PSTEP: Towards Predicting Next Solar Cycle

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The 11-year solar cycles and the longer-term variations of the solar activity may affect the Earth’s climate. Predicting the next solar cycle is crucial for the forecast of the "solar-terrestrial environment". Therefore, as a part of the PSTEP (Project for Solar-Terrestrial Environment Prediction), we are developing a five-years prediction scheme by combining the Surface Flux Transport (SFT) model and the most accurate measurements of solar magnetic fields. We estimate the meridional flow, differential rotation, and turbulent diffusivity from recent modern observations (Hinode and Solar Dynamics Observatory). These parameters are used in the SFT models to predict the polar magnetic fields strength at the solar minimum. We also plan to apply our prediction scheme to long-term variations of solar activity and investigate the possibility of grand minimums such as the Maunder Minimum in the future. In this presentation, we will explain the outline of our strategy to predict the next solar cycle. We also report the present status and the future perspective of our project and we inroduce our initial result for cycle 25 prediction.

Keywords: solar cycle prediction, polar magnetic field, solar magnetic filed

CCMC/SWRC Space Weather Forecasting Services for NASA Robotic Mission Operators

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Community Coordinated Modeling Center (CCMC) located at NASA GSFC has been one of the core US space weather activities for more than a decade. While the primary CCMC goals are to facilitate community space weather research and usage of state-of-the-art models as well as research to operations (and operations to research) activities, the more recent Space Weather Research Center (SWRC) within CCMC is dedicated to providing space weather services for NASA's robotic mission operators. CCMC/SWRC together with JSC Space Radiation Analysis Group are NASA's space weather services providers for robotic and human exploration, respectively.

In this paper we will review the latest CCMC/SWRC forecasting services that allow addressing NASA's spacecraft operators' needs. The new forecasting tools include space weather databases such as CME, Flare, and SEP Scoreboards, DONKI (Space Weather Database Of Notifications, Knowledge, Information) and novel forecasting capacity such as ensemble CME and flare prediction systems that have been implemented at CCMC. We will also discuss our work on developing future forecasting capabilities that include protoyping novel space weather prediction concepts and higher level of tailoring of services for individual NASA missions.

Keywords: Space Weather, Forecasting Services, Space Weather Scoreboards

CME Arrival-time Validation of Real-time WSA-ENLIL+Cone Simulations at the CCMC/SWRC

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The Wang-Sheeley-Arge (WSA)-ENLIL+Cone model is used extensively in space weather operations worldwide to model CME propagation, as such it is important to assess its performance. We present validation results of the WSA-ENLIL+Cone model installed at the Community Coordinated Modeling Center (CCMC) and executed in real-time by the CCMC/Space Weather Research Center (SWRC). The SWRC is a CCMC sub-team that provides space weather services to NASA robotic mission operators and science campaigns, and also prototypes new forecasting models and techniques. CCMC/SWRC uses the WSA-ENLIL+Cone model to predict CME arrivals at NASA missions throughout the inner heliosphere. In this work we compare model predicted CME arrival-times to in-situ ICME shock observations near Earth (ACE, Wind), STEREO-A and B for simulations completed between March 2010 - January 2017 (over 1500 runs). We report hit, miss, false alarm, and correct rejection statistics for all three spacecraft. For hits we compute the bias, RMSE, and average absolute CME arrival time error, and the dependence of these errors on CME input parameters. We compare the predicted geomagnetic storm strength (Kp index) to the CME arrival time error for Earth-directed CMEs. The predicted Kp index is computed using the WSA-ENLIL+Cone plasma parameters at Earth with a modified Newell et al. (2007) coupling function. We also explore the impact of the multi-spacecraft observations on the CME parameters used initialize the model by comparing model validation results before and after the STEREO-B communication loss (since September 2014) and STEREO-A side-lobe operations (August 2014-December 2015). This model validation exercise has significance for future space weather mission planning such as L5 missions.

Keywords: coronal mass ejections, simulations, space weather

Prediction and skills of Bz forecasting inside CMEs

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The direction of magnetic vectors within coronal mass ejections, CMEs, has significant importance for forecasting terrestrial behavior. However, forecasting these vectors remains largely elusive and lies predominately with the difficulty in disassociating the predictive skill of the magnetic configuration during the initiation process with the skill of understanding the evolutionary effects of the topology during propagation. Here, we discuss a simplified system for predicting the magnetic vector within CMEs, driven by observations and empirical relationships. Operating under a realtime format, this (Bz4Cast) model can provide a diagnostic threshold to compare against more complex systems. These are first steps to providing operationally reliable estimates of Kp at Earth as a long-lead time forecast. Using skill metrics, we show this model is the most unbiased, while the NOAA and NASA/CCMC tend to over-forecast. We will present preliminary results of evaluating predictive skill of the MHD driven SUSANOO model and display solutions to evaluating skills for the interplanetary magnetic field near Earth. This parameter presents unique complexity over the Kp index skills as it is a time-varing vector rather than a scalar value of fixed 3 hour time period.

Keywords: long lead-time forecast, Coronal mass ejections, skill metric validation

Shocks and their Geomagnetic Effects

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Sheath regions behind fast forward shocks are second only to magnetic ejecta in driving intense geomagnetic storms at Earth. Fast-foward shocks also routinely compress Earth's dayside magnetosphere, sometimes resulting in loss of energetic particles in the outer radiation belt through magnetopause shadowing and large geo-electric fields associated with sudden impulse. Here, we discuss the importance of the upstream medium into which shocks propagate, and, in particular the propagation of shocks inside previous ejecta, in determining their geo-effective potential. We also analyze which types of shocks result in strong geo-electric fields.

Keywords: Coronal Mass Ejections, Shocks, Geomagnetic response

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.

The May 1967 great storm and radio disruption event: Extreme space weather and extraordinary responses

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The space weather storm of late May 1967 tested numerous radio and space-based technologies that had developed during the Cold War and 'Space Race' of the mid-20th century. McMath Region 8818, at ~30 deg east of the solar central meridian was the source of a localized white-light flare and extensive H-alpha flare emissions. The storm made its initial mark at Earth with a colossal solar radio burst causing radio interference at frequencies between 0.01 and 9.0 GHz and near-simultaneous disruptions of dayside radio communication and surveillance radars by intense fluxes of ionizing solar radiation. Substantial fast (EUV-associated) and slow (soft Xray-associated) magnetic crochets were observed. Within hours a solar energetic particle event disrupted high-frequency communication in the polar cap. Subsequently, record-setting geomagnetic and ionospheric storms compounded the disruptions. Satellite orbits and satellite tracking were particularly impacted. This was one of the "Great Storms" of the twentieth century, despite the apparent lack of large geomagnetically induced currents. I will recount what we know about the state of the magnetosphere-ionosphere-thermosphere system as the Dst index dropped to nearly -400 nT. Further, I will explain how this storm expanded terrestrial weather monitoring-analysis-warning-prediction efforts into the realm of space weather forecasting.

Keywords: solar flare, solar radio burst, great geomagnetic storm, satellite drag, ionospheric storm, magnetic crochet

Historical space weather monitoring of prolonged aurora activities in Japan and in China

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Great magnetic storms are recorded as aurora sightings in historical documents. The earliest known example of “prolonged” aurora sightings, with aurora persistent for two or more nights within a 7 day interval at low latitudes, in Japan was documented on 21–23 February 1204 in Meigetsuki, when a big sunspot was also recorded in China. We have searched for prolonged events over the 600 year interval since 620 in Japan based on the catalogue of Kanda [1933] and over the 700 year interval since 581 in China based on the catalogues of Tamazawa et al. [2017] and Hayakawa et al. [2015]. Before the Meigetsuki event, a significant fraction of the 200 possible aurora sightings in Sòng dynasty (960–1279) of China was detected at least twice within a 7 day interval and sometimes recurred with approximately the solar rotation period of 27 days. The majority of prolonged aurora activity events occurred around the maximum phase of solar cycles rather than around the minimum, as estimated from the 14C analysis of tree rings. They were not reported during the Oort Minimum (1010–1050). We hypothesize that the prolonged aurora sightings are associated with great magnetic storms resulting from multiple coronal mass ejections from the same active region. The historical documents therefore provide useful information to support estimation of great magnetic storm frequency, which are often associated with power outages and other societal concerns.

Reference: Kataoka, R., H. Isobe, H. Hayakawa, H. Tamazawa, A. D. Kawamura, H. Miyahara, K. Iwasaki, K. Yamamoto, M. Takei, T. Terashima, H. Suzuki, Y. Fujiwara, and T. Nakamura (2017), Historical space weather monitoring of prolonged aurora activities in Japan and in China, Space Weather, accepted.

Investigation on past solar activities using historical documents from the East and the West

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We present the results of our survey of the records of law-latitude auroras in the historical documents, from east Asia (China, Korea and Japan) and from the West (Europe and middle east). The main results includes: discovery of the oldest datable auroras from Babylonia, discovery of the oldest sketch of dated aurora, east Asian aurora records of the Carrington event in 1859, and simultaneous observation of low latitude aurora in Europe and in Korea possiblly connected to the intense cosmic-ray event in 994. We also discuss the differense of people's response to the anomalous heavenly events in different time and place, and its implication to science communication with public.

Keywords: aurora, solar activity, historical documents

Forcing of the middle and upper atmosphere by high-energy particle precipitation and new observational opportunities by the EISCAT_3D radar

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One aspect of sever space weather is the precipitation of high-energy particles into the atmosphere at high latitudes. Recent observational and model results on the particle precipitation as source of atmospheric variability challenge us to implement better and continuously monitoring observational infrastructure for middle and upper atmospheric research. As ability to forecast of the effects by extreme individual space weather events and knowledge of space climate related coupling features in the geospace environment and atmosphere are a must in the future modern society, we need to pay attention to integrated studies utilizing space-based measurements, modeling and ground-based measurements. Here we review recent results related to atmospheric forcing by particle precipitation via effects on chemical composition. We also show the future research potential of new ground-based radio measurement techniques, such as spectral riometry and incoherent scatter by new phased-array radars. EISCAT_3D will be a new, volumetric, i.e. 3-dimensionally imaging radar, distributed in Norway, Sweden, and Finland. It is expected to be operational from 2020 onwards, surpassing all the current IS radars of the world in technology. It will be able to produce continuous information of ionospheric plasma parameters in a volume, including 3D-vector plasma velocities. For the first time we will be able to map the 3D electric currents in ionosphere, as well as we will have continuous vector wind measurements in mesosphere. The geographical area covered by the EISCAT_3D measurements can be expanded by suitably selected other continuous ground-based observations, such as optical and satellite tomography networks providing 3D imaging capability. New space missions will gain from this emerging capacity enhancement of ground-based observations.

Keywords: high-energy particle precipitation, atmospheric chemistry, incoherent scatter radar

GICs resulting from ground electric fields induced by GMDs above 3-D Earth conductivity structure - assimilating magnetotelluric array and ionospheric data sets

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The electric power grid is exposed to geomagnetically induced currents (GICs) that arise in response to geomagnetic disturbances (GMDs). During large GMDs, strong electric currents enter the grounding of transformers and saturate the cores, thus distorting the power signal AC waveforms. This can lead to system relay interference, reactive power loss, and total system collapse, including cascading failures that can propagate over a wide area. The lack of resilience of power grids to GICs presents a grave risk to the economy and to public safety. Efforts from the research and development perspective, the regulatory agencies, and from the power utilities are underway to mitigate against potential damage from these events.

We illustrate key geophysical factors that determine the intensity of ground electric fields, and hence GICs, that arise from GMDs above a crust and mantle whose electrical structure is 3-D. We apply real-world examples from temporary regional and continental-scale arrays of ground electric and magnetic field (i.e. magnetotelluric) monitoring stations that demonstrate the intensification of ground electric fields associated with strong 3-D conductivity variations, which are ubiquitous across the continental US.

We discuss two approaches to predicting the intensity of ground electric fields. The first is to solve the fully coupled, reduced form of Maxwell’ s Equations in the quasi-static approximation in the time domain, given knowledge of the ionospheric source fields in both time and space domains. In order to accomplish this, constraints on ionospheric source fields were obtained from the Poker Flat Incoherent Scattering Radar (PFISR) system at a facility north of Fairbanks, Alaska. In 2015 we operated a synchronous array of 25 long-period magnetotelluric (MT) stations beneath the ionospheric footprint of PFISR. We developed a solution for the fully coupled Maxwell’ s Equations using the Finite Difference Fictitious Wave Domain (FDFWF) method, that when combined with a cascade decimation approach to represent the time domain waveform of ground electric and magnetic fields in a low-loss compressed form, speeds the solution and reduces memory requirements by many orders of magnitude relative to conventional FDTD approaches. We report on forward and inverse solutions for determining 3-D ground conductivity structure and the resulting ground electric fields, as applied to the Alaska data set.

Our second approach avoids solving Maxwell’ s equations, and instead makes direct use of the MT impedance functions that are generated for each MT station location using well-established frequency domain methods. We have obtained approximately 1000 MT impedance functions for sites across approximately half of the area of the continental US, and using these we have constructed a set of two linear filters that: a) project real time measurements of ground magnetic fields from distant magnetic observatories onto the locations of the (former) temporary MT stations, and then b) project the predicted electric fields through the site-specific MT impedance functions to predict the real-time electric fields at those locations. These electric fields are then projected onto the path of the power grid and integrated along the path length to determine the forcing function for the GICs. We applied this Cascading Linear

Filter Algorithm (CLFA) to predicting electric fields for power grids in two regions of the US, and compare our predictions with some indirect measurements of GICs in those grids. We describe the impact of varying distance from remote magnetic observatories on the fidelity of the electric field predictions, and demonstrate the importance of factoring in 3-D variations in ground conductivity in order to produce electric field predictions that more accurately represent the GIC threat to power grids.

Keywords: GIC, GMD, Magnetotelluric, Electric Field, Impedance, Space Weather

Long term Geomagnetically Induced Current Observations from New Zealand

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Transpower New Zealand Limited have measured DC currents at transformers in the New Zealand electrical network at multiple South Island locations for many years. Near continuous archived DC current data exist since 2001, starting with 12 different substations, and expanding from 2009 to include 17 substations. From 2001-2015 a total of 61 distinct transformers were monitored. Primarily the measurements were intended to monitor the impact of the High Voltage DC system linking the North and South Islands when it is operating in "Earth return" mode. However, after correcting for Earth return operation, the New Zealand measurements provide an unusually long and spatially detailed set of Geomagnetically Induced Current (GIC) measurements.

It is recognised that GIC caused the loss of a South Island transformer in November 2001, during a storm that caused multiple alarms across the South Island. The 2009 onwards expansion in measurement locations was undertaken to better monitor the Space Weather risk caused by GIC.

Here we describe the New Zealand DC observations, and the corrections required to identify GIC in this dataset. We examine the peak GIC magnitudes observed from these observations during large geomagnetic storms on 6 November 2001 and 2 October 2013. Peak storm time currents of ~30-50 A are observed, depending on the measurement location. We then examine those GIC in transformers throughout the South Island and compare them to the various magnitude and rate of change components of the magnetic field. Our results show there is a strong correlation between the magnitude of the GIC and the rate of change of the horizontal magnetic field (*H'*). This correlation is particularly clear for transformers that show large GIC current during magnetic storms.

Our research is part of a New Zealand funded project to identify the risk posed by GIC to the New Zealand electrical network. Transpower (the transmission system operator) is a key stakeholder in this project, and has supported us with the GIC observations and detailed information on the DC characteristics of the primary transformers and transmission lines which make up the New Zealand network. Our team is now working on modelling GIC in New Zealand , with the goal of validating the model against the high-resolution transformer-level observations.

Keywords: Geomagnetic Induced Currents, Space Weather

Modelling geomagnetically induced currents (GIC) in the 500 kV power grid in Japan produced by realistic electric fields

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A realistic model of GIC in the Japanese 500 kV power system is developed for the first time to estimate the influence of the geomagnetically induced currents (GIC) on the Japanese electrical distribution grid. Previously, it is believed that there is no threat in Japanese power grid because of the Japanese location at mid-latitude far from auroral- or equatorial- electrojet. Then, scarce research has been done to assess detailly the GIC influence in Japan.

We develop the 500 kV power grid model in Japan and calculate GIC assuming uniform electric fields on Earth’ s surface and more realistic electric fields. Geomagnetically induced electric field (GIE) is obtained by Finite-difference time-domain (FDTD) method, given a uniform sheet current changing with a period of ~100 s at the upper air as a source. A three-dimensional electrical conductivity is derived from a global relief model (NOAA) and a global map of sediment Thickness (Gabi Laske and Guy Masters). The Japanese GIE exhibit strong coastal effects and some anomaly spots resulting from underground structures of the conductivity. Due to the shape of a thin bow, Japanese lands can play a role like a capacitor according to the direction of the source current. Basically, a largest magnitude of GIC is obtained at Kashiwazaki with a North-South electric field. Using our model, we can compare factors of resistance parameters of the power grid, the positional relationship, the direction of source currents, underground structures in GIC distributions in the Japanese high-voltage power grid.

Keywords: GIC, FDTD, power grid

Prediction of the midlatitude geomagnetically induced currents

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Morphologically, the midlatitude GICs are well correlated with the y-component magnetic field (By) on both the day and nightsides, while those are poorly correlated with the Bx [Watari et al., 2009]. The GIC is found to be a current induced by the By propagating into the ground as a diffusion mode. The daytime GIC is also found to be well correlated with the equatorial electrojet (EEJ), suggesting that the By is transmitted from high latitudes by the TM0 mode waves in the Earth-ionosphere waveguide [Kikuchi and Araki, 1979]. The TM0 mode waves take a major role in transmitting electromagnetic energy consumed in the GIC at low latitude, while the TE mode with the Bx is an evanescent mode not contributing to the transport of energy [Kikuchi and Araki, 1979]. The By can be predicted by predicting the ionospheric Pedersen currents and field-aligned currents (FACs). The midlatitude daytime Pedersen currents complete a circuit between the polar and equatorial ionosphere [Kikuchi et al., 1996], which are driven by magnetospheric dynamos created by the magnetospheric compression [Fujita et al., 2003] and southward IMF [Tanaka, 1995]. The FACs on the night are the substorm R1 FACs driven by the near-Earth tail and lobe mantle dynamos [Tanaka et al., 2010; Ebihara and Tanaka, 2015]. We now propose a prediction scheme of the midlatitude GIC, where the global MHD simulation with the potential solver provides the ionospheric Pedersen currents on the dayside and the substorm FACs on the nightside and the solution of the diffusion equation for the By provides the GIC.

Keywords: Geomagnetically induced current, Mid latitude ground surface current, Global ionospheric current, Magnetosphere-ionosphere field-aligned current, Ionosphere-ground transmission line

Effects of Geomagnetically Induced Currents on the New York State Electric Power Systems

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Geomagnetic storms can perturb Earth's magnetic field and generate geo-electric fields that result in the flow of Geomagnetically Induced Currents (GICs) through the transmission lines, followed by transformers and the ground. GICs are also known to have adverse effects on mid-latitude regions. Thus, this study focuses on the effects of GICs on the New York State (NYS) Electric Power Systems, located in a mid-latitude region. Although GICs affect high voltage levels, e.g. above 300 kV, the presence of a coastline in NYS makes the low voltage transmission lines also susceptible to GICs. As the ground conductivity and the power network topology significantly vary within the region, it becomes imperative to estimate the magnitude of GICs for different places. In this study, the geo-electric fields are calculated with the Geoelectric Field Calculator Tool, which allows for the calculation of the fields using both a 1-D ground conductivity and a 3-D surface impedance ground response model. The calculated geo-electric fields, and an extensive modeling of the whole NYS electricity transmission network using real data, are used to calculate the magnitude of the GICs. NYS is also home to one of the largest urban cities in the world, New York City (NYC). Therefore, understanding and mitigating the effects of GICs are important to reduce the vulnerabilities of the NYS present bulk power system, which includes NYC. Results of our study can shed some light on effects of GICs on other power systems located in mid-latitude regions like NYS, and urban cities like NYC.

Keywords: GICs, Geomagnetic Storms, Geoelectric fields, Electric Power Systems, Mid-latitude regions

Annual report of PSTEP-A01 "development of new generation space weather forecast system"

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The purpose of A01 group in PSTEP is to develop a new generation space weather forecast system through the dual communication between academic scientists and end-users. We manage the committee of space weather users to realize the purpose and develop the following four systems; (1) radio propagation simulator, (2) taylor-made space weather system for managing specific satellite, (3) the estimate system of human exposure, and (4) the estimate system of geomagnetically induced current on electric power grid. In this presentation I will report the current status of the activity and results of PSTEP A01 group.

Keywords: space weather, radio propagation, satellite anomaly, geomagnetically induced current, human exposure

Toward mitigating space weather risk of individual spacecraft in geospace

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There are numbers of commercial satellites operated in geospace. These satellites sometimes faced on the hazardous conditions because of geospace disturbances. Dynamic change of the particle environment surrounding individual satellite causes spacecraft charging/discharging 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 reason of spacecraft anomaly. To mitigate the risk of satellite anomaly, prediction of middle to high energy particle environment in geospace is important, because satellite operators can avoid critical operation if they know the exact risk of satellite anomaly in advance. Further, if the satellite operator understands the current condition of space environment surrounding individual satellite, they can quickly judge initial triage to solve the problem of satellite anomaly. Thus, nowcasting and forecasting of space environment around individual satellite is important.
However, the risk of satellite anomaly is also depending on the specification of individual satellite (e.g. surface materials, radiation tolerance, etc.). Therefore, tailor-made space weather information and risk assessment for individual satellite is needed. To estimate a risk of spacecraft charging for individual satellite, we are combining 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 current status of our project.

Keywords: space weather forecast, satellite anomaly, risk mitigation

Space weather data of the ARASE satellite

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It is well known that satellites and astronauts are always endangered in space due to plasma, radiation particles, neutral particles, ultraviolet rays/X rays and meteoroids/debris. Space radiation consists of three elements, namely solar energetic particles (SEP), galactic cosmic rays and Van Allen radiation belts particles trapped in the magnetic fields of Earth.
The ARASE satellite was lunched on December 20, 2016 from the Uchinoura Space Center in Japan. It has a mission to clarify the mechanism responsible for the decrease and increase electrons in the Van Allen radiation belts. It has 9 instruments and three of them, the MGF, the HEP and the XEP, can provide Quasi-real-time data for space weather. These data are provided from the SEES (Space Environment & Effects System) that is operated by the Research and Development Directorate in JAXA. Graphs of its Quasi-real-time data were published on the SEES website freely and numerical data files are provided for a person who sent an application form to use them. This presentation introduces space weather data of the Arase satellite and the SEES website.

Keywords: ARASE, ERG

The Impact of Auroral Electron Streams on LEO Polar Satellites As a Source of Charging

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Low Eath Orbit (LEO) satellite charging has become primary concern nowadays due to its interaction not only with ionospheric plasma but also with auroral electron streams. The interaction occasionally lead to destructive effects through accumulative electrical charge from various sources on satellite. In this study we have simulated the ionospheric plasma and auroral electron interactions with some LEO polar satellites using Electro-Magnetic Spacecraft Environment Simulator (EMSES). We exploited some polar satellites registered in Satellite News Digest (SND) database. We adopted empirical plasma parameters obtained from International Reference Ionosphere (IRI) model as an input for EMSES within particular time. The integral flux of > 30 keV electrons used in this study exceeds 10^6 particles/cm^2.s.ster. In the first phase of simulation we neglected the effects of photoelectrons together with secondary and backscatter electrons. The results show that the effect of solely ionospheric plasma on satellites is insignificant in which the floating potential varies from -0.5 to -2.25 Volts. In contrast, the impact of auroral electrons on LEO polar satellites results in electric potential of satellite on the order of -100 Volts. This large potential can be hazardous to satellite as seen in this study

Keywords: LEO satellite , Particle in Cell Simulation, Satellite Charging

The relationship between the space environments of high energy electrons and the satellite anomaly caused by internal charging

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Spacecraft charging is still the main part of the satellite anomaly which is caused by the space environment. Choi et al. (2011) analyzed satellite anomaly events occured at the geostationary Earth orbit (GEO). They found a strong relationship between the occurence of satellite anomaly and Kp index. This result suggests that the majority of anomalies are caused by enhancement of middle and high energy electrons due to geomagnetic disturbances. There are two kinds of spacecraft charging.One is surface charging and the other is internal charging. Surface and internal charging are caused by few keV and few MeV electrons respectively. In our presentation, we will report one sample case of satellite anomaly caused by the internal charging, and discuss the correlation with the enhancement of high energy electron observation, and introduce the Monte-Carlo simulation results of internal charging due to the accumulations of high energy electrons on the material of the electrical device within the satellite body.

Keywords: Spacecraft charging, Satellite anomaly, Internal charging

Measurements of multiple-band emission by FORMOSAT-2/ISUAL in the South Atlantic Anomaly region

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South Atlantic Anomaly (SAA) corresponds to a region where the geomagnetic field is relatively weak; such a magnetic field enables energetic particles of magnetospheric source to penetrate closer to the Earth's surface more easily, thus resulting in relatively high level of radiation in the environment. In this study, we analyze the nighttime emissions during 2006-2008 in the SAA region by using the data from the ISUAL (Imager of Sprites and Upper Atmospheric Lightning) experiment aboard the FORMOSAT-2 satellite. Emissions of $2PN_2$ (0,0) band at 337 nm, the $1NN_2^+$ (0,0) band at 391.4 nm and the OI(^{5}P) band at 777.4 nm are showed the yearly cyclical variation. Through comparing these multiple-band emissions, we can identify energy variation of incident particles and atmospheric compositions of SAA region.

Keywords: South Atlantic Anomaly, ISUAL

Current States and Future Needs on the Warning System for Aviation Exposure to Solar Energetic Particle (WASAVIES)

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Estimation 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. We are therefore developing a WArning System for AVIation Exposure to Solar energetic particle (WASAVIES), under the framework of Project for Solar-Terrestrial Environment Prediction (PSTEP). In the system, the SEP fluxes incident to the atmosphere are calculated by physics-based models. Thus, WASAVIES can estimate not only the current value but also time variation of the aircrew doses after a GLE event occurs. A brief outline of WASAVIES together with the status of on-going research subjects such as development of the automatic calculation algorithm will be presented at the meeting.

Keywords: SEP, radiation exposure, forecast

Cosmic Ray Modulation and Radiation Dose of Aircrews During the Coming Solar Cycle

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The variation of the galactic cosmic ray (GCR) spectrum, the so-called cosmic-ray modulation, is caused by the heliospheric environmental change. In the current weak solar cycle 24, it is expected that the flux of GCRs is getting higher than that in the previous solar cycles, leading to the increase in the radiation exposure in the space and atmosphere. In order to quantitatively evaluate the possible solar modulation of GCRs and resultant radiation exposure at flight altitude during the coming solar cycle, we develop the time-dependent and three-dimensional model of the cosmic-ray modulation. We consider physics processes such as the curvature-gradient drift motion of GCRs and therefore our results reproduce the 22-year variation of the cosmic-ray modulation. By modeling the variation of the solar wind velocity, the strength of the interplanetary magnetic field, and its tilt angle, we predict the possible solar modulation of GCRs and resultant radiation exposure at flight altitude. The effects of the drift motion on our results of prediction will be discussed in this presentation.

Current status of a dynamical model of the heliosphere with the adaptive mesh refinement

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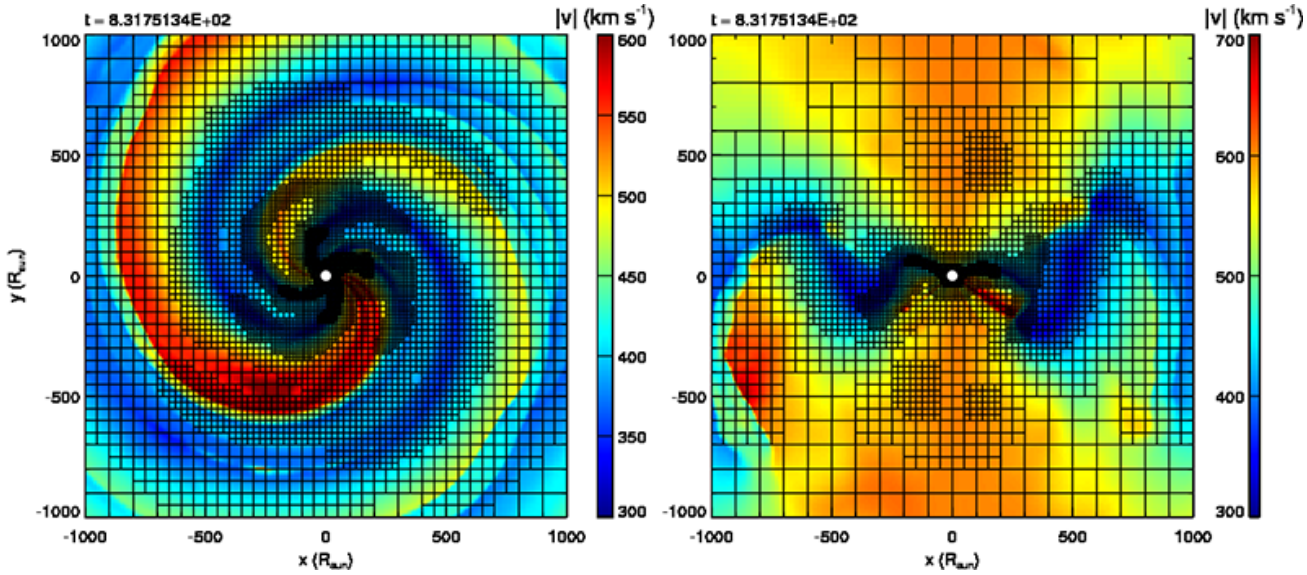
A change in the heliospheric environment plays an important role in the modulation of the galactic cosmic rays; the magnetic field structure and the speed of the solar wind affect the cosmic ray transport in the heliosphere. Since the heliospheric environment is affected by the solar wind activities, we have been developing a framework for simulating the heliosphere by using MHD simulations. The galactic cosmic rays are transported efficiently in the heliospheric current sheet (HCS), and it should be reproduced with a fine resolution in the model. We therefore utilized the adaptive mesh refinement (AMR) technique for improving the local resolution. In this talk, we present outline of our project and show the current status of the model development.

The simulation code is based on SFUMATO code (Matsumoto 2007), which employs the block-structured AMR. The HLLD- scheme (Miyoshi 2007) was adopted for the MHD solver, and it was modified to have a third order of accuracy in space and second order in time.

The time-dependent solar wind model is given by the inner boundary condition of the simulations. This model was ported from the space weather forecast system, SUSANOO (Shiota et al. 2014). It is based on the synoptic maps of the photospheric magnetic field provided by the Global Oscillation Network Group (GONG) project, the potential fields source surface (PFSS) model, and some empirical models for reconstructing the MHD parameters in the inner boundary condition.

For refinement of the grid, two types of the criteria are adopted. The first criterion is the grid-refinement according to the distance between the AMR-block and the Sun. This criterion provides linear increase in a resolution according to the distance from the Sun. The second criterion is the grid-refinement according to the HCS. When the HCS is detected, the AMR-block is refined there. The HCS is detected as a plane in which the toroidal component of the magnetic field vanishes. Due to this criterion, the HCS is resolved by a fine resolution, and numerical diffusion is considerably reduced there. Moreover, the co-rotating interaction regions (CIRs) are resolved sharply because the slow winds exist near the HCS, and the CIRs are also covered by the fine grids. The realistic reproduction of CIRs would also contribute for space weather forecast of the terrestrial radiation belt, which is sensitive to the sharp density enhancement and/or the rapid directional switch of interplanetary magnetic field within the CIRs.

Keywords: Heliosphere, Heliospheric current sheet, Co-rotating interaction regions, MHD simulation, adaptive mesh refinement



Comparison of Solar and Stellar White-light Flares

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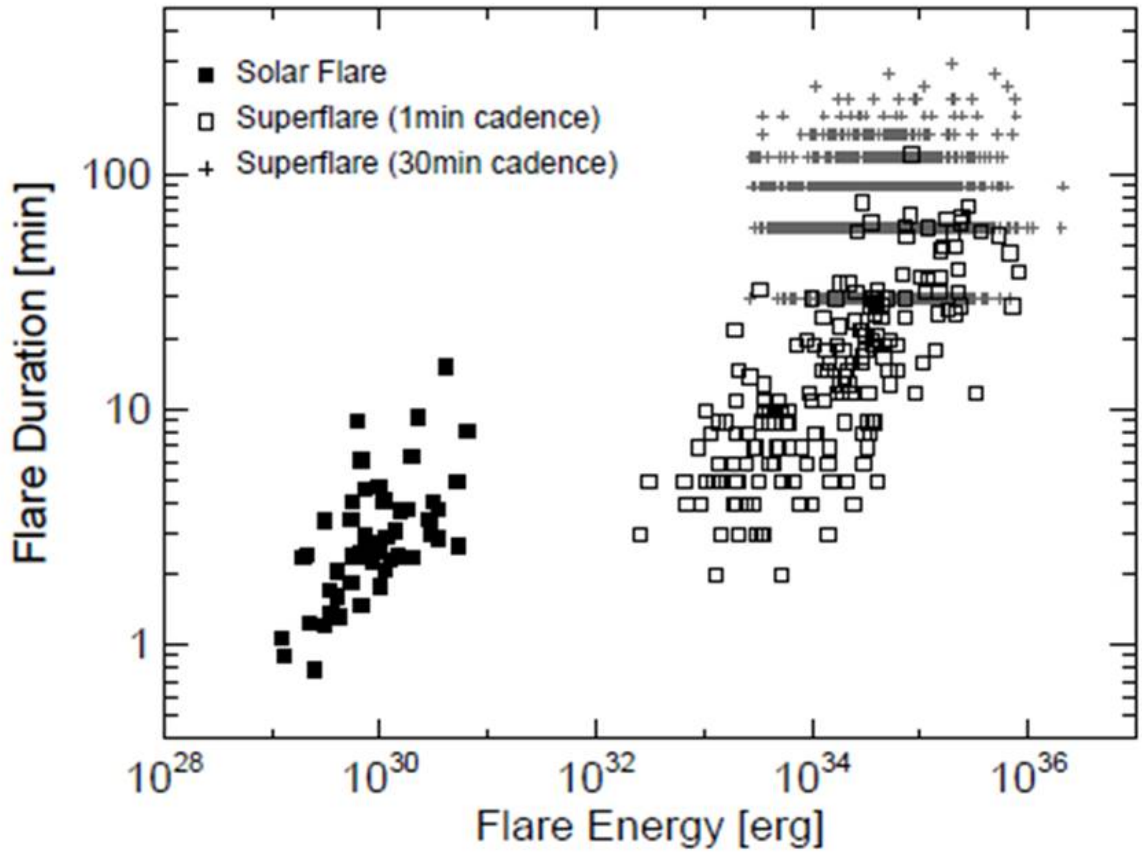
Flares are sudden brightenings on stellar surfaces. Especially, flares observed in visible continuum are called “**white-light flares**”. Recently, many superflares on solar-type stars which have 10-10,000 times larger energies than the largest solar flares are discovered as white-light flares with Kepler space telescope (Maehara et al. 2012; Shibayama et al. 2013). According to the statistical study of superflares, there is a correlation between the energies (E) and durations (t): $t \propto E^{0.39}$ (Maehara et al. 2015). This power-law relation is similar to that of the solar hard/soft X-ray: $t \propto E^{0.2\text{-}0.33}$ (Christ et al. 2008; Veronig et al. 2002). These common relations suggest the universal mechanism of energy release on solar and stellar flares (magnetic reconnection).

We present here a comparison of solar and stellar “white-light” flares on the relation between the flare energies and durations. The comparison of the same wavelength emission (visible continuum) can directly approach that of the energy release mechanism of solar and stellar flares.

The result shows that **the durations of solar white-light flares are one order of magnitude longer than that expected by the t-E relation of stellar superflares**. The discrepancy may imply the different physical properties of solar and stellar flares such as (1) flare emission / cooling mechanism or (2) magnetic field strength.

We consider that this difference between solar and stellar flare can become a clue not only to the environment of stellar superflares but also to the possibility of superflares on our Sun.

Keywords: solar flares, superflares, magnetic reconnection



Cross-disciplinary study of the possible link between space weather, geomagnetic storms and cetacean mass strandings

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1. NASA Goddard Space Flight Center

Cetacean (whales, dolphins and porpoises) mass strandings are a longstanding mystery in the field of marine biology and continue to be recorded in coastal environments around the world. It is unclear whether these events are generally increasing in number or whether the increase is due to increased observer and research efforts, or both. In cetacean mass strandings anywhere from a few to several hundred otherwise healthy animals strand in onshore environments, often for no apparent reason. In some instances, cetacean mass strandings have been attributed to impacts caused by naval sonar and, recently, a post-event analysis has implicated the use of multi-beam echosounders. However, these anthropogenic influences still do not explain the vast majority of cetacean mass strandings. Theories as to the cause of these cetacean mass strandings include magnetic anomalies and meteorological events, which are thought to disorientate the cetaceans. It has been speculated that due to the possible magnetic field sensing utilized by cetaceans, magnetic anomalies, of internal and/or external origin, could be at least partially responsible for the strandings. Internal magnetic anomalies are caused by localized structures primarily in the Earth’ s crust and the external, sometimes large-amplitude, magnetic anomalies are caused by geomagnetic storms. Geomagnetic storms having widely varying spatiotemporal signatures are caused by active solar and space weather phenomena.

While the possible link between cetacean mass strandings and magnetic anomalies has been speculated previously, no definitive work exists for quantifying this idea. In this paper, our cross-disciplinary NASA-BOEM-IFAW team composed of space weather experts, marine mammal biologists and marine mammal stranding response experts will report the initial results of the first detailed quantification of the possible link between space weather, spatiotemporal signatures of geomagnetic storms and cetacean mass strandings. We use mass stranding data from a number of “hotspots” around the globe and correlate the events with both global and local geomagnetic geomagnetic activity indicators. A number of statistical techniques are deployed to extract information about possible statistical association between mass strandings and space weather.

Keywords: geomagnetic storms, cetacean mass strandings

Cosmic rays' impact on climate is likely caused by cloud formation mechanisms

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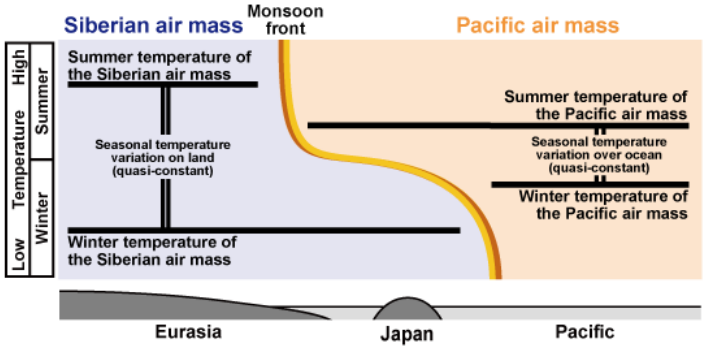
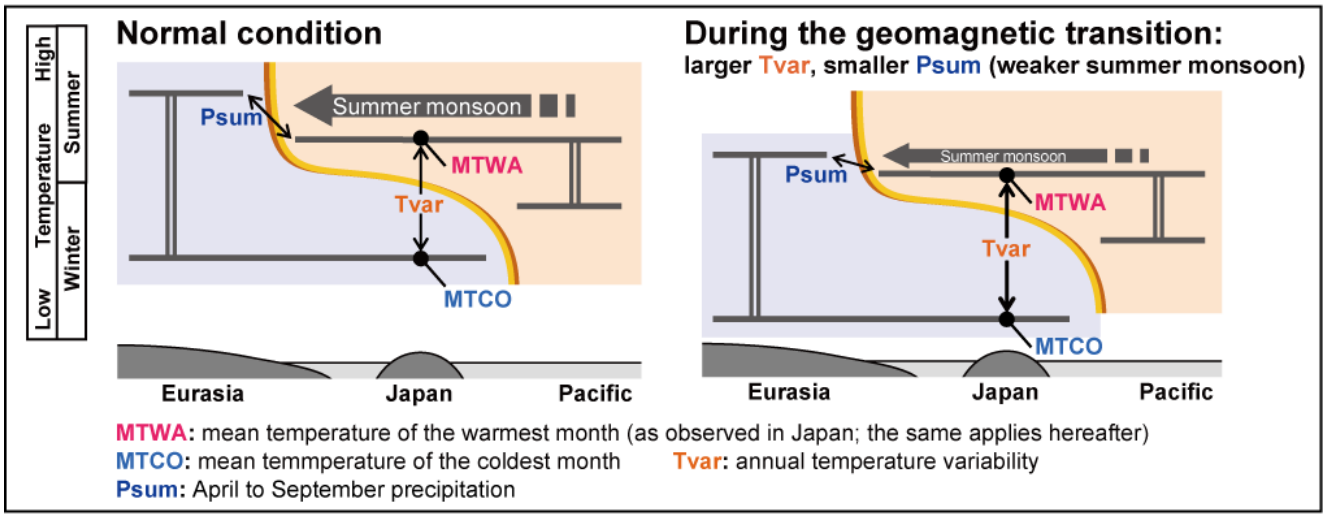
On geological time scales, the galactic cosmic ray (GCR) flux at the Earth's surface has increased significantly during many short time intervals. There is a growing body of evidence that suggests that climatic cooling occurred during these episodes. Cloud formation by GCR has been claimed as the most likely cause of the linkage. However, the mechanism is not fully understood due to the difficulty of accurately estimating the amount of cloud cover in the geologic past.

Our study focused on the geomagnetic field and climate in East Asia. The Earth's magnetic field provides a shield against GCR. The East Asian climate reflects the temperature balance between the Eurasian landmass and the Pacific Ocean that drives monsoon circulation.

Two geomagnetic polarity reversals occurred at ca. 780 ka and ca. 1,070 ka. At these times the geomagnetic field decreased to about 10% of its present level causing a near doubling of the GCR flux. Temperature and rainfall amounts during these episodes were reconstructed using pollen in sediment cores from Osaka Bay, Japan. The results show a more significant temperature drop on the Eurasian continent than over the Pacific, and a decrease of summer rainfall in East Asia (i.e. a weakening of East Asian summer monsoon). These observed climate changes can be accounted for if the landmasses were more strongly cooled than the oceans. The simplest mechanism behind such asymmetric cooling is the so-called 'umbrella effect' (increased cloud cover blocking solar radiation) that induces greater cooling of objects with smaller heat capacities.

Keywords: galactic cosmic ray, umbrella effect, cooling, East Asian monsoon, geomagnetic reversal, paleoclimatology





Kitaba et al. (2017) *Scientific Reports*

Study of flare prediction based on the critical condition of eruptive instability in the solar corona

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Solar eruptions, e.g. flares and CMEs, are believed to be the explosive liberation of magnetic energy contained in the solar corona. However, the onset mechanism of solar eruptions is not yet clearly explained. We have proposed that the feedback interaction between an ideal magnetohydrodynamic (MHD) instability driven by the electric current flowing in the solar corona and magnetic reconnection plays a crucial role to drive solar eruptions. However, the mode of instability and the critical condition of instability are not yet well understood. On the other hand, Moore et al. (2001) proposed that the tether-cutting reconnection between sheared magnetic fields may cause the solar eruptions. Recently, Ishiguro and Kusano (submitted to ApJ) clarifies that the double-arc electric current loop, which can be formed by the tether-cutting reconnection, can produce a new type of instability called double-arc instability (DAI). The objective of this study is to clarify the critical condition of the DAI using the three-dimensional MHD simulation and to apply the result to the prediction of solar eruptions. For these purposes, we have analyzed the correlation of a new parameter kappa, which is defined as the averaged magnetic twist of magnetic flux subject of tether-cutting reconnection, with the onset of eruption using the simulation data. Also, we analyzed the statistical property of magnetic twist of various active regions using SDO/HMI data and the nonlinear force-free field extrapolation technique to devise a new way to evaluate the criticality of active region for the DAI. We will discuss the prospects of physics-based new flare prediction based on those results.

Keywords: solar flares, CME, space weather forecasting

Solar flares in GOES X-ray flux forecast based on SDO/HMI and SDO/AIA images

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We have been studying methods for automated flare forecasts, and have been operating automated flare forecast services. The automated forecast of solar flares and other space-weather related events have two crucial goals. One is to enable real-time forecast and thus provide truely predictive test for the space weather theories. The other is to enable numerous variation of tailor-made space weather forecasts for various space weather users.

We have been building space weather prediction system UFCORIN (Universal Forecast Constructor by Optimized Regression of INputs), a software framework that can provide forecast based on generic time series data. Recently, we have been updating UFCORIN so that it can handle image time-series data in addition to scalar-values time series, with the help of convolutional neural network.

We have been operating space weather forecast since August, 2015 that provides 24-hour-ahead forecast of solar flares, every 12 minutes, based on the time-series data of GOES X-ray flux and wavelet features of the line-of-sight magnetic field images. However, the TSS for M and C class flares achieved so far has been approximately 0.3, much less than those values of 0.7-0.9 reported by simulated forecast studies. Especially, it is difficult to predict rim flares and those flares that take place on the East side of the Sun, where active regions have small, noisy features in magnetic field images. In order to better predict rim flares, we are now studying the effect of adding ultraviolet images to the input set, which includes solar rim information.

In this presentation, we report the method and prediction results of the system. In addition, we will report the results of adding ultraviolet images to the input data.

Keywords: Space Weather, Solar Flare Forecast, Solar Dynamics Observatory: SDO, Solar Physics

A New Solar Imaging System for Observing High Speed Eruptions: Solar Dynamics Doppler Imager (SDDI)

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A new solar imaging system was installed at Hida Observatory to observe the dynamics of flares and filament eruptions. The system (Solar Dynamics Doppler Imager; SDDI) takes full disk solar images with a field of view of 2520” x 2520” at multiple wavelengths around the H-alpha line at 6562A. Regular operation was started in May 2016, in which images at 73 wavelength positions spanning from H-alpha -9A to H-alpha +9A are obtained every 15 seconds. The large dynamic range of the line-of-sight velocity measurements (+/-400 km/s) allows us to determine the real motions of erupting filaments in 3D space. It is expected that SDDI provides unprecedented data sets to study the relation between the kinematics of filament eruptions and coronal mass ejections (CME), and to contribute to the real time prediction of the occurrence of CMEs that cause a significant impact on the space environment of the Earth.

Keywords: sun, prominence eruption, imaging system, CME

Global equatorial plasma bubble growth rates using ionosphere data assimilation

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In this study, Rayleigh-Taylor instability growth rates computed using the results of ionosphere data assimilation are used to investigate global plasma bubble occurrence. Thermosphere ionosphere electrodynamics global circulation model forecast results after assimilating total electron content measurements using ground network of global positioning system receivers are used in this work. The calculated growth rates are compared with rate of change of total electron content index (ROTI), estimated from global network of ground based global positioning system receivers, as well as ground based all sky airglow observations carried out over Taiwan. In contrast to the growth rates estimated using the model control run, the results after data assimilation show remarkable agreement with the ROTI. In addition, the all sky imager observations reveal intense bubble occurrence over Taiwan in the nights when the corresponding assimilated growth rates are significant. In the night of the St. Patrick’ s day storm on 17 March 2015, no plasma bubbles were recorded in the all sky images over Taiwan, which is supported by the smaller growth rates predicted by the assimilation model. The results further reveal that the significant improvement in the calculated growth rates could be achieved by the accurate forecast of zonal electric field in the data assimilation forecast. The results suggest that realistic estimate or prediction of plasma bubble occurrence could be feasible by taking advantage of the data assimilation approach adopted in this work.

Keywords: Equatorial Plasma Bubbles , RTI Growth Rate, Ionosphere Data Assimilation, GPS-ROTI

Predictability of thermosphere-ionosphere variations originating from the lower atmosphere using GAIA

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A numerical model of the whole atmosphere-ionosphere coupled model GAIA developed at National Institute of Information and Communications Technology (NICT) has been used to study various phenomena in the atmosphere and the ionosphere. The present version of GAIA employs the meteorological reanalysis data JRA-55 to incorporate lower atmospheric forcing to the model. Using the reanalysis data, the model is capable of reproducing actual day-to-day variations in the atmosphere and ionosphere. In space weather forecast, however, some users need information of ionospheric conditions for one or more days ahead. Since GAIA self-consistently solves the whole atmosphere and the ionosphere, it is expected that the model can reproduce realistic atmosphere and ionosphere for a certain period even without the reanalysis data. To test the predictability of thermosphere-ionosphere with GAIA, we compared two atmosphere-ionosphere simulation results: cases with and without reanalysis data starting from the same initial condition. We found that the two results are in reasonably good agreement for about one day, but that the difference becomes larger for more than two days. The result suggests that one-day prediction is possible with GAIA for variations in the thermosphere and ionosphere associated with lower atmospheric forcing.

Keywords: ionosphere, atmosphere, thermosphere, prediction, simulation, model

Forecasting the day-to-day occurrence of equatorial spread F in Southeast Asia

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We used ionosondes in Chumphon (CPN) (10.72˚N, 99.37˚E; Mag. Lat: 3˚N), Thailand; Bac Lieu (BCL) (9.30˚N, 105.71˚E; Mag. Lat: 1.5˚N), Vietnam; and Cebu (CEB) (10.35˚N, 123.91˚E; Mag. Lat: 3.09˚N), Philippines during equinox seasons from 2010 to 2016 to develop a forecast technique for equatorial spread F or plasma bubble generation. We considered that enhancement of vertical $\mathbf{E} \times \mathbf{B}$ drift after sunset in the equatorial region, so-called pre-reversal enhancement (PRE), is a primary factor for plasma bubble generation. We then used a "PRE threshold" to determine ESF whether generates or not. We collected 264, 121, and 206 nights for CPN, BCL, and CEB ionosondes, respectively. We used change of $h'f$ in time ($dh'f/dt$) during 18-19 LT from three ionosonde sites as a proxy for the vertical drift. The threshold is simply defined with a average value of vertical drifts obtained from all stations, and the value is 24 m/s. We defined the PRE 24 m/s and PRE < 24 m/s for the ESF on and off, respectively. We then compared our threshold method with the real occurrence of ESF for all stations, and the skill score is ˜0.7 for each station. We have also analyzed the skill scores by changing the threshold, and we found that the skill score of ˜0.7 is a maximum for each station. Thus, our study show that, using the average value of PRE as a threshold, it is enough to forecast ESF occurrence in Southeast Asian longitude with the maximum skill score in the "PRE threshold" method.

Keywords: Forecasting spread F, Pre-reversal enhancement, Threshold method, Space Weather

Numerical study of solar prominence formation: the reconnection-condensation model

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We propose a model in which magnetic reconnection triggers radiative condensation for solar prominence formation and demonstrate it by three-dimensional magnetohydrodynamic (MHD) simulations including anisotropic nonlinear thermal conduction and optically thin radiative cooling. Solar prominences are cool dense plasma clouds in the hot tenuous corona. Because prominences suddenly erupt and evolve into coronal mass ejections, they have potential to give an impact on the solar-terrestrial plasma environment. The formation mechanims of prominences as well as the eruption mechanism is still unclear. We propose a reconnection–condensation model in which the topological change of a coronal magnetic field via reconnection triggers radiative condensation for prominence formation. Previous observational studies suggested that reconnection at a polarity inversion line of a coronal arcade field creates a flux rope sustaining a prominence; however, the origin of the cool dense plasmas of a prominence was not clear. Using three-dimensional MHD simulations including anisotropic nonlinear thermal conduction and optically thin radiative cooling, we demonstrate that reconnection leads not only to flux rope formation but also to radiative condensation under a certain condition. This critical condition in our model is described by the Field length, which is defined as the scale length for thermal balance between radiative cooling and thermal conduction. This critical condition has a weak dependence on the artificial background heating. The extreme ultraviolet emissions through the filters of the Solar Dynamics Observatory Atmospheric Imaging Assembly synthesized with our simulation results have good agreement with observational signatures in previous studies.

Simulation of Theoretical Most-Extreme Geomagnetic Sudden Commencements

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1. University of Michigan Ann Arbor, 2. USGS Central Region Offices Denver, 3. National Center for Atmospheric Research

We report results from a numerical simulation of geomagnetic sudden commencements driven by solar wind conditions given by theoretical-limit extreme coronal-mass ejections (CMEs) estimated by Tsurutani and Lakhina [2014]. The CME characteristics at Earth are a step function that jumps from typical quiet values to 2700 km/s flow speed and a magnetic field magnitude of 127 nT. These values are used to drive three coupled models: a global magnetohydrodynamic (MHD) magnetospheric model (BATS-R-US), a ring current model (the Rice Convection Model, RCM), and a height-integrated ionospheric electrodynamics model (the Ridley Ionosphere Model, RIM), all coupled together using the Space Weather Modeling Framework (SWMF). Additionally, simulations from the Lyon-Fedder-Mobarry MHD model are performed for comparison. The commencement is simulated with both purely northward and southward IMF orientations. Low-latitude ground-level geomagnetic variations, both B and dB/dt, are estimated in response to the storm sudden commencement. For a northward interplanetary magnetic field (IMF) storm, the combined models predict a maximum sudden commencement response, Dst-equivalent of +200 nT and a maximum local dB/dt of ~200nT/s. While this positive Dst response is driven mainly by magnetopause currents, complicated and dynamic Birkeland current patterns also develop, which drive the strong dB/dt responses at high latitude. For southward IMF conditions, erosion of dayside magnetic flux allows magnetopause currents to approach much closer to the Earth, leading to a stronger terrestrial response (Dst-equivalent of +250 nT). Further, high latitude signals from Region 1 Birkeland currents move to lower latitudes during the southward IMF case, increasing the risk to populated areas around the globe. Results inform fundamental understanding of solar-terrestrial interaction and benchmark estimates for induction hazards of interest to the electric-power grid industry.

Keywords: Space Weather, Geomagnetically Induced Currents, Magnetosphere

Unified theory of substorm auroral sequence

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As the observational appearance, the substorm consists of four consecutive periods, the growth phase, the onset, the expansion phase, and the recovery phase [McPherron, 1970, 1979]. According to the development of these phases, various auroral forms occur sequentially in the ionosphere together with the corresponding auroral current system [Elphinstone et al., 1993; Kamide et al., 1996]. It is extensively studied how auroras and associated geomagnetic perturbations occur in the ionosphere. The problem is their origins in the magnetosphere. The key mechanism is the magnetosphere-ionosphere (M-I) coupling process realized by the exchange of the field-aligned current (FAC) between the ionosphere and the magnetosphere. Especially, the origin of arc type auroras must coexist with the source mechanism of the upward FAC. In this paper, we try to discuss the substorm mechanism recognizing that the generation process of the FAC has a crucial importance. We consider two main points to understand the generation of the FAC. The first point is to understand the FAC as the mechanism which transmits the motion from the magnetosphere to the ionosphere [Iijima, 2000; Birn and Hesse, 2013; Tanaka, 2015]. In other words, if there is an arc aurora, we must identify the motion (shear) that should be transmitted. The second point is to understand the FAC as the energy supplier that compensates the ionospheric dissipation to maintain the convection. For this purpose, we must search for the dynamo that energize the FAC [Tanaka, 2007; Kikuchi, 2014; Tanaka et al., 2016]. These points are clarified from the global simulation which gives numerical solutions having an extremely high resolution. The substorm solution obtained from the high-resolution simulation reproduces the precise sequence of the substorm in the ionosphere. It can reproduce sequentially the quiet arc during the growth phase, initial brightening at the onset, and the westward traveling surge (WTS) during the expansion phase. It even reproduces the onset that starts from the equatorward side of the oval, two step development of the onset aurora, and the WTS that starts two minutes after the initial brightening. Then, we investigated the counter structures in the magnetosphere that correspond to each aurora in the ionosphere. The structure in the magnetosphere promoting the initial brightening is the near-earth dynamo in the inner magnetospheric region away from the equatorial plane. The near-earth dynamo is driven by the field-aligned pressure increase due to the parallel flow associated with the squeezing, combined with equatorward field-perpendicular flow induced by the near-earth neutral line (NENL). The dipolarization front is launched from the NENL associated with the convection transient from the growth phase to the expansion phase, but neither the launch nor the arrival of the dipolarization front coincides with the initial brightening. The arrival of flow to the equatorial plane of the inner magnetosphere occurs two minutes after the onset, when the WTS starts to develop toward the west. Looking at the present result that the onset is induced by the near-earth dynamo and the details of auroral sequence is understood from it, we cannot avoid to conclude that the current wedge (CW) is a misleading concept.

Keywords: Substorm aurora sequence, Field-aligned current, Near-earth dynamo

Geomagnetic storms of March 17, 2013 and 2015: GPS phase scintillation and auroral electrojet currents

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Interplanetary coronal mass ejections compounded by high-speed plasma streams from coronal holes caused two intense geomagnetic storms on March 17-18, 2013 and 2015 during the current solar cycle. Using arrays of ground-based instruments including GPS receivers, HF radars, ionosondes, riometers, all-sky imagers and magnetometers, GPS phase scintillation is studied in the context of solar wind coupling to the magnetosphere-ionosphere system comparing the two storms. The phase scintillation index is computed for signals sampled at a rate of 50 Hz by specialized GPS scintillation receivers. It is supplemented by the phase scintillation proxy index obtained from geodetic-quality GPS data sampled at 1 Hz. We examine the relation between the scintillation and auroral electrojet currents observed by arrays of ground-based magnetometers as well as energetic particle precipitation observed by the DMSP satellites. Equivalent ionospheric currents are obtained from ground magnetometer data using the spherical elementary currents systems technique that has been applied over the ground magnetometer networks in North America and northern Europe. For both storms, preliminary results indicate that the GPS phase scintillation is mapped to strong westward electrojet and to the poleward edge of the eastward electrojet. GPS phase scintillation is mostly absent or low in the auroral zone when the electrojets are weak.

Keywords: Polar and auroral ionosphere, Ionospheric irregularities, Ionospheric currents, Radio wave propagation, Space and satellite communication, Space weather, Impacts on technological systems

GPS phase fluctuations associated with high speed flows in the cusp ionosphere

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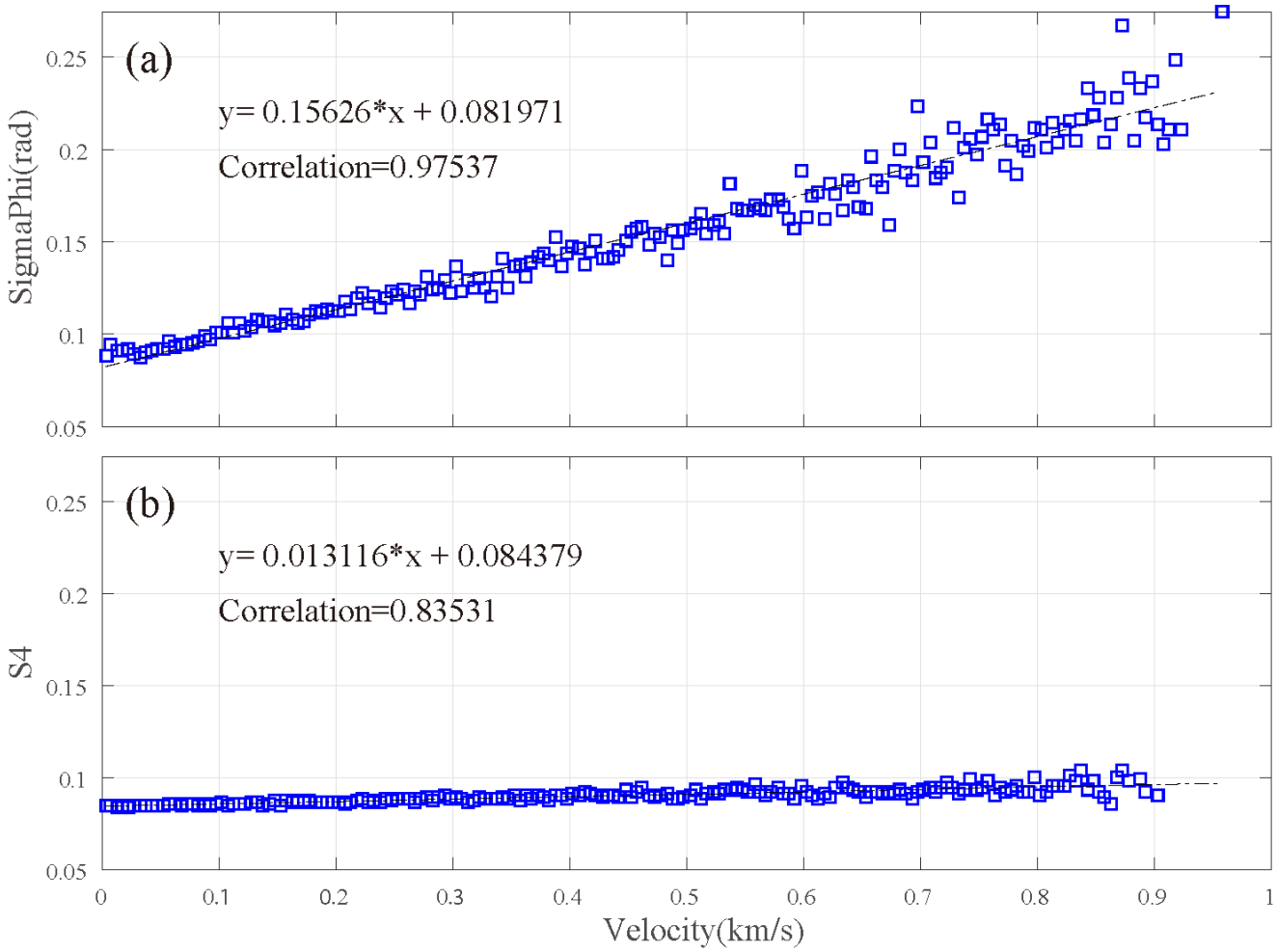
Using ionospheric scintillation measurements from GPS receivers of Canadian High Arctic Ionospheric Network (CHAIN) and flows measured by both of Kapuskasing (KAP) and Saskatoon (SAS) SuperDARN radars, we found that near cusp region the GPS phase scintillations fluctuated mostly associated with the varied velocity of flows. After statistic study over a 3 year period (2013-2015), a surprising result will be presented in this work that it is nearly linear relationship between GPS phase fluctuations and flows around cusp region. On the contrary, the behavior of GPS amplitude scintillations is always quiet even with higher velocity of flows, which is obviously different from the manners of phase fluctuations. The two various different performance associated with high speed flows may caused by differentiated dependency of flows of their possible generation mechanisms. The results will be useful to further study the scintillation mechanisms and can help to improve the scintillation models in polar region.



Current status of SCOSTEP/VarSITI - Variability of the Sun and Its Terrestrial Impact (2014-2018)

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The Scientific Committee On Solar-TErrestrial Physics (SCOSTEP) operates the unique scientific program "Variability of the Sun and Its Terrestrial Impact" (VarSITI) in 2014-2018 to focus on the recent and expected future solar activity and its consequences for the Earth, for various time scales from the order of thousands years to milliseconds, and for various locations and their connections from the solar interior to the Earth's atmosphere. Four scientific projects are carried out under the VarSITI program: (1) Solar Evolution and Extrema (SEE), (2) International Study of Earth-Affecting Solar Transients (ISEST/MiniMax24), (3) Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN), and (4) Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate (ROSMIC).

In order to elucidate various Sun-Earth connections, VarSITI has encouraged close communications between solar scientists (solar interior, atmosphere, and heliosphere) and geospace scientists (magnetosphere, ionosphere, and atmosphere). We have carried out observation/data analysis campaigns for particular intervals, such as ISEST/Minimax24 campaign (http://solar.gmu.edu/heliophysics/index.php/The_ISEST_Event_List) for Earth-affecting solar transients, ICSOM campaign (http://pansy.eps.s.u-tokyo.ac.jp/icsom/) for interhemispheric coupling during stratospheric sudden warming, and ERG-ground campaign for the dynamics of inner magnetosphere. We have supported more than ten VarSITI-related meetings and several campaign and database constructions every year using the SCOSTEP/VarSITI grants. VarSITI mailing list, which contains ~900 mail addresses from ~70 countries, was constructed for communications among scientists on various fields. VarSITI newsletters have been published every three months to introduce new scientific results, young scientists newly joined into the VarSITI science, and meeting reports. About 130 databases are registered for VarSITI-related research activities. All this information is available at the VarSITI web pages at http://www.varsiti.org/.

After the first three years of the VarSITI program, various outstanding results has been obtained, such as solar dynamo simulations, imaging measurements of earth-affecting solar transients, high-energy particle precipitation on the Earth's atmosphere and its consequence on the ozone and other constituents in the upper and middle atmosphere, and effects of lower atmosphere to the thermosphere and ionosphere through the middle atmosphere. In the presentation we will review these various recent results obtained during the VarSITI period.

Keywords: VarSITI, SCOSTEP, Sun-Earth Relationship

Starspot activity and superflares on solar-type stars

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Recent space-based observations (e.g., Kepler mission) enable us to investigate the nature of “superflares” on solar-type stars (G-type main sequence stars). The bolometric energy of superflares ranges from 10^{33} erg to 10^{36} erg which is 10-10^4 times larger than that released by a typical X10 class solar flare. Most of the stars with superflares show large-amplitude photometric variations associated with the stellar rotation which suggest that the stars with superflares have large starspots. Spectroscopic studies of superflare stars revealed that the chromospheric activity correlates with the amplitude of brightness variations.

We analyze the correlation between starspots and superflares on solar-type stars using the data from the Kepler mission. Our analysis shows that the fraction of the stars showing superflares decreases as the rotation period increases and as the amplitude of photometric variations, which is thought to correlate with the area of starspots, decreases. We found that the fraction of superflare stars among the stars with large starspots also decreases as the rotation period increases. This suggests that some of the slowly-rotating stars with large starspots show a much lower flare activity than the superflare stars with the same spot area and rotation period.
Assuming simple relations between spot area and life time and between spot temperature and photospheric temperature, we compared the size distribution of large starspots with the area of $>10^4$ MSH (micro solar hemispheres; 1 MSH=3×10^{16} cm^2) on slowly-rotating solar-type stars with that of sunspot groups. The size distribution of starspots shows the power-law distribution and that of larger sunspots lies on the same power-law line. The size distribution of spots from the Kepler data suggests that the average appearance frequency of the starspots with the area of $>3\times10^4$ MSH on the solar-type stars with the rotation period similar to that of the Sun is once in a few hundred years.
We also found that the frequency-energy distributions for flares originating from spots with different sizes are the same for solar-type stars with superflares and the Sun. These results suggest that the magnetic activity on solar-type stars with superflares and that on the Sun is caused by the same physical processes.

Keywords: flare, starspot

Solar flare impulsivity and its relationship with white-light flares and with CMEs

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There are many types of classification in solar flares. One of them is a classification by flare duration in soft X-rays; so-called impulsive flare and long duration event (LDE). Typically, the duration of an impulsive flare is shorter than 1 hour, and that of an LDE is longer than 1 hour. These two types of flare show different characteristics. In soft X-rays, impulsive flares usually have a compact loop structure. On the other hand, LDEs show a relatively large-scale loop, sometimes a large arcade structure. In hard X-rays, the difference appears clear, too. The former shows a strong and short-time (<10 minutes) emissions and intense double footpoint sources and sometimes a weak loop-top source. LDEs have relatively weaker and longer (>10 minutes) emissions and show a large coronal source. These facts suggest that hard X-ray observation becomes one of a good indicator to classify solar flares, especially for the study on the particle acceleration and the related phenomena. However, hard X-ray data do not always exist due to the satellite orbit and the small sensitivity of hard X-ray instruments. So, in this study, based on the concept of the Neupert effect (Neupert, 1968), we use soft X-ray derivative data as the proxy of hard X-ray. From this data, we define impulsivity (IP) for each flare. Then we investigate solar flares using this new index. First we apply IP index to our white-light flare research. We have already performed a statistical analysis of white-light flare to reveal the physical conditions to generate white-light enhancements. We investigate how white-light enhancement depends on IP, then it is found that white-light flares tend to have large IP values. So the flare impulsivity (IP) is one of the important factors if white-light enhancement appears or not in a solar flare. Next we investigate how CME physical parameters depend on IP index. It has been believed that most of CMEs are associated with LDEs, but we found that there is only a weak correlation between the existence of CME and IP index. We couldn’t find any relationship between CME physical parameters (speed, mass, energy) and IP. Finally, we also search for the relationship between white-light flare and CME as a function of IP and discuss the physical condition of white-light flare.

Keywords: solar flare, white-light, CME

The Relation between Time-Series Characteristics of Solar Active Region Magnetic Field Properties and Flare Activity

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Solar flares suddenly release an immense amount of energy mainly in the form of electromagnetic radiation, and consequently they can cause major disturbances in the Sun-Earth environment. An accurate prediction of flares is therefore crucial for protecting our space assets and the safety of astronauts and navigation systems. In this study, we investigated a statistical data set of 8-day time series of 18 magnetic field parameters in 94 flaring solar active regions (ARs) in 2010 to 2016. The time series data were derived from 12-min cadence photospheric vector magnetograms observed by SDO/HMI. For each AR under investigation, we calculated the mean values of the magnetic parameters from their corresponding time series data, as well as the fluctuations using detrended fluctuation analysis. Then, the mean values and fluctuations were compared with the sum of peak soft X-ray intensities of flares produced in the investigated AR (called flare index) during the eight days. As a result, we find the mean of time series of parameters measuring magnetic non-potentiality of ARs, such as vertical current, current helicity and free magnetic energy density, have a good correlation with the flare index: i.e., their correlation coefficients (CCs) are higher than 0.58. Especially, the mean of AR vertical current time series has a fairly good correlation with the flare index (CC=0.64). It is also found that the fluctuation of AR current helicity time series is well correlated with the flare index (CC=0.68). These results show that the mean and fluctuation of time series of AR non-potential magnetic parameters can be considered as a useful measure for estimating AR’ s flaring activity over the entire time series. Moreover, it is expected that further time series analysis can help improve flare prediction.

Keywords: Sun, Solar Flares, Time Series Analysis

Solar Flare Prediction using the Machine-learning and Operational Evaluation Method

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We have developed a flare prediction model using solar observation data and machine-learning techniques. From the full-sun images, we extracted features such as photospheric magnetic field, chromospheric brightening and X-ray activities in each active region, and then we predicted the maximum class of flares occurring in the following 24 hours (Nishizuka et al., 2016, oral presentation in JpGU). However, a standard evaluation method of flare prediction models has not been established. Moreover, under the sever condition that the test dataset is completely independent from the training dataset in an operational setting, we could not predict solar flares with high accuracy.

In this presentation, we introduce a method of the time-series cross-validation (CV) to evaluate flare prediction models in an operational setting, though the k-fold (10-fold) CV has ever been used in the previous studies. In some sense, these two methods are reasonable and available. However, when we focus on the operational usage, the time-series CV is superior to the k-fold CV. Furthermore, we used a machine-learning algorithm called the Gradient Boosted Trees for the first time. The boosting is a method to minimize the loss function by sequentially adding weak classifiers, or decision trees in our model. This is used to achieve a better prediction, by repeating learning of the calculation of the gradient when optimizing parameters in each step. We applied this algorithm to the flare prediction and performed the time-series CV. As a result, we succeeded in improving our prediction score, a skill score called the true skill statistic, from 0.2 to 0.6 for X-class flares and to 0.8 for M-class flares. We also compared the performance of other five different machine-learning algorithms to predict flares, and we found that the ranking of the performance of the algorithms completely differs according to the CV method.

Keywords: Solar Flare , Prediction, Modeling , Machine-learning, Evaluation Method

Energy Budget in Cold Solar Flares Observed with Nobeyama Radioheliograph

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The energy source of solar flare is magnetic energy in the solar corona. When a solar flare takes place, this energy is impulsively released, and it is converted to other kinds of energy such as thermal energy (plasma heating), kinetic energy (mass ejection), and energy of high-energy particles (particle acceleration). The ratio of these three energies seems different in each solar flare. Some solar flares show thermal energy is dominant and the others do non-thermal energy of accelerated particles is dominant. What controls the energy conversion ratio? This is so-called energy budget problem in solar flares.
A hint to solve this problem could be provided by some extreme flares such as thermal-rich flares and purely nonthermal flares. In this study, we focused on so-called cold flare which shows significant nonthermal emissions with relatively very small amount of thermal emissions. We have already analyzed a cold solar flare occurring on 10 March 2011. This flare was well observed with Nobeyama Radioheliograph (NoRH). It shows a significant microwave enhancement (about 210 SFU at 17GHz). This microwave enhancement is produced via gyro-synchrotron emissions by high-energy electrons. However, any significant enhance was not found in the GOES X-ray light curve during the flare period. RHESSI did not observe this flare, but Suzaku detected hard X-rays in the energy range above 100 keV. So it was confirmed that electrons were actually accelerated while plasma heating process did not work well in this flare. The characteristics of this flare were short duration and very compact size. From these facts, we concluded that the magnetic field of the loop top region might be very intense. This might be a key how a cold flare is produced. To confirm this, we need more analyses of similar events. From the event list of NoRH, we pick up candidates of cold flares which show a significant microwave enhancement without any counterpart in soft X-rays and analyze them. The characteristics seem to be the same as the previous event. Then we discuss why thermal emissions (plasma heating) are suppressed in these flares.

Keywords: Solar flare, radio, particle acceleration

Statistical analysis of solar flare multi-wavelength observation data

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Impulsive energy release phenomena such as solar flares, sometimes affect to the solar-terrestrial environment. Usually, we use soft X-ray flux as the index of flare scale. However, the magnitude of effect to the solar-terrestrial environment is not proportional to the GOES X-ray class. To identify the relationship between solar flare phenomena and influence to the solar-terrestrial environment, we need to understand the full spectrum of solar flares. For this purpose, we are performing statistical analysis of electromagnetic data of solar flares. In this study, we use solar flare events lager than C3-class from the Hinode flare catalogue (Watanabe et al., 2012). We use the soft X-ray flux, flare duration, location, and type and size of flaring active region as the fundamental parameters of a solar flare. For the first step, we focus on the flux of EUV emission, because the sudden ionospheric disturbance(SID) is caused by a solar flare especially due to soft X-ray and UV emissions. We use EUV data from the Extreme Ultraviolet Variability (EVE) onboard the Solar Dynamics Observatory (SDO). We examined the EUV lines (Fe VIII, Fe XII, Fe XV, Fe XVIII, Fe XX) for 111 events larger than M3-class flares, and found positive correlation between the “soft X-ray flux” and the “EUV peak intensity” for all lines. The “EUV peak time” of hot lines are earlier than that of cool lines. Next, we examined the relationship between the size of flaring active regions and the flare intensity. We found very weak correlation between them when we plot 5578 flare events larger than C-class from November 2006 to July 2016. In addition, we also check the occurrence timing of flare events during evolution or dissipation of active region, and found that there is no relationship between them. Then, we also examined the hard X-ray data obtained by Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). We also found correlation between the hard X-ray intensity and the soft X-ray intensity, especially in low energy. In this paper, we also show the spectral index of hard X-ray spectra, and discuss their relationship for other electromagnetic emissions.

Keywords: solar flare, solar flare spectra

Study of double arc instability causing the onset of solar eruption

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The stability of magnetic flux rope in the solar corona is an important issue for the understanding what causes solar eruptions, such as solar flares and coronal mass ejections (CMEs). Although various scenario has been suggested for this problem, the tether-cutting reconnection scenario suggested by Moore et al. (2001) is widely accepted. However the stability of double arc loop, which can be formed by tether-cutting reconnection of sheared magnetic field before eruption, has not been analyzed yet.
To explain such a solar eruption based on the tether-cutting reconnection model, recently we suggested Double Arc Instability (DAI). In this theory, we numerically analyzed the stability of double arc electric current loop in the same method as the axisymmetric torus instability developed by Demoulin & Aulanier (2010). As a result, we found that the double arc loop is more easily destabilized than the axisymmetric torus, and that it becomes unstable even if the external field is not decayed with altitude in contrast to the axisymmetric torus instability. It suggests that the tether-cutting reconnection can efficiently work as the onset mechanism of solar eruption, and that the decay index does not necessarily need to be larger than a criteria to trigger solar eruptions, while the torus instability can play a role in the full eruption of the flux rope to inter-planetary space. We discuss the critical conditions for the DAI to grow in the force-free magnetic field and derive that the critical parameter , which is defined as the product of the magnetic twist and the normalized tether-cutting reconnecting flux, must be larger than a certain threshold to destabilize DAI. Finally, we develop three-dimensional MHD simulation of the DAI to analyze the onset process of solar eruption in more realistic configuration of magnetic field.

Keywords: Sun, flares, instability

The statistical analysis of correlation between solar flares and photospheric magnetic field

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A solar flare is caused by the explosive release of magnetic energy and sometimes greatly disturbs the Earth’ s electromagnetic environment and may impact socio-economic system. For that reason, the prediction of flare occurrence is important for space weather forecast. However, the accurate prediction of flare occurrence has not been realized yet, because the mechanism of flare trigger is not well understood yet. According to previous studies, some parameters, such as the area of active region, total magnetic flux, the magnetic shear on PIL and the magnetic gradient have certain relation with the flare activities. Recently, Kusano et al. (2012) indicated that the magnetic reconnection in the small magnetic structures that appear in the strong-sheared magnetic field near the magnetic polarity inversion lines can trigger solar flares. In addition, Ishiguro & Kusano (M25a for ASJ meeting 2016 in March) found a possibility that the magnetic twist causes instability which is able to cause flares and CMEs.
The object of this study is to give a new parameter related to flare activity on the basis of these previous studies. In order to achieve it, we have performed the statistical analysis of magnetic field data on photosphere surface. For 294 ARs which sunspot area is relatively large in 2012 to 2016, we took the correlation analysis on the total flux and various magnetic parameter in each AR using the magnetic field data of SDO/HMI. The results suggest that not only magnetic free energy but also the shape of distribution of magnetic free energy correlates with the flare activity. We report the preliminary results of the analyses and discuss about the application to space weather forecast.

Keywords: Solar flare, Space weather, SDO/HMI

Investigation of meridional flow pattern from mangetic elements motion

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Meridional flow, which is considered a persistent flow pattern along North-South direction, is important for solar dynamo problem. Despite its importance, observation of the meridional flow pattern is difficult because the amplitude is just ~10 m/s, which is just a few percent of that of convective flow pattern covering the solar surface. Hathaway and Lightmire (2010) succeeded in detecting the meridional flow pattern as an advection of magnetic region patterns between consecutive magnetograms obtained by SoHO/MDI. However, their study is limited to investigate the averaged pattern of magnetic region, not each magnetic element. Hence we try detecting the meridional flow pattern in the magnetic elements' motion in this study, which is more direct detection and enable us to investigate deeper character of the flow.

North-south anisotropy in magnetic elements' motion is invetigated in the magnetograms obtained by Helioseismic and Magnetic Imager (HMI) onboard Solar Dynamics Observatory (SDO). The magnetic elements are tracked by feature-tracking method of magnetic concentrations which is developed by the author. Our feature-tracking method and one-month magnetograms of SDO/HMI enable us to analyze huge number of magnetic elements' motion. More than 5,000 elements are recegnized in one magnetogram with our detecting threshold and 10^8 displacements are obtained as total in our analysis. We found a small anisotropy along north-south direction and it shows similar latitudinal dependence obtained in Hathaway and Lightmire (2010), namely its amplitude increases up to ~14 m/s from the equator to ~60 degree in north and south hemisphere. Further we investigate the dependence of flow strength on magnetic elements character and newly found that larger elements have larger flow strength.

Keywords: Sun, Magnetic Field, Surface Flow

Reversed Rotation of the Sunspot and the X2.1 Flare in the Active Region NOAA12297

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We study the evolution of the magnetic field of the active region NOAA 12297 before and after the X2.1 flare. The main sunspot of this region rotated in a clockwise direction in the initial stage. After very rapid flux emergence between the sunspot and another emerging region, shear flow was enhanced and this sunspot started to rotate counterclockwise. This motion of the sunspot injected magnetic helicity opposite to global magnetic twist of the active region. As the magnetic flux emerged, the rotational speed got faster by Lorentz torque and magnetic non-potentiality developed. The rotational rate reached ~2.5 deg/h at the fastest. Soon after the occurrence of the X2.1 flare on 2015 March 11 the rotation rate began to decrease, and other physical parameters changed their behaviour. On 2015 March 13, the sunspot rotated in a clockwise dairection again. Based on this observation, we advocate that not only the flux emergence near the sunspot, but also the rotation of sunspot is needed for energy build-up and the occurrence of great flares. Our result implies that helicity injection opposite to that of the global structure is important for destabilization of magnetic field or the onset of solar flares.

Keywords: Sun, Flare, Sunspot, Energy build-up, Magnetic helicity

Quantitative relationship between Mid-latitude ionospheric ExB drift and equatorial electrojet as a function of solar zenith angle

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In order to estimate the penetration electric fields in the mid-latitude ionosphere from the equatorial electrojet (EEJ), we analyzed stormtime global Pc5 magnetic pulsations. During the recovery phase of the geomagnetic storm on 31 October 2003, the HF Doppler sounder detected large amplitude oscillations in the ionospheric electric field at mid-latitude (Oarai and Sugadaira, Japan) over 10 hours from 11 to 21 LT. Prolonged excitation of Pc5 pulsations were recorded on the magnetometer data at high-to-equatorial latitudes with significant amplitude enhancement at the dayside equator. We deduced the EEJ by subtracting the low latitude Pc5 (Okinawa) from the equatorial Pc5 (Yap) and found that the ExB drift velocity (Vvert) in the mid-latitude is well correlated with the EEJ with correlation coefficients of 0.80-0.95 and that the EEJ to Vvert ratio reached maximum at 11 LT and dramatically decreased until 18 LT as a function of cos(solar zenith angle) for the zenith angle less than 92 degrees. The quantitative relationship is evaluated by estimating the root mean square error of 2.5 m/s for afternoon sector and 1.8 m/s for dusk sector, which is small enough compared to the observed Vvert of 15-40 m/s. On the other hand, the electric field at mid-latitude is well correlated with the EEJ even during the night after 19 LT (zenith angle > 100 degrees), showing that the EEJ to mid-latitude Vvert ratio is almost constant, on average 1.65. This result indicates that the Pc5 electric field is so strong as to drive equatorial electrojet in the nighttime ionosphere. By applying the quantitative relationship to other longitudes, such as Sao Luis in Brazil, Addis Ababa in Ethiopia, we estimated a local time distribution of the electric field at the mid-latitude and obtained the day-night asymmetry of the electric field.

Keywords: ionospheric electric field, equatorial electrojet, ExB drift velocity, mid-latitude ionosphere, HF Doppler

On the relationships between EEJ distribution and plasma bubble occurrences

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To understand the relationship between distributions of Equatorial Electro Jet (EEJ) along dayside dip-equator and generation characteristic of plasma bubble, we investigate how Local Time (LT) dependence of EEJ amplitude is relating to the plasma bubble occurrences. The LT dependence of the amplitude of EEJ is characterized by using integrated value of EUEL of EE-index (produced by ICSWSE, Kyushu University) at daytime (07:00~17:00LT), noon time (09:00~15:00LT) and evening time (17:00~19:00LT)). While plasma bubble occurrence is determined by S4 index of ionospheric scintillation produced by ISEE, Nagoya University. In this study, EUEL data at equatorial station: Langkawi, Malaysia (GG Lon. =99.78, Dip Lat. =-1.07), and S4 data at Kototabang, Indonesia (GG Lon. =100.32, Dip Lat. =-10.1) from 1 January 2011 to 8 November 2014 are used to investigate the relationship between EEJ and the scintillation. Our result shows that there are relationship between plasma bubble occurrence and integrated EUEL value in all the above period; larger integrated EUEL value, larger occurrence rate of plasma bubble. Moreover it turned out that plasma bubble tends to be suppressed when integrated EUEL value in the evening is negative. Our result for evening side is consistent with previous study of Uemoto et al., [2010], while the one for daytime does not. This might be due to different way of EEJ amplitude estimation was used. In our study, EUEL value at Langkawi not only reflects EEJ amplitude but also background Sq disturbances. While in the study of Uemoto et al., [2010], EEJ amplitude is estimated by purely equatorial enhancement and/or equatorial depression component. Our results strongly suggested that plasma bubble occurrence is not only controlled by the Equatorial enhancement but also Sq structure near dip equator.

Keywords: Equatorial ElectroJet, Plasma Bubble

Solar cycle variation and its impact on Critical Frequency of F layer

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The period of approximately 11 year cycle of solar activity is characterized by the rise and fall in the numbers and surface area of sunspots. We observed a number of other solar activity indices, including the 10.7 cm radio flux, solar Mg II core to wing ratio ,relative sunspot number Rz and solar flare index and geomagnetic activity that vary in association with the sunspots for solar cycles 21,22 and 23 (1976–2008).This paper we presents an analysis of the F-region variability of the ionospheric parameter foF2 at mid latitude station Hobart (Hobart is a town in County Australia) Latitude:- 42.8806˚ S and Longitude: 147.3250˚ E during in the whole period (1976–2008) of solar cycle-21,22,and 23. The diurnal, monthly, yearly and cycle to cycle characteristics of these ionospheric F-region parameter foF2 have been studied in detail. We also compared the dependence of foF2 on solar activity indices by using a correlation analysis, and showed that a significant linear relationship between the foF2 values and Solar indices. The foF2 variation is strongly influenced by solar activity with about an 11-year solar cycle from the solar maximum to solar minimum.

Keywords: Solar cycle, foF2, , geomagnetic indices, correlation

Analysis of the ISEST/MiniMax24 WG4 campaign events on the linkage between CMEs and solar wind disturbances

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The ISEST/MiniMax24 is one of the four projects of VarSITI. Its objectives and goals are to understand the propagation of solar transients through the space between the Sun and the Earth, and develop space weather prediction capability. Toward the goals the ISEST/MiniMax24 Working Group 4 organized a campaign study by selecting 11 solar-terrestrial events. We examined the solar wind data during each period of the campaign events and identified flux rope structure in 9 cases. Then geometries of 9 interplanetary flux ropes (IFRs) were determined by a model-fitting method and compared them with magnetic structures in their solar source regions. As a result, we could confirm the general coincidence between the IFR orientations and the orientations of the polarity inversion lines (PILs) in the corresponding solar source regions. The results are summarized in Table 1. This analysis result suggests a possibility for predicting variations of solar wind magnetic fields associated with flux ropes basically by observing the causative solar eruptions. However, we found several cases in which prediction needs the precise knowledge about the flux rope structure and where the Earth encounters it with a flux rope. We report the relationships between the IFRs and the corresponding PILs with emphasis upon how the observed magnetic fields are determined by the encountering geometries.

Keywords: magnetic flux rope, coronal mass ejection, polarity inversion line

Table 1

Event ID	model	IP Flux Rope		Solar Source		S/C
		R/L	IFR tilt	N/S	PIL tilt	
1. 2012 Jul 12-14	cylinder	R	320°	S	325°	WIND
2. 2012 Oct 04-08	torus	R	323°	S	330°	WIND
3. 2013 Mar 15-17	torus	L	227°	N	230°	ACE
4. 2013 Jun 01	torus	L	272°	N	---	ACE
5. 2015 Mar 15-17	torus	R	173°	S	165°	ACE
6. 2015 Jun 22-24	Special Analysis underway					A/W
7. 2012 Mar 07-09	torus	L	37°	N	42°	WIND
8. 2012 Jul 23-24	cylinder	R	258°	S	(260°)	STEREO-A
9. 2014 Jan 06	No flux rope signature (Limb event)					A/W
10. 2014 Jan 07-09	No flux rope signature (Deflected, Möstl)					A/W
11. 2014 Sep 10-13	torus	L	247°	N	245°	

Statistical characteristics of interplanetary magnetic field near the Earth

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Space weather creates geomagnetic disturbances that can impact our life. There are many reasons that cause space weather changes, and the interplanetary magnetic field (IMF) is the most important one. Compared with other components, IMF Bz is an immediate cause as it is a parallel component to the geomagnetic field. Intense geomagnetic disturbance can be made by magnetic reconnection which can occur more strongly when the magnitude of southward IMF Bz is stronger. Nevertheless, until to date, it has not been trivial to predict IMF Bz. In this work we analyze the statistical properties of IMF Bz measured at L1 point using the data from 1996 to 2015 corresponding to a solar cycle and a half. In this study, we classify the IMF data into three groups. They are IMF conditions associated with CME, those with CIR+HSS (high-speed stream) and the remaining ordinary conditions. We find that a majority (84%) of the IMF data are during the ordinary conditions, only 5% are related to CME structure and ~11 % are associated with CIR+HSS. In order to study geoeffectiveness, we have examined relativistic electron (>2MeV) flux response at geosynchronous orbit and compared them among the three groups. We have also investigated AL index. We find that the geomagnetic response in terms of AL and geosynchronous electron flux is non-negligible during the ordinary solar wind condition intervals compared to those of CME and CIR+HSS. In addition, we examine the correlations of IMF Bz with various solar wind parameters to determine the most responsible factors for southward IMF Bz.

Numerical Study of Double-Cell-Type Solar Meridional Circulation Based on a Mean-Field Hydrodynamic Model

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Large-scale flow structures of the Sun, differential rotation and meridional circulation, play crucial roles in generating and sustaining the solar magnetic fields through the dynamo mechanism. In the framework of flux-transport dynamo model, most of the previous kinematic simulations have assumed a single-cell meridional circulation so that equator-ward migration of sunspot groups could be attributed to the equator-ward transport of toroidal magnetic fluxes by the meridional flow at the base of the convection zone. However, recent helioseismic observational results suggest the possibility of a double-cell structure for the meridional circulation with the pole-ward flow at the base, demanding some modifications for the conventional flux transport dynamo model. Therefore, the theoretical investigations on the maintenance mechanism of this double-cell meridional circulation is regarded as of a great importance.
By conducting mean-field hydrodynamic simulations where the effect of the angular momentum transport by the Reynolds stress is parameterized, we calculate the structures of differential rotation and meridional circulation self-consistently and investigate whether or not double-cell meridional circulation could be achieved along with the solar-like differential rotation. As a result, we find out that the double-cell meridional circulation can be achieved when the Reynolds stress transports angular momentum upward in the lower convection zone and downward in the upper layer. We confirm that, in the steady state, the accumulated angular momentum via the Reynolds stress in the middle layer is advected to both the upper and lower part of the convection zone by each of the upper and lower meridional circulation cells, respectively.

Keywords: The Sun, Convection

Results from the daily solar segmentation (SOLARSEG) of EUV images over a 5-years period: correlation and periodicity of the EUV irradiance.

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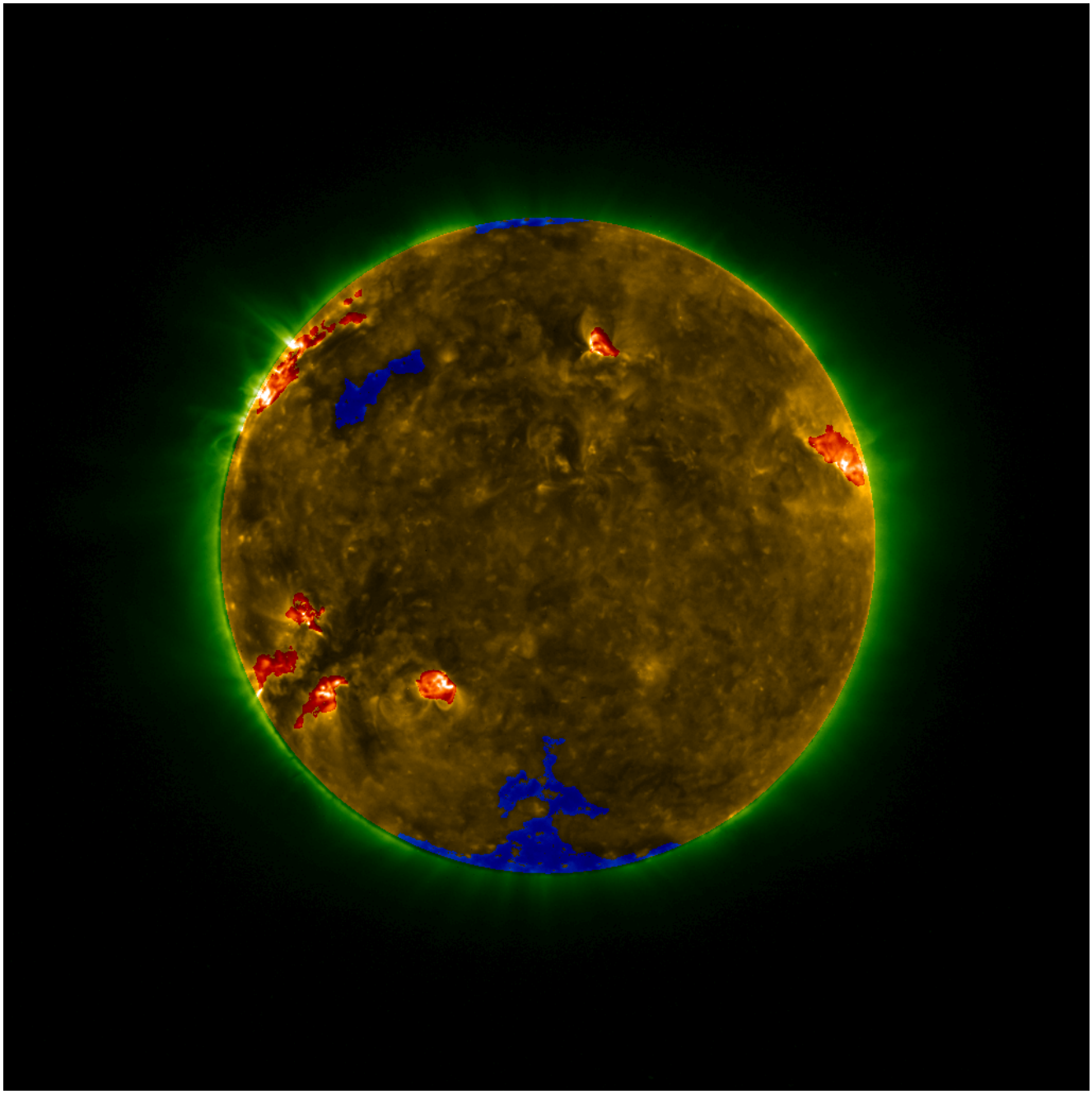
Understanding the variability of the EUV and UV irradiance on time scales from hours to months is of critical importance in the context of the Sun-Earth connection. A promising method to study the impact of the different coronal features, such as active regions and coronal holes, is by using segmentation algorithm on full-disc EUV images. In this respect, we created the Solar Segmentation (SOLARSEG) pipeline, based on the Spatial Possibilistic Clustering Algorithm (SPoCA) segmentation algorithm, which has been continuously producing daily maps (4h cadence) of the active regions (ARs) and coronal holes (CHs) using EUV images from the Atmospheric Imaging Assembly (SDO/AIA) starting from January 2011. The segmented maps were used to extract the EUV irradiance from these regions of interest using the different wavelengths provided by the AIA instrument. Initial comparison with the full-disk EUV irradiance recorded by the Large Yield Radiometer (PROBA2/LYRA) indicated a strong correlation with the irradiance extracted from EUV images, proving the usefulness of image segmentation to estimate the EUV irradiance from the different features. Maps were also be applied to other imaging instrument, namely the Sun Watcher with Active Pixel System detector and Image Processing (PROBA2/SWAP) and the Helioseismic and Magnetic Imager (HMI), to respectively compare the recorded irradiance around 17.1 nm and discuss the underlying magnetic field.

Although the end-goal of the project is to discuss the variability of the EUV irradiance over a full solar cycle period, current results for a 5-years period already contain interesting results. For example, a strong correlation was found between the coronal irradiance and the photospheric magnetic field. This correlation was expected for active regions, but was also found in the quiet sun region (i.e. region not included in either the ARs maps or the CHs maps). Such result, combined with one of our previous results estimating the contribution of the quiet sun region to more than 60% of the total EUV irradiance, suggests that the photospheric magnetic field has a more global impact on the EUV irradiance than expected, indicating its importance in understanding and predicting the EUV irradiance variability.

The present poster discusses in more details the correlation and periodicity found between the irradiance from the different atmospheric layers observed by the AIA EUV bands and the underlying magnetic field over a 5-years period, from 2011 to 2016.

Keywords: Solar physics, EUV irradiance variability



Identification of Active Longitude from the Solar Magnetograms

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It is well known that the sun has the cycle of 11 years for its activity. In the active time, we can see lots of sunspots on the solar surface and sometime it cause large flares which largely affect the Earth’s environments. For example, the release of large-scale plasma called Coronal Mass Ejection (CME) hits the Earth’s magnetosphere and causes some effects, e.g. the Earth’s magnetic field fluctuation or trouble of the satellite. The appearance of sunspots has several characteristics. For example, sunspots appear around in the higher latitudes at the beginning of the cycle and in the lower latitudes at the end of the cycle on the sun. However, recent studies have shown that the appearances of sunspots also depend on longitudinal direction. The solar longitude where the sunspots are frequently observed is called Active Longitude (AL). The presence of active longitude has been discussed long time. But it is still not clear whether there is an AL or not. In this study, we identified AL using magnetic field observation on the solar surface, not sunspots data. As a result, we can study AL for the magnetic bipoles which do not develop to sunspots. The results show that the phase of AL in the northern hemisphere and the southern hemisphere are different in cycles 23 and 24. Further, we found that there is clear AL in the strong magnetic field data($|B|>500G$), although there is no clear AL in the weak magnetic field data($|B|<40G$).

Keywords: Active Longitude, Sunspot

Cosmogenic 10Be in endogenic travertine deposits at Baishuitai, China: A pilot study

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We report on the preliminary experiment for measurement of beryllium-10 in travertine samples from Baisuitai, China. Beryllium-10 is one of the cosmic-ray induced isotopes and thus can be used as a proxy for the flux of galactic cosmic rays incident on the Earth. For example, the content of beryllium-10 in ice cores from polar region is often used for examining the past cosmic ray flux and solar variations. However, the data from ice cores is often accompanied by dating uncertainty. In this study, we seek for the possibility to use travertine which has recognizable annual layers.

Keywords: Cosmogenic nuclide, Solar cycle, Travertine deposit

Solar 27-day rotational period detected in a wide-area lightning activity in Japan

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A signal of the 27-day solar rotational period is often observed in cloud and lightning activities over the globe. Here we provide evidence of the 27-day periodicity of lightning activity in Japan using daily observational records of lightning for AD1989–2015. The 27-day period is detected only in a wide-area lightning activity over more than a few hundred thousand square kilometers. The 27-day signal is more prominent around the maxima of solar decadal cycles.

Keywords: Solar forcing of climate, Lightning activity, Solar rotational period

Long-term variation of Schumann resonance parameters at Kuju station

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The Schumann resonance (SR) is the global resonance of electromagnetic waves generated by global lightning activity. The resonance is formed by the Earth-ionosphere cavity and the specific resonance frequency appears in ground magnetic field variation. Expectations for the SR have increased recently as an indicator of global and regional lightning activity. In order to use the SR parameters for studying such earth’ s climate, we need a better understanding of the long-term variations of the SR. In this study, we focused on the long-term variation of the SR at Kuju, Japan (KUJ; M.Lat. = 23.4 degree, M. Lon. = 201.0 degree).
The ground magnetic field variation in the extremely low frequency (ELF) range has been measured by an induction magnetometer at KUJ since 2003. The observation is a part of activities by International Center for Space Weather Science and Education Kyushu University.
The fundamental mode of the Schumann resonance (SR1) around 8 Hz can be seen at KUJ. The peak frequency of SR1 correlates with F10.7. Also the correlation between SR1 amplitude and F10.7 reveals. The SR parameters seem to be affected by the ionospheric conditions which change depending on solar activity.

Keywords: Schumann resonance, solar activity

Development of an automated prediction method of CME arrival with SUANOO-CME

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CMEs, especially their internal southward magnetic fields, are one of the main drivers of geomagnetic disturbances and hence the prediction of CME arrival to the Earth. The prediction of CME arrival to the Earth and the southward magnetic flux brought by the CMEs are one of crucial tasks for space weather forecast of magnetic storms.
Recently, we have developed a new MHD simulation capable of reproducing the interplanetary propagation of multiple CMEs with internal magnetic flux rope (Shiota & Kataoka 2016) called as SUSANOO-CME. The simulation solves propagation of solar wind and CMEs in the inner heliosphere outer than the inner boundary at 30 Rs where the speed of all the balk flow exceeds fast mode speed. The information of solar wind and CME is specified at the inner boundary with empirical and analytical models. The CME model has many free parameters such as the orientations of the internal magnetic flux rope, etc. Hence, in order to execute this simulation for use in real time forecast, we need a method to specify the free parameter that we cannot get any clue in the real time observations.
In this study, we present test results of MHD simulation (SUSANOO-CME) for from May to September of 2005, applying a new method to specify the parameters of the CME model derived from only real time observations (SDO, GOES). We will evaluate the scores for forecast and discuss the current status of our capability for use in real time forecast.

Keywords: space weather, coronal mass ejection, solar wind, MHD simulation

An investigation of numerical techniques in an MHD relaxation method for NLFFF extrapolation

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Prediction of explosive phenomena in the solar corona such as solar flares and coronal mass ejections (CMEs) is one of the most important components for space weather forecast. These phenomena are considered to be processes that abruptly liberate the magnetic energy stored in the solar corona due to photospheric motions. In order to clarify these processes, three-dimensional information of the magnetic field in the solar corona is needed. The data, however, cannot be directly obtained in the solar corona though that on the photosphere can be observed. Therefore, various reconstruction methods from the vector magnetic field on the photosphere to a three-dimensional magnetic field have been proposed so far [1]. Particularly, a nonlinear force-free field (NLFFF) is often suited to model low beta coronal plasmas and seems to reconstruct the solar coronal magnetic field.

A magnetohydrodynamic (MHD) relaxation method is one of the promising methods for the NLFFF extrapolation [1]. The NLFFF obtained by the MHD relaxation method is directly usable as an initial condition of nonlinear MHD simulations because available discretization methods of the governing equations, MHD relaxation equations, are similar to the MHD simulations. However, modern numerical techniques for MHD such as upwind-type [2] and higher-order schemes [3] have not been investigated well in the MHD relaxation method. Therefore, in this paper, we study the numerical techniques for the MHD relaxation equations. We will also discuss an application to an extended MHD relaxation method for a non-force-free field (NFFF).

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Keywords: Solar corona, NLFFF, MHD relaxation method

Radiative cooling of Nitric Oxide emission observed by TIMED/SABER over asian sector during severe geomagnetic storms

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Nitric oxide (NO) is a very important trace species in the mesosphere-lower-thermosphere (MLT) region. It plays a significant role in the MLT region due to its low ionization energy and the presence of IR-active vibrational bands. The radiative emission due to NO at 5.3 μm is the main cooling mechanism in the thermosphere. It is very well known that geomagnetic storms strongly alter the energetics and chemistry of thermosphere. The effect of geomagnetic storms on the nitric oxide (NO) radiative cooling at 5.3 μm, in MLT region, has been studied over Asian sector during 26-29 September 2011 and 18-21 February 2014 using measurements made by SABER onboard the NASA's TIMED satellite. The SABER retrieved data along with the densities from NRLMSISE-00 model have been used to study the latitudinal variation of nitric oxide radiative cooling during the storm period. The variations induced in the radiative cooling are understood with the help of fluctuations in neutral species and the resulting changes in chemistry. It has been found that the NO radiative emission is strongly influenced by the storm conditions. The altitude of peak emission rate shows an upward movement in the higher latitude regions during day and night time. Similarly, the magnitude of peak emission rate is also observed to show enhancement in the high latitude sectors during the main phase of storm in day as well as night time. The atomic oxygen number density and O/N2 ratio calculated using NRLMSISE-00 model, shows depletion in the higher latitude region. Consequently, there is a negative correlation among the nitric oxide volume emission rate, atomic oxygen density and O/N$_2$ ratio over Asian sector during the geomagnetic storm period. The various factors influencing the correlation between density ratios and radiative cooling will be presented.

Keywords: space weather, radiative cooling, thermosphere,

Construction of global chorus wave intensity distribution from precipitating electron flux measurement and its application

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Whistler-mode chorus emissions are frequently observed in the inner magnetosphere during geomagnetically disturbed periods on the dawn and noon side magnetosphere. The waves have been considered as an important driver of the dynamics of inner magnetosphere. Resonant interactions of energetic electrons with chorus emissions result in flux enhancement of relativistic electrons in the outer radiation belt. On the other hand, the waves responsible for pitch angle scattering of electrons in the wide energy range from keV up to MeV range via pitch angle scattering. Previous studies show that chorus wave activities are correlated well with amount of energetic electron precipitations at low altitudes [Lam et al., 2010], and derive global intensity distributions of chorus waves during some events [Li et al., 2014; Chen et al., 2014]. It is possible that chorus wave intensity is constructed in global sense from the global map of precipitating electron fluxes. In this study we statistically investigate global distributions of > 30 keV precipitating electron fluxes observed by low-altitude POES satellites as a function of L, MLT, and Kp index. The distributions are compared with those of chorus wave intensity derived from the THEMIS satellites, and relationship between chorus wave intensity is parameterized as a function of L, MLT, and Kp index. Based on the parameterization, we successively construct global distributions of chorus wave intensity, and prediction of global chorus wave intensity variations is possible in cooperation with forecast of Kp index. In this presentation, we show the methodology of our analysis, obtained results, their performance to construct global distributions of chorus wave intensity, and its application to future research in the inner magnetosphere.

Keywords: radiation belt, whistler mode chorus, precipitation

Solar wind variations originating from the high-latitude and low-latitude coronal holes and their response to the Earth's magnetosphere

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Coronal holes are frequently observed in the declining phase of the solar cycle and have open magnetic fields expanding to the interplanetary space. The solar atmospheric plasma flows out along the magnetic field line from the coronal hole, and causes a major disturbance of the Earth’s magnetosphere such as geomagnetic storm and substorm. Tsurutani et al.(2006) proposed that analyses of the temporal area of polar coronal holes over the solar cycle [Harvey et al., 2000; Harvey and Recely, 2002] provide a good idea of the geoeffectiveness of high speed streams over the solar cycle, but the effects of isolated equatorial coronal holes has yet to be evaluated. In order to clarify the effects of the Earth's magnetosphere and ionosphere associated with solar wind disturbances originating from the equatorial coronal hole, we conducted the superposed epoch analysis of the variations of coronal hole area, solar wind, interplanetary magnetic field, and geomagnetic indices (AE and SYM), and investigated a difference of the solar wind variations from between the high-latitude and low-latitude coronal holes and their response to the Earth's magnetosphere. In the present analysis, we used the Sun whole two-dimension images taken by the solar whole the extreme ultraviolet imaging telescope (EIT) onboard the Solar and Heliospheric Observatory (SOHO). Solar wind data are obtained from the advanced composition explorer (ACE), Wind, and OMNI2 data provided by NASA CDAWeb. The data period is October 1996 –May 2013. For the coronal holes area, we defined the threshold of the solar brightness in the EUV range as a half of the median value of the intensity in a whole area and divided the solar surface in four regions: (-60 - -30, -30 - 30), (-30 - 0, -30 - 30), (0 - 30, -30 - 30), and (30 - 60, -30 - 30) (degrees) in the solar latitude and longitude, respectively. Moreover, we determined the coronal holes area as a ratio of pixel numbers less than the threshold to each region. As a result, we found 5 low-latitude coronal holes. For the response to the Earth’s magnetosphere, we used the SYM-H and AE indices provided by World Data Center (WDC) for Geomagnetism, Kyoto University. The superposed epoch analysis results showed that when the coronal hole area become maximum, the solar wind density increased from 3 to 13 /cc, rapidly. At this time, the solar wind speed was minimum, and the Bx, By, and Bz were directed sunward, dawnward, and northward, respectively. After that, the solar wind density decreased to 3 /cc, and the solar wind speed increase from 350 km/sec to 600 km/ sec within 3 days. At the same time when the solar wind speed increased rapidly, the Bx, By, and Bz were directed earthward, duskward, and southward, respectively. On the other hand, the AE and SYM indices showed a significant increase and decrease within 3 days after the solar wind speed increased and the IMF Bz component became negative. However, the magnitude of the AE and SYM variations was small in a case of the solar wind originating from the high-latitude coronal hole. Therefore, it can be concluded that the effects of the Earth's magnetosphere are larger for the equatorial coronal hole than the high-latitude one.

Keywords: Co-rotation Interaction Region, Coronal holes, Solar wind variations

High Intensity Long Duration Continuous Auroral-Electrojet Activity(HILDCAA) in relation to Geomagnetically Induced Current(GIC)

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GIC in the buried pipelines during intense geomagnetic storms has long been a subject of research because of its corroding potentiality to the pipeline material accompanied by the production of telluric current. In this work, for the first time, we have analyzed GIC statistics recorded in Finnish Natural Gas pipeline during three HILDCAA events with different interplanetary sources: CIR storm preceded, ICME storm preceded and Isolated. Despite the weak nature of HILDCAAs in terms of Dst reduction, their cumulative contribution in corrosion process is conjectured to be significant as they occur continuously several days to weeks. Analyzing the result, it is found that continuous fluctuation in GIC is observed throughout the AE intensification during all three events, which corresponds to the alfvanic wave fluctuation during HILDCAAs. However, there is no peak to peak relationship between AE index and GIC. Equivalently, every AE intensification does not necessarily account for the higher GIC amplitudes. We have adopted wavelet analysis and cross correlation methods to study the nature of GIC and its possible correlation with other parameters during HILDCAAs. From discrete wavelet transform we analyzed the singularities associated with the discontinuities present in GIC signal up to the three deconposition levels. Similarly, the result of discrete wavelt transform showed spectral variabilities in GIC with different periodicities.

Keywords: HILDCAA, GIC, Wavelet Analysis, Cross Correlation

Research for electromagnetic induction response in the low-and-mid-latitudinal region at geomagnetic disturbances

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Various types of space weather phenomena such as storm and auroral substorm cause geomagnetic field disturbances. GIC (Geomagnetically Induced Current) is known as one of the space disaster phenomena, which possibly impact on the social infrastructure. To understand the process of GIC generation and their relations to space weather phenomena, we developed geomagnetic indexes, which possibly quantify the GIC phenomena. Especially, time differences of geomagnetic Z component are equivalent to radial component of rotational densitis of horizontal induction electric filed. This induction electric field may correspond to one of dominant electromotive forces for generation of GIC in the low- and mid- latitudinal region. As the first step to estimate the horizontal component of induction electric field from geomagnetic disturbances, we investigated detailed morphology of Z-component variations by using multipoint observational data of geomagnetic field in Japan (MMB,ASB,ESA,MIZ,KAK,KNZ,KUJ,KNY,CBI) during auroral substorms. We will discuss how geomagnetic disturbances and electric field variations are related each other during substorm.

Keywords: Electromagnetism, Space weather, GIC

Simulation of Geomagnetically Induced Electric Field Originating from Field-Aligned Current

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Solar wind has a large impact on the Earth's magnetosphere. When the solar wind with southward Interplanetary Magnetic Fields (IMF) comes, magnetic storms and substorms occur in the near-Earth space. Due to this change in the space environment, field-aligned current (FAC) generated in the magnetosphere flows into the ionosphere. In addition to FAC, the magnetspheric and ionospheric currents induce geomagnetically induced electric field (GIE) on the surface of the Earth. GIE generates geomagnetically induced current (GIC) flowing in the conducting electrical wires. GIC causes severe damages on our life. In 1989, for example, large amplitude GIC flowed in the province of Quebec, Canada, and interrupted electric services over nine hours. The purpose of our study is to understand the relationship between the ionospheric current and GIE. Here, We focused on GIE in the polar region, and conducted finite-difference time-domain (FDTD) simulations. We used the 3-dimensional model that contains the ionosphere, the atmosphere, land and/or sea. We set FAC and Pedersen current as current sources. In order to evaluate the validity of our simulation, we used the Häkkinen method. This method calculates the electromagnetic field induced on the surface in frequency domain. We compared the electromagnetic field calculated by FDTD simulation with the one by the Häkkinen method. We will investigate the simulation results in future for a better understanding and modeling of GIC.

Keywords: geomagnetically induced current, geomagnetically induced electric field , field-aligned current

Multi-instrument observations of periodic poleward moving polar cap arcs

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Polar cap arcs (PCAs) are one of the outstanding phenomena in the polar cap region. We examined a case of periodic poleward moving arcs observed on January 3, 2014 by dual all-sky imagers, one at the Chinese Yellow River Station (YRS) and the other at Resolute Bay (RSB), the spaced-based SSUSI imager onboard DMSP spacecraft and Resolute Bay Incoherent Scatter Radar (RISR) during quiet geomagnetic conditions. We found that some poleward moving arcs observed at RSB were repeatedly detached from the dawnside auroral oval, which is consistent with the IMF-By polarity, and some arcs observed at YRS were likely less poleward moving from the duskside auroral oval. We also observed some periodic spatial arcs by DMSP SSUSI imagers and strong plasma velocity shears around these arcs. At the same time, the precipitating particles observed in the ionosphere associated with these PCAs showed magnetospheath-like properties. Moreover, the RISR data show that the F-region plasmas above these arcs were structured, with significant E-region ionization above an intense arc. Based on these observational results, we suggest that these periodic poleward moving PCAs may be triggered by bursts of dayside magnetic reconnection.

Keywords: periodic poleward moving arcs, plasma velocity shears, magnetic reconnection

Comparison of magnetospheric magnetic field variations at quasi-zenith orbit based on Michibiki observation and REPPU global MHD simulation

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We are developing a numerical simulator for future space weather forecast using magnetosphere-ionosphere coupling global MHD simulation called REPPU (REProduce Plasma Universe) code. We investigate the validity of the MHD simulation result as compared with observation. In this study we simulate some events including both quiet and disturbed geomagnetic conditions using OMNIWeb solar wind data. The simulation results are compared with magnetic field observations from Michibiki satellite, which is on the quasi-zenith orbit (QZO). In quiet geomagnetic condition, magnetic field variations at QZO obtained from simulation results have good consistency as compared correspondence with those from Michibiki observation. In disturbed geomagnetic condition in which the Dst < -50 nT, however, V component of magnetic field variations from simulation results tend to deviate from observations especially at the night side. We consider that this deviation during disturbed geomagnetic condition might be due to tail and/or ring current enhancement which is already suggested by many other MHD simulation studies as compared with the magnetic field observation at geosynchronous orbit. In this presentation, we will discuss the cause of this discrepancy in more detail with studying the relationship between the magnetic field deviation and some parameters such as Dst and solar wind.

Reconstructing polar asymmetry of GLE69 via WASAVIES simulation

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Solar Energetic Particle(SEP) is one of the most important components for predicting space weather. When a powerful SEP event occurs, neutron observations on the ground can detect the increase of flux. This event is called Ground Level Enhancement(GLE).
On January 20, 2005, a powerful GLE (GLE69) occurred, causing significant flux enhancement on south pole region. The McMurdo neutron monitor in Antarctica recorded 18 times more fluxes compared to Thule station in Greenland. Previous studies suggested that this asymmetry phenomenon is related to IMF direction, which has never been confirmed by the simulation.
In this research, we investigate this asymmetry of neutron flux using WASAVIES (Warning System for Aviation Exposure to SEP [Kataoka et al., 2014]) which consists of SEP simulation in the heliosphere, particle trajectory tracing in the magnetosphere, and the air shower simulation. Using WASAVIES, we investigate propagation direction of SEPs and compare the results with neutron monitor observations. Initial results of this study indicate that SEPs come mainly from southern-hemisphere, which is consistent with previous studies. The results also suggest importance of transportation of SEP in the azimuthal direction, which has not included in this study.

Keywords: WASAVIES, Solar Energetic Particle, Space Weather

The long term observation of the high energy electrons and protons on the Internatilnal Space Station

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JAXA has operated the Standard DOse Monitor (SDOM) since 2009. SDOM measures the energy distributions of high-energy light particles such as electrons, protons, alpha, which cause deterioration of component materials and malfunction of electronic components. Also in order to evaluate the dose outside the International Space Station (ISS), data has been provided to NASA since 2016 and is used as data for radiation dose assessment.
We will introduce the solar cycle variation and geomagnetic activity dependence of SDOM data. In addition, as reported in Kataoka et al. (2016), relativistic electron precipitation (REP) event related to solar activity is observed in the ISS orbit. Based on the SDOM observation data during the REP events, we will quantitatively discuss variation of the radiation belt and exposed dose in a extra vehicular activity.

Keywords: the International Space Station, Space radiation, Radiation exposure, High energy particles

Cross-calibration of high-energy electron observations at geostationary earth orbit

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Cross-calibration of high-energy electron observations obtained from individual satellites are quite essential procedure for reconstruction of high-energy electron distribution at geostationary earth orbit (GEO). To compare high-energy electron data from individual satellite, we should find the period where the L*-value (drift shell) is the same. Because the magnetic dipole axis is not aligned with the rotational axis of the Earth, L*-value of each GEO satellite is changing depending on the longitude of GEO and magnetic local time. In addition, L*-value of each GEO satellite also changes depending on geospace disturbances. We have compared Himawari-8 high-energy electron (SEDA-e) data with GOES 15 high-energy electron (MAGED and EPEAD) data during the same L*-value of both satellites with quiet geomagnetic condition. This result shows quite good correspondence of both observation, and factor of sensitivity can be estimated.
Our previous study showed seasonal dependence of sensitivity difference between high energy electron sensor onboard Himawari and that onboard Kodama. We found that this seasonal dependence might be caused by the north-south drift of the Kodama’ s orbit. Previous study, we assumed that the orbit of Kodama is aligned with GEO. This result suggests that the detailed orbit information is important for cross-calibration. Based on this cross-calibration procedure, we can produce particle distribution at GEO. In our presentation, some sample events of particle distribution at GEO will be shown, and the future plan for producing particle distribution in the inner magnetosphere using energetic electron data from ARASE(ERG), Van-Allen Probes, and GPS will be introduced.

Keywords: space weather forecast, magnetospheric particle distribution, cross-calibration of particle data

On two-dimensional distribution of trapped protons from solar cell degradation of the Akebono satellite

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We have been studying on L-shell distribution of energetic (>10 MeV) protons from solar cell degradation of Akebono satellite orbiting in the inner magnetosphere. We obtained more compact distribution of the trapped protons than given by the AP8 and AP9 models. In our previous study (Miyake et al., 2014; 2015), we assumed that proton flux varies along the field line in the same rate as in the AP8 model. If the flux is more confined around the equator, the L-shell distribution may be possibly widen and the difference from the previous models can be smaller. Recent observation of the Van Allen probe has showed that quite anisotropic distribution of pitch angle which leads to spatial distribution confined near the equator (Selesnick et al., 2014). Thus, we introduce some different variation along the field line and seek the best-fit to the observed degradation of solar cells.

Keywords: Akebono satellite, proton radiation belt, solar cell degradation

Development of information system of spacecraft surface charging potential and discharging alert

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Spacecrafts can be damaged by surface charging and resultant discharging arcs. We are developing information system of surface charging potential and discharging alert for individual spacecraft. We create lookup tables of surface potential for many combinations of plasma temperatures and densities using charging simulation for the spacecraft engineering model with a spacecraft charging analysis software and/or spacecraft observational results. Using interpolation with the lookup tables, we can estimate surface potential on demand for any given on-orbit plasma environment. The discharging alert also can be accomplished by additional information about the estimated differential potential and the experimental discharge potential of the spacecraft. We will introduce current status of our system.

Keywords: Spacecraft surface charging, Spacecraft discharging alert, Space weather

