Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM05-P01 Room:Convention Hall Time:May 21 18:15-19:30

JAXA radiation exposure management for astronauts

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On the International Space Station (ISS), a habitable artificial satellite that orbits the Earth at an altitude of about 400 km, astronauts receive space radiation exposure 0.5-1.0mSv in one day which is equivalent to what humans on the Earth receive in six months.

The Japan Aerospace Exploration Agency (JAXA) employs radiation exposure management for JAXA astronauts to minimize the health damage caused by space radiation exposure.

Because of we must take action at space environment anomaly, the space environment monitoring and space weather is important information. We use space weather mail which is commonly used, and select procedure depending on the type and level of space environment anomaly, in collaboration with pertinent unit.

In this report, we introduce space radiation exposure management by JAXA.

Keywords: Astronaut, Space radiation exposure

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Space weather expert group in the Committee on the Peaceful Uses of Outer Space of the United Nation (UNCOPUOS)

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The expert group for space weather was made under the Working Group on the Long-Term Sustainability of Outer Space Activities in the Committee on the Peaceful Uses of Outer Space of the United Nation in 2010 and T.Obara was assigned a chair of the expert group. The objective of the expert group is to gather existing information on space weather and its impacts on space activities, and also on the current practices, operating procedures and technical standards for mitigating the effects of space weather phenomena on operational space systems.

The expert group will provide this information to the Working Group for inclusion in its report and propose voluntary guidelines to enhance the safety of space activities and to reduce the risks from space weather phenomena to the long-term sustainability of space activities. The expert group intends to carry out its work and finish them by the end of 2013.

The expert group has considered the topics and methods of work regarding the following scope, and has agreed to elaborate the consideration of these topics along the lines of what is indicated below:

(a) Collection, sharing and dissemination of data, model and forecasts;

The expert group will collect information on the current practices of States and organizations in terms of space weather observation and the various models and tools being used for space weather forecasts. The expert group has noted that this is the first attempt to collect and consolidate information of this nature from around the world. Thus the information collected will be useful information for all organizations related to space weather.

(b) Capabilities to provide a comprehensive and sustainable network of sources of key data in order to observe and measure phenomena related to space weather in real or near-real time;

It is important to form a network that continuously provides key data related to space weather in real time or near-real time. Further discussion is necessary to identify which are the key data to provide. Collecting information on data provision and the available networks will be the first step.

(c) Open sharing of established practices and guidelines to mitigate the impact of space weather phenomena on operational space systems;

Established practices to mitigate the impact of space weather phenomena on space systems vary from State to State, and even basic standards for the designing of satellites are different. The expert group has noted that as the situation concerning the sharing of knowledge and practices differs in each State, it may be difficult to compile information from all States. This expert group will work toward improving standards by eventually expanding the sharing of related information.

(d) Coordination among States on ground-based and space-based space weather observations in order to safeguard space activities;

The expert group recognizes the importance of coordination among States in space weather observations. The expert group will consider the possible modalities of sharing data. The expert group will also consider the risks arising from space weather, with a view to proposing which types of key data ought to be shared in order to safeguard space activities from detrimental effects of space weather.

Keywords: Space Weather, United Nation, Committee on the Peaceful Uses of Outer Space

Japan Geoscience Union Meeting 2013
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GEMSIS-Sun phase 2

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Solar-Terrestrial Environment Laboratory (STEL) in Nagoya University started the GEMSIS (Geospace Environment Modeling System for Integrated Studies) project in 2007. In the phase 1 (2007-2009), one of subgroups, GEMSIS-Sun, mainly promoted integrated studies based on simulation/modeling and data analysis in order to understand the acceleration/transportation/loss processes in solar flares.

In the GEMSIS phase 2 (2010 - 2015), the solar cycle 24 reaches its maximum and large solar flares are highly produced. So we defined our final goal of systematically understanding the whole processes (energy-storage, flare trigger, energy-release, and particle acceleration) in solar flares, especially in large solar flares. In order to realize it, realistic models for the specific scientific targets, e.g., flare-trigger, particle acceleration, and so forth, are developped. Then, we try to compare observational results with these models and simulations in the phase 2.

We have carried on the following research activities; (1) accurate coronal magnetic field modeling and flare-trigger simulation, (2) particle acceleration modeling in solar flares, (3) multi-wavelength data analysis for solar flare researches, (4) the Hinode flare database and the database of coronal magnetic field of the flare-productive active regions. In this presentation, we briefly report these research activities.

Keywords: solar flare, particle acceleration, magnetic field

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On the Possibility of Solar Superflares

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Recent observations of Sun-like stars, similar to our Sun in their surface temperature (5600 K - 6000 K) and slow rotation (rotational period > 10 days), with the Kepler satellite by Maehara et al. (2012, Nature) have revealed the existence of superflares (with energy of 10^33 - 10^35 erg). From the statistical analysis of these superflares, it was found that superflares with energy 10^34 erg occur once in 800 years and superflares with 1035 erg occur once in 5000 years. In this paper, we examine whether superflares with energy of 10^33 - 10^35 erg could occur on the present Sun through the use of simple order-of-magnitude estimates based on current ideas relating to the mechanisms of the solar dynamo. If magnetic flux is generated by the differential rotation at the base of convection zone as assumed in typical dynamo models, it is possible that the present Sun would generate a large sunspot with total magnetic flux 2 x 10^23 Mx within one solar cycle period, and lead to superflares with energy of 10^34 erg. To store total magnetic flux 10^24 Mx necessary for generating 10^35 erg superflares it would take 40 years. Hot Jupiters have often been argued to be a necessary ingredient for generation of superflares, but we found they do not play any essential role on generation of magnetic flux in the star itself, if we consider only magnetic interaction between the star and the hot Jupiter. This seems to be consistent with Maehara et al.'s finding of 148 superflare-generating solar type stars which do not have a hot Jupiter companion. Altogether, our simple calculations, combined with Maehara et al.'s analysis of superflares on Sun-like stars, show that there is a possibility that superflares of 10^34 erg would occur once in 800 years on our present Sun.

The contents of this talk is based on the paper which will be published in PASJ, 2013, by Kazunari Shibata, Hiroaki Isobe, Andrew Hillier, Arnab Rai Choudhuri, Hiroyuki Maehara, Takako T. Ishii, Takuya Shibayama, Shota Notsu, Yuta Notsu, Takashi Nagao, Satoshi Honda, and Daisaku Nogami.

Keywords: Extreme Space Weather, Flares, Sunspots, dynamo

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Long-term variation of geomagnetic activity at Syowa-Iceland conjugate stations (3)

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Long-term variation of geomagnetic activity at Syowa Station (SYO) (S69.00 deg) in Antarctica and Leirvogur (LRV) (N64.18 deg) in Iceland was investigated. Both SYO and LRV are located at auroral latitudes and in a unique geomagnetic conjugate relationship with each other. Geomagnetic variation data from 1958 and 1966 until 2012 at LRV and SYO, respectively, were used for this analysis. Using those over four solar cycle data, similarity and dissimilarity in the solar cycle variation, seasonal variation, and diurnal variation of geomagnetic activity at those conjugate stations were investigated to understand interhemispheric difference in auroral activity responding to the variation of the solar wind input and solar activity. Following results were obtained so far:

1. Activity at LRV gradually decreased, relatively to one at SYO. Before and after around 1984-1989, magnitude at LRV was larger and smaller than SYO, respectively.

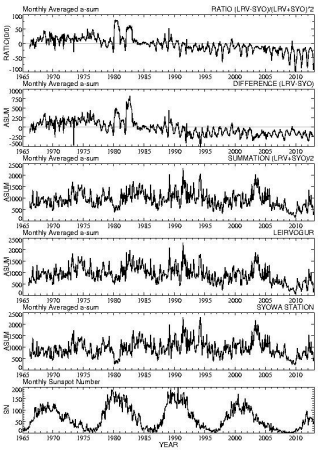
2. The year 2009 was the most quiet year at both stations in their records.

3. During the current solar cycle 24, activity was low at both stations, and relative magnitude of the annual variation of the north-south difference was large, so far.

4. A significant difference between SYO and LRV was observed in 1980 and 1982, when the activity was much more quiet at SYO than LRV.

5. Activity peak around equinox period can be seen more clearly in the nightside hours, while winter-summer difference is more clear in the dayside. In the nightside, a reversed sense winter-summer variation can be seen in the activity difference between LRV and SYO.

Keywords: magnetic activity, auroral activity, solar activity, long-term variation, conjugate observation



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An Investigation of coronal mass ejections and EUV waves for space weather forecasting

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Coronal mass ejections (CMEs) affect the terrestrial environments and technological infrastructures because they cause solar energetic particle events and geomagnetic storms. Extreme Ultraviolet (EUV) waves are large scale disturbances propagating over a significant fraction of the solar surface and are closely related to CMEs. Therefore, the EUV waves have the potential to be used for space weather forecasting. We examined CMEs and EUV waves using SOHO, STEREO and SDO associated with 176 major flares (M class and above) that occurred from 12 June 2010 to 14 June 2012. We found that 75 of the 176 flares were associated with both CMEs and EUV waves, while 83 lacked both. Although we could not determine the associations of the remaining 18 flares, there is a clear one-to-one correspondence between CMEs and EUV waves. Since approximately half of the major flares are not associated with the CMEs, space weather alerts issued by only the flare information will be false half the time. Therefore, the EUV waves are useful tool to improve the space weather forecasting. We will discuss how to estimate the CME speeds from the observation of flares and EUV waves.

Keywords: flare, CME, EUV wave

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Study on long-term variation of solar cell output of Akebono satellite

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Solar cells on any satellite degrade gradually due to severe space radiation environment. We found a fair correlation between the decrease rate of solar cell output current of Akebono satellite orbiting in the inner magnetosphere and trapped proton flux between 1989 and 1992, and reported the results elsewhere. After 1993, as a result of long-term degradation, variation of solar cell output seems more susceptible to other causes such as high temperature effect, and simple monthly averaged data show no significant relation between them. One of possible causes for the temperature variation of the solar cells is solar radiation with eccentric earth's orbit and another is terrestrial heat radiation with changing orientation of solar cell panels towards the earth. In order to remove possible temperature effect, we analyze difference of the output current for a month from that for the same month in the previous year. Then we select the data of the same distance (i.e., the same amount of the solar radiation) from the sun. We also sort the data by the geocentric angle of the satellite position from the sun-earth line. The data taken near the angle of 90 degree are expected to be least affected by the terrestrial heat radiation, because the satellite is solar-oriented with the solar cells facing towards the sun. The analysis method leads us to successfully deduce a continuous correlation between the decease rate of solar cell output and $>$ 10 MeV trapped proton flux up to 1998.

Keywords: Akebono satellite, proton radiation belt

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Diagnosing flare-productive active regions using EUV images

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Solar flares and coronal mass ejections (CMEs) are the most significant phenomena for space weather. Radiation hazard from solar flares and CMEs may cause significant damage not only to the Earth but also to the satellites on geocentric orbits and deep space probes. Furthermore, as some space probes which observe partial images of the Sun such as Hinode, the information may also enable us to manage an efficient observation. Therefore, to establish of the flare prediction system for deep space probes is one of the most essential tasks in space weather researches.

Now, we can obtain the backside EUV images of the sun, by the Solar Terrestrial RElations Observatory (STEREO). In order to develop a flare prediction algorithm for deep space probes by using STEREO EUV images, we analyzed full disk 195A images obtained by SOHO/EIT. We examined the differences between the time profiles of EUV intensity of flare productive active regions (ARs) and those of non-flare productive ARs. We found that there are bright pixels in flare productive ARs even when flares were not occurring. On the other hand, in the non-flare productive ARs, the possibility of the appearance of mildly bright pixels is much less than that in the flare productive ARs. This difference possibly may be used for an indicator of flare productivity of each AR.

Keywords: Solar flare, CME, EUV, Space weather

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Geomagnetic Reconstruction of Gaps in Solar Wind Data

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The main historical i.e., pre-1994 solar-wind and interplanetary magnetic field (IMF) observations come from measurements taken on board of the IMP-8 spacecraft. While the spacecraft crossed the magnetosheath and magnetosphere, it was not immersed in the solar wind at all times, and so large continuous gaps exist in the collected data. Even after 1994 there have been many data gaps in the solar wind data, though they are not as frequent and are usually shorter.

The behavior of Earth magnetosphere is strongly influenced by the solar wind. Various geomagnetic indices such as Kp, Dst or AE, are inferred from ground-measured, and hence time-lagged magnetic disturbances that are caused by the magnetosphere interaction with the solar wind and the embedded IMF; these indices are inferred from the ground and are typically available continuously in time, even when solar-wind data are not. Broadly speaking, these indices can be considered as a proxy for the overall time-lagged magnetospheric response to the solar driver, i.e., to the solar wind and IMF.

We will demonstrate how to reconstruct (”predict”) data in the gaps of the solar driver by using smooth spatio-temporal modes of co-variability inferred by singular spectrum analysis (SSA) from time-lagged correlations in multivariate data consisting of gappy-driver (solar wind and IMF) and continuous-response records (various geomagnetic indices), while discarding the noise. Application of the reconstructed data to radiation belts modeling will be presented.

Keywords: solar wind, gaps, singular spectrum analysis, predict

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On slow ICMEs

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[1]NICT

Even slow ICMEs cause geomagnetic storms if they carry strong southwards IMF with them. These events are a problem for space weather forecast because solar sources of these ICMEs are often ambiguous and it is difficult to estimate their effect. Speed of ICME associated with the geomagnetic storm on January 17, 2013 was almost the same speed of back ground solar wind and definite solar-disk signature associated with this ICME was not observed by the extreme ultraviolet images of the SDO satellite. However, CME associated with this event was observed by the STEREO spacecraft. The analysis of this event and similar events will be reported in our presentation.

Keywords: CME, ICME, geomagnetic storm, STEREO, SDO, space weather

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Remotely sensed of some parameters of the solar wind via a low-latitude Pc 5 index

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Pc 5 geomagnetic pulsations have been reported to be related directly to an externally drive parameters such as solar wind parameters (i.e. solar wind flow speed and pressure); and the Kelvin-Helmholtz instability on the magnetopause is known to play the role of the greatest contributor to the Pc 5 pulsations (band range: 1.7-6.7 mHz) which is observed on the ground at different latitudes. The Kelvin-Helmholtz instability excites as well the body waves that termed as waveguide modes which propagate between the magnetopause and a turning point located in the magnetosphere. Moreover, other internal mechanisms of Pc 5 pulsations have also been reported such as the drift mirror instability and the drift-bounce resonances of ring current ions with standing Alfven waves. Herein, a low-latitude Pc 5 index is defined in order that it proxy the Pc 5 pulsations amplitudes ranges observed at a low-latitude ground station, and it describes the activity of geomagnetic fluctuations in the Pc 5 range quantitatively. We investigated the reliability of remotely sensed solar wind flow speed and pressure that is by examining the reliability of estimating of both the solar wind flow speed and pressure via our defined low-latitude Pc 5 index. The designated Pc 5 index is composed by using the hourly averaged Pc 5 pulsations amplitudes observed on a ground low-latitude, magnetic data acquisition system (MAGDAS), station and assigning the Pc 5 index values with its corresponding Pc 5 amplitudes ranges; the values of the Pc 5 index are set so that they look similar to those of the Kp index with their same order; and as long as the Kp index describes the accumulative geomagnetic disturbance activity as it is designed for, our Pc 5 index is designed to describe the geomagnetic activity in the Pc 5 band range at low latitudes. The estimation of both solar wind flow speed and pressure via the Pc 5 index shows good agreement with the observed values that was true for the relatively low values of the Pc 5 index which were high in their occurrence distribution compared with the high values of the Pc 5 index which were low in their occurrence distribution. We concluded that it is considerable to rely on one of the usage of the Pc 5 index as a method for remotely sensed the solar wind right away from the ground.

Keywords: solar wind parameter, Pc5 pulsation

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Narrowband drifting fine structures in type IV bursts

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Solar Type IV bursts are a type of intense radio phenomenon that accompanies solar flares. Following the discovery by Elgaroy (1959), many observations have suggested that Type IV bursts are accompanied by several kinds of spectral fine structure. One type of prominent fine structure is fiber bursts, which are generally assumed to be emitted through the wave-wave coupling between Langmuir waves and whistler-mode waves propagating in the solar corona. Recent observations in a frequency range of several GHz with high frequency and time resolution have revealed that narrowband fine structures similar to fiber bursts occur in Type IV bursts. In the meter-wavelength range, however, few spectral observations with high resolution have been carried out, unlike at decimeter wavelengths. By performing observations that can detect spectral fine structure in metric Type IV bursts, we can obtain another powerful remote-sensing tool to survey as-yet unknown physical plasma processes, including the process responsible for the generation of energetic particles and the propagation of plasma waves during solar flares, in the region where X-ray and UV observations cannot be used.

We have developed a new solar radio spectrograph, the Zao Solar Radiospectrograph (ZSR). Development of the ZSR was carried out by modification of the array antenna system for the observation of Jovian synchrotron radiation located at the Zao observatory of Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, Japan (Watanabe et al., 2005). It has the ability to observe solar radio bursts in the frequency range from 315 to 332 MHz with a resolution of 10 ms and 100 kHz, which is ten times higher resolution than typical for previous solar radio spectral observations at meter wavelengths. The minimum detectable flux of 4.10 and 4.33 SFU are achieved in the X and Y components, respectively, where 1 SFU = 10^{-22} W m^{-2} Hz^{-1}.

During the observation of ZSR since June 2008, narrowband, fiber-like structures in the spectra of Type IV bursts were detected on 2 and 3 November 2008. Statistical analysis of the drift rates shows that most of the bursts have different spectral characteristics from those of metric fiber bursts as regards the sign and the magnitude of the drift rate. First, the observed drift rates show both positive and negative rates, whereas the metric fiber bursts usually exhibit negative drift rates. Secondly, the absolute values of the observed drift rates are tens of MHz s^{-1}, while the typical drift rate of fiber bursts at 325 MHz is approximately -9 MHz s^{-1} (Benz and Mann, 1998). In addition, all fine structures analyzed have a narrow emission bandwidth of less than 17 MHz.

The observed narrowband features with drift rates of a few tens of MHz s^{-1} have been interpreted by the generation process of metric fiber bursts; the emission features are thought to be caused by whistler-mode waves propagating in the corona.

These observed narrowband events are difficult to detect with conventional spectrographs, which are usually characterized by a frequency resolution of 1 MHz and a time resolution of 0.1 s. These results imply that higher frequency and time resolution (such as 100 kHz and 100 ms) are necessary to investigate fine structures accompanying Type IV bursts.

We also discuss particle and plasma-wave dynamics responsible for the observed fine structures. By referring the presence of a Type U burst in dynamic spectra and comparing with soft X-ray imaging data of the flare region taken by Hinode/XRT, we show that the observed fine structures can be explained as emission caused by upward- and downward-propagating whistler-mode waves inside the magnetic flux tubes of post-flare loops, while these whistle-mode waves are generated by electron beams that are accelerated by side-lobe reconnection in the lower corona.

Keywords: Sun, radio, type IV burst

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Operational Relativistic Electron Flux Forecast at GEO Satellite

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Dynamic changes of the Earth's Radiation belt are one of the well-known but still unsolved issue of solar terrestrial physics. This is also important for the practical point of view because relativistic electron can penetrate into a satellite body and causes deep dielectric charging. This phenomenon is one of the major reasons of satellite anomaly. For prediction of space environment around GEO, we will proceed to develop 1) near real time prediction model of relativistic electron environment, 2) high precision global MHD simulation in this 5-year term from 2011. As for the prediction model of relativistic electron environment, we plan to develop two types of models. One is near real time prediction model based on the AR model that is a kind of the parametric analysis methods for the time-series data. The product of this model is for daily operation of geosynchronous satellite. We have prepared the web pages of this product.

The other is high time and spatial resolution numerical forecast model based on combination between global MHD simulation code and particle tracing code and others. The product of this model is for post analysis of satellite anomalies. In this presentation, we will introduce current status and future perspective of our project.

Keywords: Space Weather Forecast, Magnetosphere, Radiation Belt, Geosynchronous Orbit, Modeling

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The initial results of high speed flare imaging system at Hida Observatory

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[1]Kwasan and Hida observatory, Kyoto University, [2]Solar Observatory, NAOJ, [3]STEL, Nagoya University

FISCH (Flare Imaging System in Continuum and H-alpha; Ishii et al. PASJ, in press) was installed in August 2011on SMART (Solar Magnetic Activity Research Telescope) at Hida Observatory of Kyoto University and started regular observation in November 2011. FISCH aims to observe solar flares in high time and high spatial resolutions. We continuously observe an active region which likely produces flares in Continuum (642.7nm) and H-alpha with a frame rate between 10 and 25 frames per second. Regularly we select good seeing frames with a cadence of 5 sec, and when an event occurs, we store all the data. Its field of view is 344 x 256 arcsecˆ2 and FISCH is highly complementary with Hinode/SOT and SDO/HMI.

The main aim of observation with FISCH is to study the emission mechanism of white light flares and to investigate connectivity of magnetic field in the flare loop system by resolving drastic evolution of flare kernels in H-alpha in the impulsive phase. White light flares are thought to be the continuum enhancement caused by high energy electrons precipitating into the chromosphere or photosphere, but ”how high the formation height is” and ”what the mechanism of the continuum enhancement is” are not solved. Time coincidence among brightenings of flare kernels in H-alpha at different points inform the pair of flare kernels that are footpoints of a flare loop created by ”magnetic reconnection”. Timing of the brightening of multiple flare kernel pairs in flare ribbons tell us configuration of coronal magnetic fields

We observed 30 events with FISCH until 2012 December 31. 22 events are C class flares, 4 events are M class flares, and 4 events are X class flares. It is unexpected result that the flare capture rate of the FISCH against the all GOES flares is quite low for C class flares (1.2%) and for M class flares (2.2%). This seems to be caused by a broad passband (3A) of the H-alpha filter so that we missed relatively weak flare kernels. After we got this result, we changed the filter of the 3A passband to a filter of the 1.5A passband on January 2013.

Among the 30 events, however, we find two white light flares and data showing clear flare kernels with a good seeing condition. We also reconstruct images with rather poor seeing condition to reduce the fluctuation of the images. We analyzed a white light event with RHESSI data and found white light flare kernel is coincidence with the HXR source spatially. We also analyzed a C class flare in which we can trace the motion of H-alpha flare kernels with HXR images and EUV spectrographs. Moreover we have an M class event data in which we can resolve the fine structure of flare ribbons. In this poster, we present the results of analysis using data taken by 2012, and show the flare capture rate after we changed the H-alpha filter.

Keywords: solar flare, visible wavelength, ground based observation

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Improvement of the radiation belt model using the data assimilation

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It is known that high energy electrons in the radiation belts often cause satellite anomaly and malfunctions. Therefore, the forecast of the time variation of energetic electrons is important to protect satellites against high energy electrons in the radiation belts. The time variations of the radiation belt electrons have been modeled with the Fokker-Plank equation. The performance of the forecast using the Fokker-Planck equations depends on the parameters used in the model, so that the improvement of the parameters is important for the space weather forecast. In this study, we estimate the radial diffusion coefficient and the whistler-mode wave amplitude that are used in the Fokker-Plank equation with the data assimilation. As a result of the data assimilation, the typical variations of the outer belt, and the slot region are well reproduced; the outer belt flux decreases and then recovers and increases during magnetic storms. On the other hand, there are several discrepancies between the simulation and the observations. Especially, we found the differential flux obtained from the data assimilation is lower than that from observations at L=5 to 6. The estimated diffusion coefficients from the data assimilation using 400 keV channel correlate roughly with that from 800 keV channel, and there are about 1-order differences between these two energy channels. The estimated wave amplitudes are lower than the result from the past observations on the plasmaspheric hiss. In this presentation, we also report the assimilation results including the non-adiabatic source term in the Fokker-Plank equation.

Keywords: radiation belts, space weather, data assimilation, particle filter

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Multi-hour-ahead prediction of Dst index using nonlinear autoregressive models with exogenous variables

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Geomagnetic storms play an important role in the framework of space weather. Disturbance storm time index (Dst index) is a geomagnetic index that monitors the geomagnetic storm level. It is well known that the geomagnetic storms may damage critical equipment, such as communication satellites, power lines and GPS links. Therefore, modeling and prediction of the Dst index are important for both scientific and economic reasons.

Two kinds of approaches have been proposed to model the DST index. One way is to use simplified analogue physical models on the basis of physical principles. An alternative approach is to directly build statistical models on the basis of the measurements. In the latter approach, the linear and nonlinear autoregressive models with exogenous variables (ARX and NARX models) were mostly used to predict the Dst index.

In most statistical approaches, the variance of the Dst index was assumed to be constant, and the estimated mathematical expectation was used to be the prediction value of the Dst index. However, according to our computational analysis, we found that the Dst index is of time-varying variance, and the proper estimation of this time-varying variance will enhance the prediction performance.

If the geomagnetic field is taken as an input-output dynamics system, the Dst index and the solar wind parameters can be referred to as the output and input, respectively. To model this input-output dynamic system, we combined the generalized additive models for location, scale and shape (GAMLSS) with the NARX models to construct the models. By using the GAMLSS type NARX models, the mathematical expectation and variance of the Dst index can be predicted.

So far, most contributions focused on predicting the Dst index in an hour ahead. Because the geomagnetic storms are harmful to critical equipment and then should be forecasted as early as possible, the multi-hour-ahead prediction models are necessary for the Dst index. For this purpose, we investigated the performance of the GAMLSS type NARX models for multi-step-prediction of the Dst index.

Finally, the statistical results, including the coefficient of determination and the prediction mean squared error, are given to comprehensively illustrate the fitting and prediction performance of the models.

Keywords: Space weather, Dst index, prediction, nonlinear autoregressive models with exogenous variables

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Dense Regional And Worldwide INternational GNSS-TEC observation (DRAWING - TEC) project

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Two-dimensional ionospheric total electron content (TEC) maps have been derived from ground-based GNSS receiver networks and applied to studies of various ionospheric disturbances since mid-1990s.
For the purpose of monitoring and researching ionospheric disturbances which can degrade GNSS navigations and cause loss-of-lock on GNSS signals, National Institute of Information and Communications Technology (NICT), Japan has developed TEC maps over Japan using the dense GPS network, GEONET, which consists of more than 1,200 GPS receivers and is operated by Geospatial Information Authority of Japan (GSI). Currently, we are providing high-resolution two-dimensional maps of absolute TEC, detrended TEC with 60, 30, 15-minute window, rate of TEC change index (ROTI), and loss-of-lock on GPS signal over Japan in realtime basis. These data and quick-look maps are archived and available in the website of NICT (http://wdc.nict.go.jp/IONO/).
NICT has collected all the available GNSS receiver data in the world to expand the TEC observation area. Figure 1 shows the distribution of the GNSS stations (more than 6,000 stations as of 2012) whose data are collected by NICT. These GNSS data are provided by IGS, UNAVCO, SOPAC, and other regional data centers. Currently, however, dense GNSS receiver networks are available only limited areas such as Japan, North America, and Europe as shown in Figure 1. More GNSS receiver data are needed especially in the sparse regions (ex. Asia, Oceania, Africa, and South America) to study the overall spatial structure and temporal evolution of various ionospheric disturbances. The difficulty of collecting GNSS receiver network data in these regions attributes mainly to the two reasons: (1) a lack of information sharing of domestic GNSS receiver network in the international ionospheric researcher community and (2) a government and/or a data provider policy to provide the original GNSS data only for domestic researchers. In order to overcome this difficulty and to expand the high-resolution TEC observation area, NICT has recently started a project, Dense Regional And Worldwide INternational GNSS-TEC observation (DRAWING-TEC). This project mainly consists of the following three items:
1.Standardizing GNSS-TEC data for high-resolution TEC maps.
2.Developing a new high-resolution TEC mapping technique using the standardized TEC data.
3.Sharing the standardized TEC data and the data or the information of GNSS receiver network among the international ionosphere and GNSS researcher community.

Keywords: Ionosphere, GPS, GNSS, Total electron content

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On the substorm-time variation of energetic electrons in the inner magnetosphere

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We studied spatial-temporal evolution of energetic electrons trapped in the inner magnetosphere (L<7.4) during an isolated substorm by using a four-dimensional drift kinetic simulation under the time-dependent electric and magnetic fields provided by a global magnetohydrodynamics (MHD) simulation. When the interplanetary magnetic field (IMF) turns southward, both the potential and induction electric fields start to increase in the inner magnetosphere, resulting in a gradual injection of low energy electrons (<51.9 keV) and deceleration of high energy electrons (>114 keV). The deceleration of high energy electrons results in a decrease in the phase space density (PSD) of the high energy electrons during the growth phase. After a while, an abrupt transition of phase state (a substorm onset) occurs in the magnetosphere, which triggers abrupt changes in the magnetosphere and ionosphere. The AL index decreases rapidly, and magnetic field lines become dipole-like. The dipolarization does not proceed smoothly in the inner magnetosphere because of significant force imbalance between the J x B force and the grad P force. As a consequence, the electric field oscillates with a period of 2-3 min, resulting in multiple injections of the low energy electrons. The low and high energy electrons are accelerated under the strong influence of the drift-betatron and gyro-betatron, so that the acceleration process is essentially non-linear. Our simulation results suggest that the force-induced processes play an essential role in the substorm-associated redistribution of energetic particles in the inner magnetosphere.

Keywords: Substorm, Inner magnetosphere, Energetic electrons