惑星間空間磁場の太陽風密度・速度-依存性

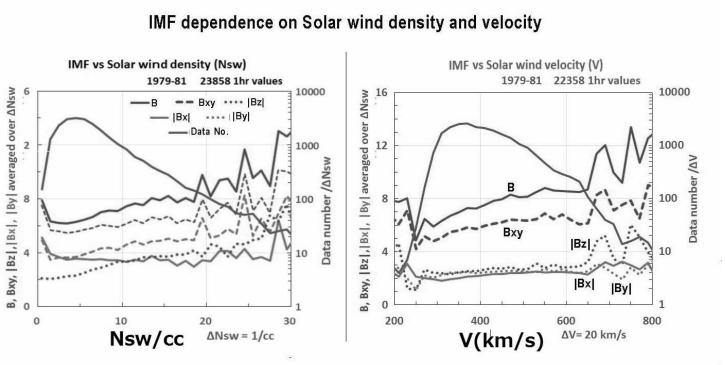
荒木 徹 [1]; 原田 裕己 [2]
[1] 京大理; [2] 京大・理・地球惑星

IMF dependence on solar wind density and velocity

Tohru Araki[1]; Yuki Harada[2]
[1] none; [2] Dept. of Geophys., Kyoto Univ.

The solar wind has several structures where IMF changes related with plasma parameters.
The interplanetary shock is a typical example where IMF is connected with plasma parameters by shock relations.
Here we show that the averaged IMF also depends upon density (Nsw) and velocity (Vsw) of the solar wind by analyzing OMNI hourly values.
Figure below are plots of the IMF (total force B, horizontal component Bxy in the ecliptic plane and the 3-component absolute values (|Bx|, |By|, |Bz|) versus Nsw (left panel) and Vsw (right panel). The data period is 1979-1981 (maximum SSN phase).
The left panel shows that (1) B, Bxy, |By|and |Bz|slowly decrease with decreasing Nsw while |Bz|slowly increases and (2) when Nsw further decreases below Nsw = 2/cc, (B,Bxy) and (|Bx|,|By|) increase to the same finite values (about 10 nT for (B,Bxy), 6nT for (|Bx|,|By|)) while |Bz|converges to zero. The property (2) suggests that IMF converges to a typical spiral pattern when Nsw converges to zero.
Two other data periods, 1999-2001 (SSN maximum) and 2007-2009 (SSN minimum) are examined. IMF observed by MAVEN orbiting Mars is also studied for the period, 2014-2018. The results of the analysis are roughly consistent with the description above.

太陽風には幾つかの構造があり，そこでの IMF は，プラズマパラメターと特有の関係を持っている．
惑星間空間衝撃波は，その典型であり，磁場とプラズマは shock relation で結ばれている．ここでは平均場としての IMF が，太陽風の密度（Nsw）と速度（Vsw）に依存することを，OMNI1 時間値を用いて示す．
下図は，IMF [振幅；B，黄道面内成分；Bxy，3 成分（Bx, By, Bz）の絶対値] の Nsw（左図）と Vsw（右図）に対するプロットである．諸量は，Nsw，Vsw の小区間（Δ Nsw, Δ Vsw）毎の平均値であり，各区間のデータ数も示している．左図は，(1) B, Bxy, |By|, |Bz| が，Nsw の減少と共に緩やかに減少し，｜Bx| は緩やかに増加する，(2) Nsw が約 2/cc より減ると，B・Bxy と｜Bx|・|By| は増加に転じて同じ値（B・Bxy は約 10nT，｜Bx|・|By| は約 6 n T）に収斂し，|Bz| は零に近づいていく．(2) は，Nsw が小さくなると IMF がスパイラル構造に近づくことを意味している．速度依存性（右図）も，|Bx| を除いて同じ傾向を示すが，低速（Vsw < 250km/s）での振舞いは，データ数が少なくなるのでよく判らない．
これらは，SSN 極大期にあたる 1979-1981 年の 3 年間の解析結果であるが，他の 2 期間，1999-2001 年（SSN 極大期）と 2007-2009 年（SSN 極小期）についても，同様の解析を行った．また，火星を周回する Maven が観測した IMF についても調べた．結果は，上の記述と矛盾しない．



2017/09/8-16 のストームイベント中に観測された長寿命の 2 つピークのリングカレント帯プラズマ圧構造

今城 峻 [1]; 能勢 正仁 [2]; 笠原 慧 [3]; 横田 勝一郎 [4]; 松岡 彩子 [5]; 桂華 邦裕 [6]; 堀 智昭 [7]; 寺本 万里子 [8]; Gkioulidou Matina[9]; Lanzerotti Louis J.[10]; Mitchell Donald[9]; 山本 和弘 [11]; 生松 聡 [12]; 野村 麗子 [13]; 藤本 晶子 [8]; 篠原 育 [14]; 三好 由純 [7]

[1] 名大・ISEE; [2] 名大・宇地研; [3] 東京大学; [4] 阪大; [5] JAXA 宇宙研; [6] 東大・理; [7] 名大 ISEE; [8] 九工大; [9] JHU/APL; [10] ニュージャージー工科大学; [11] 京大・理・地物・電磁気; [12] 京大・理・地球物理; [13] NAOJ; [14] 宇宙研／宇宙機構

Long-lasting double-peak structure of ring current pressure during the 8-16 September 2017 storm

Shun Imajo[1]; Masahito Nose[2]; Satoshi Kasahara[3]; Shoichiro Yokota[4]; Ayako Matsuoka[5]; Kunihiro Keika[6]; Tomoaki Hori[7]; Mariko Teramoto[8]; Matina Gkioulidou[9]; Louis J. Lanzerotti[10]; Donald Mitchell[9]; Kazuhiro Yamamoto[11]; Satoshi Oimatsu[12]; Reiko Nomura[13]; Akiko Fujimoto[8]; Iku Shinohara[14]; Yoshizumi Miyoshi[7]

[1] ISEE, Nagoya Univ.; [2] ISEE, Nagoya Univ.; [3] The University of Tokyo; [4] Osaka Univ.; [5] ISAS/JAXA; [6] University of Tokyo; [7] ISEE, Nagoya Univ.; [8] Kyutech; [9] JHU/APL; [10] NJIT; [11] Geophysics, Kyoto Univ.; [12] Kyoto Univ; [13] NAOJ; [14] ISAS/JAXA

We report long-lasting double-peak structures of ring current pressure during the 8-16 September 2017 storm event using ion measurements by the Arase satellite in the premidnight sector and the Van Allen Probe B satellite in the noon sector. We found two types of double peak structures: one was shown in the late recovery phase of the first strong storm starting on September 8, 2017 and the other was shown after the subsequent weaker storm starting on September 13, 2017. The inner peak of both events was created at L∗˜3 in both noon and premidnight sectors after the first storm onset, and mainly composed of protons with energy up to 80 keV. This peak lasted for about a week and slowly decayed with a time constant of ˜4 days, which is consistent with a charge exchange lifetime. For the first double-peak event, the outer peak observed by Arase at L∗˜5.5 consisted of protons with energy less than 80 keV. The double peak structure lasted for two days, and there were multiple small-scale injections associated with substorms in the interval. The pileup of remnants of these injections probably maintained the outer peak. On the other hand, Probe B in the noon sector did not observe the corresponding outer peak. For the second double-peak event, the outer peak was observed by Arase at L∗˜4.5 for 1.5 days, and the peak-like bump was observed also by Probe B at the same L∗. The outer peak consisted of protons with the energy range of less than 200 keV provided by the injection associated with the subsequent weaker storm onset. We suggest that a condition of the long-lasting double-peak pressure structure is that weaker injections occur after a strong injection (or convection) that creates the pressure peak consisting of the high-energy protons in the deep inner magnetosphere. We will further investigate the relationship between the pressure structure and field-aligned currents.

Stormtime overshielding electric fields observed by ROCSAT-1

Kumiko Hashimoto[1]; Takashi Kikuchi[2]
[1] KIU; [2] ISEE, Nagoya Univ.

The dawn-to-dusk convection electric field is an essential cause for driving the geomagnetic storm and for triggering disturbances in low- and equatorial- latitude ionosphere. The electric field is often reversed because of the convection reduction, disturbance dynamo, and substorm expansion. In this study, using the vertical plasma drift velocity measured by the Ionospheric Plasma and Electrodynamics Probe Instrument (IPEI) aboard ROCSAT-1, we examined the overshielding electric field for major geomagnetic storms during the period from 1999 to 2004. The electric field was estimated from the meridional component of the ExB drift velocity by applying the IGRF-2000 model as the ambient magnetic field. We analyzed time variations of the electric fields at different local times in the range of 25-36 degrees in geographic latitude for three storm events that occurred on 06 April, 2000, 06 November, 2001, and 20 November, 2003. During the storm main phase initiated by the SC at 1639UT on 06 April, 2000, IPEI detected the westward electric field with magnitude of 2-3 mV/m in the pre-dawn hours (5-6 LT), while the electric field turned to eastward with magnitude of 5 mV/m during the recovery phase. On the dayside (9-10 LT), the electric fields are eastward with 4 mV/m during the main phase and westward with 3 mV/m during the recovery phase. In the evening hour (19-20 LT), the electric field is eastward with 4-5 mV/m during the main phase and westward with 2 mV/m during the recovery phase. The magnitude of the electric field changed in a significantly different manner at pre-dawn (5-6 LT), afternoon(14-16 LT), evening (18-20 LT) and pre-midnight (22-23LT). The local time features of the electric field indicates that the convection electric field provided by the Region-1 field-aligned currents predominate the main phase, while the recovery phase is predominated by the overshielding electric field provided by the Region-2 field-aligned currents. Furthermore, both the convection and overshielding electric fields manifest the evening anomaly with the electric fields being in the same direction as in the daytime. Similar local time and storm phase tendencies are identified for the other storm events. These results are in good agreement with those obtained from the ground magnetometer data.

Simultaneous observation of the SC electric fields with the HF Doppler sounders on the day- and night-sides

Takashi Kikuchi[1]; Jaroslav Chum[2]; Ichiro Tomizawa[3]; Keisuke Hosokawa[4]; Kumiko Hashimoto[5]; Yusuke Ebihara[6]
[1] ISEE, Nagoya Univ.; [2] ASCR; [3] SSRE, Univ. Electro-Comm.; [4] UEC; [5] KIU; [6] RISH, Kyoto Univ.

The geomagnetic sudden commencement (SC) is composed of the stepwise increase caused by the magnetopause currents, superimposed by the preliminary impulse (PI) and main impulse (MI) caused by the ionospheric Hall currents at high latitude driven by the dusk-to-dawn and dawn-to-dusk electric fields, respectively. The PI is positive and negative in the morning and afternoon, respectively, and the MI is in opposite direction to the PI. The ionospheric currents decrease their intensity with decreasing latitude because of the geometrical attenuation (Kikuchi et al., 1978), resulting in rare observation of the PI at low latitudes, but the PI appears again at the dayside equator where the ionospheric currents are intensified by the Cowling effect. The SC electric fields have been observed at low latitude with the HF Doppler sounders on both the day- and night-sides simultaneously with the SC at high latitudes and equator, even when the PI and MI are not significant at low latitudes (Kikuchi, 1986). It should be stressed that the HF Doppler sounders have an advantage in detecting the electric field on the nightside where the ionospheric currents are too weak to be detected by the magnetometers. The SC electric fields on the nightside are in opposite direction to those on the dayside, while the electric fields in the evening are in the same direction as on the day with enhanced magnitude three folds as large as those on the dayside (Kikuchi et al., 2016). The local time features with the evening anomaly meet the solutions of the potential solvers (Tsunomura, 1999), suggesting that the electric fields of the PI and MI are potential fields associated with the ionospheric currents supplied by the field-aligned currents in contrast to their wave properties in the magnetosphere. The PI was found to start simultaneously at high latitude and dayside equator within the temporal resolution of the magnetometer data (10s) (Araki, 1977), which suggests that the ionospheric currents are transmitted instantaneously from high latitude to the equator. The instantaneous transmission has been explained by means of the zeroth-order transverse magnetic (TM0) mode waves propagating at the speed of light in the Earth-ionosphere waveguide (Kikuchi and Araki, 1979). The PI and MI electric fields have been well studied as overviewed above, but the local time and latitude features have not been evaluated by simultaneous observations over the globe. In this paper, we report an event analysis to evaluate the local time features of the SC electric fields with the HF Doppler sounders at Prague, Czech Republic, Tucuman, Argentina on the nightside, and at Sugadaira, Japan and Zhongli, Republic of China on the dayside. To identify the polar-equatorial ionospheric currents, we used magnetometer data from College, Alaska and Guam in the western Pacific. We analyzed an SC event that occurred on 17 March, 2015 with the PI starting at 0445:20s UT and reaching the peak at 0446:10s UT simultaneously at high latitude and equator, followed by the MI peaked at 0447:20s UT. The PI and MI electric fields on the dayside are westward and eastward, respectively, and the electric fields are reversed on the nightside. The onset and peak times of the PI electric field were found to be simultaneous on the day- and night-sides within the temporal resolution of data (10s). With the magnetometer data, we confirmed instantaneous transmission of the electric field from high latitude. The latitude dependence of the electric field intensity and the evening anomaly/enhancement remain to be clarified with the HF Doppler sounder observations over the globe.

航空航法用 VHF 電波を用いたスポラディック E 広域モニタリングシステムの構築

細川 敬祐 [1]; 坂井 純 [1]; 冨澤 一郎 [2]; 斎藤 享 [3]; 津川 卓也 [4]; 西岡 未知 [4]; 石井 守 [4]
[1] 電通大; [2] 電通大・宇宙電磁環境; [3] 電子航法研; [4] 情報通信研究機構

Sporadic E monitoring system using anomalous propagationof VHF radio waves for aircraft navigation

Keisuke Hosokawa[1]; Jun Sakai[1]; Ichiro Tomizawa[2]; Susumu Saito[3]; Takuya Tsugawa[4]; Michi Nishioka[4]; Mamoru Ishii[4]
[1] UEC; [2] SSRE, Univ. Electro-Comm.; [3] ENRI, MPAT; [4] NICT

Sporadic E (Es) is a thin and dense layer in the E-region ionosphere at an altitude around 100 km. Es has been known as one of the outstanding ionospheric phenomena at mid-latitudes during summer months. Because of highly enhanced electron density within Es, obliquely propagating VHF radio waves for analogue TV and FM radio broadcasting are reflected by Es, and, in such a case, they propagate for a long distance beyond the range of ground propagation. Such an anomalous propagation can introduce significant interferences in broadcasting using VHF frequencies, which has been known as one of the space weather impacts of ionosphere at mid-latitudes. Recently, propagation of VHF radio waves used for aircraft navigation (108-118 MHz: VOR, ILS, GBAS VDB) can also be affected by the occurrence of Es (Sakai et al., 2019), which may cause an interference in the aircraft navigation system. To evaluate such an effect of Es on the aircraft navigation system and eventually mitigate it, we need to monitor the occurrence of anomalous propagation in a wide area routinely. For this purpose, we have operated VHF radio wave monitoring systems at 6 stations in Japan (Sarobetsu, Chofu, Oarai, Sugadaira, Kure and Okinawa) since May 2019. The monitoring system is equipped with a digital receiver handled by the software defined radio and covers a frequency range from 98 to 118 MHz. The obtained data are processed onsite and transferred to the University of Electro-Communications every 1 hour. All the data (i.e., the occurrence of anomalous propagation) are displayed on a website (http://gwave.cei.uec.ac.jp/cgi-bin/vor/vhf.cgi). In the presentation, we give an overview of the system and introduce several cases of anomalous propagation which happened in the summer months of 2019. We also show an ability of VHF radio observation for mapping the two-dimensional structure of Es in combination with GPS-ROTI observations.

リアルタイム GAIA を用いたスポラディック E 層発生予測

品川 裕之 [1]; 陣 英克 [1]; 垰 千尋 [1]; 三好 勉信 [2]; 藤原 均 [3]
[1] 情報通信研究機構; [2] 九大・理・地球惑星; [3] 成蹊大・理工

Prediction of the sporadic E layer occurrence using the real-time GAIA

Hiroyuki Shinagawa[1]; Hidekatsu Jin[1]; Chihiro Tao[1]; Yasunobu Miyoshi[2]; Hitoshi Fujiwara[3]
[1] NICT; [2] Dept. Earth & Planetary Sci, Kyushu Univ.; [3] Faculty of Science and Technology, Seikei University

The sporadic E (Es) layer has significant influences on radio communications and broadcast, and the prediction of occurrence of the Es layer is one of the most important issues in space weather forecast. Although the Es layer occurrence has clear seasonal variations, significant day-to-day variations as well as spatial variations are present. Because of the complex behavior of the Es layer, the prediction of Es layer is though to be extremely difficult. 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 the downward ion drift velocity or in the vertical ion convergence in 120 km-130 km altitudes agree fairly well with variations in foEs. This result suggests that the probability prediction of Es layer occurrence is possible using those parameters. Our group has recently developed a real-time GAIA simulation system as well as a real-time ionosphere prediction system for a few days ahead. We will report methods of the prediction of Es layer occurrence, and present experimental results of the prediction.

スポラディック E（Es）層は、短波通信や放送にさまざま影響を及ぼすことから、その発生予測は宇宙天気予報における重要課題の一つである。Es 層の発生には明確な季節依存性があることが知られているが、日々変動が大きく、また空間分布も複雑なため、その予測は困難であると考えられてきた。我々は、この Es 層発生の予測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、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 から 130 km 付近の下向きイオンドリフト速度と鉛直イオン収束率はどちらも foEs の変動とかなり良く一致することを見出した。このことは、これらのパラメータを用いることにより、Es 層発生の確率予測の可能性となることを示唆している。我々のグループでは GAIA をリアルタイムで実行しつつ、数日先までの電離圏の予測を行うシステムを開発し、現在試験運用を行っている。本発表では、このリアルタイム電離圏予測システムを用いて Es 層 の発生を予測する方法と、それを用いた予測試験結果について報告する。

熱圏データ同化システムの開発と宇宙機軌道解析ツールとの連携

加藤 博司 [1]; 日南川 英明 [1]; 秋山 祐貴 [2]; 中村 信一 [1]; 中野 将弥 [3]; 杉本 理英 [4]; 陣 英克 [5]; 藤原 均 [6]; 三好 勉信 [7]
[1] JAXA; [2] JAXA 追跡 NW 技術センター; [3] 富士通; [4] LSAS Tec; [5] 情報通信研究機構; [6] 成蹊大・理工; [7] 九大・理・地球惑星

Development of thermospheric data assimilation system and linkage with spacecraft orbit analysis tool

Hiroshi Kato[1]; Hideaki Hinagawa[1]; Yuki Akiyama[2]; Shinichi Nakamura[1]; Masaya Nakano[3]; Yoshihide Sugimoto[4]; Hidekatsu Jin[5]; Hitoshi Fujiwara[6]; Yasunobu Miyoshi[7]
[1] JAXA; [2] STCC, JAXA; [3] Fujitsu; [4] LSAS Tec; [5] NICT; [6] Faculty of Science and Technology, Seikei University; [7] Dept. Earth & Planetary Sci, Kyushu Univ.

As the background of the satellite constellation plan by private companies in low earth orbit environment and the problem of increasing space debris in recent years, JAXA aims to improve the accuracy of spacecraft's orbit prediction in low earth orbit environment. Since a spacecraft in a low earth orbit receives drag from the atmosphere (atmospheric drag) which exists slightly in low earth orbit environment, it is important to improve the accuracy of atmospheric drag prediction in order to improve the accuracy of spacecraft's orbit prediction in low earth orbit environment. In order to predict atmospheric drag, information on five factors is required: the mass of the spacecraft, the relative velocity, the cross-sectional area, the drag coefficient, and the atmospheric density. However, there is uncertainty in each factor, and in the field of space flight dynamics, the uncertainty in atmospheric density is considered to be particularly large.

Observation is important for improving the accuracy of atmospheric density in low earth orbit environments. Indeed, many of the currently proposed atmospheric density models are developed from observation. In order to improve the accuracy of atmospheric density models, it will be necessary to expand observation. However, the methods of observation are limited, and only a few (sparse) observation is currently available.

JAXA is focusing on data assimilation that realizes state estimation based on sparse observation information and model information, and is aiming to develop an atmospheric density estimation system for low earth orbit environments using data assimilation. We call this system SUBARU (SUper ensemble BAsed Reanalysis for Upper Atmosphere). In SUBARU, the time-averaged atmospheric density on the satellite trajectory is used as the observation information, and 3 atmospheric density models (NRLMSISE00, Jacchia-Bowman 2008, and GAIA models) are currently available as the model information.

Similar works for estimating low earth orbit atmospheric density is being developed primarily in the United States. As far as we know, there is a research activity called IMPACT at Los Alamos National Laboratory and a system called Dragster at NOAA, UCAR, etc. One of the features of our SUBARU is that it uses a GAIA model that can take into account ionospheric variations that is closely related to atmospheric density variations in low earth orbit environments. The GAIA model is a coupled physics model between the thermosphere and the ionosphere, and is being developed by NICT, Kyushu University, and Seikei University in Japan. We expect that using this GAIA model for data assimilation will enable more accurate estimation and prediction of atmospheric density.

In this presentation, I would like to show the current development status of SUBARU and share the current status of development of a spacecraft trajectory analysis tool using SUBARU, which is currently under development.

近年の民間事業者による低軌道環境での衛星コンステレーション計画や、スペースデブリ増加の問題を背景として、JAXA では、低軌道環境下の宇宙飛翔体の軌道予測精度向上を目指している。低軌道環境の宇宙飛翔体は、わずかに存在する大気から抵抗（大気抵抗）を受け、大気抵抗予測の高精度化が、低軌道環境の宇宙飛翔体の軌道予測精度向上にとって重要となる。大気抵抗予測のためには、宇宙飛翔体の質量、相対速度、進行方向断面積、抵抗係数、そして、大気密度の 5 つの因子の情報が必要となる。しかし、それぞれの因子に不確かさが存在し、軌道力学分野では、特に、大気密度情報の不確かさが大きいとされている。

低軌道環境の大気密度情報の高精度化にとっては、観測情報が重要となる。実際、現在、提案されている大気密度モデルの多くは、観測情報に基づき構築されている。今後、大気密度モデルの高精度化にとっては、観測情報の拡充が必要となるが、観測方法が限られ、わずかな（疎）観測情報しか入手できないのが現状である。

JAXA では、疎観測情報とモデル情報に基づき状態推定を実現するデータ同化技術に注目し、データ同化技術を活用した低軌道環境の大気密度推定システムの開発を目指している。我々は、このシステムを、SUBARU (SUper ensemble BAsed Reanalysis for Upper atmosphere) と呼んでいる。SUBARU の中では、観測情報として、衛星軌跡上の大気密度時間平均値を用い、モデル情報としては、現在、3 つの大気密度モデル（NRLMSISE00 モデル、Jacchia-Bowman2008 モデル、GAIA モデル）を利用できるようになっている。

同様な低軌道環境の大気密度推定システムは、米国を中心に開発されている。我々が知る限り、Los Alamos 国立研究所における IMPACT と呼ばれる研究活動や、NOAA、UCAR 等における Dragster と呼ばれるシステムが存在している。

我々の SUBARU の特徴の 1 つは、低軌道環境の大気密度変動と密接な関係があるとされる電離圏変動も考慮に入れることが可能な GAIA モデルを利用している点である。GAIA モデルは、熱圏―電離圏の結合物理モデルであり、NICT、九州大学、成蹊大学を中心として精力的に開発が進められている。我々は、この GAIA モデルをデータ同化に利用することで、より高精度な大気密度推定・予測ができるのではないかと期待をしている。

本発表では、SUBARU の現在の開発状況を報告するとともに、並行して進めている SUBARU を利用する軌道解析ツールの開発状況についても共有させていただきたい。

九州工業大学宇宙環境技術ラボラトリーの活動報告

増井 博一 [1]; 寺本 万里子 [2]; 趙 孟佑 [3]
[1] 九工大・宇宙ラボ; [2] 九工大; [3] 九工大・宇宙ラボ

Activity report of Kyushu Institute of Technology, Laboratory of Spacecraft Environment Interaction Engineering (LaSEINE)

Hirokazu Masui[1]; Mariko Teramoto[2]; Mengu Cho[3]
[1] Kyutech, LaSEINE; [2] Kyutech; [3] Kyutech, LaSEINE

https://kyutech-laseine.net/

Laboratory of Space Environment Interaction Engineering (LaSEINE) in Kyushu Institute of Technology (Kyutech) was established in 2005. Research objects of LaSEINE were Spacecraft charging/arcing, Material degradation, Space debris and Nano satellite testing. The director of LaSEINE is Prof. Mengu Cho. 14 staffs are working on each object.

The main object of LaSEINE from the beginning to 2010 was the charging/arcing on a solar array of large satellites. The central theme of this research was the clarification of the arcing mechanism and the suppression of the arcing leading to catastrophic failure. In these studies, LaSEINE, NASA, CNES and many satellite venders discussed about the charging/arcing and testing method. The knowledge obtained in this activity and discussion was established as the ISO-11221, Space Systems -Space Solar Panels- Spacecraft Charging Induced Electrostatic Discharge Test Methods.

Since 2010, we have focused on the small satellite testing and development. Kyutech participated as a member of Hodoyoshi project promoted by Prof. Nakasuka in the University of Tokyo. Testing machines for the small satellite as vibration machine, shock machine and thermal vacuum chamber were installed. These testing machines are opened to outside users and we support the testing for small satellite and its component by a new player.

In 2012, we launched our first satellite "Horyu-2", which demonstrates a high voltage solar array of 300 V on orbit. 18 satellites were developed in Kyutech from 2012. These 18 satellites include 11 CubeSats of BIRDS project for the purpose of capacity building. Satellites for the technology demonstration are Horyu series for high voltage experiment on orbit, 2U CubeSat "SPATIUM" mounting a chip scale atomic clock (CSAC) and 2 U CubeSat "AOBA Velox IV" for PPT (Pulsed Plasma Thruster) demonstration.

In this presentation, we will introduce the activity of LaSEINE for space environmental measurement using small satellites developed in Kyutech.

Perturbations by under the atmosphere phenomena: space weather and problems of volcanic ionospheric disturbances studies

Yuki Nakashima[1]; Kiwamu Nishida[1]; Yosuke Aoki[1]; Kosuke Heki[2]
[1] ERI, Univ. Tokyo; [2] Hokkaido Univ.

We suppose that the most influential factor in space weather is various phenomena caused by solar activity. However, perturbations by the earth itself or events near the solid earth sometimes play a role as one of the extras on the stage. We examine ionospheric disturbances excited by volcanic eruptions. It is often observed that such signals originated from such huge near-surface events (e.g., earthquakes, tsunamis, severe weather, artificial explosions, rocket launches), in particular after the GNSS era starts. For understanding the whole upper atmosphere, it is also important to investigate them, not only drastic weather changes driven by the sun. In this presentation, we will show you our results about ionospheric disturbances excited by volcanic eruptions and expectations to space weather from our point of view.

We are studying for several years the propagation of the infrasound and the GNSS-TEC perturbation excited by the Kuchinoerabujima eruption on May 29 in 2015. Volcanic ionospheric disturbances are rarely reported comparing with that occurred by earthquakes or tsunamis, though some volcanic eruptions make huge atmospheric perturbations. Because the disturbances produced by significant eruptions has relatively smaller strength than coseismic signals, and space weather phenomena, they can easily hide the volcanic signals. However, in the Kuchinoerabujima case, we succeeded in finding a clear ˜0.1 TECU N-shaped signal, and we also obtained the infrasonic signal detected with broadband seismometers and barometers. The travel time indicates that the infrasound and TEC perturbation have the same origin. We are trying to extract explosion magnitude from both of the observations, obtain the reliability of GNSS-TEC information, and finally, consider to discuss the directivity of the explosion. We are now examining the propagation and amplitudes using ray-tracing calculation with several model parameters. The modeling is still difficult because even on a quiet day, the wind field and the electron density profile strongly influence the wave condition.

GNSS-TEC observation has the potential for estimating some information on solid earth events. Some research projects already succeeded in inverting massive earthquake or tsunami events properties from TEC data. Besides, now we are convinced volcanic ionosphere disturbances also have partially but surly important information. We encountered the uncertainty of the results. However, one of the factors that make the discussion difficult is that the background properties are unknown, and it would be improved with the progress of space weather research. Also, many researchers suggest observation results and mechanisms of ionospheric disturbances recently before earthquakes occur and actively discussed the signals are fake or not. We expect if people knew space weather more precisely, they could draw more information also about near-surface phenomena from ionosphere observation and obtain a more accurate description of the whole earth system.

太陽地球圏環境予測プロジェクト（PSTEP）:宇宙天気の理解と予測の相乗的発展を目指して

草野 完也 [1]
[1] 名大 ISEE

Project for Solar-Terrestrial Environment Prediction (PSTEP):Toward a synergy of understanding and prediction of space weather

Kanya Kusano[1]
[1] ISEE, Nagoya Univ.

http://www.isee.nagoya-u.ac.jp/~kusano/

Although the solar-terrestrial environment dynamically evolves and may impact the global environment as well as socio-economic systems, the mechanisms which determine the dynamical processes have not yet been fully understood. Therefore, modern society, which is supported by advanced information systems, is at a risk from severe space weather disturbances. Project for Solar-Terrestrial Environment Prediction (PSTEP) was launched on 2015 in order to improve this situation by developing a synergy of the understanding and prediction, supported by a Grant-in-Aid for Scientific Research on Innovative Areas from MEXT/Japan. PSTEP has developed a variety of new methodology to predict space weather based on the new model of MHD instability, machine learning technique, and the assimilation of observations and numerical simulations. In this talk, we report the main results of PSTEP and discuss the future direction and perspective of space weather prediction.

我々が生きる太陽地球圏環境はダイナミックに変動変動しますが、そのメカニズムは未だに十分解明されていません。このため、幅広い宇宙利用と高度な情報化が進んだ現代社会は太陽地球圏の環境変動に対して潜在的なリスクを抱えています。新学術領域研究「太陽地球圏環境予測プロジェクト（PSTEP）」は、そうした問題の解決を目指して 2015 年に組織された全国的な研究プロジェクトです。PSTEP では宇宙天気予報システム、太陽嵐の予測、地球電磁気現象の予測、太陽周期活動とその気候影響の解明を目指した 4 つの計画研究と公募研究の連携を通して、太陽地球圏環境変動に関する科学研究と予測研究を相乗的に発展させる取り組みを進めてきました。それによって、MHD 不安定性理論や機械学習、観測とシミュレーションの同化などを用いた様々な宇宙天気予測の新たな方法論が開発されました。本講演では PSTEP の代表的な成果を報告すると共に、それに基づいて宇宙天気予測研究が今後進むべき方向性とその展望について議論します。

Preparedness for Severe Space Weather Event

Mamoru Ishii[1]; Daikou Shiota[1]; Chihiro Tao[1]
[1] NICT

Extreme Space Weather events are rare, but once they happen social activities can be damaged severely. US government has assigned the Space Weather as a severe disaster same as earthquake, tsunami in "US strategic national risk assessment" and has prepared Space Weather national strategy and action plan in 2015. Several countries, e.g., UK, Korea and Mexico have followed this stream and prepared their strategic plans.

We have been discussing the potential hazardous of severe Space Weather events for Japanese society in the framework of PSTEP since 2015. We will show the present results for the preparation.

There are some issues to be discussed for setting the framework of this document as follows.

1.What are the characteristics of severe space weather events in Japan?

2.How do we treat multiple evaluation axes (e.g., occurrence rate of the event, regional category and utility category) for describing the document?

3.How do we treat the difference of serious level in the items?

4.How do we share the information with users?

5.How do we share the information for international collaboration?

We would like to have these discussions based on the present results.

18-19 世紀における太陽地球環境と経済活動との関係

渡辺 堯 [1]
[1] WDS-IPO

Data-led Study on the Sun-Earth Variability and Socio-Economic Movements in 18th-19th Centuries

Takshi Watanabe[1]
[1] WDS-IPO

In the Open-Science era, assuring easy multi-disciplinary usage of data is crucial to create new data-led research field. However, there still exist many obstacles in multi-disciplinary data usage. To specify the problems, a trial is performed by selecting the interval of 18th-19th Centuries, including the Dalton Minimum (DM) of the solar activity taken place in 1790-1830. In the DM period, the prices of crops in the world were generally high. These general trends of the prices were in coincidence with those of global depressions of temperatures and precipitations seen in the DM period. Concerning data, we need to pay effort to produce well documented ready-to-use datasets expecting usages by scientists out of the field. Involvement of dedicated citizen scientists will be important in the data rescue.

World Data System (WDS) においては、データが Findable, Accessible, Interoperable, Reusable であることを保証する FAIR 原則のもとで、研究者だけではなく、広く社会人によるデータの利用までを視野に入れたデータ活動を推進しつつある。しかし現状ではデータの供給・利用態勢には多くの問題点があるため、試験的な分野横断型データ解析研究として、18 － 19 世紀における社会・経済活動と、太陽活動を含む地球環境の変化との関係を選び、実際にデータにアクセスすることにより、分野間データ利用における問題点の抽出を行った。この期間は太陽黒点の Dalton Minimum (DM, 1790-1830) を含み、欧州ではフランス革命、ナポレオン戦争、産業革命などにより、社会が中世から近世に向かって大きく変化して行った時期にあたるため、環境変動と経済活動との関連を議論する上で重要と思われる。また気象・気候データについては、19 世紀後半までの期間は proxy データからの再構築データに頼らざるを得ないが、18 世紀後半から既に一部で測器観測が始まっており、Maunder Minimum の期間と比べて、データの信頼性が高い。しかしこの期間には、Laki (1783)、Tambola (1815)、Krakatoa (1883) などの歴史的火山活動が発生しているため、解析には注意を要する。太陽活動については、比較的活動周期の長い（12-14 年）DM 期間の直前に、比較的短周期（9-10 年）の時期があり、DM 期間の後は通常の 11 年周期に戻っており、DM を境にした活動周期の変化が見られる。また 18-19 世紀全般にわたって、DM を谷とした長期的な太陽活動のパターンが存在し、同時期の全球平均気温変化のパターンと良い一致が見られる。短期的に見ると、DM の期間は一部 Tanbora などの火山活動による影響も見られるが、世界的に低温で旱魃の傾向にあり、世界各地でほぼ同期した穀物価格の上昇が見られる。英国における小麦価格の動きを見ると、フランス革命やナポレオン戦争などの社会的要因による価格の高騰は一時的であり、1815-1845 年に施行された穀物法による人為的な穀物価格の高騰を除けば、この時期における穀物価格の変動は、ほぼ太陽活動の変化に伴う環境的要因によって支配されていることが示唆される。以上の試験的なデータ解析により、論文中の図又は表としてのみ存在するデータの再利用、複数のバージョンが存在する再構築データの信頼性、市民によって公開されている環境や経済関連データの活用などに関する問題点が抽出できた。

Anomalous propagation of VHF radio waves used for instrument landing system due to the sporadic E layer

Jun Sakai[1]; Keisuke Hosokawa[1]; Ichiro Tomizawa[2]; Susumu Saito[3]
[1] UEC; [2] SSRE, Univ. Electro-Comm.; [3] ENRI, MPAT

The sporadic E (Es) layer, which is a localized dense ionospheric layer occasionally appears at the altitude around 100 km, is known to be a medium of anomalous propagation of very high frequency (VHF) radio waves. A statistical study showed that the intensity of radio signal that is anomalously propagated from a distant radio station may exceed the one from a local station and this phenomenon may potentially disturb VHF air navigation receivers used in systems such as VHF omni range (VOR) and instrument landing system localizer, (ILS LOC) (Sakai et al., 2019). Using the same data set we have studied an extreme case of anomalous propagtion due to Es (EsAP) of ILS LOC radio waves. On 15 May 2014, VHF monitoring receiver recorded strong signatures of EsAP on a few ILS channels, in addition to several VOR channels, at Kure, Hioshima, observation site. In one ILS LOC channel which normally receives no signal at all, the recorded signal intensity was about -80 dBm, which is about 50 dB higher than that of the background level, for more than three hours. We found that the source location of the EsAP wave was about 1500 km away from the observation site. This EsAP signal, from an ILS LOC, is stronger than typical EsAP signal from VOR stations. Since the transmitting power of ILS LOC is relatively low (usually 10 W) compared with that of VOR (100 to 200 W), the above case is rather unexpected. This case suggests that Es may cause strong disturbace on mission-critical radio receivers.

GBAS 電離圏脅威モデルのためのプラズマバブルに伴う電離圏勾配の視線方向依存性解析

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

Line-of-sight dependence of ionospheric delay gradients associated with plasma bubbles for a GBAS ionospheric threat model

Maho Nakamura[1]; Susumu Saito[2]; Takayuki Yoshihara[3]
[1] NAV Department, ENRI; [2] ENRI, MPAT; [3] ENRI

Global navigation satellite systems (GNSS) is now implementing to the air navigation systems as a next generation technique, in addition that the satellite-based augmentation system (SBAS) is investing as the MTSAT-based Augmentation System (MSAS), the Ground-Based Augmentation System (GBAS) is planned to be implemented in Japan in the near future.

Since the GBAS uses the differential positioning technology based on the L1 frequency only, steep gradients of ionospheric delay (proportional to the total electron contents) differences between the airplane and ground station can result in large position errors which is a threat to the safety of GBAS. To design safe and available GBAS, an ionospheric threat model that defines the ranges of parameters describing the characteristics of the ionospheric gradient is necessary.

In Japan which is located from low to lower mid-latitude regions, the equatorial plasma bubbles (EPB) is one of the major souces that associate such steep ionospheric gradients. It is also known that the ionospheric gradients associated with EPBs are greater than those associated with severe magnetic storms [Saito and Yoshihara, Radio Sci., 2017; Saito et al., GPS Solutions, 2017]. Therefore, if the ionospheric threat model for EPBs are applied for all the locations in Japan and for all the satellites in view, the system availability would be limited.

On the other hand, it is known that the EPBs would have a limited latitudinal extent. It is also known that EPBs have structures stretching predominantly in the north-south direction. By taking these characteristics into account in the ionospheric threat model, the threat space could be limited and the GBAS availability would be improved.

ENRI has been executing to develop and optimize the ionospheric threat model for GBAS for the magnetic lower latitude to mid latitude region include Japan. In this study, the data used are obtained from GEONET. The single-frequency-carrier-phase based and code-aided technique which is not subject to the frequency-biases [Fujita et al., JAAA, 2011; Saito et al., ION GNSS 2012] 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; Nakamura et al., ION PNT 2019].

In this paper, the latitudinal limits of the occurrence of ionospheric gradients that are threat to GBAS and the dependence of them on the satellite line-of-sights are presented.

衛星航法 (GNSS) は、次世代の航空航法として航空システムへの導入が進んでおり、日本においても静止衛星型衛星航法補強システム (Satellite-based augmentation system: SBAS) が運輸多目的衛星用衛星航法補強システムとして運用されているほか、地上型衛星航法補強システム (Ground-based augmentation system: GBAS) の導入が進められている。GBAS 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大きな電離圏電子密度勾配が存在すると、ディファレンシャル測位誤差を生じ、安全上の脅威となる。そのため、電離圏勾配を記述するパラメータの範囲を規定する電離圏脅威モデルが必要となる。

中緯度から低緯度にかけて存在する日本付近においては、プラズマバブルに伴う電離圏遅延量（電離圏全電子数に比例）の急勾配が主な脅威の一つと考えられる。プラズマバブルに伴う電離圏勾配は、中緯度地域における磁気嵐に伴う電離圏勾配に比べて大きいことが知られている [Saito and Yoshihara, Radio Sci., 2017; Saito et al., GPS Solutions, 2017] ため、プラズマバブルを想定した電離圏脅威モデルを日本の全ての領域において、全ての可視衛星について適用すると、システムの可用性が損なわれやすくなる。一方で、日本は低緯度から中緯度への遷移領域に位置しており、プラズマバブルの影響を受ける範囲には一定の北限があると推測される。さらに、プラズマバブルには南北に延びた特徴的な構造があり、影響を受ける衛星の視線方向には一定の範囲があると予想される。これらの特徴を取り入れることにより、GBAS に対するプラズマバブルに伴う電離圏勾配の範囲を制限し、システムの可用性を向上することができると期待される。

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速度・空間スケールの変動解析 [Saito and Yoshihara, Radio Sci., 2017; Nakamura et al., ION PNT 2019] を行っている。

本研究ではこれらの解析手法を用いて、プラズマバブルに伴う GBAS に影響を与えうる電離圏勾配の発生緯度範囲と、電離圏勾配の衛星視線方向に対する特性について調べ報告する。

Relationship between the large TEC fluctuation and ionospheric echoes observed by the SuperDARN radars during a geomagnetic storm

Takuya Sori[1]; Yuichi Otsuka[2]; Atsuki Shinbori[3]; Takuya Tsugawa[4]; Michi Nishioka[4]; William A. Bristow[5]; John M. Ruohoniemi[6]; Simon G. Shepherd[7]; Nozomu Nishitani[8]
[1] ISEE, Nagoya Univ.; [2] ISEE, Nagoya Univ.; [3] ISEE, Nagoya Univ.; [4] NICT; [5] UAF; [6] ECE, Virginia Tech; [7] Dartmouth College; [8] ISEE, Nagoya Univ.

In order to investigate a global distribution of ionospheric irregularities in the auroral zone and midlatitudes during a geomagnetic storm which occurred on May 27-28, 2017 with the minimum SYM-H value of -140 nT, we analyzed global navigation satellite system (GNSS) total electron content (TEC) data and midlatitude SuperDARN radar data at Adak Island East (ADE), Adak Island West (ADW), Blackstone (BKS), Christmas Valley East (CVE), Christmas Valley West (CVW), Fort Hays East (FHE), Fort Hays West (FHW), Hokkaido West (HKW), and Hokkaido East (HOK). In this study, we calculate the GNSS-Rate of TEC Index (ROTI) as a good indicator of existence of ionospheric irregularities with the TEC data. Here, ROTI is defined as the standard deviation of rate of TEC (the TEC fluctuations per minute) [Pi et al., 1997]. We compared two-dimensional polar maps between the ROTI and the ionospheric field-aligned irregularity (FAI) echo intensity observed by the SuperDARN radars. The ROTI enhancement appears at the auroral oval and the equatorward wall of midlatitude trough during the main phase of the geomagnetic storm from 22:00 UT on May 27 until 04:00 UT on May 28. The FAI echoes with the intensity of more than 15-20 dB is also observed with correspondence to the enhanced ROTI region in the afternoon to midnight sectors (14 - 23 h MLT: magnetic local time) in North America. The enhanced ROTI and FAI regions move equatorward as the geomagnetic storm develops. However, after 04:00 UT on May 28, the ionospheric FAI echoes almost disappear in spite of existence of the enhanced ROTI region. This suggests that the ionospheric irregularity with decameter-scale disappears after 04:00 UT on May 28, or that radio waves transmitted by the SuperDARN radars are absorbed by enhanced plasma density in the D-region associated with high energy electron precipitation after 04:00 UT on May 28. However, we need further studies on the increasing electron density in D-region during this period in order to verify this hypothesis.

More interestingly, another enhanced ROTI region with a scale of 600 km appears at 30^o geomagnetic latitude (GMLAT) in North America at 1:00 UT on May 28, corresponding to the main phase of the geomagnetic storm. The enhanced ROTI region almost coincides with a region where TEC decreases by 15 TECU. This observational fact suggests that the plasma bubble having the enhanced ROTI value extends up to 50^oN (GMLAT) at 2:30 UT during the main phase of the geomagnetic storm. After that, the plasma bubble propagates westward at a velocity of 355 m/s and enters the midlatitude trough near 4:00 UT. When the enhanced ROTI region enters the field of view of the SuperDARN radar at FHE near 2:30 UT, FAI echoes are suddenly observed at the location of the ROTI enhancement. The FAI echoes in the enhanced ROTI region moved westward at a velocity of approximately 300 m/s. This velocity almost coincides almost with the westward velocity of the enhanced ROTI region.

From these analysis results, it is suggested that the spatial distribution of ionospheric irregularities as seen in the ROTI data has good correlation with that of the FAI echoes observed by the SuperDARN radars, and that the plasma bubble originating from the equatorial ionosphere can be observed by midlatitude SuperDARN radars during large geomagnetic storms.

Daily and seasonal variations of Schumann Resonance

Akihiro Ikeda[1]; Teiji Uozumi[2]; Akimasa Yoshikawa[3]; Akiko Fujimoto[4]; Shuji Abe[5]
[1] KNCT; [2] ICSWSE, Kyushu Univ.; [3] ICSWSE/Kyushu Univ.; [4] Kyutech; [5] ICSWSE, Kyushu Univ.

The Schumann resonance (SR) is the global resonance of electromagnetic waves generated by global lightning activity. The resonance is formed by the Earth-ionosphere cavity and the specific resonance frequency appears in ground magnetic field variation. Thus, the SR reflects both global lightning activity and ionospheric conditions and varies considerably with location.

We aim to construct an empirical model of the SR parameters as a function of local time and day of year. The model can be a base line of SR variations and will help us to find the new aspect of SR during solar flare and solar proton events (SPEs). In this study, we focused on the daily and seasonal variation of the SR parameters as the first step to constructing the empirical model.

The ground magnetic field variation in the extremely low frequency (ELF) range has been measured by an induction magnetometer at Kuju, Japan (KUJ, M.Lat. = 23.4 degree, M. Lon. = 201.0 degree) since 2003. The observation is a part of activities by International Center for Space Weather Science and Education Kyushu University.

The first mode of the Schumann resonance (SR1) around 8 Hz can be seen at KUJ. The power of SR1 in H (horizontal northward component) and D (horizontal eastward component) become maximum in June and July. It is reasonable to predict that the influence of the lightning activity becomes intense in summer at KUJ. Also the power of SR1 in H shows daily variations with maximum peaks around 15 UT throughout the entire period. In the case of D, the SR1 shows its maximum peak around 8 UT. The three major regions of thunderstorm activity (tropical Asia, Afria and America) affect amplitude of SR. The maximum peak times of SR1 in H and D are coincident with the enhancement of thunderstorm activity in Africa and Asia, respectively. This can be explained by the geographical location.

カナダ・ケベック州における地磁気誘導電流に起因する電力網異常と地磁気の統計的関係

Reiter Kyle[1]; 中村 紗都子 [2]; 海老原 祐輔 [3]
[1] カルガリー大学物理天文学科
; [2] 京大生存研; [3] 京大生存圏

Statistical Relations Between Geomagnetic Fields and Power Network Anomaly Caused by Geomagnetically Induced Currents in Quebec

Kyle Reiter[1]; Satoko Nakamura[2]; Yusuke Ebihara[3]
[1] University of Calgary, Department of Physics and Astronomy; [2] RISH, Kyoto Univ.; [3] RISH, Kyoto Univ.

https://science.ucalgary.ca/physics-astronomy/contacts

Geomagnetic disturbances (GMD) and resulting geomagnetically induced currents (GIC) can cause disruption of power transmission network operations. The quasi-DC nature of the potential differences induced in the power networks can result in voltage distortions at transformers, usually characterized as the total harmonic distortion (THD). This study relates geomagnetic field data from magnetometers from Quebec in the AUTUMNX network, along with NRCan geomagnetic observatories with direct measurements of harmonic distortion and GIC in the Hydro-Quebec network. Differing spatial distributions, with a limited number of magnetometers, and transformers where harmonics are measured as well as varying earth conductivity limits the ability to precisely model harmonic generation in the network. Statistical relations between harmonic distortion events as flagged by the Hydro-Quebec Systeme de Mesure de Decalage Angulaire (SMDA) and AUTUMNX geomagnetic field measurements in the three year period between October 2014 and October 2017 are explored. Canonical Correlation Analysis (CCA) of the geomagnetic and SMDA data sets indicate correlations between common modes of the two data sets. Principal Component Analysis (PCA) of the harmonic distortion data sets indicates that particular harmonics may be more sensitive to geomagnetic disturbances. Additionally, the possible persistence of common modes of THD across large areas of the power transmission network are explored.

地磁気擾乱（GMD）とその結果生じる地磁気誘導電流（GIC）は電力伝送ネットワークの運用に支障をきたす可能性がある。電力ネットワーク間に生じる準 DC 的な電位差によりトランスの出力に電圧歪みが生じることがあり、通常は全高調波歪み（THD）として特徴づけられる。本研究では、AUTUMNX と NRCan の磁力計ネットワークで得られたケベック州の地磁気データと、Hydro-Quebec 社の電力ットワークで記録された高調波歪み及び GIC を直接比較した。磁力計や高調波が測定された変圧器の空間分布が一様でないことや地下の電気伝導度の非一様性はネットワークにおける高調波発生を正確にモデル化することを難しくしている。2014 年 10 月から 2017 年 10 月までの 3 年間について、ハイドロ - ケベック社の Mesure de Decalage Angulaire（SMDA）によって観測された高調波歪みイベントと AUTUMNX 地磁気測定値との間の関係を統計的に調べた。地磁気データと SMDA データについて正準相関分析（CCA）を行い、これら 2 つのデータセットにおける共通モードの相関関係を求めた。高調波歪みデータに関して主成分分析（PCA）を行ったところ、特定の高調波が地磁気擾乱に対してより敏感である可能性があることがわかった。さらに、電力伝送ネットワークの広い領域にわたって長時間おこる全高調波歪み (T H D) のコモンモードについても調査した。

1989 年 3 月ケベック大停電太陽嵐再考

塩田 大幸 [1]; 坂口 歌織 [1]; 丸橋 克英 [1]; 石橋 弘光 [1]; 久保 勇樹 [1]
[1] 情報通信研究機構

Revisit of solar storms on 1989 March as the cause of the Quebec power blackout

Daikou Shiota[1]; Kaori Sakaguchi[1]; Katsuhide Marubashi[1]; Hiromitsu Ishibashi[1]; Yuki Kubo[1]
[1] NICT

The greatest geomagnetic storm occurred on March 13-14 1989 whose peak reached to Dst=-589nT was the greatest space weather disaster in modern history because it caused the Quebec power blackout. The origin of the greatest geomagnetic storm is inferred to be the X4.5 flare started on March 10 1848UT, from the time profiles of GOES proton observation. However, two storm sudden commencements (SSCs) of 0128UT and 0747UT on March 13 were observed in the initial phase of the magnetic storm (Fujii et al. 1992), the magnetic storm inferred to be caused by a passage of a compound structure which contains multiple CMEs. In fact, 11 X-class and 48 M-class flares occurred on the active region NOAA 5395 during March 6-19 (Allen et al. 1989). In the storm time, because there is no available in-situ solar wind measurement, it remains unclear which CMEs are the origins of the greatest storm and How the CMEs contribute to the cause of the magnetic storm.

In this study, we examined the origins using MHD simulation of solar wind and CMEs (SUSANOO-CME, Shiota & Kataoka 2016). We performed simulation with a lot of pattern of multiple CMEs occurred at NOAA 5395 and will report the most plausible result of the simulation.

1989 年 3 月 13-14 日に発生した磁気嵐は、14 日 02UT に Dst=-589nT を記録した観測史上最大規模の磁気嵐であり、ケベック州広域の大停電などを引き起こした歴史上最も大きな社会影響を及ぼした宇宙天気災害である。この磁気嵐を引き起こした太陽嵐（フレア・CME）は、GOES proton flux の時間変動から推定すると、活動領域 NOAA5395 で 3 月 10 日 1848UT から始まった X4.5 フレアと考えられる。しかし、この磁気嵐の初相の期間に 13 日の 0128UT 及び 0747UT に storm sudden commencements (SSCs) が観測されている (Fujii et al. 1992) ことから、複数の CMEs が相互作用することによって形成された複合構造が地球に到来した可能性が考えられる。活動領域 NOAA5395 では、太陽表面に現れていた 3 月 6-19 日の期間に、11 の X クラスフレア、48 の M クラスフレアが発生している (Allen et al. 1989)。太陽風の観測がなく、どの太陽フレアから放出された CME が磁気嵐を引き起こすために寄与したかについては明らかになっていない。そこで本研究では、SUSANOO-CME MHD シミュレーション (Shiota & Kataoka 2016) を用いて、NOAA5395 で発生した複数の CME を入力としたシミュレーションを行い、磁気嵐を引き起こすことが可能な太陽風・CME はどのようなものであったかについて検証した結果を報告する。

分野融合型科学創出のための試行プロジェクトAMIDER

梅村 宜生 [1]; 田中 良昌 [2]; 阿部 修司 [3]; 中野 慎也 [4]; 新堀 淳樹 [1]
[1] 名大・宇地研; [2] 国立極地研究所/総研大; [3] 九大・ICSWSE; [4] 統数研

Pilot project AMIDER for data-driven science

Norio Umemura[1]; Yoshimasa Tanaka[2]; Shuji Abe[3]; Shin'ya Nakano[4]; Atsuki Shinbori[1]
[1] ISEE, Nagoya Univ.; [2] NIPR/SOKENDAI; [3] ICSWSE, Kyushu Univ.; [4] The Institute of Statistical Mathematics

ROIS (Research Organization of Information and Systems) has established the AMIDER project in Apr 2018 for the purpose of acceleration of data science business and establishment of its technical procedure. The AMIDER project was started by some researchers in ROIS-DS (Joint Support-Center for Data Science Research), Nagoya University, Kyushu University, National Institute of Polar Research (NIPR) and Institute of Statistical Mathematics (ISM), and is now building a technical method to suggest the possibility of scientific relationship on the basis of the statistical calculation with the several sample data (climatology data, environmental data, geology data, earth-space data, biology data and so on) managed by NIPR. The steps of the statistical calculation are formed by adding several functions of Data Conversion and Data Fusion on the Data Archiving represented by IUGONET and DIAS so far.

Data Conversion converts research data from research field-dependent format to general ASCII format, so that more users can analyze the data and read the data for computer easily. Furthermore, Data Fusion reads general-format data converted by Data Conversion, and calculates and determines the relationship between these data. For example, we may be able to derive the truth of how interaction in the adjacent or entire space several sun-earth phenomena (upper atmospheric cooling due to greenhouse effect, ionospheric variation associated with earthquake and volcano activities) are generated through, how these natural phenomena affect the ecology of plants and animals, and so on. These data-driven-specific functions are expected to not only support advanced discovery across multiple fields and elucidation of their relationships in research scene, but also suggest the possibility of the occurrence of the preceding chained events in social scene.

As of July 2019, the AMIDER project achieved the step of Data Conversion (CDF and NetCDF to be tested and its provision). Then, in Nov. 2019, we have a plan to achieve the step of Data Fusion, and to provide data owners with a list of correlation analysis results between submitted data and other registered data.

情報・システム研究機構は，データ駆動型科学事業の加速とその手法の確立を目的として，2018年4月，同機構のデータサイエンス共同基盤施設，名古屋大学，九州大学，国立極地研究所，統計数理研究所の研究者らによる試行プロジェクトAMIDERを発足した．AMIDERは，機構下の国立極地研究所が所有する極域の観測および採取データ（気候・環境，地質，宇宙，生物データなど）をサンプルとして，統計手法から導かれるデータ間の数値的関係から科学的関係の可能性を示唆する仕組みの構築を進めている．そのプロセスは，これまでのIUGONETやDIASに代表されるデータアーカイブ機能に，データ変換とデータ融合の機能を付け加えて形成される．

データ解析支援は，バイナリ形式など研究の都合で採用されることの多い特異なフォーマットを普遍的なアスキー形式に変換する仕組みであり，専門外の研究者にも解析機会を与える効果があるほか，高度計算などの機械処理への入力を実現するものでもある．データ融合は，機械可読化されたフォーマットのデータを突き合わせて，その間の関係性を導出し，類似性を判定する仕組みである．例えば，太陽地球系科学分野では，地球温暖化による超高層大気の寒冷化や地震・火山活動による電離圏変動といった現象が隣接または全空間にてどのように相互作用を通じて発生しているか，分野を拡大すると，地球物理現象の変動が，植物や動物の生態にどのような影響を与えているか等の広義的な関係を見出す手がかりとなる可能性がある．これらのデータ駆動科学特有のステップは，特定の分野に留まった科学的探究に留まらず，複数の分野を跨いだ高度な発見や，その因果関係解明のための支援，また，社会の場面では，連鎖関係にある先の事象の発生の可能性を示唆する仕組みとして期待される．

AMIDERは，2019年7月時点ではデータ解析支援（テスト対象であるCDFとNetCDFの変換とその提供）を達成した．同年11月にデータ融合を達成する予定であり，同時期より，データ所有者に対して，提出されたデータと他の登録データの関係性の一覧を提供する予定である．

Recent activity and future perspective of IUGONET project based on international research collaboration

Yoshimasa Tanaka[1]; Norio Umemura[2]; Shuji Abe[3]; Atsuki Shinbori[2]; Satoru UENO[4]
[1] NIPR/SOKENDAI; [2] ISEE, Nagoya Univ.; [3] ICSWSE, Kyushu Univ.; [4] Kwasan and Hida Obs. Kyoto Univ.

In the Earth's upper atmosphere above about 60 km, including mesosphere, ionosphere, and magnetosphere, various phenomena are generated by energy input from the Sun (i.e., solar radiation and solar wind), atmospheric waves propagating from the lower atmosphere, and the interaction among multiple layers. Thus, comprehensive analysis of various kinds of satellite and ground-based observational data in the multiple regions is important to understand physical mechanism of the phenomena. Inter-university Upper atmosphere Global Observation Network (IUGONET) project has developed two useful tools to assist such a comprehensive analysis. One is a web service 'IUGONET Type-A' that helps researchers at each research step, i.e., cross-searching, knowing, visualizing, and analyzing data, and the other is an analysis software 'SPEDAS' developed based on Interactive Data Language (IDL), which enables to analyze various types of upper atmosphere data in an integrated fashion. Many recent research outcomes on the upper atmosphere were actually obtained by comprehensive data analysis with these tools.

The IUGONET project has been so far collaborating with many ground-based and satellite missions, such as THEMIS, PWING, and ERG, and is also expected to play an essential role in future projects. One of the large research projects is 'Study of coupling processes in the solar-terrestrial system' that was approved by the Master Plan 2011/2014/2017 of Science Council of Japan. In particular, we can contribute to data sharing and development of the visualization and analysis tools for effectively producing research outcomes. In addition, we will also contribute to the construction of observation networks in the Asia, Oceania, and African regions through the international research collaboration and the education of young researchers. In order to promote the collaborative researches and education, we regularly hold data analysis workshops in Asian and African countries (e.g., Indonesia, Malaysia, India, China, and Nigeria) as well as Japan. In these countries, however, MATLAB is more common for data analysis than IDL. Therefore, we are planning to develop the MATLAB routine library for loading the upper atmosphere data released by the IUGONET institutions. This new library will allow researchers in Asia and Africa to easily analyze the IUGONET data by themselves and enhance research collaborations with us.

情報通信研究機構太陽観測データベース

久保 勇樹 [1]; 石橋 弘光 [1]; 直井 隆浩 [1]
[1] 情報通信研究機構

NICT solar observation database

Yuki Kubo[1]; Hiromitsu Ishibashi[1]; Takahiro Naoi[1]
[1] NICT

NICT has observed solar activity since 1950's. A solar optical (H-alpha) observation finished in 2000's. On the other hand, a solar radio observation has still been continued although change of observation frequency and location.

These solar observation data were stored by original format and provided on the request. However, recently, we started to distribute the solar radio observation data obtained at Hiraiso (HiRAS) and Yamagawa, and solar optical observation obtained at Hiraiso as a NICT solar observation database. All the data are distributed by standard FITS format. The database can be accessed from the http://solarobs.nict.go.jp/ and the FITS file can be downloaded.

Three kinds of data (right- and left-handed circular polarization without quiet sun subtraction, and total intensity with quiet sun subtraction) for 1996-2016 (HiRAS) and 2016- (YAMAGAWA) are provided. Three wavelength data (H-alpha center, H-alpha+-0.7Angstrom) are provided for optical observation.

Although this database includes only NICT data now, it is developed so as to include Tohoku University solar radio observation (AMATERAS) data. We are now preparing to include that data in this database in cooperation with Tohoku University.

情報通信研究機構では、その前身である郵政省電波研究所が発足した1950年代から、当時の電波警報業務の一環として太陽の電波、光学観測を行っている。光学観測は2000年代後半に終了したが、電波観測については観測周波数帯域、観測場所の変更はあるものの、現在も続けられており、宇宙天気予報のための重要なデータとして利用されている。

これらの観測データは独自のフォーマットで保存されており、リクエストに応じて提供していたが、今回、平磯太陽電波観測 (HiRAS)
、山川太陽電波観測 (YAMAGAWA)、及び平磯 H-alpha 観測データ全てを標準 FITS フォーマット化し、情報通信研究機構太陽観測データベースとしてデータ公開を開始した。このデータベースには、http://solarobs.nict.go.jp/ からアクセスでき FITS ファイルのダウンロードも可能となっている。

電波観測については、HiRAS(1996年～2016年)、YAMAGAWA(2016年-) の、左右偏波の生データ及び、静穏太陽差引済みの左右偏波合成強度データを公開している。H-alpha については、1994年-2006年までの、H-alpha 中心、及び H-alpha+-0.7 Åの観測データを公開している。

本データベースは、現在は情報通信研究機構の観測データのみの公開であるが、東北大学太陽電波観測データも同時に公開できるように開発されており、現在東北大学データも一元的に公開できるように準備を進めている最中である。

Development of cross-reference framework for macro- and micro-scale simulations of the magnetosphere

Keiichiro Fukazawa[1]; Yuto Katoh[2]; Takeshi Nanri[3]; Yohei Miyake[4]
[1] ACCMS, Kyoto Univ.; [2] Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.; [3] RIIT, Kyushu Univ.; [4] Kobe Univ.

For some years we have studied the magnetospheres of Jupiter, Saturn and Earth by using 3-dimensional magnetohydrodynamic (MHD), electro-hybrid, and Particle-In-Cell (PIC) simulations. These simulations have not been able to connect each other due to substantial differences of the spatial and temporal scales which their simulations should treat. However, thanks to the recent development of supercomputer, the coupling simulations come close to be achieved in a few years.

On the other hand, these simulation codes are developed independently so that the implementation and construction of code are quite unlike and hard to understand for each simulation code developer. As a result, it is difficult to connect these simulation codes.

To overcome this difficulty, recently the cross-reference framework for macro- and micro-scale has been developed using RMA (remote memory access), which name is CoToCoA (Code to Code Adapter). CoToCoA framework can make the data generated by the different simulation codes transferred between those simulation codes easily. The main concepts of CoToCoA are that we do not add modifications to the simulation codes as possible without data transfer and we do not need to know the referred simulation code without data format. These concepts allow for many simulation codes to participate in this framework.

In this study, we will show the design of CoToCoA framework in detail and status of development. In particular, we focus on coupling MHD and electro-hybrid simulations. The magnetic field data of MHD simulation is transferred to the cross-reference framework and the magnetic field lines are calculated then these lines are transferred to the electro-hybrid simulation. Some implementations and performance evaluation of this simulation using CoToCoA will be shown.

Real-time magnetosphere simulator for space weather using REProduce Plasma Universe code

Yasubumi Kubota[1]; Aoi Nakamizo[1]; Kaori Sakaguchi[2]; Mitsue Den[1]; Yuki Kubo[2]; Tsutomu Nagatsuma[1]; Takashi Tanaka[3]
[1] NICT; [2] NICT; [3] REPPU code Institute

Surface charging of artificial satellite is one of risks caused by dynamical variations of space environment. It occurs when a satellite exposes high energy electrons around 10 keV created by plasma injection accompanied with substorm. Therefore we want to predict timing and electron energy of plasma injection using magnetosphere-ionosphere coupling global MHD simulation. 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 highly robust to extreme solar wind parameters because the unstructured grid system has no singular point and is able to calculate in the uniform accuracy over the whole region. We use the real-time solar wind data formatted in the GSM coordinate system observed by DSCOVR spacecraft. Magnetic-dipole axis is fixed to z-direction in our simulation. Therefore daily variation of magnetic-dipole axis is not reproduced. Instead, we convert the input direction of the solar wind velocity and magnetic field into that which tilts including daily variation of magnetic dipole axis in x-z plane. In the method the solar wind structure is not exact. However we can relatively reproduce the magnetosphere response including daily variation of the magnetic-dipole axis against solar wind. The resolution is 30722 grids in the horizontal direction and 240 grids in the radial direction.

In this presentation, we compare the simulation results with the CPCP, AE index, and plasma variations observed by geostationary orbit satellites. Density and temperature of plasma injection derived from MHD simulation tends to estimate larger and smaller values than observation respectively because the MHD simulation does not include kinetic heating effects. We have to interpret MHD simulation results for prediction of electron density and temperature. We will discuss how to interpret electron density and temperature between observation and MHD simulation.

Short-Term Variations of Proton Flux in South Atlantic Anomaly due to Solar Storm Conditions

KIROLOSSE M. GIRGIS[1]; Tohru Hada[2]; Shuichi Matsukiyo[3]
[1] IGSES, Kyushu Univ.; [2] IGSES, Kyushu Univ; [3] ESST Kyushu Univ.

http://www.esst.kyushu-u.ac.jp/~space/index_e.html

We study the short-term variations of the proton flux in the South Atlantic Anomaly (SAA) region due to solar storms, whose intensity is well characterized by the Dst index. We have developed a three-dimensional relativistic test particle simulation code to calculate the proton trajectories in time-varying magnetic field, provided by Tsyganenko model TS05. The South Atlantic Anomaly (SAA) is considered as an additional radiation source for Low-Earth Orbit (LEO) satellites and human operations, since this region involves high-energy charged particles (cosmic rays), emerging from the trapped radiation belts. In this study, we consider the following anomaly variables: the maximum value of the proton flux and the area of the anomaly at given altitudes, and the proton penetration depth. Our results show that when the Dst index was decreased from -7 nT to -210 nT, the penetration depth was increased from 300 km to 150 km (i.e., about 150 km deepened), and the maximal flux and the area of the anomaly region were increased to 14 % at 600 km, and 80 % at 400 km, respectively.

Data-driven model for the dynamics of the outer radiation belt in inner magnetosphere

齊藤 慎司 [1]; 坂口 歌織 [1]; 陣 英克 [1]; 垰 千尋 [1]; 久保 勇樹 [1]; 石井 守 [1]
[1] 情報通信研究機構

Data-driven model for the dynamics of the outer radiation belt in inner magnetosphere

Shinji Saito[1]; Kaori Sakaguchi[1]; Hidekatsu Jin[1]; Chihiro Tao[1]; Yuki Kubo[1]; Mamoru Ishii[1]
[1] NICT

Energetic particles in Earth’s geomagnetic fields and in solar energetic particle events can damage satellites operating in geospace. All satellites at geosynchronous, medium Earth, and low Earth orbits are at risk from the energetic particles. Electrons with energy about a few keV, which are generally transported from plasma sheet into the outer radiation belt, can cause surface charging of satellites, resulting in an electrostatic discharge and component damage. Higher energy electrons can cause internal satellite charging which also induces the electrostatic discharge that gives damage on dielectric material in the satellite. So electron radiation belts, which suddenly enhance their flux intensity more than 1000 times within a day through substorms and geomagnetic storms, pose a threat to satellites operating in the geospace. Forecasting the Earth’s radiation belts are in great demand these days in terms of satellite risk management.

Now we are developing a data-driven model to calculate the electron phase space density of the outer radiation belt in inner magnetosphere. The model consists of some empirical models and physical models. Tsyganenko model for the geomagnetic fields, Weimer model for the electric potential fields to reproduce three-dimensional electric fields for plasma convective motion, and a radial diffusion model for adiabatic scattering are utilized to demonstrate trajectories of radiation belt electrons. Plasma sheet model (Tsyganenko-Mukai model) is used to estimate the boundary condition of the outer radiation belt. Further we are planning to import nonadiabatic local acceleration/loss models including nonlinear scattering processes. All models are driven by solar wind parameters, such as the wind speed, density, and interplanetary magnetic fields. We introduce the solar wind data-driven model that aims for empirical/physical-based realtime forecast for the outer radiation belt.

Energetic particles in Earth’s geomagnetic fields and in solar energetic particle events can damage satellites operating in geospace. All satellites at geosynchronous, medium Earth, and low Earth orbits are at risk from the energetic particles. Electrons with energy about a few keV, which are generally transported from plasma sheet into the outer radiation belt, can cause surface charging of satellites, resulting in an electrostatic discharge and component damage. Higher energy electrons can cause internal satellite charging which also induces the electrostatic discharge that gives damage on dielectric material in the satellite. So electron radiation belts, which suddenly enhance their flux intensity more than 1000 times within a day through substorms and geomagnetic storms, pose a threat to satellites operating in the geospace. Forecasting the Earth’s radiation belts are in great demand these days in terms of satellite risk management.

Now we are developing a data-driven model to calculate the electron phase space density of the outer radiation belt in inner magnetosphere. The model consists of some empirical models and physical models. Tsyganenko model for the geomagnetic fields, Weimer model for the electric potential fields to reproduce three-dimensional electric fields for plasma convective motion, and a radial diffusion model for adiabatic scattering are utilized to demonstrate trajectories of radiation belt electrons. Plasma sheet model (Tsyganenko-Mukai model) is used to estimate the boundary condition of the outer radiation belt. Further we are planning to import nonadiabatic local acceleration/loss models including nonlinear scattering processes. All models are driven by solar wind parameters, such as the wind speed, density, and interplanetary magnetic fields. We introduce the solar wind data-driven model that aims for empirical/physical-based realtime forecast for the outer radiation belt.

MAGDAS9システムの10Hzデータを用いた，Pc2脈動の全球的な発生特性解明

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]
[1] 九大・理・地惑; [2] 九州大学地球惑星科学専攻; [3] 九大・イクセイ; [4] 九工大; [5] 九大・ICSWSE

Study on the global occurrence characteristics of Pc2 pulsation with the 10Hz data of the MAGDAS9 system

Taisei Kabasawa[1]; Akimasa Yoshikawa[2]; Teiji Uozumi[3]; Akiko Fujimoto[4]; Shuji Abe[5]
[1] Earth and Planetary Science, Kyushu Univ.; [2] ICSWSE/Kyushu Univ.; [3] ICSWSE, Kyushu Univ.; [4] Kyutech; [5] ICSWSE, Kyushu Univ.

Geomagnetic field disturbances observed on the ground is affected by the space weather phenomena such as magnetic storms and auroral substorms. Recent research 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 the high-energy process of activated O^+ during magnetic disturbance.

By using 10Hz sampling MAGDAS data, we found that the Pc2 type pulsations are simultaneously observed from high to middle-and-low latitudinal region during a magnetic storm time substorm. On the other hand, lower band Pc1 type pulsations relating proton-EMIC wave seem to be confirmed only at the high latitudinal region. In this study, we will report results concerning characteristics of seasonal dependence and local time disturbance about Pc2 pulsation and compare the distribution characteristics of Pc1 and Pc2 type pulsations on the ground, which will manifest a new feature of frequency dependent M-I coupling process.

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。地磁気変動現象のうち，変動周期が約数秒～1000秒程度の周期性を持つ磁場擾乱現象は古くから知られており，地磁気脈動と総称される。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変動であり，近年の研究により磁気擾乱時に活性化された O^+ の高エネルギー化に伴うEMIC wave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ている。本研究では，Pc2脈動に関する季節依存性や地方時分布などの特徴についての調査結果を報告する。さらに，大規模なストーム中のサブストームの最中に，Pc1-2帯のEMIC waveが同時に発生しているのかを地上モニタリングするため，高緯度で得られるPc1脈動との比較解析結果についても考察を行う予定である。

全球GNSS-TEC観測データベースを用いた磁気嵐時の電離圏擾乱に関する研究

新堀 淳樹 [1]; 大塚 雄一 [2]; 惣宇利 卓弥 [3]; 津川 卓也 [4]; 西岡 未知 [4]
[1] 名大・宇地研; [2] 名大宇地研; [3] 名大　ISEE; [4] 情報通信研究機構

Study of storm-time ionospheric disturbances using global GNSS-TEC observation database

Atsuki Shinbori[1]; Yuichi Otsuka[2]; Takuya Sori[3]; Takuya Tsugawa[4]; Michi Nishioka[4]
[1] ISEE, Nagoya Univ.; [2] ISEE, Nagoya Univ.; [3] ISEE, Nagoya Univ.; [4] NICT

The electron density distribution in the ionosphere is determined by the chemical and dynamical processes in addition to the solar extreme ultraviolet (EUV) ionization. Since the ionospheric electrons interacts with electric fields of electromagnetic waves, the ionosphere gives a significant influence on the ionospheric transmissions with satellites for communications, positioning, and navigation. The ionosphere changes greatly in association with the activities of the sun, magnetosphere, and the lower atmosphere, and their ionospheric variations interfere with satellite communication and enhances satellite positioning errors in the Global Navigation Satellite System (GNSS), including GPS. The most major factor of the positioning errors is the propagation delay of GNSS signals in the ionosphere. Therefore, a global total electron content (TEC) map or ionospheric model is required to investigate global ionospheric variations associated with geomagnetic storms and lower atmospheric activities and to evaluate the ionospheric delay for GNSS positioning. A scale of the ionospheric variations (traveling ionospheric disturbances (TIDs), equatorial plasma bubbles (EPB), auroral ionospheric irregularity) is in a range between several 100 km and 1000 km. A storm enhanced density (SED) phenomena observed in the mid- and low-latitude ionosphere during the main phase of geomagnetic storms appears with a wide longitudinal extent. In order to clarify generation and propagation mechanisms of these ionospheric phenomena and to investigate their effects on the GNSS positioning, dense and wide-coverage ionospheric observations and the corresponding TEC data are needed. Under these backgrounds, we have built a global TEC database (absolute TEC, detrended TEC, and ROTI) with high time and spatial resolutions and developed a TEC data analysis system in a corroboration with NICT and the IUGONET (Inter-university Upper atmosphere Global Observation NETwork) and PWING (Study of dynamical variation of particles and waves in the inner magnetosphere using ground-based network observations) projects. The two-dimensional maps of absolute TEC, detrended TEC, and ROTI have been open on the TEC database websites (http://stdb2.isee.nagoya-u.ac.jp/GPS/GPS-TEC/index.html and http://seg-web.nict.go.jp/GPS/DRAWING-TEC/). For the development of the TEC database, we have collected all the available GNSS receiver data in the world. The number of the GNSS stations reaches more than 8500 in January 2019. These GNSS data are provided by the International Geoscience Services (IGS), the University NAVSTAR Consortium (UNAVCO), Scripps Orbit and Permanent Array Center (SOPAC), and other global and regional data centers (more than 50 data providers in all). In this talk, we introduce an overview of recent new scientific results of temporal and spatial evolutions of storm-time ionospheric disturbances (longitudinal variation of the midlatitude trough [Shinbori et al., 2018], plasmaspheric erosion [Obana et al., 2019], longitudinal extent of the SED plume [Sori et al., 2019], midlatitude plasma bubbles [Sori et al., 2019]) using the global GNSS-TEC database.

Night-E layer appearance throughout the over Japanese archipelago during severe geomagnetic storm in March 1989

坂口 歌織 [1]; 塩田 大幸 [1]; 丸橋 克英 [1]; 丸山 隆 [1]
[1] 情報通信研究機構

Night-E layer appearance throughout the over Japanese archipelago during severe geomagnetic storm in March 1989

Kaori Sakaguchi[1]; Daikou Shiota[1]; Katsuhide Marubashi[1]; Takashi Maruyama[1]
[1] NICT

We found in ionograms that night-E layer had been observed during a severe geomagnetic storm on March 1989 at five sites in Japan; Wakkanai, Akita, Kokubunji, Ogimi, and Okinawa. According to magnetic field observation at Kakioka, Japan, sudden storm commencement occurred at 01:28 UT on 13 March, maximum range of H component magnetic field variation reached 644 nT, and it recovered to moderate level at 22 UT on 15 March. Night-E layer was observed almost all the night time of JST from 13 to 14 March. The appearance period corresponds to the main phase of geomagnetic storm. Generally, night-E layer appears as a consequence of auroral particle precipitation in high latitudes. During the March 1989 storm, the auroral oval extremely expanded to lower latitudes, and aurora could be seen as far south as Florida, USA of which magnetic latitude is about 35 degrees. On the other hand, aurora could not be watched in Japan because of cloudy weather. However, the magnetic latitudes about 15–35 degree of Japan is too low to interpret that night-E layer was caused by auroral particle precipitation. The possible explanation that cause ionization in the E layer is precipitation of energetic neutral atoms from the ring current rapidly developing and recovering. Energetic neutral atoms are created by charge-exchange interaction with geo corona. In the presentation, we show more details of night-E layer evolution in relation with geomagnetic storm development and discuss possible generation mechanism of night-E layer over Japan.

大気圏－電離圏結合モデルGAIA新バージョンの開発と性能評価

陣 英克 [1]; 三好 勉信 [2]; 垰 千尋 [1]; 品川 裕之 [1]; 藤原 均 [3]
[1] 情報通信研究機構; [2] 九大・理・地球惑星; [3] 成蹊大・理工

A revised version of a whole atmosphere-ionosphere coupled model GAIA and its validation

Hidekatsu Jin[1]; Yasunobu Miyoshi[2]; Chihiro Tao[1]; Hiroyuki Shinagawa[1]; Hitoshi Fujiwara[3]
[1] NICT; [2] Dept. Earth & Planetary Sci, Kyushu Univ.; [3] Faculty of Science and Technology, Seikei University

Temporal and spatial variations in the ionospheric electron density and thermospheric mass density can have significant impacts on radio communications between ground and space, and atmospheric drag environments around satellites. In order to nowcast and forecast the upper atmospheric variations and disturbances, a whole atmospheric model, GAIA, has been developed, which combines a whole atmospheric GCM, an ionospheric model and an electrodynamics model in a self-consistent manner.

After the initial version of GAIA in 2011, we have revised the mode several times. At present, the latest version is a revised one in 2013. After comparison between a long-term simulation and thermosphere/ionosphere observations as well as several analyses on specific events of vertical atmospheric coupling, we have noticed that the current version is sometimes not sufficient in the quantitative accuracy of reproducing both basic climatological features and some occasional events of upper atmosphere. For this reason, we are developing a new version of GAIA by improving several numerical schemes in GAIA and so on. In this presentation, we discuss first results of the new version of GAIA and comparison with previous version and observations.

電離圏・熱圏の変動や擾乱は、通信や測位など社会で利用されている各周波数帯の電波（LF～UHF）の伝搬に影響し、また人工衛星の軌道や姿勢などに影響することが知られている。従って超高層大気の状態を把握・予測することは重要であり、これまで我々は複数の領域モデルを結合させることにより、地表から熱圏上部までの中性大気と電離圏を包含する大気圏電離圏結合モデル（GAIA）を開発してきた。そして、我々はGAIAの下層大気部分に気象再解析データを簡易的なデータ同化手法によって取り込み、現実的な下層大気に基づく超高層大気のシミュレーションを数十年分実施し、各現象の解析を行ってきた。

GAIAはモデル間の結合を行った初期版の完成以降、精度や性能の改善のため何度か更新してきた。現在は2013年3月に更新したバージョンを主に使い続けている。しかし、長期シミュレーションと熱圏・電離圏の観測との比較や、現象の解析を行ってきたところ、現在のGAIAの再現性能の不足も見受けられ、今後超高層大気の予測への応用や観測された現象の解釈等の研究に有効に利用するためには、更なるモデルの改善が必要となった。そのため、近年GAIAの新バージョンの開発を進めており、扱っている方程式の改良や差分化の改良、光化学反応の精密化、各パラメータの調整などを通じて、熱圏・電離圏の再現性の向上が図られている。本発表では、これらの取組により、電離圏・熱圏の分布や太陽活動や季節に伴う変動や極域からの流入による擾乱の再現性の向上について観測との比較により検証する。

Comparison of FM-CW Ionosonde and MAGDAS observations with S4 index in Peru

Akiko Fujimoto[1]; Shuji Abe[2]; Akihiro Ikeda[3]; Akimasa Yoshikawa[4]
[1] Kyutech; [2] ICSWSE, Kyushu Univ.; [3] KNCT; [4] ICSWSE/Kyushu Univ.

An FM-CW (Frequency Modulated Continuous Wave) radar is a type of HF (High Frequency) radar. We have installed three FM-CW stations along the Japanese longitude, at Japan, Russia and Philippine, in order to measure the electric fields that penetrate the ionosphere (Yumoto, 2006). One of the FM-CW project goals is to understand the relationship between Equatorial Electrojet (EEJ) and the generation mechanism of the Equatorial Spread F (ESF) associated with Equatorial Plasma Bubbles (EPBs). The ionospheric plasma-density irregularities, especially ESF, could result in the scintillation of trans-ionospheric GNSS/GPS signals. The study on the generation mechanisms of ESF is the important issue to estimate the occurrence of the ionospheric scintillation for the safety human activity using the space region. The abnormal magnetic field variation along the magnetic equator, EEJ, is reported to be associated with the ESF.

In 2018, we installed a new FM-CW radar at Sicaya Observatory in Peru. ICSWSE (International Center for Space Weather Science and Education, Kyushu University) also has the ground-based magnetometer network (MAGDAS) on the world including Peru MAGDAS chain. The Sicaya FM-CW observation will give the opportunity of the simultaneous ionospheric observation, the geomagnetic field variation recorded by MAGDAS system at Huancayo and the GPS scintillation status given by S4 index operated by IGP (The Geophysical Institute of Peru).

During 15-18 March 2019, we have the high-time resolution (every 3 minutes) Ionosonde campaign observation in Sicaya. The geomagnetic activity was the weak disturbed with Dst index -41 nT at 12:00 UT on 17 March 2019. The amplitude of EEJ was smaller than the normal EEJ variation and the depressed EEJ structure was recorded at the Sicaya in the evening sector on 17 March with the high S4 value at Brazil (where is located on the east side from Sicaya). The Sicaya Ionogram shows the long-term ESF on 17 March with the couple hours. We will demonstrate the comparison of Ionospheric irregularities with the magnetic activity in the equatorial region for the GPS scintillation.

Development of prediction model of Japanese GIC

Satoko Nakamura[1]; Yusuke Ebihara[2]; Tada-nori Goto[3]; Shigeru Fujita[4]; Shinichi Watari[5]
[1] RISH, Kyoto Univ.; [2] RISH, Kyoto Univ.; [3] Kyoto Univ.; [4] Meteorological College; [5] NICT

We evaluate geomagnetically induced currents (GICs) flowing in the Japanese power grid during severe space weather by using several methods. First, the three-dimensional distribution of the geomagnetically induced electric field (GIE) was calculated by using the 3D finite-difference time-domain (FDTD) method with a three-dimensional electrical conductivity model constructed from a global relief model and a global map of sediment thickness. To simulate a time evolution of magnetic storms, the sheet current with its intensity inferred from the ground magnetic disturbance for famous magnetic storms is imposed. We compared the calculated GICs with the observed ones at substations around Tokyo, and found a certain agreement when the uneven distribution of GIE is incorporated with the simulation. The simulation result shows that GIE exhibits localized, uneven distribution that can be attributed to charge accumulation due to the inhomogeneous conductivity below the Earth's surface. The charge accumulation becomes large when the conductivity gradient vector is parallel, or anti-parallel to the incident electric field. For given GIE, we calculated the GICs flowing in a simplified 500 kV power grid network in Japan. The influence of the inhomogeneous ground conductivity on GIC appears to depend on a combination of the location of substations and the direction of the source current. Second, we assume conductivity anomaly simulating a plate boundary to test the effect of large-scale underground structure on GICs. We find that these structures may strongly enhance GIC just above them. Finally, we derive transfer functions between the GIC observation at 4 substations in Japan and geomagnetic field recorded at the Kakioka station. The transfer functions are not always applicable for Japanese GIC. We will discuss the validity of the assumption of uniform ground and influence of the time variation of earthing resistance of substations.