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ABSTRACT BOOK

International Symposium on Recent Observations and Simulations of the Sun–Earth System III

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Incidence of Extreme *dB/dt* Perturbations at Equatorial Regions: Observation and Simulation Results

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Over the years, extreme space weather events have generated global attention, because of their destructive effects ranging from satellite drag, effects of geomagnetic induced currents (GIC), satellite degradation, and HF communication outages in the Polar regions. However, recent studies revealed that GIC can have a profound effect in the equatorial latitude just as in the high latitude (e.g. [1] – [3]). In this work, 1-minute high resolution solar wind and geomagnetic data obtained from 7 equatorial/low-latitude stations during four extreme geomagnetic activities in 2003 and 2004 have been used to investigate the extreme *dB/dt* perturbations (obtained from INTERMAGNET website) at equatorial-regions. Simulation activity on the magnetospheric/ionospheric environments was also performed for varying amplitudes of solar proton density (*Np*) using the SWMF/BATS-R-US+RCM model being hosted by NASA Coordinated Community Modelling Centre (CCMC). Both the observed and simulated observations demonstrated that the appearance time of the extreme *dB/dt* perturbations at equatorial stations during disturbed conditions is instantaneous and equitable to those experienced at auroral regions yielding a time lag of the order of few seconds. These finds its explanation in the electric field of magnetospheric current origin which is being enhanced by *Np* and boosted by the equatorial electrojet current. One outstanding result is the observable solar proton density characteristic as a precursor and indicator of amplitude direction in the formation of extreme *dB/dt* enhancement at equatorial latitudes.

Keywords: SWMF/BATS-R-US+RCM model; geomagnetic; *dB/dt*; magnetosphere; equatorial latitudes

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Magnetic Environment for Solar Eruptions

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Large scale eruptive events such as coronal mass ejection and big flares, take place under solar coronal magnetic environment where conditions can lead to such events.

We will present our approach and progress to characterize such environment.

Mapping the South Atlantic Anomaly Continuously over Two Complete Solar Cycles

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The SouthAtlantic Anomaly (SAA) is a region of reduced magnetic intensity where the inner radiation belt makes its closest approach to the Earth's surface. Satellites in low Earth orbit pass though the SAA periodically, exposing them to several minutes of strong radiation each time: the International Space Station requires extra shielding to deal with this problem, astronauts on EVA try to avoid it, and the Hubble Space Telescope does not take observations while passing through it. It is also a region where many single event upsets on spacecraft are observed. We use the particle detectors on the DMSP spacecraft to map the SAA over more than two solar cycles.

The DMSP spacecraft fly in sun-synchronous, dawn-to-dusk and pre-midnight to pre-noon orbits at ~800 km altitude with ~99º inclinations and orbital periods near 100 min. They have been carrying precipitating energetic particle spectrometers (SSJ/4 and SSJ/5) since DMSP F6 was launched in 1982; the latest, F19 was launched in 2014. The SSJ sensors measure electrons and ions in 20 energy channels ranging from 30 eV to 31.3 keV, producing a complete 20-point spectrum every second. However, the instruments are susceptible to MeV particles that pass through the spacecraft skin and instrument case and get counted. This "background" is easily identified and is typically removed as noise from the data. Since there is no background channel, the data is assumed due to background when the counts in most channels are approximately equal. However, this "noise" can be used to map out the flux of energetic particle from the radiation belts. It is particularly observable within the SAA. We use this data to map the movement, extent, and intensity of the SAA over more that two complete solar cycles.

Auroral Oval Mapping and the Problem of the Acceleration of Electrons of the Outer Radiation Belt

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One of the main unsolved problem of magnetospheric physics is the appearance of great fluxes of relativistic electrons during recovery phases of magnetic storms. This problem continues to be one of the main object of space weather science. Great affords till now are concentrated to the study of wave-particle interactions. However, results of experimental observations show that the analysis of the global magnetospheric dynamics can clarify many important aspects of the process of the acceleration of outer belt electrons.

The main process which is not proper analyzed is the auroral oval motion to low latitudes during magnetic storms. Such motion is the result of the change of magnetic configuration and mainly is connected with the ring current development. Auroral oval is ordinarily considered as the region of plasma sheet mapping to the ionospheric altitudes. However latest obtained results show that the most part of the auroral oval is mapped to the outer part of the ring current. Such mapping explains the ring like form of the auroral oval. It also gives the possibility to remove the topological problem of the physics of high latitude magnetosphere as the mapping of the plasma sheet to the ionosphere leads to the infinitely thin ring like structure near noon. Obtained results [Antonova et al., 2014, 2015] are based on the comparison of plasma pressure distributions at low altitudes and at the equatorial plane and do not use any model of the magnetospheric magnetic field.

Field-aligned and transverse acceleration of ions (formation of ion beams and conics) of ionospheric origin is the consequence of auroral dynamics. Storm time motion of the auroral oval leads to the appearance of great fluxes of accelerated ionospheric ions injected into the magnetosphere at comparatively low latitudes. Such injections increase value of plasma pressure in the ring current. We analyze the role of such increases in the ring current formation and magnetic field distortion. The most powerful injections take place at the equatorial boundary of the auroral oval where ion injections produce sharp peak of plasma pressure. The coincidence of pressure maximum and the location of the maximum of new formed radiation belt is demonstrated [Antonova and Stepanova, 2015]. We discuss the possibility to predict the location of the new radiation belt using data of low orbiting satellites and ground based observations.

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Chorus, Hiss and Equatorial Magnetosonic Waves: System Science Approach to Identify Control Parameters of Wave Distribution in The Magnetosphere

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Statistical wave models for chorus, hiss and equatorial magnetosonic waves (EMS) are required to estimate diffusion coefficients employed by the first principles based modelling of relativistic electron fluxes in the magnetosphere. The standard approach is to develop statistical distributions of these waves for various levels of geomagnetic conditions expressed by geomagnetic indices AE, Kp or Dst. As current values of geomagnetic indices are used, such an approach assumes a "memoryless" magnetosphere with respect to these waves. Here we present the alternative approach based on the Error Reduction Ratio (ERR) that allows to identify parameters that control variations of wave intensity. ERR approach does not require assumption of "memoryless" magnetosphere. The presented study is based on combined data from THEMIS, Cluster and Double Star missions. It is shown that AE and solar wind velocity with various time lags are the most efficient in the control of intensity for these three types of magnetospheric emissions.

A New Anisotropic Magnetoresistive Vector Magnetometer Used in Geophysical Applications and Space Weather Monitoring

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The anisotropic magnetoresistive (AMR) effect in ferromagnetic materials was discovered by William Thomson (Lord Kelvin) in 1856. It takes more than a century until the advance in the thin-film technologies allowed its practical use. Sensors based on this effect are suitable not only for industrial applications with strong magnetic fields but also for measurements within the range of the Earth's magnetic field. Magnetometers built with these new type of sensors show a possibility to be an alternative to the classical fluxgate magnetometers used in geophysical application and particularly in Space weather monitoring.

A new magnetoresistive vector magnetometer with improved thermal stability has been developed. The instrument is installed in an observational place without magnetic disturbances. A comparative analysis between collected geomagnetic data and data from different INTERMAGNET observatories is made. Preliminary results show similarity in the observed time series and in the dynamics of registered geomagnetic processes.

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Space Weather, Dst Index and Global Temperature Evolution during Solar Cycles 19-24

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We have studied the Sun and interplanetary space conditions, which can have an influence on cosmic rays (CRs) and climate change. Since Forbush observed decreases in the cosmic rays count rate it was shown good relationship between Dst –index and CRs variations during individual geomagnetic storms. For long-term CRs variations correlation between CRs and sunspot numbers (SSN) was found also. This correlation do not adequately reflects CRs peculiarities concerned with CIRs (corotating interaction regions) because SSNs do not show CIRs. Many authors have considered the influence of galactic and solar cosmic rays on the Earth's climate and now cosmic ray activity as possible mechanism of climate change is the subject of wide speculation. Yearly average CR variations also show relationship with solar wind magnetic field B when the solar wind parameters were presented sufficiently to calculate annual averages. The problem is in sufficiently large gaps in measurements of the solar wind parameters to calculate its reliable long-term variations during some of the solar cycles. So, the geomagnetic indices have some inestimable advantage as continuous series during these gaps. In addition, it is well known that the important drivers of geomagnetic storms as CMEs (coronal mass ejections), CIRs (corotating interaction regions), and others large scale solar phenomena have very strong changes during arrival these mass emissions from the Sun to the Earth. In this connection the Sun and the solar wind characteristics and cosmic ray variations have been compared with annual global temperature variations and geomagnetic activity represented by the equatorial Dst index from the beginning 1965 to the end 2014. Because of this they do not adequately reflect peculiarities concerned with the solar wind arrival to 1 AU. We have compared the yearly average variations of SSN, total solar irradiance, the solar wind parameters, and Dst index with cosmic ray data from Moscow, Climax, Haleakala and Oulu neutron monitors during the solar cycles 19-23. During the descending phases of these solar cycles the long-lasting solar wind high speed streams occurred frequently and were the primary contributors to the recurrent Dst variations. They also had effects on cosmic rays variations but were not reflected by sunspots. We show that long-term Dst variations in these solar cycles were correlated with CRs count rate and can be used for prediction of CRs variations. Global temperature variations in connection with evolution of Dst index and CR variations is analyzed. We show that CRs can play essential role in climate change and main part of climate variations can be explained by the mechanism of action CRs modulated by the solar activity on the state of lower atmosphere and meteorological parameters. Following this we have to seek for another ways of looking for global warming reason, first of all, as a man impact on climate.

Dst Index and Its Imperfections

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Dst index of considerable current use in different tasks. Many authors bring up problems concerned with annual and semiannual Dst variations, Dst-index simulation et cetera which show Dst index imperfections. These problems require reconstruction of the index. We will first look more closely at the network selection and Sq variations using for Dst derivation. Comparison with other indices is made.

Modeling Energetic Particle Injections

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MHD simulations of magnetic reconnection, flow bursts, and magnetic field collapse are used as background for particle tracing to investigate acceleration mechanisms as well as spatial and temporal properties of energetic particle fluxes related to substorms and other dipolarization events.

Developing a Systems-Science Methodology for Statistical Data Analysis of the Solar-Wind-Driven Magnetosphere

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The magnetosphere-ionosphere system is multiply connected and it exhibits multiple time lags when driven by the time-dependent solar wind. The solar-wind data set itself has multiple intercorrelations. Our physical understanding of how the magnetosphere reacts to the solar wind is usually tested via correlation analysis with one solar-wind input (a driver function) and one geomagnetic index as a measure of the reaction. We are developing a methodology we call "global correlation analysis" into which we incorporate (1) all pertinent information about the solar wind (fields, plasma, fluctuations) and (2) multiple simultaneous measures of the state of the magnetosphere-ionosphere system (intensity of magnetospheric convection, intensity of auroral currents, ULF activity levels, plasma-sheet density, plasmaspheric filling level, substorm-injected electron population, radiation-belt intensities, …). In preliminary work [1] [2] the global correlation analysis has yielded information about internal patterns of reaction of the magnetosphere to the solar wind and information about what quantities in the solar wind drive those patterns. Using mathematical techniques from "canonical correlation analysis" it is believed that global correlation analysis will yield techniques for discerning causal versus non-causal correlations between the solar wind and the magnetosphere and to uncover why the non-causal correlations occur.

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Quantifying Ion Fluxes of Ionospheric Origin at Geosynchronous Orbit during Substorms

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Observations of ion fluxes in the source region of the ring current, the plasmasheet, are sparse. Information about this population and its composition is of significant importance since it plays a crucial role in determining the behavior of the ring current population, which in turn affects the whole magnetospheric system. However, this information is still very poor today despite our ever increasing satellite coverage. Additionally, there is no clear understanding of what are the main factors that influence the ring current ion source population and their relevance. The presence of ionospheric O+ in the ring current region may affect the whole magnetospheric system in a number of ways including wave growth and propagation, charge exchange losses and changes in substorm breakup. Using numerical simulations to look at fluxes and ion composition at the ring current boundary in a controlled manner is a good way to gauge the influence of the different parameters and validate the results with data that is available from the geosynchronous (GEO) satellites and from satellites in the plasmasheet region. Our simulation approach involves following the trajectory of test particles in time-dependent MHD model fields keeping track of their temporal, spatial, and energy characteristics. The ion population flowing out of the ionosphere, because of their low density, are an ideal population for this test particle technique. The main objective of this study is to assess and quantify, using test particle simulation methods, the fluxes and composition of the ion populations in the inner magnetosphere that make their way from the ionosphere to the ring current passing through the magnetic lobes and the plasmasheet. Results from this work will contribute to more accurate results in ring current models due to better, more realistic initial and boundary conditions. Specifically, we investigate the effects of magnetic dipolarizations of different strengths and depths occurring in the magnetotail and what is the dominant factor impacting increases in ion fluxes at GEO in the ring current energy range.

Particle Acceleration in Electromagnetic Field Structures in the Inner Magnetosphere

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Large amplitude, small scale electromagnetic field structures are prevalent in the inner magnetosphere during disturbed times. In this presentation we demonstrate how these structures have the properties of dispersive Alfven waves and how they may be expected to disrupt the adiabatic motion of heavy ions. This disruption allows acceleration of the ions by the large electric fields embedded in these structures to energies where they can make a significant contribution to ion pressure. Coincident with the occurrence of these field structures are field-aligned electron distributions driven by the wave parallel electric field. These electrons can be expected to precipitate into the ionosphere. This precipitation stimulates ion upflows which are subsequently accelerated by the wavefields to provide outflows of ionospheric sourced ions into the equatorial plane. This mechanism provides a self-consistent means to 'pump-up' heavy ion energy density in the inner magnetosphere. We demonstrate from simulations and observations the efficacy of this process during storm times.

Discrepant Responses of the Ionosphere to the Solar Cycle and Solar Rotation Variations of EUV Irradiance

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The responses of the ionosphere to the solar cycle and solar rotation variations of extreme ultraviolet (EUV) irradiance were comparatively investigated using daily mean global electron content (GEC) and SOHO/SEM 0.1–50 nm EUV flux. GEC is well correlated with EUV on both the solar cycle and solar rotation timescales; however, the responses of GEC to the solar cycle and solar rotation variations of EUV are significantly different in terms of the following two aspects: (1) The response of GEC to EUV solar rotation variation has time lag effect; the lag time is dominated by a 1-day lag and generally presents a decrease trend with decreasing solar activity. For the response of GEC to EUV solar cycle variation, however, there is no evident time lag effect. (2) GEC versus EUV slopes are different for the solar cycle and solar rotation variations of GEC and EUV; the solar cycle GEC versus EUV slope is higher than the solar rotation GEC versus EUV slope by about 40%, and this occurs in different seasons and at different latitudes. These results present an aspect of the difference between ionospheric space weather and ionospheric climatology.

Modeling the Dependence of EMIC Wave Properties on Ring Current Plasma Conditions

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Electromagnetic ion cyclotron (EMIC) waves are generated as a result of temperature anisotropy instability of ring current ions. These waves play an important role not only in ring-current dynamics but also in radiation belt dynamics, as they can resonantly scatter the high energy electrons. A goal of ring-current modeling is to self-consistently predict the generation of EMIC waves and their consequent reduction of the ring current temperature anisotropy. We seek to understand the relationship between the ring current plasma conditions (ion composition, density, temperature, temperature anisotropy) and the generated electromagnetic ion cyclotron (EMIC) wave properties (amplitude, frequency) using self-consistent hybrid (kinetic ion, fluid electron) simulations and linear dispersion theory. Results indicate that EMIC wave amplitudes can be related to the linear properties of the anisotropy-driven instability through simple analytic formulas.

ISS radiation environment in the period 23 October 2014 - 11 January 2016

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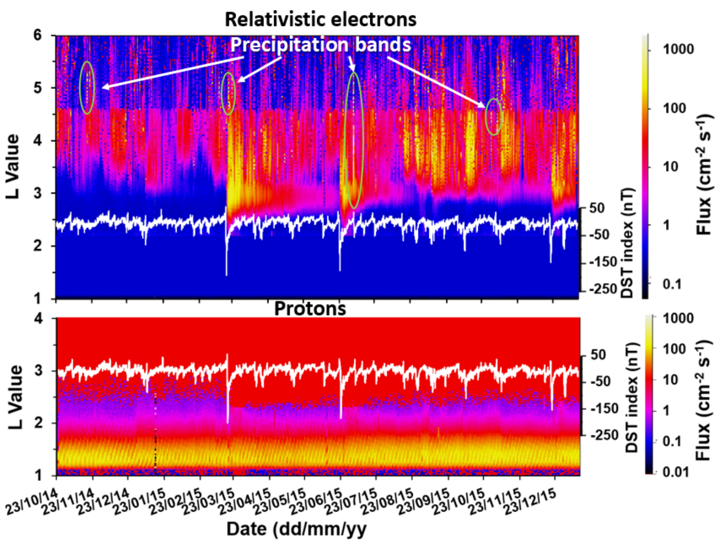
The Bulgarian build R3DR2 instrument performed measurements with a 10 s resolution on the ESA EXPOSE-R2 platform outside the Russian "Zvezda" module of ISS in the period 23 October 2014-11 January 2016 at average altitude of 415 km and inclination of the orbit of 52.6°. It is Liulin-type deposited energy spectrometer (DES) [1]. The cosmic radiation is measured with a semiconductor detector (2 cm^2 area and 0.3 mm thick). A pulse height analysis technique is used to measure the deposited energy (dose) in the detector. The amplitudes of the pulses are detected and converted into digital signals by a 12 bit analog to digital converter, which are subsequently sorted into a 256 channels spectrum according to their amplitudes by a multi-channel analyzer. The spectra were further used for calculation of the absorbed dose rate (D) and flux (F) of particles. We calculate the absorbed dose (in Grey) in the silicon of the detector by dividing the summed energy deposition (in Joules) in the spectrum by the mass of the detector in kilograms.

The technological shielding of the detector specified the required kinetic energy of normally falling particles to reach the detector and shows that it is between 0.67 and 0.95 MeV for electrons and between 12.5 and 20.5 MeV for protons (http://physics.nist.gov/PhysRefData/Star/Text/contents.html).



Using special software and experimentally obtained formulas for the relation between the specific dose and the type of the predominant radiation source the R3DR2 data were sorted into four separate categories: (i) galactic cosmic rays (GCR) particles and their secondary products with daily average dose rate of 71.6 μGy d^{-1}; (ii) protons in the South Atlantic Anomaly (SAA) region of the inner radiation belt (IRB) with daily average dose rate of 567 μGy d^{-1}; (iii) relativistic electrons and/or bremsstrahlung in the outer radiation belt (ORB) with daily average dose was 278 μGy d^{-1} but reaches almost 3000 μGy d^{-1} in the periods after magnetic storms; (iv) solar energetic protons (SEP). During the SEP event on 22 June 2015 the hourly dose rate reaches more than 5000 μGy h^{-1} [2]. The time profiles of these 4 radiation sources are analyzed in the paper [3].

The figure illustrates in two panels the logarithmic value of the daily averaged maximal fluxes, measured by the R3DR2 instrument on ISS (in cm^{-2} s^{-1}) from 23 October to 11 January 2016. The dose rates are proportional to the fluxes. Data are plotted according to the color bar to the right of panels. The vertical axis is the L shell parameter. The Dst index (http://wdc.kugi.kyoto-u.ac.jp/index.html) during the same period (in white) is overplotted.

The upper panel presents the relativistic electron flux data. Because the asymmetries in the Earth magnetic field, the ISS flux data cover the whole L range from 1 to 6 in Southern hemisphere, while in the Northern hemisphere the flux is extended only up to L=4.6. From upper panel of the figure we can see that the penetration of relativistic electrons to lower L values and strong temporary enhancements of the flux usually takes place when the negative value of Dst is large [4]. Later, during the recovery phase of the magnetic storm reverse process take place. Most of the time the ORB was with single maximum L distribution but after the storms in center of the figure periods with 2 maxima, especially in southern hemisphere, are observed. Sporadic, short time-scale relativistic electron precipitation "bands" [5] were observed in the data and statistically analyzed. The highest single "band" event of relativistic electron flux of 11,814 cm^{-2} s^{-1} was observed on 09.11.2015 at 15:12:08 UT and continue 10 s or less.

The lover panel data of the figure presents the IRB protons flux variations. It is seen that the flux is large in the interval October-December 2014, fall down till the end of June 2015 and rise up again till the end of measurements. These long-term variations correlate with the variations of the altitude of the station. Higher fluxes at the end of mission are connected also with the lower solar activity and lower sink of the IRB protons, respectively, in the decreased neutral atmosphere density. Obvious depletions in the IRB fluxes seen in the bottom of the figure correlate well with the magnetic storms and substorms, which is similar to the described by Zou et al. [6].

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SUITS/SWUSV: A Small-Size Mission to Address Solar Spectral Variability, Space Weather and Solar-Climate Relations

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We present the SUITS/SWUSV microsatellite mission investigation: "Solar Ultraviolet Influence on Troposphere/Stratosphere, a Space Weather & Ultraviolet Solar Variability" mission. SUITS/SWUSV was developed to determine the origins of the Sun's activity, understand the flaring process (high energy flare characterization) and onset of CMEs (forecasting). Another major objective is to determine the dynamics and coupling of Earth's atmosphere and its response to solar variability (in particular UV) and terrestrial inputs. It therefore includes the prediction and detection of major eruptions and coronal mass ejections (Lyman-Alpha and Herzberg continuum imaging), and the solar forcing on the climate through radiation and interactions with the local stratosphere (UV spectral irradiance measures from 170 to 400 nm). The mission is proposed on a Sun-synchronous polar orbit 18h-6h (for almost constant observing) and proposes a 7 instruments model payload of 65 kg – 65 W with: SUAVE (*Solar Ultraviolet Advanced Variability Experiment*), an optimized telescope for FUV (Lyman-Alpha) and MUV (200–220 nm Herzberg continuum) imaging (sources of variability); SOLSIM (*Solar Spectral Irradiance Monitor*), a spectrometer with 0.65 nm spectral resolution from 170 to 340 nm; SUPR (*Solar Ultraviolet Passband Radiometers*), with UV filter radiometers at Lyman-Alpha, Herzberg, MgII index, CN bandhead and UV bands coverage up to 400 nm; HEBS (*High Energy Burst Spectrometers*), a large energy coverage (a few tens of keV to a few hundreds of MeV) instrument to characterize large flares; EPT-HET (*Electron-Proton Telescope – High Energy Telescope*), measuring electrons, protons, and heavy ions over a large energy range; ERBO (*Earth Radiative Budget and Ozone*) NADIR oriented; and a vector magnetometer. Complete accommodation of the payload has been performed on a PROBA type platform very nicely. Heritage is important both for instruments (SODISM and PREMOS on PICARD, LYRA on PROBA-2, SOLSPEC on ISS, …) and platform (PROBA-2, PROBA-V, ...), leading to high TRL levels (>7). SUITS/SWUSV was initially designed in view of the ESA/CAS AO for a Small Mission; it is now envisaged for a joint NASA/ESA/CNES opportunity with Europeans and Americans partners for a possible flight in 2021.

SOLAR/SOLSPEC: Major Results of 8 Years of Solar Observations from the ISS

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Accurate measurements of Solar Spectral Irradiance (SSI) are of primary importance for a better understanding of solar physics and of the impact of solar variability on climate (via Earth's atmospheric photochemistry). The acquisition of a top of atmosphere reference solar spectrum and of its temporal and spectral variability during the unusual solar cycle 24 is of prime interest for these studies. These measurements are performed since April 2008 with the SOLAR/SOLSPEC spectro-radiometer from the far ultraviolet to the infrared (166 nm to 3088 nm). This instrument, developed under a fruitful LATMOS / BIRA-IASB collaboration is part of the Solar Monitoring Observatory (SOLAR) payload, externally mounted on the Columbus module of the International Space Station (ISS). The SOLAR mission, with its actual 8 years duration, will cover almost the entire solar cycle 24. We present here the in-flight operations and performances of the instrument, including the engineering corrections, calibration and the improved know-how for aging corrections. A SSI reference level from the UV to the NIR will be presented, together with its UV variability, as measured by SOLAR/SOLSPEC. Uncertainties on these measurements and comparisons with other instruments will also be briefly presented and discussed.

Spacecraft Charging via Numerical Simulations: Computational Design Choices and Physics Applications

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The electrical charging of spacecraft due to bombarding charged particles affects their performance and operation. We study this charging using CPIC, a particle-in-cell code specifically designed for studying plasma-material interactions [1]. CPIC is based on multi-block curvilinear meshes, resulting in near-optimal computational performance while maintaining geometric accuracy. It is interfaced to a mesh generator that creates a computational mesh conforming to complex objects like a spacecraft. Relevant plasma parameters can be imported from the SHIELDS framework (currently under development at LANL), which simulates geomagnetic storms and substorms in the Earth's magnetosphere.

An overview of the code will be presented, with emphasis on the design choices that were followed to guarantee computational performance. These include: (1) a curvilinear formulation of the model equations, where a coordinate transformation is introduced between the physical space, where the mesh in non-uniform and conforms to the spacecraft, and a logical space, where the mesh is uniform and Cartesian; (2) the use of structured meshes; (3) the use of a scalable solver for the electrostatic field based on the multigrid technique; and (4) the use of a hybrid mover where computational particles move in the logical space so that particle tracking is avoided. The challenges and the solutions developed to handle multi-block meshes in CPIC will also be discussed.

Selected physics results will be presented. These include (1) some preliminary spacecraft-charging results of geometries representative of the Van Allen Probes spacecraft and (2) a recent study that investigates the conditions for which a high-power (>keV) electron beam could be emitted from a magnetospheric spacecraft [2-3]. The latter study proposes a spacecraft-charging mitigation strategy based on the plasma contactor technology that might allow beam experiments to operate in the low-density magnetosphere. High-power electron beams could be used for instance to establish magnetic-field-line connectivity between ionosphere and magnetosphere and help solving long-standing questions in ionospheric/magnetospheric physics.

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The Complex Nature of Storm-Time Ion Dynamics: Transport and Local Acceleration

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A summary of ion composition changes in the inner magnetosphere during the 21-25 June 2015 geomagnetic storm is presented. Analysis of data from the HOPE (Helium, Oxygen, Proton Experiment) instruments on board Van Allen Probes A and B spacecraft reveals hitherto unresolved spatial structure and rapid dynamics in ion populations, with the two-spacecraft orbital configuration allowing these populations to be studied over time-scales never previously investigated. Complex regions of O+ dominance, at energies from a few eV to >10 keV, are observed throughout the inner magnetosphere (L<~6). We report on the origin of such regions along with the dynamics and energization of the pre-existing H+ dominant plasma. The drift of injected plasma from the nightside is shown to mimic signatures of in-situ local acceleration of low-energy plasma at L~2-3. Particle-tracing simulations demonstrate that the presence of a discrete spatial region of heavy-ion-rich plasma is the result of the complex energy-dependent transport and differences in charge-exchange rates acting upon injected ions that originated in the magnetotail.

Substorm Behavior Dependence of Space Weather Conditions in the 23th and 24th Solar Cycles

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On the base of the IMAGE magnetometer chain observations and the OMNI solar wind and Interplanetary Magnetic Field (IMF) data, we have analyzed the occurrence of the magnetic substorms at high geomagnetic latutudes. Substorms observed close to the minimum and maxima the 23-th and 24-th solar cycles were considered (namely, periods 1995-96; 2008-09; 1999-2000 and 2012-2013). All considered substorms were divided into 3 types according to their location in relation to the auroral oval dynamics. The first type – the substorms which are observed only at the auroral latitudes (called "usual" substorms); the second type – the substorms which propagate from the auroral geomagnetic latitudes to the polar ones (called "expanded" substorms, according to an expanded oval dynamics); and the third type – the substorms which are observed only at the geomagnetic latitudes above ~70 degrees in the absence of simultaneous magnetic disturbances below 70 degrees (called "polar" substorms, according to a contracted oval dynamics). We have analyzed the space weather conditions before the onset of these three types of substorms. Namely, we have considered the influence of the different types of the solar wind streams, of the solar wind and IMF parameters, of the geomagnetic indexes values etc. The substorm seasonal variations have been studied as well. It was found that although "polar" and "expanded" substorms observed at almost identical high geomagnetic latitudes, they appear under different space weather conditions. We argue that the space weather conditions differ for different types of the considered substorms and could be a useful tool for the investigation of the various magnetospheric plasma processes (or their location) related to these substorms.

A Study of the Magnetosheath Plasma Properties with the Gasdynamics Framework

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This is an attempt to represent the dynamics of the plasma in the magnetosheath with response to the solar wind conditions. The numerical magnetosheath-magnetosphere model is utilized in our research. The overall model considers the self-consistent interaction between the regions of the magnetosheath and the magnetosphere. The magnetosheath region is described with the gasdynamics framework. Data-based magnetic field model with numerically calculated shielding field is applied in the magnetosphere. The boundaries of the magnetosheath – bow shock and magnetopause are determined with respect to the given solar wind conditions. We consider examples of actual satellite crossings of the magnetosheath. The results from the satellite measurements are consistent with the model simulations.

Comparison of >1 Mev Relativistic Electron Microburst Characteristics with Whistler Mode Chorus and EMIC Wave Occurrence

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We investigate the distribution of relativistic electron microburst occurrence and flux magnitude in the Earth's outer radiation belts. Using an automated detection algorithm (published in [1]) on low-altitude SAMPEX HILT >1MeV electron flux observations from 1996 – 2007, we have created a large database of events from which we have determined microburst properties. The HILT instrument samples different pitch angle distributions over different parts of the world, such that in different regions HILT is dominated by either trapped, drift loss cone or bounce loss cone fluxes [2]. We limit our database of relativistic electron microbursts to those which occurred over the North Atlantic region, where HILT only samples the bounce loss cone. This resulted in a total of 21,746 detected events.

It is thought that relativistic microbursts are a result of the pitch angle scattering of trapped outer radiation belt electrons by either whistler mode chorus waves [3] or EMIC waves [4]. Thus, we compare the microburst characteristic in our database with whistler mode chorus distributions and EMIC distributions reported in the literature. In particular, we investigate the MLT and L shell distributions of relativistic electron microburst properties under three different geomagnetic conditions defined by AE*.

We find that relativistic microburst occurrence distributions are similar to but not identical with the reported distributions for chorus wave amplitudes, when considering the three geomagnetic disturbance levels. However, we have also found that the magnitude distribution of the relativistic microbursts has the opposite relationship with chorus wave intensity. This is unexpected if high amplitude chorus waves drive the scattering processes associated with relativistic electron microbursts.

In addition, we test the suggested link between EMIC waves and microbursts. We use the Halley magnetometer in Antarctica to investigate any EMIC wave activity seen on the ground, at times when the microbursts in the North Atlantic region are occurring near Halley's magnetic conjugate location. Our initial results suggest that any EMIC activity observed at the time of microbursts is coincidental and not causative; success rates are roughly equivalent to success rates of EMIC activity observed 10 days after the microburst has occurred, taken as a control group. More detailed analysis will be presented at the meeting.

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Solar Wind Control of the Plasma Sheet Thermal Electrons at r=6-11 Re: Empirical Model

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The thermal electron population characteristics in the transition region between the inner magnetosphere and magnetotail are of special interest because this region can be considered as a source of the electrons which are end up in the radiation belts, accelerated up to several MeV. We present an empirical model of the electron temperature and density on the nightside for geocentric distances r = 6-11 Re. The model is constructed using measurements onboard THEMIS probes during geomagnetic storms taking place in 2010-2013. We use the data of ESA and SST detectors in the energy range from tens eV to 300~keV. The total size of the dataset is equivalent to ~400 hours of the observations in the plasma sheet complemented by the observations in the solar wind. The model outputs the electron temperature and density in the equatorial plane as a function of coordinate and interplanetary medium parameters. The model shows a better performance if the input solar wind parameters are lagged and time averaged over certain intervals. The optimal lags and the intervals of averaging were determined for each input parameter.

The density distribution showed no significant dawn-dusk asymmetry (see Figure 1a). The density increases toward the earth and shows a moderate variation with MLT. The model is parameterized by the solar wind proton density averaged over [t-0.5h; t-4.5h] interval, and southward component of interplanetary magnetic field (IMF B_S), averaged over [t-0.5h; t-6.5h] interval. The density increases with the increase in either input parameter. Note that the interval of the IMF integration (6 h) is much longer that a typical substorm growth phase and it rather corresponds to the geomagnetic storm main phase duration. In agreement with previous studies [1,2], the solar wind proton density is the main controlling parameter but the IMF B_S becomes of almost the same importance in the near-Earth region. The root-mean-square deviation between the observed and predicted plasma sheet densities is 0.23 cm^{-3} and the correlation coefficient is 0.82, the highest correlation ever obtained for this kind of empirical models [1,2].

The electron temperature equatorial distribution is highly asymmetric with respect to the local midnight. The electron temperature can be very low on the dusk flank and the temperature maximum is located in the post-midnight - morning MLT sector. The model is parameterized by solar wind velocity (averaged over [t-0.5h; t-2.5h]) and southward and northward IMF components (averaged over [t-0.5h; t-1.25h] and [t-0.5h; t-2.5h], respectively). The solar wind velocity is a major controlling parameter and the importance of B_S and B_N is comparable. In contrast to the density model, the optimal interval of IMF B_S averaging is 45 min (substorm growth phase time scale). The plasma sheet electron temperature increases with the solar wind velocity and IMF B_S increase and decreases with the IMF B_N increase. The effect of the northward IMF component manifests mostly in the outer part of the modelled region (r > 8 R_E). The influence of the IMF B_S is strongest in the midnight — post-midnight MLT sector. The correlation coefficient between the observed and predicted plasma sheet electron temperature values is 0.76 and the root-mean-square deviation is 2.6 keV. Both models showed their best performance in the dawn MLT sector. The model can be used as a boundary condition for inner magnetosphere simulations. The research leading to these results was partly funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No 606716 SPACESTORM and by the European Union's Horizon 2020 research and innovation programme under grant agreement No 637302 PROGRESS

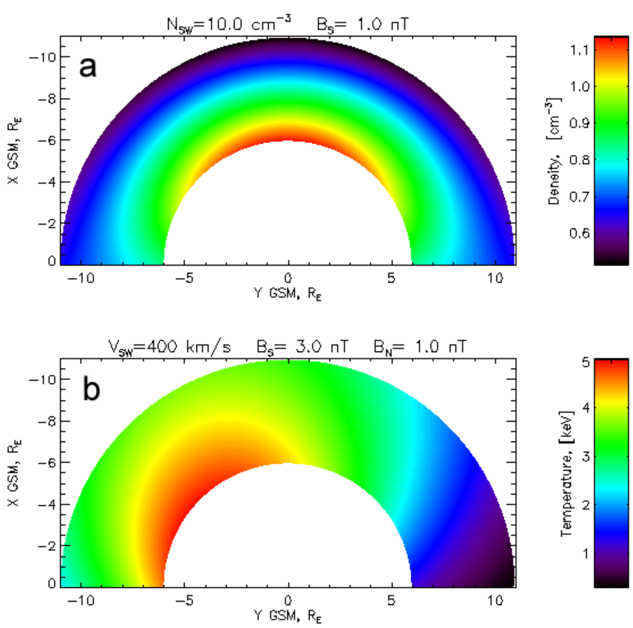

Figure 1. The electron density (a) and temperature (b) distributions in the equatorial plane. The model input parameters are specified at the top of the panels.

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An Introduction to Recent Progress on a Future Chinese Mission to Observe the Coupling between the Earth's Magnetosphere, Ionosphere and Thermosphere

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The Earth's magnetosphere, ionosphere and thermosphere are main regions where disastrous space weather events like the magnetic storms happen, and they are coupling together through energy, mass and momentum exchange as well as electromagnetic forces. The O^+ ions flowing from the ionosphere into the magnetosphere are tracers for the mass upflow in the polar region (Fig 1), and they are ion source for the magnetic storms because they form most of the ring current during storm time. MIT is a Chinese mission targeting at the coupling processes of the earth's magnetosphere-ionosphere-thermosphere system. The mission's science objectives focus on the acceleration mechanism and the origin of outflow O^+ ions and other related outstanding scientific questions. The mission plans a constellation composed of four satellites orbiting the earth at different altitude. The proposed payloads include particles detectors, field detectors, aurora and neutral imaging system. These payloads will measure the plasma compositions and the electromagnetic waves, therefore determine the key acceleration mechanisms for the oxygen ions. This mission is selected as a background model supported by the strategy pioneer program of Chinese Academy of Science. In this poster, we report the orbits, payloads and the current status for the MIT mission.

Plasma Sheet Injections and Their Relationship to Magnetotail Transients

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Measured as sudden increases in flux across several energy channels, particle injections are signatures of particle energization and transport. Observed both in the inner magnetosphere and throughout the plasma sheet, injections play a role in coupling the two regions. Understanding particle energization and transport throughout the magnetotail is therefore fundamental to modeling particle sources and losses in Earth's inner magnetosphere. Injections have been correlated with dipolarization, earthward flows, and dawn-dusk electric fields. We simulate injection signatures by modeling the electromagnetic fields describing a transient dipolarizing flux bundle and tracing electron guiding-center motion analytically. This simple model can reproduce most injection signatures at multiple locations simultaneously, reaffirming earlier findings that an earthward-traveling DFB can both transport and accelerate electrons to suprathermal energies, and can thus be considered as the primary driver of short-lived (~10 min) injections. We find that energetic electron drift paths are greatly influenced by the sharp magnetic field gradients around the localized DFB. If the gradients are weak the energetic electrons initiating at reconnection will drift out of the flow channel such that the observed injection is comprised mostly of plasma sheet electrons. However, if the duskward magnetic field gradients on the DFB's dawn flank are strong they can cause electrons to ∇B drift further earthward from the reconnection site than due to E x B alone. Similarly, strong dawnward magnetic field gradients on the DFB's dusk flank can extract energetic electrons from the inner magnetosphere out to the plasma sheet, where they can either be recirculated earthward or remain at higher L-shells. Therefore, the source of electrons observed during injection depends on the spacecraft location relative to the DFB and on the DFB's properties.

Forecasting the Kev-Electrons in the Inner Earth's Magnetosphere Responsible for Surface Charging

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Low energy (up to 100-200 keV) electron fluxes are very important to specify when hazardous satellite surface charging phenomena are considered. These electrons are the critical seed population, being further accelerated to MeV energies by various processes in the Earth's radiation belts. The fluxes of electrons with keV energies are not usually analyzed and modeled in details when studying the electron radiation belts. Accurate modeling and forecasting of low energy electrons is very challengeable, since the electron flux at the keV energies is largely determined by convective and substorm-associated electric fields and varies significantly with geomagnetic activity driven by the solar wind on the time scales on tens of minutes. Significant variations in the low-energy electrons can be seen during isolated substorms, not related to any storm periods. Moreover, electron flux variations depend on the electron energy.

We present the model for low energy (< 200 keV) electrons in the inner magnetosphere, which is the version of the Inner Magnetosphere Particle Transport and Acceleration model (IMPTAM) for electrons [1, 2, 3]. This model has been operating online since March 2013 (http://fp7-spacecast.eu, imptam.fmi.fi, http://csem.engin.umich.edu/tools/imptam/). The model is driven by the real time solar wind and Interplanetary Magnetic Field (IMF) parameters with 1 hour time shift for propagation to the Earth's magnetopause, and by the real time Dst index. The presented model provides the low energy electron flux at all L-shells and at all satellite orbits, when necessary. We present the model performance analysis as accumulated model output compared to GOES MAGED data (40, 75, 150 keV) and demonstrate the model's forecasting abilities on several real space weather events. We developed a new model for electron number density and temperature in the plasma sheet as dependent on solar wind and IMF conditions based on THEMIS data analysis. We introduced the electron lifetimes due to interactions with chorus and hiss waves. We show that the IMPTAM model for electrons provides very good nowcast and forecast of keV-electrons in the inner magnetosphere. The research leading to these results was partly funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No 606716 SPACESTORM and by the European Union's Horizon 2020 research and innovation programme under grant agreement No 637302 PROGRESS

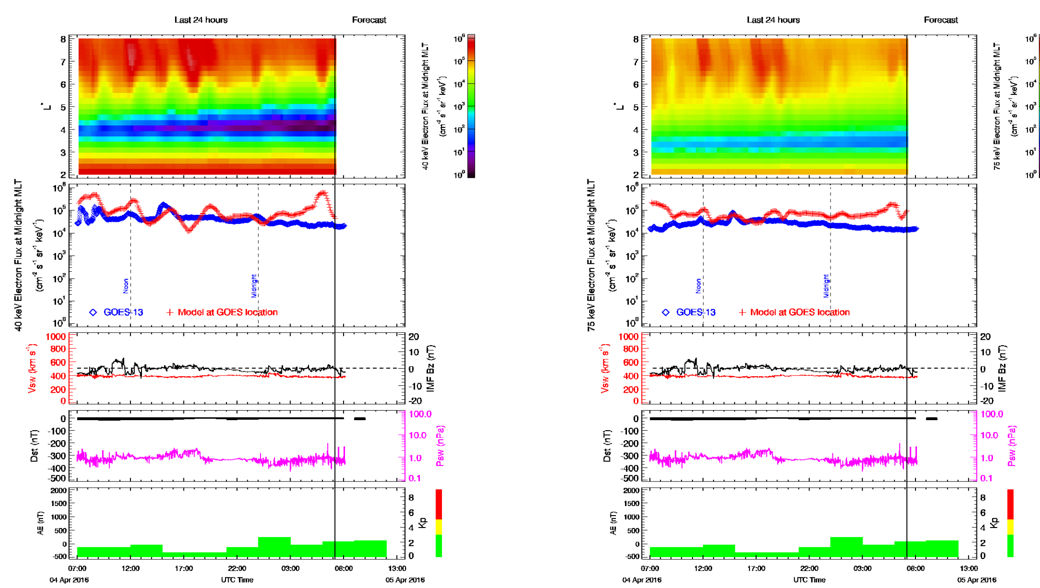

Figure 1. Example of low energy electrons' nowcast during April 4, 2016, 0700 UT to April 5, 2016, 1300 UT for 40 (left) and 75 (right) keV electrons at http://fp7-spacecast.eu: (1st panel) The modeled by IMPTAM electron flux at L=2-8 at midnight, (2nd panel) the electron flux measured at GOES 13 MAGED (blue) together with the model flux (red), (3d panel) IMF Bz and solar wind velocity, (4th panel) solar wind dynamic pressure and Dst index, (5th panel), Kp and AE indices (not shown for this event).

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Influence of the IMF B_Y Field on the Magnetotail Current Sheet Structure and Particle Dynamics

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The magnetotail Current Sheet (CS), which separates the northern and southern lobes, plays a key role in the dynamics of the Earth's magnetosphere. Numerous in situ observations performed by Geotail, Cluster and Themis spacecraft (s/c) reported different features of magnetic field topology in the magnetotail CS such as flapping, flattening, tilting, waving, twisting and bifurcation [1-3]. Usually, the magnetic field lines, crossing the magnetotail equatorial plane, have a normal component B_Z due to the Earth's dipole field and a smaller component along the dawn-dusk direction, B_Y. Sometimes, however, the B_Y component in the magnetotail CS becomes significant A strong B_Y field can shear the magnetic field of the CS making the CS thin and causing a cross-tail field-aligned current [4,5], influencing the adiabaticity and orbits of charged particles in the CS, that, in turn, may affect the CS structure and stability [6]. Thus, it is important to know the spatial distribution of the B_Y field across the CS as well as the characteristic scale of the CS region where this component dominates. This knowledge is tightly connected with the understanding of mechanisms, which are responsible for the strong B_Y field generation in the magnetotail CS.

The B_Y component in the magnetotail may exist due to the direct penetration of the interplanetary magnetic field (IMF) [7]. However, Cluster observations demonstrated that at some periods the strength of the B_Y component can be enhanced at the center of the CS relative to that in the CS boundaries, so that the spatial profiles of the B_Y component along the north-south direction have a "bell-like" shape. The mechanism of the B_Y field enhancement in the center of the CS was unclear [5,8].

In this work we performed test ion simulations in a thin CS with the initially small guide B_Y field originated from the IMF B_Y penetration into the magnetotail. We show the possibility of the B_Y field enhancement in the center of the CS and formation of a "bell-shaped" B_Y field profile due to the self-consistent influence of the nonadiabatic ions on the CS structure. We also discuss the kinetic features of the nonadiabatic ion dynamics leading to the enhancement of the core B_Y field in the CS of plasmoids.

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Substorms during Geomagnetic Storms Observed at Apatity in the Course of the Descending Phase of SC24

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We studied substorms in enhanced geomagnetic activity, when geomagnetic storms developed, during the descending phase of the current SC24. Observations of the **M**ultiscale **A**urora **I**maging **N**etwork (MAIN) in Apatity have been used. Solar wind and interplanetary magnetic field parameters were estimated by the 1-min sampled OMNI data base. Substorm onset and further development were verified by the 10-s sampled data of IMAGE magnetometers and by data of the all-sky camera at Apatity. Subject of the study was the substorm development. The particularities in the behaviours of substorms connected with different storms and storm phases were discussed.

WN4 Variability in the Topside Ionosphere

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Atmospheric tides are global-scale periodic oscillations of the atmosphere, with scale sizes of thousands to tens of thousands of kilometers. Non-migrating tides, which do not follow the apparent motion of the Sun, can significantly alter the global ionospheric structure. In particular the wave-number 4 (WN4) pattern, which has four peaks equally spaced in longitude when viewed in a constant local time frame, is thought to be a signature of the DE3 non-migrating tide propagating upward from the lower atmosphere, and is therefore an important clue to whole-atmosphere coupling. While DE3 and WN4 signatures have been much studied in recent years in the mesosphere-lower thermosphere region, relatively little is known about how WN4 impacts the ionosphere above the F-peak. We present an analysis of WN4 in the topside ionosphere at low latitudes as measured by the Defense Meteorological Satellite Program (DMSP) spacecraft. We investigate how the location and strength of WN4 in ion densities changes over two solar cycles and across local time and season, and interpret these variations in terms of composition and transport modified by the magnetic field geometry. Monthly averages of evening ion densities often clearly show a WN4 pattern along the magnetic equator which is strongest at equinox. In June solstice, WN4 moves 5-10^{o} north, and ion densities are enhanced in regions of positive magnetic declination; in December solstice these effects are reversed. WN4 also moves slightly in latitude across the solar cycle, but this effect is much smaller than the seasonal effect. In general WN4 is strongly present in topside ion densities across all levels of solar activity and local times throughout the afternoon and evening.

Multi-point Observations and Modeling of Particle Injections during Substorms

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Dispersionless and dispersed particle injections associated with substorms have been studied for many years based on observations acquired primarily at geosynchronous orbit. A general picture that has emerged is that particles are energized and rapidly transported/organized behind an "injection boundary" that penetrates closer to Earth in some magnetic local time sector (e.g. the so-called double-spiral injection boundary model). While this picture provides a very good description of injections at geosynchronous orbit, with the launch of the Van Allen Probes mission, we are now able to explore the evolution of injection signatures well inside of geosynchronous orbit at multiple locations as well. We find that the injection boundary model also appears to reproduce a number of complicated types of dispersion patterns observed in the Van Allen Probes particle data (e.g. the detached blade-like features shown in Figure 1.) The dispersion patterns are found to depend dramatically on orbital configuration and timing of onset relative to the phasing of the spacecraft in their orbits. In addition to observational results, we present results of simulated dispersion patterns obtained from the injection boundary model using guiding center particle tracing in two different field configurations: 1) a simplistic dipole magnetic field with Volland-Stern electric field, and 2) RAM/SCB running in the SHIELDS Framework

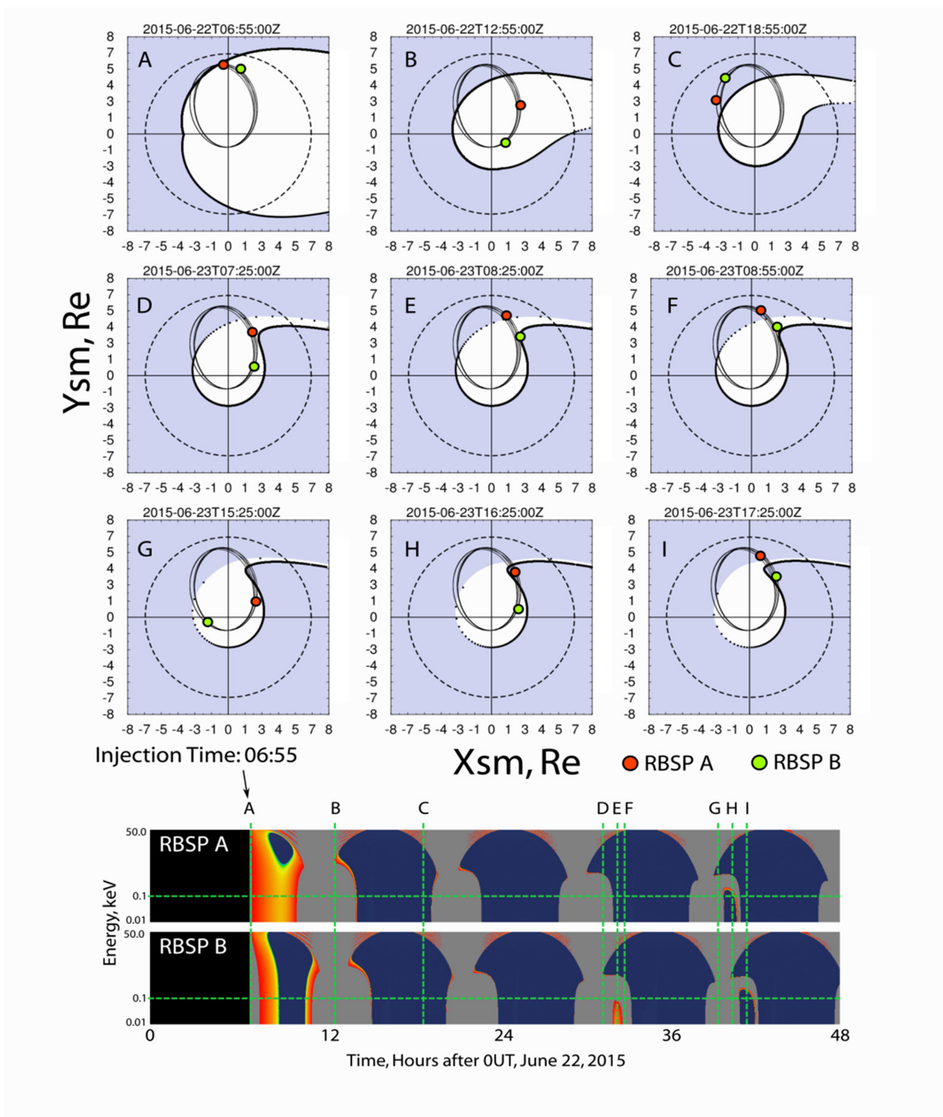

Figure 1. Simulation of "blade-like" or "finger-like" detached regions in the Van Allen Probes HOPE spectrograms.

Magnetic Local Time Dependency in Earth Radiation Belts' Modeling

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For many years, ONERA has been at the forefront of the Earth radiation belts' modeling thanks to the Salammbô model, which robustly reproduces their dynamics over a time scale of the particles' drift period. This implies that we implicitly assume an homogeneous repartition of the trapped particles (in Magnetic Local Time) along a given drift shell. However, radiation belts are inhomogeneous in MLT and we need to take this into account to model accurately the finest dynamical structures induced during a geomagnetic storm. For this purpose, we are working on both the numerical resolution of the Fokker-Planck diffusion equation included in the model and on the MLT dependency of physic-based processes acting in the Earth radiation belts. The aim of this talk is first to present the 4D-equation used (see [1] and [2]) and bias induced by numerical diffusion before focusing on physical processes taken into account in the Salammbô code.

In order to characterize the numerical diffusion induced by advection terms, we have implemented an equation with no diffusion terms. We will present the methodology used (a Beam-Warming scheme combined with a Superbee limiter, see [3]) to limit numerical diffusion and to find the best compromise between a physically reasonable criteria and computational constraints. Results about this numerical part can be seen in Figure 1, which represents initial and final Phase Space Density (PSD) for equatorial electrons of 5 MeV at L* = 8, after 4 drift periods and with respect to the discretization scheme.

Then, we focused on physical mechanisms to implement in the Salammbô model. Figure 2 illustrates the radial diffusion process. We can see the PSD of equatorial electrons at constant magnetic moment after 8 days of simulation. A Gaussian distribution of particles is centered on 00h00 MLT at L* = 8 to simulate the injection from the plasmasheet. We will discuss about this physical process, and about wave-particle interactions.

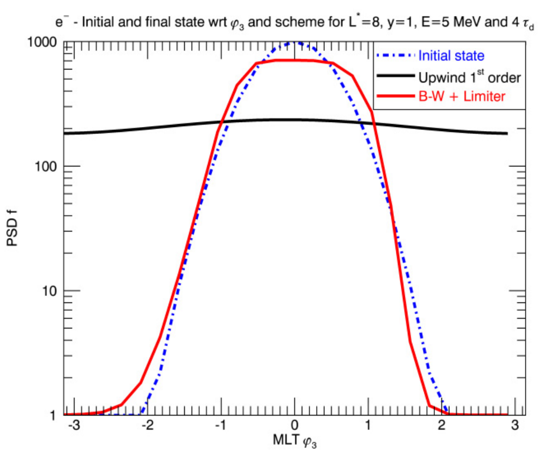

Fig 1 – Initial and final state according to the numerical method used.

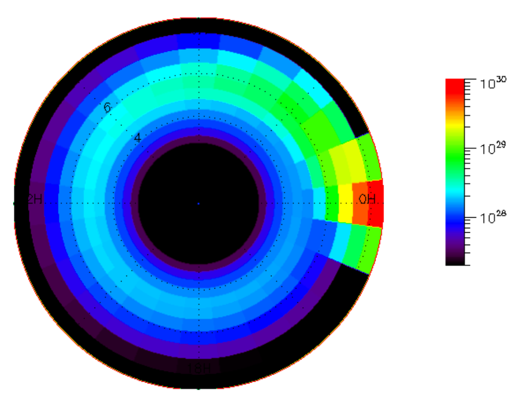

Fig 2 – PSD of equatorial electrons at constant magnetic moment (1 keV at L* = 8) after 8 days of simulation.

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Progress and Challenges in Heliophysics

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Heliophysics as a scientific discipline is exceptionally diverse in terms of physical regimes as well as replete with unsolved, fascinating, scientific problems. Heliophysics comprises the whole spectrum of plasma parameters, from high-density, low-temperature, collisional environments such as the solar photosphere and the ionosphere-thermosphere-mesosphere system, to exceptionally collisionless plasmas in the magnetosphere. Many dynamical processes, which often initiate eruptively and seemingly unpredictably, are shaped by the interaction of different regions with different plasma conditions. For these reasons, Heliophysics processes are often complex and resist immediate attempts at understanding.

While many aspects of Heliophysics are still in need of resolution, we have nevertheless made progress in the understanding, and sometimes even quantification, of some key processes. This presentation will provide an overview of this progress, as well as list key scientific questions, which wait to be addressed by future research.

Propagation and Linear Mode Conversion of Magnetosonic and Electromagnetic Ion Cyclotron Waves in The Radiation Belts

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Magnetosonic waves and electromagnetic ion cyclotron (EMIC) waves are important for electron acceleration and loss from the radiation belts. It is generally understood that these waves are generated by unstable ion distributions that form during geomagnetically disturbed times. Here we show that magnetosonic waves could be a source of EMIC waves as a result of propagation and a process of linear mode conversion. The converse is also possible. We present ray tracing to show how magnetosonic (EMIC) waves launched with large (small) wave normal angles can reach a location where the wave normal angle is zero and the wave frequency equals the so-called cross-over frequency whereupon energy can be converted from one mode to another without attenuation. While EMIC waves could be a source of magnetosonic waves below the cross-over frequency magnetosonic waves could be a source of hydrogen band waves but not helium band waves.

Modelling Space Weather Events and Mitigating their Effects on Spacecraft with SPACESTORM

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Over the last ten years the number of operational satellites has grown significantly to more than 1200. We depend on these satellites more than ever before for applications such as communications including TV and mobile phones, navigation, positioning and timing signals and other applications such as Earth observation. All these satellites must be designed to withstand the harsh radiation in space for up to 15 years or more. Space weather events can increase radiation levels by five orders of magnitude in the Earth's radiation belts and trigger bursts of high energy particles which can disrupt satellite operations and sometimes cause a complete satellite loss. Here we present some of the latest results from the European FP7 SPACESTORM project. We present results from computer models including IMPTAM to simulate changes in the low energy electron population during magnetic storms, and BAS-RBM to simulate changes in the relativistic electron flux in the radiation belts during magnetic storms. We present results from a 30 year re-construction of the radiation belts for Medium Earth Orbit (MEO) using data from the GOES satellite as boundary condition and compare some of the results against data from the Giove A satellite in Medium Earth Orbit as well as RBSP. We also present the results of an analysis of severe space weather events that shows that the 24 hour electron fluence at geostationary orbit is up to seven times higher than previous calculations. We discuss some of the SPACESTORM experiments on long duration radiation exposure and on new materials and techniques designed to reduce surface charging on solar arrays. Finally we discuss how the models are being combined with radiation effects to help forecast risk to satellites on orbit via our web site www.fp7-spacecast.eu.

Geometry of the Sun as seen with HMI (SDO) during Cycle 24

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Geometry of the Sun and its temporal variations observed with ground-based instruments are still subject to questioning. The geometry, which inform us on the interior of the Sun, is achieved by high resolution measurements of the radius, oblateness and gravitational moments c2 and c4. Several space missions were developed these last decades to validate or refute its observed variations with ground experiments and the link with solar activity. High angular resolution of solar radius measurements and its long term trend is however a challenge in Space. The first attempts with MDI (Soho) then SODISM (PICARD) and HMI (SDO) revealed the difficulties of such measures due to hostile environment which introduces thermal variations of the instruments along the satellite orbit. These variations have non negligible impacts on optical properties of onboard telescopes and therefore on images and parameters extracted, such as the solar radius. We need to take into account the thermal behavior (housekeeping data) recorded together with the science data to correct them. Solar oblateness and gravitational moments ask for both special spacecraft operations and appropriate processing methods to obtain the needed accuracy for their measurements. We present here some results on the solar radius and oblateness obtained with HMI data. Images analyzed cover six years since May 1, 2010 (beginning of Cycle 24), untill now. Results show that the geometry of the Sun presents some temporal variations related to solar activity. In particular we evidence a Quasi-Biennale Oscillation (QBO) correlated with the solar cycle, as was observed with ground observations.

Radiation Measurements - Concepts and Misconceptions

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The salient characteristic of radiation measurements is the discrete nature of the measured substance. The radiation manifests itself as energetic quanta that are emitted and interact with the radiation detectors randomly in time. In addition, the radiation measurement signals are always subject to statistical fluctuations due to the nature of the radiation-matter interactions and the detector signal generation.

Various concepts address the challenges presented by the amplitude and the temporal randomness associated with the radiation measurements. These concepts are often associated with other science and engineering fields such as electronics, physics, chemistry, mechanical engineering and others. The measurement concepts in general are dynamic - new ones are often created, old ones are forgotten, some are improved and some are resurrected. With this dynamics come misconceptions - some less profound, some with a more lasting and perhaps noticeable impact.

In this presentation we are analyzing few of these concept-misconception relationships. They can be very simple - for example, the concept of counting rates, random in nature, and the misconception of using the deterministic frequency measurement unit Hz. The more complex concept-misconception controversy is associated with the concept of analytical spectroscopy performance and the misconception that it can be maintained at any counting rate using adaptive pulse processing. Other concept-misconception topics are also presented in view of a generalized model of radiation measurement systems.

Specification of Space Hazards Induced near Earth by Large Dynamic Storms (SHIELDS)

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We present a recently funded project through the Los Alamos National Laboratory Directed Research and Development (LDRD) program that is developing a new modeling capability for the specification of Space Hazards Induced near Earth by Large Dynamic Storms, the SHIELDS framework. The project goals are to understand the dynamics of the hot (keV) electrons (the source and seed populations for the radiation belts) on both macro- and micro-scale. Important physics questions related to rapid particle injection and acceleration associated with magnetospheric storms and substorms as well as plasma waves are investigated. These challenging problems are addressed using a team of world-class experts in the fields of space science and computational plasma physics and state-of-the-art models and computational facilities. In addition to physics-based models (like BATS-R-US[1] and RAM-SCB[2]), new data assimilation techniques employing data from LANL instruments on the Van Allen Probes and geosynchronous satellites are developed. The SHIELDS framework enhances our capability to reliably model and predict the near-Earth space environment where operational satellites reside.

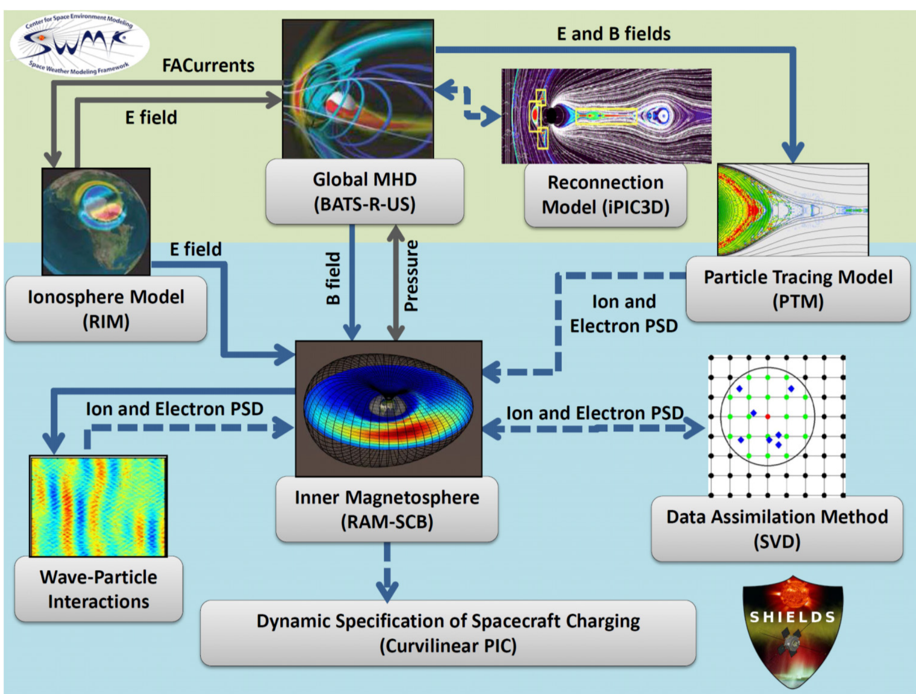

Figure 1. Schematic flow chart of the SHIELDS framework. Solid arrows indicate existing coupling, while dashed arrows indicate couplings to be completed.

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Advancements in Time-of-Flight Mass Spectrometers

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Instruments to measure ion composition over the energy range from ~20 eV up to ~100 keV now commonly use the time-of-flight technique. This technique is versatile in that the specific design of the instrument can be tailored to meet the requirements of specific missions. A time-of-flight section combined with an electrostatic analyzer gives mass per charge, which is normally sufficient for the major species in the magnetosphere. Adding a solid state detector allows both the mass and charge state to be determined, which is important for solar wind composition. High mass resolution can be obtained using a linear electric field that makes the mass resolution independent of incoming energy and angle. In this talk we review the basic principles of these instruments, discuss some of the developments that have been key to implementing the current generation of instruments, and discuss new developments that will improve the resolution and efficiency of these sensors.

Whistler Wave Energy Flow in the Plasmasphere

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The measured wave properties of plasmaspheric hiss are important to constrain models of the generation of hiss as well as its propagation and amplification. For example, the generation mechanism for plasmaspheric hiss has been suggested to come from one of three possible mechanisms: 1) local generation and amplification, 2) whistlers from lightning, and 3) chorus emissions which have refracted into the plasmasphere. The latter two mechanisms are external sources which produce an incoherent hiss signature as the original waves mix in a stochastic manner, propagating in both directions along the background magnetic field. In contrast, local generation of plasmaspheric hiss within the plasmasphere should produce a signature of waves propagating away from the source region. For all three mechanisms scattering of energetic particles into the loss cone transfers some energy from the particles to the waves. By examining the statistical characteristics of the Poynting flux of plasmaspheric hiss, we can determine the properties of wave energy flow in the plasmasphere. We report on the statistics of observations from the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) Waves instrument on the Van Allen Probes for periods when the spacecraft is inside the plasmasphere. We find that the Poynting flux associated with plasmaspheric hiss has distinct and unexpected radial structure which shows that there can be significant energy flow towards the magnetic equator. We show the properties of this electromagnetic energy flow as a function of position and frequency.

Geomagnetic and Ionospheric Disturbances during Storms in March 2013 and March 2015

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This study presents analysis of the satellite-borne and ground-based observations of the geomagnetic disturbances and ionospheric electron density distribution during two St. Patrick's Day geomagnetic storms on March 17, 2013 and 2015. The first event on 17 March 2015 is the principal event covering the interval from 15 to 18 March 2015, in which solar eruptive phenomena (a long-enduring C9-class solar flare and associated CME(s) on 15 March) and a strong geomagnetic storm on 16-18 March (Max. D_{st} was -228 nT) were reported. This magnetic storm is the largest one observed in the current solar cycle. The second event is the period on 17-18 March 2013 which is strong geomagnetic storm (the D_{st} index ~ -140 nT) developed. This storm was caused by magnetic cloud (15 UT, 17 March – 6 UT, 18 March 2013) in the solar wind. Solar wind and interplanetary magnetic field parameters were taken from OMNI data base. The magnetograms of the IMAGE network and Observations of the Multiscale Aurora Imaging Network (MAIN) in Apatity were used as indicator of auroral activity. These two storms characterized by one moment of storm sudden commencement (SSC), but 2015 geomagnetic storm have much greater magnetospheric input into thermosphere-ionosphere system. The particular attention is given to the ionospheric disturbances during the main and recovery phase of the geomagnetic storms. The Global Self-consistent Model of the Thermosphere, Ionosphere and Protonosphere (GSM TIP) allows us to reveal the main processes that influence on the behavior of the total electron content and the *F*2 layer peak electron density during these storms' events.

Transient Plasma Structures in the Magnetotail Lobes

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The analysis of hundreds of hours of INTERBALL-1 lobe observations shows that lobes are not "empty" but a variety of plasma structures are encountered. They can be organized in two main classes reflecting their origin: plasmas in which both electrons and ions have energies typical for the plasma sheet (PS) and structures, in which the electrons have energies up to few hundreds eV typical for the magnetosheath, accompanied by ions with different characteristics (1). In the present work we discus the first class of structures – those with PS-like electrons and ions. Previous studies performed on the basis of only ion (IB-1) measurements (2) found two types of lobe ion structures with PS energies - field-aligned beams of accelerated ions and plasma structures of various durations with quasi-isotropic velocity distribution functions. The field-aligned ion beams (beamlets) were successfully interpreted as a result of non-adiabatic ion acceleration in the current sheet of the Earth's magnetotail. The mechanism of formation of the PS-structures (plasma clouds) was not obvious and it seemed that different mechanisms act depending on the direction of the interplanetary magnetic field. Re-examination of the plasma clouds, already using electron and magnetic field measurements, gives new insight of their nature. For example, it proved that some cases were identified as different structures only because week ion fluxes in the lobes are more difficult to be measured in comparison with the electron fluxes. The multi-point analyses of several cases of plasma clouds registered by CLUSTER satellites showed that plasma clouds are transient observations of the plasma sheet – lobe interface. At this interface simultaneously exist field-aligned beamlets and PS-like structures - a result of localization in dawn-dusk direction of the non-adiabatic beamlet acceleration. An MHD disturbance of the PS boundary magnetic tubes propagates earthward. This gives us the ground to suggest, that the PS-like plasma structures encountered in the lobes are not discrete structures but transient observations of the plasma sheet – lobe interface.

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Properties of Whistler-Mode Waves in Plasmaspheric Plumes

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We analyze occurrence rates and propagation properties of whistler mode waves in plasmaspheric plumes using systematic observations of the Cluster spacecraft. We use a list of nearly 1000 crossings of plasmaspheric plumes which has been compiled using the data of the WHISPER instruments from 2001 to 2006. We combine this list with a database of measurements of the STAFF-SA instruments. Amplitudes of the whistler mode waves in plumes are investigated in connection with the geomagnetic activity. We found that the integrated VLF amplitudes reach up to 200 pT with median values of 2-40 pT in the plume intervals.

We combine the list of crossings of plasmaspheric plumes with all available measurements of the WBD instrument. We inspect sixty five plasmaspheric plume crossings which are covered by the WBD data. High-resolution power spectrograms allow us to classify whistler-mode waves occurring inside the plasmaspheric plumes and analyze their fine properties. Our results show that strong whistler-mode wave activity below 1 kHz is observed during 98% of analyzed plume time intervals. Additional frequency bands at higher frequencies (up to 16 kHz, in up to 3 separate bands) are found in 37% of analyzed spectrograms, whereas discrete emissions can be identified in 32% of cases.

Low-Order Data-Driven Applications in the Sun-Earth System

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Advances in observational and data mining techniques allow extracting information from the large volume of Sun-Earth observational data that can be assimilated with first principles physical models. However, equations governing Sun-Earth phenomena are typically nonlinear, complex, and high-dimensional. The high computational demand of solving the full governing equations over a large range of scales precludes the use of a variety of useful tools that rely on applied mathematical and statistical techniques for quantifying uncertainty and predictability. Effective use of such tools requires the development of low-order approximations of either the full governing equations or the phenomenon itself. An overview of several low-order data-driven applications in Sun-Earth system will be presented.

Motivated by the emergence of Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE), we report here on the first results of assimilation of low-altitude ionospheric magnetic perturbations into the Lyon-Fedder-Mobarry (LFM) global magnetospheric model coupled with the Rice Convection Model (RCM) [1]. Adopted assimilation approach relies on the assumption of a quasi-steady, linear approximate relation between equatorial magnetospheric pressure and ionospheric Region 2 field-aligned currents. This approximation is implemented numerically by perturbing large-scale modes from the Fourier decomposition of equatorial magnetospheric pressures and computing responses of the corresponding modes in the ionospheric magnetic field.

Stochastic approaches to model critical but unresolved or poorly understood physical processes in low-order models, are becoming increasingly important in atmosphere, ocean, and climate models applications [2]. Such low-order models are typically facilitated by data-adaptive decompositions of the observational data, such as Singular Spectrum Analysis. Promising cross-disciplinary applications of such approaches to radiation belts and solar wind [3] will be presented.

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Spatial and Temporal Characteristics of Long-Lasting Poloidal Pc4 Pulsations in the Dayside Magnetosphere

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We use magnetic field and plasma observations from the Van Allen Probes, THEMIS and GOES spacecraft to study the spatial and temporal characteristics of long-lasting poloidal Pc4 pulsations in the dayside magnetosphere. The pulsations were observed after the main phase of a strong storm during low geomagnetic activity. The pulsations occurred during various interplanetary conditions and the solar wind parameters do not seem to control the occurrence of the pulsations. The most striking feature of the Pc4 pulsations was their occurrence at similar locations during successive orbits. We used this information to study the latitudinal nodal structure of the pulsations and demonstrated that the latitudinal extent of the magnetic field pulsations did not exceed 2 Earth radii (R_E). A phase shift between the azimuthal and radial components of the electric and magnetic fields was observed in the region of 0.30 $R_E > Z_{SM} >$ -0.16 R_E. We used magnetic and electric field data from Van Allen Probes to determine the structure of ULF waves. We showed that the Pc4 pulsations were radially polarized and appeared to be second mode harmonic waves. We found that a phase shift between the azimuthal and radial components of the electric and magnetic fields occurred in the range of Z_{SM} between 0.30 R_E and -0.16 R_E. We demonstrated that the latitudinal nodal extent of the magnetic field pulsations did not exceed 2 R_E. We suggest that the spacecraft were near a magnetic field null during the second orbit when at the local times where pulsations were observed on previous and successive orbits. We investigated the spectral structure of the Pc4 pulsations. We found that the dominant frequencies in the spectra depend on orbit and increase with radial distance. On orbit 1 they varied from 19 to 28 mHz, on orbit 3 from 11 to 16 mHz, and on orbit 4 from 10.5 to 12 mHz. The differences between the ranges of frequencies of the Pc4 pulsations observed by spacecraft on orbit 1 and orbit 3 and 4 may originate from external sources such as different interplanetary input parameters and from internal sources such as changes of plasma density distribution along the field lines or at the equator.

Spectral Analysis of Solar Total Irradiance Behaviour during Cycle 23-24

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Solar total (integrated over all wavelengths) irradiance measurements by the VIRGO experiment on the SOHO satellite have been analysed during cycle 23-24, covering the period 1996 till 2014. The most recent minimum of solar activity was deeper and longer than any previous period as evidenced by various indicators of solar activity (e.g. sunspots, geomagnetic indices) as well as total solar irradiance (TSI). Solar activity levels during solar maximum are considerably different from those during the declining or minimum phases of a solar cycle. Daily mean TSI measurements are used to identify how several harmonics of the 27-day recurrent period change during cycle 23-24, applying a 95% confidence level. Spectral analysis using Lomb-Scargle and Morlet wavelet techniques of TSI data showed that during the solar maximum of cycle 23 the 27-day recurrence period is dominating, while during the anomalously low minimum of cycle 23-24 the 13.5 and 9.0-day periods corresponding to the 2nd and 3rd harmonics of the synodic solar rotation period, are prominent above the 95% confidence level, as shown in Figure1. It will also be shown, using Pearson correlation, that the detection of these recurrence intervals can be traced to an unusual combination of the sectorial spherical harmonic structure in the solar magnetic field and the tilting of the solar dipole field. It is therefore reasonable to conclude that the recent minimum 23-24 was characterised by the solar dynamo obtaining a state of unusual asymmetry. These results confirm previous findings by Krivova et al. (2011) that the behaviour of TSI variations over cycle 23 is consistent with the solar surface magnetism mechanism.

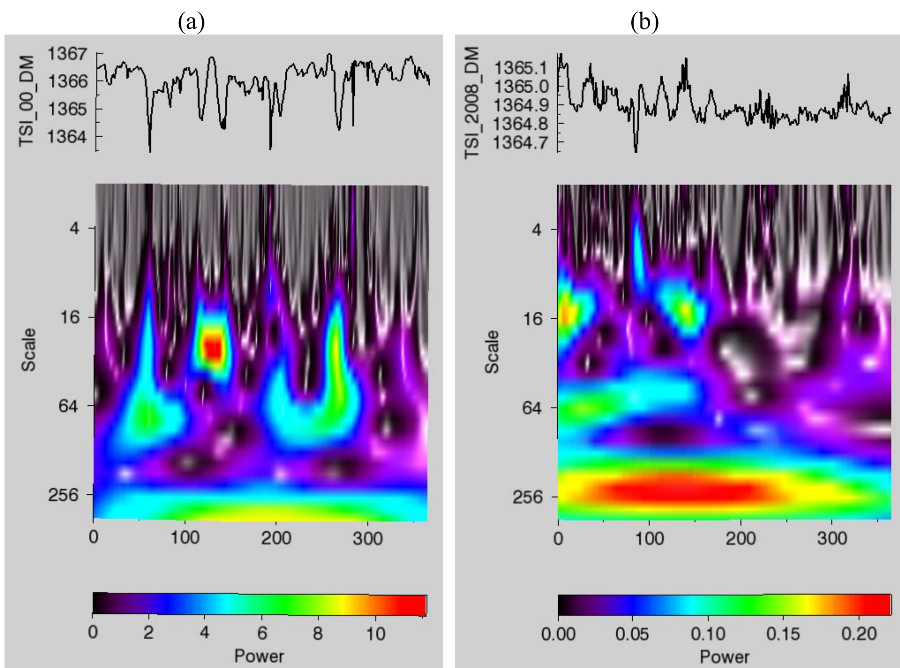

Figure 1. Morlet wavelet analysis of VIRGO daily mean TSI measurements during 2000(a), showing the dominance of the 27-day synodic period, while during 2008(b) the 9.0 and 13.5-day periodicities are clearly visible.

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SEP Acceleration by CME-Driven Shocks in the Solar Corona

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Most Coronal Mass Ejections (CMEs) are known to originate from well-located regions low in the corona, and are often accompanied by flares. They are usually the consequence of an instability in flux ropes, or a tether cutting mechanism in filaments. Studies have shown that most CMEs exhibit a typical three-stage kinematic profile from their onset until they reach interplanetary space (>5 R_S) (Zhang & Dere, 2006). It consists of an initial relatively slow onset very low in the corona, followed by a period of rapid acceleration and expansion, and finally a longer period, in which their speed adjusts asymptotically to the surrounding solar wind speed and their expansion slows down (Bein et al. 2011). The first stage corresponds to the initial release (flux rope destabilization, filament tether cutting) of the erupting material. The second stage corresponds to an impulsive conversion of the stored magnetic energy to kinetic energy, and, depending on the background plasma environment before the CME eruption, possible CME overexpansion and shock driving. This stage ends below 3 R_S for most CMEs launched in the low corona (Bein et al. 2011). The third stage corresponds to the CME interacting with the overlying coronal environment and slowly equilibrating its speed to that of the local solar wind. Most of the Solar Energetic Particle (SEP) acceleration associated with the CME evolution is expected to occur during these three stages, especially the second one. However, the lack of in situ observations near the Sun requires the use of indirect methods for constraining the acceleration. We present remote EUV and white light observations of the kinematics and morphology of early-stage CME-driven compressive waves and shocks. Using the observations, we have constrained and applied analytic and numerical models of diffusive shock acceleration of protons in model CME shocks. We present the modeling results of acceleration efficiency and extent in this dynamic region near the Sun, for several cases of CME kinematic profiles, showing the dependence on time and CME evolution stage. Comprehensive understanding of where and when CMEs accelerate SEPs is important for constraining the heliospheric populations and to improve the mitigation of space radiation; exploring CME-driven shock acceleration near the Sun is a crucial piece of this puzzle.

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Calculation of the Radiation Doses and Particle Fluxes Obtained from the Liulin-MO Dosimetric Instrument Onboard Exomars 2016 Mission to Mars

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The particle telescope Liulin-MO is devoted to measurement of the radiation environment onboard the ExoMars 2016 Trace Gas Orbiter (TGO) satellite that has been launched on 14 March 2016 to Mars. Liulin-MO measures the energy deposition spectra, dose rates, fluxes, linear energy transfer spectra of the charged particles of the galactic cosmic rays and solar energetic particles in two perpendicular directions. Described is the procedure developed for the calculation of the dose rates and particles fluxes obtained from the single detectors and dosimetric telescopes of Liulin-MO. Presented are the first results based on that procedure obtained during the TGO cruise to Mars.

Structural Aspects of Biogenic Iron-Rich Products of Neutrophilic Bacterial Origin

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The biogeochemical cycles proceed through biological, geological and chemical interactions along hydrological, gaseous, and solid state routes. Iron (Fe) is one of the most abundant elements (fourth) found in nature; it is accounting for at least 5% of the earth's crust and for many microorganisms that persist in water, soils and sediments it is an essential element for various cellular processes and metabolic routes. Iron-metabolizing microorganisms, Fe(II)-oxidizing bacteria (FeOB), Fe(III)-reducing bacteria (FeRB), were among the first groups of microorganisms to have been recognized for carrying out the bacterial iron redox cycling. As such, biological iron apportionment is described as one of the most ancient forms of microbial metabolism on Earth, and as a conceivable extraterrestrial metabolism on other iron-mineral-rich planets such as Mars. Microorganisms that are able to oxidize Fe (II) are diverse in their morphology and overall physiology. Those that oxidize iron and/or accumulate iron oxides are, in general, placed into one of two groups: the acidophilic and the neutrophilic prokaryotes as the behavior of the latter is less known.

We report on our results, illustrated in part by Fig.1 and Fig.2, from prompt gamma analysis (PGA), neutron activation analysis (NAA), X-ray, electron microscopy (SEM, TEM) investigations on the elemental composition, crystal structures and the capabilities for accumulation of iron and manganese in the bio-products of neutrophilic bacteria of Leptothrix genus. A biogenic material was obtained after growing Leptothrix spp. in SIGP, Adler's and Isolation (MY, NF) nutrient media [1,2]. The Leptothrix spp. are capable of oxidizing Fe^{2+} and Mn^{2+} and as a result of their metabolism they form extracellular iron oxides/(oxy)hydroxides accumulated in their tubular "sheaths".

High enrichment level of Fe was found by the NAA and PGA techniques in cultivated isolates as compared to the reference sample (product of nature). The enrichment rate varied between 3.8 times for the Adler's medium (AM) and 7.4 times for the isolation medium (IM). Remarkably, only iron-containing phases were revealed in the studied biogenic samples. Three types of iron oxide compounds were found after cultivation in Adler's medium: lepidocrocite (γ-FeOOH), non-stoichiometric magnetite ($Fe_{3-x}O_4$) and goethite (α-FeOOH). Magnetite and maghemite are especially significant in geology because of their contribution to the magnetism of sediments but maghemite was not established. The cultivation in the isolation medium and SIGP medium yielded a single phase bacterial product – goethite and lepidocricite, respectively. XRD and SEM and TEM results show that the biogenic oxides are nanosized and could be used in appropriate nano- and biotechnologies, e.g. drug transport or remediation of contaminated environments.

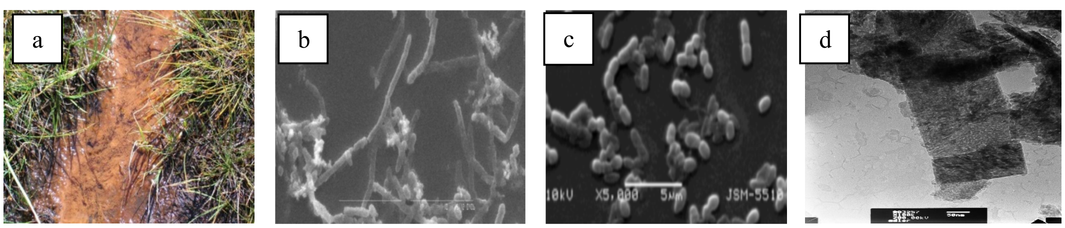

Figure 1 (a) Typical bacterial deposits in the water flow in Vitosha Mountain (Aleko locality, 1783 m altitude); SEM images (JEOL, x5000) of Leptothrix sp. bacteria cultivated in SIGP (b) and AM (d); (d) TEM image: bacterial isolates on AM

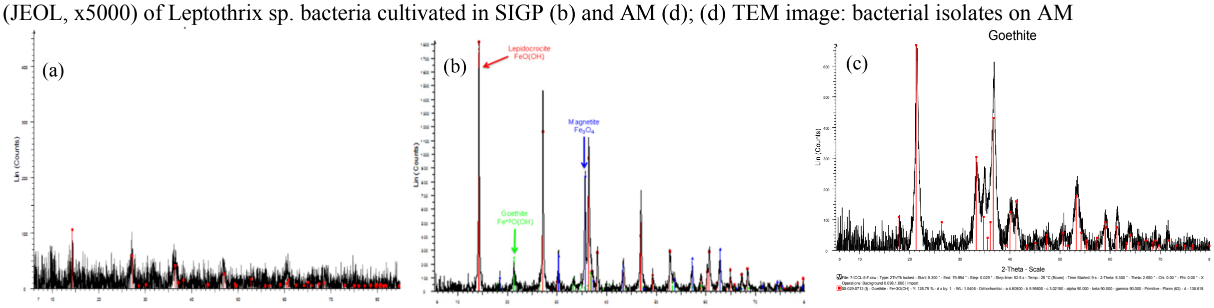

Figure 2. XRD analysis of biogenic powder from cultivated bacteria in an elective medium: (a) SIGP: lepidocrocite of poor crystallinity; (b) Adler's medium: lepidocrocite – 59.67 % - 29.93 nm, magnetite – 21.56 % - 23.860 nm, goethite – 18.77 % - 12.03 nm; (c) Isolation-MY: goethite – 100 % - 5.306 nm; Isolation-MF: goethite – 100 % - 6.198 nm

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Application of Advanced Spectral Remote Sensing Techniques for Assessment of the Plant Health

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Vegetation covers a considerable portion of the Earth and has an effect on the weather and climate. Plants can influence the climate directly through the carbon dioxide and energy fluxes, and indirectly through the atmospheric circulation and plant-emitted volatiles. Plants affect climate and weather mostly through evapotranspiration and albedo. They control the humidity and temperature surrounding their leaves through the process transpiration. Most plants and forests have a very low albedo (about 0.3 to 2.0) and absorb a large amount of energy. However, plants do not contribute to overall warming because the excess warmth is offset by evaporative cooling from the transpiration. Contemporary remote sensing methods aid the analyses of these interactions and, ultimately, contribute information to decision makers for improved management. The development of hyperspectral sensors, collected data in hundreds of narrow spectral bands simultaneously, allows accurately studying terrestrial vegetation at regional and global scales. Remote sensing technique based on hyperspectral measurements of leaf reflectance provides the possibility for early, efficient and objective assessment of the spectral responses of plants to different changes in the environment.

In this paper some results of the application of leaf spectral reflectance for valuation of the effect of adverse environmental conditions to plant health are discussed. Stress factors such as enhanced UV-radiation, acid rain, viral infections, etc., were applied to some young plants (apple trees, paulownia, potato, tomato). Hyperspectral reflectance data were collected by means of a portable fiber-optics spectrometer in the visible and near infrared ranges of the electromagnetic spectrum (350-1100 nm). The differences between the reflectance data of healthy (control) and injured (stressed) species were assessed by means of statistical (Student's t-criterion), first derivative analyses and several vegetation indices (NDVI - Normalized Difference Vegetation Index, f_D - Disease Index, SR –Simple Ratio, TCARI - Transformed Chlorophyll Absorption Reflectance Index). Statistical analyses were carried out in four most informative for the investigated species regions: green (520-580 nm), red (640-680 nm), red edge (680-720 nm) and near infrared (720-780 nm). Strong relationship was found between the results from the remote sensing technique and some biochemical and serological analyses (stress markers, DAS-ELISA test), indicating the importance of hyperspectral reflectance data for conducting, easily and without damage, rapid assessments of the plant health.

3D Reconstruction of Electron Density Distribution over Europe in Real Time

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TaD (TSM-assisted Digisonde) profiler, developed on the base of Topside Sounder Model (TSM), provides vertical electron density profiles (EDP) over Digisonde sounding stations from the bottom of ionosphere up to the GNSS orbit heights. TSM (Topside Sounder Model) is an analytical representation of the measured profiles obtained by the topside sounders on Alouette and ISIS satellite series. TSM consists of three models providing the topside scale height H_T, the upper transition height h_T and their individual ratio R_T as functions of 5 parameters: time of the year, local time, geomagnetic latitude, solar flux, and Kp. TaD electron density profile (EDP) uses the bottomside profile provided by Digisonde software and extends it above the F layer peak by representing the O^+ distribution by α-Chapman formula and H^+ distribution by a single exponent. The profile above F layer peak takes the topside scale height H_T and transition height h_T from TSM and plasmasphere scale height Hp defined as a function of H_T. All these profile parameters are adjusted to the current conditions by comparing the profile integral with measured GNSS-TEC.

A method for reconstruction of the 3D electron density distribution (EDD) over Europe [-15°, 25°)E, (35°, 60°)N] in real time is developed on the base of the TaD profiler. TaD calculates first EDPs over the Digisonde stations. Then TaD profile parameters H_T, h_T, Hp, and Digisonde parameters NmF2, hmF2 are calculated at each grid node of the mapping area by using the Polyweight interpolation method. TaD profiler calculates EDP at each grid node and adjusts it to the GNSS-TEC values. ED profiles at all grid nodes in the area constitute the 3D EDD. ED at any point in the 3D space is obtained by a simple interpolation from the neighbor EDPs. The modeled 3D EDD is compared with vertical and slant TEC from EUREF database (http://vanallen.space.noa.gr/tid/tidTEC.php). The agreement between the model and data is excellent: model error (relative deviation of model from the data), based on 6840 data values is 10% for sTEC and 6% for vTEC.

Vertical TEC (vTEC) values obtained by the European GNSS receivers were de-trended in order to produce maps of TEC disturbances during 07-10 March, 2012 and 01-03 June, 2013 geomagnetic storms. The TEC disturbances are analyzed and the possible generation mechanisms are discussed.

Response of the Lower Atmosphere to Changes in the Global Atmospheric Electric Circuit (GEC) Associated with Solar Wind Variability

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The existence of a meteorological response in the polar regions to fluctuations in the interplanetary magnetic field (IMF) component B_y is well established [e.g, 1]. More controversially, there is evidence to suggest that this Sun–weather coupling occurs via the action of the global atmospheric electric circuit (GEC) on cloud physics [e.g., 2, 3]. Here I present our recently published evidence of the solar wind's influence on the polar troposphere, communicated via the GEC. Firstly, our results show an air pressure response to IMF B_y in the Antarctic troposphere within about 1-5 days, and indications of a resulting delayed influence on the lower stratosphere[4]. We observe an increase in the response time with increasing altitude which is suggestive of an upward propagation of the influence of the solar-wind-induced variability on the lower troposphere. These results are in contrast to the observed slower downward propagation of meteorological effects, from the stratosphere to the lower troposphere, due to mechanisms associated with solar variability involving energetic particle precipitation[5] or ultra-violet radiation[6].

In addition, it has been assumed that the meteorological response to fluctuations in IMF B_y maximizes at high latitudes and is negligible at low and mid-latitudes, because the perturbation by the IMF is concentrated in the polar regions. We demonstrate, however, a previously unrecognized influence of IMF B_y on mid-latitude surface pressure[7]. The difference between the mean surface pressures during times of high positive and high negative IMF B_y possesses a statistically-significant mid-latitude wave structure similar to atmospheric planetary waves. Our results show that a mechanism that is known to produce atmospheric responses to the IMF in the polar regions is also able to modulate pre-existing weather patterns at mid-latitudes. The amplitude of the effect is comparable to typical initial analysis uncertainties in ensemble numerical weather prediction so could have an important effect, via the nonlinear evolution of atmospheric dynamics, on critical atmospheric processes.

Finally, we present recent results of the seasonality in IMF B_y-related changes to Antarctic surface air temperature. Significant B_y-related anomalies in surface air temperature in Antarctica of several degrees appear to be due to solar-wind-driven meridional winds near the Antarctic coast moving air across large meridional gradients in air temperature. This is demonstrated to indeed be the case in autumn for the regions east and west of the Antarctic Peninsula.

The IMF B_y-related input to the GEC system that I will present is just one of a number of different types of input that cause variability to the global circuit that are associated with day-to-day variability in tropospheric dynamics. These tropospheric signatures agree in their onset time, duration, amplitude, location and sign of response with respect to each GEC input variation[3], together providing compelling evidence of a role for the GEC in weather and climate.

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Solar Corona and Space Weather

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It is now well established that the activity in the solar corona plays a major role in the processes at the origin of space weather effects in the heliosphere. The almost uninterrupted observations by the LASCO coronagraph onboard SOHO since January 1996 have allowed an unprecedented view of the coronal activity over almost two solar cycles 23 and 24 which reflects to a larger extent the magnetic activity of the Sun. I will report on the evolution of the corona and its large scale structure through various parameters, such as its radiometry and its three-dimensional electron density. The temporal variations will be compared with standard solar indices and various proxies of solar activity in order to identify the driving mechanisms that control the activity of the corona. Coronal mass ejections (CMEs) are strongly controlling space weather and the ARTEMIS-II catalog based on their automatic detection on high-quality calibrated synoptic maps of the corona allows performing an unbiased statistical analysis of their properties and investigating how they evolve with solar activity. I will present the results for occurrence and mass rates, waiting times, position angle, angular width, kinetic energy, and mass flux first globally and then separately for the two solar cycles 23 and 24 emphasizing the differences. I will further compare the statistical properties of CMEs with those of the standard indices of solar activity as well as those of their potential progenitors, flares and eruptive prominences. I will finally discuss the implications of these results for space weather.

Boundary Oriented Global Empirical Model of Subauroral Polarization Streams

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Subauroral Polarization Streams (SAPS) are important electromagnetic phenomena associated with geomagnetic storms that affect the inner magnetosphere and ionosphere. They are characterized by strong sunward plasma flows caused by poleward-directed electric fields in the region of the ionosphere equatorword of the auroral zone. To examine the effects subauroral electric fields have on ionosphere-thermosphere-magnetosphere coupling and magnetospheric convection we are developing an empirical model of the SAPS using several decades of *in situ* satellite measurements of ionospheric ion drifts and precipitating auroral particles. These measurements are used to characterize the latitudinal drift profiles, relative to the location of the auroral boundary, at varying magnetic local times and magnetic activity levels. As a critical component of this model, we have developed a model of the equatorword particle precipitation boundary of the auroral oval parameterized by AE and MLT, using boundary identifications derived from DMSP data. This will allow the incorporation of the empirical SAPS model into other global models. A global empirical model of SAPS electric fields of this kind is required to realistically model storm-time thermosphere-ionosphere coupling and inner-magnetospheric convection.

Currents and Associated Electron Scattering and Bouncing near the Diffusion Region at Earth's Magnetopause

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Based on high-resolution measurements from NASA's Magnetospheric Multiscale mission, we present the dynamics of electrons associated with current systems observed near the diffusion region of magnetic reconnection at Earth's magnetopause. Using pitch angle distributions (PAD) and magnetic curvature analysis we demonstrate the occurrence of electron scattering in the curved magnetic field of the diffusion region down to energies of 20 eV. We show that scattering occurs closer to the current sheet as the electron energy decreases. The scattering of inflowing electrons, associated with field-aligned electrostatic potentials and Hall currents, produces a new population of scattered electrons with broader PAD which bounce back and forth in the exhaust. Except at the center of the diffusion region the two populations are collocated and behave adiabatically: the PAD of inflowing electrons focuses inward (towards lower magnetic field), while the bouncing population gradually peaks at 90° away from the center (where it mirrors owing to higher magnetic field and probable field-aligned potentials).

Empirical Kp Forecast Model Using Solar Wind Parameters: Implications for Solar Wind – Magnetosphere Coupling

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An empirical forecast model is introduced to predict the Kp index. The model is based on the data for years 1995 to 2004, using solar wind as main input. Compared with previous models, much attention was paid to the time delay between geomagnetic activity and solar wind disturbance at the magnetopause, through a high time resolution study of correlations between solar wind parameters and geomagnetic indices. This not only enables longer forecast lead time by additional 30 min, but also improves the forecast accuracy. Finally, the model gives a linear correlation of r=0.91 and a prediction efficiency of PE 0.82. The out of sample test and comparison with the commonly used nowcast Kp in operational geomagnetic storm alerts suggest that given a continuous and reliable upstream solar wind measurement at the L1 point, the model can be used in operational geomagnetic storm warnings with comparable accuracy as nowcast Kp, but 1.5 hours in advance of the later. Revealed by the newly developed model, it is recommended that time lag should be considered in solar wind - magnetosphere coupling research, and the coupling function should be optimized for the specific geomagnetic index one intends to forecast.

2013 March 17 Storm: Synergy of Observations Related to Mid-Latitude Electric Field Drivers and their Auroral, Current, Plasma Sheet Penetration, and Ring Current

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The 2013 March 17 storm has excellent coverage from ground-based all-sky imagers and radars and the Van Allen Probes, as well as from the usual ground-based magnetometers, GPS receivers, and low-altitude spacecraft. The storm shock impacted the magnetosphere during a period when the auroral oval was extremely thin, with some weak activity and some weak convection that penetrated to mid-latitudes. This impact drove activity almost immediately: dramatic poleward expansion of the poleward boundary of the auroral oval, strong auroral activity, and strong penetrating mid-latitude convection and ionospheric currents. During the expansion phase, the auroral oval expanded gradually equatorward in association with mid-latitude electric fields. These electric fields were at first relatively smooth as is often employed in storm modeling, but then became extremely bursty and were associated with equatorward extending auroral streamers. These three different modes of mid-latitude electric fields, one during the main phase, and two during the expansion phase give substantial, but different, storm-time phenomena seen in the aurora and its equatorward penetration, in ionosphere densities, in ionospheric and field-aligned currents, and in ring current particle injection. More should become apparent if additional ionospheric and magnetospheric datasets are synergistically brought into the study of this event, and the synergetic use of such data sets for other events should allow us to evaluate the commonality of the different modes and the effects of the modes seen for the 2013 March 17.

Data Assimilation in the Radiation Belts

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The natural energetic electron environment in the Earth's radiation belts is of general importance as dynamic variations in this environment can impact space hardware and contribute significantly to background signals in a range of other instruments flying in that region. The most dramatic changes in the relativistic electron populations occur during enhanced periods of geomagnetic activity. The relative importance of all competing physical processes involved in the radiation belt dynamics changes from storm to storm and the net result on particle distribution might then be very different. Several mechanisms and models have been proposed for the electron radiation belts dynamics.

Modeling Earth's radiation belts constitutes an active field of research. The most common practice is to deduce empirical formulae of physical processes amplitudes versus one or more proxies like Kp, Dst, solar wind parameters from statistical studies [1], [2]. On one hand, this introduces errors in the system, which becomes even more important for high magnetic activity conditions for which statistics are usually poor. On the other hand, past observational studies use data from single or limited multiple points in space and have only been able to rigorously distinguish between possible acceleration processes in one or two cases.

It has been shown in the recent years that a data assimilation scheme based on an Ensemble Kalman Filter (EnKF) [3] may lead to great improvements in (1) the accuracy of modeling the different regions of Earth's radiation belts, (2) the possibility to accurately predict the state of the radiation belts, and (3) in accurately reanalyzing a long time period as a basis for specification model and climatology [4]–[7]. Figure 1 describes how works such a sequential data assimilation scheme. Two phases can be distinguished: a prediction phase during which the scheme is driven purely by the modelling (during a given time interval) and an analysis phase during which data are ingested in order to optimally correct the global "trajectory" of the modelling.

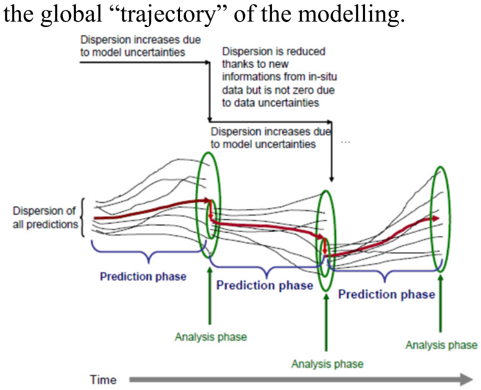

Figure 1. Schematic description of how works a typical sequential data assimilation scheme (here focusing on an EnKF scheme).

However, to be fully useful, such a framework has to be optimized in terms of physics-based models and the data accuracy it relies on. Many efforts have been undertaken to improve data (FP7-MAARBLE project, AE9-AP9 developments, see [8], [9]). In parallel to these data-oriented improvements, [5] also showed that improving the uncertainties in estimations of physics-based processes, which drive the physical model in a data assimilation scheme (the Salammbô code in that case), was necessary.

This talk aims at presenting a global overview of data assimilation status in the radiation belts, then focusing on developments performed at ONERA. In particular, we will describe the way we have taken into account uncertainties in the modelling of different processes (for radial diffusion see [10], for wave-particle interactions see [11] and for outer boundary conditions see [12]). We will finally present the global reanalysis of the radiation belts conducted during the Van Allen Probes life.

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Ion Heating by Kinetic Alfven Waves in the Solar Wind

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The power spectra of magnetic fluctuations in the solar wind typically follow a turbulent power law dependence with respect to the observed frequencies and wave-numbers. The background magnetic field often influences the plasma properties, setting a preferential direction for plasma heating and acceleration. At the same time the evolution of the solar wind turbulence at the ions and electron scales in return is influenced by the plasma properties through micro-instabilities and wave-particle interactions. The solar wind plasma temperature and the solar wind turbulence at ion and electron scales simultaneously show anisotropic features, with different temperature and fluctuation power in parallel and perpendicular direction with respect to the orientation of the background magnetic field. The ratio between the power of the magnetic field fluctuations in parallel and perpendicular direction at the ion scales may vary with the heliospheric distance and depends on various parameters, such as the plasma compressibility, wave properties and the non-thermal plasma features, such as temperature anisotropies and relative drift speeds. Which type of waves dominate in the turbulent spectra and what is the relative importance of each type of waves for the plasma heating and acceleration at the ion and electron scales is still an unresolved problem, which requires further investigations. In this work we have performed 2.5D hybrid simulations consisting of fluid electrons, kinetic (particle-in-cell) protons and a drifting population of minor ions. Our goal is to study the importance of kinetic Alfven waves for the anisotropic minor ion heating and the formation of relative drifts in the multi-species solar wind plasma. We provide a detailed comparison between the heating and acceleration rate of kinetic Alfven waves at different propagation angles and study how their effect on the ions compares to heating and acceleration based on non-resonant ion-cyclotron waves. For this purpose we initialize the simulations with turbulent spectra consisting of oblique and parallel propagating Alfv\'en-waves at different angles, and we add the effects of the relative drifts between the separate ion species. In the course of nonlinear evolution of the system we find strong heating by the kinetic Alfven waves. We also observe substaintial anisotropic cascade of the magnetic field power spectra towards perpendicular wave numbers.

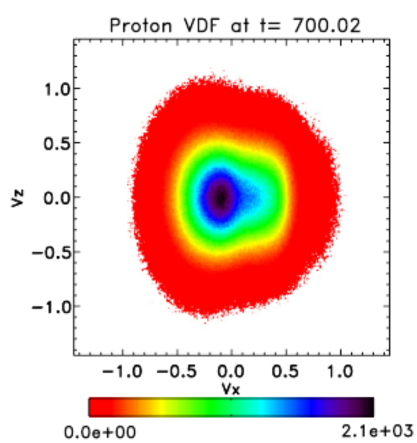

Figure 1. Example proton velocity distribution function with formation of ion beam due to wave-particle interactions.

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Kinetic Features of Magnetic Reconnection in Coupled MHD-PIC Magnetosphere Simulations

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Recently a new modeling capability to embed Particle-in-Cell (PIC) simulations in large-scale extended MHD simulations of planetary magnetosphere has been developed [1]. PIC regions are instantiated in simulation regions, where kinetic effects are important. For instance, PIC regions can cover magnetotail and dayside regions where magnetic reconnection occurs and a kinetic treatment is necessary. The model provides a two-way coupling of MHD and embedded PIC regions. The MHD-PIC coupling has been implemented using the implicit Particle-in-Cell code iPIC3D and the extended MHD code, BATS-R-US.

For the first time, the new modeling capability allows for PIC simulations in a realistic configuration of the magnetic field and density asymmetries with appropriate boundary conditions determined by the large-scale MHD simulations. In this talk, we discuss the new modeling capability and we show its effectiveness in simulating three-dimensional magnetic reconnection in Ganymede's magnetosphere [2]. We focus on kinetic aspects of magnetotail and asymmetric magnetic reconnection by providing electron and ion phase space and distribution functions signature. Finally, we discuss the applications of this new modeling capability to larger planetary magnetospheres.

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Variation of Ionospheric TEC and Scintillation during the Magnetic Storm on 17 March 2015 Observed in Low Latitude: Over Indonesia

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The magnetic storm on March 2015 is the big storm during the 24th cycle of the solar activity. The main phase of the storm occurred on 17 March 2015, with Disturbance storm index (DST) reached minimum of -228 nT at 05.00 UT, due to double - halo coronal mass ejections (CMEs) at 04.30 UT, Kp index reaches 8. Two large eruptions that left the sun on 15 March 2015 caused G4 storm. G4 storm is considered as a "severe" storm when Kp reaches 8. We consider this storm is superstorm. In this study we present the variations of vertical Total Electron Content (VTEC) and Ionospheric scintillation index S_4 during geomagnetic storm occurs on 15 - 19 March 2015 at Manado, Indonesia (geographic coordinates: Lat 1.34°S and Lon 124.82°E, magnitude latitude 8.9°S) observed from dual frequency GPS receiver that is GISTM (GPS Ionospheric Scintillations and TEC Monitor). The results showed that on 15-17 March 2015, on main phase of the storm, there is an enhancement of the equatorial ionization anomaly; amplitudes of the crest increase. On 18 - 19 March 2015 on the recovery phase of the storm there is a significant decrease of the equatorial ionization anomaly. The results show the peak value of TEC on (16 March) reach to 75TECU at 0700 UT, during main phase (17 March) of the storm reached to 70 TECU at 0600 - 0900 UT, and during recovery phase of the storm (18 March) the TEC value decreasing to 20 TECU at 0100 - 0900 UT. The S_4 index indices obtained during this storm. The observations show a strong scintillations on 16 March 2015 with S_4 index reach to values of 0.5 - 1 at 1300 UT, and on main phase (17 March), S_4 index reach to values of 0.2 - 0.25 at 1100 UT . The analysis shown that prompt penetration of electric field during day time at low latitude contributed to TEC increase, which storm induced electric field due to under shielding condition are eastward, which will add up to the preexisting electric field and can lead to enhancement in the upward vertical *E X B* drift at the equator.

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On the Regional Imminent Seismic Activity Forecasting and the Possibilties for "When, Where and How" Earthquake's Prediction

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In this abstract is presented an approach for forecasting of the regional imminent seismic activity based on the analysis of the geomagnetic and Earth tide code data as well as the possibility for prediction the time period, magnitude, depth and epicentres' coordinates of impending earthquake based on the inverse problem method for analysis the behaviour of different earthquakes possible precursors like the geoelectromagnetic field, the boreholes water level, the radon earth-surface concentration, the local heat flow, the ionosphere variables, low frequency atmosphere and Earth core waves.

One have to note the use of Dubna method for for definition and solving the inverse problems for discovering the hidden dependeces.

After the observation the **geomagnetic quake** one can forecast the increasing of regional seismic activity in the time periods (approximately +/- 2 days) around the next extreme of the diurnal mean value of the Sun-Moon tide vector module. The geomagnetic signal is defined as positive derivative of geomagnetic field variability ***Gs.*** The variable ***Gs*** is daily averaged of standard relative deviations of geomagnetic fields. The Sun storms influence is avoided by using data for daily A-indexes (published by NOAA). The **precursor signal** for forecasting the imminent regional seismic activity behaviour is a simple function of the present and previous day ***Gs*** and A-indexes values. The condition for observation of **geomagnetic quake** is the calculation of **precursor signal** positive derivative.

The reliability of the **geomagnetic quake** "when, regional" p**recursor** is demonstrated by using statistical analysis of day difference between the times of "predicted" and occurred earthquakes. The base of the analysis is a natural hypothesis that the "predicted" earthquake is the one whose surface energy density S_{chtm} in the monitoring point is bigger than the energy densities of all occurred earthquakes in the same period and region. The reliability of the approach was tested using the INTERMAGNET stations data located in Bulgaria, Panagurishte, PAG (Jan 1, 2008-Jan 29, 2014), Romania, Surlari, SUA (Jan 1, 2008-Jan 27, 2014), Italy, L'Aquila, AQU (Jan 1, 2008-May 30, 2013).

One possible way for imminent prediction of earthquakes' magnitude, depth and epicenter coordinates can be the solving the inverse problem using a data acquisition network system for geophysical variables – reliable precursors. Among many possible precursors the most reliable are the geoelectromagnetic field, the boreholes water level, radon earth-surface concentration, the local heat flow, ionosphere variables, low frequency atmosphere and Earth core waves.

The analysis of Japan Memambetsu, Kakioka, Kanoya INTERMAGNET stations and NEIC earthquakes data (Jan 1, 2010 – Jan 1, 2015) on the basis of S_{chtm} hypothesis permits to formulate and solve the inverse problem for explicit form of **Precursor signal (Ps)** like a function of magnitude, depth and distance from a monitoring point of occurred earthquakes

Ps(M, Depth, R(x,y), a),

where **a** is a set of inverse problem digital parameters.

Thus, in the case of data acquisition network system existence, which includes monitoring of more than one reliable precursor variables in at least four points distributed within the area with a radius of up to 700 km, there will be enough algebraic equations for calculation of impending earthquake's magnitude, depth and distance by solving the overdetermined algebraic system.

Obvously, the accuracy of predictions will depend from the relybility level of precursors, the values of depth and magnitude, the number of monitoring points, from the geology of the region and as well as the from the ill-possed quality of the received overdetermined non- linear algebraic system .

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Determination of the 1 in 10, 1 in 50 and 1 in 100 Year Space Weather Event

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Space weather is an increasingly important natural hazard risk as society becomes ever more heavily dependent on satellite technology for communications, navigation, defence and Earth observation. Modern satellites have a life expectancy of 10-20 years. Satellite operators and engineers therefore require realistic estimates of the worst case environments that may occur on these and longer timescales. Satellite insurers also require this information to help them evaluate realistic disaster scenarios. We report on recent work conducted as part of the EU FP7 project SPACESTORM to determine the 1 in 10 and 1 in 50 and 1 in 100 year space weather event. We first conducted an extreme value analysis of the E > 2 MeV relativistic electrons at geosynchronous orbit using ~20 years of data from the GOES satellites. We found that the 1 in 10 and 1 in 100 year flux of E > 2 MeV electrons at GOES West were factors of 3 and 7 times larger than previously published [1] and identified a 1 in 50 year event. We then performed an extreme value analysis of the E > 30, E > 100 and E > 300 keV electron fluxes in low Earth orbit using 16 years of data from the NOAA POES satellites. We found that the 1 in 10 year flux of E > 30 keV electrons exhibited a general increasing trend with L* ranging from 1.8×10^7 $cm^{-2}s^{-1}sr^{-1}$ at L* = 3.0 to 6.6×10^7 $cm^{-2}s^{-1}sr^{-1}$ at L* = 8.0. In contrast the 1 in 10 year flux of E > 300 keV electrons shows a general decreasing trend with L* ranging from 2.4×10^6 $cm^{-2}s^{-1}sr^{-1}$ at L* = 3.0 to 1.2×10^5 $cm^{-2}s^{-1}sr^{-1}$ at L* = 8.0. The fact that potentially large fluxes of energetic electrons can penetrate as low as L* = 3 is a concern for the new method of launching satellites with electric orbit raising [*2*]. Finally we conducted an extreme value analysis of the internal charging currents in medium Earth orbit using 10 years of data from the SURF instrument on ESA's Giove-A satellite. Averaged along the orbit path the 1 in 10 year daily-averaged plate currents were found to be 0.22 and 0.094 $pAcm^{-2}$ for the top and bottom plates respectively. The results of our extreme value analysis suggest that the return period of the 0.1 $pAcm^{-2}$ NASA guideline threshold is 113 days and 13.3 years for the top and bottom plates respectively.

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Response of the Ionosphere to the Solar Wind

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Most dynamic phenomena within the magnetosphere are driven by magnetic reconnection occurring at the magnetopause between the interplanetary and terrestrial magnetic fields. The resulting circulation of magnetic flux and plasma within the magnetosphere results in geomagnetic storms and substorms, and other more benign phenomena such as transpolar arcs. The most straightforward way to infer the occurrence and influence of reconnection is to observe the effects on the ionosphere, including the dynamics of the auroral ovals and ionospheric convection. The former can be monitored using space-borne auroral imagers (e.g., the Imager for Magnetopause-to-Aurora Global Exploration, IMAGE) and field-aligned current detectors (e.g., the Active Magnetosphere and Planetary Electrodynamics Response Experiment, AMPERE), and the latter can be measured using ground-based auroral radars (e.g., the Super Dual Auroral Radar Network, SuperDARN). This talk will review our current understanding of the dynamics of the ionosphere in response to solar wind driving and discuss avenues for future research.

Observations of Space Weather and Space Climate over the past 15 years from SABER

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We present observations of Space Weather and Space Climate over nearly 15 years from the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on the NASA TIMED satellite. Observations of infrared (IR) emission from carbon dioxide and nitric oxide are used to derive the rates at which IR radiation cools the atmosphere above 100 km. The IR emissions exhibit prompt response to geomagnetic variability on short (daily) timescales. Long-term variability associated with the 11-year solar cycle is also evident in the data. In addition, we have developed a reconstruction of the global IR energy budget extending back 70 years using a combination of SABER data and standard solar and geomagnetic indices. This reconstruction allows us to examine the variability of energy output from the thermosphere, and indirectly, assess the variability of energy input over the same 70-year time period. We find that the IR energy output from the thermosphere, integrated over a solar cycle, is nearly invariant over 5 successive solar cycles. This result strongly suggests that the geo-effective solar energy input over the length of a solar cycle is also nearly invariant from one solar cycle to the next. Furthermore, as solar minimum is approaching, we are searching for evidence of previously observed harmonics of the solar rotation period in spectral analyses of the IR energy budget, and will present updated findings. Finally, in looking to the future, we will discuss the SABER-II instrument proposed to continue this exciting record well into the next decade.

Regional Climate Effects of High-Speed Solar Wind Streams: Global Connection and Preconditioning Emphasized

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High-speed solar wind streams (HSS) are the most effective long-term driver of magnetospheric energetic particles. HSSs and, thereby, the flux of energetic particles maximize in the declining phase of the solar cycle when the polar coronal holes have long equatorial extensions. Moreover, there is evidence that HSS related effects in the Earth's upper atmosphere may have interesting consequences even down in the tropospheric climate, especially in winter at high latitudes. Processes related to HSSs modulate regional/hemispheric climate patterns in winter, in particular the NAO/NAM oscillation, the dominant climate pattern in the northern hemisphere. The positive phase of the NAO/NAM oscillation is systematically favored during the declining phase of the solar cycle. Possible HSS related processes include, e.g., enhanced precipitation of energetic particles leading to stratospheric ozone loss and circulation changes, or changes to the global electric current system. Moreover, it has been established that the HSS related effects are strongly dependent on the phase of the equatorial Quasi Biannual Oscillation (QBO) pattern. Positive relation between HSS and NAO/NAM is found to be valid in the easterly QBO(30 hPa) phase during the whole 20th century. We also find that the Holton-Tan relation is only observed during early/mid winter, while an anti-Holton-Tan relation is found in the late winter for strong geomagnetic activity. These results indicate an intimate, global connection between low and high latitudes, and underline the importance of considering the preconditioning of the atmosphere when studying the solar (wind)-related effects upon climate. We review related observations and compare the effects of solar irradiance and solar wind to northern winter climate.

The Asymmetric System during the Magnetic Storm on August 17, 2001

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On August 17, 2001 a strong magnetic storm caused significant compression and reconfiguration of the Earth's magnetosphere as well as highly asymmetric aurora in the conjugate hemispheres. During this event, the Polar VIS Earth camera and the IMAGE FUV system provided simultaneous imaging data for 5 hours of the Northern hemisphere and 2 hours from the conjugate hemispheres. During this time interval the entire auroral ovals were imaged in both hemispheres. By analyzing all three imaging channels from IMAGE, the WIC, SI12 and SI13, as well as the one VIS Earth channel, we identify symmetric and asymmetric features. Combined with supporting data from other satellites, such as DMSP and NOAA, as well as ground based networks as SuperDARN and SuperMAG, we try to understand the dynamical behavior of the interaction between solar wind, magnetosphere and the two polar regions of the ionosphere. As the event was an extreme IMF By (~30 nT) event our understanding about how such conditions lead to a very asymmetric magnetosphere as well as an asymmetric response in the two polar regions are tested [1,2,3].

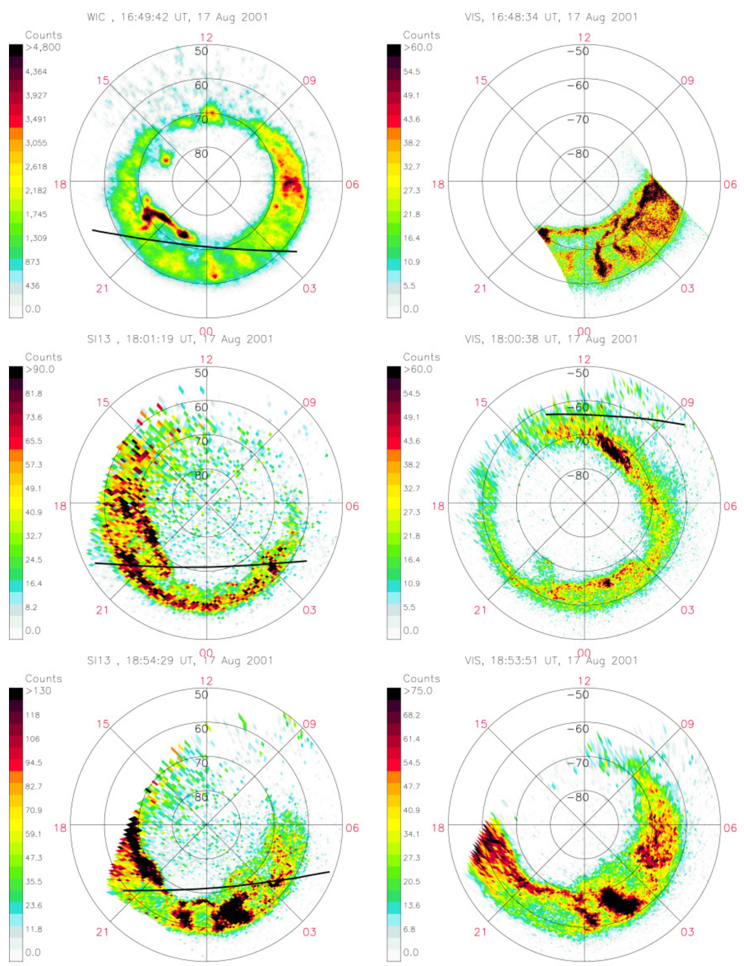

Figure 1. Three examples of highly asymmetric aurora observed during the August 17, 2001 magnetic storm.

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Dependency of the Thermospheric Dynamics on the Auroral Morphology

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At high latitudes, energy from electromagnetic fields and precipitating particles are transferred from the magnetosphere to the ionosphere and the thermosphere. The polar ionosphere and thermosphere act as an energy and particle sink, where the energy is transformed into both heated and accelerated plasmas and neutral particles. The former and latter processes can be regarded as energy transformation to thermal and mechanical energies, respectively. These processes cause, for example, accelerated winds and atmospheric gravity waves in the polar thermosphere with various spatiotemporal scales. The causality is highly related to development of the ionospheric current circuit linking the field-aligned currents (FAC) with enhancements of the perpendicular electric field because the Joule heating and ion drag processes are two dominant mechanisms for the thermospheric modulations. The FAC is attributed to the FA-potential evolution in the magnetosphere, i.e., inverted-V structure, which results in the discrete aurora. Thus the magnetosphere-ionosphere-thermosphere (MIT) coupled system has been mainly studied on phenomena nearby the discrete aurora and at the growth and expansion phases of the substorm activity. These analyses have provided fundamental but qualitative understanding of (1) correlation of temporal developments between the magnetospheric-origin energy dissipation and thermospheric response in dynamics [e.g. 1], (2) height-dependent active role of the thermosphere in the Joule energy dissipation process [e.g. 2,3], and (3) unexpectedly quick acceleration of the thermospheric wind at the beginning of geomagnetic disturbances [e.g. 4]. Theoretical and simulation analyses have tried to understand these results by applying fundamental physical equations, but we have not yet reached the sufficient maturity of quantitative understanding.

Another outstanding question is the MIT-coupled system at the substorm recovery phase. The aurora appeared at the recovery phase is characterized by pulsation of the emission intensity and patches approximately drifting along the ionospheric convection. It is generally considered that wave-particle interaction in the magnetospheric equator plays a major role for causing auroral particle precipitation. The precipitating electron energy frequently becomes above 10s keV, which causes ionization at the lower ionosphere than the inverted-V type auroral precipitation. While the ionization increases the ionospheric conductivity, it is known that the convection electric field is not significantly large on average at the substorm recovery phase. It has been thus considered that the corresponding Joule heating rate and the Lorentz force cannot reach a sufficient level to modulate the thermospheric winds. However, well-designed simultaneous measurements with the Fabry-Perot interferometer, low-noise CCD camera, and the incoherent-scatter radar found thermospheric wind fluctuations isolated in the pulsating auroral patch [5,6]. Taking into account magnetospheric substorm evolution of plasma energy accumulation and release, the large wind fluctuation at the recovery phase is a fascinating result.

In the causality to produce the wind fluctuations, the particle collision between ions and neutrals is a fundamental process throughout the substorm evolution, but magnetospheric/ionospheric environment during the thermospheric-wind fluctuations appears to depend on the substorm phase as mentioned above. Measurements with ground-based remote sensing have been applied to this field such as the incoherent-scatter radar and the Fabry-Perot interferometer. The methodology continues to play an important role in this field. However, due to the difficulty in the precise measurements of the particle collisional system, demand for in-situ measurements in the ionosphere/thermosphere will be growing up for further understanding. This paper will present previous results of the polar MIT-coupled phenomena, particularly focusing on the substorm-phase dependencies. Several questions to be useful in initiating a new advancement in the MIT-coupled physics will be addressed. It is hoped to discuss plausible methodology and diagnostics to provide measurements for answering these questions.

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A New Solar Wind and CME Evolution Model

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We present the latest results of the new physics-based forecasting-targeted inner heliosphere model EUHFORIA (‘EUropean HelLliospheric FORecasting Information Asset’) that we are developing.

EUHFORIA consists of a coronal model and a magnetohydrodynamic (MHD) heliosphere model with CMEs. The aim of the baseline coronal model is to produce realistic plasma conditions at the interface radius r = 0.1 AU between the two models thus providing the necessary input to the time-dependent, three-dimensional MHD heliosphere model. It uses GONG synoptic line-of-sight magnetograms as input for a potential (PFSS) field extrapolation of the low-coronal magnetic field coupled to a current sheet (CS) model of the extended coronal magnetic field. The plasma variables at the interface radius are determined by employing semi-empirical considerations based on the properties of the PFSS+CS field such as the flux tube expansion factor and distance to nearest coronal hole. The heliosphere model computes the time-dependent evolution of the MHD variables from the interface radius typically up to 2 AU. Coronal mass ejections (CMEs) are injected at the interface radius using a hydrodynamic cone-like model using parameters constrained from fits to coronal imaging observations. In order to account for the modification of the heliosphere due to the presence of earlier CMEs, the standard run scenario includes CMEs launched five days prior to the start of the forecast, while the duration of the forecast extends up to seven days.

In addition to presenting results of the modeling, we will highlight our on-going efforts to advance beyond the baseline in the forecasting pipeline. In particular we discuss our path towards using magnetized CMEs, the application of a time-dependent coronal model as well as modeling the transport of solar energetic particles (SEPs) in the heliosphere. We also discuss the tests with solution AMR (Adaptive Mesh Refinement) for the background wind and the evolution of magnetized CME clouds and shock waves.

Effects of ULF Wave Power on Relativistic Radiation Belt Electrons: 8-9 October 2012 Geomagnetic Storm

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Electromagnetic ultra low frequency (ULF) waves in the range of 150 - 600 s periods are known to play a substantial role in radial transport, acceleration and loss of relativistic particles trapped in the Earth's outer radiation belts. Using in-situ observations by multiple spacecraft operating in the vicinity of outer radiation belts, we analyze the behavior of ULF waves throughout the geomagnetic storm of 8-9 October 2012 and compare with the dynamics of relativistic electron fluxes on-board the twin Van Allen Probes spacecraft. The analysis shows that the relativistic electron fluxes reduce from their pre-storm levels during the first phase of the storm and rapidly increase during the second phase of the storm. We demonstrate that the behavior of ULF wave power changes throughout the storm, from ULF oscillations being a mixture of compressional and shear magnetic components during the first phase of the storm, to ULF oscillations being dominated by transverse (shear) components during the second phase. We analyze the parameters of ULF-driven radial diffusion as a function of time and magnetic L-shells, separating the diffusion coefficients into electrostatic and electromagnetic components and comparing the observed diffusion coefficients with their statistical averages. We will demonstrate that the observed diffusion coefficients are strong enough to impact the redistribution of relativistic electron fluxes from and to the outer boundary of radiation belts and the diffusion might influence the effects of any local electron acceleration by transporting fluxes down phase space density gradients.

MMS Observations of Turbulence and Turbulent Dissipation in Earth's Magnetosheath and Upstream Solar Wind

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It has been proposed that magnetic reconnection plays a role in collisionless plasma turbulence, similar to that played by viscosity in liquid and gaseous fluid turbulence. If this is true, then we must look to plasma kinetic dissipation mechanisms that are likely varied, depending on the local situation. It has been further argued that plasma turbulence will exhibit a high degree of both spatial and temporal intermittence. NASA's Magnetospheric Multiscale (MMS) mission is well suited to study kinetic dissipation and turbulent statistics, both with E&M measurements provided by the Fields Investigation and the fast electron & ion distribution function measurements provided by the Fast Plasma Investigation (FPI). We present a survey of what MMS has had to say about the role of reconnection in plasma turbulence using Phase 1A data in Earth's magnetosheath and upstream solar wind. We present statistics on observation times available (Burst + Fast Survey vs Fast Survey only) in the magnetosheath and solar wind during MMS Phase 1A. We characterize the observed plasmas in terms of their magnetic Reynolds Numbers and conformance to Kolmogorov-type turbulent cascade. The Partial Variance of Increments (PVI) method pioneered by Greco et al. [2008] is used to discriminate the strongest current sheets. These strongest sheets are analyzed to determine their orientation, vector velocity and dissipative signatures. The results provide insight to the turbultne kinetic structure of the Earth's magnetosheath and upstream solar wind and the dissipation processes operating there.

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Experimental Observations of Electron Precipitation by EMIC Waves

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It has long been recognised that Electromagnetic Ion Cyclotron Waves (EMIC) waves should be able to pitch angle scatter energetic electrons from the radiation belts, causing them to be lost into the polar atmosphere. At various times the apparent importance of EMIC waves as a loss mechanism has varied; it is probably reasonable to suggest that EMIC is currently viewed as likely to play a highly significant role in radiation belt electron loss. To date, investigations of this precipitation process have been largely theoretical in nature, limited to calculations of precipitation characteristics based on wave properties, and more recently a small number of case studies [e.g., 1, 2, 3, 4].

Analysis of electron flux data from the POES (Polar Orbiting Environmental Satellites) spacecraft has been suggested as a means of investigating EMIC wave-driven electron precipitation characteristics, using a precipitation signature thought to be particular to EMIC waves [5, 6]. An algorithm to detect precipitation with such signatures has been developed [7], identifying 3337 events between 1998 and 2014 inclusive (17 years of data from up to 7 satellites). The majority of events were observed at L-values within the outer radiation belt ($3<L<7$), were more common in the dusk and night sectors as determined by magnetic local time, and were slightly outside the plasmasphere (L-values ~1 RE greater than the plasmapause location). However, until now the lack of supporting wave measurements for these POES-detected precipitation events has meant that there is uncertainty as to whether they are indeed caused by EMIC; in particular the MLT and L range of the precipitation triggers exhibits some differences when compared with the commonly expected EMIC wave distributions [8, 9].

In this talk we present a statistical study comparing the POES precipitation triggers with wave data from several ground-based search coil magnetometers - here we particularly focus on observations from Halley (Antarctica) and Athabasca (Canada). We show that a very significant proportion of the precipitation events do correspond with EMIC wave detections on the ground; for precipitation events that occur within ±15º in longitude and $\Delta<0.5º$ in latitude from the magnetometers this detection rate can be as high as 90%. Generally the observed precipitation triggers are associated with helium-band rising-tone Pc1 waves on the ground. Such waves are also known as IPDP (intervals of pulsations of diminishing periods).

The high success rate linking the POES triggers with observed EMIC waves confirms the detection algorithm [7] is a valid means of detecting EMIC wave activity via POES electron precipitation data. This makes it possible to use the POES precipitation trigger data to further investigate the characteristics of the observed EMIC waves and their interactions with radiation belt electrons.

One question around the significance of EMIC-losses to the dynamics of the outer radiation belt has been the minimum electron energy likely to be precipitated. Using a set of different fitting relationships we investigate the minimum energy of the electron precipitation in the trigger events, and find a much wider range than generally expected. Minimum energy values can be commonly as small as a few hundred keV, but can also occur in the MeV range.

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Nature's Grand Experiment: Linkage Between Magnetospheric Convection, Substorms and the Radiation Belts

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The solar minimum of 2007-2010 was unusually deep and long-lived. In the later stages of this period the electron fluxes in the radiation belts dropped to extremely low levels. The flux of relativistic electrons (>1 MeV) was significantly diminished, and at times were below instrument thresholds both for spacecraft located in geostationary orbits and also those in low-Earth orbit. This period has been described as a natural "grand experiment" allowing us to test our understanding of basic radiation belt physics and in particular the acceleration mechanisms which lead to enhancements in outer belt relativistic electron fluxes.

Here we test the hypothesis [1] that processes driven by magnetospheric convection initiate repetitive substorm onsets, which in turn triggers enhancement in whistler mode chorus that accelerates radiation belt electrons to relativistic energies. Conversely, individual substorms would not be associated with radiation belt acceleration. Contrasting observations from multiple satellites of energetic and relativistic electrons with substorm event lists, as well as chorus measurements, shows that the data are consistent with the hypothesis.

We show that repetitive substorms are associated with enhancements in the flux of energetic and relativistic electrons and enhanced whistler mode wave intensities. This is consistent with the recent RBSP case studies [2], which suggested that substorms were the trigger for chorus which lead to acceleration of radiation belt electrons to relativistic energies. However, in our study we see a two stage chorus wave power enhancement, the first starts slightly before the repetitive substorm epoch onset, suggesting that magnetospheric convection leading the chorus activity may be the trigger. This conclusion requires some care, as the second and strongest enhancement in chorus is very slightly after the onset, complicating the picture

During the 2009/2010 period the only relativistic electron flux enhancements that occurred were preceded by repeated substorm onsets, consistent with enhanced magnetospheric convection and repetitive substorms as a trigger. This work has been recently published in JGR [3].

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New Insights into the Origin and Evolution of CMEs

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Coronal Mass Ejections (CMEs) play a leading role in driving the Sun-Earth System (SES) because of their large-scale, energetics and direct impact on the Earth. As CMEs evolve in heliospace they drive shocks, which act to produce Solar Energetic Particles (SEPs). CMEs and SEPs can strike our planet, and they can disrupt satellites and knock out power systems on the ground, among other effects. That is why it is important to better understand and predict the ever-changing environmental conditions in outer space due to solar eruptive events, the so-called Space Weather.

This talk summarizes recent advances in modeling the evolution of CMEs in the low solar corona and inner heliosphere by means of 3-D compressible MHD simulations. By comparing simulations results with directly observable quantities (e.g., Thompson-scattered white light, EUV, and X-ray intensities), it becomes possible to constrain the physical models of CMEs, and learn a great deal about the interaction of the ejecta with the pre-existing magnetic field and ambient solar plasma. We will present new physical insights into the evolution of CMEs gathered from our numerical investigations.

Really "Guests" from the Sun System or Simply Earth Rocks or Scrap

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Meteorites from the Sun System are rare "guests" on the Earth surface [1]. Often earth rocks or manufactured iron have been wrongly considered to be of extraterrestrial origin, the so-called meteorwrongs. After publication [2] scientists, collectors, dealers and amateurs approached us with the request for doubtless identification of many findings. In stony, iron and stony-iron meteorites Fe-Ni alloys with different Ni contents (minerals kamacite, taenite and plessite which is a meteorite iron texture consisting of a fine-grained mixture of the minerals kamacite and taenite), troilite (FeS), olivine ($(Mg, Fe)_2[SiO_4]$), pyroxene ($(Mg, Fe)[SiO_3]$) and silicate mineralogical phases containing Fe^{3+} are always identified. The mineral cohenite ($Fe(Ni,Co)_3C$), schreibersite ($(Fe,Ni)_3P$) and many others in non-considerable amounts have been found, too.

In man-made iron steels and cast iron the iron-bearing component cementite (Fe_3C) is present in large quantity, which is absent in all meteorites. High concentration of iron-bearing minerals makes the Mössbauer spectroscopy a promising tool for authentication of the meteorites. The high Ni content in mineralogical components as a "finger print" for extraterrestrial origin can be confirmed by Energy Dispersive X-ray analysis (EDXRF) and Scanning Electron Microscope (SEM) images. One example with the Pavel meteorite is presented on Fig. 1. Additionally the X-ray diffraction studies of the minerals can get useful information about their extraterrestrial origin.

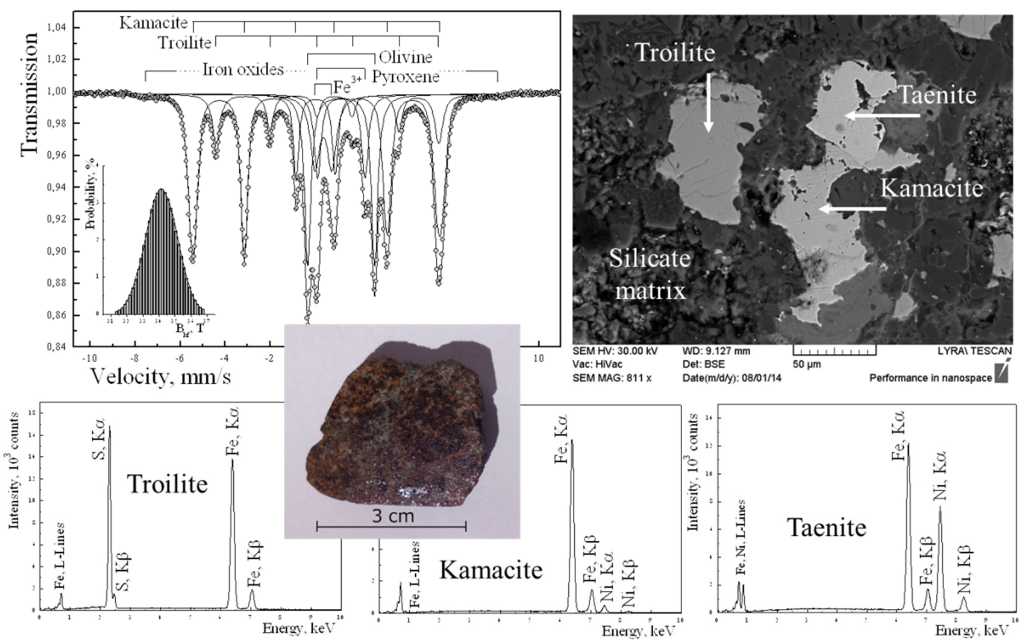

Figure 1. Example of investigations of a supposed part of the Pavel meteorite (in the middle). (top left) Typical Mössbauer spectrum of stony meteorite with high concentration of Fe-Ni alloys with different Ni contents. The kamacite-taenite mixture higher experimental line widths were fitted with value distribution of the hyperfine magnetic field B_{hf} shown inset. The Pavel meteorite fall on February 28, 1966 and formation of some iron oxides on the surface cannot be excluded. (top right) Scanning electron microscope image confirm inclusions of troilite, kamacite and taenite in silicate matrix. (down) X-ray fluorescence analysis of troilite grain containing only chemical elements Fe and S, kamacite incrustation of iron with about 6 % Ni and taenite with higher about 46 % Ni concentration.

Only one object found after the decease of Bulgarian astronomer Prof. N. Nikolov [3, 4] in its small mineralogical collection was undoubtedly identified as polished section from the Pavel meteorite, Fig. 1. Unfortunately a dozen other investigated findings were unambiguously rejected as meteorwrongs. They are simply earth rocks, steel fragments or man-made cast iron and rests from antic metallurgical processes, incombustible matter left after a charcoal fire, the so-called clinker, or probably some kind of slag.

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Survey of Whistler-Mode Plasma Waves in the Inner Magnetosphere Using Measurements of the Van Allen Probes

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Recent results of measurement, data analysis, theory, and simulations confirm that whistler mode waves play an important role in the dynamical behavior of the Earth's magnetosphere. This especially concerns the outer Van Allen radiation belts. In spite of these new advances, many questions related to the origin and effects of these waves still remain open.

We analyze whistler-mode waves using a database of survey measurements of the Waves instruments of the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) onboard the Van Allen Probes. We use multicomponent data to estimate wave polarization and propagation parameters and we especially pay attention to the variability of wave amplitudes. Usual approach is to calculate average or median values as a function of position or geomagnetic activity. These values then serve as inputs for modeling. We show the importance of using a more elaborated statistical description.

Penetration of Super-Low Frequency Disturbances from Solar Wind and Magnetosheath towards Ionosphere

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We do a multi-point study of the influence of the lowest frequency resonances (0.02-10 mHz) at the outer magnetospheric boundaries and in the solar wind on the fluctuations inside the magnetosphere and ionosphere. The correlations of the dynamic pressure data from CLUSTER, DOUBLE STAR, GEOTAIL, ACE/ WIND, particle data from LANL, GOES with the magnetic data from polar ionospheric stations on March 27, 2005, show that:

i) the waves generated by boundary resonances and their harmonics penetrate inside the magnetosphere and reach the ionosphere;
ii) correlations between the dynamic pressure fluctuations at the magnetospheric boundaries and magnetospheric/ ionospheric disturbances, including indices such as AE and SYM-H, can exceed 80%;
iii) the new resonance frequencies are lower by an order of magnitude compared with our previous studies, which are as low as 0.02 mHz. Furthermore, such resonances are characteristic also for the night-side geostationary/ionospheric data and for the middle tail, i.e., they are global magnetospheric features.

Analysis of different types of correlations yields the unexpected result that in 48% of the cases with pronounced maximum in the correlation function the geostationary/ ionospheric response is seen before the magnetosheath (MSH) response. We propose that some global magnetospheric resonances (e.g. surface bow shock (0.2-0.5 mHz) and/or magnetopause (0.5-0.9 mHz) modes along with the cavity MHS/ cusp (1- 10 mHz) and magnetospheric global modes (0.02-0.09 mHz)) can account for the data presented.

The multiple jets at the sampled MSH locations can be a consequence of the global resonances, while an initial disturbance (e.g. through the interplanetary shocks, Hot Flow Anomalies, foreshock irregularities etc.) were not observed by particular spacecraft in MSH because they were localized in the plane perpendicular to the Sun-Earth line. So, in the explorations of the solar wind - magnetosphere interactions one should take into account these resonances and their effects through the jet appearance modulations and amplification of the resulting jet-induced transport inward and outward the magnetosphere.

Prompt Relativistic Electron Acceleration in the Inner Magnetosphere Due to Interplanetary Shocks

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Interplanetary shocks can have a dramatic, rapid effect on Earth's radiation belts. For example, *Blake et al.*[1] observed >15 MeV electrons almost instantaneously (~ 1 min) injected to 2 < L < 3 with the CRRES spacecraft. *Li et al.*[2] were able to accurately reproduce the observations by modeling the sudden compression and relaxation of Earth's magnetosphere from the interplanetary shock. Their model used a bi-polar shock-induced magnetosonic pulse based on CRRES observations to energize electrons to 40 MeV and transport them to L=2.5 during a fraction of their drift period. Recent studies have used Van Allen Probe observations to show that less severe shocks can induce similar injections and accelerations. *Kanekal et al.*[3] showed that electrons of >6 MeV were energized and injected deep into the magnetosphere to L~3 by the 17 March 2013 shock and resulting magnetosonic pulse. *Foster et al.*[4] showed electrons of >5 MeV at L=3.5 were a product of shock induced acceleration for the 8 October 2013 shock. These studies indicate that prompt acceleration by impulsive shock-induced electric fields can be a significant mechanism for the acceleration of highly relativistic electrons deep inside the inner magnetosphere.

In this study, we analyze 58 interplanetary shock events during the Van Allen Probes era as measured by the University of Maryland Time of Flight Proton Monitor (UMTOF) on the Solar and Heliospheric Observatory spacecraft (SOHO). We study individual shock events, as well as perform statistical analyses. 59% of the events produced shock induced relativistic particle acceleration as seen by the Relativistic Electron-Proton Telescope (REPT) on the Van Allen Probes, with 17% observed by both spacecraft. The strength of particle energization is well correlated with radial distance at which they are observed, since resonant particles interact with the inward propagating magnetosonic pulse for a larger extent in space and time. Our measurements are consistent with previous observations and modeling. Additionally, we investigate the relationship between the radial extent and intensity of the energizations with shock parameters, such as the shock compression ratio and shock strength.

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Strategy for Improved Representation of Magnetospheric Electric Potential Structure on a Polar-Capped Ionosphere

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In some simple models of magnetospheric electrodynamics such as [1], the normal component of the convection electric field is discontinuous across the boundary between closed and open magnetic field lines, and this discontinuity facilitates the formation of auroral arcs there. The requisite discontinuity in **E** is achieved by making the scalar potential proportional to a positive power (typically 1 or 2) of L on closed field lines and to a negative power (typically $-1/2$) of L on open (i.e., polar-cap) field lines. This suggests it may be advantageous to construct more realistic (and thus more complicated) magnetospheric and ionospheric electric-field models from superpositions of mutually orthogonal (or not) vector basis functions having this same analytical property (i.e., discontinuity at $L = L^*$, the boundary surface between closed and open magnetic field lines). The present work offers a few examples of such constructions. A major challenge in this project has been to devise a coordinate system that simplifies the required analytical expansions of electric scalar potentials and accommodates the anti-sunward offset of each polar cap's centroid relative to the corresponding magnetic pole. For circular northern and southern polar caps containing equal amounts of magnetic flux, one can imagine a geometrical construction of coordinate contours such that arcs of great circles connect points of equal quasi-longitude (analogous to MLT) on the northern and southern polar-cap boundaries. For more general polar-cap shapes and (in any case) to assure mutual orthogonality of respective coordinate surfaces on the ionosphere, a formulation based on harmonic coordinate functions (expanded in solutions of the two-dimensional Laplace equation) may be preferable.

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Investigating the Effect of Geomagnetic Storms and Equatorial Electrojet on Equatorial Ionospheric Irregularity over East African Sector

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The African equatorial ionosphere has shown unique ionosphere electron density irregularity structure; however, this region ionosphere is not yet well investigated due to lack of multiple ground-based ionospheric monitoring instruments. But, as a result of IHY initiative, which was launched in 2007, some facilities are being deployed since then. Therefore, recently deployed SCINDA-GPS receiver (2.64 ^{o}N dip angle) for TEC and amplitude scintillation index (S_4) data and two magnetometers, which are deployed on and off the magnetic equator, data collected in the March equinoctial months of the years 2011, 2012, and 2015 have been used for this study in conjunction with geomagnetic storm data obtained from high resolution OMNI WEB data center. We have investigated the triggering and inhibition mechanisms for ionospheric irregularities using Equatorial Electrojet (EEJ), Interplanetary Electric Field (IEF_y), symH index, AE index and Interplanetary Magnetic Field (IMF) B_z on five selected storm days. It is found that the daytime EEJ magnitude and direction fluctuation suppressed the post-sunset scintillations. In all the days in our study, EEJ magnitude and direction fluctuation resulted in total disappearance of post-sunset equatorial spread F (ESF) during ESF occurrence season and undisturbed smooth pattern of EEJ is found to be precursor for the later occurrence of unaffected ESF during ESF occurrence season. It is also found that the EEJ magnitude is fluctuated during westward fluctuating IEF_y , southward fluctuating B_Z , strong and fluctuating AE index and minimum symH. Nearly constantly eastward IEF_y is found to intensify the daytime EEJ. We have also found that the rate of change of B_Z (i.e. electric field produced by Faraday's Induction law), between 15 UT and midnight , is nicely correlated with strong post-sunset scintillations. Moreover, discussions about the likely causes for the occurrence of ionospheric scintillation have been presented in this paper.

Keywords: Ionospheric scintillation, Equatorial electrojet (EEJ), AE index, Geomagnetic storm, Interplanetary electric field (IEF_y)

Radiation Investigations on the International Space Station: Summary of Results for Years 2007/2015 Obtained with Liulin-5 Charged Particle Telescope

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The radiation field around the Earth is complex, composed of galactic cosmic rays, trapped particles of the Earth's radiation belts, solar energetic particles, albedo particles from Earth's atmosphere and secondary radiation produced in the space vehicle shielding materials around the biological objects. Dose characteristics in near Earth and space radiation environment also depend on many other parameters such as the orbit parameters, solar cycle phase and current helio-and geophysical conditions. Since June 2007 the Liulin-5 charged particle telescope has been observing the radiation characteristics in two different modules of the International Space Station (ISS). In the period from 2007 to 2009 measurements were conducted in the spherical tissue-equivalent phantom of MATROSHKA-R project located in the PIRS module of ISS. From 2012 to 2015 measurements were conducted in and outside the phantom located in the Small Research Module of ISS. In this paper attention is drawn to the obtained results for the dose rates, particle fluxes and dose equivalent rates in and outside the phantom from the galactic cosmic rays, trapped protons and solar energetic particle events occurred in that period.

Experimental Investigations of the Radiation Environment Onboard Exomars 2016 and 2018 Interplanetary Missions

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Deep space manned missions are already a near future of the astronautics. Radiation risk on such a long-duration journey appears to be one of the basic factors in planning and designing the mission. The paper relates to scientific objectives and instrumentation for investigation of the radiation environment to be carried out during the ExoMars 2016 and 2018 missions to Mars. Described are: 1) The particle telescope and the experiment Liulin-MO for measurement the radiation environment onboard the ExoMars 2016 Trace Gas Orbiter (TGO) satellite as a part of the Fine Resolution Epithermal Neutron Detector (FREND) and 2) Liulin-ML experiment and instrument for investigation of the radiation environment on Mars as a part of the active detector of neutrons and gamma rays ADRON-EM on the Surface Platform for ExoMars 2018 mission. The dosimetry experiments will provide data for the radiation parameters (energy deposition spectra, dose rates, fluxes, linear energy transfer spectra of the charged particles) of the galactic cosmic rays, solar energetic particles and secondary radiation during the cruise, in Mars orbit and on the surface of Mars.

The ExoMars TGO has been launched on 14 March 2016. The firs data from the radiation measurements conducted on TGO with Liulin-MO during the cruise to Mars will be presented.

On the Role of Solar Wind Plasma State in the Magnetospheric Plasma Acceleration

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A well-known substorm-related plasma acceleration in the magnetosphere, launched by the arrival of southward IMF and dayside reconnection, is considered as a primary magnetospheric acceleration process. Less appreciated is that the state of solar wind plasma controls the background plasma sheet parameters, which themselves influence the acceleration of magnetospheric plasma. Recently importance of such solar wind control was discussed in relation to the chorus wave acceleration (which provides the population for the radiation belts) as well as to the intensity of field-aligned electrostatic acceleration (contributing to the ionospheric conductivities and ground magnetic perturbations) [1], which depends on plasma sheet electron parameters T_e and N_e proportionally to $eTN = (T_e)^{1/2} / N_e$. In this talk we emphasize the comparative role of SW control and substorm acceleration on the eTN parameter variations, which regulates both the field-aligned auroral electron acceleration and precipitation as well as energetic ion outflows into the magnetosphere from these regions.

Using data of six THEMIS tail seasons we confirm statistically that behavior of PS parameters, taken near the central plane of nightside plasma sheet at ~10Re distance, depends on two different factors: solar wind state and substorms. The character of SW dependences of electron T_e and proton T_p in the plasma sheet differ, indicating that plasma sheet electrons are more sensitive to the substorm-related acceleration in the magnetotail. Superposed epoch study of plasma sheet parameter variations during substorms as well as the analyses of plasma acceleration at the dipolarization fronts both confirm, that during the substorm expansion phase new (accelerated and plasma-depleted) population comes into the inner CPS, causing an average increase of eTN parameter by a factor 2 above its background values. This variation is, however, smaller than the SW-induced modulation of eTN background.

Based on 10 years long data base of EISCAT and IMAGE observations in Scandinavia, we also investigate statistically the ionospheric conductivity variations, and confirm that the electron energization provides a major increase of the precipitated electron energy flux and preferential increase of Hall conductivity and ground magnetic perturbations. These effects are of key importance in understanding the real basics of magnetic variation-based monitoring of magnetospheric activity. We also discuss the question of solar illumination control of acceleration signature in the ionosphere, and discuss which of three acceleration mechanisms (substorm acceleration, chorus acceleration or field-aligned acceleration) provide the major control of the conductivity variations.

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Solar Signal at Regional Scale: A Study of Possible Solar Impact upon Cloud Cover and Associated Climatic Parameters in Romania

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In the attempt to quantify responses of various climatic processes to solar variability we have searched for a solar signal in climate paremeters at regional scale, using the ROCADA database (Bîrsan et al., 2014) for Romania. The database covers the 1961-2013 period for 9 climate parameters. In our study we will focus on parameters which may help in understanding mechanisms by which cloud cover may be affected by solar variability: mean air temperature, maximum air temperature, minimum air temperature, relative humidity, cloud cover, atmospheric pressure, precipitation amount and sunshine duration. Some indication of solar signal exist for temperature and cloud fields at national level, especially in the spatial distribution of differences between solar maximum and solar minimum, for particular seasons. The observed links are in line with the expected solar influence, taking into account the atmospheric circulation, solar effects on synoptic pressure fields and Northern Atlantic Oscillation, which are the main drivers of climate in the Romanian sector. This research was supported by the the research project SOLACE PN-II-ID-PCE-2011-3-0709.

Similarities and Features of GPS TEC Fluctuations Occurrence during Auroral Activity

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We have been analysed space weather conditions during several magnetic storms and substorms in numerical works. The storms were different intensity, duration and time of start. Now our target is to find general signatures and features of geomagnetic space storm impact on high orbital navigation satellites signal. The comparative study of the ionospheric total electron content (TEC) together with auroral activity and geomagnetic disturbances, which characterized the polar ionosphere, is presented. The rate of TEC fluctuation obtained from dual-frequency GPS measurements both from individual navigation satellite passes under ground-based GPS receivers and from network of GPS receiver stations in a map format. We also analyzed latitudinal occurrence of TEC fluctuations over Europe (near 20°E) from high to midlatitudes. The ground-based geophysical measurements were provided by the geomagnetic measurements on the network of stations, auroral observations by optical all-sky cameras and by calculations of the auroral oval model in depend on Kp index of geomagnetic activity.

There were found good similarities between temporal development of the substorm auroral activity and intensity of TEC fluctuations. The best correlation of GPS data fluctuations and optical and magnetic disturbances was achieved during the great storms. Detail analysis of the comparison was done for several events. Rather good correlation were found by the spectral images in main auroral emissions OI 555.7, OI 630.0, N_2^+ 470.9 at subauroral Yakutsk and auroral Poker Flat stations. During this time both auroral activity and quantity of irregularities sharply increased in the same sector of local time. Moreover sometime temporary variations show similarity in details. Strong TEC fluctuations were registered until 56-57 °N when auroral activity were occurred mostly in evening and night time. The fluctuation level was highest while B_Z was negative. Strong fluctuations were observed at subauroral latitudes even in local day time during 7 January 2015 storm while B_Z exited -15nT. The auroral oval position predicted by the model NORUSKA was compared with position of the ionospheric irregularities from GPS measurements in numerical stations, constructed by means of daily GPS measurements from 130-150 selected stations. These images demonstrate the irregularities oval, which was comparing with the auroral oval model. The auroral and irregularities ovals shifted to equator during this storm. The analysis shown that the high latitude phase fluctuations of GPS signals is very sensitive to change of auroral activity and can be used as indicator of space weather conditions. Authors thank to grants of RFBR 14-05-98820 r-sever-a and 15-45-05090r_vostok-a.

Surfatron Acceleration of Weakly Relativistic Electrons by Electromagnetic Waves Packet in Space Plasma

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Researches on resonant interactions between electromagnetic wave packet and charged particles based on digital calculations are reported. The strong surfatron acceleration of weakly relativistic electrons by electromagnetic waves packet in space plasma was studied. In the central area of the wave packet the electric field amplitude is above of a threshold value and this makes it possible to capture particles in the surfing mode. The work was carried out by numerically solving second order nonlinear, nonstationary equations for the wave packet phase on the particle trajectory. Numerical modeling shows that weakly relativistic electrons trapping in strong acceleration mode occurs immediately for a wide enough range of favorite initial wave phase values. It has been demonstrated that the combination of ranges of the particles' initial parameters corresponding to capturing in surfatron acceleration is large enough. Temporal dynamics of momentum components and velocities for accelerated particles, the particularities of their trajectory, taking into account cyclotron rotation at the initial stage and phase plane structure for digitally solved nonlinear equations are considered. Conducted simulations allow drawing conclusions about possibility of surfatron acceleration of weakly relativistic charges in space plasma by electromagnetic waves packet.

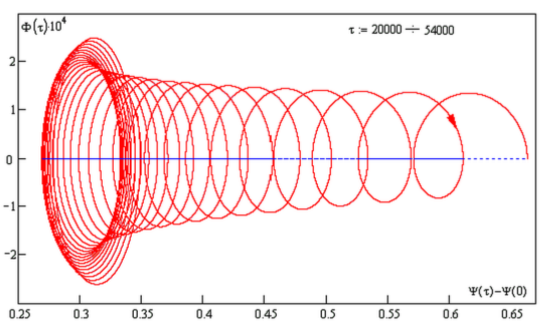

Fig. 1. Trapped electron trajectory on the phase plane (Φ, $\delta\Psi$) in the time interval $2\times10^4 \le \tau \le 5.4\times10^4$

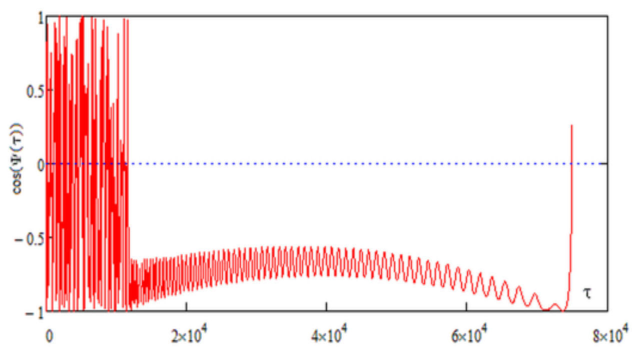

Fig.2 Time evolution of function $\cos\Psi$ defining the rate of particle acceleration.

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Surfatron Acceleration of Relativistic Protons by Electromagnetic Wave in Space Plasma

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In this work the wave-particles resonance interactions for the case of heavy charges like protons in the space plasmas are discussed. The problem of strong surfatron accelerations of the relativistic protons by single electromagnetic wave was studied on the basis of numerically solving of nonlinear, nonstationary, second order differential equation for the wave phase on the charged particle's trajectory. The features of acceleration temporal dynamic of relativistic protons for different variants of the particle initial parameters sets are considered. The optimal conditions for maximum ultrarelativistic surfatron acceleration by electromagnetic wave in space plasma are analyzed. An estimation of accelerated protons energy in local interstellar plasma clouds is obtained. An analytical approximation of energy strong growth for captured protons was done.

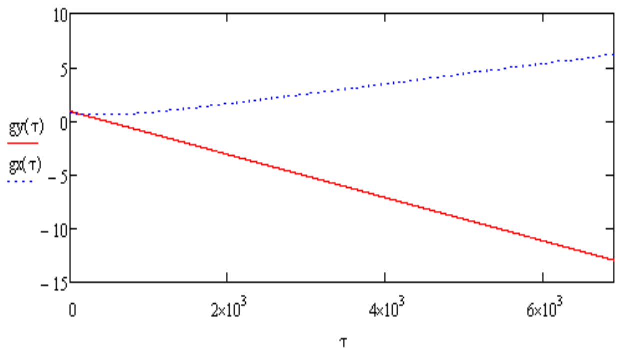

Fig. 1. Accelerated proton momentum transverse components dynamics.

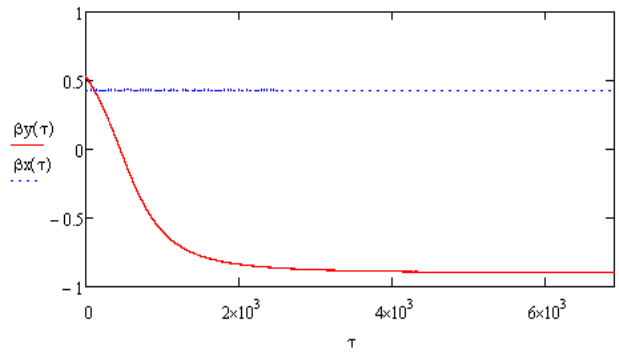

Fig. 2. Velocity components β_x and β_y of accelerated proton temporal dynamics.

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Science Objectives for the Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) Mission

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SMILE, the novel stand-alone Solar wind Magnetosphere Ionosphere Link Explorer mission, will observe the signatures of solar wind-magnetosphere interaction in soft X-rays emitted from the magnetosheath and cusps, and ultraviolet emissions generated in the auroral oval, while making its own observations of the solar wind magnetic field and plasma from apogee on its highly inclined, high apogee orbit. The mission, currently being developed by ESA and the Chinese Academy of Sciences, will carry four instruments: a wide field-of-view lobster-eye soft X-ray imager, a UVI imager, a magnetometer, and a top hat plasma instrument. This presentation describes the scientific issues that motivate the mission, presents simulations of the images expected, describes how interested theorists, space- and ground-based observationalists can become involved, and shows how closure will be obtained with the assistance of global models for the solar wind-magnetosphere interaction.

Transitioning Models from Research to Operations at NOAA Space Weather Prediction Center

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NOAA's Space Weather Prediction Center (SWPC) is the nation's official source of space weather watches, warnings and alerts with a mission to "deliver space weather products and services that meet the evolving needs of the nation." The scope of SWPC activities ranges from understanding the needs of those affected by space weather to the delivery of products and services that protect national assets and human activities. To carry out this work we benefit from partnerships such as those with other agencies, universities, the international community and commercial service providers. In this presentation we will describe the continuum of activities involved in the research to operations process and the essential role played by scientific research throughout the process. We will identify research that is needed to provide better scientific understanding, to enable improved models and to carry out much needed observations. The presentation will highlight recent work on the transition of space weather models to operations and focus on examples related to large-scale numerical models of the Geospace environment.

Observations of Energetic Protons and Neutral Atoms (ENA) at Low Altitudes during Geomagnetic Storms

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ENA in the Earth's magnetosphere are produced via charge exchange mechanism between singly charged ions and neutral atoms in the exosphere. The produced neutrals leave the interaction region with essentially the same energy and velocity as the originally ions, and are unaffected by ambient electric and magnetic fields.

ENA emission is markedly brightest at the lowest altitudes, in the auroral zone, because the density of the ambient neutrals strongly increases with decreasing height. These ENAs produced by the proton aurora are spread in all directions and some move away from the Earth and are lost into space.

During geomagnetic storms a Storm Time Equatorial Belt (STEB) of Energetic Neutral Atoms (ENA) and ions is found to exist at low altitudes around the geomagnetic equator. Their source is the ring current protons existing at larger L-values.

Using several POES, low altitude polar orbiting satellites at different MLTs, the MLT dependence of the STEB can be studied. The energy thresholds of the POES proton detectors, however, changes with time due to radiation damages. Thus in the same radiation environment different satellites will measure different flux levels. This has until now inhibited quantitative studies combining data from several satellites. Recently, however, comprehensive studies (Asikainen, Sandanger and Ødegaard) have been performed to evaluate the changes in energy thresholds on the POES detectors. It is thus now possible to perform quantitative studies combining data from several POES.

Ring Current asymmetry and symmetry inferred from the STEB are largely in accordance with results from ground based magnetic observations. The STEB appears first in the midnight/evening sector and then later in the morning sector largely consistent with the drift of the RC ions. Maximum particle injection into the ring current is associated with a rapid fall in Dst occurs when the proton precipitation in the auroral oval is most intense. The maximum STEB intensity, ENA production, is associated with minimum Dst and strongest ring current.

Low altitude observations of proton precipitation and ENA in the equatorial and polar regions based on a number of POES will be presented.

Trapped and Precipitating Energetic Electrons during Geomagnetic Storms Driven by Corotating Interaction Regions (CIRs)

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The processes leading to acceleration and loss of energetic electrons in the magnetosphere during geomagnetic storm time have yet to be fully understood, and whether a geomagnetic storm will lead to enhanced or depleted fluxes of relativistic electrons is not always evident. Relativistic electron precipitation can penetrate deep into the atmosphere and influence its composition and dynamics. To study the effect of energetic electron precipitation (EEP) upon the atmosphere, the energy and intensity of the electrons need to be accurately determined. We use the MEPED detectors on board the POES satellites to study the behavior of the electrons with energy E>50 keV, E>100 keV, E>300 keV, and E>1000keV during geomagnetic storms.

The MEPED vertical telescope measures the flux of precipitating electrons and the horizontal telescope measures the flux of trapped electrons at high magnetic latitudes (>60º). Using a newly developed technique, we can derive the flux of electrons depositing their energy into the atmosphere (the bounce loss cone flux) from the pair of detectors on each satellite. 41 isolated CIR storms were identified in the period 2006–2010 in the declining phase and near minimum in the solar activity cycle. By combining measurements from several satellites, we obtain a close to global view of the energetic electron fluxes, enabling us to study the relationship between the EEP and different geomagnetic indices and solar wind drivers.

We perform a superposed epoch analysis with solar wind parameters, geomagnetic indices, radiation belt fluxes and precipitating electron fluxes. The storms that lead to enhanced precipitating fluxes have in general high solar wind velocities over longer time periods compared to other storms. Geomagnetic indices show that these storms have longer lasting geomagnetic activity (AE index), but are not necessarily stronger in magnitude.

Cosmic Ray Variations as a Tool for Studying Surface Layer Baric and Temperature Fields

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During the analysis of solar activity impact on climate the emphasis is on temperature changes. Earth's atmosphere is a dynamic system with a complex movement in space and time[1]. In the last quarter century it has become especially interesting to study the dynamic baric and temperature fields of the lower atmosphere and their impact on the microclimate of caves in Karst. An important aspect in the study of change of thermodynamic state of the cave atmosphere is the search for processes affecting directly or indirectly air temperature in the zone of constant cave temperatures.

In the paper is shown that studied models of the ground atmospheric circulation and thermal and mass exchange with the cave air have energetically significant spatial-temporal variations. Their basic thermodynamic parameters are mainly related to dynamic efficiency of atmospheric motions in the lower atmosphere. They in turn are strongly influenced by the rapid change of falling on the Earth cosmic rays and evolution of the current solar cycle[2].

The specific mechanism of influence of the galactic cosmic rays (GCR) on the atmosphere has not yet been fully investigated. One of the possible ways is to use information on the speed of response of the selected atmospheric parameter with the change of GCR flow[3]. In this work we compare the average daily and average monthly changes in pressure and temperature of the ground atmospheric layer in the region of caves Uhlovitsa (Smolyan) and Snezhanka (Pazardjik) in the period 2005-2015, with the results of measurements of neutron monitors in the same period, located in Troitsk (200 m), Russia and the alpine station Jungfraujoch (3475 m), Switzerland.

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Influence of High-Speed Solar Wind on Galactic Cosmic Rays

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Sometimes, in the examination of the modulation process in the intensity of galactic cosmic rays due to sporadic solar phenomena interference with large amplitude is detected[1]. The observations of the solar wind in areas near the earth show that it consists of three components: a) quiet solar wind produced by a constant flow solar plasma; b) the quasi high-speed flows of solar plasma, causing recurrent geomagnetic disturbances; c) sporadic high-speed solar plasma streams, creating erratic magnetosphere disturbances[2]. Searching for experimental evidence for the contribution of solar impact on the processes in the lower earth atmosphere, influence of high-speed solar wind on galactic cosmic rays is especially interesting[3].

Statistical data of neutron monitors located at Jungfraujoch (Switzerland), Kiev (Ukraine) and Moscow (Russia) for the period 2004 - 2014 are used in the report. Influence of the impact of high-speed solar wind streams on the intensity of galactic cosmic rays off 1AU in the plane of the Earth's orbit has been investigated.

Levels of GCR modulation induced by high-speed solar plasma flow as well as amplitude, duration and time delay of different type Forbush-effects have been examined[4].

It is shown that many of the high-speed solar plasma streams weakly modulate the GCR flow. The main reductions are generated by recurrent high-speed solar wind streams. Also, the study shows that reduction in the intensity of GCR is registered 3-5 days after the registration of high-speed solar wind stream coming from the coronal hole. This process directly affects and modulates thermodynamic processes in the lower atmosphere of the Earth.

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Coronal Mass Ejections and their Space Weather Impact

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The Sun is an active star and its most violent activity phenomena are flares and coronal mass ejections (CMEs). CMEs abruptly disrupt the continuous outflow of solar wind by expelling huge clouds of magnetized plasma into interplanetary space with velocities of a few hundred to a few thousand km/s.

Earth-directed CMEs may reach Earth after transit times of about one to five days, in detail depending on their initial velocity, size, and mass, as well as on the coupling processes with the ambient solar wind flow in interplanetary space. Due to the interaction with the Earth's magnetic field, CMEs can cause severe geomagnetic storms and are therefore of high research interest.

This talk is dedicated to present the current understanding of the physical processes of CME evolution from Sun to Earth and their effects on geomagnetic activity. With respect to CME evolution, focus is put on the flare-CME relation (cf. Figure 1) as well as on measurements and modeling techniques for the interaction of CMEs with the ambient environment in interplanetary space.

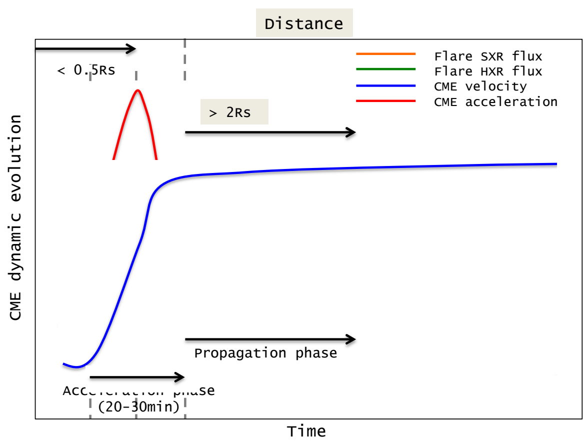

Figure 1. Schematic view on the dynamic evolution of CMEs close to the Sun and related flare energy release as measured by hard X-ray (HXR) and soft X-ray (SXR) emission. While the HXR flux is synchronized with the CME acceleration phase, the measured SXR flux goes along with the CME speed until its maximum. From [1].

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Modeling the Observed Dynamic Variability of Earth's Radiation Belts

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Earth's radiation belts exhibit rapid dynamic variability in response to solar wind drivers. Much of the variability is a consequence of wave-particle interactions, which can lead to either loss or enhancement of energetic electron flux. The injection of low to medium energy (~ 1-100 keV) plasma sheet ions and electrons into the inner magnetosphere during enhanced convection events provides both the source of free energy for plasma wave excitation and the seed population for subsequent radiation belt enhancement. Here we report on recent advances in our understanding of such processes, based on the unprecedented wave and energetic particle observations obtained from the Van Allen probes during the prime mission. Specifically, we show that stochastic energy diffusion during resonant interactions with electromagnetic chorus emissions[1] is a dominant mechanism for the development of pronounced peaks in phase space density[2] and the observed enhancement of outer belt energetic electron flux during some magnetic storms. Chorus emissions are also primarily responsible for the precipitation of injected plasma sheet electrons into the atmosphere leading to the observed global distribution of diffuse aurora[3] for L < 8. The pitch-angle distribution of injected radiation belt electrons is also modified during interactions with other magetospheric plasma waves. Scattering by plasmaspheric hiss causes the slow decay of electrons in the recovery phase of a storm leading to the reformation of the two-zone structure. Waves excited by the injected ring current ion population can also interact parasitically with radiation belt electrons. Highly oblique magnetosonic waves lead to the formation of butterfly pitch-angle distributions in the slot region and inner radiation zone, and electromagnetic ion cyclotron waves can contribute to the loss of relativistic electrons during storms.

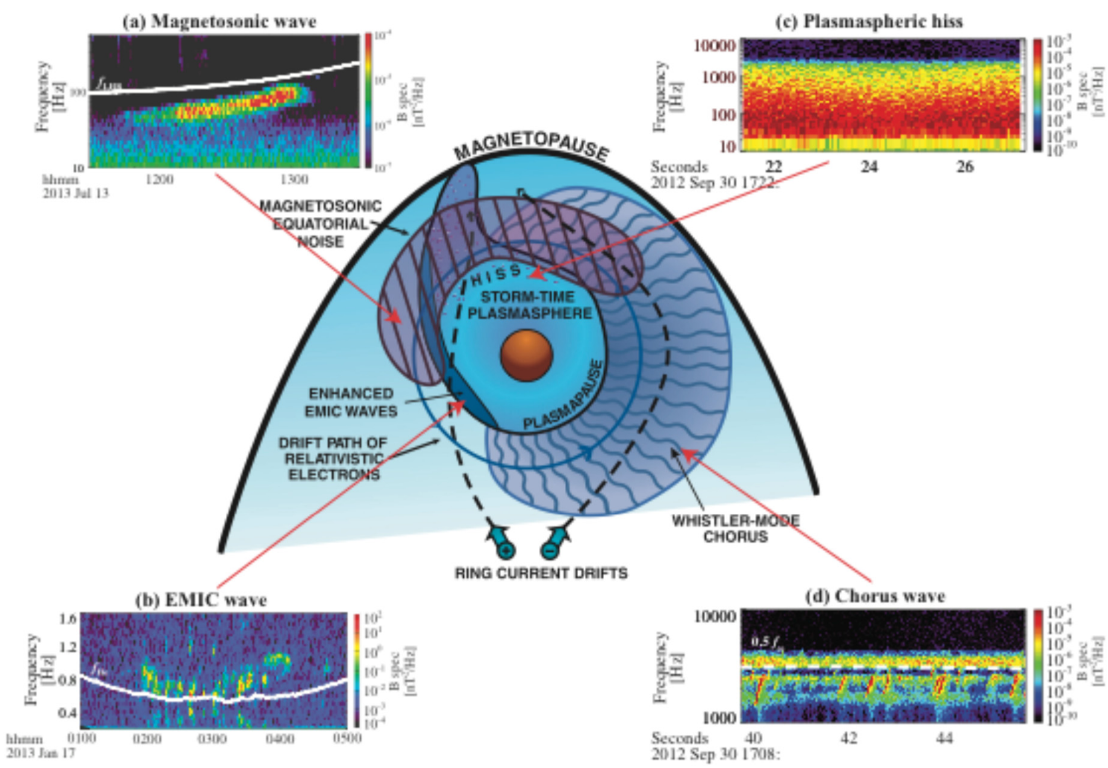

Figure 1. Plasma waves which affect radiation belt dynamics and their global distribution.

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Impacts of Geophysical and Network Parameters on Evaluation of Geomagnetically Induced Currents in Ground Networks

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Significant impacts of large geomagnetically induced currents on power systems lead to the necessity to properly evaluate the size of these currents. Traditionally, the GIC are modelled using several simplified assumptions, which might decrease the quality of the results. In the presentations the impacts of the geophysical parameters as well as impacts of the network parameters will be discussed, including the following:

1. "Geophysical" parameters, such as:
a) Latitude of the network location and resulting differences in the amplitudes of geomagnetic field;
b) Geomagnetic sampling rate on the "true" waveform of the geomagnetic disturbance;
c) One-dimensional layered earth models;

2. Network modelling parameters, such as DC-approximation of the response of line conductor

The results of presented research will help in proper evaluations of the GIC and, therefore, in preparing the adequate mitigation measures to counteract the space weather impacts on critical infrastructure.

Kinematics of Prominence Eruption

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Observations, obtained by Solar Dynamics Observatory/Atmospheric Imaging Assembly (He II 304 A) were used to study the plasma dynamics of five solar eruptive prominences. We tracked the behavior of the prominence body during the eruptive process. Height-time profiles of the eruption and changes of the velocity of the prominence material are presented. Reasons causing oscillations in the material movement are discussed.

Transient Ion Foreshock Phenomena on Earth's Dayside

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Earth's ion foreshock is a dynamic region upstream of the quasi-parallel bow shock. The foreshock is characterized by suprathermal ions backstreaming into the incident solar wind and enhanced wave activity that results from kinetic instabilities between the solar wind and foreshock plasma. Large-scale (i.e., > several Earth radii, R_E) kinetic phenomena often develop in the ion foreshock, such as hot flow anomalies (HFAs), foreshock bubbles (FBs), and foreshock cavities and cavitons, all of which we group under the umbrella term: transient ion foreshock phenomena (TIFP). We focus in particular on HFAs and FBs, both of which can form as discontinuities in the interplanetary magnetic field (IMF) interact with foreshock plasma. In both HFAs and FBs, foreshock plasma is concentrated at or near the IMF discontinuity plane, resulting in enhanced plasma temperatures, low plasma densities and magnetic field strengths, and strong plasma velocity variations. These plasma conditions are associated with significant changes in total pressure, and when these TIFP impact the dayside bow shock, the disturbances can transmit through the sheath and impact the magnetopause. Here, we present multipoint observations from NASA's THEMIS mission revealing HFAs and FBs forming in the ion foreshock and subsequently impacting Earth's bow shock and magnetosphere. We discuss recent discoveries concerning the nature these two TIFP, in particular multipoint observations of their size and growth rates, how FBs can form from tangential discontinuities in the solar wind, and how TIFP can result in very significant acceleration of solar wind electrons up to >100 keV. We next present a brief discussion on TIFP impacts observed from within the magnetosheath, along the magnetopause, and in the magnetosphere. We finish with looking forward to better understanding of TIFP that can be obtained with MMS during the dayside portions of phase 2 of the mission.

EISCAT and EISCAT_3D Incoherent Scatter Radar Facilities – New Techniques and Science Opportunities for Geospace and Atmospheric Research

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Incoherent scatter (IS) the most advanced radio method to remotely sense the upper atmosphere and the near-Earth space. Since 1981 the EISCAT IS radars in Northern Fennoscandia provide unique measurements from the upper atmosphere in the polar regions, where forcing both by solar activity and lower atmospheric phenomena are present. The facilities are maintained by the EISCAT Scientific Association (http://www.eiscat.se), an international research organisation registered in Kiruna, Sweden. The mainland EISCAT system consists of high-power VHF (224 MHz) and UHF (930 MHz) radars and the ionospheric modification facility (3.85 - 8 MHz) in Tromsø (Norway), as well as radar receiving sites in Kiruna (Sweden) and in Sodankylä (Finland). In addition, the EISCAT Svalbard Radar (ESR) operates at 500 MHz in the polar cap region.

In December 2008, the European Strategy Forum on Research Infrastructures (ESFRI) selected the proposed new generation phased-array radar facility, EISCAT_3D to the Roadmap of Large-Scale European Research Infrastructures.

EISCAT_3D will be a volumetric, i.e. 3-dimensionally imaging radar, distributed in Norway, Sweden, and Finland. It will surpass all the current IS radars of the world in technology and act as a pathfinder for other types of radar facilities worldwide. When realized, EISCAT_3D will make continuous measurements of the geospace environment and its coupling to the Earth's atmosphere in the polar region and at the southern edge of the polar vortex for the next 30 years. It will be able to produce continuous information of ionospheric plasma parameters in a volume, including 3D-vector plasma velocities. For the first time we will be able to map the 3D electric currents in ionosphere, as well as we will have continuous vector wind measurements in mesosphere. Selection of frequency and enhanced transmitter power will also allow better measurements in the tenuous plasma of the topside ionosphere.

EISCAT_3D will be realised as a multi-sited infrastructure using phased-array antennas and a key aspect is the use of advanced software and data processing techniques. In the first phase of construction a transmitter/receiver site in Skibotn, Norway and 2 receiver sites in Bergfors, Sweden and Karesuvanto, Finland will be built. Each site has 10 000 individual antennas. Transmitter power is designed to be 5 GW and later enhanced to 10 GW. Here we review the current status of preparations towards realizing EISCAT_3D and give a summary of the planned characteristics and science goals of the proposed international research infrastructure, highlighting the emerging new science opportunities for geospace and atmospheric research.

Van Allen Probes Observations of Oxygen Cyclotron Harmonic Waves in the Inner Magnetosphere

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Waves with frequencies in the vicinity of the oxygen cyclotron frequency and its harmonics have been regularly observed on the Van Allen Probes satellites during geomagnetic storms. We focus on properties of these waves and present events from the main phase of two storms on November 1, 2012 and March 17, 2013 and associated dropouts of ~few MeV electron fluxes. They are electromagnetic, in the frequency range ~0.5 - several Hz, and amplitude ~0.1- a few nT in magnetic and ~0.1- a few mV/m in electric field, with both the wave velocity and the Poynting vector directed almost parallel to the background magnetic field. These properties are very similar to those of electromagnetic ion cyclotron (EMIC) waves, which are believed to contribute to loss of ring current ions and radiation belt electrons and therefore can be also important for inner magnetosphere dynamics.

Calculation of Total Electron-Ion Production Rates Due to Solar Energetic Particles during Halloween Events 2003

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The possible effect of solar variability, respectively cosmic rays variation on atmospheric physics and chemistry is highly debated over the last years. According to several recent models the induced by cosmic rays atmospheric ionization plays a key role in several different processes in the Earth [1-19], the planets and their moons [20]. At recent, an apparent effect on minor constituents and aerosols over polar regions during major Solar Energetic Particles (SEP) events was observed [3].

The electron-ion production rate during a special case of events, namely Ground Level Enhancements (GLEs) abruptly increases. These relativistic and sub-relativistic solar protons lead to an atmospheric cascade development with secondary particles, which reach the ground level. Then it occurs a superposition of the contribution of cosmic rays with galactic and solar origin. The solar cycle 23 provided overall 16 GLEs (http://cosmicrays.oulu.fi/GLE.html), several of which are strong enhancements [3]. The period of end October - beginning of November 2003 was characterized by a strong cosmic ray variability, namely a sequence of three events: GLE 65 (28.10.2003), GLE 66 (29.10.2003) and GLE 67 (02.11.2003) was observed. In addition, there were several Forbush decreases, which led to a suppression of galactic cosmic ray flux. As a consequence the cosmic ray induced electron-ion production in the atmosphere and the corresponding ionization effect were subject of dynamical changes.

In the present study we compute the total electron-ion production due to cosmic rays during the Halloween sequence of GLEs 65, 66 and 67 on October-November 2003 and we estimate the ionization effect. The calculations are made with physics computer software CORSIKA (**CO**smic **R**ay **SI**mulations for **KA**scade) for simulation of extensive air showers induced by high energy cosmic rays. Hadronic interactions at lower energies are described by the model FLUKA (a German acronym for **FLU**ctuating **CA**scade), which is based on the Gribov-Regge theory. The time evolution of electron-ion production is computed in a realistic manner. The spectral and angular characteristics of the solar protons are explicitly considered throughout the events as well their time evolution. The ionization effect during the SEP period is computed at several altitudes above the sea level in a regions with geomagnetic cutoff rigidity $R_c \leq 1$ GV, i.e. over the high latitude, sub-polar and polar regions.

The investigated SEP cause variations of conductivity in the mesosphere and stratosphere during the considered Halloween events 2003, which can lead to changes in sprite-driving electric fields, and therefore, in sprites [21]. Accounting for the effects of sprites on minor constituents (in particular NOx), a link between SEP flux and chemical balance in the mesosphere and stratosphere is considered, as well.

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Calculation of Short, Mid and Long Term Ionization Effects by Solar Energetic Particles during Bastille Day on 14 July 2000

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The galactic cosmic rays are the main source of ionization in the Earth stratosphere and troposphere [1-16] and in the atmospheres of the planets and their satellites [17]. This ionization (induced by the primary cosmic ray particles) is important in various processes related to atmospheric physics and chemistry, specifically the minor constituents [4]. The electron-ion production in the atmosphere is enhanced compared to the average following major solar energetic particles (SEP) events, specifically over the high latitude areas and polar and sub-polar regions (with the geomagnetic cutoff rigidities $R_c \leq 1$ GV).

During the solar cycle 23 (1996-2008) we observed 16 Ground Level Enhancements (GLE) (http://cosmicrays.oulu.fi/GLE.html) of cosmic rays [4]. One of the strongest among them was the Bastille day event on July 14, 2000 (GLE 59), the national day of France, occurring near the peak of the solar maximum in solar cycle 23. It was the biggest solar radiation event since 1989. The SEP event was four times more intense than any previously recorded since the launches of SOHO in 1995 and ACE in 1997. The flare was also followed by a full-halo coronal mass ejection and a geomagnetic super storm on July 15 (the Dst index reached a minimum value of -301 nT and the Kp index run up to Kp,max = 9).

In the work presented here we apply a full Monte Carlo 3-D model in order to compute the cosmic ray induced ionization during GLE 59. The computations are based on atmospheric shower simulation with the code CORSIKA (**CO**smic **R**ay **SI**mulations for **KA**scade) using the hadron generators FLUKA and QGSJET (**Q**uark **G**luon **S**tring with **JET**s) II [1, 2]. In such a manner the electron-ion production rates are considered as a superposition of cosmic rays with galactic and solar origin. The electron-ion production rates are computed as a function of the altitude above the sea level and the short, mid and long term ionization effects relative to the average due to galactic cosmic rays are calculated. It is determined the planetary distribution in the Earth environment of the enhanced ionization rate due to solar energetic particles during the investigated GLE 59.

We consider again the hypothetical role of the cosmic rays and SEP in triggering the lightning discharges. We suppose a correlation between SEP flux and thunder days, even more that it is found a positive correlation between the intensity of the galactic cosmic rays and the ionospheric electrical potential, which could show the sensitivity of the cloud electrification process to SEP and the level of solar activity at all [18].

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Model Predictions of Complex System Behavior

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Evaluation of robustness (reliability) of model predictions is challenging for models representing complex systems. In the applied sciences of complex systems, such as hydrogeology, astrophysics, macroeconomics, different alternative physics models may describe equally well the available data and are physically reasonable based on the available knowledge. In the same time, these models could give us very different predictions about the future states of the studied system. Furthermore, in the case of complex systems, we often must do modeling under the effect of only partially-resolved understanding of the underlying of modeled processes and model parameters. This poses a challenge not seen in other sciences. These analyses are particularly challenging when we perform uncertainty quantification of rare events in the model predictions that can have major consequences (also called "black swans"). Here we demonstrate the application of a general tool for Model Analysis & Decision Support (MADS; http://mads.lanl.gov) which can be applied to perform analyses of uncertainty in model predictions using any available physics or systems model. The coupling between MADS and the external model can be performed using different methods. The MADS code have been already applied to perform high-performance computational analyses for environmental and water-energy-food nexus problems.

Space Climate Proxies Versus Internal Climatic Modes Imprints on Terrestrial Cloud Cover

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The effect of solar variability on terrestrial climate is largely unknown, despite increasing research efforts. There is no clear assessment of the existence of solar effects on cloud cover. Studies showing correlations at long-term scale are contradicted by opposing opinions stating that correlations might be random or they are affected by artefacts. Cloud cover is not accurately shown in General Circulation Models due to the fact that continuous, long-term observations of cloud cover are missing. We present a review of results showing solar fingerprints identified in high and low cloud cover data, both retrieved by satellite instruments. Comparison with long term reanalysis data is also shown, which might indicate whether observation and reanalysis data show similar fingerprints. This might also help in identifying possible mechanism of energy transfer from Sun to clouds. High clouds seem to be affected by solar variability via sea surface temperature, while low clouds might be affected by solar UV, cosmic rays or, as we lately have shown, interplanetary electric field variations. Often, climate variations are expressed through climate modes, which are defined by their specific spatial patterns. Based on observational and reanalysis data, we present footprints of known climate modes, like AMO and ENSO, on high cloud cover and attempt to identify the associate physical mechanisms. We show results identifying areas where the correlation is coherent and supported by valid mechanism. Possible mechanisms connecting various solar proxies as solar radiation, cosmic rays, solar wind fields with clouds are also briefly presented.

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The Ionospheric Source of Magnetospheric Plasma is Not a Black Box

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Including ionospheric outflow in global magnetohydrodynamic models of near-Earth outer space has become an important step towards understanding the role of this plasma source in the magnetosphere. Of the existing approaches, however, few tie the outflowing particle fluxes to magnetospheric conditions in a self-consistent manner. Doing so opens the magnetosphere-ionosphere system to non-linear mass-energy feedback loops, profoundly changing the behavior of the M-I system.

This talk exemplifies a feedback loop that develops in two-way coupled ionosphere-magnetosphere-ring current simulations. A moderate magnetospheric storm event is modeled with the Space Weather Modeling Framework using a global MHD code (BATS-R-US), a polar wind model (PWOM), and a bounce-averaged kinetic ring current model (RAM-SCB). Initially, each code is two-way-coupled to all others except for RAM-SCB, which receives inputs from the other models but is not allowed to feed back pressure into the MHD model. The simulation is repeated with pressure coupling activated, which drives strong pressure gradients and region 2 FACs in BATS-R-US. It is found that the region 2 FACs increase heavy ion outflow by up to six times over the non-coupled results. The additional outflow further energizes the ring current, establishing an ionosphere-magnetosphere mass feedback loop. This study further demonstrates that ionospheric outflow is not merely a plasma source for the magnetosphere, but an integral part in the non-linear ionosphere-magnetosphere-ring current system.

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Climate Forcing Factors Influences on Climate Change at Large Regional Scales

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Both external climate forcing factors such as atmospheric CO_2 content, volcanic emissions, and the total solar irradiation, and internal factors such as El Niño-Southern oscillation, Pacific decadal oscillation, Atlantic multidecadal oscillation and North Atlantic oscillation were included directly or as indexes in a linear regression model describing the surface temperature changes. Using the gridded temperature data sets of the UK Met office, the temperature signals of the different climate forcings were obtained. The cross-correlations between the different forcings and between the temperature anomalies and the forcing factors were calculated. The regression coefficients as well as the temperature responses to peak to peak changes of the forcing factors were determined. The correlation and the significance of the correlation, the regression coefficients and the corresponding temperature changes and their significances induced by the maximal change of the forcing factors were presented as maps. It was found out that some factors such as the atmospheric CO_2 content and the Atlantic multidecadal oscillation were characterized by an influence on the global climate but with different strength depending e.g. on the mean surface albedo of the considered region. The North Atlantic oscillation influences only temperatures in the Northern Hemisphere. Other forcing factors such as the total solar irradiation show significant temperature signals only at some regions. Regional differences of the climate factor influences are presented in detail and the results are discussed.

Simulations of Magnetosphere-Ionosphere Coupling Using Geospace Models

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Numerical simulation of the interaction of the solar wind with the magnetosphere-ionosphere system is now conducted by coupling models of the regions together into an integrated modeling framework. The Coupled-Magneotsphere-Ionsophere-Thermosphere Model (CMIT) now includes a global scale magnetohydrodynamic (MHD) for the magnetosphere, a regional model for the ring current, a high-latitude electrodynamic model, a general circulation model of the thermosphere and ionosphere, and a polar wind outflow model. This combination of models allows for numerous investigations into the coupling between the magnetosphere and ionosphere. Work with the MHD and electrodynamic coupler has highlighted the importance of ionospheric conductivity to the response of the system ranging from the location of the magnetopause, strength of convection, and timing of substorms. Including the general circulation model of the thermosphere-ionosphere into the framework allows for an examination of the role of particle and joule heating on the structure and dynamics of the thermosphere. Early work with including ionospheric outflow into multi-fluid MHD illustrated the role this outflow plays in creating multiple substorm or sawtooth events. More recent simulations with a realistic polar wind model have also highlighted the important role outflow plays in the onset of sawtooth events.

Modeling Magnetospheric Particle Fluxes during the March 17, 2013 Geomagnetic Storm

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In this paper, we will present results from a study of inner magnetospheric particle dynamics during the large geomagnetic storm that occurred on March 17-18, 2013. For this study, we will model the storm using the Space Weather Modeling Framework with the BATS-R-US global magnetosphere, RAM-SCB inner magnetosphere, and the RIM ionospheric electrodynamics components. The results of this simulation will be used to drive a test particle tracing simulation to model particle fluxes along the Van Allen Probes and LANL GEO spacecraft orbits during this event. We will then compare the results from the test particle simulation to both RAM-SCB's internal plasma model and data from in situ spacecraft data.

A New Ionospheric Electron Precipitation Module Coupled with RAM-SCB within the Geospace General Circulation Model

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Electron precipitation down to the atmosphere due to wave-particle scattering in the magnetosphere contributes significantly to the auroral ionospheric conductivity. In order to obtain the auroral conductivity in global MHD models that are incapable of capturing kinetic physics in the magnetosphere, MHD parameters are often used to estimate electron precipitation flux for the conductivity calculation. This however lacks self-consistency in representing the magnetosphere-ionosphere coupling processes. In this study we improve the coupling processes in global models with a more physical method. That is, we calculate the physics-based electron precipitation from the ring current and map it to the ionospheric altitude for solving the ionospheric electrodynamics. In particular, we use the BATS-R-US MHD model coupled with the kinetic ring current model RAM-SCB that solves pitch angle dependent electron distribution functions, to study the global circulation dynamics during the January 25-26, 2013 storm event. Since the electron precipitation loss is governed by wave-particle resonant scattering in the magnetosphere, we further investigate two methods of specifying electron precipitation loss associated with wave-particle interactions:(1) using pitch angle diffusion coefficients $D_{\alpha\alpha}(E,\alpha)$ determined from the quasi-linear theory, with wave spectral and plasma density obtained from statistical observations, (2) using electron lifetimes $\tau(E)$ independent on pitch angles. Simulation results indicate that unlike the lifetime method that underestimates the intensity of precipitation, the diffusion coefficient method produces much better agreement with NOAA/POES measurements on the spatial distribution and temporal evolution of electron precipitation in the region from the pre-midnight through the dawn to the dayside. In addition, the ionospheric conductance caused by diffuse electron precipitation shows clear correlation with wave distribution in the magnetosphere, indicating the importance of wave-particle interactions in influencing the ionospheric electrodynamics.

Longitudinal Dependence of the Topside Ionospheric and Plasmaspheric Electron Content's Seasonal Variations: Observational and Model Results

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Radio signals transmitted from GPS satellite going through the ionization zone above the Earth will be refracted by the ionized components in the ionosphere and the plasmasphere, which would produce additional transfer delay relative to the situation in vacuum and generate extra errors in satellite navigation and positioning, timing, remote sensing and telemetering. These errors have strong relation with the total electron content (TEC) along the signal's travelling path. The topside ionospheric and plasmaspheric electron content (TPEC) makes a large contribution to TEC. Study on the variations of TPEC is a significant part of the space weather issues. In another hand, an increasing number of users of the ionospheric models also require information about the plasma conditions above the ionosphere in the plasmasphere. As is well known, the International Reference Ionosphere (IRI) model is a model widely used in practice by many communities for different usage purpose. Extension of the IRI model to the plasmasphere is one of the main goals of the IRI community [1]. A number of approaches have been proposed for extending IRI model to the plasmaspheric altitudes, among them is the plasmasphere model developed by the Institute of Terrestrial Magnetism, Ionosphere and Radiowaves Propagation (IRI_IZMIRAN-Plas) [2]. The IRI_IZMIRAN-Plas model is an empirical model based on whistler and satellite observations. It presents global vertical analytical profiles of electron density smoothly linked with the IRI electron density profile at altitude of one basis scale height above the F2 peak and extended towards the plasmapause up to 36000k. Validation study on such an extended model is very important and a necessity.

In a previous study [3], we have conducted a study on the latitudinal, diurnal and seasonal variations of TPEC between the heights of 800-20200km above the Earth derived from the upward looking TEC measurements (podTEC) of the COSMIC LEO satellites' precise orbit determination antenna directed to the GPS signals. In that study, we found that the seasonal variations of TPEC at 120^0 E and 300^0E are remarkably different. In the present study, we present out recent continuing study on the longitudinal dependence of TPEC's seasonal variations by using data from different longitudes of the whole globe. A comparison study of the observed TPEC with the IRI_IZMIRAN_Plas model results is also made. Our study showed that TPEC shows different seasonal variations at different longitudinal sectors: for the 240^0 E-60^0 E longitudinal sector, TPEC shows a strong annual variation with lowest value in the June solstice and highest value in the December solstice months; In contrast, very weak seasonal variations are observed for PEC at 60^0 E-240^0 E longitudinal sector. Comparison study showed that this longitudinal dependence feature of the observed TPEC's seasonal variation is not captured well by the IRI_IZMIRAN_Plas model result and additionally, the IRI_IZMIRAN_Plas model results generally underestimate the observed TPEC values. Moreover, the IRI_IZMIRAN_Plas model results tend to show double peaks in the low-latitude region, a feature not appearing in the observational results.

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