Challenge of PSTEP (Project for Solar-Terrestrial Environment Prediction)

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Although solar activity may significantly impact the global environment as well as socio-economic systems, the mechanisms for solar eruptions and the subsequent processes have not yet been fully understood. Thus, modern society is at a risk from severe space weather disturbances. Project for Solar-Terrestrial Environment Prediction (PSTEP) was launched in order to improve this situation through synergy between the basic science research and the forecast operation. PSTEP is a nation-wide research collaboration supported by a Grant-in-Aid for Scientific Research on Innovative Areas from MEXT/Japan. By this project, we seek to answer some of the fundamental questions concerning the solar-terrestrial environmental system, and aim to contribute to building a next-generation space weather forecast system to prepare for severe space weather disasters. PSTEP is organized by four research groups and proposal-based research units with the participation of more than 90 scientists. In this presentation, we will talk about the key aims and strategies of PSTEP.

Keywords: space weather, space climate, prediction

Analysis of Needs-Seeds Matching for Using Space Weather Information

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NICT has been investigating the needs of space weather (SWx) information with asking users by paper and face to face meeting on 2013 and 2014, in addition to arranging "space weather users forum" for ten years since 2005.
"Project for Solar-Terrestrial Environment Prediction" (PSTEP) was accepted on the Grant-in Aid for Scientific Research on Innovative Areas (2015-2019), MEXT, Japan. One of the main theme of PSTEP is o provide useful products ot users with developing with cutting-edge results from academic work. It is essential to build a communication framework among the scientists, adata providers, and users for achieving this goal.
As our first action, we have been analyzing gap analysis between needs and seeds of SWx information.
Especially, the aviation is one of the most advanced fields for using SWx information to the operation. We will discuss the matching using these examples.

Keywords: space weather, user investigation, aviation

Solar Flare Prediction with Vector Magnetogram and Chromospheric Brightening using Machine-learning

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Solar flares have been empirically predicted based on the solar surface observations. Before large class of flares, photospheric magnetic field in the active region becomes complex and sharp magnetic neutral lines are formed. It is also known that chromospheric brightening recurrently occurs at around the neutral lines. In NICT, solar flares occurring in the next 24 hours have been predicted by scientists in the daily forecast operations, but the flare mechanism has not been well revealed and we still have a difficulty in predicting flares with high accuracy and good confidence. Currently, we can access huge amount of observation data, so we developed a system to automatically predict flares using the near real-time observation data by satellites and the machine-learning technique.
We used observation data sets taken by SDO and GOES satellites during 2010-2015: (1) line-of-sight direction magnetogram and vector magnetogram data by HMI/SDO, (2) lower chromospheric brightening data by AIA 1600 Angstrom filter/SDO, and (3) soft X-ray emission by GOES. Firstly, we automatically detect active regions using full-disk images of magnetogram every 1 hour, to predict a flare class occurring in the region in the next 24 hours. Secondly, we extract solar features for each region, i.e., the maximum magnetic field strength, the maximum gradient of magnetic field in the line-of-sight direction, the number of magnetic neutral lines, the maximum length of neutral lines, the magnetic free energy, the shear angle, the time variations of magnetic field configurations, the history of X/M-class flares, the background GOES X-ray emission, and the activity of chromospheric brightening. Thirdly, we apply the machine-learning technique to the dataset of solar features to predict flares. We divided the total data set into two for training and test. We adopted three machine-learning techniques for comparison: the support vector machine (SVM), the k-nearest neighbor (k-NN) and the extra random trees (ERT). As a result, we succeeded in achieving good prediction of X-class flares, as verified by the True Skill Score (TSS) larger than 0.7, which is better than human forecast operations (TSS~0.5). In this presentation, we would like to introduce our flare predictions model and to discuss flare triggering mechanism.

Keywords: Space Weather Forecast, Solar Flare, Statistical Analysis, Machine-Learning, Photospheric vector Magnetic field, Chromosphere

Solar Flare Prediction Studies Using Universal Time Series Predictor UFCORIN

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We have been studying space weather forecast using time-series prediction engine UFCORIN(Universal Forecast Constructor by Optimized Regression of INputs.) In our studies (Muranushi et al. 2015), we have compared 6'160 different prediction strategies that uses subset of wavelet features of SDO/HMI images as well as GOES past light curves.
Use of TSS (True Skill Statistics) as the indicator of flare forecast performance has been widespread since it is proposed by Bloomfield et. al(2012). However, we found that variation of bare TSS values over different cross-validation (CV) data sets is too large, so that we cannot measure significant difference between different forecast strategies. We found by using the z-value, or standard deviation of TSS, we can distinguish such strategies that show forecast performance consistently better than the average. We suggest the use of z-value as a method of finding good forecast strategies from thousands of candidates.
In our studies, the laregest TSS for X,M, and C class flare forecast, were 0.75 ± 0.07, 0.48 ± 0.02, and 0.56 ± 0.04, respectively.
Based on (Muranushi et al. 2015), we have been operating real-time flare forecast server since August 2015. The system have been making forecast every 12 minutes, except for some down times. We would also like to report on the latest state of this experience.

Keywords: Space Weather Forecast, Flare Forecast

Realtime Solar X-ray Flux Forecast using Deep Learning

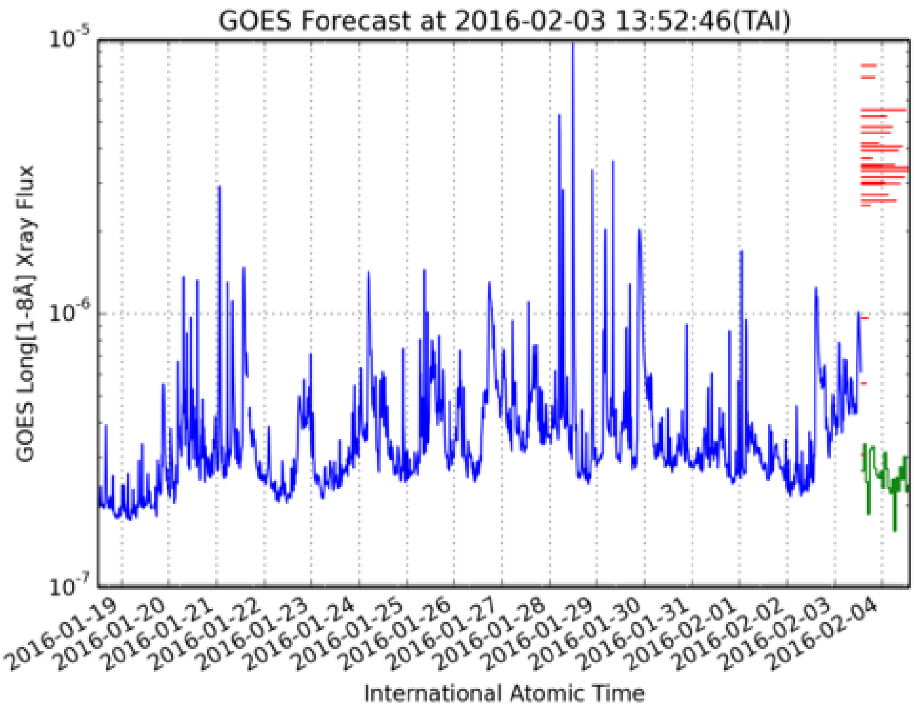
We present the 24-hour forecast of GOES X-ray flux, based on realtime GOES data and HMI-720s Near-Real-Time data.

The forecast is produced by regression of the time series using Long-Short Temporal Memory (LSTM) neural network.

The feature vector is produced from (1) GOES X-ray flux and (2) wavelet analyses of HMI images, as described in Muranushi et al (2015): http://arxiv.org/abs/1507.08011 .

The source code is available under MIT license at https://github.com/nushio3/UFCORIN/tree/master/script .

Largest flare in next 24 hours: 3.3e-06 W/m²
Flare category forecast: C Class



Radiation Protection of Humans in Space and Aviation: Current States and Future Needs on the Warning System for Aviation Exposure to SEP (WASAVIES)

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Forecast of radiation doses for astronauts as well as aircrews due to the exposure to solar energetic particles (SEP) is one of the greatest challenges in space weather research. In last 5 years, we have developed a WArning System for AVIation Exposure to Solar energetic particles: WASAVIES. In this system, the SEP fluxes incident to the atmosphere are calculated by physics-based models, and they are converted to radiation doses using a database developed on the basis of air-shower simulation. However, it takes approximately 2.5 hours to determine the parameters used in the physics-based models after the detection of GLEs, and thus, the current WASAVIES cannot predict doses during the peak of GLEs. Therefore, we are trying to reduce the time for evaluating the parameters, as well as to develop a nowcast system for the radiation dose due to SEP exposure, under the framework of Project for Solar-Terrestrial Environment Prediction (PSTEP, http://www.pstep.jp/) in Japan. A brief outline of WASAVIES together with our future strategy will be presented at the meeting.

Keywords: SEP, Radiation Exposure, Space Weather

Recent Progress in Space Weather Modeling and Forecasting at NOAA's Space Weather Prediction Center

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We discuss the current state of the art of space weather modeling and forecasting at the NOAA Space Weather Prediction Center (SWPC) in Boulder, Colorado. Recent progress in modeling the solar wind using a data assimilative flux transport model (ADAPT) from the Air Force Research Laboratory (AFRL) has shown that incorporating current and modeled solar magnetic field data results in a better correlation with measurements of the solar wind at the ACE spacecraft in L1 orbit. SWPC is also transitioning the University of Michigan's "Geospace" model to operations, enabling 15-30 minute forecasts of geomagnetic storming and regional K-value predictions. In addition SWPC and the University of Colorado Cooperative Institute for Research in the Environmental Sciences (CIRES) are developing the Whole Atmosphere Model (WAM) and the Ionosphere Plasmasphere Electrodynamics (IPE) coupled system to enable three-day forecasts of ionospheric conditions as well as neutral atmosphere density for satellite drag calculations. In accordance with the new National Space Weather Strategy released by the White House in October 2014, these and other models and products will be integrated into the Space Weather Forecast Office to enable SWPC forecasters to deliver impact-based decision support services to satellite operators, commercial airlines, GNSS users, and electrical grid operators to protect critical infrastructure from the threat of extreme space weather events.

NASA Heliophysics and the Science of Space Weather

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NASA formulates and implements a national research program for understanding the Sun and its interactions with the Earth and the solar system and how these phenomena impact life and society. This research provides theory, data, and modeling development services to national and international space weather efforts utilizing a coordinated and complementary fleet of spacecraft, called the Heliophysics System Observatory (HSO), to understand the Sun and its interactions with Earth and the solar system, including space weather. NASA’s space-based observational data and modeling efforts have provided significant contributions to the science of space weather. Current and future space weather research will provide key information to improve the ability of the United States and its international partners to prepare, avoid, mitigate, respond to, and recover from the potentially devastating impacts of space-weather events.

Scientific research in support of space weather goals

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Unlike terrestrial weather, space weather is immature from a scientific point of view. While the last decades have seen tremendous scientific progress, which, among others, manifested itself in form of advanced space weather models, many key scientific processes underpinning space weather remain poorly understood or not understood at all. These processes span the gamut of Heliophysics domains; starting from magnetic filed generation processes in the solar interior and reaching to Earth's upper atmosphere, where we still lack kowledge of the processes responsible for ionospheric scintillations. In addition, we are in many, rather fundamental from a space weather point of view, cases not able to predict with any confidence the expected amplitudes of space weather phenomena. This presentation will review scientific progress to-date, and attempt to map out a path forward toward the desired quantitative and accurate predictabily.

Keywords: Space weather, Space research, Heliophysics

Geomagnetically induced currents: the latest science, engineering and policy actions in the US

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Geomagnetically induced currents (GIC) flowing in long manmade conductor systems have become one of the main space weather concerns. The potential for widespread problems in operating high-voltage power transmission systems during major geomagnetic storms has prompted increasing federal regulatory, science, industry and public interest in the problem. The impact caused by extreme storm events has been of special interest and consequently much of the recent GIC research has been focused on defining extreme GIC event scenarios and quantifying the corresponding transmission system response. In addition, there is an elevated need for developing next generation GIC prediction products for the power industry. In this presentation, I will discuss the latest science, engineering and policy actions around the topic especially in the US. Perhaps the most significant policy action are the standards work pushed by the US Federal Energy Regulatory Commission. GIC are centerpiece also in the newly released National Space Weather Strategy reflecting the strong interest in the topic at the highest levels of the US government. Much of the recent progress in understanding GIC and its impact on power grids has resulted from improved scientific community-power industry interactions. The common language and information exchange interfaces established between the two communities have led to significant progress in transitioning scientific knowledge into detailed impacts analyses. We also face a number of future challenges in specifying GIC, for example, in terms of more realistic modeling of the three-dimensional geomagnetic induction process. I will discuss briefly some of these future challenges.

Keywords: Space weather, Geomagnetically induced currents

Empirical estimation of GICs from the geomagnetic data in Japan

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Pulkkinen et al (2007) proposed the new method of estimating geomagnetically induced currents (GICs) at a transformer station by employing the linear relation between the GICs and the corresponding geomagnetic variations as

$GIC(\omega)=A(\omega)B_y(\omega)+B(\omega)B_x(\omega)$ (1)

By using the two transfer functions in the frequency domain ($A(\omega)$ and $B(\omega)$ in Eq. (1)), we obtain

$GIC(t)=\int A(\tau)B_y(t-\tau)d\tau + \int B(\tau)B_x(t-\tau)d\tau$ (2)

This method (the transfer function method) successfully reproduced the GICs from the geomagnetic variations in Finland [Pulkkinen et al., 2007] and in Hokkaido [Pulkkinen et al., 2010]. However, as the electrical conductivity distributions in both areas are rather uniform, it is important to evaluate how this method is applied to GICs observed at a station in other area of Japan with heterogeneous conductivity distribution. This is the motivation of this research. We employ one-minute values of the GICs observed at a transformer station and those of the geomagnetic data at Kakioka Magnetic Observatory during the Halloween event.

To confirm how this method is effective, we need to investigate how the GICs during one event are reproduced from the geomagnetic data in this event with the transfer function obtained from the other event. Fortunately, the Halloween event has two activities on Oct/30 (the event #1) and on Oct/31 (the event #2), we can calculate separately two transfer functions for the two events. First, we confirm that the transfer functions obtained from the events are essentially identical. This fact indicates that the transfer function method by Pulkkinen et al. (2007) is applicable to the GIC data in Japanese transformer station. Next, the GICs in the event #1/#2 are estimated from the geomagnetic data in the event #2/#1 and the transfer function of the event #2/#1. When calculating GICs in time domain in Eq. (2), we noticed that the integral from t=0 to 50min reproduces sufficiently accurate GICs. This fact is a little bit different from Pulkkinen et al. (2007) who estimated the GICs through the integral only at t=0 and 1min. At last, we confirm that the reproduced GICs are essentially similar to the observed ones.

In the last, we estimate the GICs at the transformer station in the magnetic storm in 1989 which caused the large-scale blackout in Canada and US.

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Keywords: geomagnetically induced current, transformer station, transfer function

Polar cap potential saturation during the Bastille day storm using global MHD simulation

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We are developing a real-time numerical simulator for the solar wind-magnetosphere-ionosphere coupling system using next generation magnetosphere-ionosphere coupling global MHD simulation called REPPU (REProduce Plasma Universe) code. The feature of simulation has an advanced robustness to strong solar wind case because a triangular grid is used, which is able to calculate in the uniform accuracy over the whole region. Therefore we can simulate extreme event such as the Bastille day storm. The resolution is 7682 grids in the horizontal direction and 240 grids in the radial direction. The inner boundary of the simulation box is set at 2.6 Re. We investigate the reproduction of the magnetosphere-ionosphere coupling simulation in strong solar wind case. Therefore we compared the simulation results with the observation of the Bastille day storm event (2000/7/15), in which the solar wind velocity is above 1000 km/s and the value of Bz reached -60 nT. Especially, we focus the CPCP saturation and time variation because the CPCP represents the value of magnetospheric - ionospheric convection strength via region 1 current. The CPCP depends on solar wind electric field, dynamic pressure and ionospheric conductivity [Siscoe et al., 2002; Kivelson et al., 2008]. The model of Kivelson et al. [2008] shows a good reproduction to the CPCP variation. However their study assumes that the ionospheric conductivity is constant. The conductivity in our simulation of the Bastille day event is varied by the auroral activity. In this lecture, we discuss the effect of both the auroral conductance and solar EUV-driven conductance to CPCP saturation.

Keywords: global MHD simulation, polar cap potential, extreme event

Space weather forecast of energetic particles and extreme space weather of magnetic storms

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I review our recent research activities on the space weather forecast of energetic particles, including galactic cosmic rays, solar protons, ring current, and radiation belt electrons. Theoretical approaches on the extreme space weather of geomagnetically induced currents and on extreme space climate during grand minima are also discussed. A new citizen science approach to investigate world-wide aurora sightings during extreme magnetic storms is also introduced.

What is the Largest Flare that can Occur on the Sun?

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The question of whether so-called superflares (energies from 10^{33}-10^{35} ergs) could occur on the Sun is of great interest scientifically. There are also obvious practical (space weather) implications. Shibata et al. (2013) suggested that flares on the order of 10^{34} ergs could occur every 800 years on the Sun, while Schrijver et al. (2012) argued that the magnetic energy for such a flare would require a sunspot 20 times greater then ever observed, and that 10^{33} ergs was a practical upper limit for flares.
Major solar eruptions such as X-class flares and very fast coronal mass ejections originate in active regions on the Sun. The energy that powers these events is believed to be stored as free magnetic energy (energy above the potential field state) prior to eruption. Therefore, the maximum free energy that can be stored in an active region bounds the largest possible eruption that can emanate from it. Using line-of-sight or vector magnetograms, the maximum energy that can be stored in a region can be estimated with the aid of the Aly-Sturrock theorem. We have investigated the active regions where the largest flares in the last 30 years have originated. We have found six cases where the maximum free energy is on the order of or greater than 10^{34} ergs. Our results suggest that 10^{34} erg solar flares cannot be ruled out based on magnetic energy storage.

Solar Origin of a Sequence of SEP-Producing CMEs via the "Lid Removal" Mechanism

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Both coronal mass ejections (CMEs) and solar energetic particle (SEP) events are of concern for space weather. Here we report on the solar source of a pair of CMEs that produced a strong SEP event. The CMEs resulted from back-to-back ejective eruptions from a single active region on 2012 January 23. We examine the onset of these eruptions using magnetograms and EUV images from the HMI and AIA instruments on the Solar Dynamics Observatory (SDO) spacecraft, and EUV images from the STEREO spacecraft. Cheng et al. (2013) showed that the first eruption's (``Eruption 1'') flux rope was apparent only in ``hotter'' AIA channels, and that it removed overlying field that allowed the second eruption (``Eruption 2'') to begin via ideal MHD instability; here we say Eruption 2 began via a ``lid removal'' mechanism. We show that during Eruption-1's onset, its flux rope underwent ``tether weakening'' (TW) reconnection with the field of an adjacent active region. Standard flare loops from Eruption 1 developed over Eruption-2's flux rope and enclosed filament, but these overarching new loops were unable to confine that flux rope/filament. Eruption-1's flare loops, from both TW reconnection and standard-flare-model internal reconnection, were much cooler than Eruption-2's flare loops (GOES thermal temperatures of ~9 MK compared to ~14 MK). This eruption sequence produced a strong solar energetic particle (SEP) event (10 MeV protons, >10^3 pfu for 43 hrs), apparently starting when Eruption-2's CME blasted through Eruption-1's CME at 5---10 R_s. This occurred because the two CMEs originated in close proximity and in close time sequence: Eruption-1's fast rise started soon after the TW reconnection; the lid removal by Eruption-1's ejection triggered the slow onset of Eruption 2; and Eruption-2's CME, which started ~1 hr later, was three times faster than Eruption-1's CME.

Keywords: Coronal Mass Ejection (CME) Onset, Solar Energetic Particles (SEPs), Solar Filament Eruptions, Solar Flares

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 investigate 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.

Keywords: Sun, Coronal activity, Space weather

Generation mechanism of large-scale magnetic field revealed with high-resolution solar dynamo calculation

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We carry out series of high-resolution solar dynamo calculations in spherical geometry to investigate generation mechanism of large-scale magnetic field. Solar observations indicate large-scale magnetic field in the solar interior in spite of the chaotic and turbulent fluid motion. Recent high-resolution calculations show that higher-resolution calculations generate weaker large-scale magnetic field, since small-scale turbulence tends to destruct the coherent large-scale magnetic field. In order to address this issue, we carry out a series of higher-resolution calculations. In our "middle"-resolution calculation, we find the same result as previous studies, i.e., when we increase the resolution, the large-scale magnetic field loses its energy. In our unprecedentedly high-resolution calculation, however, large-scale magnetic energy is recovered. In the calculation, we find an efficient small-scale dynamo which leads to strong Lorentz feedback in the small scale. The small-scale turbulent motion, which tends to destructs the large-scale magnetic field is suppressed. As a consequence, the large-scale magnetic field is maintained even with large Reynolds numbers.

Keywords: Sun, Thermal convection, Dynamo

Modeling the thermosphere ionosphere system and space weather impacts

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The thermosphere-ionosphere-plasmasphere system has several direct impacts on space weather. Uncertainty in thermospheric neutral density affects satellite drag, orbit prediction, and collision avoidance. Variations in total electron content, together with steep gradients in plasma density, disrupts GNSS navigation signals and positioning accuracy, affecting a range of users including civil aviation. Changes in ionospheric layers modifies HF propagation due to absorption in the D-region and changes in reflection from F-region positive and negative storm phases. During a geomagnetic storm these changes can be dramatic. The modeling challenges are significant and diverse. The response of the system to geomagnetic storms has to capture dynamic neutral density changes, huge increases in storm-enhanced plasma densities by a factor of five, followed by extreme negative phases where the ionosphere can be severely depleted. During geomagnetically quieter conditions the day-to-day changes can be more subtle. The impact of waves propagating from instabilities in stratospheric jets or convective storms in the troposphere, produce persistent ionospheric variability perturbing HF propagation. Predicting the day-to-day variability of equatorial ionospheric irregularities, and their impact on satellite communication and navigation, remains a challenge, although there are hints that variability of lower atmosphere waves may be playing a role. Improvement in thermosphere-ionosphere and whole atmosphere models show promise in being able to simulate the response of the system to solar, geomagnetic, and lower atmosphere forcing with a goal of mitigating some of the impacts of space weather on operational system.

Keywords: Thermosphere-Ionosphere Modeling, Space Weather, Satellite drag, Geomagnetic storms

Effects of energetic particle precipitation and solar irradiance on ozone

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The term energetic particle precipitation (EPP) commonly refers to particles of different energy which routinely impact the polar regions. EPP ionizes the atmosphere and triggers catalytic cycles of ozone depletion driven by odd nitrogen (NOx) and odd hydrogen (HOx) species. While the most energetic particles can directly affect ozone in the mesosphere, during winter the (almost) continuous flux of auroral electrons produces high NOx amounts which can be transported downwards inside the polar vortex and influence stratospheric ozone. On the other hand, the wavelength dependence of the solar irradiance variation can induce stratospheric ozone changes in phase with solar activity. Here, we investigated ozone variability in response to EPP and solar activity during the 1979-2014 period by combining satellite ozone observations from Solar Backscatter Ultraviolet Radiometer and Microwave Limb Sounder on Aura. In particular, we analyze the correlation of the polar ozone variability with EPP and with solar irradiance in an attempt to distinguish between the two effects and to quantify the ozone variations caused by EPP on long time scales.

Keywords: Energetic particle precipitation (EPP), ozone, solar radiation

International joint study of EEP effects on the atmospheric minor components during pulsating aurora

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In recent years, variations of the atmospheric minor component (NOx, HOx, O3, etc) due to energetic electron precipitation (EEP) have been widely studied by many researchers. There are several sources to cause EEP, such as solar proton event, electron precipitation during pulsating aurora, and relativistic electron precipitation. This study focuses on pulsating-auroral (PA-) EEP, which is an almost daily occurrence in the morning sector of the auroral ionosphere. EISCAT measurements and GEMSIS-RBW simulation reveal that energy range of the PA-EEP is higher than 10 keV to a few hundred keV [Saito et al., 2012; Miyoshi et al., 2015]. Such energetic electrons can cause ionization in the mesosphere and upper stratosphere, resulting in forced modifications in the chemical equilibrium of the atmospheric minor components. This process is essentially important for understanding solar-climate relationships.
Japanese and Finnish researchers organize an international joint team, and conduct observation campaigns with the EISCAT radars, optical instruments, KAIRA riometer, and VAPs satellites in order to understand generation mechanism of PA-EEP and its impact on the ionosphere and atmosphere. Additionally we will analyze the archived data sets to understand EEP features. These scientific objectives will be accomplished by collaborations with the GEMSIS-RBW model and Sodankyla Ion Chemistry (SIC) model. In this presentation we will introduce some case studies of measurements and model calculations.

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Keywords: pulsating aurora, atmospheric minor component

Exploring Predictive Performance of Ground dB/dt Models: A Reanalysis of the Geospace Model Transition Challenge

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Geomagnetically Induced Currents (GICs) are electric currents driven by activity in near-Earth outer space as our magnetic field interacts with that of the Sun's. These currents can flow through any conducting path, including pipelines and high voltage electric power lines. When GICs become strong enough, these technological systems can be interrupted or damaged, drastically affecting those who depend on them. Developing systems to accurately monitor and predict GIC events has therefore become a critical task for national security. An initial effort to assess the performance of five operationally-promising GIC models was presented by *Pulkkinen et al.* [2013]. The results of this validation effort showed that the models can provide predictive value, but shortcomings exist. While this work represents a landmark first-step towards numerical space weather forecasting, many questions remain concerning each of the models' capabilities. How do the models perform for different levels of geomagnetic activity? What is the range of activity for which the models have been validated? Based on the assumptions and input data for each model, what is the maximum driving for which the results can be considered valid?

This study presents a reanalysis of the *Pulkkinen et al.* [2013] results to extend our understanding of the models' capabilities and answer the questions posed above. Data-model errors between predicted and observed magnetometer dB/dt values are binned by activity (solar wind electric field or D_{ST}). The bins are arranged to yield error as a function of driving. Input data for empirical relationships, on which the models either rely or of which they comprise entirely, are binned by activity to determine the range of conditions over which each model is valid. A comparison of each model is presented to further illustrate previously published results. Additionally, because GICs are intimately linked to the electrojets which are in turn closely related to field-aligned currents, we also compare Birkeland currents from the different models to observations. For this we use radial current distributions from AMPERE based on the Iridium satellite constellation, providing assessments of the intensities and distributions of the global scale currents every ten minutes. From this new analysis, we place error bars on recent predictions of dB/dt made by the Space Weather Modeling Framework.

Keywords: Geomagnetically Induced Currents, Space Weather Modeling

Substorm simulation: Current system and auroral structure

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Substorm is known to cause strong geomagnetically induced current (GIC) on the ground in the polar region. The GIC is primarily caused by the ionospheric current that is intensified by field-aligned current (FAC) during the substorm. On the basis of the result obtained by a global magnetohydrodynamic (MHD) simulation, we propose a scenario for the evolution of the current system associated with a substorm expansion. (1) Near-Earth neutral line releases magnetic tension in the near-Earth plasma sheet to compress plasma and accelerate it earthward. (2) Earthward, perpendicular flow is converted to parallel flow when flow braking takes place. (3) Plasma moves earthward parallel to a field line. The plasma pressure is additionally enhanced at off-equator. (4) Flow vorticities coexist near the off-equatorial high-pressure region. Resultant FAC is connected to the ionosphere, which may manifest initial brightening of aurora. The ionospheric current starts to increase. (5) Due to continued earthward flow, the high-plasma pressure region continues to expand to the east and west. (6) The ionospheric conductivity continues to increase in the upward FAC region, and the conductivity gradient becomes steeper. (7) The convergence of the Hall current gives rise to divergent electric field near the steep gradient of the conductivity. (8) Due to the divergent electric field, magnetospheric plasma moves counterclockwise at low altitude (as seen in the Northern Hemisphere). (9) The additional flow vorticity generates a localized upward FAC at low altitudes, which may manifest westward traveling surge (WTS) of aurora. As a consequence, the ionospheric current, conductivity, and the magnetospheric current system are redistributed. The evolution of the substorm depends on the solar wind condition as well as the magnetospheric condition. We will discuss the optimal condition that potentially causes the strong substorm.

Keywords: Substorm, Aurora, Geomagnetically Induced Current (GIC)

Identification of ionospheric plasma density changes due to solar flares and energetic particle precipitation using the SuperDARN radar data

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Watanabe and Nishitani (Adv. Polar Sci, 2013) showed that during solar flares the SuperDARN data show positive Doppler velocities in ground / sea scatter echoes, and that this velocity change can be interpreted mainly in terms of the abnormal ionization of the D-region ionosphere due to EUV / X-ray, leading to the shortening of the HF ray paths. They also showed that it is possible to identify the plasma density changes from the Doppler velocity distributions. These result suggests that it might be possible to identify the D-region plasma density changes due to energetic particle precipitation events such as substorms using the same technique.

Ionospheric convection around substorm expansion onset are characterized by reduction of sheared flow and enhancement of equatorward flows (e.g., Bristow et al., J. Geophys. Res., 2007). However, there have been no studies on the effect of D-region HF wave absorption due to particle precipitation, which could lead to positive Doppler shift, which is independent of beam number but could be positively (negatively) correlated with the range (elevation angle) Initial result of the quantitative estimation of Doppler velocities associated with particle precipitation will be presented.

Keywords: SuperDARN radars, ionospheric plasma density change, solar flare / energetic particle precipitation

Total electron content forecast model over Japan using a machine learning technique

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Forecasting ionospheric condition is important for space weather operation, especially for predicting propagation delay of the radio waves in the ionosphere. National Institute of Information and Communications Technology (NICT), Japan, develops an ionospheric forecasting system of total electron content (TEC) in addition to a TEC monitoring system. Although several empirical and theoretical models have been developed in a decade, no model is available for forecasting TEC over Japan. Our purpose is to accomplish an operational TEC model over Japan using an artificial neural network technique which is developed by Maruyama [2007]. In our model, absolute TEC values for each day over Japan were projected on a two-dimension TEC map, that is, a local-time and latitudinal map. Then the time-latitudinal variation was fitted by using the surface harmonic function. The coefficients of the expansions were modeled by using a neural network technique. For the learning process, we used absolute TEC value from 1997 to 2014. The input parameters are proxies of the season, the solar activity, and the geomagnetic activity. Thus, daily two-dimensional TEC maps can be obtained for any days when the input parameters are available. We used input parameters which are provided in real-time by some institutes and achieved one-day TEC prediction over Japan.

Keywords: machine learning, total electron content, TEC forecast

GPS phase scintillation during the geomagnetic storm of March 17, 2015: The relation to auroral electrojet currents

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Ionospheric irregularities cause rapid fluctuations of radio wave amplitude and phase that can degrade GPS positional accuracy and affect performance of radio communication and navigation systems. The ionosphere becomes particularly disturbed during geomagnetic storms caused by impacts of coronal mass ejections compounded by high-speed plasma streams from coronal holes. Geomagnetic storm of March 17, 2015 was the largest in the current solar cycle. The high-latitude ionosphere dynamics is studied using arrays of ground-based instruments including Global Navigation Satellite System (GNSS) receivers, HF radars, ionosondes, riometers and magnetometers. GPS phase scintillation index is computed for L1 signal sampled at the rate of up to 100 Hz by specialized GNSS scintillation receivers of the Expanded Canadian High Arctic Ionospheric Network (ECHAIN) and the Norwegian Mapping Authority network supplemented by additional GNSS receivers operated by other institutions. To further extend the geographic coverage, the phase scintillation proxy index is obtained from geodetic-quality GPS data sampled at 1 Hz. In the context of solar wind coupling to the magnetosphere-ionosphere system, it has been demonstrated that GPS phase scintillation is primarily enhanced in the cusp, tongue of ionization (TOI) broken into patches drawn into the polar cap from the dayside storm-enhanced plasma density (SED) and in the auroral oval during energetic particle precipitation events, substorms and pseudo-breakups in particular. In this paper we examine the relation to auroral electrojet currents observed by arrays of ground-based magnetometers and energetic particle precipitation observed by DMSP satellites. Equivalent ionospheric currents (EICs) are obtained from ground magnetometer data using the spherical elementary currents systems (SECS) technique developed by Amm and Viljanen (1999) that has been applied over the entire North American ground magnetometer network by Weygand et al. (2011).

References:

Amm, O., and A. Viljanen, Earth Planets Space, 51, 431-440, 1999.
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Keywords: Polar and auroral ionosphere (Ionospheric irregularities, Ionospheric currents, Energetic particles), Radio science (Radio wave propagation, Space and satellite communication), Space weather (Impacts on technological systems)

Ionospheric data assimilation with TIE-GCM and GPS-TEC during geomagnetic storm period

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The main purpose of this study is to investigate the latency time for the ionosphere data assimilation during the geomagnetic storm. An Ensemble Kalman Filter (EnKF) module developed by National Center for Atmospheric Research (NCAR), called as Data Assimilation Research Testbed (DART), is applied to assimilate the ionospheric electron density into a theoretical model (Thermosphere-Ionosphere-Electrodynamics General Circulation Model, TIE-GCM) with ground-based GPS total electron content (TEC) observations during the 26 September 2011 geomagnetic storm period. Effects of various assimilation time intervals, 60-, 30-, and 10-minute, on the ionospheric forecast responses are examined by their global root-mean-square errors (RMSEs) during the entire storm period. Substantial reduction of RMSEs for 10 minutes assimilation cycle suggests the ionospheric data assimilation system greatly improve the capability of model forecast during the geomagnetic storm period. Further examination shows that the neutral state variables in the assimilation model are the important factor to change the trajectory of model forecasting. However, the assimilation model with neutral state variables still needs the shorter assimilation cycle (10-minute in this study) to restrain overfitting of neutrals and lead to higher forecast accuracy during the geomagnetic storm.

Keywords: Ionospheric data assimilation, geomagnetic storm

Development of a whole atmosphere-ionosphere model GAIA for higher accuracy and its application toward data assimilation modeling

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The origins of upper atmospheric variations do not only come from the solar activities and rotation, but also from the Earth’s lower atmosphere. In order to now-cast and forecast the upper atmospheric disturbances and variations, we have developed a whole atmosphere-ionosphere coupled model called GAIA. The model incorporates the Japanese meteorological reanalysis (JRA) into its lower atmospheric part as well as the daily F10.7 index, in order to reproduce the effects of realistic forcing both from the lower atmosphere and solar irradiance. We have validated the model through the comparison of its long-term run with observations of ionosphere and ionosphere, and found out that further development of the model is necessary for higher accuracy.
In this talk, we will show the results from several updates of the model, such as improvement of ionospheric dynamics and energetics, and increase of model resolution. We have developed the interface of GAIA to data assimilation system and will show future plan.

Keywords: ionosphere, thermosphere, simulation, modeling, data assimilation

SUSANOO-Aurora Activity Forecast: Forecast of the aurora index with the real time data assimilation

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The AU/AL indices are a manifest of the global aurora activity, and their forecast is useful to recognize the future evolution of geospace. In order to forecast the aurora activity, we have developed the forecast system of the aurora index based on the prediction model of Goertz et al.(1992). The model calculates the time evolution of the aurora index using the solar wind electric fields. The real time space weather forecast system SUSANOO (Shiota et al., 2014, http://st4a.stelab.nagoya-u.ac.jp/susanoo/) has provided the next 7 days solar wind parameters at 1 AU, and we calculate the time variations of the aurora indices using the electric fields from the SUSANOO-solar wind simulation. The Goertz model includes several empirical parameters, and the forecast skill depends on the accuracy of these parameters. We have implemented the real-time data assimilation to improve these parameters by comparing the model results and the actual aurora index. The developed system consists of the hindcast and forecast stages. In the hindcast stage, prediction, smoothing and filtering in the data assimilation are performed for the previous 7 days using the data from the SUSANOO-solar wind simulation and the observed aurora index, which improves the parameters for the model. Using the estimated parameters from the hindcast stage, we calculate the time evolution of the aurora index for the next 7 days as the forecast stage. In this presentation, we will present the concept of SUSANOO-aurora activity forecast and initial results from test-operations.

Keywords: Data assimilation, Forecast, Auroral activity index

New solar radio telescope of NICT and its space weather forecasting

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The solar corona contains many eruptive phenomena such as flares. Non-thermal electrons accelerated in the coronal eruptive phenomena emit radio waves. As a result, many types of solar radio bursts are observed. The radio emission propagates faster than the particles. Hence, the monitoring observation of the solar radio bursts is one of the efficient tools to forecast the arrival of the space weather phenomena such as coronal mass ejections (CMEs) and solar energetic particles (SEPs). National Institute of Information and Communications Technology (NICT) have been observed the solar radio burst since 1980's at Hiraiso. The current solar radio observation instruments named HiRAS have been used to monitor the solar radio burst for more than 20 years. Recently, we developed a new solar radio telescope to improve the observation quality and achieve the better space weather forecasting. The new telescope was constructed in the Yamagawa radio observation facility of NICT at Kagoshima prefecture. This telescope has an 8m parabola dish. The feed system of this telescope consists of two wideband log-periodic antennas. These two antennas are tuned for different frequency bands and the entire observation frequency band of this telescope is between 0.07 GHz and 9.0 GHz. The apparent diameter of the Sun is about 0.5 degree. The higher band of the feed system is de-focused to cover the entire solar disc on the field of view. The received signal is divided in the receiver system and fed to the digital fast Fourier transform (FFT) spectrometers made of the field-programmable gate array (FPGA). We developed two types of digital spectrometers. The one has 2 GHz bandwidth and 4096 FFT points. The other one has 1 GHz bandwidth and 32768 FFT points. These spectrometers have no dead time and spectra are accumulated inside the FPGA processors. The accumulated spectra are recorded every 8ms. The observation system has a total of 10 digital spectrometers. The entire system can simultaneously observe the right and left handed circular polarizations of the solar radio emission between 0.07 and 9.0 GHz with 8ms time resolution. This wide observation frequency band is very efficient to capture the various types of solar radio bursts. Therefore, the new observation system will improve the detection accuracy of the space weather phenomena. In addition, the high time resolution of this instrument has a significant benefit to detect the various fine spectral structures of the radio bursts that are thought to be generated by the micro plasma processes in the corona. Hence, the new system will also be sued to understand the coronal plasma physics such as the particle acceleration processes of the solar flares.

Keywords: Sun, solar rasio burst, space weather forecasting, solar energetic particle, radio observation

Cross-field superslow propagation by phase-mixing of Alfven/slow mode waves in solar corona

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We discuss the apparent cross-field propagation by phase mixing of continuum Alfven waves or continuum slow mode waves in the solar coronal magnetic structures.
Recent observations and numerical simulations for coronal waves have found waves propagating across magnetic field lines at rather slow speed. Although only fast mode waves can propagate across magnetic field lines, the observed propagation speed is much slower than the typical fast mode speed. Hence it has been difficult to understand the nature of this cross-field ‘superslow’ propagation. We show that the phase-mixing of continuum Alfven or slow mode waves can explain this phenomenon. Phase-mixing of continuum Alfven or slow mode waves produces phase velocities perpendicular to magnetic field that decrease with time. Hence phase mixing can produce a cross-field superslow propagation after a sufficient lapse of time. We show that the analytical solutions of apparent wavelength and phase speed of phase-mixing quantitatively explain the superslow waves in the results of numerical simulation. We also show the existence of superslow waves in coronal potential arcades and discuss the applicability of our results to coronal seismology.

Keywords: Solar corona, Solar prominence/filament, MHD wavess

Magnetohydrodynamic simulation of interplanetary propagation of multiple coronalmass ejections with internalmagnetic flux rope (SUSANOO-CME)

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Coronal mass ejections (CMEs) are the most important drivers of various types of space weather disturbance. Here we report a newly developed magnetohydrodynamic (MHD) simulation of the solar wind, including a series of multiple CMEs with internal spheromak-type magnetic fields. First, the polarity of the spheromak magnetic field is set as determined automatically according to the Hale-Nicholson law and the chirality law of Bothmer and Schwenn. The MHD simulation is therefore capable of predicting the time profile of the southward interplanetary magnetic field at the Earth, in relation to the passage of a magnetic cloud within a CME. This profile is the most important parameter for space weather forecasts of magnetic storms. In order to evaluate the current ability of our simulation, we demonstrate a test case: the propagation and interaction process of multiple CMEs associated with the highly complex active region NOAA 10486 in October to November 2003, and present the result of a simulation of the solar wind parameters at the Earth during the 2003 Halloween storms. We succeeded in reproducing the arrival at the Earth’s position of a large amount of southward magnetic flux, which is capable of causing an intense magnetic storm. We find that the observed complex time profile of the solar wind parameters at the Earth could be reasonably well understood by the interaction of a few specific CMEs.

Keywords: CME, solar wind, MHD

A dynamical model of the heliosphere with the adaptive mesh refinement

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A change in the heliospheric environment plays an important role in the modulation of the galactic cosmic rays; the magnetic field structure and the speed of the solar wind affect the cosmic ray transport in the heliosphere. Since the heliospheric environment is affected by the solar wind activities, we have been developing a framework for simulating the heliosphere by using MHD simulations.

The simulation code is based on SFUMATO code (Matsumoto 2007), which employs the block-structured adaptive mesh refinement (AMR) technique. The solar wind model gives the inner boundary condition of the simulations, and it is based on the model of Kataoka et al. (2009) and Shiota et al. (2014). The solar wind model adopted here is reconstructed by the observation of the solar magnetic fields. At this moment, the refinement criterion of AMR grid is only a function of the distance from the Sun. Our model reproduces the Parker spiral owing to the solar rotation.

We also measured the performance of the simulation code for massively parallel calculations. In the case of 1024/2048 cores calculations, our code exhibits parallel ratios of 99.945-99.982% and parallel efficiencies of 73.4-86.4%, depending on the implementation of a refinement manner. Such a high scalability is demonstrated even by a flat MPI parallelization.

Keywords: heliosphere, solar wind, MHD

A humid climate of the last stage of the Little Ice Age in central Japan reconstructed using oxygen isotopes from tree-ring

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The Asian monsoon is an important part of the Earth’s climate system that is characterized by variations in the strength and expansion of the summer rain band. Rainfall reconstructions in China have revealed changing patterns of rainfall during the Little Ice Age (LIA), but few hydroclimate reconstructions around Japan have hindered the understanding of physical processes associated with the atmospheric system in the western North Pacific. Here, we report on rainfall variations in the Meiyu/Baiu season from AD 1600–1959 by using tree-ring cellulose oxygen isotopes from central Japan; this is the longest record in the eastern most regions under the monsoon’s influence. Data suggest that the wettest period occurred around AD 1790–1860, the final stage of the LIA. This shift was concurrent with sea surface temperature anomalies around the Philippines and off eastern Japan. Thus, meridional atmospheric circulation was likely weak during the last stage of the LIA.

Keywords: Little Ice Age, Monsoon, tree-ring, oxygen isotopes

Relationship between typhoon occurrence and solar activity

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It has been pointed out that atmospheric activity has ~27-day periodicity, which implies the connections between solar activity and the earth’s climate since the rotation period of the sun near its equator is 27 days. We have showed a close relationship between globally synchronized thunderstorm/cloud activities in the tropical latitudinal range and solar parameter with ~one-month periodicity for a certain half year, using lightning data, a proxy of thunderstorm activity, obtained by the global radio wave network and a proxy of cloud amount, Outgoing Longwave Radiation (OLR). It was reported that the thunderstorm activity in Asia Maritime Continent (AMC) shows a seesaw correlation with the cloud in Western Pacific Warm Pool (WPWP), which show strong correlation with intensity of cosmic ray without time lag. It was revealed that this cloud increases in WPWP correspond to typhoon occurrences. Here we found a strong similarity and synchronization between the variation of lightning activity in AMC and that of the averaged OLR in broad longitudinal range in equatorial region (280E - 110E, 10S - 10N), where very limited numbers of typhoons take place. Moreover, all these parameters apparently show a clear correlation with solar parameters, such as galactic cosmic rays or F10.7 for the one-month periodicity. This fact suggests further and extensive studies, involving scientists in broader research fields, are needed to understand the global climate.

Keywords: typhoon, solar activity, 27-day, thunderstorm, WPWP

A critical review on solar cycle variation of interplanetary magnetic flux ropes

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The interplanetary magnetic flux rope (IFR) has been a subject of extensive research activity since its discovery in 1981 as a key structure in the solar wind that provide important information on the solar eruption phenomena and on how the southward magnetic fields are carried from the Sun to the Earth. In this review, we discuss solar-cycle variation of occurrence frequency of IFRs that still remains unsettled, based on our own results. First, we have found more than 500 IFRs in the time period from 1995 to 2009, whereas the survey by Lepping et al. (AnnGeo, 2006) identified 82 IFRs during 1995-2003. The difference mainly comes from the fact that their survey was not successful in identifying IFRs when the spacecraft passed only near the surface of IFRs. Our result indicates that the rate of IFR occurrence to the ICMEs should be much higher than those which were suggested by previous evaluation. Secondly, the following trend is clearly seen: namely, the occurrence rate of IFRs increases rapidly after the 1996 solar minimum, reaches maximum in 1998, and then decreases monotonically toward the next solar minimum. This trend seems in concert with the trend of the magnetic butterfly diagram (Hathaway, http://solarscience.msfc.nasa.gov/images/magbfly.jpg). The time of rapid increase of IFR rate coincides with the time when the active regions begin to emerge at mid latitude (Li et al., Solar Phys., 2011). In addition, Marubashi et al. (Solar Phys. 2015) found that 2/3 of IFRs were erupted from neutral lines at the Hale boundaries, using another data base. An important implication is that the IFR occurrence should be closely related with the evolution of large-scale solar magnetic fields. An interesting question arises also: how the Hale boundaries are preferably selected for any instabilities to occur that lead CMEs. In a more general term, interrelationships among the occurrence of IFRs, CMEs, flares, and sunspot cycle seem to be an unsettled problem.

Keywords: coronal mass ejection, solar-cycle variation

Formation of a Quadrupolar Active Region Producing a Magnetic Flux Rope

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It is suggested that most of the largest flares in the Sun are produced in active regions hosting delta-sunspots (Sammis et al., 2000). The formation process of delta-sunspots is not clearly understood but some of them may be formed by the merging of two beta-sunspots, which produces a quadrupolar active region. Toriumi et al. (2014) showed that the quadrupolar active region was successfully reproduced in their MHD simulation only when the two merging bipoles were magnetically connected with each other in the convection zone. Toriumi et al. (2014) aimed at reproducing an active region similar to an observed one, NOAA AR 11158, which had produced several flares including one X-class event. However, no flux ropes or eruptions were found in their simulation. Therefore, in this work, we aim to propose a theoretical model which produces not only the quadrupolar active region but also the magnetic flux rope. As a result of MHD simulation, we succeeded in reproducing a flux rope above the polarity inversion line as a consequence of an emergence of a flux tube from the convection zone. Also we found that the flux rope could reach the upper boundary when reconnection-favored coronal magnetic field was introduced above the developing active region. In this presentation, we will discuss the formation process of the flux rope and physical conditions for its ascent.

Keywords: Sun, Flares, Sunspots

Studies on homologous flares at quadrupole magnetic field using force-free field modeling

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Solar flares are known as abrupt energy release events by magnetic reconnection. The standard 2D model of solar flares, which is called CSHKP model, explains large eruptive flares well. We analyzed three M-class flares occurring on 2 February 2014, which are difficult to understand with the CSHKP model. Our investigations primarily focused on the 3D coronal magnetic field structures formed in the flaring region for attempting to understand why three similar flares (labeled flare 1, flare 2, and flare 3, respectively) are successively produced in the region.
Four flare ribbons were observed at the footpoints of three flaring structures by Atmospheric Imaging Assembly aboard the *Solar Dynamics Observatory*. The observed flare ribbons and coronal flaring structures show similarity in the three flares, which are called homologous flares. The flare ribbons were located in the four magnetic regions (P1, P2, N1, and N2) at the solar surface. We derived the three dimensional magnetic field configuration using force-free field modeling with *Hinode*/Spectropolarimeter data. We used the squashing factor defined by Titov (1999) to identify the location of quasi-separatrix layers, i.e., QSLs. The magnetic field lines from the force-free field modeling give fairly good correspondences among many bright flare kernels in the flare ribbons, although we still need to improve the modeling fidelity. The magnetic field lines rooted on the flare ribbons forms the three-dimensional quadrupole magnetic configuration with an X-shape separatrix structure in the upper atmosphere.
The region of the highest squashing factor is located at the height of 2000~3000km from the photosphere, suggesting that the magnetic reconnection may take place at the lower atmosphere. The magnetic flux in the N1 sunspot appears to be highly twisted, because the QSLs structure derived with the assumption of the potential field is completely different from what obtained with 3D magnetic field configuration from the NLFFF modeling. The QSLs structure derived with the NLFFF results for the SP data taken one day before the occurrence of flare 1 is different from that derived with the data taken one hour before flare 1. This indicates that the QSLs structure was formed during the day due to the emergence or the transverse photospheric motions of the magnetic flux in N1. The temporal evolution of magnetic flux suggests that both the existence of emerging activities and the conversing motions in and around the N1 sunspot region. Focused on homology and differences in the flares, although the spatial distribution of the flare ribbons is similar to each other in the main period of the flares, there is a little difference in the temporal evolution of X-ray flux. Such a difference might attribute to the difference in triggering the onset of these flares. Flare 1 occurred after the occurrence of another flare event at the east side of the flare 1 region, while flare 2 occurred after the upward motion of a dark material. This may indicate that the magnetic field shows a similar topology, but the trigger mechanism can alter the temporal behaviors of the energy release.

Keywords: Solar flare, Magnetic reconnection

Double Arc Instability in the solar corona

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The stability of flux rope in the solar corona must be related to the occurrence of solar flares and coronal mass ejections (CMEs), which are primary cause of solar weather disturbance. Torus Instability (TI) was recently proposed by Kliem & Toeroek (2006) as the cause of solar eruptions. However, how the instability can be initiated is not yet well understood. On the other hand, one of the most likely scenario for the process causing unstable flux rope is the tether-cutting reconnection suggested by Moore et al. (2001). This scenario suggests that magnetic reconnection between sheared magnetic fields forms a double-arc loop which can erupts. However, the stability of double-arc loop was not analyzed yet.
The objective of this study is to analyze the stability of double-arc loop theoretically. We model double-arc electric current loop using two circular tori connected each other, and numerically calculate the stability of it. As the result, we found that the double-arc current loop can be destabilized even if the external field is uniform in contrast to the TI. The results indicate that the Double-Arc Instability (DAI) is different from the TI. The decay index which is used as a criteria for TI is not applicable to DAI. Furthermore, we found that in order to make the DAI the twist of magnetic field line must be larger than one-half. We also show that the growth of DAI is similar to the observation of flux eruption. These results indicate that the DAI caused by the tether cutting reconnection is a possible scenario, which can well explain how solar eruption can be triggered.

Keywords: Sun, solar flare, instability

Continued Operation of Nobeyama Radioheliograph by the International Consortium (ICCON)

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Nobeyama Radioheliograph (NoRH) is a radio interferometer specially designed to observe the full disk of the Sun at 17 and 34 GHz. Eighty-four antennas with a diameter of 80 cm were installed along a T-shape baseline (North - South: 250 m, East - West: 500 m). The spatial resolution is about 10 arcseconds and 5 arcseconds in 17 GHz and 34 GHz, respectively. The time resolution of NoRH is typically 1 second and 0.1 second for the event mode. NoRH continuously observes the full sun for about eight hours (22:45 - 6:30 UT) every day. The system has been quite stable and NoRH data are available in the period more than 99 % out of the total possible operational window.
The National Astronomical Observatory of Japan (NAOJ) has successfully operated NoRH during these two decades. From April 2015, the Solar-Terrestrial Environment Laboratory (now the Institute for Space-Earth Environmental Research), Nagoya University started the operation of NoRH as a representative of the International Consortium for the Continued Operation of Nobeyama Raidoheliograph (ICCON; http://hinode.stelab.nagoya-u.ac.jp/ICCON/). The current ICCON representatives are N. Gopalswamy (NASA), Y. Yan (NAOC), K. S. Cho (KASI), M. Ishii (NICT), K. Shibasaki (Nagoya University and Solar Physics Laboratory) and S. Masuda (Nagoya University).
In addition to the core members of this consortium, about 30 researchers collaborate the operation of NoRH. Among them, one chief observer is assigned to check the health of the instrument/computers and to verify the data quality every day. These daily tasks can be done via internet from a remote site. This system also works very well for the first one year.
NoRH data are automatically transferred from the observational site (Nobeyama) to Solar Data Analysis System (SDAS; http://hinode.nao.ac.jp/SDAS/index_e.shtml) of NAOJ at Mitaka, and then all of them are automatically mirrored to Hinode Science Center at Nagoya (http://hinode.stelab.nagoya-u.ac.jp/index.shtml.en). Any researcher registered in either system can access all of the NoRH data. The software for the data analysis is supplied as a part of the solarsoft (IDL-based software system mainly maintained by Lockheed Martin Solar and Astrophysics Laboratory) and distributed via internet.

Keywords: Sun, radio

Calculation of solar rotation rate using the magnetic field observation, and its long-term variation

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Space environment around Earth have been influenced by solar wind that is plasma which is released from the Sun. The plasma is explosively released by phenomena such as solar flare and CMD, and that exerts a huge damage to our planet and artificial satellite. This is called solar storm. In addition, the entire change in the solar wind is called space weather that has been studied in a variety of fields. There is a study of solar activity mechanism in one of the Solar-Terrestrial Environment prediction research.
The Sun it is known that the magnitude of the activity varies 11 year cycle. When activity is strong, it is called the maximum. Opposite, when weak, it is called the minimum. Along with it also varies the strong of solar wind occur many solar storms during the maximum phases. In addition it is reported that magnitude of the activity is different in every cycle. It is known that there is a correlation in the intensity of pole magnetic field and the solar activity in the next cycle when solar minimum period. So, knowing the pole magnetic field of the current minimum period is useful to predict the next solar cycle.
In this study, determine the parameters from solar magnetic field observation by the solar observation satellite SDO/HMI. The parameters (such as differential rotation, meridional flow and turbulent diffusion coefficient) are important for surface flux transport model calculations. We have developed a module that calculates the parameters of the sun from observed data by two differential ways (Local Correlation Tracking (LCT), Magnetic Element Tracking (MET)), using the actual data analysis. Compare the results to be estimated by LCT and MET, discussing about the differences and characteristics obtained two ways. Further, by analyzing the data up to now from launched (about 6 years), we report the results of consideration for long-term variation of the three physical parameters in the sun.

Keywords: Sun, Magnetic field observation, Rotation rate, Meridional flow

The role of η-quenching in MHD flux transport dynamo

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“Flux-transport dynamo” (FTD), which is one model of the solar dynamos, succeeded to reproduce the basic solar cycle features. However, most of FTD studies have addressed the time-development of the magnetic field in a purely kinematic regime. In a kinematic regime, the fluid velocity is given from observation or other theories, so only magnetic induction equation is solved. On the other hand, in a non-kinematic (or MHD) regime, both of magnetic field and fluid velocity field are computed by solving magnetic induction equation and Navier-Stokes equation. So this regime allows for the feedback of the Lorentz force on fluid velocity field. Rempel (2006) conducted FTD simulation in a non-kinematic regime and showed FTD model worked successfully even if strong feedback on fluid velocity existed.

Here we address FTD simulation based on the model of Rempel (2006) and includes “η-quenching”, which is not considered in Rempel (2006). It is known that the turbulent magnetic diffusivity used in the solar dynamos is quenched by the existence of strong magnetic fields. This phenomenon is called as η-quenching. And η-quenching can be a powerful mechanism for amplifying magnetic fields (Gilman & Rempel, 2005). The following presents the reasons why we include the effect of η-quenching. One reason is that the maximum magnetic field strength is around 15 kG in Rempel (2006), though rising flux tube simulation (Weber et al., 2011) concluded that magnetic flux tubes forming sunspots should have field strengths around 40-50 kG. The other reason is that no study has investigated the role of η-quenching in a non-kinematic FTD model. Stronger magnetic fields amplified by η-quenching result in stronger feedback to fluid velocity. To investigate this effect, we need to conduct a non-kinematic dynamo simulation in which both of velocity fields and magnetic fields are computed.

We find that η-quenching can amplify magnetic fields even in a non-kinematic regime and the maximum magnetic field strength can be up to around 2 times larger than the case without the effect of η-quenching. However, this amplification leads to the significant feedback to fluid velocity. This feedback makes the amplitude of temporal variations of the solar rotation rate, which is known as torsional oscillations, too large to be consistent with observation.

Reconstruction of high energy particle environment in geostationary orbit based on several satellite observations

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Currently there are several geostationary satellites which monitor high energy particle environment, although more than four hundreds of satellite exist in this orbit. New Japanese geostationary meteorological satellite, Himawari-8, has operated space environment data acquisition monitor since Nov. 2014. Because the magnetic dipole axis is not aligned with the rotational axis of the Earth, L-value of each GEO satellite is not the same and it changes depending on space weather conditions. To monitor the current condition of high energy particle environment for each satellite in GEO, which is a risk of spacecraft charging, we need to reconstruct high energy particle environment in GEO using several high energy particle observations. Before combining individual data from high energy particle sensors, cross calibration of each sensor is essential. However, the cross calibration needs some technique, because the specification of individual sensor is not the same. So we need to develop method of cross calibration of the sensor, and of combining individual particle data for reconstruction. In this presentation, we will introduce cross calibration method of high energy particle sensor and how to reconstruct high energy particle environment in geostationary orbits using data from the sensor onboard Himawari-8, GOES-13, 15, and Kodama. We also introduce our online database for archiving and providing Himawari-8 high energy particle data.

Keywords: Space Weather Forecast, Geostationary Orbit, High Energy Particle Observation

The status of the SEDA-AP/Heavy Ion Telescope

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Space radiation such as solar energetic particles (SEP), galactic cosmic rays (GCR) and trapped particles cause to our space activities. Heavy ions, in particular, have high linear energy transfer (LET), which exacerbates the risks of radiation exposure for astronauts and errors of electric circuits for satellites. The Japan Aerospace Exploration Agency (JAXA) has operated the Space Environment Data Acquisition Equipment-Attached Payload (SEDA-AP), installed at the International Space Station (ISS) Japanese Experiment Module (Kibo) - Exposed Facility, since 2009. On July 10 2015, JEM-EF was configured with the relocation of the SEDA-AP from no. 9 to no. 11. The Heavy-Ion Telescope (HIT) is the one of the SEDA-AP instruments, which comprises two position-sensitive silicon detectors and 16 silicon detectors. Based on the dE×TE particle-identification method, HIT measures fluxes and energies of energetic ions from Li to Fe and. The results of HIT are consistent with the general GCR model and other experiment inside the ISS in terms of abundances of elements and LET distributions. In addition, HIT has observed heavy ions from a X5.4 solar flare. We will report the new results of analysis for data from July 2015, and the changes of the temperature environment and the count rates in order to evaluate the effects of relocation.

Keywords: ISS, SEDA-AP, heavy ions

The solar modulation of galactic cosmic rays and radiation dose of aircrews during the solar cycle 24/25

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The variation of galactic cosmic rays (GCRs) in the heliosphere is caused by the solar-terrestrial environmental changes. Owing to this variation known as the solar modulation of GCRs, the counting rate of the ground-based neutron monitors and a radiation dose of aircrews at the top of the troposphere also change with the solar-terrestrial environmental changes.
We have developed the time-dependent and three-dimensional model of the solar modulation of GCRs, based on the stochastic numerical method. Our model can reproduce and predict the intensity of GCRs in the heliosphere by assuming the variation of the solar wind velocity, the strength of the interplanetary magnetic field, and its tilt angle. Moreover, we can calculate the neutron monitor counting rate and the radiation dose of aircrews at an aircraft altitude by using our model coupled with the results of air-shower simulation performed by PHITS (Particle and Heavy Ion Transport code System).
In this presentation, we report the results of the solar modulation of GCRs, neutron monitor counting rate, and the radiation dose at flight altitude from the solar cycle 22/23 until the cycle 24/25. We also discuss about the possibility of increase of the radiation dose of aircraft at the cycle 24/25.

Keywords: galactic cosmic rays, heliosphere, radiation dose, neutron monitor

The verification experiment for aerosol nucleation focused on a kind of secondary cosmic rays

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It is considered that the solar activity may affect the global climate, but the correlation mechanism is still not understood. One of the possible mechanisms for the correlation is the cloud formation by the galactic cosmic rays, which are modulated by the variation of solar magnetic activity. This relation was clearly indicated by the good correlation observed for the galactic cosmic-ray intensity and the global low-cloud amount. This hypothesis includes the ion-induced nucleation model, in which new particles in the atmosphere are created efficiently through atmospheric ions produced by cosmic rays, and finally these particles grow up to the size of cloud condensation nuclei. In this study, a laboratory experiment for verification of the hypothesis has been conducted with a reaction chamber. A flow of clean air with water vapor, ozone and sulfuric dioxide was introduced to a metallic chamber, where we irradiated UV light for solar irradiance and accelerator beam for cosmic rays. The beam of the heavy ion accelerator HIMAC at National Institute of Radiological Sciences was used in the present experiment.
In this presentation, I will report the results of the proton and nitrogen ion irradiation experiments. These high-energy ions have different ionization loss. The ionization loss is an index representing the ability to ionize the air molecules, that is, a parameter that contributes to the atmospheric ion generation. Furthermore, the simulation shows that the proton and the neutron contained in the secondary cosmic rays, keep the variation of solar activity even on the ground surface. Neutrons in secondary cosmic rays may generate energetic heavy ions (nucleus) through nuclear collisions with atmospheric atoms. Then, these energetic ions produce ionization ions through electronic energy loss process. Since it is considered that the aerosol particle generation would be increased according to the amount of ions produced in the energy loss, the experiment was carried out by using these heavy ions.
We will present the experimental result and discuss the difference of aerosol nucleation efficiency between different kinds of secondary cosmic rays.

Relationship between solar wind dynamic pressure and amplitude of geomagnetic sudden commencement (SC)

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Although the primary cause of the geomagnetic sudden commencement (SC) is the enhanced magnetopause current, induced field aligned currents, ionospheric currents and earth currents produce a complex global distribution of the amplitude and waveform of SC. As the result the SC amplitude shows a clear latitudinal and local time variation. These variations have not been taken into account in the Siscoe's linear relationship (dH = C* d(Pd**0.5)) which connects the SC amplitude (dH) with the corresponding dynamic pressure (Pd) variation of the solar wind.
By considering the physical background of SC we studied which local time is best to extract the information of the solar wind dynamic pressure and concluded that the SC amplitude at 4-5h local time of middle- and low-latitude stations most directly reflects the dynamic pressure effect.
This result is used to re-check the order of magnitude of the largest 3 SCs (dH > 200 nT at Kakioka) observed since 1868 (Araki, 2015). The SC occurred on March 24, 1940 still keeps the first rank even if
the LT variation is taken into account.

Keywords: geomagnetic sudden commencement(SC), solar wind dynamic pressure , , ionospheric current, field aligned current, LT variation, Siscoe's relationship

On measurement plan of geomagnetic induced current of power transformers in Japan

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It has been considered that the effect on power system by geomagnetically induced current (GIC) is not significant in Japan because of its geomagnetic latitude. However, the damage of the power transformers was reported in Republic of South Africa located in the same geomagnetic latitude as the northern part of Japan when a series of geomagnetic storms occurred between in the end of October and in the beginning of November 2003. It is known that amplitude of GIC depends on underground conductivity structure. We need to consider the complex underground structure in Japan when we make a GIC model. We report the measurement plan of GIC for the modeling.

Keywords: geomagnetically induced current, geomagnetic storm, power system

Three components analysis of ground magnetometer network data toward understanding GIC excited by space weather disturbances

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The aim of this study is to make hazard maps of induced electric field from geomagnetic disturbances for estimating possible GIC (Geomagnetically Induced Current) effects from space weather events in mid- and low- latitude region, including Japan. As a first step, we performed frequency analyses to three components of 10 ground magnetometers data all over Japan. 5 magnetometers belongs to MAGDAS project managed by International Center for Space Weather Science and Education, Kyushu University, 3 magnetometers belongs to Japan Meteorological Agency, and 2 magnetometers belongs to Geospatial Information Authority of Japan. The analysis period is one month (July, 2012). In this study, we put a focus to not only H- and D-components, reflecting global space weather disturbances, but also Z-component, reflecting local electromagnetic structure around an observation point. The analysis methods are as follows: 1) Comparison of similarities between H- and D-component (global effect) and Z-component (local effect) at each station, 2) Frequency analysis using above data set, 3) Pre-estimation of GIC effect using time derivative data. As a result, we found that the Z-component shows very complex changes because of the difference of underground structure at each station. In this presentation, we will introduce detailed results of our analyses and future plans.

Keywords: GIC, magnetometer network

Studies of the thermosphere and ionosphere with the EISCAT radar and whole atmosphere/ionosphere model: GAIA

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The thermosphere/ionosphere is the region that shows both the features of the atmosphere and space. For example, the behaviors of the neutral and ionized gases characterize the region through some collision and radiative processes. In addition, interactions between neutral and ionized gases cause various phenomena in the thermosphere/ionosphere.
The thermosphere/ionosphere is also important for radio wave propagation and operation of artificial satellites due to the atmospheric drag force. The accuracy of navigation systems and life time of the satellites depend strongly on the thermospheric/ionospheric conditions.
In order to investigate the thermosphere/ionosphere, we have developed a numerical model which includes all the atmospheric regions and ionosphere named GAIA. GAIA has reproduced some thermospheric/ionospheric phenomena and revealed physical mechanisms in association with the phenomena. In this study, we present a brief description of GAIA and show some recent results. The collaboration with radar observations enables the GAIA simulations to be more productive. We will show some European incoherent scatter (EISCAT) radar observations in cooperation with GAIA simulations. The future plans of the EISCAT observations and GAIA simulations will be also shown here.

Keywords: thermosphere, ionosphere, GAIA, EISCAT

Occurrence probability of plasma bubbles deduced from GAIA simulation data

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In the forecast of ionospheric disturbances, it is important to predict mesoscale ionospheric phenomena such as plasma bubbles, sporadic E layers (Es), and Storm Enhanced Density (SED), which have significant influences on radio communication and broadcast systems as well as global positioning systems. Prediction of those phenomena requires real-time observation and a high-resolution numerical model of the ionosphere and atmosphere. We have been developing a whole atmosphere-ionosphere coupled model, GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy), which self-consistently solves the entire region from the lower atmosphere to the ionosphere. Although present version of GAIA does not have enough spatial resolution to reproduce individual plasma bubbles, it is possible to deduce the occurrence probabilities by estimating the linear growth rate of the ionospheric Rayleigh-Taylor instability in the GAIA simulation data. We have performed a long-term simulation using GAIA covering a period from 1996 to the present. Using the database we calculated the linear growth rate, and compared the result with plasma bubble observations. We found that a period in which large linear growth rates appeared in the simulation data tends to correspond to a period of plasma bubbles occurrence, suggesting a possibility of prediction of plasma bubble occurrence using GAIA simulation.

Keywords: plasma bubble, GAIA, linear growth rate, Rayleigh-Taylor instability, ionospheric disturbance

The Mid-Latitude Trough and the Plasmapause Detected by DEMETER

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This paper finds the mid-latitude trough and the plasmapause by the daytime/nighttime (about 10:00/22:00 LT, local time, respectively) electron density, electron temperature, and whistler of DEMETER during 2006-2009. The electron density and the electron temperature are useful to allocate the trough, while the whistler can be used to find the plasmapause. It is found that the trough is very unclear and complex in the daytime, and however the plasmapause can be detected in both daytime and nighttime. Therefore, we focus on the relationship of nighttime trough and plasmapause in various seasons and geomagnetic actives. Results show that the mid-latitude trough tends to appear in the polarward side of the plasmapause, and the trough moves equatorrward during a higher geomagnetic activity, while the plasmapause is insensitive to the activity.

Keywords: ionosphere, mid-latitude trough, plasmapause

Latitudinal and Longitudinal Variations of Ionospheric Storms by the Global Ionosphere Map of Total Electron Content

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In this study, we examine latitudinal and longitudinal variations of the total electron content (TEC) during the 2003 Halloween storm. The global ionosphere map (GIM) of TEC retrieved from Center for Orbit Determination in Europe is used to investigate the positive and negative storm signatures at various universal times (UT) and global fixed local times (GFLT). The positive and negative storm signatures are prominent at low and middle latitudes, respectively. The UT results show clear longitudinal phase shifts in both positive and negative storm signature. The positive (negative) storm signature reveals the period of 26 (24) hrs and the phase velocity of 14 (15) deg/hr in the longitudinal direction. On the other hand, the GFLT results show that the positive (negative) storm signature tend to appear at equatorial-equatorial iononization anomaly (low-middle) latitudes in daytime. Finally, a statistical analysis of the ionoospheric storm signature is carried out and cross compared with that of the 2003 Halloween storm.

Ionospheric Data Assimilation Model by Using Radio Occultation and Ground-based GPS Observations

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Ionospheric data assimilation is a powerful approach to reconstruct the three-dimensional distribution of ionospheric electron density from various types of observations. The ionospheric data assimilation model based on the Gauss-Markov Kalman filter with the International Reference Ionosphere as the background model is used to assimilate two different types of total electron content (TEC) observations from ground-based GPS and space-based FORMOSAT-3/COSMIC (F3/C) radio occultation (RO). The new satellite mission FORMOSAT-7/COSMIC-2 (F7/C2) will place 12 micro satellites in orbits with two launches in 2016 and 2018, the satellite mission is expected to yield more than 8,000 RO observation per day. The Observing System Simulation Experiments (OSSEs) of assimilating FORMOSAT-7/COSMIC-2 (F7/C2) RO and ground-based GPS data in the data assimilation model are implemented in the study, the OSSEs results demonstrate that the F7/C2 RO data can increase model accuracy more than assimilating F3/C RO data. The new ionospheric data assimilation model that employs the location-dependent background model error covariance, Kalman filter forecast step, and Kalman filter measurement update step could reconstruct the three-dimensional ionospheric electron density distribution satisfactorily from both ground- and space-based GPS observations.

Keywords: Ionosphere, Data Assimilation, FORMOSAT-3/COSMIC

Monitoring global ionospheric structures using a near real-time Global Ionospheric Map

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To efficiently monitor the fast changing ionospheric weather events, such as magnetic storms, solar flares, solar eclipses, earthquake precursors, etc., a near real-time (4-hour delay) Taiwan Global Ionospheric Map (TGIM) is constructed from global vertical total electron content (TEC) observations using a spherical harmonics expansion. The TEC is measured by about 120 ground-based GPS stations and FORMOSAT-3/COSMIC. The high correlation (correlation coefficients > 0.95) of the TGIM and the CODE and JPL GIMs suggests that the TGIM show global scale ionospheric structures as well as the other two GIMs. The high temporal resolution of the TGIM (5 to 15 minutes) reveals that it is capable of showing the variation in ionospheric density structures in more detail. Here we also examine a severe geomagnetic storm, which is the largest during the weak solar cycle 24, occurred on 17 March 2015 at 0445 UT, using the GIMs. The results show the positive storm is pronounced at mid- and low-latitudes in the first day after the storm onset. The negative storm remains present in the equatorial ionization anomaly crest regions more than one week. The sudden change in TEC at middle and low latitudes during the main phase period maybe associated with the equatorward disturbance wind and the prompt penetration electric field.

Keywords: Ionospheric weather, Global ionospheric map, FORMOSAT-3/COSMIC, GPS TEC

Operational forecast of foF2 above Tokyo using solar wind input to a neural network

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A new empirical prediction model of foF2 above Tokyo, Japan (Uchida et al., 2016, submitted), has started its forecast operation at National Institute of Polar Research. Solar wind parameters are used for the first time to the input of a neural network (NN) to predict foF2 in that study. The model showed better forecast results compared to an existing operational NN model (Nakamura et al., 2009) which forecasts foF2 using K-index to the input. The results support our expectation that the NN can represent the physics between the ionospheric variations and the solar wind better. The forecast is operated every day at 0 UT for next 24 hours. The model uses day of year, sunspot number, F10.7 solar proxies, solar wind proton velocity, IMF By and Bz to the input. Prior 24 hour values to the forecast are lined to the input at once. To represent the time dependences, 24 of individual NNs are constructed for each hour and concatenated at forecast. We introduce the operational model and report the summary of current operation, and discuss several possibilities to improve the forecast.

Keywords: Forecast, foF2, Neural network, Solar wind

Preliminary development of radio propagation simulator for HF

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To investigate an ionospheric effect on the HF radio propagation, we are developing the radio propagation simulator. Because radio waves in the high frequency (HF) band can be reflected back to Earth by the ionosphere layer, they are widely used for long-distance communication. HF is not only popular among amateur radio users, but it is also valuable remote communication during a disaster e.g. Tsunami and big earthquake. Being involved in the ionosphere, an integrity of HF wave, however, unavoidably relies on sunlight/ darkness of the transmission and reception sites, season, sunspot number, solar activity, aurora activity, and magnetic activity. While the maximum usable frequency (MUF) has a direct variation with the electron density, the lower usable frequency depends on the absorption in the D-layer of the ionosphere. This paper presents a preliminary effort for an integration of the radio propagation knowledge and the ionospheric knowledge. The current status of the simulator development will be reported.

Keywords: Radio propagation, HF, Ionosphere

Nonlinear reflection process of linearly-polarized, broadband Alfven waves in the fast solar wind

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Alfvén waves are frequently observed both in the solar atmosphere (DePontieu et al. 2007 Science, Okamoto et al. 2007 Science) and the solar wind (Belcher & Davis 1971 JGR), and widely believed to play a significant role in the coronal heating and the solar wind acceleration. Since the reflection of Alfvén waves triggers Alfvénic turbulence in the solar atmosphere and the solar wind (Matthaeus et al. 1999 ApJL, Dmitruk et al. 2002 ApJ), turbulent heating rate of the corona is sensitive to the reflection rate. Comparison of recent studies (Suzuki & Inutuska 2005 ApJL, Cranmer & van Ballegooijen 2005 ApJS) strongly suggest that the compressibility of plasma, in other words the nonlinearity of Alfvén waves, enhance the reflection rate up to 100-1000 times, whose mechanism is still unclear.
Using one-dimensional numerical simulations, we study the elementary process of Alfvén wave reflection in a uniform medium, including nonlinear effects. In the linear regime, Alfvén wave reflection is triggered only by the inhomogeneity of the medium, whereas in the nonlinear regime, it can occur via nonlinear wave-wave interactions. Such nonlinear reflection (backscattering) is typified by decay instability. In most studies of decay instabilities, the initial condition has been a circularly polarized Alfvén wave. In this study we consider a linearly polarized Alfvén wave, which drives density fluctuations by its magnetic pressure force. For generality, we also assume a broadband wave with a red-noise spectrum. In the data analysis, we decompose the fluctuations into characteristic variables using local eigenvectors, thus revealing the behaviors of the individual modes.
Different from circular-polarization case, we find that the wave steepening produces a new energy channel from the parent Alfvén wave to the backscattered one. Such nonlinear reflection explains the observed increasing energy ratio of the sunward to the anti-sunward Alfvénic fluctuations in the solar wind with distance (Bavassano et al. 2000 JGR) against the dynamical alignment effect (Dobrowolny et al. 1980 Phys.Rev.Lett.).

Keywords: solar wind, Alfvén wave

Solar energy transport with significantly suppressed velocity

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We carry out a series of 2D convection calculations with highly suppressed velocity. Thermal convection in the solar interior is thought to maintain differential rotation and meridional circulation. Although the solar equator is rotating faster than polar region, recent high-resolution calculations with solar parameters accelerate the pole. This problem can be attributed to over-excited thermal convection in numerical calculations. Local helioseismology also supports this finding. Recent MHD simulations suggest that the small-scale Lorentz force is able to suppress the convection velocity, but the suppression is not enough and has not been numerical converged, i.e., higher resolution shows stronger suppression.

In this study, we assume that the Lorentz feedback in extremely high resolution, i.e., the sun, becomes stronger enough to explain equator acceleration and the result of the local helioseismology. In order to investigate this extreme condition, we carry out series of 2D hydrodynamics simulations with high viscosity mimicking the strong Lorentz force. The purpose of our research is to investigate energy flux transported by the thermal convection. Even if the velocity is reduced, convection needs to transport imposed energy flux at the bottom boundary. Generally it is expected that upflow and down flow become hotter and cooler, respectively than those without viscosity. We also find that the correlation becomes better with high viscosity with suppressing the small-scale chaotic motion.

Keywords: Sun, Thermal convection, Magnetic field

A study for the improvement of SUSANOO-solar wind model

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The Earth is exposed to solar wind that emanates constantly from the Sun and influences the structure and dynamics of the magnetosphere of the Earth. Hence, the prediction of solar wind is crucial for the space weather forecast.
In recent years, our group have developed a space weather prediction model: SUSANOO (Space-weather-forecast-Usable System Anchored by Numerical Operations and Observations), which can predict the solar wind profile at the Earth’s orbit and high-energy electrons flux of the radiation belt on the basis of three-dimensional MHD simulation of solar wind (SUSANOO-SW) [Shiota et al., 2014]. Although SUSANOO-SW may reproduce the large-scale three-dimensional structures of solar wind on the basis of observation of the photospheric magnetic field, the model is not yet able to well reproduce the observation of the short term variation of solar wind and the amplitude of fast solar wind velocity.
In this research, we study the cause of deviation between the model and observations focusing on the solar wind speed model which is used to specify the solar wind distribution on the inner boundary condition of SUSANOO-SW. We found that peculiar high speed structures around pseudostreamers, which must be formed by the Wang-Sheeley model [Arge and Pizzo, 2000], might be a cause of degradation of reproducibility.
In order to improve it, we take into account not only of the expansion factor but also of the magnetic intensity based on a theoretical work by Suzuki [2006]. I will quantitatively evaluate the performance of the new model, and discuss about what is needed to improve the predictability of solar wind model based on the comparison with the in-situ observation.

Keywords: solar wind

Three-Dimensional MHD Simulation of the Interaction between CME and Ambient Plasma in Solar Corona

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Coronal mass ejections (CMEs) are one of main drivers of various disturbances in space weather. In particular, the timing of arrival, the strength, and the amount of southward magnetic flux brought by CMEs are important for the magnitude of the space weather disturbances, and those are depend on the following factors: whether the CMEs hit the earth or not, speeds of the CMEs, and the magnetic field structures within the CMEs. Because the factors are determined as a results of the dynamics in their propagation as well as in formation in the solar corona, the understanding of the influence of ambient corona on the dynamics of CMEs is necessary for an improvement of space weather forecast. However, what determines the structure and intensity of magnetic field of CME is not yet well understood.
In this study, we performed magnetohydrodynamic simulations of a formation process of CMEs in the solar corona, focusing on the interaction between an ejecting flux rope and its ambient field by extending the work by Shiota et al. (2010). We examined the dynamics of magnetic flux rope in three different ambient plasma conditions: the uniform atmosphere, the hydrostatic atmosphere, and the steady state of the solar wind.
In the uniform atmosphere case, the flux rope are decelerated very much with continues rotation around the propagation direction as same as the previous study (Shiota et al. 2010). In contrast, we found that in the other two cases the flux rope speed is much faster than in the uniform atmosphere case because of a much weaker drug force in the stratified or steadily flowing plasma. Since the magnetic interaction between the flux rope and the ambient field seems to be weaker in those cases, the rotation of CME becomes weaker. We will discuss how the ambient plasma influences the dynamics of the CMEs.

Keywords: magnetohydrodynamic, coronal mass ejections (CMEs), corona

Mode Conversion of Alfven Waves Propagating in the Solar Chromosphere and Contribution to the Heating

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Alfven waves, which are generated in the solar photosphere and propagate along magnetic flux tubes, have been suggested to carry sufficient energy to the upper solar atmosphere and heat the atmosphere through wave dissipation. The chromosphere is an intermediate layer connecting the photosphere to the corona. Propagation and dissipation of waves in the chromosphere regulate the energy flux penetrating the corona. The chromospheric heating by waves is important for understanding the mechanism of solar atmospheric heating and solar wind acceleration. In this presentation, we report on our numerical works of Alfven wave propagation along open flux tubes from the solar convection zone to the corona. In 1.5-dimensional magnetohydrodynamic (MHD) numerical simulations, it is shown that 60–90% of the upward-propagating Alfvenic pulse with frequencies of 3–100 mHz are reflected at the transition region, which is the top boundary of the chromosphere. Meanwhile, most of the waves reflected at the transition region penetrate the convection zone without being reflected at the bottom of the photosphere. These results suggest that Alfven waves are unlikely to be trapped in the chromosphere. During the wave propagation in the chromosphere, Alfven waves exhibit nonlinear effects with longitudinal wave generation. The mode conversion rate is calculated with different plasma beta in the chromosphere. In the case with low plasma beta (~ 0.1–1), 0.01–1% of input Alfven wave energy is converted to the longitudinal wave energy. This energy is almost comparable to the required energy for the chromospheric heating. As plasma beta becomes larger and background Alfven speed becomes smaller in the chromosphere, more longitudinal wave appears due to increase of nonlinearity of the Alfven wave. In the case with high plasma beta (~ 1–10), the mode conversion rate becomes 1–10%. The generated longitudinal waves carry sufficient energy to heat the chromosphere.

Keywords: chromosphere, wave, nonlinear, heating

Influence of solar wind and ozone on the temperatures of the troposphere and stratosphere

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The correlation between global atmosphere and solar magnetic activity is evident though the cause is not clear. In this presentation, we analyze the influence that solar wind and ozone give to the global atmosphere to examine the cause on the basis of the previous observations [1].
The AE index data were used to detect the influence of the solar wind on the total ozone and the air temperature change of the troposphere and stratosphere.
In the analysis, the following factors were taken into account: 1)EPP-NOx effects on ozone at low latitudes may be comparable to the effects of solar UV radiation [Callis et al., 2000, 2001; Langematz et al., 2005; Rozanov et al., 2005]. 2) Since the ozone generated at low latitude is conveyed to the pole aria of the winter hemisphere, EPP-NOx has affected the ozone reduction of the pole area.
As the analysis result, showalter stability index which is calculated from the temperature of 500hPa and 850hPa in polar regions correlates with the AE index, Especially when the Arctic Oscillation is changed from the positive phase to the negative phase, the tendency is strong.
This increase in high-energy particles with the solar wind, to reduce the stratospheric ozone polar, it is possible to increase the amount of solar radiation reaching the troposphere, there is a possibility that influence the stability of the atmosphere.
Thus, changes in the stratospheric ozone due to the influence of the solar wind appears to affect the climate of the troposphere.

Reference

[1]K.Itoh, JpGU. 2008-2015

Keywords: atmospheric stability, AE index, AO index, ozone

Space Weather and Terrestrial Weather during the Transition Period of the Solar Activity in 13th and 14th Century: an Examination on Disaster Records in Yuan Dynasty.

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Space Weather and Terrestrial Weather during the Transition Period of the Solar Activity in 13th and 14th century: an examination on disaster records in Yuan Dynasty. In the 13th century, the rapid fall down of the solar activity ended the Medieval Maximum (1100-1250) and started the Wolf Minimum (1280-1340). This change of the solar activity also caused a considerable climate change on the earth and brought an end of the Medieval Warm Period (10c-13c) and the Little Ice Age (14c-19c). In the 13th century, Eurasia witnessed an unexampled worldwide empire by the Mongolian Empire and the trade routes across the Eurasia had gotten connected between the West and the East under the "Pax Mongolica". Even this worldwide Empire could not conquer the contemporary climate change and had disintegrated in the early Little Ice Age. It is frequently pointed out that hunger or social unrests caused by extreme weathers are one of its biggest reasons. However, as for such extreme terrestrial weathers, they have only gotten pointed out vaguely and they have left unexamined till now. So, in this presentation, we treat the records of disasters in the China under Mongolian rule (1235-1368) and show the detail of the extreme terrestrial weather caused in the period during the transition of the solar activity, shown by the records of carbon-14 in tree rings. Historical records provides important information on the regional differences of solar influence on climate. It also gives some clues on the ocean-atmospheric circulation during the time.

Keywords: Wolf Minimum, Medieval Warm Period, solar activity, Extreme Terrestrial Weathers

Aurora Candidates from the Chronicles of *Qing* Dynasties for Decoding Past Solar Activities

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We present the survey result of observational records of auroras in chronicles of *Qing* dynasties, *Qingshigao*, the draft chronicle of *Qing* dynasty (1644-1912 CE). In total we found 111 records of aurora candidates associated with the keywords such as vapor (*qi*), cloud (*yun*), and light (*guang*). Among the 111 records we found, 14 records are considered as very likely to be low latitude auroras with corresponding records of simultaneous observation in the western world, and 6 records are newly found low latitude aurora candidates after moon phase analysis in order to eliminate a possibility of atmospheric optics involving. Some of our presenting candidates of low latitude aurora are dated during the Maunder minimum, and therefore we would suggest our presenting data potentially helpful for further discussion on past solar activities.

Keywords: Aurora, Space Weather, Historical Resources

Development of user-oriented space environment prediction model for individual satellite

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Geospace environment is dynamically changing depending on the solar wind conditions. As a result, space environment disturbances, such as substorms and relativistic electron enhancements are occurred. These are the key subjects of space weather research. On the contraly, there are numbers of commercial satellites operated in geospace. These satellites sometimes faced on the hazardous conditions because of geospace disturbances. Changing the particle environment surrounding individual satellite causes spacecraft charging problem. Less than 100 keV energy of charged particles, and more than 500 keV energy of charged particles cause surface and internal charging to satellites, respectively. Spacecraft charging is one of the major reasons of spacecraft anomaly. To mitigate the risk of satellite anomaly, prediction of middle to high energy particle environment in geospace is important.

However, the risk of spacecraft anomaly is also depend on the specification of the satellite (e.g. surface materials, radiation tolerance, etc.). Therefore, the prediction of space environment is still not enough for satellite operators. These information should be interpreted to the risk of individual satellite.

To estimate a risk of spacecraft charging for individual satellite, we try to combine forecasting model of space environment and engineering model for individual satellite. Based on the combination of these models, we will provide specific information of charging risk for individual satellite. In this presentation, we will introduce our approach of developing user-oriented space environment prediction model for individual satellite, and our initial results.

Keywords: Space Weather Forecast, Spacecraft Charging, User-Oriented

Space weather effects on aeronautical communication, navigation and surveillance systems

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Space weather can be defined as the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems.
It becomes more important especially when the reliability are of relevance. Aeronautical applications are one of those which requires high level of reliability and safety. In fact, International Civil Aviation Organization (ICAO) is working on standardizing the space weather information for aeronautical operations.
The main objective of this paper is to present necessary space weather studies to which the science community are expected to contribute to enhance the performance, reliability and efficiency of aeronautical communications, navigation and surveillance (CNS) systems. Space weather phenomena which can influence the aeronautical CNS systems are presented from the operation point of view. Possible impacts of space weather phenomena on aeronautical CNS systems and necessary space weather studies to evaluate the operational impact and devise effective mitigation methodology are discussed.

Keywords: aeronautical applications, ionosphere, communications, navigation, and surveillance systems

