscillations are important to study recent climate change and to improve our knowledge about the climate dynamics. The main sources of these oscillations are the influence of solar activity on climatic variations and global warming. The solar activity affects climatic processes by the Total Solar Irradiance (TSI) variations, solar wind and solar magnetic field. The solar magnetic field and solar wind modulate the variations of heliosphere, geomagnetic field and cosmic rays, whose effect on atmosphere and climate is stronger on high-latitude polar regions. The cycles of solar magnetic field are connected with the North-South (N-S) solar asymmetry of sunspots. The solar influence on Antarctic Oscillations are analyzed by centennial time series of TSI and N-S solar asymmetry. The Antarctic Oscillations are represented by the time series of Southern Annular Mode (SAM) since 1850. The Common cycles of solar activity and Antarctic Oscillations are determined by the Method of Partial Fourier Approximation (PFA). Various common solar and atmosphere cycles in narrow frequency bands are detected, whose periodicity is between 3 and 80 years. This result may help to divide natural solar from anthropogenic effect in recent global warming and to improve scenario of future climate change.

Solar Activity and Climate Change Recorded in Korean Chronicles During the Last Millennium

Yang H.-J.[1], Park C.-G.[2], Kim R.-S.[1], Cho K.-S.[1], Jeon J.[3]
[1]Korea Astronomy and Space Science Institute;
[2]Chonbuk National University;
[3]Chungbuk National University

Korean chronicles have a large amount of observational records of natural phenomena, including astronomical and meteorological events over two thousand years. Here we examine the correlation of solar activity and climate change from historical sunspot and frost records in the Korean chronicles. There are 42 sunspot records in Goryeo Dynasty (918–1392 CE) and 13 records in Joseon Dynasty (1392–1910 CE). The sunspot records in

Goryeo Dynasty show a periodicity in good agreement with the well-known solar activity of 11 years. Korean sunspot records suggest that the solar activity in Joseon Dynasty decreased compared with that in the previous ∼500 years. In order to examine the long-period variation of solar activity, we include Chinese historical sunspot records in our analysis to supplement the lack of Korean records, and find a new ∼240-yr long-period

solar activity from the power spectral analysis. Korean chronicles also have about 700 frost records during the last millennium. We investigate these frost records and find a sign of cooling down that can be interpreted as climate change during the last millennium. We also find ∼240-yr cooling period from the historical frost re-cords, which is well in accord with that of solar activity. Therefore, we conclude that the solar activity has decreased during the last one thousand years and also has a long-term variation of ∼240 years."

In this review We will describe its above mentioned agents, and explain the suggested mechanisms by which they influence the atmosphere and climate. We will present observational evidences of such influences, highlight the recent advances, and the still unsolved questions and uncertainties.

Solar Activity Influences on the Polar Vortex

Georgieva K.[1,2], Kirov B.[1], Veretenenko S.[3]
[1]Space Research and Technologies Institute, Bulgarian Academy of Sciences, Bulgaria
[2]Climate, Atmosphere, and Water Research Institute, Bulgarian Academy of Sciences, Bulgaria
[3]Ioffe Institute, Russian Academy of Sciences, Russian Federation

One of the main problems in solar-atmospheric influences is the temporal variability of the correlations found between solar activity and characteristics of the atmosphere. In earlier studies it has been found that the sign of the correlations depends on the strength of the stratospheric polar vortex - a large-scale circulation pattern in the stratosphere which develops during polar winter and which can impact the tropospheric circulation patterns, including the position and intensity of the jet stream. We study the long-term evolution of the two main manifestations of solar activity and the influences of each of them on the solar vortex. We find the variations in the intensity of the polar vortex are related to the changing relative impact of the geoeffective solar activity drivers.

Ionospheric Effects of Mesoscale Cyclone Zyprian on the Ionospheric Variability over Europe

Koucká Knížová P.[1], Potužníková K.[1], Podolská K.[1], Kouba D.[1], Mošna Z.[1], Chum J.[1], Barta V.[2], Szárnya C.[2], Berényi, K.A.[2], Buzás A.[2], Bozsó I.[2]
[1]IAP CAS, Czechia;
[2]ELKH EPSS, Hungary

Mesoscale systems are effective sources of atmospheric disturbances that can reach ionospheric heights and significantly alter atmospheric and ionospheric conditions. Certain part of the generated waves is capable to travel through the atmosphere and reach the ionospheric heights. The resulting effects induced within ionospheric plasma are caused by primary and/or secondary waves. Moving frontal systems are recognized to effectively launch atmospheric waves. Convective systems could affect Earth's atmosphere on a continental scale and up to F-layer heights. In the contribution we will focus on ionospheric disturbances caused by severe Mesoscale system Zyprian that occurred at the beginning of July, 2021. Variability within the ionosphere are attributed mainly to the Zyprian cyclone as it developed during low geomagnetic activity and stable solar forcing. Zyprian dominated weather above Western Europe. Large frontal border was characterized by high temperature drop with strong cyclogenesis. Frontal boundary moved rapidly across Europe. High wind gusts were recorded. Heavy rains caused large damages, especially in Germany. Within the stratosphere, a shift of polar jet stream was observed. At the ionospheric heights irregular stratification and radio wave reflection planes undulation was observed. Our study involves European DPS-4D digisondes in order to analyze time evolution of the Zyprian induced variability.

Study of Ground Level Electric Field Response to Solar Eclipses

Michnowski S.[1], *Kobylinski Z.*[2]
[1]Institute of Geophysics, Warszawa, Poland;
[2]High School of National Economics, Kutno, Poland

We present in this paper results of two our measurements of the atmospheric electric field the at ground level during solar eclipses: in Polish geophysical Observatory Swider 30 Jun 1954 realized by Michnowski and in Manavgat Turkey on 29 Mar 2006 executed by Kobylinski. We compare the results with some other measurements. During the eclipse Ez and variance have became decreased. The obtained plots enter in to the whole twenty-four hour Carnegie curve. Our discussion is based on the idea of the global circuit.

Forcing Energetic Particles on the Middle Atmosphere During Geomagnetic Disturbances

Mironova I.
St. Petersburg State University

In this paper, we compared the spectra of precipitating energetic electrons in the range from tens of keV to relativistic energies of more than 1 MeV, based on observations in the high-latitude atmosphere on balloons and precipitation of energetic electrons recorded by the NOAA POES satellites in 2003. Here we estimate the spectra and ionization rates of the atmosphere during precipitation of energetic electrons, obtained from different observations, in different periods of geomagnetic disturbances.

The work was carried out at the ""Laboratory for the Study of the Ozone Layer and Upper Atmosphere"" with the support of the Ministry of Science and Higher Education of the Russian Federation under contract No. 075-15-2021-583.

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Ground-Based Monitoring of Cosmic Particles (Neutrons) and Space Weather

Petrov N.[1], Tsvetkov Ts.[1], Tyutyundzhiev N.[2], Semkov E.[1], Mishev A.[4], Shirov G.[1], Zinkova Y.[1], Mutafov A.[1], Nichev H.[2], Petrov M.[2], Angelov H.[3], Arsov T.[3], Serafimov N.[3], Georgiev G.[3]
[1]Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences
[2]Institute of Electronics, Bulgarian Academy of Sciences
[3]Institute of Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences
[4]University of Oulu, Finland

During the various cosmic events, including supernova explosions, star formation processes, collisions or strong accretion processes in stars and black holes, etc., photons (light) covering the entire electromagnetic spectrum and high-energy particles (called cosmic rays) are released, with energies from tens of eV to thousands of GeV. Cosmic rays (CRs) consist of mainly protons (about 90%), atomic nuclei (primarily helium), as well as free electrons propagating in space with speed close to the speed of light. Of course, the diverse energy spectrum of CRs also includes high-energy particles that are product of solar activity processes.

On the one hand, the answer to the nature and physics of these questions is directly related to the continuous monitoring of various manifestations of solar activity, such as sunspots, solar prominences, solar flares and coronal mass ejections. But on the other hand, the possibility of continuous observational series of data has opened up new fields of scientific debate with increasing attention being paid to small-scale structures and short-living manifestations of solar activity. They turn out to have a significant role in a global interconnection with all other members of the Solar system, including our planet Earth. Solar activity and the resulting solar radiation, together with the total cosmic radiation, appear to be the main cosmic factors influencing the Earth's global climate.

Summer Tropospheric Mesoscale Situations with Impact on the Ionospheric Plasma

Potužníková K., Koucká Knížová P., Chum J., Podolská K., Kouba D., Mošna Z.
Institute of Atmospheric Physics CAS, Prague, Czech Republic

As we have already shown in our recent studies, tropospheric dynamics may significantly influence atmosphere up to the ionospheric heights. The atmospheric waves that propagate upwards to the ionosphere tend to be triggered both by synoptic patterns of continental dimensions, such as large-scale pressure lows and highs, horizontally extensive atmospheric fronts in the low troposphere, or high-altitude polar front, and by mesoscale phenomena.

Convective storms form during sunny hot summer days. Their occurrence tends to increase in central Europe in recent decades. These storms can reach mesoscale dimensions and induce oscillation effects detectable as high as in the ionosphere. In our study, we focus on the meteorological synoptic conditions and the convective environment giving rise to these storms. We will distinguish between frontal storms, that is, storms at the moving interface of two air masses with very different temperatures, and storms produced by thermal convection inside an unstable air mass which is filled with hot and humid air.

In our study, we use available model analyses of the pressure fields of different tropospheric layers, radiosonde measurements of the tropospheric profile, and ground-based measurements from the IAP weather station. We identify common ionospheric reflection pattern associated with specific tropospheric situations within digisond DPS-4D data and Continuous Doppler Sounding time series. We introduce effective tool for detection of height and frequency dispersion in the ionograms recorded by the digisonde DPS-4D using an original model based on a convolutional neural network coded in python with the help of the tensorflow library.

Hypothetic Atmospheric Response to SEP Explaining Peculiar Electric Fields and Currents at High Latitudes

Tonev P., Asenovski S.
STIL-BAS

Experimental studies of the electric fields and currents in the stratosphere and at surface at high geomagnetic latitudes during strong solar proton events (SPE) accompanied by GLE demonstrate systematical and well expressed peculiarities. Essentially, these are strong (more than 100%) and long-lasting (hours) deviations of the vertical electric current Jz from the fair-weather current. The deviations include an increase of Jz on the first phase of SPE, as well as reversals of Jz on its later phase: these cannot be explained by the theory of the global atmospheric electric circuit (GEC). A hypothetical reaction of the middle atmosphere to SPE is proposed here to explain these peculiarities. The respective mechanism takes into account not only the process of enhanced ionization in middle atmosphere at polar and high latitudes caused by the flux of energetic solar protons, but also a process of creation of aerosol particles which has been observed in a series of experimental studies. While the first process leads initially to increase of conductivity, the second one can cause strong conductivity decrease later. As a result, significant redistribution of electric fields and currents in GEC occurs which can explain the peculiar variations observed. Simple estimations are given to confirm the hypothetical mechanism.

Solar Activity Influences on Extratropical Cyclone Trajectories in the North Atlantic

Veretenenko S., Dmitriev P.
Ioffe Institute, St. Petersburg, Russia

In this work we continue studying long-term variability of the main trajectories of extratropical cyclones (storm tracks) in the North Atlantic, basing on the data of MSLP (Mean Sea Level Pressure) archives from Climatic Research Unit, UK (1873-2000) and NCEP/DOE AMIP-II Reanalysis (1979-2021). It was revealed that in the cold half of the year (October-March) the average latitudes of cyclones passing over the longitudes from 60ºW to 10ºW undergo oscillations with the periods of about 80-100, 40-47 and 22 years, which indicates their possible connection with solar activity. Cyclone trajectories were found to be shifted to the south at the maximum of the secular Gleissberg cycle and to the north at its minimum, with the peak-to-peak amplitude of the secular variations reaching 5º in the western North Atlantic. Since 1960s, at the descending branch of the secular cycle, cyclone trajectories have been shifted to the north again. On the bidecadal time scale, a northward shift of storm tracks was revealed in even-numbered solar cycles, the effect being the most pronounced (1-2º) in the eastern North Atlantic. The detected oscillations of cyclone trajectories indicate long-term changes in the position of the polar jet stream, which is closely associated with the state of the stratospheric polar vortex. A possible mechanism of solar influences on the polar vortex intensity involves ionization changes due to energetic charged particles (galactic cosmic rays and auroral electrons), which affect the chemical composition and temperature regime of the polar atmosphere.

Solar Effects in the Biosphere and Lithosphere

Geoelectric Field over Romanian Territory during the Strongest Geomagnetic Storms of Solar Cycle 24

Dobrica V., Demetrescu C., Stefan C.
Institute of Geodynamics, Romanian Academy

The surface geoelectric field, the geophysical input in assessing ground space weather impact of geomagnetically induced currents (GICs), associated to geomagnetic variations over Romanian territory during strongest magnetic storms of the solar cycle 24 (2008-2019) is analysed. Using the plane wave approximation for the depth propagation of the geomagnetic disturbance recorded at the Surlari (SUA) geomagnetic observatory and information regarding the underground electric conductivity, the spatial variability of the maximum value of the geoelectric field vector has been determined. A comparison to geomagnetic observatories (GCK and PAG) within region is done as well, even though the risks produced by the space weather hazard in the countries from middle latitudes might seem small, their are important to be studied.