T H I R T E E N T W O R K S H O P

Solar Influences on the Magnetosphere, Ionosphere and Atmosphere

Primorsko, Bulgaria, September 13÷17, 2021

SPACE RESEARCH AND TECHNOLOGY INSTITUTE
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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
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ФОНД НАУЧНИ ИЗСЛЕДВАНИЯ
МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА

The present workshop is organized with the support of the Bulgarian National Science Fund, grant No КП-06-МНФ/47

DOI: 10.31401/WSoz.2021.abs

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Analyse of Ionospheric and Geomagnetic Pre -earthquake Anomalies

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Aiming at earthquake precursors apportionment the earthquake preparation display of VARDENIS (Armenia, 29.04.2008, M=3.7) BORISAKHO (Georgia, 09.06.08, M =4.1), NAKHITCEVAN (Azerbaijan, 02.09.2008, M=5.1), earthquakes in time-series have been studied using the geomagnetic and ionospheric tools. Aiming at earthquake forecasting the anomaly in the ionosphere plasma is investigated by a radio-astronomical method. 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.

The Duration of High Speed Solar Wind Stream

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This research investigates the behavior of the high-speed solar wind streams (HSS) with reference to determine their time duration. While the beginning of an HSS can be considered well defined based on the main solar wind parameters, such as solar wind speed, temperature, magnetic field, etc., the question related to the end of this phenomenon is not clarified. In this work the possible introduction of new criteria related to the solar wind parameters characterizing evidence of HSS ending will be discussed.

First Flare M 1.9 AR 10365: Comparing Results Real-Scale Time MHD Modeling and Observational Data

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As shown by the first results of MHD modeling in real scale of time over active region 10365: the maximum current density appeared before the first flare of M 1.9 (05/26/2003 05:34) in the neighborhood of a X-type line of magnetic field with overlaid extensive diverging magnetic flux (magnetic trap field) at a height of about 18,000 km (in the solar corona). This diverging magnetic field hinders the formation of the current sheet in the neighborhood of a X-type line. Nobeyama (NoRH 17 GHz) and SOHO data confirms the appearance of the flare source M 1.9 at the heights of the solar corona. Since neighborhood of a X-type line is presented clearly in coronal ultraviolet spectral lines Fe IX / X, FE XII, Fe XV (SOHO / EIT 171A, 195A, 284A), the authors suggest possible formation of current sheets stretched in height from the lower corona and above. Possibly the current sheet can appear at height above 18,000 km (NoRH 17 GHz data).

The accuracy of MHD modeling in real scale of time is significantly higher than those previously performed by the authors in MHD simulation in strongly reduced (in 10,000 times) scale of time (Podgorny IM, Podgorny AI, 2019).

Simultaneous Observations of Solar Radio Bursts with Ukrainian Radiotelescopes and by Parker Solar Probe During its Encounter

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The analysis of solar radio bursts observed by the Parker Solar Probe (PSP) and their interpretation are of great interest. In the encounter phase the space-based instrument has the time resolution about 7 sec in the frequency range of 10 kHz - 19 MHz. However, this is not enough to recognize a fine structure of solar bursts, especially in high frequencies. It is useful for understanding intrinsic properties of emission mechanism in the solar corona. The problem can be overcome (partially or completely) by simultaneous ground-based observations using more advanced antennas and receivers. In this context the Ukrainian radiotelescopes are very useful, because they record solar radio emission at extremely low frequencies, near the ionospheric cutoff. We detect directly the radio events, observed by PSP, having the frequency range that intersects with the frequency band of our instruments. This allows us to discover solar phenomena in the corona reliably and confidently.

Geomagnetic Data as a Source of Information on Past Evolution of the Solar Activity/Space Climate

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It is common knowledge that during geomagnetic storms the horizontal component (H) recorded by geomagnetic observatories is depressed; this is not compensated by increased values during the recovery phase, so at the solar maximum, characterized by large and numerous geomagnetic storms, H annual means are lower than in the descending phase of the solar cycle, with less and weaker storms. As a consequence, H annual means time series bear a solar cycle component. This should also happen as regards other well-known oscillations in the solar activity, namely the magnetic, Hale and the long, Gleissberg cycles. If not eliminated from input data before constructing main field geomagnetic models, residual external variations leak in these models. We`ll show the presence of oscillations at three time scales, `sub-centennial` (60-90 years), `inter-decadal` (20-30 years), and `decadal` (~11-year), in time series of long-operation geomagnetic observatories and in the long timespan main geomagnetic model gufm1, by means of a Hodrick-Prescott analysis, that separates in data a cyclical oscillation (`decadal`) from a `trend`, followed by a Butterworth filtering of the `trend` to infer information on the other two oscillations at larger timescales. Such information is then compared to Schwabe, Hale, and Gleissberg solar activity cycles, as detected in parameters that illustrate it (sunspot number, reconstructed heliospheric magnetic field, reconstructed solar wind parameters, reconstructed total solar irradiance etc), concluding that the space climate can be characterized back to cca 1600, including information on the two grand minima of the solar activity (Maunder and Dalton), using available geomagnetic data.

Solar Activity Variations Characterised by Spectroscopic Proxies and Excess Brightness Indices

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The Potsdam Echelle Polarimetric and Spectroscopic Instrument (PEPSI) is a state-of-the-art, thermally stabilized, fiber-fed, high-resolution spectrograph for the Large Binocular Telescope (LBT) at Mt. Graham, Arizona. It can be fed with sunlight from the Solar Disk-Integrated (SDI) telescope. Synoptic solar observations with PEPSI/SDI produce daily spec-tra with high signal-to-noise ratio, providing access to unprecedented, quasi-continuous, long-term, disk-integrated spectra of the Sun with high spectral and temporal resolution. Theobserved spectra contain a multitude of photospheric and chromospheric spectral lines in the wavelength range of 380 – 910 nm. Strong chromospheric absorption lines, such as the CaiiH & K lines, are powerful diagnostic tools for solar activity studies, since they trace thevariations of the solar magnetic field. Derivation of activity indices, such as the CaiiH & Kemission ratioS-index provides insight into the chromospheric magnetic field and its variabi-lity over the solar activity cycle. The well known relation between solar calcium indices andUV flux variations motivates us to compute an excess brightness indices from CaiiK full-disk images from of the Chromospheric Telescope (ChroTel) at the Observatory del Teide onTenerife, Spain and UV data of the Solar Dynamics Observatory (SDO). We present a setof indices representing magnetic activity at various heights in the solar atmosphere. In thepresent work, we carefully compare the indices computed from various datasets and discussthe differences in terms of physical and observational properties.

On the Correlation Between EUV Solar Radiation Proxies and Their Long-Term Association

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EUV solar radiation proxies, in particular monthly mean Mg II, Lyman alpha flux, F10.7 and Rz, are analyzed during the period 1979-2020. Their variability is compared through a correlation analysis and also through their role in ionospheric parameters filtering. The linear correlation along the whole period analyzed is greater than 0.95 between each pair of solar proxies but, when sub-periods are considered, this value decreases markedly during maximum and minimum solar activity levels. This result may be due to the random noise part of each series as we show it through a "statistical experiment". Their sensitivity to solar activity variation is analyzed as well, together with their hysteresis along a solar activity cycle considering the geomagnetic activity effect along the different cycle phases.

Criteria for Identification of Geoeffective Solar Events

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"Space weather" is defined as conditions in the interplanetary and near-Earth space that can affect the performance and reliability of space-borne and ground-based technology, as well as human life and physiological conditions. It is well known that the drivers of space weather are geoeffective solar transients propagating from the Sun to the Earth. These drivers have different characteristics and different effects on the Earth. Various authors have proposed different criteria to identify these solar activity drivers. After a brief overview of the proposed so far criteria, we formulate our own criteria to be used for identifying geoeffective solar drivers and their effects on space weather.

Solar Wind and Geomagnetic Activity

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The prolonged and deep sunspot minimum after solar cycle 23 and the following weak cycle 24 marked the end of the recent Grand Maximum of solar activity. A widely discussed question is whether what follows is a regular minimum of the centennial Gleissberg cycle, or the Sun is entering a Maunder type Grand Minimum.

The Earth immersed in the solar wind – the continuously expanding solar corona with embedded magnetic fields – is a sort of a probe registering the variations in the solar dynamo, the driver of solar activity. Here we combine solar wind and geomagnetic data to assess the mode of operation of the solar dynamo, to forecast whether the Sun is entering a Grand Minimum.

Relationship Between the Intensity of the SCR Proton Flux and the Parameters of Type II Radio Bursts in the 25-180 Mhz Range

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The relationship between the intensity of the SCR proton flux and various parameters of type II radio bursts in the 25-180 MHz range has been investigated. The sample under study contains 112 proton events registered for the period from 24-11-2000 to 20-12-2014. For the analysis, we used the original records on the fluxes of protons with proton energies > 1-100 MeV from the GOES series spacecraft, as well as the original records of the dynamic spectra of solar radio emission in the 25-180 MHz range according to data from the solar radio spectrograph (SRS). Comparative analysis showed that there is a fairly strong relationship between the intensity of the SCR proton flux and the drift velocity and the relative distance between the harmonics of type II radio bursts.

Statistical Characteristics of Radio Source Scintillations at Decameter Wavelengths

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Electron density inhomogeneities in the interplanetary and ionospheric mediums cause intensity scintillations of radio emission from cosmic radio sources. It is well known that analysis of intensity scintillations allows interplanetary and ionospheric plasma parameters to be estimated effectively. It is usually done by fitting the calculated curves into the experimental ones. The accuracy of such procedures depends among other things on the knowledge of the scintillation statistical characteristics, their dynamics and the perfection of the used techniques.

The report describes the results of investigations of interplanetary and ionospheric scintillations characteristics. Data includes analysis of spectra, cross-correlation and probability density functions. We use scintillations data obtained with UTR-2, URAN-2 and URAN-3 radio telescopes (8 - 32 MHz) during the last decade. The obtained results can be used for improving techniques used for estimation interplanetary and ionospheric plasma parameters, separation interplanetary and ionospheric scintillations, assessing the interfering influence of interplanetary and ionospheric plasma during radio astronomy experiments of a wide range of targets.

The Solar Activity, Cosmic Ray Intensity and Geomagnetic Changes During Solar Cycles 16 Till 24 and Our Previsions for the Next Time.

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The purposes of the paper are at first: to inspect the solar activity, cosmic ray intensity and geomagnetic variations during the earlier cycles from 16th till 24th and the second: to calculate the solar number progression during the next time basing on the earlier cycles data by means of the artificial neural networks (ANN). We focus our attention on Elman ANN because comparisons of an ANN type effectiveness in modeling of disturb course of different solar and geomagnetic parameters indicated by the recurrent ANN as better predictor than equivalent feed-forward ANN. Daily data averaged by Bartels rotation of different activity parameters as sunspot numbers, aa geomagnetic indices, neutron monitor records from three stations with different rigidities are used. Additionally the wavelet technique and recurrence plots are used to show the coherence between studied data. We estimate that the solar activity would be rather small during the next solar cycle.

Predictions for SC25, SC26 and SC27 Magnitudes in Relation to the Long-Term Solar Activity Changes

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In this work the results about the near-maximal amplitudes of present (SC25) as well as the next two Schwabe-Wolf`s sunspot cycles SC26 and SC27 are discussed. For this aim two data series has been used: They are the mean monthly sunspot numbers (the new SILSO_version 2) for the epoch Jan. 1818- Jul.2021 and the complemented `historical ` Schove`s series (214 BC - 2009AD). It has been found on the base of mean monthly data analysis for the first 20 months after the starts (minima) of sunspot cycles that the SC25 near-maximal amplitude should expect to be 149±39, which corresponds to 99.5±26 as a classical Wolf`s number. On the other hand by using of kinematic model based on time series analysis (T-R periodogram algorithm) the corresponding near maximal Wolf`s number of SC25 is in range 75±38 . Taken into account that the near-maximal amplitude of SC24 in 2014 AD is ~82 it could to conclude that a violation of the amplitude Gnevishev-Ohl-Kopecky`s rule for the even-odd sunspot cycles pair SC24-SC25 is possible. It has been found by using of auto-regression models of sunspot cycles amplitudes in Schove`s series that the magnitude of the next SC26 should be expect in range of 90-95 as Wolf`s number. There is also prediction for a very shallow sunspot minimum between SC26 and SC27 in 2038-2040AD.

Properties of Filament Eruption and Associated Flare Ribbons on 2021 May 9

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We present the first results from the investigation of a filament eruption (FE) and associated ribbon flare, occurring in the southern solar hemisphere on 2021 May 9. Before the eruption, the filament was located in a plage region close to the disk center and lay along the S-shaped magnetic polarity inversion line, i.e. it represented a sigmoid filament. The filament began to rise slowly at 09:30 UT and at 10:00 UT it erupted, which was accompanied by spreading ribbons at its base. During the FE, two flare ribbons slowly separated. During the ribbons evolution, hot post-flare loops (PFL) appeared at 11:00 UT and later, at 11:55 UT they formed PFL arcade.

Using the high resolution multi-wavelength data from the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamic Observatory (SDO) we study the kinematics and morphology evolution of the eruption and flare ribbons. The event was registered also by STEREO-Ahead Observatory, which allows us to explore the event kinematics and evolution from two different points of view.

The filament evolution before the eruption was traced by H-alpha data from the Global Oscillation Network Group. The photospheric magnetic field configuration was analyzed with the Helioseismic Magnetic Imager onboard the SDO.

Temporal Analysis of the GCR Flux Obtained From the LIULIN Instrument in Orbit Around Mars

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The LIULIN instrument has been in Martian orbit since 2016. The accumulated data allow us to study some variations in the intensity of CGR at a distance of 1 au. Variations caused both by the change in the parameters of the IMF and by the relative position of the instrument with respect to Mars are considered. The correlation between the intensity of GCR and the sunspot number was studied. A comparison was made between the existing models for GCR and the data obtained from LIULIN.

Solar Wind Stream Structure by IPS Observations at Decameter Wavelengths

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Solar wind is a set of streams which outflow from different places on Sun and have different parameters. Among other things, solar wind stream structure is one of the most powerful factors that affect the state of space weather. Spacecrafts allow solar wind stream structure to be study effectively, but not everywhere, for example, at high solar latitudes and large distances from the Sun, where space missions are extremely rare. There is another possibility for the investigations of solar wind stream structure then spacecraft measurements. This is a ground-based observation of the interplanetary scintillations.

Our report is devoted to the investigations of the solar wind streams by IPS observations at decameter wavelengths. The report includes both the results of theoretical studies and the results of processing the experimental data obtained by coordinated IPS observations with UTR-2 (8 - 32 MHz) and URAN-2 (8 - 32 MHz) radio telescopes. The brief results of the observational data processing are the next. In most cases we detect the presence of several solar wind flows with different velocities, densities and thicknesses along the line of sight to the radio source. The variations of the solar wind velocity and the scintillation index obtained by IPS method are usually in good agreement with ones measured by spacecrafts on Earth`s orbit.

Interferometer observations of solar Type II and Type IV bursts by the radio telescope UTR-2 on 29 May 2014

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Results of solar radio emission observations by the radio telescopes UTR-2 (Kharkiv, Ukraine) and URAN-2 (Poltava, Ukraine) on 29 May 2014 are discussed. Observations by the radio telescope UTR-2 were carried out in the interferometer regime using West-East arm of the UTR-2 with bases 225m, 450m and 675m at frequencies 20 MHz and 25 MHz. There were 4 tracks of Type II bursts before Type IV burst this day. They had approximately the same frequency drift of about 60 kHz/s. All Type II bursts consisted of sub-bursts, which had sizes from 10 to 24`. Distances from the Sun, at which Type II sources situated, were essentially different, from 25 to 45`. Some of them coincided with front of CME and some situated at other places as regards to CME. All this says about registration of radio emission in the form of Type II bursts from different parts of the spherical shock initiated by CME. The source of Type IV burst at frequencies 20 and 25 MHz was located at the same distance of about 30` during all the time of observations. This points out that this Type IV burst was stationary, not moving. Sizes of Type IV source were 35-40` at 20 MHz and 25-30` at 25 MHz and it agreed with CME. It seems to say that source of Type IV burst is CME core. Brightness temperatures of bursts as well as harmonics of their radio emissions are also discussed.

Details of the Sunspot Groups` Decay

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Different mechanisms govern the decay and the development of the sunspot groups.

The decay of the leading and following parts of groups was studied on almost 150 different active regions. The length and the temporal resolution of the used datasets make it possible the examinations of the internal dynamics and their asymmetries as well as their temporal variation during the decay and the cycles. The results pointed out that the schedule of the decay is the following: the following penumbrae and umbrae decay and after that the leading penumbrae and umbrae. The decay rates show cycle and cycle phase dependences. The asymmetry index between the leader and follower spots changes during the decay of the groups. This asymmetry depends on the maximum area of groups and is more pronounced for the umbrae.

The variation of the distances between the two parts during the decay is also studied and the results show that the leading-following distance grows for a while.

This investigation has received funding from National Research, Development and Innovation Office -- NKFIH under grant agreement 129137.

Preliminary Results of Statistical Study on the Solar Cycle 24

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To better understand the relation between different solar activity phenomena we summarized the data from various sources to create a catalog of active regions (ARs) and associated prominences, flares, coronal mass ejections for the period of solar cycle 24 (2009-2019). The initial sample consists of 1735 ARs. We tracked the changes in their position and configuration for each day they were observed on the Sun, which makes overall more than 12 000 different AR records in our catalog. Here we present our first results of statistical analyses on the behavior of different active processes during the last solar cycle.

Estimating the Kinematics of Coronal Bright Fronts and the Associated Plasma Parameters using the SPREAdFAST Framework

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In this work, we present a comprehensive characterization of 62 coronal shock waves associated with Coronal Mass Ejections (CME) in the low solar corona by using the Solar Particle Radiation Environment Analysis and Forecasting, Acceleration, and Scattering Transport (SPREAdFAST) framework. These CME-driven compressive waves were also associated with Solar Energetic Particle (SEP) events near Earth.

SPREAdFAST is a physics-based, operational heliospheric system that incorporates a chain of data-driven analytic and numerical models. It is dedicated to forecasting the SEP fluxes at multiple locations in the inner heliosphere, by modeling their acceleration at CMEs near the Sun, and their subsequent interplanetary transport.

We used sequences of base-difference images obtained from the AIA instrument onboard the SDO satellite, with a 24-second cadence to calculate a) time-dependent speeds in both the radial and lateral directions, b) mean intensities, c) thicknesses of the wavefronts, and d) major and minor axes. We modeled the time-dependent shock and plasma parameters at the wavefronts by utilizing the kinematic measurements and plasma model results from the Magnetohydrodynamic Algorithm outside a Sphere (MAS) model and Differential Emission Measure (DEM) modeling. Statistical relations and distributions of both the shock and plasma parameters are reported.

Medium-Term Oscillations of the Solar Activity

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Besides the well-known 11-year cycle, longer and shorter characteristic periods can be isolated in variations of the parameters of helio-geophysical activity. Periods of ~36 and ~60 years were revealed in geomagnetic activity variations and a ~60-year periodicity, in correlation between the pressure in the lower atmosphere and the solar activity. Similar periods are observed in the cyclonic activity. Such periods in the parameters of the solar activity are difficult to identify because of a limited database available; however, they are clearly visible in variations of the asymmetry of the sunspot activity in the northern and southern solar hemispheres. In geomagnetic variations, one can also isolate oscillations with characteristic periods of 5-6 years (QSO) and 2-3 years (QBO). We have considered 5-6-year periodicities observed in variations of the sunspot numbers and the intensity of the dipole component of the solar magnetic field. Comparison with different magnetic dynamo models allowed us to conjecture the origin of these oscillations. As a result of the study, we conclude that the 5-6-year activity variations are related to the processes of nonlinear saturation of the dynamo in the solar interior. Quasi-biennial oscillations are actually separate pulses related little to each other. Therefore, the methods of the spectral analysis do not reveal them over large time intervals. They are a direct product of local fields, are generated in near-surface layers, and are reliably recorded only in the epochs of high solar activity.

Temporal Variation of Solar Flare Index for the Last Solar Cycle (Cycle 24)

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In this study we compared selected some monthly and yearly mean solar activity indices with hemispheric and total Hidrogen-alpha Flare Index (FI) during the last solar cycle (cycle 24). First we plot the temporal variations of 13 step running average smoothed data sets. Then the cross correlation analyses were performed between FI and other solar indices. Finally, we performed hysteresis analysis by using the yearly mean data sets. We found following results; 1) In general FI data sets show higher correlations with F10.7 compared to other parameters. 2) Total FI show higher correlation with all other parameters compared to the hemispheric FI data. 3) All data sets show some amount of time delay with FI data sets except F10.7 that it does not show any time delay. 4) Hysteresis behavior generally appears during the ascending and descending phases of the cycle.

MHD Simulation of a Flare Situation in Real Scale of Time Above AR 10365: Development of a Technique, Choice of Parameters, the Appearance of Field Singularities at Flare Sites

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The mechanism of release of the magnetic energy of the current sheet formed in vicinity of singular X-type magnetic field line explains the observed primordial release of solar flare energy in corona. The observed manifestations of the flare are explained by the electrodynamic model of a solar flare proposed by I.M. Podgorny. The study of the flare mechanism is impossible without performing MHD simulations above a real AR, MHD simulation in the solar corona in real time can only be carried out thanks to parallel calculations using CUDA technology. To select the conditions for the numerical solution of MHD equations under which the numerical solution is stable and a real flare situation appears, calculations are performed for various viscosities in the computational domain and conditions at the photospheric boundary.

Mainly, the configuration of the magnetic field at the maxima of the current density, the positions of which coincide reasonably well with the observed positions of the flares, is the configuration of the X-type singular line, which is strongly distorted by superimposed diverging magnetic field, which inhibits the accumulation of magnetic energy, causing rotational motion of plasma around the singular line. Perhaps for this reason, solar flares above AR 10365 on May 26 and 27, 2003 were not very large. It is also possible that the planned simulation with a more accurate choice of the calculation parameters and conditions on the photospheric boundary will show the appearance of singular X-type lines without significant distortion by the superimposed diverging magnetic field.

Determination of the Solar Rotation Elements and Period from Ruđer Bošković's Sunspot Observations in 1777

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This paper deals with the observation of sunspots performed by Ruđer Bošković in 1777. We derived the expressions needed to calculate the elements of the Sun's rotation and period from observations. Modern ephemeris data were used in the processing of the observation results. The obtain results are very similar to Bošković's original calculations. In addition to historical significance, they also provide scientifically valuable data on the Sun's differential rotation, which plays a significant role in generating and maintaining solar magnetic activity.

Solar Gravitational Moments: What are They and What Do They Do? A Little Comprehensive Review.

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Among all the fundamental solar parameters, mass, diameter, surface gravity, temperature, luminosity..., all well inventoried since several years in reference books, multi-gravitational moments are not yet well documented. Several theoretical estimates have been proposed through different approaches, mainly theory of Figure, helioseismology. We will show their own merits. Exact values of multipolar gravitational moments are important as they are at the crossroads of solar physics, solar astrometry, celestial mechanics, and General Relativity. Their temporal variations are still often neglected; they are yet an essential aspect for constraining solar-cycle modeling or solar-evolution theories. They induced planet-planet inclinations in multi-transiting systems gravitating in the neighboring of a star, leading to future studies. This lecture will emphasize some key issues to understand the role of these parameters.

Radiation Environment in the Interplanetary Space and Mars Orbit During the Declining Phase of 24th and Beginning of 25th Solar Cycles According Measurements Aboard Exomars TGO

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The dosimeter Liulin-MO operates onboard ExoMars Trace Gas Orbiter (TGO) since April 2016. Presented are results from measurements of the radiation quantities at ExoMars TGO Mars orbit, provided by Liulin-MO from May 2018 to August 2021. The data show that: an increase of the dose rates and fluxes from May 2018 to February 2020 corresponding to the increase of galactic cosmic rays (GCR) intensity during the declining phase of 24th solar cycle; From March to August 2020 the measured radiation values are maximal, corresponding to the minimum of the solar activity; Since September 2020 a decrease of the dose rates and fluxes is observed, corresponding to the increasing solar activity in the 25th cycle. The cosmic ray fluxes and doses measured in Mars orbit are recalculated into values meaningful for the deep interplanetary space and are compared to data obtained during the TGO transit to Mars and to previous measurement. The results demonstrate that the radiation conditions in the interplanetary space worsen in the minimum of 24th cycle compared to the previous solar minimum.

Acknowledgements

The work in Bulgaria is supported by Contract No 4000133961/21/NL/SC funded by the Government of Bulgaria through an ESA Contract under the Plan for European Cooperating States and by Grant No KP_06_Russia-24 for bilateral projects of the National Science Fund of Bulgaria and Russian Foundation for Basic Research. The work in Russia is supported by Grant 19-52-18009 for bilateral projects of the National Science Fund of Bulgaria and Russian Foundation for Basic Research.

Determination of the CME Core Parameters by Means of the Associated Spikes

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The paper presents the analysis of the event observed on August 22, 2015 with UTR-2 and NDA radio telescopes. On this day the flare of M1.2 class occurred. This flare manifested itself in the meter and decameter wavelength bands as Type II, III, IIIb, IV bursts and spikes.

The main attention is paid to the study of the Type IV burst and spikes which were observed during and after Type IV burst. We analyzed more than 200 spikes for each of two cases. It was found that the durations and bandwidths of spikes observed during and after the Type IV burst differ by 1.5 and 1.2 times respectively. While the fluxes were approximately the same in both cases and equaled 25 s.f.u.

Assuming that the emission of spikes associated with the Type IV burst escapes from the CME core and that their durations and bandwidths are determined by the plasma parameters in the place of their generation we tried to reconstruct the profiles of the temperature and the magnetic field from the core center to its periphery.

On the Magnetosphere Stand-Off Distance at the Timescale of Geomagnetic Storms

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The magnetosphere shape and dimensions are a result of the equilibrium between the magnetic pressure of the geomagnetic field and the dynamic pressure of the solar wind in which the Earth and its magnetosphere are embedded. Our previous studies (Dobrică et al., 2012, Ștefan et al., 2013) concerned the long term evolution (timescale the last ~ 150 and, respectively, 300 years) of the stand-off distance, i.e. the sub-solar distance to the magnetopause, commeasured in Earth`s radii (RE). In the present paper we tackle the stand-off distance evolution at much shorter time scale, i.e., during 21 moderate and intense geomagnetic storms (Dst<-100 nT) occurred in the solar cycle 24. While the long-term evolution of the stand-off distance shows variations between 11.6 and 9.5 RE, during geomagnetic storms it shows variations of 6-12 RE. An attempt is done to use the superposed epoch analysis in comparing various storms.

Key words: solar activity, solar wind, geomagnetic storms, superposed epoch analysis

Continuous Component of Solar Activity Spectrum and Solar Dynamo

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Solar magnetic activity spectrum contains a spectral line known as 11(22)-year cycle as well as contituous component. The nominal 11-year cycle is believed to be explained by solar dynamo. The nature of continuous component of the spectrum remaines much less clear. We discuss possible physical mechanisms to otain this component in the framework of solar dynamo scenarios.

Advanced Image Preprocessing and Feature Tracking for Remote CME Characterization with Wavetrack Software: towards Deep-Learning Models for Solar Eruptive Feature Characterization.

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Coronal Mass Ejections (CMEs) influence the interplanetary environment over vast distances in the solar system by injecting huge clouds of fast solar plasma and energetic particles (SEPs). A number of fundamental questions remain about how SEPs are produced, but current understanding points to CME-driven shocks and compressions in the solar corona. At the same time, unprecedented remote (AIA, LOFAR, MWA) and in situ (Parker Solar Probe, Solar Orbiter) solar observations are becoming available to constrain existing theories. As part of the MOSAIICS project under the VIHREN programme, we have recently developed a suite of Python tools (Wavetrack) to reliably characterize the dynamics in radio and EUV remote imaging observations of CMEs and shock. With the data represented hierarchically, our method allows for smart characterization and tracking of solar eruptive features, based on the A-Trous wavelet decomposition technique, intensity rankings and a set of filtering techniques. We showcase its performance on a set of CME-related phenomena observed with the SDO/AIA telescope. We use the Wavetrack framework to develop a curated dataset of the compressive waves observed by AIA on the Sun for training machine learning models, such as Convolutional Neural Networks (CNN) for the purpose of image classification and segmentation. The method presented here is general and applicable to detecting and tracking various solar and heliospheric phenomena in imaging observations.

Properties of Solar Activity Phenomena Detected during 2020 December 14 Total Solar Eclipse

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During the total solar eclipse on 2020 December 14 a coronal mass ejection has been detected above a prominence on the eastern solar limb. Two active regions at the base and a streamer higher in the corona completed the diversity of activity phenomena on the Sun at that time.

Unfortunately, the expedition that our team planned to Argentina to observe the total solar eclipse failed and we had to use SDO/AIA and SOHO/LASCO data to analyze the parameters of the observed processes and trace the connection between the various manifestations of solar activity.

Decrease in Solar Wind Parameters After a Minimum of 22-23 Solar Cycles

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On the basis of the OMNI database data, the behavior of plasma and magnetic field parameters of 21-24 solar cycles (1976-20190) is analyzed. In the analysis, the data are selected according to the types of large-scale solar wind phenomena (see the site http://www.iki.rssi.ru/pub/omni and paper by Yermolaev et al., 2009) and phases of solar cycles. The analysis showed that during the minimum of 22-23 solar cycles, the parameter values decreased by 20-40% in different types of solar wind and continued to be low during the 23 and 24 cycles (Yermolaev et al., 2021). The effect of this decrease in solar wind parameters on space weather is discussed.

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Solar Activity Enters the Modern Grand Solar Minimum: Magnetic Field Observations and Models of Dipole and Quadruple Waves

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In this paper we present the Principle Component Analysis of solar background magnetic field observed by Wilcox Solar Observatory including the two principal components reproducing dynamo magnetic waves produced by dipole magnetic sources (Zharkova et al., 2015) and the next pair of independent components of magnetic waves produced by quadruple magnetic sources (Popova et al, 2018). For the first time we present separately thee quadruple observed waves and extrapolate them back by a few hundred years. We explore their joint effects of dipole and quadruple observational waves on the averaged sunspot numbers in the past few decades and confirm beating effect in the formation of grand solar minima in solar magnetic waves defining the solar activity. The observational magnetic waves are compared with the dynamo waves produced by dipole and quadruple magnetic sources. The implications of the modern grand solar minimum for the terrestrial temperature and other activity will be also discussed.

Solar Wind-Magnetosphere Interactions

Supersubstorm on 28 May 2011: Geomagnetic Effects

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We selected the supersubstorm (SSS) occurred during the strong magnetic storm on 28 May 2011 (SYM/H~100 nT). The ground-based magnetic effects of SSS were studied basing on the data from the magnetometer SuperMAG, INTERMAGNET and IMAGE networks, as well as the magnetic measurements by the ionospheric satellite AMPERE system. According to the SML-index behavior, the SSS event maximum was identified at ~09:00 UT on 28 May 2011 (SML= ~-2600 nT). The SSS occurred during the passage of the magnetic cloud in the solar wind. Before the SSS, the Bz component of the Interplanetary Magnetic Field (IMF) was negative, the IMF By component was positive, and the local jump in the solar wind dynamic pressure was registered. We found that SSS developed in the magnetosphere in the global scale. In the evening and night sectors, a strong westward electrojet was observed from the evening side at auroral latitudes to the dayside. In contrast to the typical scenario of the classical substorm, a very intense eastward electrojet in the evening sector was detected, which may be the result of the formation of an additional partial ring current during the supersubstorm. The study was supported by the RFBR (project number 20-55-18003_Bulg_a) and NSFB (project KP-06-Russia/15).

Several Features of Intense Geomagnetic Substorms (Supersubstorms): A Review

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Supersubstorms (SSS) were recently distinguished as extremely intense bay-like disturbances with large negative values of the SML index (≤ -2500 nT). It was found that SSSs occur mainly during disturbed geomagnetic conditions associated with certain large-scale types of the solar wind: SHEATH and magnetic cloud (MC). Besides, before SSS appearance, several additional solar wind conditions were registered: the local jumps of the dynamic pressure and strong enhancement of the PC- index, as well as increased values of the southern Bz component of the IMF and etc. In the magnetosphere, the SSS were associated with the unusually large dipolarization and extremely intense magnetic reconnection in the magnetotail. The initial studies of auroras accompanied SSS events showed that the development of the visible aurora was nonstandard, intense auroras were registered in the pre-midnight and morning sectors of MLT, but not in the midnight sector, where usually the brightening of the equatorial arc and the breakup of auroras observed. In our study of the spatio-temporal electrojet development during the SSS, based on the analysis of the SuperMag and AMPERE global maps, it was found some specific features: the westward electrojet developed on a global scale by the longitude; the intense eastward electrojet occurred at the dusk side. The geomagnetic effects of several selected SSS examples are discussed. This study was supported by the RFBR (project number 20-55-18003_Bulg_a) and NSFB (project KP-06-Russia/15).

Certain Space Weather Events in SC24 and Their Associated Hazard Assessed by Surface Geoelectric Field

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Certain geomagnetic storms have occurred in SC24 which constituted the space weather events with hazardous response in various technological systems. In this study, these events are analyzed both from point of view of solar cause and from point of view of near-Earth/ground effects, based on the evolution of the solar wind parameters, of the corresponding geomagnetic indices as means of characterizing the sources of the geomagnetic disturbances, as well as of the geomagnetic field, in certain time intervals that include the disturbance one. The surface electric field, the geophysical input in assessing ground space weather impact of geomagnetically induced currents (GICs), produced by the variable magnetic field of geomagnetic storms, has been determined and its geographical distribution at continental scale is presented.

Super Thin Current Sheets of Electron Scales Observed in Planetary Magnetotails

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Current sheets (CSs) play a crucial role in the storage and conversion of magnetic energy in planetary magnetotails. MMS observations in the Earth magnetotail and MAVEN observations in the Martian magnetotail with high time resolution revealed the formation of Super Thin Current Sheet (STCS) in the cross-tail CS. The spatial structure of the cross-tail CS is, thus, multiscale and has similar features in the magnetotails of both planets in spite of very different local plasma characteristics. We revealed that the typical half-thickness of the STCSs is of the order of few gyroradii of thermal electrons or less. In such thin current structures the electric current is carried by the unmagnetized electrons while low-energy magnetized electrons support the stress balance and the stability of the STCSs. Thus, in spite of the significant differences in the CS formation, ion composition, and plasma characteristics in the Earth and Martian magnetotails, similar kinetic features are observed in the CS structures in the magnetotails of both planets. This phenomenon can be explained by the universal principles of nature. The CS once has been formed, then it should be self-consistently supported by the internal coupling of the total current carried by particles in the CS and its magnetic configuration, and as soon as the system achieved the quasi-equilibrium state, it forgets the mechanisms of its formation, and its following existence is ruled by the general principles of plasma kinetic described by Vlasov-Maxwell equations.

This work was supported by Volkswagen Foundation (grant # 97 742)

Work Out of a Substorm Catalog Based on the Ground Based Magnetic Data at the Panagjurishte Station, Bulgaria

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A substorm catalog based on the magnetic field measurements at the Bulgarian station Panagjurishte (~37deg. GMLat, ~97deg. GMLon) is under construction. In this work the first results of the FTP positioned catalog creation are presented. The catalog was designed and its content was determined. The catalog main part consists of two sections containing results, derived by the Panagjurishte magnetic measurements. In the first section, processed every day X and Y components and computed horizontal power of the magnetic field as figure and text files are mounted. In this purpose, special processing tools were developed. The second section includes additional data about every substorm, i.e. some parameters of the observed midlatitude positive bays (MPB). MPB is the midlatitude effect of substorm, which developed at auroral latitudes, where it is presented by a negative bay in the X magnetic component. At midlatitudes, in contrast with this, a positive bay in X is observed. These magnetic effects on the Earth surface are related to a current system, namely the substorm current wedge (SCW). In the catalog, a complimentary part is envisaged, containing concomitant data about the substorm days. Up to now all prosedures: data processing, substorm identification and determination of the characteristics of the positive bays were performed for two months, January and February 2013 and the results have been put in a convenient folder and file structure of the catalog. This study was supported by the National Science Fund of Bulgaria (NSFB) (project number KP-06-Russia/15) and RFBR (project number 20-55-18003).

Characteristics of the Midlatitude Effects of Different Substorms

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Depending on the interplanetary conditions and the solar wind transients, different substorms can develop. By one classification they can be divided in `usual`, `expanded` and `polar`. The `usual` substorms begin and develop at auroral latitudes (~60deg.- ~ 71deg. GMLat). When the substorm onset is at auroral latitudes, but the substorm propagates to higher latitudes (>~70deg. GMLat), the substorm is `expanded`. And in the case, when the substorm originates and develops at latitudes above ~70deg. GMLat, without expansion to South, it is ranked among the `polar` ones. The substorm effect at midlatitudes consists of the appearance of peaks in the X component of the magnetic field at ground, called midlatitude positive bays (MPB). A number of characteristics as conversion latitude of the magnetic bay sign, amplitude and duration of the MPB, horizontal power of the magnetic field etc., can be attributed to the midlatitude effects of substorms.

In January and February 2013, 67 substorm were identified and put down to one of the enumerated above types of substorms. The characteristics of the mislatitude effects have been determined by data of the Bulgarian midlatitude station (~37deg. GMLat, ~97deg. GMLon). The differences between the MPB characteristics for the different types of substorms have been analyzed.

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

Polar Substorms, Svalbard Auroras and Mid-Latitude Positive Magnetic Bays

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Bay-like magnetic disturbances observed at high latitudes above 70 CGM in the absence of disturbances in the lower auroral latitudes, are called `polar substorms` or `substorms on a contracted oval`. It is believed that the source of such substorms is located in a distant magnetotail. The polar substorms are poorly studied and their mid-latitude effects still remain unknown. To study this problem, we collected the polar substorms observed at the Scandinavian IMAGE magnetometer chain in association with the visible auroras observed by the Svalbard all-sky-cameras in the 2010-2011 winter. It was found that the considered polar substorms were accompanied by the localized enhancement of the Field Aligned Currents (FACs) recorded by the AMPERE satellite system in the vicinity of the polar border of the auroral oval. We compared the polar substorms recorded at Svalbard with the magnetic data from the mid-latitude stations located at the same meridian, e.g., Borok (BOX) and Kiev (KIV). We found that all polar substorms under consideration were accompanied by the well-defined mid-latitude positive magnetic bays at the amplitudes of ~ 15-40 nT in the X-component. That fact can be interpreted as the WTS development and appearance of the dipolarization process. This allows us to conclude that the polar substorm source is located at the closed magnetic field lines. The analysis of three events of the selected polar substorms is presented. The study was supported by the RFBR (project number 20-55-18003_Bulg_a) and NSFB (project KP-06-Russia/15).

Relationship Between Gics and Supersubstorms: A Case Study

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Space weather generally refers to the physical conditions in the Sun-Earth system that can affect the performance of ground-based technological systems. Geomagnetic field disturbances associated with magnetic storms and substorms are known as the key factor for the generation of GICs. Strongest GIC events are recorded in the high geomagnetic latitude zone in association with large amplitude magnetic field fluctuations during intense and frequent auroral activities. We studied the connection between the appearance of geomagnetically induced currents (GICs) and the development of a very intense substorms (supersubstorms - SSS). SSS are called the extremely intense bay-like disturbances with large negative values of the SML index (≤ -2500 nT). For this purpose, data of magnetometers networks SuperMag, IMAGE and AMPERE satellite system were compared with data of two different technological networks: 1) on the `Nothern Transit` power line (Vykhodnoy, Revda and Kondopoga stations) located in the auroral zone 2) on the Finnish natural gas pipeline near Mantsala located in the subauroral zone. Several events show a good correlation between the GIC appearance and increasing of geomagnetic indexes: IL index, which characterized of westward electrojet intensity on the IMAGE meridian and Wp- index, which describes the wave activity of the substorm. Besides, in some event managed to trace the connection between the thin spatio-temporal structure of the substorm development and the GIC appearance on the different latitudes. This study was supported by the RFBR (project number 20-55-18003 Bulg `a`) and National Science Fund of Bulgaria (NSFB).

Impact of Space Weather on Ionospheric Scintillation

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Amplitude and phase fluctuations of a field of an incident electromagnetic wave arise when the radiation passes through a plasma layer with electron density inhomogeneities. This phenomenon is found in interstellar medium, interplanetary plasma and in the Earth`s ionosphere when radio astronomy observations are carried out. Such amplitude and phase scintillation significantly impact on radio astronomy studies at low frequencies and should be taken into account during the observations and data reduction. Ionospheric scintillation affects an accuracy of radio astronomy observations most severely. On the other hand, observational data distorted by the scintillation provide information on parameters of the scattering medium itself. We observed powerful radio sources with the URAN decameter interferometer network to study a temporal and spatial variation of the ionospheric scintillation in order to determine their relationship with terrestrial phenomena and space weather. We found, that an increase of the ionospheric scintillation measured by the UTR-2 radio telescope coincide with disturbances in the solar wind detected by space laboratories in Earth`s orbit and with the URAN interferometers.

The Relationship between Solar Activity and Geomagnetic Activity Indices in the Last Four Solar Cycles

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In this study, Lyman-alpha Solar Spectral Irradiance (SSI compared with geomagnetic Ap, Dst and PC index time series for the time period of 1975-2020. All data sets used in this study are taken from OMNIWeb. To compare Lyman-alpha SSI and geomagnetic indices cross correlation and Morlet wavelet analysis methods were used. In results of our analysis we found following results; (i) selected geomagnetic activity indices weakly correlated with Lyman-alpha SSI. ii) The Lyman-alpha SSI is ahead of all geomagnetic activity indices except Dst index. iii) All indices used in this study show 11-year solar cycle and 27-day solar rotation periodicities. iv) Contrary to Lyman-alpha SSI all geomagnetic activity indices show about 500-day periodicity.

Calculation of the Horizontal Power Perturbations of the Earth Surface Magnetic Field

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The substorm effect at midlatitudes is expressed by a rise and decay of the X-component of the surface magnetic field, called midlatitude positive bay (MBP). McPherron has introduced a new geomagnetic index based on the on the calculation of the horizontal power perturbations of the Earth surface magnetic field. In this work, a developed processing tool to determine the horizontal power of the magnetic field is presented. A main element in these calculations is the estimation of the main field by smoothed spline fits to the midnight field using 25 consecutive daily observations centred over the day in consideration. The estimated field was removed from the measurements. We used the Grubs test for detection of days with strong magnetic disturbances. Excluding the disturbed days from further calculations, the mean solar variations under quiet conditions (Sq) were determined by averaging the field components and were subtracted from the magnetic field observations of the central day. The resulting X and Y horizontal components were high pass filtered to suppress periods longer than 3 hours. Thus, adopting the McPherron s algorithm we have calculated the horizontal power for the Panagjurishte station (PAG). In the algorithm we have incorporated procedures for gape and peak detection and removing. The MPB index is defined as the average of the horizontal power of a multitude of stations and monitors the power in the substorm disturbances. This study was supported by the National Science Fund of Bulgaria (NSFB) (project number KP-06-Rusia/15) and RFBR (project number 20-55-18003).

Pitch Angle Distributions of Accelerated Particles of Solar Wind in 3D Current Sheets with Magnetic Islands

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We present multispacecraft observations of counterstreaming strahls and heat flux dropouts in PADs within a region filled with plasmoids and RCSs unaffected by interplanetary shocks, comparing observed PAD features with those predicted by particle-in-cell simulations. We show typical PAD patterns determined by local acceleration of thermal-core electrons up to hundreds eV. Resulting PAD views depend on properties and magnetic topology of particular RCSs, MIs, and plasma/magnetic field parameters. Our study suggests that solar-wind-borne suprathermal electrons co-exist with those of solar origin. Therefore, some of heat flux dropout and bidirectional strahl events can be explained by local dynamical processes involving magnetic reconnection. Possible implications of the results for the interpretation of the actively debated decrease in the strahl/halo relative density with heliocentric distance and puzzling features of suprathermal electrons observed at crossings of the heliospheric current sheet and cometary comas are also discussed.

Data Proccessing and Modelling

A New Approach for Forecasting the Main Ionospheric Parameters Over Bulgaria

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In order to build up a new reliable approach for forecasting the short-term variability of the main ionospheric parameters (foF2 and MUF3000) over Bulgaria the following two conditions have to be fulfilled: (i) a detailed study of the main physical processes defining the observed short-term ionospheric variability over the considered mid-latitude aria, and (ii) the use of an appropriate mathematical apparatus enabling the observed relationships to be described correctly. The results of the regression and correlation analysis of ionospheric characteristics demonstrating how the external factors, as short-term solar anomalies and geomagnetic activity, affect the ionosphere over Bulgaria. The obtained results are used for justifying the functional dependence choice incorporated in the established empirical model for short-term forecast of foF2 and MUF3000 for the territory of our country, taking into account the variations in Kp and F10.7 indices. The proposed model is based on the data from the ionosonde station Sofia for the period of 1995-2014 and is designed to make prediction of the radio wave propagation up to three days ahead if the ionospheric reflection occurs over the territory of Bulgaria. The practical application of this model consists of its ability to predict the basic parameters of a particular radio path at a given distance determined by the user.

On the Long-Term Consistency of the Magnetic D Component Registered at Swider and Several Nearby Geomagnetic Stations (1921-1966)

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The Polish geomagnetic observatory Swider (geog. coordinates: 52.7 N; 21.15 E) has been in operation since 1921 till 1975. Hourly values of the geomagnetic field components H, D and Z are attainable from the published tabular data of this station for the period 1921-1967. Our group has digitized these time series. In the paper we compare absolute values of declination component and the daily IHV indices derived from this component with records of nearby European stations: Rude Skov, Wingst and Lovo downloaded from WDC-C2. We apply the wavelet technique with establishing of the significance levels of the resultant power spectra and he recurrence plots. Generally our analysis of above mentioned data shows the good quality of the Swider registration which agrees with the results of other stations at that time. A small inconsistence in the registration during thirties should be corrected before further elaboration by means of the neuron network reconstructions.he both methods used here are sensitive for the on consistence of measured equally sampling time series and could be employed in other similar experimental studies. This paper is a continuation of the earlier presentation at Sozopol workshop and would by useful before publishing the collection of Swider data at WDC.

Detail Analysis of Stratospheric Trends Using ERA 5

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We analyze temperature, wind and other dynamical parameters climatology and trend. We study trends for every decade from 1980 to 2020 and their changes during this period. This study is focused on the pressure levels between 100-1 hPa which covers whole stratosphere and part of the mesosphere. We will also analyze impact of SSW or other stratospheric phenomenon. This will help us to find detail of trend behaviour in stratosphere. ERA 5 is one of the newest reanalysis which is widely used for middle atmospehere. It based mainly on the sattelite observations.

Relativistic Electrons Resonant Acceleration an Analysis of the Analytical Approximation Model

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An approximate analytical formula describing the resonant electrons acceleration in space plasma is presented. An analysis made is based on a comparison between approximate analytical solutions results with the numerical simulations of second order nonlinear nonstationary differential equation for the wave phase on the charged particle`s trajectory. In both simulations, the initial energies of the electrons are assumed to be relativistic. The analytical formula values for the relativistic factor, (main parameter, characterizing trapped particles energy growth), were compared with the results of the differential equation numerical solutions. The differences between the analytical approximation model and the numerical simulation of the differential equation are presented in graphical form and discussed. Conclusions about accuracy, possible applicability and efficiency of the analytical formula in numerical calculations analysis on the resonant wave-particle interactions in space plasma are provided.

Instrumentation for Space Weather Monitoring

Prediction and Measurement of the Space Radiation Altitudinal Profile During the Flight of the Virgin Galactic SpaceShipTwo

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The paper presents the `Portable Dosimeter-Spectrometer (PDS) Liulin-CNR-VG`, which is expected to measure the space radiation altitudinal profile during the flight of the Virgin Galactic SpaceShipTwo. The PDS is with a size 66x56x26 mm and weight of 0.092 kg. The PDS should measure the following parameters: - the flux of the charged particles in the range from 0.1 to 20,000 particles per square cm per sec; - the absorbed dose in the range from 0.3 nGy to 1.56 mGy; the dose rate in the range from 0.04 μGy/hour to 0.18 Gy/hour. The altitude profile during the flight of Virgin Galactic SpaceShipTwo up to the 37.2 km altitude is expected to be similar to the profiles measured with three Liulin battery operated units during the June 8, 2005 certification flight of the NASA Deep Space Test Bed balloon flight at Ft. Sumner, New Mexico, USA. During the first part of the flight up to 13.7 km, the dose rate rises from 0.058-μGy/hour up to 2.5 μGy/hour. The Pfotzer maximum is not expected to be well observed in the ascending part of the SpaceShipTwo flight. Above the maximum at about 86 km altitude, the dose falls down to 2.4 μGy/hour. During the re-entry, the SpaceShipTwo will observe the Pfotzer maximum of an expected dose rate of 3.4 μGy/hour. In the glide to land part of the flight, the dose rate decreases back to 0.058-μGy/hour.

Solar Influences on the Lower Atmosphere and Climate

Solar and Cosmic Rays Influence on Winter Temperature Variations in North Siberia

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The global warming is not uniformly distributed over the Earth surface. Some regions are strongly affected by the global warming. The mean temperature of Siberia is rising stronger during last decades. The anthropogenic factors of this rise cause positive linear trend since 1970, while various natural factors, like solar activity, cosmic rays, geomagnetic field, stratospheric ozone, excite periodic oscillations of the temperature and non-linear trends. The time series of winter temperature of North Siberia (55N-65N; 50E-170E) is analyzed by means of the Method of Partial Fourier Oscillations. The cycles of Siberia winter temperature in narrow frequency bands are compared with corresponding oscillations of Total Solar Irradiance (TSI) and Cosmic Rays (CR) in order to determine the existence of common cycles. The worming trend after 1970 is determine by moving average of time series.

Atlantic Multidecadal Oscillation Driven by Solar Harmonics

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The oscillations of climatic parameters of North Atlantic Ocean play important role in various events in North America and Europe. Several climatic indices are associated with these oscillations. The long terms of Atlantic temperature anomalies are presented by Atlantic Multidecadal Oscillation. Its time series is analyzed by means of the Method of Partial Fourier Oscillations. The cycles of AMO in narrow frequency bands are compared with corresponding oscillations of Total Solar Irradiance (TSI). Very good agreement exists between interannual and decadal cycles of AMO and TSI.

Regionality of Climate Change and its Explanation

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Recently, the regional differences in the contemporary climate change are in the focus of scientific community. The explanation of this regionality is not easy, due to the fact that the main supposed driver of climate change (i.e. anthropogenic forcing) is largely homogeneous at climatic time scales. The impact of other external forcings (e.g. solar luminosity or solar magnetic field, galactic cosmic rays or gravitational influences of other planets in the Solar system) is also homogeneous.

Another external for climatic system, but internal for the planetary interior, is geomagnetic field. The geomagnetic field is heterogeneously distributed across the planet, evolving continuously with the evolution of the Earth. The synchronisation between geomagnetic and climatic changes has been reported from many authors, but the lack of mechanism of influence is a serious obstacle for further development of the idea about geomagnetic influence on climate. This study gives an explanation of the mechanism for geomagnetic-climate variability.

Geomagnetic Field's Contribution to the Global Raise of Air Surface Temperature

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CO2 is recognized as the greatest contributor to the global warming observed since the mid-20th century. Being a long-lived gas, the spatial distribution of CO2 is largely homogenized by the global atmospheric circulation -- particularly near the tropopause, where the effective radiative temperature of all atmospheric gases is very low and their impact in the greenhouse effect is largest. This spatially homogeneous forcing (inserted on the climate system) is not able, however, to explain the regional specificity of temperature evolution, observed during the period under review (1900-2010). Consequently, it is quite probable that the regional variability of the near surface temperature is determined by the action of some unknown additional forcing.

The current investigation demonstrates that the geomagnetic field could be a significant contributor not only to the regional variations but also to the global climatic changes. Analysis of the impact of globally averaged CO2 density and geomagnetic field intensity into the global surface temperature variability reveals that the latter could be an alternative explanation of the global raise of near surface temperature (typically attributed to the increased anthropogenic forcing) -- at least for the analyzed 110 years.

Tropospheric Mesoscale Systems and Their Signatures within Ionosphere

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Ionosphere behavior is predominantly determined by solar and geomagnetic forcing. An important part of its energy budget however, comes from the lower-laying atmospheric regions. The energy transfer between distant regions happens due to atmospheric waves that propagate from their source region up to ionospheric heights. Experimental observations and teoretical studies show the importance of involvement of the troposphere mesoscale systems. With the changing climate severe weather systems occur more often. On the measurements from troposphere up to ionosphere we demonstrate changes within atmospheric parameters up to ionospheric F layer induced by severe tropospheric frontal system passing above Europe. We also clearly show the importance of consideration of the lower atmosphere sources to the ionospheric variability, dynamics and its energy budget.

Detecting Common Origin of Atmospheric Electric Responses during SEP

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Experimental investigations of the electric response of atmospheric regions at different latitudes during major SPE for decades demonstrate systematically peculiar and large electric field and currents exhibiting typical large variations. Here examples of such measurements are considered in mesosphere, in stratosphere, and at surface, as well as at high and low latitudes. The first case considered demonstrates the behavior of the electric characteristic obtained by rocket-borne measurements at latitude 58.5S during the major SEP on 20 October 1989 accompanied on 21 October (the experiment day) by very strong geomagnetic storm (Kp reaches 8+). Extremely large vertical electric fields Ez in mesosphere have been observed: 12.2 V/m at ~58 km. This indicates severely reduced conductivity in the mesosphere and upper stratosphere, and presence of extra downward electric current to the surface. Another types of experimental measurements discussed are of: 1) Electric characteristics in auroral stratosphere (31-33 km) during GLE69 obtained at balloon station; 2) Ez variations at surface at geomagnetic latitude +63.8 during three major SEP in 2002; 3) Ez variations at surface at low latitudes (31.8S, 69.3W) with geomagnetic rigidity ~9.8 GV, and at altitude 2552 m, observed during 16 SEP. Our interpretation is that these and other cases of large electric field variations due to SEP represent a unique response of the global electrical atmospheric circuit to SEP, and not local effects of energetic protons.

Influence of Solar Proton Events of January 2005 on the Middle Atmosphere Circulation: Southern Hemisphere

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Experimental investigations of the electric response of atmospheric regions at different latitudes during major SPE for decades demonstrate systematically peculiar and large electric field and currents exhibiting typical large variations. Here examples of such measurements are considered in mesosphere, in stratosphere, and at surface, as well as at high and low latitudes. The first case considered demonstrates the behavior of the electric characteristic obtained by rocket-borne measurements at latitude 58.5S during the major SEP on 20 October 1989 accompanied on 21 October (the experiment day) by very strong geomagnetic storm (Kp reaches 8+). Extremely large vertical electric fields Ez in mesosphere have been observed: 12.2 V/m at ~58 km. This indicates severely reduced conductivity in the mesosphere and upper stratosphere, and presence of extra downward electric current to the surface. Another types of experimental measurements discussed are of: 1) Electric characteristics in auroral stratosphere (31-33 km) during GLE69 obtained at balloon station; 2) Ez variations at surface at geomagnetic latitude +63.8 during three major SEP in 2002; 3) Ez variations at surface at low latitudes (31.8S, 69.3W) with geomagnetic rigidity ~9.8 GV, and at altitude 2552 m, observed during 16 SEP. Our interpretation is that these and other cases of large electric field variations due to SEP represent a unique response of the global electrical atmospheric circuit to SEP, and not local effects of energetic protons.