太陽地球圏環境予測プロジェクト（PSTEP）の挑戦
Challenge of PSTEP (Project for Solar-Terrestrial Environment Prediction)

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我々が生きる太陽地球圏の環境は太陽活動に起因して大きく変動しますが、そのメカニズムは未だに十分解明されていません。このため、幅広い宇宙利用と高度な情報化が進んだ現代社会は太陽地球圏の環境変動に対して潜在的なリスクを抱えています。太陽地球圏環境予測プロジェクト(PSTEP)は、こうした問題の解決を目指して文部科学省科学研究費補助金新学術領域によって組織された全国的な研究プロジェクトです。PSTEPには９０名以上の研究者が参加し、４つの計画研究と公募研究の有機的な連携を通して太陽地球圏環境変動についての科学研究と予測研究を相乗的に発展させることを目指しています。これによって、太陽フレア発生機構、地球放射線帯の生成機構、太陽活動の気候影響機構といった重要な科学課題を解決すると同時に、激甚宇宙天気災害に備える社会基盤の形成を推進しています。本講演ではPSTEPの主要なねらいとその研究戦略を紹介します。

キーワード：宇宙天気、宇宙気候、予測
Keywords: space weather, space climate, prediction

宇宙天気情報利用におけるニーズ・シーズマッチングの検討
Analysis of Needs-Seeds Matching for Using Space Weather Information

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情報通信研究機構では、2005年よりほぼ毎年「宇宙天気ユーザーズフォーラム」を開催してきたことに加え、2013・14年の2年にわたり宇宙天気情報の利用者に対して姉k-戸やヒアリングを通しそのニーズの調査を行ってきた。
2015年に新学術領域「太陽地球圏環境予測」（PSTEP)が採択された。この中の主要な目標の一つとして「宇宙天気情報の双方向システムの構築」が挙げられている。この実現のために、新たに「宇宙天気ユーザー協議会」を立ち上げるとともに、研究者側から提供できる情報と、利用者が必要としている情報の調査を行い、ギャップ解析およびマッチングに向けた分析を行っている。
現在、宇宙天気情報の実利用検討で最も進んでいる分野として、航空運用が挙げられる。2014年には、国際民間航空機関（ICAO)で航空気象を規定する第三付属書の改訂が検討され、使用される宇宙天気情報の仕様が示された。しかしながら航空関係者にとってはこの利用について未だ十分な理解を得られているとは言えない状況である。このような事例を挙げつつ、ニーズ・シーズマッチングに向けた議論を行う。

キーワード：宇宙天気、市場調査、航空運用
Keywords: space weather, user investigation, aviation

ベクトル磁場と彩層発光を用いた機械学習による太陽フレア予測
Solar Flare Prediction with Vector Magnetogram and Chromospheric Brightening using Machine-learning

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

キーワード：宇宙天気予報、太陽フレア、統計解析、機械学習、光球ベクトル磁場、彩層
Keywords: Space Weather Forecast, Solar Flare, Statistical Analysis, Machine-Learning, Photospheric vector Magnetic field, Chromosphere

汎用時系列予報機UFCORINを用いた太陽フレア予測の進展について
Solar Flare Prediction Studies Using Universal Time Series Predictor UFCORIN

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我々は、自動化された宇宙天気予報を提供するためのソフトウェアプラットフォームUFCORIN(Universal Forecast Constructor by Optimized
Regression of INputs)を開発し、それを用いて宇宙天気予報を研究している。
これまでの実験では、2011-2012年の二年間の期間において、GOES衛星の観測による太陽X線フラックスの時系列データを予測対象とし、GOESデータの過去データおよびSDO/HMIによる太陽面視線垂直磁場画像データをもとに、6160通りの予報戦略を試し、その性能比較を行った(Muranushi et al. 2015)。
太陽フレア予測の研究では、
Bloomfield et. al(2012)の提案以来、予報性能の指標としてTSS(True Skill Statistics)が広く使われている。ところが我々は、数多くの予報戦略を比較する
場合、TSSの値は、予報戦略どうしの平均値の差にくらべ、交差検定データを変
えたときのゆらぎが大きすぎて、適切な性能比較ができないことを発見した。
そこで、交差検定データごとに、各予報戦略のTSSの偏差値(z-value)を算出したところ、交差検定データを変えても一貫して高い偏差値を示す予報戦略の存在が観察された。我々はこの偏差値を用いる手法を、数多くの予報戦略を比較する手段として提案する。
本研究の中で、X,M,Cクラスフレアに対する最善の予報戦略のTSSはそれぞれ0.75 ± 0.07, 0.48 ± 0.02, および 0.56 ± 0.04であった。
また、我々は(Muranushi et al. 2015)を元に、２０１５年８月よりリアルタイムフレア予報を提供している。この予報はサーバ障害等によるダウンタイムがあるものの、１２分おきに自動的に提供されている。本発表ではこのリアルタイム予報実験の進捗についても報告する。

キーワード：宇宙天気予報、フレア予測
Keywords: Space Weather Forecast, Flare Forecast

Realtime Solar X-ray Flux Forecast using Deep Learning

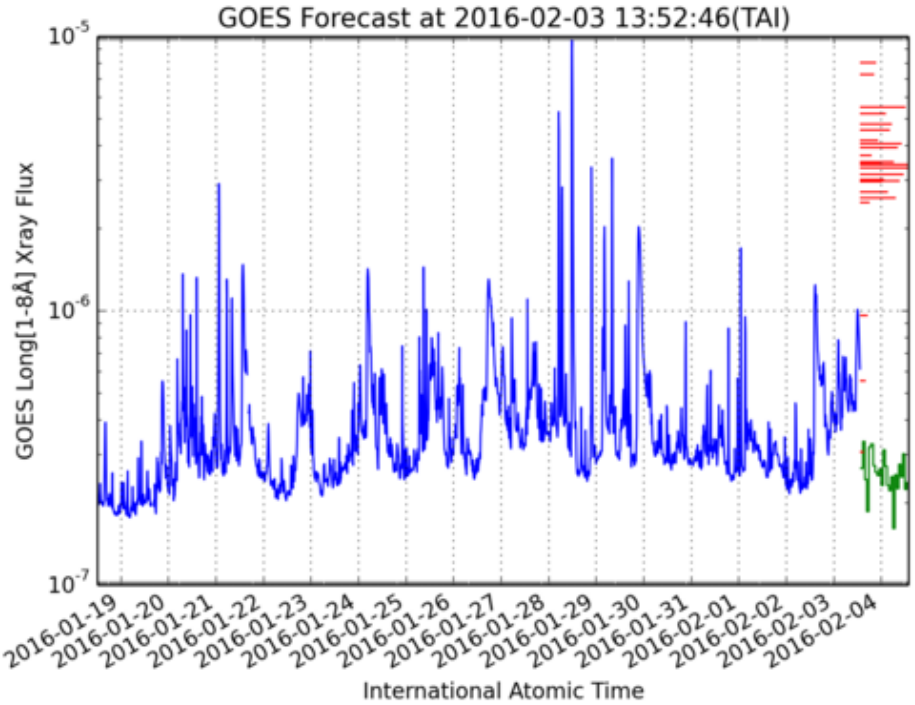
We present the 24-hour forecast of GOES X-ray flux, based on realtime GOES data and HMI-720s Near-Real-Time data.

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

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

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

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



宇宙及び航空機高度における放射線防護：WASAVIES開発の現状と今後の展望
Radiation Protection of Humans in Space and Aviation: Current States and Future Needs on the Warning System for Aviation Exposure to SEP (WASAVIES)

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

キーワード：太陽高エネルギー粒子、放射線被ばく、宇宙天気
Keywords: SEP, Radiation Exposure, Space Weather

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

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

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

NASA Heliophysics and the Science of Space Weather

NASA Heliophysics and the Science of Space Weather

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

Scientific research in support of space weather goals

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

Keywords: Space weather, Space research, Heliophysics

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

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

Keywords: Space weather, Geomagnetically induced currents

地磁気データから変電所GICの推定
Empirical estimation of GICs from the geomagnetic data in Japan

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

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

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

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

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

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

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

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キーワード：地磁気誘導電流、変電所、伝達関数

Keywords: geomagnetically induced current, transformer station, transfer function

グローバルMHDシミュレーションを用いたバスティーユイベント時の極冠電位差飽和の研究
Polar cap potential saturation during the Bastille day storm using global MHD simulation

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

キーワード：グローバル磁気圏シミュレーション、極冠電位差、極端現象
Keywords: global MHD simulation, polar cap potential, extreme event

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

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

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

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

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

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

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

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

Solar Corona and Space Weather

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It is now well established that the activity in the solar corona plays a major role in the processes at the origin of space weather effects in the heliosphere. The almost uninterrupted observations by the LASCO coronagraph onboard SOHO since January 1996 have allowed an unprecedented view of the coronal activity over almost two solar cycles 23 and 24 which reflects to a larger extent the magnetic activity of the Sun. I will report on the evolution of the corona and its large scale structure through various parameters, such as its radiometry and its three-dimensional electron density. The temporal variations will be compared with standard solar indices and various proxies of solar activity in order to identify the driving mechanisms that control the activity of the corona. Coronal mass ejections (CMEs) are strongly controlling space weather and the ARTEMIS-II catalog based on their automatic detection on high-quality calibrated synoptic maps of the corona allows performing an unbiased statistical analysis of their properties and investigate how they evolve with solar activity. I will present the results for occurrence and mass rates, waiting times, position angle, angular width, kinetic energy, and mass flux first globally and then separately for the two solar cycles 23 and 24 emphasizing the differences. I will further compare the statistical properties of CMEs with those of the standard indices of solar activity as well as those of their potential progenitors, flares and eruptive prominences.

Keywords: Sun, Coronal activity, Space weather

世界最大の太陽ダイナモ計算で明らかになった大規模磁場生成のメカニズム
Generation mechanism of large-scale magnetic field revealed with high-resolution solar dynamo calculation

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

キーワード：太陽、熱対流、ダイナモ
Keywords: Sun, Thermal convection, Dynamo

Modeling the thermosphere ionosphere system and space weather impacts

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

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

Effects of energetic particle precipitation and solar irradiance on ozone

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

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

脈動オーロラに伴う高エネルギー電子がもたらす大気微量成分変動の解明に向けた国際共同研究
International joint study of EEP effects on the atmospheric minor components during pulsating aurora

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

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

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Geomagnetically Induced Currents (GICs) are electric currents driven by activity in near-Earth outer space as our magnetic field interacts with that of the Sun's. These currents can flow through any conducting path, including pipelines and high voltage electric power lines. When GICs become strong enough, these technological systems can be interrupted or damaged, drastically affecting those who depend on them. Developing systems to accurately monitor and predict GIC events has therefore become a critical task for national security. An initial effort to assess the performance of five operationally-promising GIC models was presented by *Pulkkinen et al.* [2013]. The results of this validation effort showed that the models can provide predictive value, but shortcomings exist. While this work represents a landmark first-step towards numerical space weather forecasting, many questions remain concerning each of the models' capabilities. How do the models perform for different levels of geomagnetic activity? What is the range of activity for which the models have been validated? Based on the assumptions and input data for each model, what is the maximum driving for which the results can be considered valid?
This study presents a reanalysis of the *Pulkkinen et al.* [2013] results to extend our understanding of the models' capabilities and answer the questions posed above. Data-model errors between predicted and observed magnetometer dB/dt values are binned by activity (solar wind electric field or D_{ST}). The bins are arranged to yield error as a function of driving. Input data for empirical relationships, on which the models either rely or of which they comprise entirely, are binned by activity to determine the range of conditions over which each model is valid. A comparison of each model is presented to further illustrate previously published results. Additionally, because GICs are intimately linked to the electrojets which are in turn closely related to field-aligned currents, we also compare Birkeland currents from the different models to observations. For this we use radial current distributions from AMPERE based on the Iridium satellite constellation, providing assessments of the intensities and distributions of the global scale currents every ten minutes. From this new analysis, we place error bars on recent predictions of dB/dt made by the Space Weather Modeling Framework.

Keywords: Geomagnetically Induced Currents, Space Weather Modeling

サブストームのシミュレーション：電流系とオーロラ構造
Substorm simulation: Current system and auroral structure

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

キーワード：サブストーム、オーロラ、地磁気誘導電流(GIC)
Keywords: Substorm, Aurora, Geomagnetically Induced Current (GIC)

SuperDARNレーダーデータを用いた太陽フレア・粒子降り込みによる電離圏電子密度変動の同定
Identification of ionospheric plasma density changes due to solar flares and energetic particle precipitation using the SuperDARN radar data

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

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

キーワード：SuperDARNレーダー、電離圏電子密度変動、太陽フレア・粒子降り込み
Keywords: SuperDARN radars, ionospheric plasma density change, solar flare / energetic particle precipitation

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

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

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

キーワード：machine learning、total electron content、TEC forecast
Keywords: machine learning, total electron content, TEC forecast

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

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

TIE-GCMモデルと地上GPS-TEC観測による磁気嵐時の電離層データ同化
Ionospheric data assimilation with TIE-GCM and GPS-TEC during geomagnetic storm period

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

キーワード：電離層データ同化、磁気嵐
Keywords: Ionospheric data assimilation, geomagnetic storm

大気圏電離圏結合モデルGAIAの高精度化およびデータ同化に向けた取り組み

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

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超高層大気領域は人工衛星や地上 - 衛星間をつなぐ電波の通り道であり、その擾乱や変動は衛星の軌道や姿勢、また電波の伝搬に影響する。超高層大気の擾乱や変動の起源は、太陽フレアなど太陽面の活動が磁気圏を通して入ってくるだけではなく、地表付近の気象の影響も中層大気を通り入ってくることが知られてきた。我々は、電離圏・熱圏の全球分布を将来的に数値的に推測・予測するために、地表から熱圏上部までの中性大気領域と電離圏領域を相互に結合する大気圏電離圏結合モデル（GAIA）を開発してきた。しかし、長期シミュレーションと電離圏・熱圏の観測などとの比較・検証を行ったところ、数値予測への応用や大気研究により有効利用するためには、モデルの高精度化を進める必要があると分った。
本発表では、モデル高精度化の一環として、電離圏のダイナミクスやエネルギーの扱いの改良や、高分解能化などの試みとその結果について紹介する。また、数値予測に向けてデータ同化に対するインターフェースを開発しており、今後のデータ同化への取り組みについて紹介する。

キーワード：電離圏、熱圏、シミュレーション、モデリング、データ同化
Keywords: ionosphere, thermosphere, simulation, modeling, data assimilation

実時間データ同化にもとづくオーロラ活動指数の予測

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

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

キーワード：データ同化、予測、オーロラ活動指数
Keywords: Data assimilation, Forecast, Auroral activity index

NICTの新太陽電波望遠鏡と宇宙天気予報
New solar radio telescope of NICT and its space weather forecasting

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太陽ではフレアに代表される爆発現象が絶えず起きている。この爆発現象に伴い、高エネルギー粒子(SEP)や、コロナ質量放出現象(CME)が発生する。これらの一部は地球にも到来し、人工衛星の運用や電波通信に大きな影響を与えることがある。太陽の爆発現象では突発的な電波が放射される(太陽電波バースト)。電波は粒子よりも早く伝搬するため、太陽電波バーストを定常的に観測することは、宇宙天気の予報にとって極めて有効である。
NICTでは太陽活動を監視することを目的に茨城県平磯にて太陽の電波観測を行ってきた。今回、より高性能な太陽電波の広帯域分光観測を目指し、観測場所をNICTの山川電波観測施設(鹿児島県指宿市)に移転するとともに、新しい太陽電波望遠鏡の開発を行った。本望遠鏡は、口径8メートルのパラボラアンテナからなる。太陽電波バーストはメートル波からマイクロ波にかけて発生する広帯域の連続波放射である。本望遠鏡は焦点に2種類の広帯域アンテナを用いることで、0.07GHzから9.0GHzまでを1台のアンテナでカバーしている。太陽の視直径は約0.5度あり、太陽フレアはどこで発生するか事前の予報が難しいため、望遠鏡は太陽全面の視野を持つ必要がある。そこで高周波側のアンテナ位置をデフォーカスすることで、観測する全帯域で太陽全面の視野を確保した。受信信号は受信機内で分割され、FPGAを用いたデジタル分光計に供給される。本望遠鏡に開発されたデジタル分光計は、帯域幅2GHz・分光点数4096点と、帯域幅1GHz・分光点数32768点の2種類があり、合計10台で9GHzの帯域幅の両円偏波同時観測を実現した。分光計はデッドタイム無く連続的に分光可能で、スペクトルは内部で積算され、8ms毎に積算スペクトルを記録することで、高時間分解観測を可能とした。本装置の広帯域な感度特性は、様々な周波数で発生する電波バーストの観測に有効であり、宇宙天気現象の検出精度向上に大いに活用できること考えられる。また、本装置の高分解なスペクトルデータは、太陽電波バーストに含まれる微細なスペクトル構造を分解可能であり、フレアにおける非熱的粒子の生成過程の解明につながる成果も期待される。

キーワード：太陽、太陽電波バースト、宇宙天気予報、太陽高エネルギー粒子、電波観測
Keywords: Sun, solar rasio burst, space weather forecasting, solar energetic particle, radio observation

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

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

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

キーワード：太陽コロナ、太陽プロミネンス/フィラメント、磁気流体波動
Keywords: Solar corona, Solar prominence/filament, MHD wavess

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

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

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

キーワード：コロナ質量放出、太陽風、MHD
Keywords: CME, solar wind, MHD

適合格子細分化法を用いた太陽圏の動的モデルの構築

A dynamical model of the heliosphere with the adaptive mesh refinement

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A change in the heliospheric environment plays an important role in the modulation of the galactic cosmic rays; the magnetic field structure and the speed of the solar wind affect the cosmic ray transport in the heliosphere. Since the heliospheric environment is affected by the solar wind activities, we have been developing a framework for simulating the heliosphere by using MHD simulations.
The simulation code is based on SFUMATO code (Matsumoto 2007), which employs the block-structured adaptive mesh refinement (AMR) technique. The solar wind model gives the inner boundary condition of the simulations, and it is based on the model of Kataoka et al. (2009) and Shiota et al. (2014). The solar wind model adopted here is reconstructed by the observation of the solar magnetic fields. At this moment, the refinement criterion of AMR grid is only a function of the distance from the Sun. Our model reproduces the Parker spiral owing to the solar rotation.
We also measured the performance of the simulation code for massively parallel calculations. In the case of 1024/2048 cores calculations, our code exhibits parallel ratios of 99.945-99.982% and parallel efficiencies of 73.4-86.4%, depending on the implementation of a refinement manner. Such a high scalability is demonstrated even by a flat MPI parallelization.

キーワード：太陽圏、太陽風、MHD
Keywords: heliosphere, solar wind, MHD

伊勢スギの酸素同位体比分析から明らかになった小氷期末期の降水量増加
A humid climate of the last stage of the Little Ice Age in central Japan reconstructed using oxygen isotopes from tree-ring

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

キーワード：小氷期、モンスーン、樹木年輪、酸素同位体比
Keywords: Little Ice Age, Monsoon, tree-ring, oxygen isotopes

台風の発生と太陽活動の関係
Relationship between typhoon occurrence and solar activity

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

キーワード：台風、太陽活動、27日周期、積乱雲、西太平洋暖水プール
Keywords: typhoon, solar activity, 27-day, thunderstorm, WPWP

太陽風磁気ロープ発生頻度と太陽活動サイクルに関する検討
A critical review on solar cycle variation of interplanetary magnetic flux ropes

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

キーワード：solar wind、interplanetary magnetic flux rope
Keywords: coronal mass ejection, solar-cycle variation

太陽磁気フラックスロープを生む4重極活動領域の形成
Formation of a Quadrupolar Active Region Producing a Magnetic Flux Rope

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

キーワード：太陽、フレア、黒点
Keywords: Sun, Flares, Sunspots

フォースフリー磁場モデリングを用いた四重極磁場構造におけるホモロガスフレアの研究
Studies on homologous flares at quadrupole magnetic field using force-free field modeling

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

キーワード：太陽フレア、磁気リコネクション

Keywords: Solar flare, Magnetic reconnection

太陽コロナにおけるダブルアーク不安定性
Double Arc Instability in the solar corona

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太陽コロナにおけるフラックスロープの安定性は、太陽フレアやコロナ質量放出（CME）といった宇宙天気擾乱の主たる原因となる現象の発生に関連している。近年、太陽面爆発現象の原因としてトーラス不安定性がKliem & Toeroek (2006)によって提案された。しかしながら、いかにして不安定性が駆動されるのかについてはよくわかっていない。その一方で、不安定なフラックスロープを生じさせる過程のシナリオとして有名なものの一つに、Moore et al. (2001)で提案されたテザーカッティングリコネクションがある。このシナリオは強くシアした磁力線間の磁気リコネクションがダブルアーク型ループを形成し、やがて爆発現象が生じることを提案している。しかしながら、この初期段階の際に見られるダブルアーク型ループの安定性は未だに解析されていない。
本研究の目的は、ダブルアーク型電流ループの安定性を理論的に解析することである。そのため、ダブルアーク型電流ループをお互いに結合した二つの円形トーラスでモデル化し、その安定性を数値的に計算した。その結果TIとは対照的に、ダブルアーク型電流ループは一様な外部磁場の元でも不安定化しうることを見出した。この結果はダブルアーク型電流ループに対する不安定性、すなわちダブルアーク不安定性（DAI）はTIとは異なるものであることを示している。またTIの臨界の基準として用いられるdecay indexはDAIには適用できず、さらにDAIの必要条件は磁力線の半回転以上のねじれであることが分かった。DAI後の成長はフラックスロープの爆発の観測結果ともよく一致している。これらの結果は、テザーカッティングリコネクションに基づくDAIは実際に爆発現象のもとで機能し、どのように爆発現象が駆動されるのかよく説明しうる、ということを示している。

キーワード：太陽、太陽フレア、不安定性
Keywords: Sun, solar flare, instability

国際コンソーシアムによる野辺山電波ヘリオグラフの科学運用
Continued Operation of Nobeyama Radioheliograph by the International Consortium (ICCON)

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

キーワード：太陽、電波
Keywords: Sun, radio

太陽磁場観測による自転速度算出とその長期変動について
Calculation of solar rotation rate using the magnetic field observation, and its long-term variation

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太陽から放出されるプラズマ（太陽風）により地球周辺の宇宙環境は影響を受け続けている。太陽から放出されるプラズマはフレアやCMEなどの現象により、爆発的に放出され、地球及び人工衛星に甚大な被害を及ぼす。これを太陽嵐と呼ぶ。また、太陽風の変動全体を宇宙天気と呼び、それを正しく予測するための研究が様々な角度から行われている。太陽地球環境予測研究のひとつに太陽の活動メカニズムの研究が挙げられる。太陽は約11年周期で活動の大きさが変動することが知られており、活動が強い時、弱い時をそれぞれ極大期、極小期と呼ぶ。それに伴って太陽風の強さも変動し、極大期には太陽嵐も多く起こる。さらに、周期毎に活動の強さが異なることが過去の長期に渡る観測によって報告されている。太陽活動極小期において、極磁場（太陽の北極及び南極の磁場）の強さと次サイクルの太陽活動度には強い相関があることが知られており、現在の太陽活動極小期の極磁場を知る事は次期太陽サイクルを予測するのに有用である。
そこで本研究では差動回転、子午面循環流、乱流拡散係数などの表面磁束輸送モデル計算によって極磁場を見積もるのに重要なパラメターを太陽観測衛星SDO/HMIによる太陽磁場観測から求める。２つの異なる方法（Local Correlation Tracking (LCT)、Magnetic Element Tracking (MET)）で観測データから太陽のパラメターを算出するモジュールを開発し、実際のデータ解析に用いた。LCTとMETから見積もられる結果を比較し、両者の方法での違い・特徴について議論を行う。また、打ち上げ(2010年)から現在までのデータ（およそ６年分）を解析することにより、太陽における３つの物理パラメターの長期変動について考察を行った結果を報告する。

キーワード：太陽、磁場観測、自転速度、子午面循環流
Keywords: Sun, Magnetic field observation, Rotation rate, Meridional flow

MHD磁束輸送ダイナモにおけるη抑制の役割

The role of η-quenching in MHD flux transport dynamo

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

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

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

複数衛星粒子観測データを用いた静止軌道高エネルギー粒子環境の再構成

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

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

キーワード：宇宙天気予報、静止軌道、高エネルギー粒子観測
Keywords: Space Weather Forecast, Geostationary Orbit, High Energy Particle Observation

ISS/JEM-EF搭載SEDA-AP重イオン観測装置のデータ取得状況
The status of the SEDA-AP/Heavy Ion Telescope

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

キーワード：国際宇宙ステーション、SEDA-AP、重イオン
Keywords: ISS, SEDA-AP, heavy ions

太陽サイクル24/25における銀河宇宙線の太陽変調と航空機搭乗員の被ばく線量
The solar modulation of galactic cosmic rays and radiation dose of aircrews during the solar cycle 24/25

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

キーワード：銀河宇宙線、太陽圏、被ばく線量、中性子モニター
Keywords: galactic cosmic rays, heliosphere, radiation dose, neutron monitor

二次宇宙線の種類に着目したエアロゾル核生成の検証実験

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

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

地磁気急始変化（SC）振幅と太陽風動圧変化の関係

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

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太陽風衝撃波・不連続面の動圧（Pd）急増によって生じる地磁気急始変化（SC）は、地上観測からPd変化を知るプローブとして有効に使える。これは、飛翔体観測開始前時代には特に重要である。Siscoe et al.(1968)は、SC振幅(dH)が、Pd**0.5の衝撃波・不連続面前後の変化量、ｄ(Pd**0.5)に比例する（ ｄH =C・ｄ(Pd**0.5)）と仮定して、観測から比例係数Cを定めた。その後、Cを決める幾つかの解析がなされている。、
SC振幅（ｄH）は、緯度とLTに依存して大きく変わる。これは、磁気圏急圧縮時には、磁気圏界面電流（MC）と共に、沿磁力線電流（FAC）・電離層電流（IC）・地電流（EC）も急変化し、それらの磁場が複雑な緯度・LT依存性を示すからである。しかし、Cを決める際に、この緯度・LT依存性は、考慮されてこなかった。
ここでは、FAC・ICが作る磁場日変化の計算と、赤道から中緯度までの４観測所のデータから求めたCの日変化の解析から、４－５ｈLTに観測されるSCは、FAC・ICの影響を最も受けにくく、MC変化（従って、Pd変化）を直接的に表しているとの結論を得た。
これに従って、1868年以降に観測された３大SC（柿岡でｄH＞200nT）の振幅のLT依存性を考察し、最大とされていた1940.3.24SCが、やはり最大であることを確かめた。

キーワード：地磁気急始変化(SC)、太陽風動圧、電離層電流、磁気圏電流、日変化、Siscoe関係式
Keywords: geomagnetic sudden commencement(SC), solar wind dynamic pressure , , ionospheric current, field aligned current, LT variation, Siscoe’s relationship

日本での電力トランスの地磁気誘導電流の測定計画について
On measurement plan of geomagnetic induced current of power transformers in Japan

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日本は、地理緯度に比べて地磁気緯度が低いこともあり、地磁気誘導電流（GIC, Geomagnetically Induced Current）による電力システムへの影響はそれほど大きくないと考えられている。しかし、2003年10月末から11月の始めにかけて発生した大きな地磁気嵐の際には、日本の北部とほぼ同じ磁気緯度に位置する南アフリカ共和国で、電力トランスの障害事例が報告されている。また、GICの大きさは、地下導電率構造に依存することが知られており、GICのモデリングにおいて日本の複雑な地下構造の影響を考慮する必要がある。GICのモデリングのために計画しているGICの測定について報告する。

キーワード：地磁気誘導電流、地磁気嵐、電力システム
Keywords: geomagnetically induced current, geomagnetic storm, power system

磁気擾乱により励起されるGICの理解に向けた地上磁場変動の全成分解析

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

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

キーワード：地磁気誘導電流、磁力計ネットワーク
Keywords: GIC, magnetometer network

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

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

Keywords: thermosphere, ionosphere, GAIA, EISCAT

GAIAシミュレーションデータを用いたプラズマバブル発生確率の推定
Occurrence probability of plasma bubbles deduced from GAIA simulation data

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プラズマバブルやスポラディックE層、SED (Storm Enhanced Density)などの電離圏擾乱現象は、通信、放送、測位などに障害を起こすため、宇宙天気予報における最重要課題の一つとなっている。これらの現象は、一般に水平スケールが数100km以下のメソスケール現象であり、その予測には、リアルタイム電離圏観測と高精度の大気圏・電離圏モデルが必要である。我々のグループでは、電離圏擾乱現象の再現と予測を目的とした全大気圏-電離圏結合モデル（GAIA）を開発してきた。現在のGAIAは、これらのメソスケール現象を直接再現するには分解能がまだ十分でないが、プラズマバブルについては背景場から線形成長率を見積もることにより、発生しやすさを推定できる可能性がある。今回我々は、1996年から現在までの長期シミュレーションデータから、各日についてレイリーテイラー不安定の線形成長率の最大値を求め、プラズマバブル発生の観測データと比較した。その結果、GAIAデータから計算された線形成長率が大きい期間は、実際にプラズマバブルが発生した期間に対応する傾向があることがわかった。この結果は、GAIAのシミュレーションデータを用いてプラズマバブルの発生確率を推定できる可能性を示すものと言える。

キーワード：プラズマバブル、GAIA、線形成長率、レイリー・テイラー不安定、電離圏じょう乱
Keywords: plasma bubble, GAIA, linear growth rate, Rayleigh-Taylor instability, ionospheric disturbance

The Mid-Latitude Trough and the Plasmapause Detected by DEMETER

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

Keywords: ionosphere, mid-latitude trough, plasmapause

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

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

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

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

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

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

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

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

ニューラルネットワークを用いた太陽風入力によるfoF2の予報

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

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

キーワード：予報、foF2、ニューラルネットワーク、太陽風
Keywords: Forecast, foF2, Neural network, Solar wind

Preliminary development of radio propagation simulator for HF

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

Keywords: Radio propagation, HF, Ionosphere

高速太陽風における直線偏波・広帯域アルフベン波の非線形反射過程

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

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

キーワード：太陽風、アルフベン波
Keywords: solar wind, Alfvén wave

強く速度場が抑えられたときの太陽のエネルギー輸送について
Solar energy transport with significantly suppressed velocity

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We carry out a series of 2D convection calculations with highly suppressed velocity. Thermal convection in the solar interior is thought to maintain differential rotation and meridional circulation. Although the solar equator is rotating faster than polar region, recent high-resolution calculations with solar parameters accelerate the pole. This problem can be attributed to over-excited thermal convection in numerical calculations. Local helioseismology also supports this finding. Recent MHD simulations suggest that the small-scale Lorentz force is able to suppress the convection velocity, but the suppression is not enough and has not been numerical converged, i.e., higher resolution shows stronger suppression.
In this study, we assume that the Lorentz feedback in extremely high resolution, i.e., the sun, becomes stronger enough to explain equator acceleration and the result of the local helioseismology. In order to investigate this extreme condition, we carry out series of 2D hydrodynamics simulations with high viscosity mimicking the strong Lorentz force. The purpose of our research is to investigate energy flux transported by the thermal convection. Even if the velocity is reduced, convection needs to transport imposed energy flux at the bottom boundary. Generally it is expected that upflow and down flow become hotter and cooler, respectively than those without viscosity. We also find that the correlation becomes better with high viscosity with suppressing the small-scale chaotic motion.

キーワード：太陽、熱対流、磁場
Keywords: Sun, Thermal convection, Magnetic field

太陽風モデルSUSANOOの改善に向けた研究
A study for the improvement of SUSANOO-solar wind model

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

キーワード：太陽風
Keywords: solar wind

3次元MHDシミュレーションにおける太陽コロナ中での背景場プラズマとCMEの相互作用
Three-Dimensional MHD Simulation of the Interaction between CME and Ambient Plasma in Solar Corona

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

キーワード：磁気流体力学、コロナ質量放出、コロナ
Keywords: magnetohydrodynamic, coronal mass ejections (CMEs), corona

太陽彩層伝播アルフベン波のモード変換と加熱への寄与
Mode Conversion of Alfven Waves Propagating in the Solar Chromosphere and Contribution to the Heating

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

キーワード：彩層、波、非線形、加熱
Keywords: chromosphere, wave, nonlinear, heating

対流圏及び成層圏の気温に対するオゾンと太陽風の影響

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

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太陽磁気活動と地球大気の温度変化は相関関係にあることは間違いないが、その原因は明らかではない。この問題に対して今までの研究成果[1]に基づき、太陽風とオゾンが地球大気に与える影響について分析検討する。
今回、太陽風の影響を確認するためＡＥ指数データを使用し、オゾン全量と対流圏及び成層圏の気温の変化を解析した。
なお、解析を進めるにあたって次に点に注意した。低緯度でのオゾンに対するＥＰＰ－ＮＯｘの影響がＵＶ紫外線に匹敵する可能性がある[Callis et al.,2000,2001;Langematz et al.,2005;Rozanov et al.,2005]。低緯度で生成されたオゾンは冬極域に輸送されるため、ＥＰＰ－ＮＯｘが極域のオゾン減少に影響を与えている。
解析結果として、極域における５００ｈＰａ面の気温と８５０ｈＰａ面の気温から計算したショワルター安定指数（ＳＳＩ）は、ＡＥ指数と相関関係にあり、特に北極振動が正の位相から負の位相へ変化するときにその傾向が強い。このことは太陽風に伴う高エネルギー粒子の増加が、極域おける成層圏オゾンを減少させ、対流圏に到達する日射量を増加させることで、大気の安定度に影響を与えている可能性がある。
以上のことから太陽風の影響による成層圏オゾンの変化は、対流圏の気候に影響を与えていることを示唆している。

[1]伊藤公紀、地球惑星科学連合大会２００８－２０１５

キーワード：大気安定度、AE指数、北極振動、オゾン
Keywords: atmospheric stability, AE index, AO index, ozone

13-14世紀の太陽活動移行期における宇宙気候と地球気候：元王朝の災異記録の検討を通して
Space Weather and Terrestrial Weather during the Transition Period of the Solar Activity in 13th and 14th Century: an Examination on Disaster Records in Yuan Dynasty.

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13世紀、太陽活動は急速に低調になり、中世極大期（1100-1250）を終えて、所謂ウォルフ極小期（1280-1340）に突入した。このような太陽活動の変化は地球にも大きな気候変動をもたらし、いわゆる中世温暖期(10c-13c）が終わり、小氷期（14c-19c)が始まった。当初、ユーラシア大陸はモンゴル帝国による空前の世界帝国を経験し、東西の交易路が「モンゴルの平和」の下に統合される稀有な時代にあったが、かような世界帝国も折からの気候変動には勝てず、小氷期の始まりと時期を同じくして解体し、その背景に異常気象による飢餓や社会不安があったことは夙に語られるところである。しかし、そのような異常気象については漠然とその存在が語られるのみで従来踏み込んだ検討がなされてこなかった。そこで本報告では、モンゴル治下中国（元王朝: 1235-1368)の災異記録を検討し、C14などの科学データとの比較を通して、太陽活動の移行期に地球上にもたらされた異常気象の具体像に迫る。

キーワード：ウォルフ極小期、中世温暖期、太陽活動、異常気象
Keywords: Wolf Minimum, Medieval Warm Period, solar activity, Extreme Terrestrial Weathers

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

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

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

キーワード：オーロラ、宇宙天気、歴史資料
Keywords: Aurora, Space Weather, Historical Resources

個別の衛星のためのテーラーメード型宇宙環境予測モデルの開発
Development of user-oriented space environment prediction model for individual satellite

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

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

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

キーワード：宇宙天気予報、衛星帯電、テーラーメード型
Keywords: Space Weather Forecast, Spacecraft Charging, User-Oriented

航空用通信・航法・監視システムに対する宇宙天気現象の影響について
Space weather effects on aeronautical communication, navigation and surveillance systems

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

キーワード：航空利用、電離圏、通信・航法・監視システム
Keywords: aeronautical applications, ionosphere, communications, navigation, and surveillance systems

