Starspot activity and superflares on solar-type stars

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

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

Keywords: flare, starspot

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

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

Keywords: solar flare, white-light, CME

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

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

Keywords: Sun, Solar Flares, Time Series Analysis

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

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

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

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

Energy Budget in Cold Solar Flares Observed with Nobeyama Radioheliograph

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

Keywords: Solar flare, radio, particle acceleration

Statistical analysis of solar flare multi-wavelength observation data

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

Keywords: solar flare, solar flare spectra

Study of double arc instability causing the onset of solar eruption

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

Keywords: Sun, flares, instability

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

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

Keywords: Solar flare, Space weather, SDO/HMI

Investigation of meridional flow pattern from mangetic elements motion

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

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

Keywords: Sun, Magnetic Field, Surface Flow

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

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

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

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

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

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

On the relationships between EEJ distribution and plasma bubble occurrences

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

Keywords: Equatorial ElectroJet, Plasma Bubble

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

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

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

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

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

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

Table 1

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

Statistical characteristics of interplanetary magnetic field near the Earth

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

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

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

Keywords: The Sun, Convection

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

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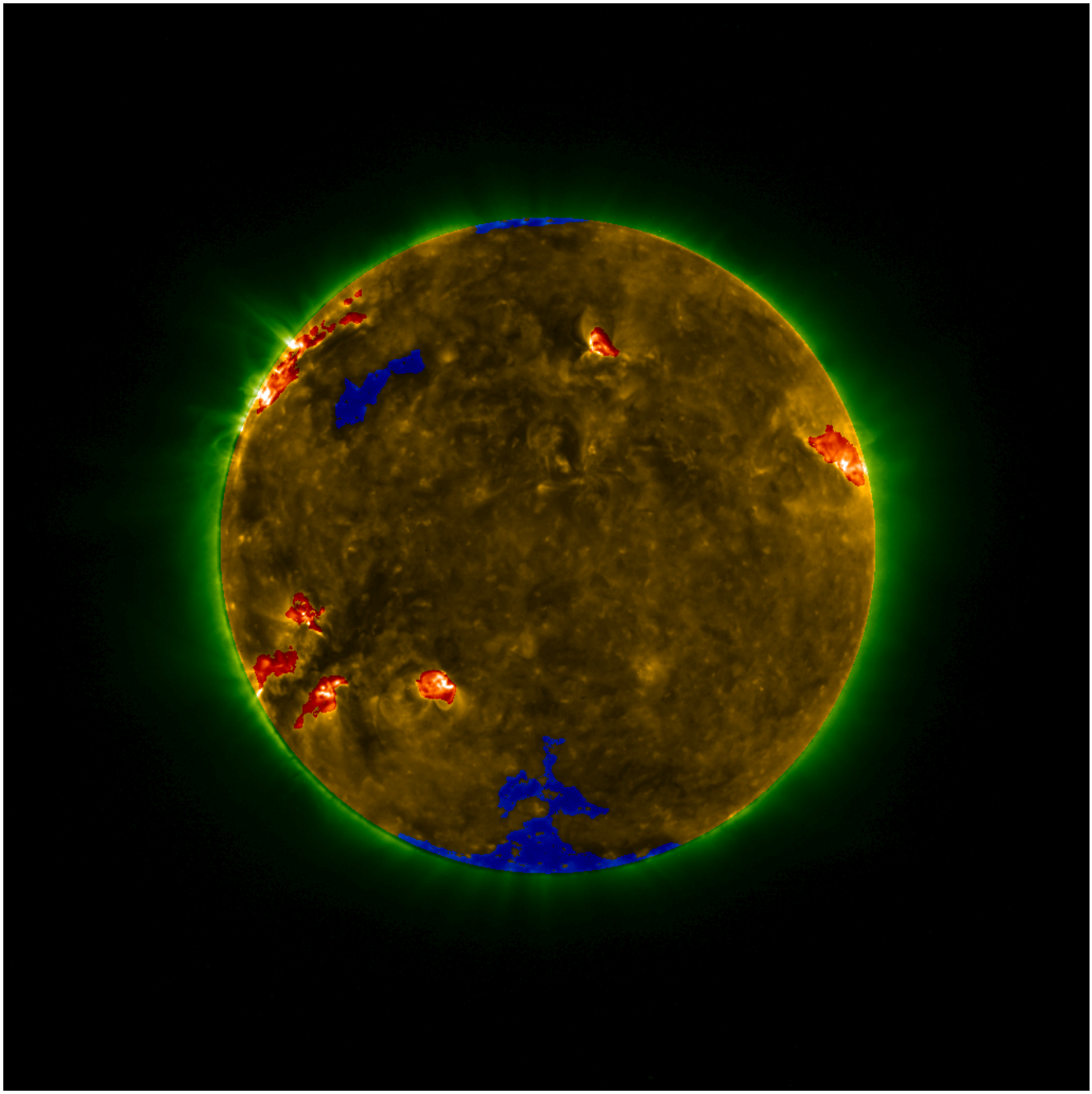
Understanding the variability of the EUV and UV irradiance on time scales from hours to months is of critical importance in the context of the Sun-Earth connection. A promising method to study the impact of the different coronal features, such as active regions and coronal holes, is by using segmentation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

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

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

Keywords: Solar physics, EUV irradiance variability



Identification of Active Longitude from the Solar Magnetograms

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

Keywords: Active Longitude, Sunspot

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

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

Keywords: Cosmogenic nuclide, Solar cycle, Travertine deposit

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

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

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

Long-term variation of Schumann resonance parameters at Kuju station

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

Keywords: Schumann resonance, solar activity

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

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

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

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

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

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

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Keywords: Solar corona, NLFFF, MHD relaxation method

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

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

Keywords: space weather, radiative cooling, thermosphere,

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

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

Keywords: radiation belt, whistler mode chorus, precipitation

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

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

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

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

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

Keywords: HILDCAA, GIC, Wavelet Analysis, Cross Correlation

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

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

Keywords: Electromagnetism, Space weather, GIC

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

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

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

Multi-instrument observations of periodic poleward moving polar cap arcs

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

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

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

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

Reconstructing polar asymmetry of GLE69 via WASAVIES simulation

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

Keywords: WASAVIES, Solar Energetic Particle, Space Weather

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

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

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

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

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

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

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

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

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

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

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

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

