R010-01
A 会場 ：9/24　PM1 （13:45-15:30）
13:45〜14:00

SUSANOO-CME を用いたリアルタイム太陽嵐到来予測システムの開発

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Development of a real-time prediction system of CME arrival and its magnetic field with ensemble SUSANOO-CME simulation

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The predictions of CME arrival to the Earth and the southward magnetic field brought by the CME flux ropes are one of crucial tasks for space weather forecast. We have recently developed a new prediction system of the CME impact (arrival of CME and magnetic field) with the MHD simulation SUSANOO-CME (Shiota & Kataoka 2016). The current prediction system has been used at the NICT space weather forecast operation since August 2022. Based on the real-time observations of flares and CMEs, ensemble simulations can be conducted on the supercomputer in NICT and the results are automatically visualized within 1 hour. The system is designed to be operated through a browser and is available to a forecaster who does not have a supercomputer account. In cases of X-class flares (X10 and above?), we conduct ensemble simulations without the CME observations because there is a large latency of the CME observations. We estimate the CME speed and width from the empirical relationship between the flare and the CME parameters.

The solar activity increases toward the maximum of Solar Cycle 25 expected around 2025, and the chance that an extremely large flare occurs becomes higher. In the presentation, we introduce an overview of the developed system showing the results used in the actual forecast operation, and discuss future directions.

CME およびそれに伴う磁場の地球への到来予測は、宇宙天気予報にとって需要なタスクの一つである。そのためのツールとして、NICT では惑星間空間の太陽風・CME の伝搬を解く MHD シミュレーション SUSANOO-CME (塩田&片岡 2016) を用いた太陽嵐到来予測システムを開発しており、2021 年 10 月より初期運用を、2022 年 8 月から機能を追加した本格運用を開始した。このシステムでは、スパコンのアカウントを持たない予報担当者がウェブブラウザからアクセスし、SOHO/LASCO 等のコロナグラフの観測データを解析、SDO 等の太陽フレアの観測と合わせて CME の入力パラメータを推定し、複数の予測シミュレーションを開始、1 時間前後で予測結果を得ることができる。特に、社会に影響が及ぶ大規模な太陽フレア・CME では、地球に到来するまでの所要時間が短くなり、早急な予測が求められる。コロナグラフのデータが揃うにはフレア発生から数時間程度かかるため、そのデータを待たなくても速度等のパラメータを仮定することで、太陽フレアの情報から予測シミュレーションを開始する機能も備えている。2019 年 12 月より始まった第 25 太陽活動周期は、2025 年前後に極大を迎えると推定されており、黒点数が増加し、大規模な太陽フレアの発生する可能性が高まりつつある。本講演では、システムの概要を紹介するとともに実際に予測に使用した事例を示し、今後の展望について議論する。

R010-02
A 会場 ：9/24　PM1 （13:45-15:30）
14:00〜14:15

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A Periodic Variation of Solar Wind Origins in Solar Cycles

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The solar wind is an important piece of information in space weather, space climate, and heliophysics, however, we have not yet fully understood its origin and acceleration mechanism and behavior in the heliosphere. Especially for the space climate, a variation of the global solar wind structure provides the key to understanding. Interplanetary scintillation (IPS) observation at the Institute for Space-Earth Environmental Research (ISEE) started routinely in 1985, and it allows us to reconstruct global solar wind velocity structure in each Carrington rotation (CR) without winter. Here, to derive long-term variations, the ISEE-IPS data are converted into latitudinal velocity structure data such as sunspot butterfly maps. It is clearly seen that the solar wind is composed of two types of solar wind with about 400 km/s (slow solar wind) and 800 km/s (fast solar wind), known as the bimodal solar wind, and their boundary latitudes depend highly on solar cycles. Subsequently, we employed the Potential Field Source Surface (PFSS) model to estimate the origins of the solar wind and investigate the characteristics of its long-term variation. Our findings reveal that the majority of the slow solar wind emanates from coronal holes situated at mid- and low-latitudes, whose spatial distribution aligns with the sunspot butterfly diagram. In this presentation, we concentrate on the variability of the solar wind origins and their statistical properties from 1985 to the present.

R010-03
A 会場 ：9/24　PM1 （13:45-15:30）
14:15〜14:30

深層学習による動画予測手法を用いたSDO紫外線画像の全球時系列予測

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([1)] 新大

Time-Series Prediction of SDO Ultraviolet Full-disk Images using a Video Prediction Method with Deep Learning

#Akira Sasaki[1)],Yusuke iida[1)]
([1)]Niigata University

Space weather disturbances in the vicinity of the Earth have a significant impact on the operation of aircraft and artificial satellites, and the importance of space weather forecasting is increasing year by year with the proliferation of space utilization in recent years. Solar full-disk ultraviolet images are often used in predicting solar activities that influence space weather.

In this study, we conduct prediction and generation of full-disk solar ultraviolet images for earlier space weather forecasting using a method known as video prediction.

Video Prediction is a deep learning model that takes a part of a video as input and generates and outputs frames that are predicted to follow that input. Video prediction has made remarkable progress in recent years, especially since the advent of ConvLSTM (Shi, Xingjian, et al 2015), with models such as Pred-RNN (Wang, Yunbo, et al. 2017) that model spatial features and temporal changes in a unified memory flow, and E3D-LSTM (Wang, Yunbo, et al. 2018) that introduces three-dimensional convolution. In this study, we used the Motion-Aware Unit (MAU) based on Pred-RNN proposed by Chang, Zheng, et al. (2021).

As a dataset, we used full-disk images of SDO/AIA211, where large structures such as coronal holes and active regions can be clearly seen. Data from 2010 to 2022 were sampled at 4-hour intervals. We built a model that takes 48 hours of data, or 12 full-disk images, as input and estimates the following 48 hours at 4-hour intervals.

The model we built generally reproduced large-scale structures that were visible on the disk at the time of the most recent input, along the differential rotation. We compared the UV intensity of the same pixel in the predicted image and the correct image for ten such active regions and calculated the correlation coefficient, which was 0.86 after 4 hours, 0.76 after 24 hours, and 0.63 after 48 hours. In addition, the model also roughly reproduced the distribution of UV intensity for active regions that existed on the eastern limb at the time of the latest input and appeared on the disk after time passed.

These results demonstrate the usefulness of deep learning-based video prediction technology in space weather forecasting.

地球周辺の宇宙天気撹乱は航空機や人工衛星の運用に大きな影響を持ち、近年の宇宙利用の普及から宇宙天気予報の重要性は年々増加している。宇宙天気に影響を持つ太陽活動の予測には太陽の全球画像の紫外線像がしばしば用いられる。

本研究では、より早期の宇宙天気予報のために、動画予測と呼ばれる手法により、太陽全球紫外線像の予測及び生成を行う。

動画予測 (Video Prediction) は、動画の一部分を入力としてモデルに渡すと、その入力に続くと予測されるフレームを生成し出力する深層学習モデルである。動画予測は ConvLSTM(Shi, Xingjian, et al 2015) の登場を機に近年目覚ましい発展を遂げており、空間的特徴と時間的変化を統一的なメモリフローでモデル化した Pred-RNN(Wang, Yunbo, et al. 2017) や、三次元畳み込みを導入した E3D-LSTM(Wang, Yunbo, et al. 2018) などが提案されている。本研究では、Chang, Zheng, et al.(2021) で提案された、Pred-RNN をベースとする Motion-Aware Unit(MAU) を用いた。

データセットとして、コロナホールや活動領域などの大規模構造が明瞭に見られる SDO/AIA211 Å 全球画像を使用した。2010 年から 2022 年のデータを 4 時間間隔でサンプリングした。48 時間分のデータ、つまり全球画像 12 枚、をインプットとし、その後の 48 時間を 4 時間毎に推定するモデルを作成した。

作成したモデルは、直前の入力の時点で球面に確認できている大規模な構造を、差動回転に沿って概ね再現した。そのような活動領域 10 個に対して予測画像と正解画像の同ピクセルの輝度強度を比較し相関係数を計算したところ、4 時間後で 0.86、24 時間後で 0.76、48 時間後で 0.63 であった。また、直前の入力の時点で東の外縁部に存在し、時間経過後に球面に現れる活動領域も輝度強度の分布をおおよそ再現した。

これらの結果は、深層学習による動画予測技術の宇宙天気予報における有用性を示している。

R010-04
A 会場 ：9/24　PM1 （13:45-15:30）
14:30〜14:45

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Development of a coronal hole detection method from extreme ultraviolet images using deep learning

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Coronal holes are regions of open magnetic fields which observed as dark areas in the solar corona because of their low density and temperature compared to other coronas. They are the source of high-speed solar wind streams, whose interaction with Earth's magnetosphere causes geomagnetic storms. In recent years, coronal hole detection methods based on deep learning has been reported by several researches, and detection results are expected to be more accurate than conventional detection methods with image processing technique. On the other hand, although the significant correlation between the coronal hole area and the solar wind parameter has been reported, the model accuracy for coronal hole detection has not been directly evaluated. In this study, we developed a coronal hole detection method using machine learning, evaluated, and improved it focusing on the area of coronal holes.

We developed a coronal hole detection model using U-Net, a semantic segmentation model that classifies each pixel to the defined categories. The detection model uses the full-disk EUV images from SDO/AIA as input, and classifies each pixels whether it is a coronal hole. We used 754 images of three types in the 171 angstrom, 193 angstrom, and 211 angstrom waveband for about two years. Also, we used the coronal hole identification via multi-thermal emission recognition algorithm (CHIMERA ; Garton et al., 2017) to create class labels in ground-truth data. CHIMERA analyses multi-thermal images from the AIA/SDO to detect coronal holes with image processing by their intensity ratio across three passbands, e.g. 171 angstrom, 193 angstrom, and 211 angstrom.

We achieved F-score=0.859 and IoU=0.759 for coronal hole detection using U-Net. In addition, we evaluated using RMSE to compare the area of each coronal hole in the predicted images and the label images, as a result, we achieved RMSE=1098.0[pixel]. In the next experiment, we focused on the normalization method for input data to improve the accuracy of coronal hole detection. Finally, we achieved F-score=0.881, IoU=0.792 and RMSE=835.1[pixel] for coronal hole detection by changing to the normalization method using stretch function.

R010-05
A 会場 ：9/24　PM1 （13:45-15:30）
14:45〜15:25

太陽地球環境研究への HPC の挑戦

#堀田　英之 [1)]
(1 名大

HPC Challenge to Solar-Terrestrial Environmental Research

#Hideyuki Hotta[1)]
(1Nagoya University

Program for Promoting Researches on the Supercomputer Fugaku (Elucidation of the Sun-Earth environment using simulations and AI) has started in FY2023. This program targets the solar interior, surface, corona, solar wind, interplanetary space, and Earth's magnetosphere, and aims to understand the elementary processes of solar-terrestrial environmental change phenomena and realize inter-disciplinary collaboration by using large-scale simulations with "Fugaku" and AI.

The origin of the phenomena of the Sun-Earth system is the dynamo motion in the solar interior. Part of the magnetic field generated by the dynamo appears on the solar surface as sunspots and causes explosive flares. The magnetic field on the solar surface generates solar wind, which, along with coronal mass ejections, has a significant impact on the Earth's environment. Although these phenomena are closely related, their comprehensive treatment has been limited because of their significantly different spatial and temporal scales. In addition, some elementary processes, such as dynamo and coronal heating, are poorly understood, which hampers their study as a whole. On the other hand, our field has fully benefited from supercomputers, which have evolved over the years and have allowed for a better understanding of physical processes as computations have become larger and larger.

In this talk, we will review the current status of Sun-Earth environmental research using HPC and discuss the future direction of this research.

かす太陽地球環境変動」が開始した。本プラグラムでは、太陽内部・表面・コロナ・太陽風・惑星間空間・地球磁気圏までを対象とし、「富岳」を用いた大規模シミュレーションと AI を用いて太陽地球環境変動現象の素過程の理解・分野間連携を実現する。

太陽地球系の現象の起源は、太陽内部のダイナモ運動にある。ダイナモで生成された磁場の一部は黒点として太陽表面に現れ、爆発的なフレアを引き起こす。それとともに、太陽表面の磁場は太陽風を発生させ、コロナ質量放出とともに地球環境に多大な影響を及ぼす。これらの現象は密接に関係しているが、空間・時間スケールが大きく異なるためにこれまで包括的な取り扱いは限られてきた。また、ダイナモ過程やコロナ加熱など、素過程にも理解できていない部分があるために、全体としての研究を阻害している。一方、我々は年々進化するスーパーコンピュータの恩恵を十分に受けている分野でもあり、計算の大規模化に伴い、物理過程の理解を深めてきた。

本講演では、HPC を利用した太陽地球環境の現状をレヴューするとともに、今後の当該研究の進めむべき方向について議論する。

R010-06
A 会場 ：9/24　PM2 （15:45-18:15）
15:45〜16:00

社会的影響を考慮した新たな宇宙天気予報・警報基準導入の進捗状況

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Progress in introducing new space weather forecasting and warning types criteria that take into account social impacts

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While many countries are studying the impact of space weather phenomena on social infrastructure and how to respond to them, the Ministry of Internal Affairs and Communications (MIC) ”Study Group on the Advancement of Space Weather Forecasting” has been held in Japan in 2022, and the report was released in June 2022.(https://www.soumu.go.jp/menu_news/s-news/01tsushin05_02000047.html). Among the recommendations discussed in the study group, such as future observation, analysis, and forecasting related to space weather forecasting, and strengthening of the warning system, the formulation of new forecasting and warning standards that take into account the impact on social infrastructure and reliable warning distribution by the National Institute of Information and Communications Technology (NICT) is identified as particularly urgent issues.

The current NICT’s forecasting and warning information focuses on the scale of the space weather phenomena and do not include information on social impacts, but forecasting and warning information based on social impacts are necessary for users to determine specific responses. Therefore, the Working Group on Space Weather Warning Criteria, established under the Study Group, examined new warning types and criteria that take into account the social impact of space weather phenomena, and established a total of 17 types of forecasts and warnings in the five fields of communications and broadcasting, positioning, satellite operations, electric power, and aviation exposure. For the fields of communications and broadcasting (HF band), space system operation (satellites), and aviation exposure for which thresholds have been established, we have studied the content and timing of warning distribution and developed an automatic distribution system.

宇宙天気現象の社会インフラへの影響やその対応について各国で検討が進められている中、日本でも 2022 年 1 月から総務省「宇宙天気予報の高度化の在り方に関する検討会」が開催され、同年 6 月に報告書が公開された（https://www.soumu.go.jp/menu_news/s-news/01tsushin05_02000047.html）。本検討会で議論された宇宙天気予報に係る今後の観測・分析・予報の在り方、警報に関する体制強化などの提言のうち、特に喫緊の課題として、社会インフラのリスク（被害）を考慮した新たな警報基準の策定と情報通信研究機構（NICT）による確実な警報伝達が挙げられ、総務省とも連携して対応を進めている。

現在の NICT による予報・警報は現象の規模に着目した基準とし、社会的影響についての情報は含まれないものとなっているが、宇宙天気予報の利用者が具体的な対応を判断するためには社会的影響を基準とする予報・警報が必要である。そのため、宇宙天気現象がもたらす社会的影響の大きさも考慮した新たな警報の種類・閾値について検討会の元に設置された「宇宙天気の警報基準に関する WG」において検討され、通信・放送、測位、衛星運用、電力、航空機人体被ばくの 5 分野で計 17 種類の予報・警報の種類が設定、そのうち 12 種類については基準の閾値が策定された。基準の閾値が策定された、通信・放送（HF 帯）、宇宙システム運用（衛星）、航空機人体被ばく分野について、警報等の送信内容、タイミング等について検討し、自動通報の配信システムの開発を進めている。

R010-07
A 会場 ：9/24　PM2 （15:45-18:15）
16:00〜16:15

物理モデルに基づくフレア警報システムの開発

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Development of a large-flare warning system based on κ-scheme

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NICT provides space weather forecast and predicts the largest solar flare which is expected to occur within 24 hours. We announce the urgent solar flare alert right ”after” the large flare occurred. However, it does not sometimes work to prevent geoeffective incidents (e.g., Dellinger phenomena), because the electromagnetic waves immediately reach to Earth from the Sun. It is thus required to develop the large flare warning system that predicts and notices the large flare occurrence at least a few hours ”before” its onset. On the other hand, a new large flare prediction model ”κ-scheme” was recently developed by Kusano et al. 2020. In κ-scheme, the critical condition of the large flare occurrence is quantitatively described based on the double-arc instability theory (Ishiguro & Kusano 2017).

In this study, we develop an X-class flare warning system based on the κ-scheme, in order to practically use in our space weather forecast operation. We first extrapolate the three-dimensional coronal magnetic field (nonlinear force-free field; NLFFF) in an active region from the photospheric magnetic field data obtained by SDO. We then calculated the following parameters based on the NLFFF: High Free Energy Region (HiFER) where the strong magnetic free energy is stored, the critical radius r_c to trigger the double-arc instability in the reconnection region, and the estimated minimum energy E_r that can be released by the double-arc instability. Kusano et al. 2020 suggests that flares larger than X2-class occur under the condition of r_c <0.1 [Mm], E_r >10^{32} [erg]. We are planning to issue the advisories and/or alerts for the imminent X-class flare based on the HiFER together with the r_c, and E_r conditions. In the presentation, we report the progress of the system development and tasks to utilize the system in our space weather forecast operation.

情報通信研究機構（NICT）における宇宙天気予報業務では、今後 24 時間以内に発生が期待されるフレアの最大規模を予報している。特に大規模なフレアが観測された際などには臨時情報を配信しているが、地球からフレアを観測した時点で既にその影響（例えば、デリンジャー現象による短波通信への影響）は現れており、フレアによる通信等への影響を回避・軽減するための対応が間に合わない可能性が高い現状である。そこで、少なくともフレア発生の数時間「前」に、その発生を確定的に予測し注意喚起する「フレア警報」の提供が求められる。一方、近年、太陽表面で発生する不安定性の理論（ダブルアーク不安定性, Ishiguro & Kusano 2017）に基づきフレア発生の条件を導くことで、大規模フレアを予測する新しい物理モデル「κスキーム」が開発された（Kusano et al. 2020）。

そこで本研究では、NICT 宇宙天気予報業務への実装を目指した、κスキームに基づく大規模フレア発生予測および警報配信を行うシステムの構築を行なっている。まず Solar Dynamics Observatory (SDO) により取得した太陽活動領域の光球面磁場データから、非線形フォースフリー磁場（NLFFF）モデリングにより 3 次元コロナ磁場を外挿し、活動領域の中で特にエネルギーが蓄積されている「High Free Energy Region (HiFER)」を算出した。次に、HiFER 内に含まれる磁気中性線上のすべての点に対して、ダブルアーク不安定性によりフレアを起こすために必要なリコネクション領域の臨界半径 r_c およびその領域で実際にリコネクションが起きた際に解放可能な最小のエネルギー E_r を算出した。Kusano et al. 2020 では、X2 クラス以上の大規模な太陽フレアは r_c <0.1 [Mm], E_r >10^{32} [erg] の点から起こることが示唆されており、本研究では HiFER の出現や (r_c, E_r) の条件により段階的に X クラスフレア発生「注意報」「警報」を出すことを目指している。発表では、警報システム開発の進捗状況とともに、予報業務の中でリアルタイム運用できるシステムを構築するための課題等について報告する。

R010-08
A 会場 ：9/24　PM2 （15:45-18:15）
16:15〜16:30

機械学習を用いた太陽フレア時の太陽 EUV 放射スペクトル予測

#前田　護 [1)], 渡邉　恭子 [1)], 西本　将平 [1)], 北島　慎之典 [1)], 下条　圭美 [2)], 行方　宏介 [2)], 増田　智 [3)]
[(1] 防衛大,[(2] 国立天文台,[(3] 名大

Prediction of solar EUV spectra during solar flares using Machine Learning

#Mamoru Maeda[1)],Kyoko Watanabe[1)],Shohei Nishimoto[1)],Shinnosuke Kitajima[1)],Masumi Shimojo[2)],Kosuke Namekata[2)],Satoshi Masuda[3)]
[(1]National Defense Academy,[(2]National Astronomical Observatory of Japan,[(3]Nagoya University

X-ray (0.1-10 nm) and extreme ultraviolet (EUV: 10-124 nm) emissions from the Sun ionize atoms and molecules in the Earth's upper atmosphere and contribute to the formation of the ionosphere. The ionosphere is used for satellite and terrestrial communications. Since the ionospheric environment fluctuates with the 11-year solar cycle and sudden space weather phenomena such as solar flares, it is necessary to monitor and predict the ionospheric environment to keep a stable communication environment.

Observations of solar X-rays and EUV emissions, which have a large impact on the ionosphere, are limited to the period of satellite operation. On the other hand, microwave emissions from the Sun can be observed on the ground. It is known that there is a good correlation between solar microwaves and solar EUV emissions, and microwave at 2.8 GHz (F10.7) have traditionally been used as proxies for EUV emission when estimating the impact of solar emissions on the Earth's upper atmosphere, including the ionosphere. Recently, however, it has become clear that F10.7 alone cannot explain the actual affect to the Earth's upper atmosphere, because the variation of the EUV spectrum varies with wavelength. For this reason, studies such as Zhang & Paxton (2018) have recently been conducted to reproduce solar EUV radiation from multiple frequencies of radio observation data using machine learning.

We have studied solar cycle variations by using machine learning method to reproduced EUV emission spectra from multi-frequency radio emissions. By using data from the NoRP (1, 2, 3.75, 9.4 GHz) and Learmonth solar radio telescopes monitor (610, 1415 MHz) , we have succeeded in reproducing the EUV emission spectrum observed by TIMED/SEE. The machine learning method also revealed which frequencies contribute to the reproduction of EUV emissions and found that lower frequencies such as 1 GHz and 2 GHz contribute significantly to the reproduction of EUV emissions.

In this study, we try to reproduce of solar EUV emission spectrum observed by SORCE/XPS during solar flare by using multi-frequency data from NoRP. The time resolution of SORCE was only about 5 minutes, which was not enough to obtain sufficient data during flares, so it was not possible to discuss time variability. Therefore, we first tried to reproduce the total amount of EUV emission for each flare event using SDO/EVE data with high temporal resolution of 10 seconds. The time-integrated intensities of both radio and EUV data for each flare event are used as input values and as output values for machine learning. As a result, a good correlation is observed at a ten few nm, and we are able to reproduce to some extent the amount of EUV radiation during solar flares from the radio data.

In this presentation, we will report the results of reproduced solar EUV emission spectrum during solar flares by machine learning method, and discuss the reproduction of the temporal variation of EUV emission with radio data.

太陽からの X 線（0.1-10 nm）と極紫外線（EUV: 10-124 nm）放射は、地球上層大気中の原子や分子を電離することで、電離圏の形成に寄与している。電離圏は衛星通信や地上の通信に使用されているが、電離圏の環境は太陽の 11 年周期や太陽フレアなどの突発的な現象によっても変動するため、安定した通信環境を確保するためには、電離圏環境を監視・予測することが必要である。

電離圏への影響の大きい太陽 X 線・EUV 放射の観測は、人工衛星の運用期間に限られている。一方、太陽からの放射のうち電波は地上で観測できる。太陽電波と太陽 EUV 放射は相関が良いことが知られており、これまで電離圏を含む地球圏環境への太陽放射の影響を見積もる際には F10.7 という 2.8 GHz の電波が EUV 放射のプロキシとして用いられてきた。しかし近年、EUV 放射スペクトルの変動は波長によって異なるため、F10.7 だけでは実際に地球圏環境に影響している放射を説明できないことが分かってきた。そのため最近では、Zhang & Paxton (2018）のような機械学習を用いて複数周波数の電波観測データから太陽 EUV 放射の再現をおこなう研究がなされている。

これまで太陽周期変動において、多周波の電波放射から EUV 放射スペクトルを再現する研究を行った。野辺山強度偏波計 (NoRP; 1, 2, 3.75, 9.4 GHz) と Learmonth solar radio telescopes monitor（610, 1415 MHz）の観測データを用いることで、TIMED/SEE で観測された EUV 放射スペクトルを機械学習で概ね再現することに成功した。また、機械学習の手法を用いることによって、どの周波数の電波が EUV 放射の再現に寄与しているかについても分かり、1 GHz や 2 GHz といった低い周波数の電波が EUV 放射の再現に大きく寄与していることが分かった。

今回は太陽フレア時における太陽 EUV 放射スペクトルの再現を試みた。NoRP の多周波データからフレア時に SORCE/XPS で観測された EUV データの再現を試みたところ、元々良い相関が見られていた十数 nm の放射は再現できたが、相関が悪い EUV 放射の再現は難しく、また SORCE の時間分解能は５分程度でありフレア時のデータが十分に得られなかったため、時間変動に関する議論はできなかった。そこで、時間分解能が 10 秒の SDO/EVE のデータを使用し、

まずフレアイベントごとの EUV 放射量の総量の再現を目指した。電波、EUV データ共にフレアイベントごとの放射強度を時間積分したものを入力値、出力値とし機械学習に入力し学習させた。その結果、やはり十数 nm では良い相関が見られ、電波データから太陽フレア時における EUV の紫外線放射量をある程度再現できた。

今回の発表では、太陽フレア時における太陽 EUV 放射スペクトルの再現について試みた結果について報告するとともに、電波データと EUV 放射の時間変動の再現についても議論する。

太陽からの X 線（0.1-10 nm）と極紫外線（EUV: 10-124 nm）放射は、地球上層大気中の原子や分子を電離することで、電離圏の形成に寄与している。電離圏は衛星通信や地上の通信に使用されているが、電離圏の環境は太陽の 11 年周期や太陽フレアなどの突発的な現象によっても変動するため、安定した通信環境を確保するためには、電離圏環境を監視・予測することが必要である。

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今回は太陽フレア時における太陽 EUV 放射スペクトルの再現を試みた。NoRP の多周波データからフレア時に SORCE/XPS で観測された EUV データの再現を試みたところ、元々良い相関が見られていた十数 nm の放射は再現できたが、相関が悪い EUV 放射の再現は難しく、また SORCE の時間分解能は５分程度でありフレア時のデータが十分に得られなかったため、時間変動に関する議論はできなかった。そこで、時間分解能が 10 秒の SDO/EVE のデータを使用し、まずフレアイベントごとの EUV 放射量の総量の再現を目指した。電波、EUV データ共にフレアイベントごとの放射強度を時間積分したものを入力値、出力値とし機械学習に入力し学習させた。その結果、やはり十数 nm では良い相関が見られ、電波データから太陽フレア時における EUV の紫外線放射量をある程度再現できた。

今回の発表では、太陽フレア時における太陽 EUV 放射スペクトルの再現について試みた結果について報告するとともに、電波データと EUV 放射の時間変動の再現についても議論する。

R010-09
A 会場 ：9/24　PM2 （15:45-18:15）
16:30〜16:45

地球電離圏 E 層を直接生成する太陽放射波長

#家田　章正 [1)], 渡邉　恭子 [2)], 北島　慎之典 [2)], 西岡　未知 [3)], 陣　英克 [3)], 堀　智昭 [1)]
[(1] 名大宇宙地球研,[(2] 防衛大,[(3] 情報通信研究機構

Solar radiation wavelengths that directly generate the Earth's ionospheric E-layer

#Akimasa Ieda[1)],Kyoko Watanabe[2)],Shinnosuke Kitajima[2)],Michi Nishioka[3)],Hidekatsu Jin[3)],Tomoaki Hori[1)]
[(1]Institute for Space-Earth Environmental Research, Nagoya University,[(2]National Defense Academy of Japan,[(3]National Institute of Information and Communications Technology

Solar radiations ionize the Earth's neutral atmosphere to generate the ionosphere. The ionospheric E-layer is characterized by horizontal electric currents, which cause geomagnetic variations and Joule heating. These quantities are often modeled using the maximum electron density of the E-layer. According to Chapman's ionospheric formation theory, this maximum electron density is proportional to the square root of the solar radiation energy flux. The solar radio flux F10.7 (10.7 cm, 2.8 GHz) index has been often utilized as a proxy for solar flux in models of ionosphere, including the model of E-layer maximum electron density. However, this usage of F10.7 may be inappropriate because the E-layer is not generated by the solar radio wave but Lyman β.

In this study, we compared the maximum electron density with solar fluxes, namely, the F10.7 index, Lyman β (103 nm), and Lyman α (122 nm). We used the Lyman α data (daily values) collected by the University of Colorado using multiple satellite observations. We calculated Lyman β flux using an empirical relationship with Lyman α. Hourly values of maximum electron density were obtained from ionosonde observations conducted at Yamagawa station in Kagoshima, Japan, operated by the National Institute of Information and Communications Technology. Data from 1991 to 2023 were used for the analysis.

A least squares fitting to the data gave similar correlation coefficient with the maximum electron density among the three solar flux quantities. However, the fitted lines showed qualitative differences regarding the origin. The line fitted to the Lyman β data passed through near the origin. This result suggested that Lyman β directly controls the Earth's ionospheric E-layer. In contrast, the line fitted to the F10.7 index deviated from the origin. This result implies that the F10.7 index should not be directly used in models associated with E-layer, and its offset needs to be subtracted prior to calculations. This correction presumably improves models of ionospheric conductivity, geomagnetic variations, and Joule heating.

地球電離圏では、E 層に集中した水平電流が、地磁気変動やジュール加熱を引き起こしている。これらの物理量は、E 層の最大電子密度を用いてモデル化される。この最大電子密度は、Chapman の電離層生成理論によると、太陽放射フラックスの平方根に比例する。これまで、太陽放射フラックスとして、太陽電波 F10.7 指数 (10.7 cm, 2.8 GHz) が用いられている。しかし理論的には、最大電子密度を生成しているのは、太陽電波ではなく Lyman β放射 (103 nm) である。F10.7 指数を用いることの妥当性は明らかでなかった。

本研究では、F10.7・Lyman β・Lyman α (122 nm) を、E 層最大電子密度と比較した。Lyman αはコロラド大学が複数の衛星観測から作成したデータ (1 日値) を用いた。Lyman βは、Lyman αとの経験的な関係式から算出した。最大電子密度は、情報通信研究機構が運営している、鹿児島県山川のイオノゾンデの観測（1 時間値）を用いた。1991 年から 2023 年までのデータを用いた。

最小二乗法によって、太陽放射フラックスと最大電子密度との関係を調べた。Lyman β放射では、フィットした直線は原点付近を通った。このことは、Lyman βが地球電離圏 E 層を直接支配していることを示唆している。一方、F10.7 指数ではフィットした直線は原点から離れた。従って、F10.7 を E 層に関係したモデルに間接的に用いる場合は、平方根を取る前にオフセットを引くことが必要であると考えられる。この知見を用いることにより、電離圏電気伝導度モデルや地磁気変動モデルの改良が期待できる。

R010-10
A 会場 ：9/24　PM2 （15:45-18:15）
16:45〜17:10

宇宙天気研究における SuperDARN の役割

#西谷　望 [1)]
(1 名大 ISEE

SuperDARN – powerful tool for space weather studies

#Nozomu Nishitani[1)]
(1Institute for Space-Earth Environmental Research, Nagoya University

In space weather research, knowledge of the temporal and spatial distribution of ionospheric and thermospheric disturbances is essential not only for applications, but also in terms of understanding their relationship with the solar, solar wind, and magnetospheric disturbances, which can be utilized for future space weather forecasts.

SuperDARN (Super Dual Auroral Radar Network) is a High-Frequency (HF) radar network consisting of more than 35 large HF radars in high and mid-latitude regions of the northern and southern hemispheres, based on international cooperation among more than 10 countries. From the HF radio wave echoes backscattered by ionospheric or ground/sea surface irregularities, the distribution of ionospheric convective velocity and ionospheric plasma density variations can be obtained with a high temporal resolution of 1-2 minutes.

The SuperDARN provides unique information on ionospheric convection distribution information with high temporal resolution (1-2 minute intervals) on a global scale, which can never be obtained by any other instruments. The radars also yield ionospheric plasma density fluctuation distributions associated with TIDs (Traveling Ionospheric Disturbances), and lower thermospheric neutral wind velocity distributions obtained from meteor echoes and other sources. Furthermore, it has recently been found that they provide detailed information on ionospheric density variations associated with solar flares, and detailed information (including parameters that cannot be obtained by other instruments) on ionospheric variations associated with earthquakes and volcanic eruptions.

Initially, SuperDARN was established to cover the geomagnetic latitudes poleward of 60^o to deal with aurora-related phenomena. However, ionospheric / thermospheric disturbances at subauroral latitudes, in the expanded auroral ovals during geomagnetic disturbances, and mid-latitude disturbances, were also found to be the targets of SuperDARN. Since around 2005, mid-latitude SuperDARN radars have been installed in various regions, and currently, more than half of the longitude areas in the Northern Hemisphere are covered by mid-latitude SuperDARN radars. Moreover, several equatorial and low-latitude SuperDARN-type radars are under construction or planned to monitor ionospheric disturbances in the equatorial and low-latitude regions.

This presentation will present an overview of SuperDARN and its importance in space weather research, scientific achievements on selected recent topics utilizing SuperDARN, and its future directions.

宇宙天気研究において、電離圏・熱圏高度での擾乱の時間・空間分布をいち早く知ることは、実務的な応用だけでなく、太陽・太陽風・磁気圏擾乱との関連性を正しく理解し、将来的な宇宙天気予報に活用するという意味で極めて重要である。

SuperDARN (Super Dual Auroral Radar Network) は 10 か国以上の国際協力に基づく、南北両半球の高・中緯度領域に設置された 35 基以上の大型短波レーダーから構成されるレーダー観測網である。短波帯の電波を送信して受信されたエコーから、電離圏のプラズマ構造の対流速度・密度変動の分布を 1-2 分程度の高時間分解能で得ることができる。

上記の SuperDARN は、地球的規模での高時間分解能 (1-2 分間隔) のプラズマ対流速度分布情報という、他の観測手段では決して得ることのできないユニークな情報を提供する能力を有している。さらには伝搬性電離圏擾乱等に伴う電離圏プラズマ密度変動分布、流星エコー等から得られる熱圏下部中性風速度分布も得ることが可能である。さらには、太陽フレアに伴う電離圏密度変動の詳細情報や、地震や火山噴火に伴う電離圏変動に関する詳細な (他の手段で得ることができないパラメータを含む) 情報を提供していることも、近年判明している。

当初 SuperDARN はオーロラに関連した現象を扱うことを目的として、60 度以上の広域に設置されたが、それより少し低緯度側のサブオーロラ帯、あるいは地磁気活動擾乱時にオーロラオーバルが拡大した環境の下でのオーロラ帯・サブオーロラ帯、加えて中緯度の擾乱もターゲットとなりうることが判明し、2005 年頃より中緯度 SuperDARN レーダーが諸地域に設置されるようになり、現在北半球では半分以上の経度域が中緯度 SuperDARN レーダーによりカバーされている。さらに最近では、赤道域・低緯度域の電離圏擾乱現象をモニターすることを目的とした赤道・低緯度域用 SuperDARN タイプのレーダーが複数の領域において建設中・建設準備中あるいは検討中の段階にある。

本講演では、SuperDARN の概要及び宇宙天気研究における重要性、SuperDARN を活用した最近の話題を中心とした研究成果、および今後の方向性について紹介する。

R010-11
A 会場 ：9/24　PM2 （15:45-18:15）
17:10〜17:25

#北島　慎之典 [1)], 渡邉　恭子 [1)], 陣　英克 [2)], 垰　千尋 [2)], 西岡　未知 [2)], 村瀬　清華 [3)]
([1] 防衛大,[2] 情報通信研究機構,[3] 総研大・極域科学

Reproduction of electron density variation in the ionospheric D region during solar flares by the PHITS and GAIA models

#Shinnosuke Kitajima[1)],Kyoko Watanabe[1)],Hidekatsu Jin[2)],Chihiro Tao[2)],Michi Nishioka[2)],Kiyoka Murase[3)]
([1]National Defense Academy of Japan,[2]National Institute of Information and Communications Technology,[3]Department of Polar Science, the Graduate University for Advanced Studies

Solar flares emissions cause ionization of the ionosphere and rapid variation in electron density. In particular, shortwave communication failure caused by increased electron density in the ionospheric D region (60-100 km) is known as the Dellinger phenomenon (Dellinger 1937) and are mainly attributed to flare X-ray emission. In order to estimate the occurrence of Dellinger phenomenon and their magnitude, it is necessary to accurately understand the altitude distribution of electron density variation in the ionosphere caused by solar flare emission. The GAIA (Jin et al., 2011) is one of the effective numerical simulation models which can provide the electron density variations throughout the ionosphere in solar flare emissions, but it does not yet account for ionization in the ionospheric D region.

In this study, we used PHITS code (Sato et al., 2018), a particle transport and collision simulation code using the Monte Carlo method, to simulate electron density variations in the ionospheric D region due to flare X-ray emission. The X-ray data observed by GOES/XRS are input into PHITS with the solar zenith angle taken into account, and the altitude distribution of the ionization rate (q) is calculated. The electron density (n_e), which includes ionized recombination, is derived from $n_e{}^2 = \alpha_{eff} / q$ using the effective recombination coefficient (α_{eff}) given by Gledhill (1986).

The scale of the Dellinger phenomenon can be known from the minimum reflection frequency f_{min} value observed by the ionosonde. We derived f_{min} value from the PHITS calculation results, and are compared with the f_{min} values obtained from the GAIA calculation and the observed. The results showed that the f_{min} value derived from the PHITS calculation more accurately reproduces the observed f_{min} value than the f_{min} value from the GAIA, and the blackout capture rate is better.

In this presentation, the differences between the PHITS and GAIA simulations and their evaluation will be discussed in detail.

R010-12
A 会場 ：9/24　PM2 （15:45-18:15）
17:25〜17:40

#村瀬　清華 [1)], 片岡　龍峰 [1,2)], 西山　尚典 [1,2)], 小川　泰信 [1,2)], 田中　良昌 [1,2)], 堤　雅基 [1,2)], 佐藤　薫 [3)]
([1] 総合研究大学院大学,[2] 国立極地研究所,[3] 東京大学

Atmospheric ionization impact of EMIC-wave driven energetic electron precipitation events

#Kiyoka Murase[1)],Ryuho Kataoka[1,2)],Takanori Nishiyama[1,2)],Yasunobu Ogawa[1,2)],Yoshimasa Tanaka[1,2)],Masaki Tsutsumi[1,2)],Kaoru Sato[3)]
([1]The Graduate University for Advanced Studies（SOKENDAI),[2]National Institute of Polar Research,[3]The University of Tokyo

Electromagnetic ion cyclotron (EMIC) waves have been known as one of the main drivers of energetic electron precipitation (EEP) into the Earth's atmosphere. Ozaki et al. (2022) showed that EEP associated with EMIC wave activity causes localized mesospheric ozone depletion, suggesting a non-negligible impact on atmospheric variabilities. However, it is difficult to quantitatively discuss the global impact of EMIC-wave driven EEPs due to the lack of comprehensive observations of the energy range (i.e., ionization altitude), ionization intensity, and spatial extent.

In this study, we attempt to characterize these ionization profiles focusing on the evaluation of the ionization impact of EMIC-wave driven EEPs based on the intensity, duration, and spatial extent of the ionization captured by ground-based measurements. We use observational data from the imaging riometer, the atmospheric radar, PANSY, and the magnetometer at Syowa Station (CGMLAT=-66.5) in 2016-2019, which provide information of the intensity/spatial structure of ionization, ionization altitudes, and wave spectra, respectively, respectively. We found at least 350 events of EMIC-EEP candidates in which the mesospheric ionization coincides with the EMIC wave activities. The MLT distribution of events peaks on the afternoon side (14 MLT). Most of the events were related to injections of particles during substorms, and only about 10% were thought to be caused by solar wind compressions. Ionization signatures at altitudes below 60 km, indicating >MeV electron precipitation, were confirmed for ˜40 % of the events. So far, only these basic statistical investigations have been completed, while the the evaluation of ionization impact is still ongoing. In this presentation, we will discuss the evaluation in terms of the characteristics of ionization profiles due to differences in the physical properties of waves, i.e., wave intensity/frequency, and compare them to ionization impacts from EEPs by other mechanisms, such as chorus waves.

R010-13
A 会場 ：9/24　PM2 （15:45-18:15）
17:40〜17:55

SOLAR-C/SoSpIM が観測する太陽放射の地球上層大気への影響

#渡邉　恭子[1)], 北島　慎之典[1)], 大窪　遼介[1)],Harra　Louise[2)],Buchel　Valeria[2)], 今田　晋亮[3)], 原　弘久[4)], 清水　敏文[5)], 三好　由純[6)], 西谷　望[6)], 堀　智昭[6)], 家田　章正[6)], 陣　英克[7)], 垰　千尋[7)]
([1] 防衛大,[2]PMOD/WRC,[3] 東大,[4] 国立天文台,[5] 宇宙研,[6] 名大 ISEE,[7] 情報通信研究機構

Effects of solar radiation by SOLAR-C/The Solar Spectral Irradiance Monitor (SoSpIM) observation on the Earth's upper atmosphere

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JAXA's next solar mission, SOLAR-C, is designed to provide a comprehensive understanding of energy and mass transport and energy release from the solar surface to the solar corona and interplanetary space using EUV spatial spectroscopy of the EUV High-Throughput Spectroscopic Telescope (EUVST). To enhance the scientific capabilities of SOLAR-C/EUVST, The Solar Spectral Irradiance Monitor (SoSpIM) has been developed by the Physical Meteorological Observatory in Davos World Radiation Center (PMOD/WRC) in Switzerland to be installed on the SOLAR-C. SoSpIM will provide full Sun irradiance with sub-second time cadence combined with the spatially resolved spectroscopy from EUVST, and specifically address solar flares and the effects of solar radiation on the Earth and planets.

SoSpIM observes radiation from full Sun in two observational wavelength bands, EUV (17.0-21.5 nm) and Lyman-α (111.5-127.5 nm). By having a redundant system with three independent channels for each wavelength band, SOLAR-C/EUVST degradation and contamination can also be monitored.

Extreme ultraviolet (EUV) radiation observed by SoSpIM plays a major role in controlling the composition of the Earth's upper atmosphere: EUV channel radiation is absorbed mainly in the ionospheric E and F regions and Lyman-alpha channel radiation is absorbed in the ionospheric D region, and the composition of the Earth's atmosphere is believed to change around these altitudes. In particular, rapid fluctuations of these radiations due to solar flares are known to cause significant changes in the composition and altitude distribution of the ionosphere, leading to space weather phenomena such as communication failures.

Therefore, we have established an international SoSpIM science team to discuss what kind of space weather research is possible using SoSpIM data. In particular, the Japanese side is studying the specific impact of the solar radiation spectrum on the ionosphere by comparing the data with observations of the Earth's ionosphere (e.g., Ionosonde and SuperDARN) and model calculations (GAIA).

In this presentation, we will report on the current development status of SoSpIM and the results of our study of the impact of solar radiation which will be observed by SoSpIM on the Earth's upper atmosphere.

JAXA の次期太陽観測計画 SOLAR-C は、太陽表面から太陽コロナ・惑星間空間へのエネルギーと質量の輸送やエネルギー解放を、極端紫外線分光観測（EUVST）を用いて総合的に理解することを目的としています。SOLAR-C の科学的能力を強化するために、スイスの PMOD/WRC が開発した太陽スペクトル放射照度モニター（SoSpIM）も搭載されます。SoSpIM は、EUVST の空間分光観測と組み合わせて、１秒以下の時間分解能で太陽放射照度を提供することにより、特に太陽フレアと太陽放射が地球や惑星に及ぼす影響について探求します。

SoSpIM は、EUV（170-215Å）とライマン-α（1115-1275Å）の 2 つの観測波長帯で太陽全面から放射を観測します。各波長帯に独立した 3 つのチャンネルの冗長システムを持つことで、SOLAR-C/EUVST の劣化や汚染もモニターすることができます。

SoSpIM によって観測される極端紫外線（EUV）放射は、地球上層大気の組成を制御する上で主要な役割を果たしています。EUV チャンネルの放射は電離圏 E・F 領域で、ライマン-α チャンネルの放射は電離圏 D 領域で主に吸収され、これらの高度付近で地球大気の組成を変化させると考えられています。特に、太陽フレアによるこれらの放射の急激な変動は、電離層の組成や高度分布を大きく変化させ、通信障害などの宇宙天気現象を引き起こすことが知られています。

そこで、国際的な SoSpIM サイエンスチームを立ち上げ、SoSpIM のデータを使ってどのような宇宙天気研究が可能かを議論しています。特に日本側では、地球電離層の観測データ（イオノゾンデや SuperDARN など）やモデル計算（GAIA）と比較することで、太陽放射スペクトルが電離圏に与える具体的な影響を研究しています。

本発表では、SoSpIM の現在の開発状況と、SoSpIM が観測する太陽放射の地球上層大気への影響について検討した結果を報告します。

R010-14
A 会場 ：9/25　AM1 （9:00-10:30）
9:00〜9:15

#高橋　直子 [1)], 中溝　葵 [1)], 坂口　歌織 [1)], 塩田　大幸 [1)]
([1] 情報通信研究機構,[2] 情報通信研究機構,[3] 情報通信研究機構

Forecast of Geomagnetic Field Disturbances Using the Empirical Model for Space Weather

#Naoko Takahashi[1)],Aoi Nakamizo[1)],Kaori Sakaguchi[1)],Daikou Shiota[1)]
([1]National Institute of Information and Communications Technology,[2]National Institute of Information and Communications Technology,[3]National Institute of Information and Communications Technology (NICT)

The geomagnetic field disturbance, known as the indicator of the magnetospheric disturbance on the Earth, is one of the essential indicators for the space weather forecast. The magnetospheric condition strongly depends on the solar wind variation associated with, for example, coronal mass ejection and/or co-rotating interaction region. Particularly, strong solar wind inputs cause a drastic change of the ring current, resulting a magnetic storm that can be detected as a global change of magnetic field both in space and on the ground. The disturbance field (Dst) index, which is a parameter that indicates the magnitude of the ring current, is referred to understand the magnetospheric condition. In this study, we adapt the Dst index forecasting model based on two empirical models proposed in O'Brien and McPherron (2000) and Keika et al. (2015). We also attempt to estimate K-index that commonly used as the criteria for geomagnetic disturbance alerts in Japan.

For a few hours forecast, DSCOVR spacecraft data are used as the inputs. The estimated Dst index shows a good correlation with the observed Dst index, especially during when the solar wind has a strong southward interplanetary magnetic field (IMF). The comparison between observation and model indicates that the main contribution for our model is solar wind velocity and north-south component of IMF during the moderate magnetic storm. We also estimate K-index using the Dst index and compare with the K-index calculated from the geomagnetic field variation at Kakioka (called as Kakioka K-index). The estimated K-index can predict the disturbed condition of real magnetosphere, which timing corresponds to the Kakioka K-index. However, the estimated K-index overestimates comparing with Kakioka K-index. Since the Dst index is defined as an envelope of magnetic field variation observed at four low latitude stations, such error is likely to cause when Kakioka is away from the station where the maximum variation is detected. We also perform a few days forecast using SUSANOO-CME data as the inputs. The decrease of Dst index estimated from SUSANOO-CME data is reproduced though it is smaller than that of the observed Dst index.

R010-15
A 会場 ：9/25　AM1 （9:00-10:30）
9:15〜9:40

#中村　紗都子 [1)], 海老原　祐輔 [2)], 藤田　茂 [3)], 後藤　忠徳 [4)]
([1]ISEE,[2] 京大生存圏,[3] データサイエンスセンター/統数研,[4] 兵庫県立大学

Modeling of Geomagnetically Induced Current (GIC) in Japan assuming various three-dimensional ground inhomogeneities

#Satoko Nakamura[1)],Yusuke Ebihara[2)],Shigeru Fujita[3)],Tadanori Goto[4)]
([1]Nagoya University,[2]Research Institute for Sustainable Humanosphere, Kyoto University,[3]Joint-support center for data science research/The Institute of Statistical Mathematics,[4]Graduate School of Life Science, University of Hyogo

We modeled the time series of geomagnetically induced currents (GICs) flowing in the Japanese 500 kV power grid. The three-dimensional distribution of the electric field was calculated using the finite-difference time-domain (FDTD) method. A three-dimensional electrical conductivity model was constructed from a global relief model and a global map of sediment thickness. First, we imposed a uniform sheet current at 100 km altitude to illuminate the influence of the structured ground conductivity. The simulation result shows that geomagnetically induced electric field (GIE) exhibits localized, uneven distribution that can be attributed to charge accumulation due to the inhomogeneity below the Earth's surface. The charge accumulation becomes large when the conductivity gradient is parallel to the incident electric field. Using the uneven distribution of GIE, we calculated the GICs flowing in a simplified 500 kV power grid network in Japan. The influence of the structured ground conductance on GIC appears to depend on a combination of the location of substations and the direction of the source current. Uneven distribution of the power grid system gives rise to intensification of the GICs flowing inremote areas where substations/power plants are distributed sparsely. Secondly, we used the equivalent current inferred from the ground magnetic disturbance for some magnetic storms. We show the sensitivity of the GIC magnitude on the three-dimensional ground inhomogeneity.

R010-16
A 会場 ：9/25　AM1 （9:00-10:30）
9:40〜9:55

磁気圏 MHD シミュレーションによる地磁気誘導電流（GIC）予測の検討 5

#亘　慎一 [1)], 中溝　葵 [2)], 海老原　祐輔 [3)]
[(1] 情報通信研究機構,[(2] 情報通信研究機構,[(3] 京大生存圏

Estimation of geomagnetically induced current (GIC) using the global MHD simulation of the magnetosphere 5

#Shinichi Watari[1)],Aoi Nakamizo[2)],Yusuke Ebihara[3)]
[(1]National Institute of Information and Communications Technology,[(2]National Institute of Information and Communications Technology,[(3]Research Institute for Sustainable Humanosphere, Kyoto University

We are studying the estimation of geomagnetically induced current (GIC) using the result of the real-time global magnetosphere MHD simulation conducted at NICT. To make estimation of GIC, the following steps are required: (1) calculation of geomagnetic variation from the simulation result, (2) calculation of electric field variation from the geomagnetic variation, and (3) calculation of GIC from the electric field variation. We are considering the necessary points for these. The results of the simulation were used to calculate high-latitude geomagnetic variations at the required points because the coupling between the high-latitude ionosphere and the magnetosphere was calculated in the simulation. We calculated the electric field variations at several points using a time series of the geomagnetic variations obtained by the simulation and one-dimensional earth conductivity model. High-density geomagnetic observations are desirable for the GIC calculation although actual observation density is not so high. We examined the applicability of the Spherical Elementary Current Systems (SECS) model (Amm and Viljanen, 1999) for the Japan area using the observation data. We will report the results of these studies.

NICT で行っているグローバル磁気圏 MHD シミュレーションのリアルタイム計算の結果を用いて地磁気誘導電流（GIC, Geomagnetically Induced Current）を予測するための検討を行っている。GIC の予測を行うためには、（1）磁気圏シミュレーションの結果から地磁気変動の計算、（2）地磁気変動から電場変動の計算、（3）電場変動から GIC の計算という手順が必要となる。これらに必要となる点について検討を進めている。NICT の磁気圏シミュレーションでは、高緯度の電離圏と磁気圏とのカップリングを計算しているので、高緯度領域の地磁気変動に関しては、シミュレーションの結果を用いて、必要な地点での地磁気変動を計算することができる。シミュレーションにより計算された地磁気変動の時系列データを作成し、一次元の地下伝導度モデルを仮定していくつかの点で電場変動の計算を行った。中低緯度の地磁気変動に関しては、数点の地上観測データを入力とする計算手法について検討を行った。GIC の計算を行う際には、密度の高い観測点の地磁気変動データを用いるのが望ましいが、国内の地上観測の密度はそれほど高くない。そこで、SECS（Spherical Elementary Current Systems）モデル（Amm and Viljanen, 1999）の日本周辺への適用可能性に関して検討を行った。地上の地磁気観測データを入力とし SECS モデルを用いてメッシュ状に配置した地点での地磁気変動の計算して評価を行った。本発表ではこれらの検討結果について報告する。

R010-17
A 会場 ：9/25　AM1 （9:00-10:30）
9:55〜10:10

#坂口　歌織 [1)], 齊藤　慎司 [1)], 長妻　努 [1)]
([1] 情報通信研究機構,[2] 情通機構

Annual electron dose on Himawari8: comparison of SEDA-e observation with empirical model estimation

#Kaori Sakaguchi[1)],Shinji Saito[1)],Tsutomu Nagatsuma[1)]
([1]National Institute of Information and Communications Technology,[2]National Institute of Information and Communications Technology

Total ionizing dose (TID) effects are common problem in space. Major sources of TID at geostationary orbit are energetic electrons in the outer Van Allen radiation belt and solar energetic particles (SEPs) accompanied by solar flares. Space environment data acquisition monitor (SEDA) onboard Japanese geostationary meteorological satellite Himawari8 have been observing such energetic electrons and protons since November 2014. In this study, annual changes in electron dose are estimated from the SEDA-e observation by inputting yearly fluence data to SHIELDOSE-2 model assuming 1-mm Aluminum sphere shield. The annual electron dose was found highly varying year to year. It was highest in 2017 during the declining phase of solar cycle 24, and lowest in 2020 in the period near-minimum of the cycle. The electron dose based on SEDA-e observations are compared estimation based on AE8 trapped electron model which are commonly used for spacecraft designing. Recently AE9 was newly released as upgraded model of AE8. Observation based dose values were also compared with AE9 and other available model-based doses. The comparison results will be presented in the talk.

R010-18
A 会場 ：9/25　AM1 （9:00-10:30）
10:10〜10:25

#長妻　努 [1)], 坂口　歌織 [2)]
([1] 情報通信研究機構,[2] 情報通信研究機構

Improvement of bias current subtraction for Himawari-8/SEDA-e observation (No.2)

#Tsutomu Nagatsuma[1)],Kaori Sakaguchi[2)]
([1]National Institute of Information and Communications Technology,[2]National Institute of Information and Communications Technology

Space environment data acquisition monitor (SEDA) onboard Himawari-8 has been operating since Nov. 2014. SEDA has two sensors. One is high energy electron sensor (SEDA-e) and the other is high energy proton sensor (SEDA-p). SEDA-e measures internal charging currents produced from high energy electrons (from 0.1 to 4.5 MeV) collected by 8 plates arranged in a stack. Electron fluxes are estimated from the charging currents. Since the charging currents are quite small, it needs to be amplified by operational amplifier. This means that bias current is contaminated as a offset of particle flux. Therefore, we need to remove the bias current effect. We use bias current model based on the pre-flight measurements for subtraction. The bias current model is a function of temperature. This works well for the beginning of Himawari-8/SEDA observation. However, the background flux level tends to be increase as time goes on especially for higher energy channels. Using long period of high energy electron flux and temperature data of the sensor, we try to estimate the optimal bias current as a function of temperature. In this presentation, we will introduce improving bias current subtraction for SEDA-e observation and evaluate the quality of data using inter-calibration of GOES/SEISS data. We also introduce operational space weather intercalibration activity under Global Space-based Inter-Calibration System (GSICS).

R010-19
A 会場 ：9/25　AM2 （10:45-12:30）
10:45〜11:10

#宮原　ひろ子 [1)], 草野　完也 [2)], 片岡　龍峰 [3)], 島　伸一郎 [4)], トゥベール　エミール [5)]
([1] 武蔵野美術大学,[2] 名古屋大学,[3] 極地研,[4] 兵庫県立大学,[5] 沖縄科学技術大学院大学

Response of high-altitude clouds to the GCR variations in tropical regions

#Hiroko Miyahara[1)],Kanya Kusano[2)],Ryuho Kataoka[3)],Shin-ichiro Shima[4)],Emile Touber[5)]
([1]Musashino Art University,[2]Nagoya University,[3]National Institute of Polar Research,[4]University of Hyogo,[5]OIST

Correlations between solar activity and climate have been reported for various time scales; however, the detailed mechanisms behind the connection still need to be clarified. Galactic cosmic rays (GCRs) are one of the possible mediators of the Sun-climate relationship, and it has been suggested that they may impact cloud activity by forming aerosols or by promoting the collisional processes in clouds. Originally, it was suggested that low-altitude clouds over oceans are responding to GCR variations; however, a consensus has not been established. Cloud chamber experiments have indicated that GCR-induced aerosol formation is more efficient at lower temperatures (i.e., upper troposphere). In this presentation, we show that tropical clouds associated with deep convections respond to the variations of GCRs. We show that a number of conditions are required for clouds to be affected by GCRs.

R010-20
A 会場 ：9/25　AM2 （10:45-12:30）
11:10〜11:25

宇宙線データの公開・解析環境の刷新へ向けた取り組み

#小財　正義 [1)], 林　優希 [2)], 加藤　千尋 [2)], 宗像　一起 [2)], 田中　良昌 [1)], 南山　泰之 [3)]
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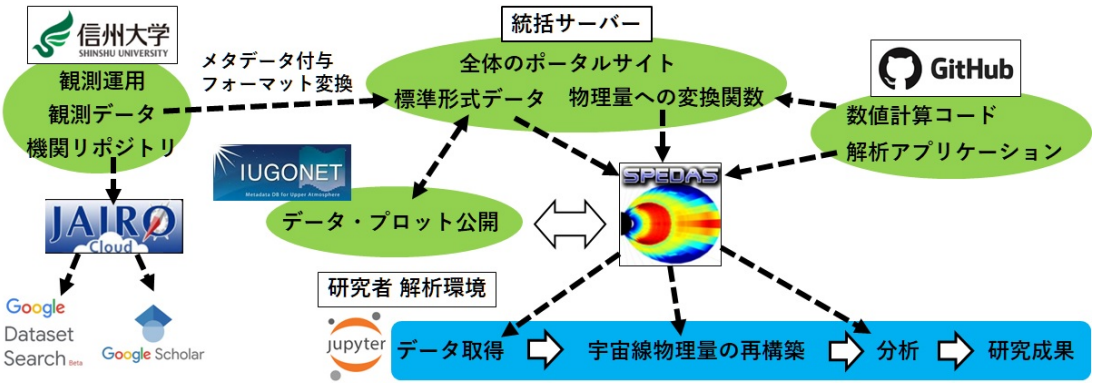
Activities for the renovation of cosmic-ray data publication and analysis environment

#Masayoshi Kozai[1)],Yuki Hayashi[2)],Chihiro Kato[2)],Kazuoki Munakata[2)],Yoshimasa Tanaka[1)],Yasuyuki Minamiyama[3)]
[(1]ROIS-DS,[(2]Faculty of Science, Shinshu University,[(3]National Institute of Informatics

Galactic cosmic rays observed on Earth reflect the environment on various scales, such as the heliosphere, interplanetary space, magnetosphere, and atmosphere. In particular, ground-based observations of muons and neutrons are characterized by excellent statistics, or temporal resolution, and long-term stable observations by robust observation systems. These diverse scientific topics and large data accumulation of our cosmic-ray observations are expected to have a high affinity with data-driven approaches. We are constructing a new data publication and analysis scheme (figure below) that utilizes external services and remote repositories, aiming to promote further utilization of cosmic ray data and cross-disciplinary collaboration. In this presentation, we will report on these activities.

銀河系内で加速され地球で観測される宇宙線は、太陽圏・惑星間空間・地球磁気圏・地球大気など多様なスケールの環境を反映し、それらを「串刺し」にする物理現象である。特に地上でのミューオン・中性子観測は高い統計量（時間分解能）や堅牢な観測システムによる長期連続観測を特長としている。これら多彩な研究トピックや膨大なデータ蓄積はデータ駆動型アプローチとの高い親和性が期待される。我々は宇宙線データのさらなる利活用促進や異分野連携への発展を目指し、外部サービスやリモートリポジトリを積極的に活用した新たなデータ公開・解析スキームを構想している（下図）。
これまでに、機関リポジトリ登録へ向けた準備、IUGONET 及び SPEDAS との連携へ向けたフォーマット変換と登録関数の試作、データ解析のための数値計算コードの整備、その出力データのリモートストレージでの整備などを進めている。また、研究成果へ直結する解析環境の整備として、それらに基づくデータ解析パイプラインを整備している。本講演では、これら宇宙線データの公開・解析環境の刷新へ向けた取り組みについて報告する。



R010-21
A 会場 ：9/25　AM2 （10:45-12:30）
11:25〜11:40

#張　天 [1)], 海老原　祐輔 [1)], 田中　高史 [2)]
([1] 京大生存圏,[(2] 九州大学 国際宇宙天気科学・教育センター

Nighttime geomagnetic response to jumps of solar wind dynamic pressure: A possible cause of Quebec blackout in March 1989

#Tian Zhang[1)],Yusuke Ebihara[1)],Takashi Tanaka[2)]
([1]Research Institute for Sustainable Humanosphere, Kyoto University,[(2]International Center for Space Weather Science and Education, Kyushu University

By performing a global magnetohydrodynamic (MHD) simulation, we investigated magnetic disturbances on the ground at high-latitudes in response to jumps in the solar wind dynamic pressure, namely a sudden commencement (SC). After the arrival of the jump, a pair of field-aligned currents (FACs), related to the preliminary impulse (PI), develop and travel in the anti-sunward direction. Soon after, another pair related to the main impulse (MI), travel in the anti-sunward direction. The MI current remains strong when propagating to the nightside, and it flows clockwise on the dawnside. Consequently, northward (southward) magnetic disturbance appears at higher (lower) latitudes in the post-midnight sector. These features are similar to those observed in the high-latitude post-midnight sector during which the Quebec blackout took place on 13 March 1989. The MI current appears regardless of the amplitude of the jumps of the solar wind dynamic pressure and the polarity of north-south component of IMF. The amplitude of the geoelectric field, which is closely related to the geomagnetically induced currents (GICs) reaches the maximum value just before and around the maximum of the southward magnetic disturbance. This is consistent with the moment at which the blackout occurred during the southward magnetic perturbation. We suggest that the blackout in Quebec was caused by the MI-associated Hall current passing over the Hydro-Quebec power system on the nightside. The nighttime polar region is shown to be sensitive to hazardous GICs when a large-amplitude jump of the solar wind dynamic pressure comes.

R010-22
A 会場 ：9/25　AM2 （10:45-12:30）
11:40〜11:55

放射線帯外帯電子変動予測モデルの開発と XAI によるモデル解釈

#西宮　祐太 [1)], 三好　由純 [2)], 堀　智昭 [3)], 中村　紗都子 [4)], 小路　真史 [1)], 田　采祐 [5)], 三谷　烈史 [6)], 篠原　育 [7)], 高島　健 [7)], 浅村　和史 [8)], 東尾　奈々 [8)], 齊藤　慎司 [9)], 塩田　大幸 [10)]
([1] 名大 ISEE,[2] 名大 ISEE,[3] 名大 ISEE,[4] 名大 ISEE,[5] 名大 ISEE,[6] 宇宙研／宇宙機構,[7] 宇宙研／宇宙機構,[8] 宇宙研／宇宙機構,[9] 情報通信研究機構,[10] 情報通信研究機構

Development of an outer radiation belt forecast model using the XAI

#Yuta Nishimiya[1)],Yoshizumi Miyoshi[2)],Tomoaki Hori[3)],Satoko Nakamura[4)],Masafumi Shoji[1)],ChaeWoo Jun[5)],Takefumi Mitani[6)],Iku Shinohara[7)],Takeru Takashima[7)],Kazushi Asamura[8)],Nana Higashio[8)],Shinji Saito[9)],Daikou Shiota[10)]
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The radiation belt is a region in the inner magnetosphere where the most energetic electrons in geospace are trapped by the Earth's magnetic field. Large flux variations of energetic electrons are observed in association with geomagnetic disturbances, and a sustained large flux of the outer belt electrons often leads to the satellite anomaly. The prediction of flux variations for energetic electrons is therefore essential in mitigating these risks. We have developed a forecast model of the outer belt flux variation using the recurrent neural network (RNN) with the long short term memory (LSTM). This model is designed to forecast the time-variation of the electron flux in the outer radiation belt at energies ranging from several hundred keV to several MeV at L = 4-6. As inputs for the model, we used daily average solar wind parameters (solar wind velocity and IMF-Bz), and electron flux obtained by HEP and XEP onboard the Arase satellite for last three days. The model succeeded in predicting the electron flux for most of the time intervals to which the model was applied, although the forecast skill became small in cases when the flux decreased at high L positions. To improve the model in this regard, we have incorporated additional solar wind parameters into the model. The previous studies have indicated that the solar wind dynamic pressure contributes to the loss of the outer belt flux via magnetopause shadowing. In fact, our revised model, using the solar wind density, improves the forecast skill. Moreover, we have also incorporated eXplainable Artificial Intelligence (XAI) into our developed model to investigate relative contributions of the input parameters on the electron flux variations. The diagnosis using XAI technique indicates that the time-integrated value of southward IMF is more important than its simple daily average, suggesting that prolonged southward IMF causes the flux enhancement more efficiently in the outer radiation belt.

R010-23
A 会場 ：9/25　AM2 （10:45-12:30）
11:55〜12:10

#ギルギス　キロロス [1)], 羽田　亨 [1)], 松清　修一 [1,2)], 吉川　顕正 [1,3)], アブラハム　チアン [4,5)]
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The Impact of the Geomagnetic Storm Event of February 2022 on the Inner Radiation Belt by Test Particle Simulations

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We investigate the impact of the geomagnetic storm event of 3-5 February 2022, known as the “SpaceX” storm, on the inner radiation belt response. Observations showed that an M1.1 solar flare erupted on January 29 and ended up as a shock-driving magnetic cloud (MC), which was the reason for the occurrence of this geomagnetic storm.

A three-dimensional relativistic test particle simulation code was developed to compute the particle trajectories in the inner magnetosphere region. The guiding center Tao-Chan-Brizard model was selected to study the particle dynamics of the radiation belt. The implemented background magnetic field was a time-varying field reproduced by the IGRF-13 and Tsyganenko Model TS05, with the associated inductive electric field computed by the Biot-Savart Law.

The numerical simulations reveal the inner proton belt dynamics during the three geomagnetic storm phases, including the variations of the proton flux in the South Atlantic Anomaly (SAA).

In order to estimate the resulting radiation impacts on the Low-Earth Orbit (LEO) satellites, adequate modelling of the inner proton belt during a magnetic storm is relevant.

R010-24
A 会場 ：9/25　AM2 （10:45-12:30）
12:10〜12:25

孤立型サブストーム時の CW 構造の発達に応じた、中低緯度電場応答の研究

#林　萌英 [1)], 吉川　顕正 [2)]
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Mid- and low-latitude electric fields response to CW development during isolated substorms

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The purpose of this study is to understand the development of a global three-dimensional current system from the polar to equatorial regions during substorms based on ground-based magnetic field observations and FM-CW electric field observations.

The polar ionospheric current system consists of Region 1 currents that fluctuate in conjunction with the magnetospheric convection system and Region 2 currents that vary with the pressure gradient region of the inner magnetosphere [Iijima and Potemra, 1976, 1978]. In addition, at substorm onset, a current wedge (CW) current system develops that forms a current closure similar to that of the R1 ocean current system.

The magnetic field variations associated with CW are prominent in the night-side mid to low-latitude regions. It was modeled by McPherron et al.(1973). Using ground-based magnetic field data from MAGDAS and SuperMAG, we capture the development of CW current systems during substorms. By comparing the results with electric field data from the FM-CW Ionospheric Observatory installed by Kyushu University in Paratunka (PTK), Russia, we analyze the electromagnetic response in the mid- and low-latitude regions.

In this research, we investigated 418 quiet event (pre-substorm electric field was within ± 2mV/m from one hour before onset to onset), out of 1790 isolated substorm cases that occurred between September 21, 2006, and December 31, 2010, when PTK was on the night side (19:00-24:00, 0:00-05:00). Among these 418 cases, we compared the electric and magnetic fields for the 50 cases in which the electric field fluctuated more than ± 2 mV/m with substorm onset. As a result, we found that the amplitude of electric field fluctuations correlates with the intensity of the westward auroral electrojet. Furthermore, we found that the direction of the electric field is correlated with the Hall polarization effect induced by the ionospheric currents excited by the CW [Yoshikawa et al., 2013], by classifying the relative position of the CW and the observation point from mid-latitude magnetic field data.

On the other hand, significant fluctuations were not observed at the onset in many other events (368/418) compared to the pre-substorm fluctuations. In investigating these events, we found that even at the same auroral electrojet intensity and local time, electric fields fluctuated significantly in some cases, but not in others. Therefore, we believe that the magnitude of electric field fluctuations reflects not only the auroral electrojet and CW, but also the background magnetosphere/ionosphere conditions and the solar wind conditions. In this presentation, we report the results of a comprehensive discussion of night-side electric field variations during substorms, based on a detailed classification of geomagnetic disturbances, analyzed in combination with the Kp index and the IMF Bz of the solar wind, in addition to the index (SML) of substorms.

本研究の目的は、サブストーム時の極域から赤道域までのグローバルな 3 次元電流システムの発達を地上磁場観測と FM-CW 電場観測に基づき包括的に理解することにある。

極域電離圏の電流システムには、磁気圏対流系の消長と連動する Region1-電流と、内部磁気圏の圧力勾配領域の消長と連動する Region2-電流が存在する [Iijima and Potemra, 1976, 1978]。これに加えて、サブストームのオンセット時には、R 1 電流系と同様の電流クロージャーを形成するカレント・ウェッジ（CW）電流系が発達することが知られている。

CW の成長に伴う沿磁力線電流が作る磁場変動は、夜側の中低緯度領域で顕著であり、その発展の様子は McPherron et al.(1973) によってモデル化されている。我々は、MAGDAS および SuperMAG の地上磁場データを用いて、オーロラサブストーム時の CW 電流系の成長を捉え、九州大学がロシア・パラツンカに設置する FM-CW 電離圏観測機器の電場データと比較することにより、中低緯度領域の電磁力学的応答特性の解析を進めている。

本研究では、2006 年 9 月 21 日〜2010 年 12 月 31 日に発生した孤立型サブストームのうち、パラツンカが夜側（19:00-24:00, 0:00-05:00）にある 1790 例の中で、イベント前の電場が± 2mV/m 以内で静穏なイベント 418 例について調査を行った。418 例の中で、サブストームのオンセットに伴って電場が± 2mV/m 以上変化した 50 例について、電離圏電場と地磁気を比較解析した。その結果、電場変動の振幅は西向きオーロラエレクトロジェット電流の強度と相関関係があることがわかった。さらに、電場の向きについては、中緯度の地磁気データから CW と観測点の相対位置を詳細に分類した結果、CW に伴い励起される電離層電流による Hall 分極効果によって生じる電場特性 [Yoshikawa et al., 2013] を反映していることが明らかになった。

一方で、その他の多くのイベント（368/418）では、サブストーム前の変動に比べてサブストーム開始時に有意な変動が見られなかった。これらのイベントについて、サブストームの条件（オーロラエレクトロジェット電流の強度や、電場変動を観測した地方時）を調査したところ、同じ電流強度、地方時であっても電場が発生する場合としない場合があるこ

とがわかった。したがって、電場変動の大きさはオーロラエレクトロジェット電流や CW だけでなく、背景の磁気圏・電離圏の状態や、太陽風の影響が現れていると考えられる。そこで本発表では、サブストームの指標 (SML) に加えて、Kp 指数や太陽風の IMF Bz などと複合的に解析し、サブストームの背景にある地磁気擾乱を詳細に分類した上で、サブストーム時の夜側電場変動を包括的に考察した結果を報告する。

R010-P01
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#寺本　万里子 [1)], 奥村　哲平 [2)], 古賀　清一 [2)],Kletzing　Craig[3)],Wygant　John[4)], 谷嶋　信貴 [2)], 岡本　博之 [2)], 北村　健太郎 [1)]
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Dawnside Surface Charging Events on the Defense Meteorological Satellite Program F16 Satellite

#Mariko Teramoto[1)],Teppei Okumura[2)],Kiyokazu Koga[2)],Craig Kletzing[3)],John Wygant[4)],Nobutaka Tanishima[2)],Hiroyuki Okamoto[2)],Kentaro Kitamura[1)]
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To predict surface charging events in the low Earth orbit (LEO), we investigated the interactions between LEO surface charging and plasma environments using precipitating electrons and ions flux data from the Special Sensor J5 (SSJ5) instrument onboard the Defense Meteorological Satellite Program (DMSP) F16 spacecraft, which orbits at an altitude of 833 km and an inclination of 98.9 deg in dawn/dusk local time. SSJ5 can detect the differential flux of electrons and ions with energies from 30eV to 30 keV using 19 energy channels. The aperture of SSJ5 is tied to the spacecraft ground. Therefore, the aperture of the instrument has the same potential as the satellite when the satellite surface is charged negatively with respect to ambient plasmas. The negative-floating aperture accelerates ambient cold ions and enables the SSJ5 to detect an extreme enhancement in ion flux within a single energy channel. By identifying such extreme enhancements in ion flux data, we can monitor anomalous charging events of the DSMP F16 satellite.

In this study, we analyzed the ion flux data of SSJ5/DMSP F16 between 2009 and 2019 and found approximately 1400 surface charging events. The charging events were distributed at auroral latitudes (65-80 deg MLat) as well as pre-midnight (20-24MLT) and morning sectors (03-06MLT). This result indicates that the surface charging events are not only associated with auroral arcs, whose occurrence is maximized in the pre-midnight sector (Partamies et al. 2014). From the surface charging event list, we examined one conjunction event where the DMSP F16 was located at ˜05:50 MLT while the RBSP-B satellite was located at 05:00 MLT. During this event, the RBSP-B detected clear chorus waves. This result may suggest that high-energy electrons precipitated by the chorus waves contribute to the surface charge in the LEO.

Van Allen Probes のデータを用いた内部磁気圏における衛星表面帯電を誘起するプラズマ環境の統計解析

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[(1] 大阪公大,[(2] 大阪公大・工・航空宇宙

Statistical analysis of the surface charging plasma environment in the inner magnetosphere using the Van Allen Probes data

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[(1]Osaka Metropolitan University,[(2]Department of Aerospace Engineering, Osaka Metropolitan University

Electrostatic discharging associated with spacecraft surface charging sometimes causes damage to solar panels and spacecraft anomalies. We study the plasma environment inducing spacecraft surface charging in the Earth's inner magnetosphere. We have analyzed spacecraft potential and plasma environment from the Electric Field and Waves Suite (EFW) and the Helium, Oxygen, Proton, and Electron (HOPE) onboard the Van Allen Probes. We found that negative surface charging is observed around the geostationary orbit from the midnight sector to the morning sector. We also found that the ambient electron pressure of the negative surface charging events in daylight is higher than most of the noncharging events. We will discuss the statistical results on the plasma environment's characteristics that induce surface charging.

人工衛星の故障原因の一つに宇宙プラズマに起因した衛星表面帯電による放電現象が挙げられる．表面帯電は，数 keV〜数十 keV 程度のエネルギーをもつ電子が衛星表面に衝突，付着し，電荷が蓄積されることで発生し，それに伴う放電現象は，太陽電池パネル損傷や衛星の異常動作などを引き起こす．これらは，人工衛星の運用にとって極めて重大な問題であり， 表面帯電による故障の予防と軽減のためにも発生領域および発生条件を理解することは重要である．そのため，衛星表面を誘起する衛星周囲のプラズマパラメータ（フラックス量， 温度，密度など）について統計解析を行い，条件を明らかにする必要がある．

本研究では，数多くの人工衛星の運用がなされている地球内部磁気圏に注目し，そこでの表面帯電の発生領域，条件について解析を行なう．使用する観測機器は Van Allen Probes 衛星に搭載の Electric Field and Waves Suite（EFW）と Helium, Oxygen, Proton, and Electron (HOPE) である．同衛星の全運用期間にあたる約 7 年間のデータを用いる．これまで，EFW の衛星電位データをもとに，太陽極大期，減衰期間，極小期のそれぞれの期間における日照条件で表面帯電の発生領域，頻度の分布を調べた．L 値が約 4 Re 以下（プラズマ圏）の領域を除いた解析結果では，太陽活動極大期から極小期にかけて，負の衛星電位の発生領域の大きさ，発生頻度は小さくなっており，太陽活動依存性が見られた．それら発生領域は，夜側から朝方にかけての静止軌道付近に集中していた．また，これら衛星負帯電発生時には，HOPE の公開データの電子温度と密度から，周囲の電子圧力が高くなっていることが確認された．しかし，同様の条件でも帯電の有無があり，観測時期でも違いが見られるため，HOPE のプラズマのエネルギースペクトルを直接解析することで，衛星位置に対して正負電荷の積算フラックス値や密度と温度などを検証し，表面帯電を誘起するプラズマ環境特徴について統計的に調査して議論する．

R010-P03
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#北村　健太郎 [1)], 増井　博一 [1)], 阿部　修司 [2)], 魚住　禎司 [1)], 寺本　万里子 [1)], 藤本　晶子 [1)], 佐野　圭 [1)], 吉川　顕正 [3)], 趙　孟佑 [1)],YOTSUBA-KULOVER　Team[4)]
[(1] 九州工大,[(2]ROIS-DS,[(3] 九州大学,[(4]YOTSUBA-KULOVER Team

Geomagnetic Field Observation Project by YOTSUBA-KULOVER Satellite with COTS Magnetomete

#Kentarou Kitamura[1)],Hirokazu Masui[1)],Shuji Abe[2)],Teiji Uozumi[1)],Mariko Teramoto[1)],Akiko Fujimoto[1)],Kei Sano[1)],Akimasa Yoshikawa[3)],Mengu Cho[1)]
[(1]Kyushu Institute of Technology,[(2]Joint Support-Center for Data Science Research,[(3]Kyushu University,[(4]YOTSUBA-KULOVER Team

Geomagnetic observation by the satellite has been conducted by many institutes to understand the global structures of the ionospheric and magnetospheric currents. It is well known that understanding temporal and spatial variations of these current systems is much important to improve the space weather forecast.

We started a development of CubeSat as a student program mostly for undergraduate students to observe the small perturbation of the geomagnetic field at the LEO, especially, altitude of less than 400km. Focus of the observation is to measure the global distribution of the Sq (Solar quiet) currents in the dayside ionosphere as well as the disturbed magnetic field variations (such as 3D-structure of the substorm current wedge and Pc5 pulsations) associated with Storm/Substorms.

In this study, we propose the 2U-size CubeSat in which the COTS (Commercial Of-The Shelf) fluxgate magnetometer is installed to observe the small perturbation of the geomagnetic field. The fundamental feasibility studies depending on the electric power budget, the link budget, and specification of the magnetometer show that the observation of the Sq current by CubeSat is well feasible with a short duration of the development and quite low-cost.

R010-P04
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

次期太陽風観測衛星 SWFO-L1 地上局の整備

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Current Status of SWFO-L1 ground station

#Yuki Kubo[1)],Daikou Shiota[2)],Hiroyuki Yamakawa[1)]
[(1]National Institute of Information and Communications Technology,[(2]National Institute of Information and Communications Technology（NICT),[(3]National Institute of Information and Communications Technology

Real-time monitoring of the solar wind in 24/7 is extremely important for space weather forecasting. In order to monitor the solar wind in interplanetary space, the Advanced Composition Explorer (ACE) spacecraft was launched at the first Lagrange point (L1) in 1997 and started observations. Subsequently, the Deep Space Climate Observatory (DSCOVR), the successor to ACE, was launched also at the L1 point and has been monitoring the solar wind since 2015.

Since these spacecraft are located at the L1 point, the data cannot be downlinked during nighttime on the ground, so international colaboration is essential to achieve real-time monitoring in 24/7. Currently, the National Institute of Information and Communications Technology (NICT) is contributing to the 24/7 monitoring of solar wind as one of the centers of an international network of ACE and DSCOVR real-time receiving ground stations called the Real-time Solar Wind Net.

DSCOVR has already taken 8 years since its launching, and the SWFO-L1 project, the successor to DSCOVR, is currently underway under the leadership of the NOAA, aiming for a launch in 2025. NICT has been approached by NOAA to participate in the SWFO Antenna Network (SAN), and is now preparing the SWFO-L1 ground station as one of the SAN members.

In this presentation, we will report on the progress of the SWFO-L1 ground station in the NICT Kashima Space Technology Center.

24 時間 365 日、途切れることなく太陽風をリアルタイムに監視することは、宇宙天気予報を行う上で極めて重要である。惑星間空間で太陽風を直接監視するために、1997 年に Advanced Composition Explorer (ACE) 探査機が第一ラグランジュ点（L1 点）に打ち上げられ観測を開始した。その後、ACE の後継機として Deep Space Climate Observatory (DSCOVR) が同じく L1 点に打ち上げられ、2015 年から太陽風の監視を続けている。

これらの探査機は、L1 点に位置していることから、地上の夜間には、データをダウンリンクすることが出来ないため、24 時間 365 日のリアルタイム監視を実現するためには、国際協力が必須である。現在、情報通信研究機構（NICT）は、Real-time Solar Wind Net と呼ばれる ACE 及び DSCOVR のリアルタイム受信地上局の国際ネットワークの一拠点として太陽風の 24 時間 365 日監視に貢献している。

DSCOVR は打ち上げ後既に 8 年が経過し、現在、米国 NOAA 主導で 2025 年打ち上げを目指して、DSCOVR 後継機 SWFO-L1 計画が進んでいる。SWFO-L1 も SWFO Antenna Network (SAN) と呼ばれるリアルタイム太陽風監視ネットワークが組織されることになっている。NICT は NOAA から SAN への参加を打診され、SAN の一拠点として SWFO-L1 地上局の整備を進めている。

本ポスターでは、NICT 鹿島宇宙技術センターに整備中の、次期太陽風観測衛星 SWFO-L1 地上局整備の進捗状況について報告する。

R010-P05
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#三澤　浩昭 [1)], 土屋　史紀 [2)], 小原　隆博 [3)], 岩井　一正 [4)], 桑山　陽次 [5)]
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New open database of high-resolution solar radio bursts observed by the spectro-polarimeter AMATERAS

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We have performed daily observation of solar radio bursts since 2010 using the high-resolution spectro-polarimeter named AMATERAS (the Assembly of Metric band Aperture TElescope) installed on IPRT (Iitate Planetary Radio Telescope) for the purposes of investigating acceleration processes of solar energetic particles and plasma environment of the solar corona. The AMATERAS system has a real time FFT function which provides continuous solar radio bursts data with the temporal resolution of 10msec and spectral resolution of 61KHz (‘high-resolution’) for both right and left handed circular polarized waves in 150-500MHz. Since the start of solar radio bursts observation with AMATERAS, we have made the ’low-resolution’ database with the temporal resolution of 1sec and spectral resolution of 1MHz in the FITS format and have opened to the public via the internet. On the other hand, we have provided the high-resolution data only on request because the data are stored in a proprietary format and the individual data sizes are too large for online data transfer. Recently we have converted the data format to FITS and have created a database by reducing a single file size by shortening its duration with the aid of the IUGONET (Inter-university Upper atmosphere Global Observation NETwork) project. Now, the new database is just ready for public release via internet. In the presentation, we will introduce this new high-resolution solar radio bursts database with some examples of highly resolved solar radio bursts, and will also mention the on-going project of updated AMATERAS with a wider wave length range and more sensitivity.

Acknowlegements: This work was carried out by the joint research program of the Institute for Space − Earth Environmental Research (ISEE), Nagoya University, and with the supports of the IUGONET project.

R010-P06
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

太陽フレア時における Ly α と Ly β 放射の関係

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[(1] 防衛大

Relationship between Ly α and Ly β emissions during solar flares

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[(1]National Defense Academy of Japan

Electromagnetic radiations of various wavelengths are emitted during solar flare events and are known to have a significant impact on space weather. Lyman-α (Ly α, 121.6 nm) is ultraviolet emission from the chromosphere and transition region, is the strongest emission in VUV region even in radiation from the quiet Sun and is said to contribute to the formation of the Earth's ionosphere. However, Lyman-β (Ly β, 102.6 nm) has a shorter wavelength than Ly α, so Ly β is considered to have a greater impact on the Earth than Ly α, and this is also same during solar flares.

Lemaire et al. (2012) investigated the relationship between Ly α and Ly β irradiance in solar cycle variations. From this previous study, it was found that the Ly α/Ly β irradiance ratio varies from solar maximum to minimum and that it fluctuates periodically. However, the relationship between Ly α and Ly β radiation during solar flares have not been discussed or studied. In this study, we investigate the relationship between Ly α and Ly β emissions during solar flares and their effects on the Earth's upper atmosphere.

In this study, we used Ly β data from SDO/EVE, which can observe ultraviolet radiation from the entire solar surface with high wavelength resolution, and data from GOES/EUVS-E, which regularly observes Ly α. First, the relationship between Ly α and Ly β emission was investigated using data from M-class or larger flares that occurred from February 2010 to 2014, when these instruments were observing simultaneously.

The temporal variation of Ly α and Ly β emissions during solar flares are similar in most cases. The increase in Ly α irradiance is about 10% , consistent with previous observations (e.g. Dominique et al., 2018). The Ly α/Ly β irradiance ratio during flare showed a tendency for the Ly α/Ly β ratio to decrease as the Ly α emission increased. This indicates that Ly β emission has a higher increase rate than Ly α emission. In fact, the increase rate in emission was less than 10% for Ly α and about 20% for Ly β.

On the other hand, there were a few flare events in which the light curves of Ly α and Ly β irradiance was not consistent. In these events, the flare duration was relatively long, and the peak time of soft X-ray and Ly α emission sometimes deviated by more than 10 minutes. It is possible that the Ly α/Ly β ratio may have changed during the flare in events with longer flare emission durations.

In this presentation, we will report on the details of the variability of Ly α and Ly β emissions in solar flares, compare them with data from ionosonde observations of the Earth's ionosphere, and discuss the impact of Lyman series radiation from the Sun on the Earth's ionosphere.

太陽フレア発生時には様々な波長の電磁波が放射され、宇宙天気に大きな影響を与えることが知られている。ライマンα線（Ly α、波長：121.6 nm）は太陽の彩層・遷移層から放射される紫外線であり、静穏太陽からの放射においても強い放射線で、地球電離圏の形成にも寄与していると言われている。しかし、ライマンβ線（Ly β、波長：102.6 nm）放射の方が波長が短いため、Ly α よりも Ly β の方が地球に大きな影響があると考えられ、これは太陽フレア時においても同様である。

Lemaire et al. (2012) では太陽活動周期変動における Ly α と Ly β 放射の関係が調べられていた。この先行研究より、Ly α/Ly β 放射照度比は極大期から極小期で値が異なり、周期的に変動することが分かった。しかし、太陽フレア時における Ly α と Ly β 放射の関係については知られていない。そこで本研究では、太陽フレア時における Ly α 及び Ly β 放射の関係、及びこれらの放射が地球上層大気に及ぼす影響について調べた。

本研究では、太陽全面からの紫外線放射を高い波長分解能で観測できる SDO/EVE の Ly β のデータと、Ly α を定常的に観測している GOES/EUVS-E のデータを用いた。まず、これらの装置が同時に観測を行っていた 2010 年 2 月から 2014 年 5 月に発生した M クラス以上のフレアの観測データを用いて Ly α と Ly β 放射の関係を調べた。

太陽フレア時において Ly α と Ly β の放射照度の時間変動は、ほとんどの場合同様であった。また、Ly α 放射照度の増加率は 10% 程度であり、これまでの観測とも一致していた（Dominique et al., 2018）。フレア時の Ly α/Ly β 放射照度比を調べたところ、Ly α 放射が大きくなると Ly α/Ly β 比が小さくなる傾向が見られた。これは Ly β 放射の方が Ly α 放射よりも増加率が高いことを示している。実際、放射の増加率は Ly α が 10% 以下で、Ly β は 20% 程度であった。

一方、Ly α と Ly β の放射照度の時間変動が一致していないイベントも数例見られた。これらのイベントではフレアの継続時間が比較的長く、軟 X 線強度ピーク時間と Ly α 放射のピーク時間が 10 分以上ずれていたりしていた。フレア放射の継続時間が長いイベントでは、フレア中に Ly α/Ly β 比が変化している可能性が考えられる。

今回の発表では、太陽フレアにおける Ly α と Ly β 放射の変動の詳細について報告するとともに、イオノゾンデに

よる地球電離圏の観測データと比較し、太陽からのライマン系列の放射が地球電離圏に及ぼす影響についても議論する。

R010-P07
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

地球磁気圏軟 X 線発光モデリングに対するダイポールモーメントの傾きによる影響

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Dipole Tilt Effects on Modeling of Soft X-ray Imaging of the Earth's Magnetosphere

#Ryota Momose[1)],Yosuke Matsumoto[2)],Yoshizumi Miyoshi[3)]
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The charge exchange between high charge-state ions in the solar wind and the Earth's exosphere (geocorona) emits soft X-rays. This emission process, termed SWCX (Solar Wind Charge eXchange), is useful for visualizing the dayside magnetosphere and its response to solar wind variations. The SMILE and GEO-X missions have been proposed to provide soft X-ray images of the magnetosheath and cusps and will contribute to a better understanding of the dynamic response of the Earth's magnetosphere.

For this purpose, we have developed a global magnetohydrodynamic simulation model of the magnetosphere (Matsumoto and Miyoshi, 2022). The model can provide three-dimensional distributions of the soft X-ray intensity from the plasma parameters. Then line-of-sight integrations of the intensity distribution give a two-dimensional X-ray map as a virtual observation in the simulation domain. In this model, however, the magnetic dipole axis is aligned to the z-axis of the computational domain. To run simulations under more realistic conditions, we introduce the dipole tilt. This inclination leads to the position change of the bright emission regions: cusps and magnetic reconnection sites. In this presentation, we report the status of the model development and discuss the dipole tilt effects on the intensity and distribution of 2D X-ray maps seen from a high-latitude spacecraft orbit at solstice during northern summer. The inclusion of the dipole tilt into the numerical model will contribute to more accurate predictions and physical understandings for the imaging missions.

R010-P08
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#井上　一成 [1)], 藤本　晶子 [2)]
([1] 九工大,[2] 九工大

Effects of CME-driven and CIR-driven storms to satellites and debris orbital decay

#Issei Inoue[1)],Akiko Fujimoto[2)]
([1]Kyutech Institute of Technology,[2]Kyushu Institute of Technology

Space weather refers to the environmental conditions near the Earth as influenced by solar activity, and is closely related to our daily lives. For example, solar flare is a typical space weather phenomenon and can cause malfunctions of spacecraft flying near the Earth. Various Space weather phenomena especially affect the plasma environment in the upper atmosphere, known as the ionosphere. As, a recent sever space weather impact related to the ionosphere, February in 2022, a geomagnetic storm caused by CME knocked out about 40 satellites of SpaceX Starlink network shortly after launch. The February CME-driven geomagnetic storm created a disturbance in the upper atmosphere that enhanced satellite drag conditions and reduced satellite stability, leading to the loss of 38 satellites. In other words, most of the satellites were forced into lower levels of the atmosphere where they burned up.

Recent increase in the number of near-Earth flying objects means an increase in the risk of collisions between flying objects, such as satellites and debris, and their re-entry into the atmosphere, causing them to fall to the ground. Engineering approaches include satellite operation planning and satellite design to prevent further increase of space debris.

On the other hand, as a space weather research approach, it is important to estimate the scale of influence of space weather phenomena (especially, magnetic storms), which are external factors of orbital change and decay of satellite and debris, and to monitor there orbits by using appropriate space weather-induced orbital decay effect prediction models. This study addresses the latter perspective.

We investigated the relationship between space weather and debris parameters (Dst, IMF Bz, debris size, inclination and initial altitude) and orbital decays of satellite and debris during 55 magnetic storms occurring from 2006 to 2018. The 55 magnetic storms include both CME-driven and CIR-driven storms. We divided them to two groups corresponding to the source of storms and analyzed the effect of the size, inclination and initial altitude of satellites or debris to the orbital decays. During the analysis period, we found the long-duration large-amplitude IMF Bz, as a proxy of the Rule heating effect to the thermospheric dynamics and composition, significantly associated with large decay events. We will discuss the influence of CME-driven and CIR-driven magnetic storms on satellite and debris decays in the short, medium, and long term in terms of space weather.

R010-P09
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#齊藤　慎司 [1)], 久保　勇樹 [2)]
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Improvement of real-time probabilistic forecast of >2 MeV electron fluence levels on geostationary orbit

#Shinji Saito[1)],Yuki Kubo[2)]
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Relativistic electrons that constitute Earth's radiation belts are considered as a cause of anomalies on artificial satellite. As space weather monitoring and forecast in NICT, we have monitored the variation of the radiation belt electron flux on geostationary orbit observed by GOES-16 and 18 satellites.

We developed the probabilistic forecast model of radiation belt electrons by using a deep learning (DL) method, RadeAI. The method implements multi-layer perceptron which has the input layer, three hidden layers, and the output layer. The softmax function is applied on the output layer which generates probabilities of four fluence levels of radiation belt electrons with 24 hours lead time. The input layer receives the solar wind and electron fluence data past 72 hours with time resolution of 1 hour. We evaluated the accuracy of the forecast by taking ROC curves and reliability diagram with consistency bars. The results show that there was room for improvement in accuracy.

In order to improve the accuracy of RadeAI, we consider input data set to be more appropriate for the forecast of fluence level of >2 MeV electrons than the current model. The input data set for the current model was 1-hour averaged data, so the information of temporal variation within 1 hour was completely eliminated. We will evaluate the influence of solar wind temporal variation within 1 hour on the >2 MeV electron fluence. By choosing the input data set that has higher correlation with the variation of the fluence, RadeAI would become possible to forecast more accurately. In this presentation, we will show the performance of the improved RadeAI by comparing with the current one.

R010-P10
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

モデルパラメタ等による大気・電離圏シミュレーションの不確定性の評価

#陣　英克 [1)], 三好　勉信 [2)], 垰　千尋 [1)], 安藤　慧 [3)], 品川　裕之 [4)], 藤原　均 [5)]
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Evaluation of model uncertainty due to input and internal parameters of GAIA

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([1]National Institute of Information and Communications Technology,[2]Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University,[3]National Institute of Information and Communications Technology,[4]International Research Center for Space and Planetary Environmental Science, Kyushu University,[5]Faculty of Science and Technology, Seikei University

Prediction of the earth's upper atmosphere is one of the important issues in the space weather research. Variations of ionospheric electron density and thermospheric mass density have significant impacts on the use of GNSS applications, the stable operation of satellites in low earth orbits, and so on.

For the purpose of upper atmospheric prediction, we are developing a data assimilative model using a whole atmosphere-ionosphere model called GAIA, with an ensemble Kalman filter method. The assimilation method is to find the most probable solution from observation errors and model uncertainties, and therefore it is important to reproduce the model uncertainty well in the ensemble in order to improve the performance of the assimilation calculation. It is also useful to understand how much model error exists and what causes it when interpreting model results.

In this study, we selected several input and internal parameters used in GAIA that could be uncertain. and examined the degree to which these uncertainties contribute to the extent of spatial distributions and temporal changes in the ionosphere and thermosphere.

From this result, we discuss the optimal uncertain parameters to introduce into the data assimilation scheme.

電離圏や熱圏大気の予測は宇宙天気研究・実用の重要テーマの一つであり、我々は大気圏電離圏モデル GAIA を用いたアプローチにより、取り組んでいる。その一環として、現実の大気状態を推測・予測するために、GAIA にアンサンブル手法のデータ同化を適用し、電離圏観測データとの融合を行っている。このデータ同化手法では、観測の誤差とモデルの不確定性から、最もありうる解を見出そうとするものであり、そのためにモデルの不確定性をアンサンブルで上手く表現することが重要である。

本研究では、データ同化モデルの開発のため、およびモデルの計算結果をより的確に解釈するため、モデルの誤差がどれくらいあるか、何によって生じるかを調べる。このため、まず我々は GAIA モデル内の入力および内部パラメタについて、不確定性が大きそうなパラメタを検討し、いくつか選択した。そして、それらの不確定性がどれくらい電離圏および熱圏の空間分布・時間変化の範囲に寄与するか調べる。これらの結果を基に、各パラメタの不確定性の情報をデータ同化に導入し、性能が改善することを確かめる。

R010-P11
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#藤本　晶子 [1)]
[(1] 九工大

Ionospheric Space Weather Informatics

#Akiko Fujimoto[1)]
[(1]Kyushu Institute of Technology

Dynamic changes in the environment caused by the sun and solar wind often also affect telecommunication networks, power grids, and other infrastructure. One significant influence of solar activity is seen in disturbances in satellite navigation services, GPS/GNSS, due to space weather impacts on the upper atmosphere, known as the ionosphere. We operate ground-based FM-CW radars to observe the ionosphere at four sites in Japan and overseas. Also we have developed the SDR (Software-Defined Radio) -based scintillation detector system and examine the GPS scintillation. These remote sensing have generated big data of ionospheric environment observation. In order to understand the ionospheric environment in real time and to infer future space weather, we have developed a technique to obtain useful information from past cases that occurred under similar space weather conditions by high-speed computation and processing of observation data. We will present examples of our current research efforts in Ionospheric Space Weather Informatics.

R010-P12
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#中村　駿仁 [1)], 藤本　晶子 [1)], 阿部　修司 [2)]
([1] 九工大,[2] 九大・i-SPES

Development of compact GNSS scintillation system based-on SDR technology and packaged S4 index visualization tool

#Hayato Nakamura[1)],Akiko Fujimoto[1)],Shuji Abe[2)]
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Characteristics of radio propagation related to the ionosphere are used in fields such as positioning and communications. Disturbances in the ionospheric environment cause changes in the amplitude and strength of signals passing through the ionosphere, which have various adverse effects on our society. Continuous monitoring of the ionospheric environment is important to predict these effects. The objective of this study is to develop a scintillation sensor using GNSS signals as an ionospheric monitoring system. The proposed system requires to be based-on the software defined radio technology device as a signal processing unit (it will be combined with the existing FMCW radar in near future) and to reduce the cost of equipment and transportation for multipoint observations.

In this study, the proposed system consists of a GNSS scintillation unit based-on the software defined radio technology, and a scintillation index calculation unit based-on a Raspberry Pi and Python . The GNSS scintillation unit obtains the GNSS signal strength values from the navigation data (ephemeris) received in the process of coordinate positioning and flows them to the following S4 index (signal strength scintillation index) calculation processor. The scintillation index calculation unit provides S4 index and produce several summary statistical variables and quick look figures for visualizing the GNSS scintillation variation.

We will present that continuous operation test resulted in the successful S4 index observation with our proposed system. The observation time resolution of the present system is 30 seconds. We will also report a new improved system with a higher time-resolution (20 Hz) than the current measurement model and a proposed visualization tool (application) for the GNSS signal intensity and S4 index.

R010-P13
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

文字列照合等を用いた赤道ジェット電流地磁気変動の特性抽出とその応用

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([1] 九大,[2] 九大/理学研究院,[3] 九工大

Search for geomagnetic variation of equatorial electrojet using string matching and its application

#Ryoma Nishiguchi[1)],Akimasa Yoshikawa[2)],Akiko Fujimoto[3)]
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The strong eastward zonal current near the magnetic equator on the day side (Equatorial Electrojet: EEJ) is enhanced by the cowling effect, especially within ± 3 degree. The EEJ causes significant changes in the ground magnetic field, especially in the north-south component on the dayside. EEJ is superimposed over various physical phenomena, including the interaction between the atmosphere and ionospheric plasma, solar wind disturbances. Thus, it plays a critical role in the coupling of the solar wind-magnetosphere-ionosphere system.

Over 150,000 days of geomagnetic field data has been collected at Kyushu University. It takes an enormous amount of time and effort to manually detect specific patterns from this large amount of data. Therefore, an automatic and quick detection method is needed. Matsuyama (2021) showed that ”string pattern matching” is useful for analyzing EEJ geomagnetic variation patterns of EEJ. In the proposed method captured the characteristics of the graph by replacing numerical increases and decreases with strings. By searching for specific string patterns, similar variations are extracted. They also demonstrated the rapid and automatic detection of EEJ variation patterns from hourly magnetic field data. Furthermore, a comparison of search speeds between two string search algorithms, the Knuth-Morris-Pratt (KMP) algorithm and the Rabin-Karp algorithm, revealed that the Rabin-Karp algorithm is effective when searching for longer strings. On the other hand, the characteristics of geomagnetic variation are captured by replacing geomagnetic variation patterns with characters, so if the number of characters to be replaced is small, the original characteristics cannot be captured correctly, resulting in a problem with search accuracy.

In this study, we conducted string conversion on 1-minute low-pass filtered data. We used approximately 4000 days from 2012 to 2018 of magnetic field data collected at the DAVAO [GM Lat.-2.2] station. We found that 12 and 18 characters could represent 70% and 99% of the total variation pattern, respectively. This method enables the extraction of typical EEJ, morning CEJ, and afternoon CEJ patterns under quiet conditions from over 4000 days of data in approximately 0.2 seconds, using a standard PC. This high search speed allows for more efficient analysis compared to traditional manual extraction techniques. In this presentation, we will discuss the results of classifying the variation patterns of the extracted EEJ using string matching. Furthermore, we plan to discuss the classification of various types of events, including DP2-type events, sudden geomagnetic variations caused by solar flares (solar flare effect: SFE), and events that take place during complex magnetic disturbance.

昼側磁気赤道付近には、強い東向きの帯状電流（赤道ジェット電流：EEJ）が流れており、特に± 3° 以内はカウリング効果によって強化されている。EEJ は地上磁場に大きな変動をもたらし、その南北成分が昼側で卓越する変動パターンとして観測されてきた。EEJ は、大気と電離圏プラズマの相互作用や太陽風の擾乱現象など様々な物理現象が重畳することから、その変動を解析することにより、太陽風ー磁気圏ー電離圏結合系の理解が進むことが期待される。

地上磁場データは、九州大学が 40 年に亘り蓄積した 15 万日以上のデータを含め、世界中で大量のデータが蓄積されている。この大量のデータから、特定の変動パターンを手動で検出するには膨大な時間と手間がかかる。そのため、変動パターンを自動かつ高速に抽出する手法が必要である。松山 (2021) にて EEJ の地上磁場変動パターンの解析には、文字列照合という手法が有用であることが示された。提案された文字列照合を応用した EEJ 検出法では、数値増減を文字に置き換えることでグラフの特徴を捉え、特定の変動パターンを文字列として検索することで類似した変動を抽出する。同論文では、1 時間値の磁場データから EEJ の変動パターンを高速に自動検出できることを明らかにした。更に、KMP 法と Rabin-Karp 法の 2 種類の文字列検索アルゴリズムの検索速度の比較することにより、検索する文字列が長い場合は Rabin-Karp 法が有効であることが示された。一方で文字列検索は，地磁気変動パターンを文字に置き換えることで変動の特徴を捉えるため、置き換える文字の種類が少ないと，正しく元の特徴を捉えることができず，結果として検索精度に問題があることも示唆されている。

本研究では、ローパスフィルタをかけた 1 分値のデータに対して文字列化を行い、性能評価を行った。用いたデータは磁気赤道域の DAVAO [GM Lat.-2.2] 観測点における 2012 年から 2018 年の 7 年間に取得された約 4000 日分の磁場データである。1 日の変動パターンは、12 文字で全変動パターンの約 70% を表すことができ、18 文字以下で全体の約 99% を特定できる。この検索手法を用いると、例えば、標準的な PC を用いて、静穏時における典型的な EEJ や朝型逆ジェット電流（CEJ)、夕方 CEJ の発生イベントの分離・抽出なども、上記 4000 日分のデータに対して約 0.2 秒で完了する。この検索スピードは従来型の目視による現象抽出に対して、飛躍的な高効率解析を可能とする。本発表では文字列照合によって抽出した EEJ の変動パターンを分類した結果について報告し、更に DP2 タイプイベント、太陽フレアによる突発的な地磁気変動 (太陽フレア効果：SFE)、複合的な磁気擾乱時イベントなどの、分離抽出についても議論する予定で

ある。

R010-P14
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#出井　駿 [1)], 中村　紗都子 [2)], 三好　由純 [3)], 海老原　祐輔 [4)], 亘　慎一 [5)]
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Geomagnetically Induced Currents (GICs) Related to Ionospheric Sq Currents in Mid-Latitude Regions: A Case Study in Japan

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Geomagnetically induced currents (GICs) are electric currents induced near the Earth's surface due to fluctuations of the Earth's geomagnetic field, which are caused by variations of currents in the magnetosphere and ionosphere. GICs, possessing properties like direct current, are known to significantly affect transformers, which are designed for alternating current. The main causes of geomagnetic fluctuations that cause GICs are equatorial ring currents in the magnetosphere and ionospheric Sq currents caused by the tidal winds due to the solar heating of the thermosphere. These current changes in the upper atmosphere induce variations of geomagnetic fields, subsequently causing GICs. Much research has been conducted on GICs caused by equatorial ring currents because of their potential risk to significantly damage the safety of power transmission systems. On the other hand, GICs associated with ionospheric Sq currents occur every day, and their fluctuations may impact the stability of power supply, potentially causing power losses. However, research on this topic has not yet been adequately advanced. Particularly, very little research on long-term analyses of GIC measurements possibly related to ionospheric Sq currents in mid-to-low latitude regions like Japan have been performed. In this study, we have analyzed a long-term data set of GIC measurements recorded in a specific region in Japan. Utilizing statistical methods, specifically the Seasonal-Trend Decomposition using LOESS (STL), we have attempted to isolate and remove fluctuations in GICs caused by equatorial ring currents to identify variations of GICs during geomagnetic quiet periods. We compared the derived GICs with ionospheric Sq currents. We also compare with variations of the geomagnetic indices to validate the reliability of our model. Our research contributes to understanding the underlying causes of power irregularity related to GICs and provides insights into the mitigation of potential adverse impacts on power transmission systems.

R010-P15
ポスター 3 ：9/26　AM1/AM2 （9:00-12:30）

#池田　昭大 [1)], 魚住　禎司 [2)], 吉川　顕正 [3)], 藤本　晶子 [4)], 阿部　修司 [5)]
([1] 鹿児島高専,[2] 九工大革新的宇宙利用実証ラボラトリー,[3] 九大/理学研究院,[4] 九工大,[5]ROIS-DS

Schumann resonance parameters at Kuju and global lightning activity

#Akihiro Ikeda[1)],Teiji Uozumi[2)],Akimasa Yoshikawa[3)],Akiko Fujimoto[4)],Shuji Abe[5)]
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The Schumann resonance (SR) is the global resonance of electromagnetic waves generated by global lightning activity. SR parameters, which are amplitude and frequency, reflect the properties of both global lightning activity and the state of the Earth-ionosphere cavity. In this study, we compared SR amplitudes with global lightning activity and examined their relationships in terms of seasonal variation.

We investigated the SR detected by an induction magnetometer at low-latitude station Kuju (KUJ; 33.06 N, 131.23 E) by comparing global lightning activity. The global lightning activity was derived from the satellite-based total lightning data obtained by the Optical Transient Detector (OTD) and Lightning Imaging Sensor (LIS). Monthly time series of flash rate were investigated in this study.

Generally, SR amplitudes in a day show peaks which correspond with the major thunderstorm centers. Lightning activity develops after a mean delay time of ~3hours with respect to the solar zenith. Thus, the lightning activities of Africa, Asia, south-east Asia, South America, and North America peak at around 15 UT, 10 UT, 08 UT, 20 UT, and 23 UT, respectively. The peak of flash rate in north America appeared in July and August. SR amplitude at 23 UT became correspondingly maximum in August. In the case of Africa, flash rate became minimum in June and July. Similarly, SR amplitude at 15 UT became smaller in June, July, and August. The feature suggests that the SR corresponds with African lightning activity. The flash rate for specific regions and SR amplitudes at specific UT showed the similar seasonal variations. We concluded that the SR amplitudes at KUJ reflects global lightning activity.