R010-01
Zoom meeting B ：11/3 AM2 (10:45-12:30)
10:45-11:00

Extreme space weather: A statistical study

#Ryuho Kataoka
NIPR

Statistical distributions are investigated for substorms, sudden commencements (SCs), and magnetic storms to identify the possible amplitude of 100-year event from a limited data set of less than 100 years. It is found that majorities of events essentially follow the log-normal distribution, as expected from the random output from a complex system. However, it is uncertain that rare events follow the log-normal distributions, and the possible excess from the log-normal distribution may rather follow the power-law distributions. The amplitudes of 100-year (1000-year) events estimated from both the log-normal and power-law distributions for magnetic storms, substorms, and SCs are 750 nT (1100 nT) ranging 5000 nT (6200 nT), and 230 nT (450 nT), respectively. The mechanisms to cause the statistical distributions are discussed, consulting the other space weather phenomena such as solar flares, coronal mass ejections, and solar protons.

R010-02
Zoom meeting B ：11/3 AM2 (10:45-12:30)
11:00-11:15

Study of IMF By dependence of plasma injection position using real-time magnetosphere simulation data

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Surface charging of artificial satellite is one of the risks caused by dynamical variations of space environment. It often occurs when a satellite is exposes by electrons of ~10 keV injected from the tail plasma sheet during substorms. Magnetosphere-ionosphere coupling global MHD simulation is one of the powerful ways to predict the timing and location of plasma injection.
Now we are developing a real-time numerical simulator for space weather forecast using magnetosphere-ionosphere coupling global MHD simulation called REPPU (REProduce Plasma Universe) code. The feature of the simulation code is high robustness for extreme solar wind parameters; the unstructured grid system enables us to calculate the whole region with the uniform accuracy. The spatial resolution is 30722 grids in the spherical planes and 240 grids in the radial direction. The simulator is driven by the real-time solar wind data obtained by the DSCOVR spacecraft.
We investigate the IMF By dependence of plasma injection position using real-time simulation data. We found that injection position tends to distribute in the dusk side (dawn side) when the IMF By is positive (negative). Comparison of the simulation results with the CPCP, AE index, and plasma variations observed by geostationary orbiting satellites will also be reported.

R010-03
Zoom meeting B ：11/3 AM2 (10:45-12:30)
11:15-11:30

Forecast of energetic electron flux variations at different L-shells using the machine learning

#SATOSHI FUKUOKA[1], Yoshizumi Miyoshi[1], Daikou Shiota[2], Satoshi Kurita[3], Inchun Park[4], Tomoaki Hori[5], Shun Imajo[1], Takefumi Mitani[6], Takeshi Takashima[7], Iku Shinohara[8], Ayako Matsuoka[9]
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The relativistic/sub-relativistic electron flux variations often cause serious damage on the satellite operations through the dielectric charging. In order to forecast flux variations of these electrons, various forecast methods based on the physical based simulation and empirical modeling have been developed. For the physics-based simulation, the SUSANOO that operates a code-coupling simulation of heliosphere and radiation belt provides MeV electron flux variations for the next couple of days. For the empirical modeling, the linear prediction filter and the auto-regressive moving average are popular methods, which have been used for the forecast of MeV electrons at geosynchronous Earth orbit (GEO). Recently, the machine learning techniques have widely been used for the space weather forecast, for example, ionospheric variations, the flare prediction, etc. In this study, we have developed the forecast system of relativistic/sub-relativistic electron flux variations based on long short-term memory recurrent neural network (LSTM-RNN). As the training data, we use the solar wind data and energetic electron data observed by Arase/HEP, XEP instruments at different L-shells of the outer belt. Our developed network provides time variations of the energetic electron flux around L=6 using the solar wind data as an input parameter. On the other hand, the network does not reproduce the observed flux variations at L=4, suggesting that other parameters are necessary as input parameters of the network. In this presentation, we will present the initial results of our developed network and discuss effective solar wind parameters to reproduce the observed flux variations at different L-shells.

R010-04
Zoom meeting B ：11/3 AM2 （10:45-12:30）
11:30-11:45

Proton Flux Response in the South Atlantic Anomaly due to Inductive Electric Field

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The South Atlantic Anomaly (SAA) is considered as a harmful radiation source for the Low-Earth Orbit (LEO) missions because it involves high-energy charged particles precipitating from the inner trapped radiation belt. In this research, we studied the short-term response of the proton flux in the South Atlantic Anomaly (SAA) region during the geomagnetic storm event of 15 May 2015. We have developed a three-dimensional relativistic test particle simulation code by implementing Tao-Chan-Brizard guiding center model in order to calculate the trajectories of protons with energy range 140-400 MeV in a time-varying magnetic field, provided by Tsyganenko model TS05 as well as the corresponding inductive electric field solved by Biot-Savart law. In this study, we considered the following SAA variables: the maximum value of the proton flux and the area of the anomaly at given altitudes. Numerical results showed that the proton flux was enhanced during the main storm phase and totally decreased during the recovery phase. The previous results were compared with observations from satellites.

R010-05
Zoom meeting B ：11/3 AM2 （10:45-12:30）
11:45-12:00

宇宙環境の時間変動を考慮した人工衛星帯電数値解析手法の開発

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Development of Spacecraft Charging Analysis Method Considering Dynamically-Changing Space Environment

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Numerical simulations based on the particle-in-cell method are widely used for quantitative analysis of spacecraft charging processes in space environment. Due to the high computational cost for calculating the motions of a large number of plasma particles, the method allows us to simulate only phenomena of very limited temporal and spatial scales within practical computation time. This feature makes it difficult to analyze temporal evolution of a spacecraft potential in dynamically-changing space environment.
In this study, we newly develop a numerical analysis method that enables us to assess a spacecraft potential variations in a longer time period, which can cover geospace environmental changes. The basic design of the method is as follows. First, we perform a large number of plasma particle simulation runs to construct a data set of spacecraft current-voltage characteristics for various space environmental parameters. In each simulation, the spacecraft potential is fixed at a prescribed value, while the plasma currents into the spacecraft will be updated and monitored to obtain their equilibrium values. Such a simulation configuration is advantageous in terms of a required number of time integrations to obtain a steady-state solution, in comparison with the conventional setup, for which the simulation is performed until an equilibrium value of the spacecraft potential is obtained.
As a next step of the analysis method, time-series data of environmental parameters extracted from spacecraft observations or global simulations are used as an input. Based on the input parameters, we can obtain the plasma currents into the spacecraft by referring to the current-voltage characteristic database constructed above. Then, we numerically integrate an analytical equation, which describes the time evolution of a spacecraft potential, to see the spacecraft potential response to the environmental parameter changes. In this process, the spacecraft potential response is solved with reference to the pre-constructed current database, its calculation cost is much lower than that of the plasma particle simulations. This feature enables us to evaluate a spacecraft potential behavior in a time period that is long enough to cover the space environment changes.
For a case study using the proposed method, we chose a spacecraft failure event of the Galaxy 15 in 2010, which is considered to be triggered by a large solar flare. The Earth's magnetosphere environment during the spacecraft failure is simulated by means of a global MHD simulation, and the obtained time-series data of environmental parameters will be served as an input for the spacecraft charging analysis. We report the recent progress of the method development, particularly construction of a current-voltage characteristic database based on particle-in-cell simulations.

宇宙環境における人工衛星帯電現象の定量評価のため、プラズマ粒子計算手法を用いた数値シミュレーション解析が広く活用されている。しかし、非常に多くのプラズマ粒子の運動を計算する当該手法の計算コストの高さ故に、現実的に実行できるシミュレーションはその時空間スケールが大きく制限され、宇宙環境のプラズマパラメータの時間的変動を考慮した帯電解析は困難であった。
本研究では、太陽活動度に応じてダイナミックに変化する宇宙環境を考慮しつつ、従来より長時間の衛星電位計算に対応可能な数値解析手法を新たに開発する。本手法の基本設計は以下の通りである。まず事前に多数回のプラズマ粒子シミュレーションを実施し、様々な宇宙環境パラメータに対応した電流電圧特性のデータベースを作成する。このとき、各シミュレーション中では衛星電位を固定して、衛星流入電流の定常解が得られるまで時間更新を行うことにする。これにより、一般的に行われる衛星電位の定常解を求める計算に比べて、1 シミュレーションあたりの所要時間を短縮することが可能である。
次に衛星観測やグローバルシミュレーションから抽出した宇宙環境パラメータの時系列データを入力とし、蓄積された電流電圧特性データベースを参照して、衛星電位の時間発展方程式を数値積分することで、変動する宇宙環境に対する衛星電位応答を計算する。この計算では、衛星近傍のプラズマ粒子の軌道計算ではなく、データベース化された衛星流入電流を用いて衛星電位の時間発展を解くため、その計算コストはプラズマ粒子シミュレーションに比べて非常に低く、宇宙環境パラメータが変動するのに十分な長時間の衛星電位について解析することができる。
上記の解析手法開発のためのテストデータとして、2010 年に太陽フレアの影響によって障害を起こしたとみられる静止軌道衛星「Galaxy15」の事例を用いる。太陽フレア発生時を模擬した地球磁気圏 MHD シミュレーションを事前に実施し、衛星障害発生時の宇宙環境パラメータを抽出する。現在は、得られたパラメータを入力として電流電圧特性データベースを作成しており、その進捗を報告する。

R010-06
Zoom meeting B ：11/3　AM2 （10:45-12:30）
12:00-12:15

静止気象衛星の衛星異常と宇宙環境の関連性

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Relationship between spacecraft anomalies of geostationary meteorological satellite and space environment

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Spacecrafts in orbit may have failures possibly due to changes of the space environment. However, because detailed information of satellite anomalies is often not publicly available, it is hard to say that the causal relationship between space environment and satellite anomalies is well defined. The Japanese meteorological satellites Himawari 8 and 9 have space environment data acquisition monitors (SEDA), which measure high-energy particles around the spacecraft for the purpose of satellite housekeeping and using the data for analysis in case of failure. The Meteorological Satellite Center of Japan Meteorological Agency routinely provides the report of observation including observation plan, observation interruption, and so on. The list of observation interruption includes attitude control, sensor calibration, satellite maintenance, and satellite anomaly. In Himawari-8 satellite, 10 cases of satellite anomalies that cause observation interruption, have been reported from the start of operation in July 2015 to 2017. An analysis of the relationship between the satellite anomaly and the space environment based on the data measured by SEDA revealed that 6 cases correspond to the increase of high-energy electron fluxes and 1 case correspond to the increase of high-energy proton flux. The high-energy proton flux enhancement was associated with the X-class solar flare that occurred in September 2017. During the same period from 2015 to 2017, it has been reported that the European geostationary meteorological satellite; Meteosat also experienced multiple satellite anomalies. In this presentation, we will report the detailed analysis results of space environment data at the time of these spacecraft anomalies.

軌道上の人工衛星は宇宙環境変動が原因と考えられる不具合が発生することがある。しかしながら、衛星異常の詳細情報を得ることが困難であるために、衛星異常と宇宙環境変動との因果関係については十分に理解できているとは言い難い。気象衛星ひまわり 8 号 9 号には宇宙環境データ取得装置（SEDA）が搭載され、衛星のハウスキーピング及び故障解析時にデータを利用することを目的に衛星周囲の高エネルギー粒子を計測している。気象庁気象衛星センターでは、ひまわり 8 号衛星の観測運用情報として観測運用計画と共に観測休止履歴を公表している。観測休止の原因は、衛星の軌道制御や計測装置の校正、衛星メンテナンス等、様々な理由があるが、中には衛星異常とされているものが含まれている。ひまわり 8 号衛星では 2015 年 7 月の運用開始以降から 2017 年末の間に気象観測に影響を及ぼした衛星異常の発生が 10 例報告されている。これらの衛星異常について SEDA が計測したデータをもとに宇宙環境との関連性について解析をすると、6 例は高エネルギー電子フラックスの増大時、1 例は高エネルギープロトンフラックスの増大時と対応していることが明らかになった。高エネルギープロトンフラックスの増大は、2017 年 9 月に発生した X クラスの太陽フレアに関連した現象である。2015 年から 2017 年の同期間には欧州の静止気象衛星 Meteosat でも複数例の衛星異常が発生していることが報告されている。本発表では、これらの衛星異常発生時の詳細な宇宙環境データの解析結果について報告する。

R010-07
Zoom meeting C ：11/4　AM1 （9:00-10:30）
09:00-09:15

磁気流体緩和法で再現された黒点上空磁場の三次元構造

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Three-dimensional structure of the magnetic field above the sunspots modeled by the MHD simulation

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It is well known that solar flares and coronal mass ejections (CMEs) tend to occur in sunspot regions. Toriumi & Takasao (2017) conducted a series of flux emergence simulations and succeeded in reproducing four types of typical sunspot structures that have been observationally suggested to cause strong flares. However, the magnetic structure in the corona above these reproduced sunspots, its time development, and the force-freeness known to exist in the actual solar corona have not been analyzed in detail yet.

Therefore, we set two purposes in this study. First, we investigate the magnetic structure in the corona of the simplest standard sunspots in Toriumi & Takasao (2017). Then, we apply the nonlinear force-free field (NLFFF) extrapolation method to these sunspots and compare with the original 3D simulation data.

On the structural analyses of the magnetic field in the simulation, first, we visualized the magnetic field lines and investigated the time development of the three-dimensional magnetic structures and of the distribution of the magnetic field strength. These emerging magnetic field lines expand into the corona and then gradually settle into a steady state. Second, we calculated epsilon-force value (Wiegelmann et al. (2009)), which measures the force-freeness, and investigated the relationship between the height and epsilon-force. The epsilon-force value decreases with height and with time, that is, the coronal field gradually becomes force-free state. Furthermore, we will calculate NLFFF using the 2D slices at various heights in the 3D simulation data as the bottom boundary conditions and report these results.

In the presentation, we report on the detailed analysis results of sunspots modeled by Toriumi & Takasao (2017) and NLFFF extrapolations using these simulation data.

太陽フレアや CME は、黒点周辺での発生が多いことが知られている。Toriumi & Takasao (2017)は、太陽対流層に埋め込んだ磁束管を浮上させる磁気流体シミュレーションを行ない、太陽表面で観測された 4 種類の典型的な黒点構造を再現することに成功した。しかし、再現された黒点上空の詳細な磁場構造やその時間発展、太陽コロナに見られるフォースフリー状態がどの程度再現されているかについてはまだ調べられていない。

　そこで、本研究の目的は以下の二つである。一つは、Toriumi & Takasao (2017)で示されたシミュレーションのうち最もシンプルな基準データを解析し、コロナ中の磁場構造を明らかにすること。もう一つは、その結果に基づいて非線形フォースフリー磁場(NLFFF)外挿計算を行い、シミュレーションで得られた磁場構造との違いを調べることである。シミュレーションデータの構造解析は以下の二手法で行った。はじめに、三次元の磁力線を可視化することで、磁場構造や磁場強度の時間変化を調べた。その結果、浮上磁場が光球面を突破してしばらく発展した後、徐々に定常状態に落ち着いていくという結果が見られた。次に、フォースフリーの度合いを評価する指標である ε_force (Wiegelmann et al. (2009))を計算し、各時刻における高度と ε_force の関係を調査した。その結果、光球面から高度とともに急激に ε_force が減少する、すなわちフォースフリー状態に近づく傾向が見られた。また、時間とともに領域全体として ε_force が小さくなることから、時間経過に伴って磁場がフォースフリー状態に近づくことが分かった。また、シミュレーション結果の様々な高度の 2 次元平面データを底面境界条件として NLFFF 外挿計算を行い、フォースフリー度の変化に対する外挿計算の再現度を調べる予定である。本講演では、以上のような Toriumi & Takasao (2017)で再現した黒点の解析結果とそのデータを用いた NLFFF 計算の結果の詳細を報告する。

R010-08
Zoom meeting C ：11/4 AM1 (9:00-10:30)
09:15-09:30

活動領域 12673 は 2017 年 9 月 6 日以前に大規模フレアを発生させることは可能であったか？

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Possibility of a Large Solar Eruption Before September 6th 2017 in Solar Active Region 12673

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Solar active region (AR) 12673, which appeared in September 2017, produced not only multiple M-class solar flares but also several X-class flares. Among them, the X9.3 flare was the largest solar flare to occur in the solar cycle 24. Recently, Ymasaki et al. identified the presence of highly twisted field lines at polarity inversion line, on which X-class flares are observed, from the nonlinear force-free field (NLFFF) extrapolation two days prior to the occurrence of the X9.3 flare(Ymasaki et al. Under Review). This raises the questions, why did the twisted field lines remain stable until September 6th? And could they possibly have produced an eruption before September 6th?

In order to answer these questions, we performed magnetohydrodynamic (MHD) simulations using the NLFFF as an initial condition. We used the NLFFF reconstructed at 18:00 UT in September 4th , 2 days before the X9.3 flare. As a result, although the NLFFF is stable to small disturbances, an eruption can be triggered through a magnetic reconnection enhanced by an anomalous resistivity. We find that the twisted field lines in our extrapolation had a potential to erupt even 2 days prior to the X9.3 flare. This result suggests that if the triggering element inducing the reconnection appeared in the photosphere, the eruption could be possibly achieved up to 2 days before the X-class flares. Furthermore, Yamasaki et al. reported that many of M- and C-class flares on September 4th and 5th were observed at the polarity inversion line other than which X-flares were observed. This suggests that the triggering element which induces the magnetic reconnection was not appeared until September 6th. Therefore, the intruding motion of the negative polarity into opposites observed in September 6th drives reconnection at local site, resulting in the X-class flares.

活動領域 12673 は、2017 年 9 月に複数の X フレアを発生させた。特に、9 月 6 日に X9.3 や 10 日に X8.2 等の巨大フレアを発生させたことから、本活動領域は太陽サイクル 24 において非常に活発な活動領域であった。山崎らは 9 月 4 日から 6 日までの時系列の太陽表面観測磁場データに基づいて、3 次元のコロナ磁場をフォースフリー近似に基づいて 12 時間おきに数値的に外挿した。その結果、X フレアを引き起こした強く捩れた磁力線群(磁気フラックスロープ)が、X フレアが発生する 2 日前にすでに形成されていたことがわかった(Yamaski et al. Under Review)。そこで、(1)磁気フラックスロープが X フレアの 2 日前に形成されていたにも関わらず、なぜ安定に存在できたのか？(2)9 月 4 日の時点で、大規模フレアの発生は可能なのか? 等の疑問が挙げられる。本研究はこれらの疑問に答えるため、太陽表面の観測磁場データから外挿されたコロナ磁場を初期条件とした磁気流体シミュレーションを実施した。

その結果、9 月 4 日の 18:00 UT に外挿された磁気フラックスロープは、微小な擾乱に対しては安定であることがわかった。その一方で、強い電流領域に異常抵抗を与えて、捩れた磁力線の間で磁気リコネクションを誘発すると、さらに強く捩られた磁気フラックスロープが形成され、その結果、上空へと放出されることがわかった。つまりこの結果は、磁気リコネクションをトリガーするような擾乱が太陽表面に現れれば、9 月 4 日の時点で大規模なフレアが発生していた可能性を示唆している。山崎らの報告によれば、9 月 4 日以降の多くの M, C フレアは、X フレアを起こした磁気中性線とは異なる中性線で発生しており、リコネクションを十分に促進する擾乱が X フレアを起こす磁気フラックスロープに与えられなかったことが示唆されている。それゆえ、9 月 6 日まで磁気フラックスロープは安定に存在することができたが、6 日に観測された黒点の強い貫入運動によって、磁気リコネクションが駆動され、X フレアが発生したシナリオが考えられる。

R010-09
Zoom meeting C ：11/4 AM1 (9:00-10:30)
09:30-09:45

Reproduction and validation of flare spectra and their impact on the global environment at the X9.3 event of September 6, 2017

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The radiation from the Sun is the most important ionization and heating energy source for the Earth's upper atmosphere. Sudden increase of soft X-ray and extreme ultraviolet (EUV) emissions due to the solar flare accelerates the ionization and molecular dissociation of atmospheric components in the ionosphere and thermosphere, and it may cause strong increase in electron density. This phenomenon is called the sudden ionospheric disturbance (SID), and communication failure caused by the absorption of the short-wave by the SID is known as the Dellinger phenomenon (Dellinger 1937). In order to verify which wavelength of the solar flare spectrum affects the occurrence of the Dellinger phenomenon, we first need observation data of the full wavelength spectrum of solar flare emission and compare with them. However, EUV flare spectra observation with high spectral and temporal resolution are very limited, the numerical model for predicting EUV emissions is needed. One of them is the Flare Irradiance Spectral Model (FISM; Chamberlin et al., 2008). Although FISM is the most widely used model now, this model has some problems such as uncertain physical processes due to empirical model. Therefore, we constructed new flare emission model with physical processes (Imada et al. 2015, Kawai et al. 2020) in order to reproduce the observed flare emission. In our model, the physical process of the plasma in the flare loop is reproduced by combining the one-dimensional hydrodynamic calculation using CANS (Coordinated Astronomical Numerical Software) 1D package with the CHIANTI atomic database (Dere et al. 2019}. Using this model, we reproduced EUV dynamic spectra for some flare events. When we compared observed SDO/EVE MEGS-A spectra with our calculation results, we found that our result clearly reproduced most of the EUV lines during flare.
Furthermore, in order to examine the effect of flare emission on the Earth's atmosphere, we put our calculated flare spectra into the Earth's atmospheric model GAIA (Ground-to-Topside Model of Atmosphere and Ionosphere for Aeronomy; Jin et al., 2011), and then we reproduced the variation of total electron content (TEC). We tried to reproduce the TEC variation of the X9.3 flare on September 6, 2017, then we compared calculated results with the observed TEC amount.
When we used the FISM flare spectrum, difference of TEC amount from the background could be almost reproduced. On the other hand, when the flare spectrum of the CANS model was used, the result varied depending on the presence or absence of the background. This difference which depends on the models is thought to represent which EUV radiation is primarily responsible for increasing TEC. From the flare spectrum obtained from these models and the calculation result of TEC fluctuation using GAIA, it is considered that the EUV emission about 15-40 nm is mainly effect to increasing TEC than that of X-ray emission that has been thought to be mainly effective for SID. Also, from the altitude/wavelength distribution of the ionization rate of Earth's atmosphere by GAIA, it was found that EUV radiation of about 15-40 nm affects a wide altitude of 120-300 km, and TEC is mainly generated by ionization of nitrogen molecules.

R010-10
Zoom meeting C ：11/4 AM1 (9:00-10:30)
09:45-10:00

Validation of Extreme Ultraviolet Emission Spectra During Solar Flares

#Shohei Nishimoto[1)], Kyoko Watanabe[1)], Toshiki Kawai[2)], Shinsuke Imada[2)], Tomoko Kawate[3)], Kyoung-Sun Lee[4)]
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X-rays and extreme ultraviolet (EUV) emissions from solar flares rapidly change the physical composition of the Earth's thermosphere and ionosphere, thereby causing space weather phenomena such as communication failures. To predict the effects of flare emissions on the Earth's upper atmosphere, numerous empirical and physical models have been developed.

We verify the extent of reproducing the flare emission spectra using a newly developed simple method based on the physical process of the flare loop (Kawai et al., 2020). In this method, we convert the soft X-ray light curves observed during flare events into EUV emission spectra using a one-dimensional hydrodynamic calculation and the CHIANTI atomic database.

To verify the proposed method, we use the observed EUV spectra obtained by the extreme ultraviolet variability (EVE) on board the Solar Dynamics Observatory (SDO).
We examined the “EUV flare time-integrated irradiance" and “EUV flare line rise time" of the EUV emissions for 21 the events by comparing the calculation results of the proposed method and observed EUV spectral data.

Proposed method succeeded in reproducing the EUV flare time-integrated irradiance of the Fe viii 13.1 nm, Fe xviii 9.4 nm, and Fe xx 13.3 nm, as well as the 5.5-35.5 nm and 5.5-13.5 nm bands. For the EUV flare line rise time, there was acceptable correlation between the proposed method estimations and observations for all Fe flare emission lines.

These results demonstrate that the proposed model can reproduce the EUV flare emission spectra from the emitting plasma with relatively high formation temperature.
This indicates that the physics-based model is effective for the accurate reproduction of EUV spectral flux.

R010-11
Zoom meeting C ：11/4　AM1　(9:00-10:30)
10:00-10:15

NICT 宇宙天気 R&D の現状と今後

#石井　守
情報通信研究機構

The present status and future plan of NICT space weather Research and Operation

#Mamoru Ishii
NICT

The fourth mid-term research plan in NICT is going to finish on the end of FY2020 and the fifth plan starts on FY2021. I will introduce several remarkable results in the fourth plan and draft of the fifth plan in the session.
The period of fourth plan overlaps almost that of PSTEP. In PSTEP, many cutting-edge researches of space weather have improved both in domestic and international cooperation under the leadership of Prof. Kusano, Nagoya Univ. and the scheme to use these produces in operational space weather forecast services in NICT has established. We also established “Space Weather users' committee" for discussing needs-seeds matching in space weather operation and trying to build easy-using products. In addition, we have published space weather hazardous map for showing possible space weather impact on Japanese society.
The X9.3 solar flare occurred in Sep. 2017 which is maximum in solar cycle 24. This event was taken by many Japanese presses and most of Japanese became to know the social impact of space weather. After this event, Japanese government strengthened the space weather monitoring framework, e.g., 24/7 operation of space weather forecast.
ICAO has been discussing the use of space weather information in civil aviation since the beginning of 2000s, and three global centers were established in 2018 which includes NICT/Japan. The operation started in Nov. 2019.
Following these fruitful results, we are now discussing the fifth mid-term research plan. The present draft includes development of data assimilation system, development of AI system, and satellite sensors for precise space weather forecast.
I will show some detailed information in my presentation.

情報通信研究機構(以下 NICT)は 2020 年度末を持って第 4 期中長期計画(2016-2020 年度)を終え、2021 年度より第５期に入る。第 4 期では NICT の宇宙天気 R&D において数々の歴史的ともいえる変化と進展があったことから、ここに総括しておきたい。併せて現在検討中の第 5 期計画案についての概要を紹介する。
第 4 期は、科研費新学術領域研究「太陽地球圏環境予測（PSTEP）」の期間（2015-2019）とほぼ一致している。PSTEP では名古屋大学宇宙地球環境研究所草野教授のリーダーシップのもとに国内外の最先端の宇宙天気関連の研究が推進されるとともに、その成果の NICT 宇宙天気予報業務への展開というスキームが形成され、太陽・太陽風・磁気圏および電離圏それぞれの領域でのモデルの改良・導入が進められた。またユーザーとの双方向協議のため、宇宙天気ユーザー協議会を 2015 年に発足し、ユーザーの視点から使用しやすいモデルの開発を進めるとともに米国ホワイトハウスが発行した“Space Weather National Strategy"等を参考に"宇宙天気災害に向けた「科学提言のためのハザードマップ」を作成した。
2017 年 9 月に発生した一連の太陽フレアは最大 X9.3 となり、サイクル 24 の中で最大かつ 11 年ぶりの規模であった。わが国においては多くのメディアに取り上げられ国民の注目を集めた。この件をきっかけに我が国の宇宙天気状況監視体制の強化が進められ、電波法の改正、予報業務の 24 時間運用、観測設備の二重化等が進められた。
2000 年代初頭から国連国際民間航空機関（ICAO）で議論されたきた宇宙天気情報の民間航空での利用については書面および対面査察を経て我が国がグローバル宇宙天気センターの一角を担うこととなり、2019 年 11 月よりその運用を開始した。
これらの実績を踏まえ、第 5 期においては予報業務の確実な執行とともに、宇宙天気予報精度の向上のための研究をさらに進めていく。具体的には、各領域におけるリアルタイムデータ同化による数値予報システム、AI を用いた予報の推進、衛星センサ開発等を柱とした研究計画を現在策定中である。
講演においてはさらに詳細な検討を紹介したい。

R010-12
Zoom meeting C ：11/4 AM2 （10:45-12:30）
10:45-11:00

太陽風領域の識別について

#亘 慎一
情報通信研究機構

On identification of solar wind regimes

#Shinichi Watari
NICT

In solar wind, there are various regimes: high-speed solar wind from CHs (coronal holes), ICMEs (interplanetary coronal mass ejections) associated with CMEs (coronal mass ejections) from the sun, HCSs (heliospheric current sheets) and plasma sheets. These solar wind regimes are characterized by speed, temperature, density, magnetic field, ion composition and charge states, electron heat flux and bi-directional flow, and so on.
However, not all spacecraft measures ion composition and charge states and electron pitch-angle distributions in solar wind. For example, the DSCOVR (Deep Space Climate Observatory) satellite only measures speed, temperature, density and magnetic field of solar wind. Hence, we considered the identification method based on the categorization scheme proposed by Xu and Borovsky (2015) using speed, temperature, density, and magnetic field.
Objective identification of solar wind regimes enables us to be accurately aware of present solar wind situation by real-time solar wind data. It is also enables us to analyze solar activity dependence of solar wind regimes using long-term data.

太陽風は、CHs（coronal holes）からの高速風の領域、太陽からの CMEs（coronal mass ejections）による ICMEs（interplanetary coronal mass ejections）の領域、HCSs（heliospheric current sheets）や HCSs に伴うプラズマシートの領域など様々な領域が存在する。これらの太陽風の領域は、太陽風の速度、温度、密度、磁場に加えて、イオンの組成・荷電状態、電子の heat flux や bi-directional flow などにより特徴づけられる。
しかし、すべての衛星で太陽風中のイオンの組成・荷電状態や電子のピッチアングル分布の測定を行っているわけではない。たとえば、DSCOVR（Deep Space Climate Observatory）衛星では、太陽風の速度、温度、密度、磁場の測定しか行われていない。そこで、Xu and Borovsky (2015)が提案した方法をベースとした太陽風の速度、温度、密度、磁場を用いた太陽風領域の識別手法についての検討結果について報告を行う。
太陽風領域の識別を客観的に行えるようになると、リアルタイムの太陽風データを用いた正確な現状認識が可能になる。また、長期間のデータを用いた太陽風領域の太陽活動依存性についての統計的な解析が可能となる。

R010-13
Zoom meeting C ：11/4 AM2 （10:45-12:30）
11:00-11:15

2020 年の惑星直列期間における太陽風・CME の MHD シミュレーションおよび in situ 観測との比較研究

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Simulation of solar wind and CME during Syzygy period from late June to mid-July 2020

#Daikou Shiota[1),2)], Yoshizumi Miyoshi[2)], Go Murakami[3)], Iku Shinohara[3)], Takeshi Imamura[4)], Kazumasa Iwai[2)], Chihiro Tao[1)]
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Solar wind and coronal mass ejection (CME) coming from the sun to Earth are the main causes of various space weather disturbances. However, since the observation of solar wind and CME in the interplanetary space far from the Sun is limited, the modeling by the numerical simulation becomes a useful means in order to predict the arrival accurately in advance. Recently, in Nagoya University and National Institute of Information and Communications Technology, we have developed a prediction system SUSANOO using three-dimensional MHD simulation of inner heliosphere (Shiota et al. 2014, Shiota & Kataoka 2016). The MHD simulations which can reproduce global solar wind structures and can predict the relatively long-term structure of solar wind, but it requires further improvement through comparative studies with observations for more accurate predictions. In recent years, several space craft to explore inner heliosphere are launched successively: The Parker Solar Probe launched in August 2018, the BepiColombo launched in October 2018, and the Solar Orbiter launched in February 2020. The BepiColombo is originally designed to explore the Mercurial atmosphere, and it will observe in situ environment during its cruise phase until its arrival at Mercury in 2025. These multi-site observations in the heliosphere can be particularly useful information for validating MHD simulations.
In the period from late June to mid-July 2020, in addition to these spacecraft, Mercury, Venus, Mars, Jupiter, and Saturn, were aligned at the near longitude of the heliosphere. This situation is so-called "Syzygy". During this period, BepiColombo conducted an observation campaign. On July 9, 2020, a relatively bright CME was observed in the coronagraph, and the CME was ejected in the direction of longitude where the planets and probes were located. CME bright southward magnetic field lasting more than half a day, up to 9 nT, from July 13 to 14, and then it causes a small magnetic storm with a Dst (tentative) of - 65 nT. In this study, the solar wind and CME in the Syzygy period were reproduced using the SUSANOO-MHD simulation, and compared with in situ observation obtained by DSCOVR. No in situ observations other than DSCOVR / ACE were available at the time of this submission, but they will be compared with simulations as soon as they are available. In the presentation, we will report the outline of solar wind and CME fluctuation in the Syzygy period and the initial results of simulation and in situ data analysis and discuss prospects.

太陽から地球に到来する太陽風・CME は、さまざまな宇宙天気じょう乱を引き起こす原因である。しかし、太陽から離れた惑星間空間で太陽風・CME の観測が限られているため、その到来を事前に正確に予測するためには数値シミュレーションによるモデリングが有用な手段となっている。これまで名古屋大学および情報通信研究機構では、内部太陽圏 3 次元 MHD シミュレーション（Shiota et al. 2014, Shiota & Kataoka 2016）を用いた予測システム SUSANOO が開発されてきた。MHD シミュレーションはグローバルな太陽風構造の再現が可能で、太陽風の比較的長期の構造を予測するために有用であるが、より詳細な予測のためには、観測との比較研究によるさらなる改良を必要としている。近年、2018 年 8 月に Parker Solar Probe、2018 年 10 月に BepiColombo、2020 年 2 月に Solar Orbiter と、内部太陽圏に向かう宇宙探査機が次々と打ち上げられた。BepiColombo は水星の探査を目的とした宇宙探査機であるが、水星への到着の 2025 年までの間その場の環境の計測を行うため、その観測結果を利用することができる。このような太陽圏内の多地点の観測は MHD シミュレーションを検証するために有用な情報となる。
2020 年 6 月末から 7 月中旬にかけた期間は、これらの探査機に加えて、水星、金星、火星、木星、土星が、太陽圏の近接した経度に位置する「惑星直列」の状態が発生した。この期間、BepiColombo は観測キャンペーンが行った。この期間中の 2020 年 7 月 9 日にはコロナグラフで明瞭な CME が観測され、惑星・探査機の位置した経度方向へ放出された。CME は 7 月 13～14 日に最大 9nT の半日以上続く南向き磁場をもたらし、Dst (暫定値)=-65nT の小規模な磁気嵐を引き起こした。本研究では、惑星直列期間の太陽風・CME の変動について、SUSANOO-MHD シミュレーションを用いて再現し、DSCOVR の観測結果との比較を行った。投稿時点では DSCOVR・ACE 以外の in situ 観測データをまだ入手できていないが、入手でき次第シミュレーションとの比較を行う予定である。講演では、惑星直列期間の太陽風・CME の変動の概要とシミュレーション・in situ データ解析の初期結果を報告するとともに今後の展望を議論する。

R010-14
Zoom meeting C ：11/4 AM2 （10:45-12:30）
11:15-11:30

再考：1991.3.24 の特異 SC

#荒木 徹
京大理

Reconsideration of peculiar SC on 1991.3.24.

#Tohru Araki
none

The geomagnetic sudden commencement(SC)that occurred on March 24, 1991 at 0341 UT was a unique and unprecedented one. The features can be summarized as follows.
(1) Geomagnetic change
① A large and sharp global pulse appears in the early stages of SC.The amplitude and pulse width of the H- component at Kakioka(27deg geomagnetic latitude) around noon, was 202nT and about 90 sec.
② The rise time of this pulse is extremely short (28 seconds at Kakioka).
(3) Since the rise and peak of this pulse are sharp, the pulse propagation can be measured accurately, and as a result, it was found that there are two modes, electromagnetic wave and HM wave, in the propagation from the day side to the night side.
(2) Change of radiation belt
CRRES and Akebono observed the drift echo phenomenon of high-energy trapped charged particles. It means instantaneous formation of the inner radiation belt. It lasted for one year.
(3) Ulysses observed disturbances with the counter-streaming event at 2.5AU and 60 degree east in the ecliptic longitude but it cannot be associated with this SC phenomenon. There is no other observation of the solar wind.
(4) Li et al (1994) calculated the particle acceleration due to a pulse propagating from the magnetopause at 15h LT and obtained a drift echo suitable for the observation.
The problems of reconsideration here are as follows.
(1) What is the solar wind structure that produces such a large and sharp magnetospheric pulse? A pulse corresponding to the pulse observed in the magnetosphere must exist in the solar wind, but it is unlikely that the pulse was produced near the sun and propagated as it was without changing the waveform. Could it be made by shock-stream or stream-stream interaction near the earth?
(2) To make a pulse of 200nT on the ground, it is necessary to increase the dynamic pressure of the solar wind by 200nPa or more. Is this possible?
(3) Rise time is considered to be the time for a shock to sweep a distance effective for compression of the magnetosphere. A rise time of 30 seconds requires a solar wind speed of 2000 km/s or more. Is it possible?

1991 年 3 月 24 日 0341UT の SC（geomagnetic sudden commencement）は、前例のない特異なものであった。その特徴は、以下のように要約できる。
(1) 地磁気変化
① SC の初期に大きくて鋭い汎世界的パルスが現れている。正午過ぎの柿岡（地磁気緯度 27 度）での H 成分の振幅とパルス幅は、202 nT、約 1.5 分であった。短いパルスなので 1 分値では正確に測れないが、正午付近の 210 度子午面チェーン（1 秒値）と明け方の SAMNET チェーン（5 秒値）・EISCAT クロス磁力計チェーン（20 秒値）で観測されている。
② 静止衛星 GOES6、GOES7 は、LT18.7h、20.5h で振幅 67nT、50nT の、また、CRRESS は、（2.5Re, 3hLT, -12 度 MLat）で約 130nT のパルスと peak-to-peak 振幅約 80mV/m の双極型電場パルスを観測した。
③ このパルスの立ち上がりとピークが鋭いので、伝搬を精度よく測定でき、その結果、昼側から夜側への伝搬には、電離層の下を伝わる電磁波と、上を伝搬する HM 波の二つのモードがあることが判った。
(2) 放射線帯の変化
この SC によって放射線帯内帯が瞬時に強化され、CRRES とあけぼのが高エネルギー捕捉荷電粒子の drift echo 現象を観測した。形成された内帯は、以後約 1 年維持された。
(3) 1991.3.24-4.2 の間、地球から経度約 60 度東の 2.5AU で counter-streaming event を含む太陽風擾乱をユリシーズが観測したが、この SC 現象との対応ははっきりしない。
(4) Li et al (1994)は、15hＬＴの磁気圏界面から尾部へ伝搬するパルス波動による粒子加速を計算し、観測に合うドリフトエコーを得た。
ここでの再考察の問題点は、下記の通りである。
(1) 地上と磁気圏で観測される磁場パルスの振幅と波形は、緯度と LT に依存して変わりながらも汎世界的に現れているので、対応する大パルスが太陽風に存在しなければならない。 しかし、そのような大きくて鋭いパルスが太陽近くで出来て伝搬したとは考え難い。地球近傍で、ショックとストリーム、ストリームとストリームの干渉などで作れるであろうか。
(2) 地表で 200nT のパルスを作るには、200nPa 以上の太陽風動圧増加が必要だが、可能か。

(3)　ライズタイムは、ショックが磁気圏の圧縮に有効な距離をスイープする時間だと考えられている．30 秒のライズタイムには、2000km/s 以上の太陽風速度が必要だが、あり得るか？

R010-15
Zoom meeting C ：11/4　AM2 （10:45-12:30）
11:30-11:45

太陽活動極小期の発生プロセスの詳細解析に向けて

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Towards a detailed analysis of the onset process of the grand solar minimum

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In this presentation, we report our recent attempts to reveal the detailed onset process of the grand solar minima. Annually measured carbon-14 data have suggested that solar cycles got lengthened during the grand minimum and that it had even started a few cycles before the onset. In order to accurately determine the transition of the cycle lengths around the onset of the grand minima, we are improving the precision of the measurements with Accelerator Mass Spectrometer at Yamagata Univ. We have also developed a new methodology to reconstruct past solar and cosmic-ray variations using carbonate deposits. We introduce the present status of our experiments and discuss future prospects.

R010-16
Zoom meeting C ：11/4 AM2 （10:45-12:30）
11:45-12:05

過去 1.8 世紀の歴史的アナログ記録に基づく激甚磁気嵐の規模推定の事例研究

#早川 尚志 [1],海老原 祐輔 [2],服部 健太郎 [3]
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Case studies for the intensity estimates of the historical geomagnetic superstorms with analog records for the last 1.8 centuries

#Hisashi Hayakawa[1], Yusuke Ebihara[2], Kentaro Hattori[3]
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Solar eruptions frequently release fast and massive interplanetary coronal mass ejections with southward interplanetary magnetic field. They often cause geomagnetic superstorms (minimum Dst < -500 nT) and form significant threats on the modern civilization due to its increasing dependency on the technological infrastructure. Despite their significant impacts, such superstorms are rare and only one storm (the 1989 storm; Dst = -589 nT) fits in this category during the space age since the late 1950s. So far, the largest recorded superstorm has been considered the Carrington superstorm in 1859 (Dst estimate ~ -900 nT). However, it has not been immediately clear how unique the Carrington superstorm was within the multi-century time scale. Here, we have analyzed the analog magnetograms and reports of low-latitude aurorae in the past to identify and measure superstorms in history. Our investigations have shown at least 7 superstorms and their source active regions, within the coverage of the systematic geomagnetic measurements for the last 1.8 centuries. We show several case studies for the reconstructions of intensity and time series of such superstorms in history. These results increase the data for superstorms and improve the existing models for their simulations for such geomagnetic superstorms.

R010-17
Zoom meeting C ：11/4　PM1 （13:45-15:30）
13:45-14:00

北極域ナトリウムライダーによる中性大気温度・風速観測： 下部熱圏（80km-200km）と年間観測への拡張

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Upgrading the sodium lidar observation of the neutral temperature and wind velocity to the lower thermosphere

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We have been continuing wintertime wind/temperature lidar observations of the MLT region (upper mesosphere and lower thermosphere) since October 2012 at Tromso (69.6N, 19.2E), Norway. With the highly advanced lidar technique, wind velocity in the range of 80-115 km can be measured by detecting the frequency difference in the accuracy of 1 MHz between the laser and the returned photon frequency.
With 0.5 km vertical and 10 min temporal resolutions the error bars are estimated to be 1.0 K and 1.5 m/s, respectively, at the sodium layer peak (e.g., 90 km), and 5 K and 10 m/s, respectively at both sodium layer edges (typically around 80 km and 105 km). Recent researches show the very low Na density in the altitude region up to 170km. To upgrade the Na lidar at Tromso, the development of the ultra-narrow optical bandpass filter is a key device to reject the background light from the sky. In this presentation, we will summarize the detail of this upgrading lidar project to contribute to the observation of the neutral atmosphere in the lower thermosphere.

熱圏に伝播する大気波動による中性大気の温度・風速変動は、熱圏高度の中性大気と電離大気の定常的な変動に大きく影響している。一方で、近年の低調な太陽活動度(Kasatkina et al., JASTP, 2019)を踏まえると、下層から伝搬してくる大気波動による熱圏・電離圏の日常的な変動を連続的・定量的にモニターする絶好の機会であるが、有効な観測手段が欠如しているのが現状である。
信州大学では、名古屋大学、理化学研究所と共同で、ノルウェーにある EISCAT トロムソ観測所(69.6N, 19.2E)に高性能ナトリウム(Na)ライダーを設置し、2010 年から 2018 年まで総計 3000 時間以上の冬季（10 月-3 月）の観測を継続してきた。我々の Na ライダーは、高度 80-110km に存在する Na 層における中性大気温度と水平・鉛直風速を、温度精度 1K、風速精度 1.5m/s で計測できる性能を持つ（@Na ピーク 90km 高度、高度分解能 0.5km、時間分解能 10 分）。一方、近年、Na 層よりも高高度、高度 120km から 170km までの下部熱圏領域に Na ピーク密度の 1/1000 程度の Na 原子が薄く分布していることがライダー観測により報告された[Liu et al, 2016 他]。これは、北極域における中性大気温度・風速の観測上限を、現在の 110km から 200km 程度にまで大きく拡張できることを意味する。ただし、下部熱圏の Na からの微弱な散乱光の検出には夜間観測においても背景光を大きく減らす光学フィルタが必要となる。これを達成するキーとなるのが超狭帯域磁気光学フィルタ（ファラデーフィルタ）の開発である。背景光除去は昼間観測にも有効であるため、このフィルタを用いれば観測時期を夏季まで含めた通年観測へと発展させることもできる。中間圏界面領域の冬季観測に限られていた北極 Na lidar 中性大気観測を、高度 80-200km までの広域観測かつ通年観測まで拡張させられれば、電離大気/中性大気の相互作用を観測結果により議論ができ、GAIA などの全地球大気のシミュレーションモデルを用いて検証し、宇宙天気の災害予報につなげることが可能となる。本講演では、ライダー観測の拡張性について紹介する。

R010-18
Zoom meeting C ：11/4 PM1 (13:45-15:30)
14:00-14:15

Calculation of the ray paths and propagation times of HF radio waves in the simulator of HF-START project.

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To provide the information of nowcast of radio propagation, HF simulator Targeting for All user's Regional Telecommunications (HF-STRAT) was launched as a collaborative project with NICT, ENRI and Chiba University. In this project, propagation paths of HF radio waves are calculated by a ray-tracing calculation. Using the results of the ray-tracing calculation, we have determined whether HF radio wave travels between any two points. We have compared the differences of the propagation time determined by the ray-tracing calculation with the observation of the HF radio waves transmitted from Nagara transmitter, RadioNIKKEI (35.46 N, 140.20 E). HF receivers are located at Chiba University (Chiba, 35.62 N, 140.10 E), Sarobetu (Hokkaido, 45.16 N, 141.74 E), Yamagawa (Kagoshima, 31.20 N, 130.61 E), Ogimi (Okinawa, 26.68 N, 128.15 E). By comparing the propagation time between Chiba and the other receivers, it is found that there was a difference of the propagation time between the ray-tracing results and the observations. This is because it is assumed that ground waves are propagated from Nagara to Chiba. Considering the decay of wave intensity between Nagara and Chiba, we found that the decay of sky wave that is reflected by the ionosphere was almost comparable to that of ground wave. It is considered that the radio wave propagation between Nagara and Chiba is not ground wave but sky wave that is reflected by the ionosphere or both ground wave and sky wave signals are received simultaneously at Chiba. In addition, the comparison between observation of propagation time differences using distant receivers except Chiba and propagation times derived from ray-tracing calculation is in progress to validate results of the simulator. Propagation times derived from waveforms obtained at Yamagawa and Ogimi were compared with those derived by ray-tracing calculations so far. In the simulator, we also plan to provide users with options to choose three types of electron density models (IRI, GNSS tomography, GAIA). For these options, we calculated ray-paths using three electron density models in four seasons of 2018 and examined differences between the ray-tracing calculation results derived from each electron density model.

R010-19
Zoom meeting C ：11/4　PM1 （13:45-15:30）
14:15-14:30

日本 GBAS における電離圏脅威となる電離圏急勾配発生時の特性解析

#中村　真帆 1),斎藤　享 2),吉原　貴之 3)
1)電子航法研,2)電子航法研,3)電子航法研

Characteristic analysis of the occurrence condition of steep gradients in the ionosphere that poses a threat for GBAS in Japan

#Maho Nakamura1), Susumu Saito2), Takayuki Yoshihara3)
1)NAV Department, ENRI,2)ENRI, MPAT,3)ENRI

Since the Ground-Based Augmentation System (GBAS) uses the differential positioning by L1 frequency, steep gradients of ionospheric delay differences between the airplane and ground station of which scales about several tens of kilometers are the main threat of the GBAS.
In the low latitude region include Japan, it is thought that the equatorial plasma bubbles (EPB) induce such a steep ionospheric gradient.
However, it is not clear under what conditions it develops into a steep slope that may pose a threat, and on the correlation with parameters such as the width and speed of the slope that cause such conditions.
ENRI has been developing an ionospheric threat model optimized for GBAS optimized for
the low magnetic latitude to mid latitude region include Japan using GEONET data.
In particular, the single-frequency-carrier-phase based and code-aided technique which is not subject to the frequency-biases [Saito and Yoshihara, Radio Sci., 2017] to estimate ionospheric delay variations and for the auto detection of plasma bubbles candidates. In addition, dual-frequency observations for ionospheric delay variations are also used for the speeds and spatial scale analyses of the ionospheric gradients [Saito and Yoshihara, Radio Sci., 2017].
This paper presents the analyzes of the conditions of the parameters of gradients when the steep ionospheric gradients occur. Plasma bubble structures when such steep gradient occurs is also analyzed.

地上型衛星航法補強システム(GBAS)システムでは、1 周波を用いたディファレンシャル測位が用いられており、地上観測装置と航空機の間に急な電離圏電子密度勾配が存在すると GBAS 運用上の脅威となる。日本付近においては、低緯度地域におけるプラズマバブルが引き起こす幅が数十 km 以下になるような電離圏急勾配が主にこれに該当する脅威と考えられるが、どのような条件において脅威となり得るような急な勾配に発達するのか、またそのような条件を引き起こすような勾配の幅や速度等のパラメータとの相関は明確でない。
電子航法研究所（ENRI）では、日本が位置する中緯度から低緯度の電離圏現象の遷移領域における GBAS のための電離圏脅威モデルの最適化に取り組んでおり、GNSS 観測網を用いて、GBAS に影響を与えうるプラズマバブルを抽出、スケールサイズ等のパラーメタ算出を行う解析手法を開発し解析を実施してきた。具体的には、周波数間バイアスの影響を受けない L1 信号のみを用いた Single-Frequency Carrier-Based and Code-Aided 法[Fujita et al., JAAA, 2011; Saito et al., ION GNSS 2012] により電離圏遅延量勾配を推定するとともに、2 周波観測を用いた電離圏遅延量時間変動を利用し電離圏遅延量勾配の空間スケール、速度の変動解析[Saito and Yoshihara, Radio Sci., 2017]を行っている。
本研究ではこれまでの解析で抽出された急勾配のイベントについて、勾配の幅や速度などの特性を表すパラメータを用いて、電離圏急勾配が発達する原因と考えられる条件について解析を行い報告する。 また急な勾配を含むイベントについて発生時のプラズマバブル との比較も行う。

R010-20
Zoom meeting C ：11/4 PM1 （13:45-15:30）
14:30-14:45

Study of Sporadic E layer characteristics by using ROTI maps

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[1)ENRI, MPAT,[2)UEC,[3)SSRE, Univ. Electro-Comm.

The density of the sporadic E (Es) layer can be so high as to reflect VHF radio waves. It has been shown that aeronautical VHF navigation signals in 108-118 MHz band can propagate beyond the radio horizon to cause potential interference. Therefore, it is important to monitor the occurrence and distribution of the Es layer, and even to predict its occurrence. For the Es layer prediction, it is important to understand the detailed physics of the Es layer.
Recently, multiple ways of observing the Es layer have been developed, such as observations of anomalous propagation of VHF radio waves from known locations, synthetic aperture radar measurements, perturbation in the ionospheric total electron contents (TECs) derived from a dense GNSS network. However, these methods can show the two-dimensional distribution of the Es layer.
In this study, we use the ROTI (rate of TEC index) values derived from the dense GNSS network over Japan (GEONET). When the strong Es layer appears, a well-defined frontal structure of a high ROTI value region is often seen. We have further developed a method to derive the front direction and velocity automatically. By using these Es layer parameters and time series of TEC variation, the vertical structures of the Es layer can be inferred. We have applied this method to several intense Es events and successfully derived Es layer velocities.
Our results are useful not only in understanding the three-dimensional structure of the Es layer but also in regularly monitoring the occurrence and propagation of the Es layer, as the Es layer signature in the ROTI map can automatically be detected.

R010-21
Zoom meeting C ：11/4 PM1 （13:45-15:30）
14:45-15:00

スポラディック E 層発生の数値予測－現状と問題点

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Numerical prediction of sporadic E layer occurrence: Current status and problems

#Hiroyuki Shinagawa[1], Chihiro Tao[1], Hidekatsu Jin[1], Yasunobu Miyoshi[2], Hitoshi Fujiwara[3]
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Prediction of ionospheric disturbances is one of the most important issues in the space weather forecast. For the prediction of ionospheric storms, prediction information on disturbances of the solar wind as well as the magnetosphere is necessary, but it is still difficult to make an accurate prediction at the moment. In contrast, the sporadic E (Es) layer is little influenced by the solar wind and the magnetosphere, and it may be possible to predict the occurrence of the Es layer more accurately than other ionospheric disturbances. In order to study the possibility of the Es layer occurrence prediction, we analyzed the simulation data of the whole atmosphere-ionosphere coupled model GAIA, and compared the data with foEs data obtained by ionosonde observations. We found that variations in some parameters such as vertical ion convergence in 120 km altitudes agree fairly well with variations in the observed foEs. This result suggests that the probability prediction of Es layer occurrence is possible using the parameter as an index of the occurrence. At National Institute of Information and Communications Technology, we have recently developed a real-time forecasting system of the ionosphere using GAIA for one or two days ahead. Preliminary result of the experimental prediction suggests that the system is able to provide meaningful information on the prediction of the Es layer occurrence. At the same time, the result also suggests that there are limitations to the accuracy of numerical prediction of the Es layer occurrence. We will report the current status and problems of the numerical prediction system of the Es layer occurrence.

電離圏擾乱の予測は宇宙天気予報における重要課題の一つである。しかし、電離圏嵐の発生予測に関しては太陽風や磁気圏擾乱に関する予測情報が必要であり、現状では高い精度の予測は難しい。それに対してスポラディック E(Es) 層については、太陽風や磁気圏の影響は比較的小さいことから、気象データを含めた全大気圏-電離圏モデルを用いることによって精度の高い予測を行える可能性がある。我々は Es 層発生の数値予測の可能性を調べるため、全大気圏-電離圏結合モデル GAIA のシミュレーションデータの解析を行い、Es 層の変動に関係すると思われるパラメータと、イオノゾンデ観測で得られる foEs との関係を調べた。その結果、高度 120 km 付近の鉛直イオン収束率などのパラメータが foEs とかなり良い相関があることを見出した。現在、情報通信研究機構では GAIA をリアルタイムで実行して、数日先までの大気圏と電離圏の予測を行うシステムの試験運用を行っている。このシステムを用いてこれまでに行った Es 層の発生予測試験では、１～２日先までの Es 層発生に関して、GAIA による数値予測は有意な情報を与えることがわかった。一方で、数値予測の精度には限界があることも明らかになってきた。本発表では、Es 層発生の数値予測の現状と問題点について報告する。

R010-22
Zoom meeting C ：11/4 PM1 （13:45-15:30）
15:00-15:15

Statistical analysis of short-wave fadeout for extreme event estimation

#Chihiro Tao[1)], Michi Nishioka[1)], Susumu Saito[2)], Daikou Shiota[1)], Kyoko Watanabe[3)], Hidekatsu Jin[1)], Hiroyuki Shinagawa[1)], Naoto Nishizuka[1)], Takuya Tsugawa[1)], Yasunobu Miyoshi[4)], Hitoshi Fujiwara[5)], Mamoru Ishii[1)]
[1)]NICT,[2)]ENRI, MPAT,[3)]NDA,[4)]Dept. Earth & Planetary Sci, Kyushu Univ.,[5)]Faculty of Science and Technology, Seikei University

Solar flares trigger an increase in plasma density in the ionosphere including the D-region and cause the absorption of radio waves, especially in high-frequency (HF) ranges, called short wave fadeout (SWF) or Dellinger phenomena. In order to evaluate SWF duration and absorption statistically, we analyze long-term ionosonde data observed by the National Institute of Information and Communications Technology (NICT). The minimum reflection frequency, fmin, is used to detect SWFs from 15-min-resolution ionosonde observations at Kokubunji, in Tokyo, from 1981 to 2016. Since fmin varies with local time (LT) and season, we refer to dfmin, which is defined as fmin subtracted by its 27-day running median at the same LT. We found that the occurrence of SWFs detected by three criteria, (i) dfmin >=2.5 MHz, (ii) dfmin >=3.5 MHz, and (iii) blackout, during daytime associated with any flare(s) greater than the C-class is maximized at local noon and decreases with increasing the solar zenith angle. We confirm that the dfmin and duration of SWFs increase with the solar flare class. We estimate the absorption intensity from observations, which is comparable to an empirical relationship obtained from sudden cosmic noise absorption. A generalized empirical relationship for absorption from long-distance circuits shows quantitatively different dependences on solar flare flux, solar zenith angle, and frequency caused by different signal passes compared with that obtained from cosmic noise absorption. From our analysis and the empirical relationships, we estimate the duration of extreme events with occurrence probabilities of once per 10, 100, and 1000 years, to be 1.8?3.6, 4.0?6.8, and 7.4?11.9 h, respectively. The longest duration of SWFs of about 12 h is comparable to the solar flare duration derived from an empirical relationship between the solar flare duration and the solar active area for the largest solar active region observed so far.
In this presentation, we will also discuss relationship between the signal absorption and plasma density profiles derived from numerical simulations using GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy).

R010-23
Zoom meeting C ：11/4 PM2 （15:45-17:30）
15:45-16:00

MAGDAS システムの 10Hz データを用いた、Pc2 脈動の全球的分布特性の解明

#樺澤 大生 [1],吉川 顕正 [2],魚住 禎司 [3],藤本 晶子 [4],阿部 修司 [5],塩川 和夫 [6],Connors Martin[7]
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Study on global characteristics pf Pc2 distribution with the 10Hz data of the MAGDAS system

#Taisei Kabasawa[1], Akimasa Yoshikawa[2], Teiji Uozumi[3], Akiko Fujimoto[4], Shuji Abe[5], Kazuo Shiokawa[6], Martin Connors[7]
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Geomagnetic field distribution observed on the ground is affected by space weather phenomena such as magnetic storms and auroral substorms. Yu et al.[2015] shows that the Pc2 pulsation of which frequency range 5-10 seconds is observed at the inner magnetosphere as EMIC wave that is associated with enerization process of O^+ during magnetic storm.
By using 10Hz sampling MAGDAS data, we found that the Pc2 type pulsation are simultaneously observed from high to middle-and-low latitudinal region during a magnetic storm time substorm. Also, we found that such Pc2 have a local time distribution peaked around 6LT and during 11-15LT. Moreover, we found occurrence of Pc2 shows a seasonal dependence enhanced mainly at March, May-Jun and October.
In this presentation, we will report tha preliminary results of observational analysis of Pc2 pulsation by using MAGDAS network. We also discuss the occurrence characteristics of high latitudinal Pc2 by PWING induction magnetometers data.

地上の磁場は磁気嵐やオーロラ嵐等の宇宙天気現象の影響を受け、日々変化し続けている。Pc2 脈動は地磁気脈動の中でもその変動周期が 5-10 秒の比較的高周波な地磁気脈動であり、近年の研究(Yu et al.[2015]等)により磁気擾乱時に活性 k された O^+の高エネルギー化に伴う EMIC 波として内部磁気圏で観測されることが示されている。
我々は九州大学が展開する地上多点磁場観測ネットワーク(MAGDAS)で取得した磁場の 10Hz データ解析の初期結果として、ストーム中のサブストーム時に衛星で観測される Pc2 帯脈動が高緯度から低緯度までグローバルに観測されることを確認した。また、グローバルに観測される Pc2 帯脈動は 6LT と 11-15LT にピークを持ち、0-4LT に発生頻度が比較的少ない地方時分布を示した。さらに、3 月、5-7 月、10 月にそれぞれピークを持つような季節依存性も確認した。
本講演ではこのような MAGDAS で確認したグローバルな Pc2 脈動に関する発生特性を報告するとともに、PWING による高緯度 Pc2 に関する発生特性についても議論する予定である。

R010-24
Zoom meeting C ：11/4 PM2 （15:45-17:30）
16:00-16:15

サブストームオンセットにおける中緯度電離圏全球応答の精査

#林 萌英[1),吉川 顕正[2),藤本 晶子[3),Ohtani Shinichi[4)
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A close examination of the mid-latitude ionospheric global response at the substorm onset

#Moe Hayashi[1), Akimasa Yoshikawa[2), Akiko Fujimoto[3), Shinichi Ohtani[4)
[1)Kyushu Univ.,[2)ICSWSE/Kyushu,[3)Kyutech,[4)The Johns Hopkins University Applied Physics Laboratory

The polar ionosphere is known to have an R1-current system linked to the dynamics of the magnetospheric convection system and an R2-current system linked to the dynamics of the pressure gradient region of the inner magnetosphere [Iijima and Potemra, 1976, 1978]. The polar current-wedge current system, which grows with the substorm onset, forms a magnetosphere-ionosphere current closure with the same sense of the R-1 current system. The R2-current system, which is located at lower latitudes, forms a current closure with the opposite polarity of this R1 current system. The growth of the R2 current is linked to the increasing pressure in the inner magnetosphere associated with the substorm, and its dynamics does not necessarily correspond to the dynamics of the current-wedge system. As a result, the R2 current system not only produces a shielding effect that weakens the effect of the growth of the current-wedge current system on the ionosphere reaching low latitudes and equatorial regions, but also produces an overshielding effect that sometimes excels it and causes the current system to grow in the opposite direction [(Kelley et al., 1979; Gonzales et al., 1979; Fejer et al., 1979)]. On the other hand, the ground magnetic field fluctuations during substorms are affected not only by the ionospheric currents, but also by the magnetic field fluctuations created by the field line currents associated with the growth of the current wedge. In mid to lower latitudes, where this effect is large, it is difficult to identify from magnetic field data only whether the changes in the magnetic field during substorms are due to the formation of the ionosphere current system or to remote field effects of the current system.

The present study is aimed at a more global understanding of the current system caused by the substorm. In this presentation, we investigate the mid-latitude ionospheric variations of the substorm onset and its dependence on LT. We used electric field data from the HF Doppler radar at Palatunka, Russia, and magnetic field data from SuperMag and MAGDAS.

極域電離圏には、磁気圏対流系の消長と連動する R1-電流システムと、内部磁気圏の圧力勾配領域の消長と連動する R2-電流システムが存在することが知られている[Iijima and Potemra, 1976, 1978]。サブストームのオンセットとともに成長する極域カレント・ウェッジ電流系は、R-1 電流系同じセンスの磁気圏－電離圏電流クロージャーを形成しており、より低緯度側に位置する R2 電流系は、この R1 電流系と逆センスの電流クロージャーを形成している。R2 電流の成長はサブストームに伴う内部磁気圏の圧力増加と連動しており、その消長はカレント・ウェッジ電流系の消長と必ずしも一致しない。その結果 R2 電流系は、カレント・ウェッジ電流系の成長に伴う巨視的な電離層電流系が低緯度・赤道域まで到達する効果を弱めるシールディング効果をもたらすだけでなく、時にはそれを卓越し、逆方向の電流系を成長させるオーバーシールディング効果をもたらすことが知られている［(Kelley et al., 1979; Gonzales et al., 1979; Fejer et al., 1979)]。一方、サブストーム時に観測される地上磁場変動は電離層電流の効果だけでなく、カレントウェッジの成長に伴う沿磁力線電流そのものが作る磁場変動も大きな影響をもたらしている。特にこの影響が大きい中低緯度領域では、サブストーム時に変動する磁場変化が電離層電流系の形成によるものなのか、カレントウェッジ電流系の遠隔磁場効果であるのかを磁場データのみから同定することは難しく、より本質的な理解の為には電離層電場の直接観測との比較が不可欠となる。

本研究ではサブストームによって引き起こされる電流システムをより包括的に捉え、理解することを目的とした解析を遂行している。本発表では、ロシアのパラツンカに設置した HF ドップラーレーダーによる電場データと SuperMag, MAGDAS の磁場データを用いて、サブストームオンセットの中緯度電離圏変動とその LT 依存性を調査した結果について報告する。

R010-25
Zoom meeting C ：11/4 PM2 （15:45-17:30）
16:15-16:30

Seasonal dependence of semidiurnal equatorial magnetic variation during quiet and disturbed periods

#Akiko Fujimoto[1)], Akimasa Yoshikawa[2)], Teiji Uozumi[3)], Shuji Abe[4)]
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The analysis of 20-year long-term semidiurnal lunar tidal variations along the magnetic equator gave the evidence that the semidiurnal variations are completely different between the magnetic quiet and disturbed periods. This is the first time that the seasonal dependence of disturbance-time semidiurnal variation has been provided from the analysis of the EE-index. We found the Kp dependence of semidiurnal variation: For full and new moon phase, counter troughs are amplified during disturbance time, possibly related to disturbance dynamo. For all moon phase, there are positive enhancements in dawn and strong depressions after sunset, resulting from the penetration of polar electric filed. For seasonal dependence, semidiurnal variations are divided to three seasonal groups, and characterized as deep trough, enhanced crest and weak structure for D-solstice, Equinoxes and J-solstice, respectively. There is no significant longitudinal difference between Ancon and Davao, except for the amplitude of semidiurnal variations. The deep troughs occur during D-solstice and the enhanced crests during Equinoxes, at both Ancon and Davao.

R010-26
Zoom meeting C ：11/4 PM2 (15:45-17:30)
16:30-16:45

Implementation of SDR-based scintillation detector system and preliminary observation with magnetometer and radar

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The upper part of Earth's atmosphere is ionized by solar ultraviolet and X-ray radiation. This region is called the ionosphere. It is located from about 60km to 1000km altitude and separated to some regions according to their characteristics. The ionosphere plays an important role for radio wave propagations. These propagations are dependent on the condition of the ionosphere, because the ionosphere changes these conditions temporally and spatially by background fluctuations. Some disturbances are regular and repeated, such as daily, seasonal, and solar activity. In addition, some disturbances are irregular, such as sporadic E layer, and plasma bubbles. These disturbances cause the ionospheric scintillation, rapid intensity and phase changes of radio waves which pass through the ionosphere. Therefore, the observation of ionospheric scintillation is equivalent to observing the state of the ionosphere, which is very important for space weather research.

We operate a worldwide magnetometer and FM-CW network, MAGDAS. We have produced many scientific results related to space weather research by using these data. At this time, we developed the SDR (Software-Defined Radio) -based scintillation detector system for our additional observation. We use the USRP N210 with WBX daughter board from Ettus research as the front end, and signal processing software based on some open source products. Active GPS antenna with 30db gain and additional low noise amplifier are connected to the system for signal receiving. The operating system for signal processing part is Linux(64bit) on Core i5 system. We installed this system at Sasaguri, Fukuoka, Japan (33.64N, 130.51E, in Geographic Coordinate). We operate magnetometers and a FM-CW radar at Sasaguri station. Thus, our new device can observe GPS scintillation simultaneously with magnetic field variation recorded by magnetometer and ionosphere plasma density profile detected by FM-CW ionogram. In this paper, we will introduce the progress of this development and preliminary data.

R010-27
Zoom meeting C ：11/4 PM2 （15:45-17:30）
16:45-17:00

Schumann resonance parameters at Kuju during solar flares and solar proton events

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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 addition, it was revealed that the SR is also affected by the solar activities. We newly aim to utilize SR for monitoring of solar activity (e.g., solar flare, solar proton event) and its effects on the ionosphere. For the first step, we investigate relationship between SR parameters and intense solar activities in Oct.-Nov., 2003.
We examined fundamental mode of the SR at Kuju, Japan (KUJ, M.Lat. = 23.4 degree, M. Lon. = 201.0 degree) by comparing solar X-ray, EUV and Proton flux. The data of X-ray and Proton flux were obtained by the GOES series of the satellites on a geostationary orbit. The EUV data were obtained by SEM/SOHO at the Lagrangian point L1.
We found that the flares were associated with increase of SR frequency in H (horizontal northward component). Since X-ray and EUV contribute the most to ionization of Earth's ionosphere, the variation of the SR frequency seems to reflect the electron density in the ionospheric D-region during the solar flare.
We also found that the variation of the SR frequency in D (horizontal eastward component) corresponded with enhancement of the Proton flux (40-80 MeV) during solar proton events. It is assumed that the SR frequency in D component relates to the polar ionosphere which is strongly affected by solar proton events.