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 $OI(^5P)$ 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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1. National Institute of Technology, Ibaraki College, 2. National Institute of Polar Research, 3. Japan Atomic Energy Agency

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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1. Hosei University, 2. National Institute of Polar Research, 3. Nagoya University, 4. Musashino Art University, 5. National Institute of Technology, Ibaraki College

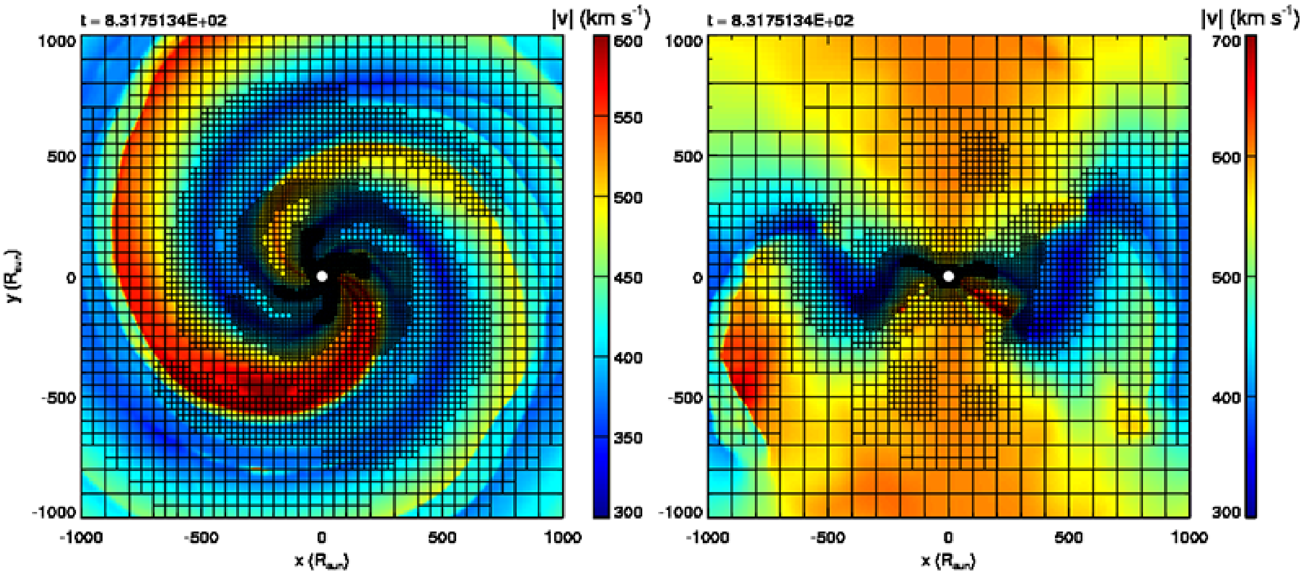
A change in the heliospheric environment plays an important role in the modulation of the galactic cosmic rays; the magnetic field structure and the speed of the solar wind affect the cosmic ray transport in the heliosphere. Since the heliospheric environment is affected by the solar wind activities, 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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|v| (km s⁻¹)
y (R_sun)
x (R_sun)
t = 8.3175134E+02
|v| (km s⁻¹)
x (R_sun)

Comparison of Solar and Stellar White-light Flares

*Kosuke Namekata[1], Takahito Sakaue[1], Yuta Notsu[1], Shota Notsu[1], Kai Ikuta[1], Kyoko Watanabe[2], Ayumi Asai[1], Hiroyuki Maehara[3], Satoshi Honda[4], Daisaku Nogami[1], Kazunari Shibata[1]

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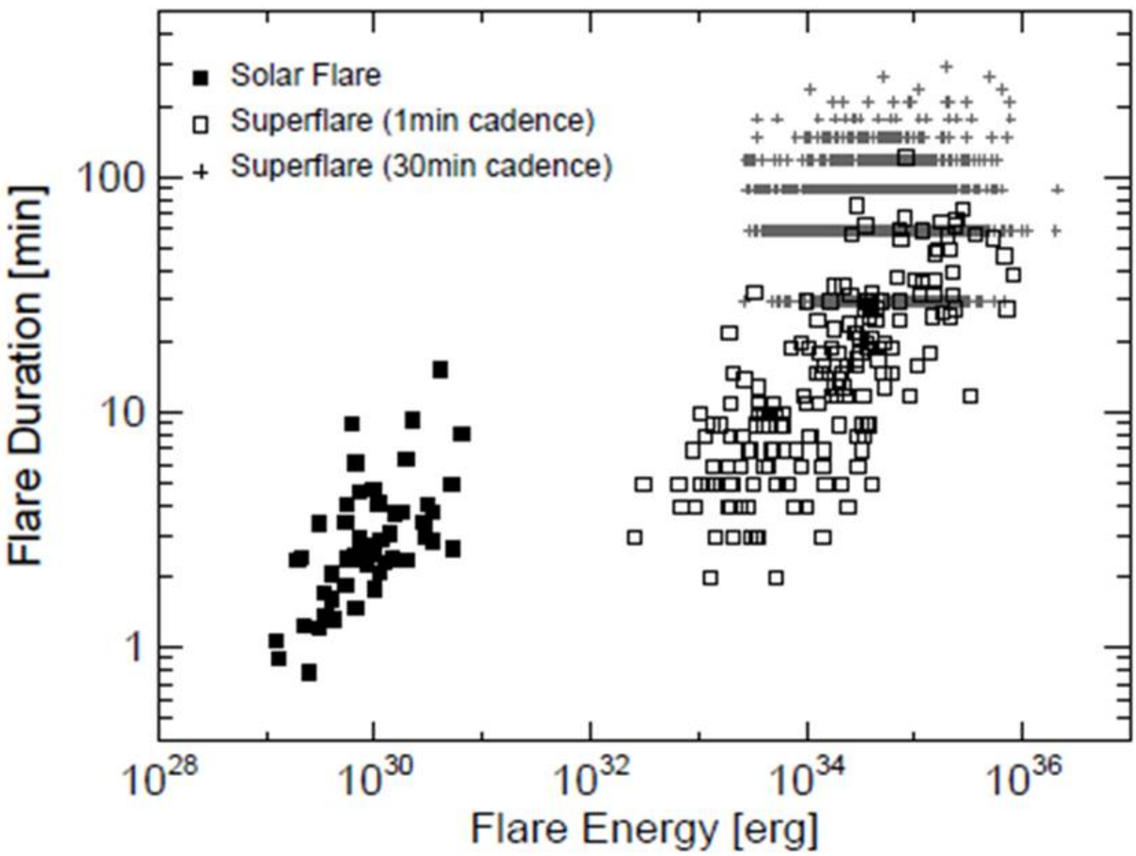
Flares are sudden brightenings on stellar surfaces. Especially, flares observed in visible continuum are called “**white-light flares**”. Recently, many superflares on solar-type stars which have 10-10,000 times larger energies than the largest solar flares are discovered as white-light flares with Kepler 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


Solar Flare
Superflare (1min cadence)
Superflare (30min cadence)
Flare Duration [min]
100
10
1
10^{28}
10^{30}
10^{32}
10^{34}
10^{36}
Flare Energy [erg]

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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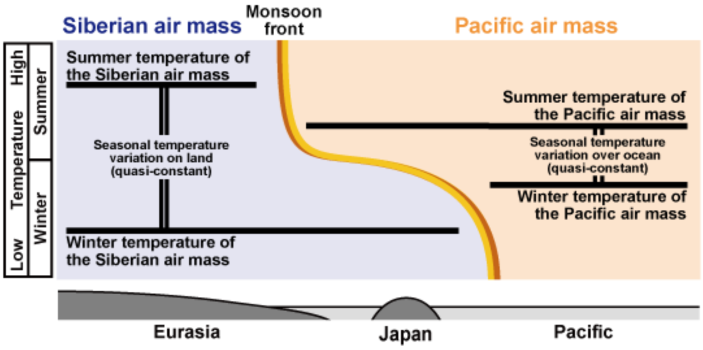
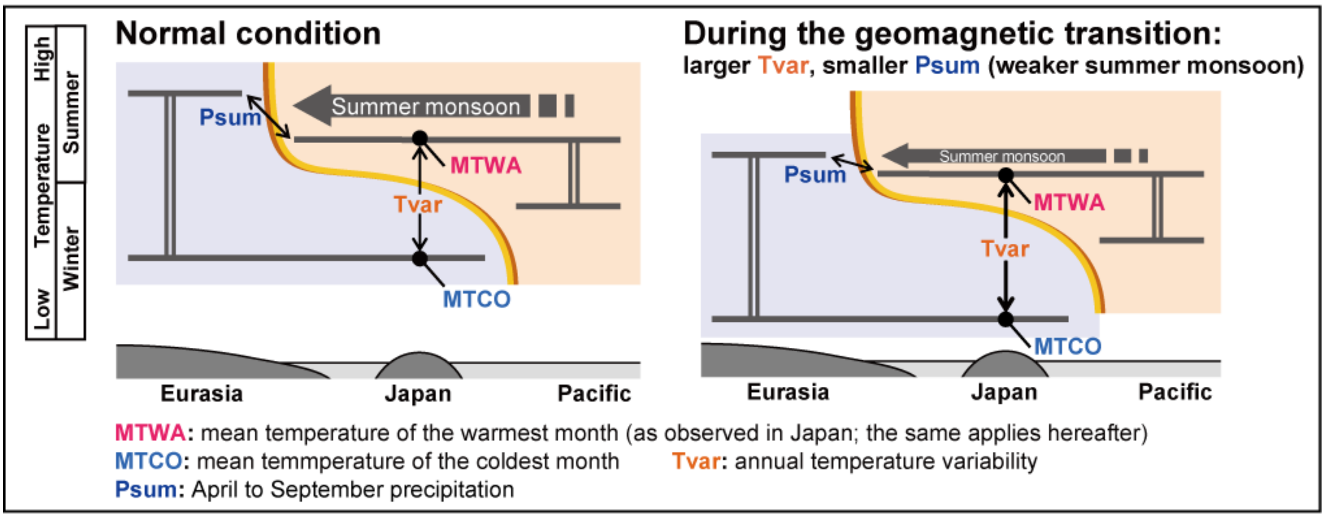
On geological time scales, the galactic cosmic ray (GCR) flux at the Earth's surface has increased significantly during many short time intervals. There is a growing body of evidence that suggests that climatic cooling occurred during these episodes. Cloud formation by GCR has been claimed as the most 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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1. Kyoto University, 2. RIKEN Advanced Institute for Computational Science, 3. Broadband Tower, Inc.

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

*Daniel T Welling[1], Jeffery J Love[2], Michael James Wiltberger[3], Erin Joshua Rigler[2]

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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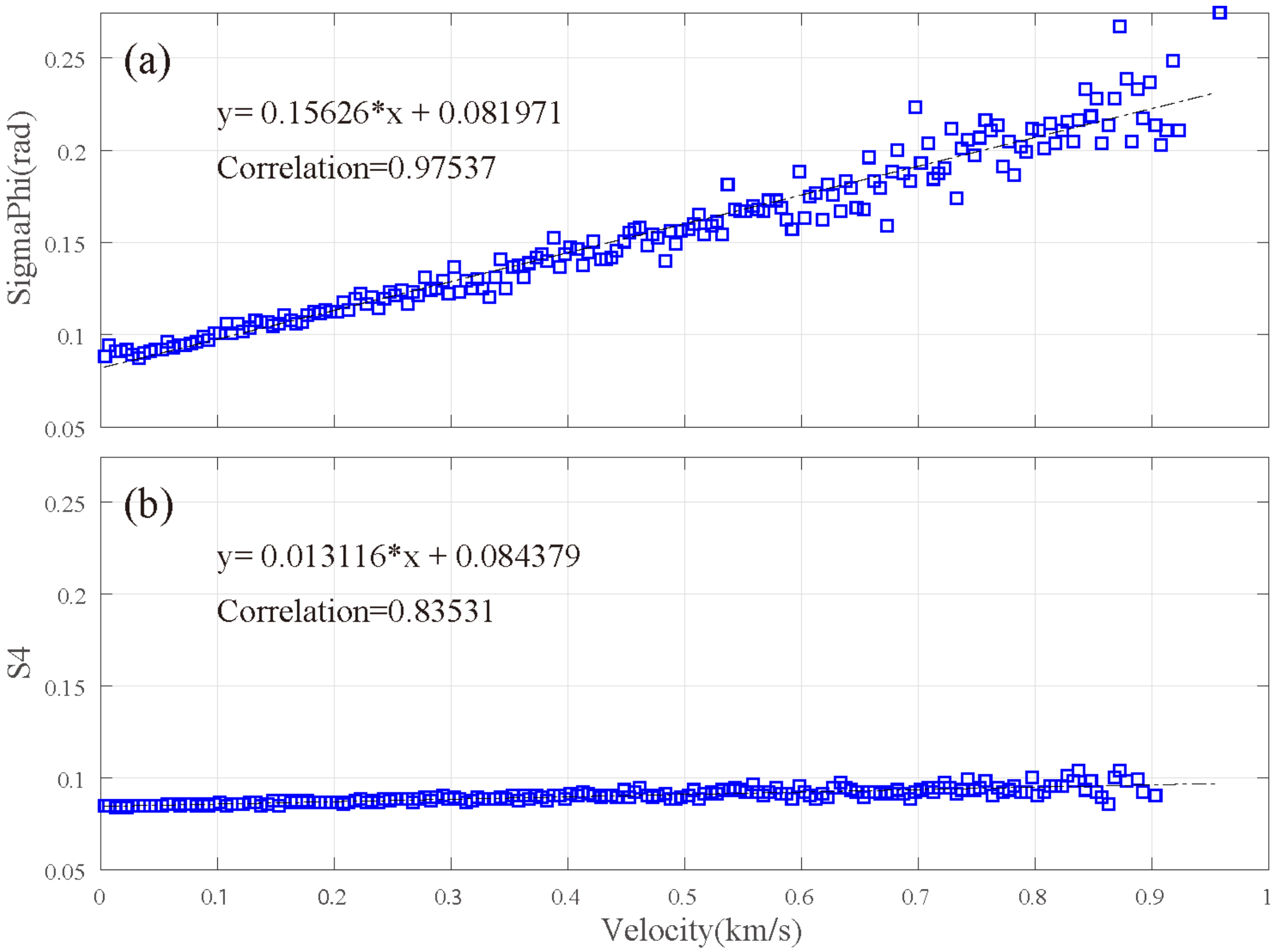
Using ionospheric scintillation measurements from GPS receivers of Canadian High Arctic Ionospheric Network (CHAIN) and flows measured by both of Kapuskasing (KAP) and Saskatoon (SAS) SuperDARN radars, we found that near cusp region the GPS phase scintillations fluctuated mostly associated with the varied 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