航空航法における宇宙天気情報の利用について

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Utilizing Space Weather Information for Air Navigation

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Global Navigation Satellite System (GNSS) has been widely used for air navigation and is going to be used in all flight phases from oceanic en route to precision approach and landing. Since safety is extremely important for air navigation, systems must satisfy the international standards specified by International Civil Aviation Organization (ICAO). However, core satellite systems available for aviation purposes (GPS and GLONASS) cannot satisfy the standards by themselves. Thus, augmentation systems that corrects ranging errors and check the navigation information broadcast by satellites are necessary. For GNSS-based systems for precision approach and landing that require extremely high safety level, rare safety issues must be considered. However, too conservative systems may not be practically usable although they are safe.

Spatial and temporal variation of ionospheric total electron content (TEC) are one of the most difficult error sources in GNSS to correct. Currently available GNSS augmentation systems assumes that such ionospheric disturbances always exist with the worst geometry for users because of difficulty in quantifying the probability of existence of ionospheric disturbances by closed systems that do not rely on external systems. However, if any systems could provide information on existence and non-existence of ionospheric disturbances with quantitative reliability, they could potentially be used for air navigation to realize advanced GNSS applications. Indeed, ICAO is working on standardizing utilization of space weather information for various aspects of aircraft operations.

In this talk, what is required for ionospheric monitoring information as a part of space weather is presented. Based on the requirements, possible means of ionospheric monitoring will be introduced. Some simulation results to evaluate the monitoring performance for GNSS augmentation systems will be demonstrated.

航空航法では GPS に代表される全地球的衛星航法システム (Global Navigation Satellite System: GNSS) の利用が増大しており、洋上飛行から精密進入・着陸に至る全ての飛行フェーズで GNSS の利導入が進められている。航空航法においては安全性が極めて重要であり、GNSS を航空機の運航に用いるためには国際民間航空機関 (ICAO) が定める厳しい安全性基準を満足する必要がある。しかし、現在航空用途で利用可能な GNSS コア衛星システム (GPS、GLONASS) 単独では ICAO が定める基準を満足できないため、測位誤差の補正や衛星の起動情報の監視・検証を行う補強システムが必要となる。精密進入などの必要な安全性のレベルが高い GNSS アプリケーションにおいては、極めて稀な現象に対しても対策をとる必要があるが、保守的すぎる対策は実利用システムとしての可用性を損なうため、安全性と可用性のバランスが重要である。

衛星航法の誤差要因としては、電離圏擾乱に伴う電離圏全電子数の空間・時間変動が最も大きく、また最も補正が難しいものである。現在実用化されている衛星航法補強システムにおいては、電離圏擾乱が常に GNSS ユーザにとって最悪の配置で存在していると仮定して安全性設計を行っている。これは、衛星航法補強システムが外部のシステムに依存しないクローズドなシステムとする設計思想の基で、電離圏擾乱の存在・不存在を定量的に示すことができていないためであるが、このような保守的な設計のために、より高度な GNSS 利用において可用性が損なわれる原因となっている。しかしながら、電離圏擾乱の存在・不存在の情報が、その定量的な信頼性情報とともに提供されれば、航空航法において利用できるものとなり、衛星航法の高度な利用を可能とする可能性を持つ。実際に、ICAO においては航空航法が宇宙天気情報の航空における様々な面での利用を目指して国際標準の策定に向けた活動が行われている。

本講演では、宇宙天気の重要な一部としての電離圏監視情報に必要な条件を述べ、それに基づいて利用可能性のある電離圏監視手法を紹介する。さらに、一部の手法についてはシミュレーションに基づく、衛星航法補強システムに対する効果の性能評価の初期結果についても紹介する。

GAIA を用いたスポラディック E 層及びプラズマバブルの発生予測

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Prediction of the occurrence of sporadic E layers and plasma bubbles using GAIA

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In space weather forecast, it is important to predict mesoscale ionospheric disturbances such as plasma bubbles, sporadic E layers (Es), and Storm Enhanced Density (SED). Our group has been developing a whole atmosphere-ionosphere coupled model, GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy), which self-consistently solves the entire region from the lower atmosphere to the ionosphere. Although the present version of the model has a horizontal spatial resolution of 1 degree, it is not enough to reproduce the structures of plasma bubbles or Es. We found, however, that it is possible to deduce their occurrence probabilities by estimating occurrence conditions in the model. We will report results of occurrence prediction of plasma bubbles and Es.

宇宙天気予報では、プラズマバブル、スポラディック E 層（Es）、Storm Enhanced Density（SED）などのメソスケール電離圏擾乱の予測が重要な課題である。我々のグループでは、気象庁の再解析データを入力として、対流圏から熱圏、電離圏までの領域をシームレスに解く全大気圏-電離圏結合モデル (GAIA: Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy) の開発を進めてきた。このモデルは現在、水平分解能が約１度であるが、プラズマバブル、Es などの構造自体を再現するにはまだ精度が十分でない。しかし、その発生条件や背景の状態から発生確率を予測することはある程度可能であることがわかった。本発表では、Es とプラズマバブルそれぞれの発生予測を行った結果を報告する。

大気圏電離圏結合シミュレーションデータの紹介および今後の開発

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A long-term whole atmosphere-ionosphere simulation database and future model development

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Disturbances and variations in the upper atmosphere can have significant impacts on the satellite orbit and attitude as well as the radio propagation between the satellites and ground facilities. The origins of upper atmospheric disturbances and variations do not only come from the eruptive solar activities on its surface but also from the Earth's lower atmosphere. In order to now-cast and forecast these upper atmospheric disturbances and variations in the future, we have developed a whole atmosphere-ionosphere coupled model called GAIA. Recently, we incorporate the Japanese meteorological reanalysis (JRA) into the lower atmosphere part of GAIA as well as the daily F10.7 index, in order to reproduce the effects of realistic lower atmospheric forcing and solar irradiance variation. The result shows that the model can reproduce major features of the observed disturbances in the ionosphere and thermosphere during the major stratospheric sudden warming in 2009 [Jin et al., 2012; Liu et al., 2013, 2014].

In this talk, we will introduce the simulation database which has been obtained from a realistic whole atmosphere-ionosphere simulation during the period from 1996 to 2013. We will also introduce the future model development, including numerical prediction using a data assimilation technique.

超高層大気領域は人工衛星や地上 - 衛星間をつなぐ電波の通り道であり、その擾乱や変動は衛星の軌道や姿勢、また電波の伝搬に影響する。超高層大気の擾乱や変動の起源は、太陽フレアなど太陽面の活動が磁気圏を通して入ってくるだけではなく、地表付近の気象の影響も中層大気を通り入ってくることが知られてきた。我々は、電離圏・熱圏の全球分布を将来的に数値的に推測・予測するために、地表から熱圏上部までの中性大気領域と電離圏領域を相互に結合する大気圏電離圏結合モデル（GAIA）を開発してきた。さらに、現実の太陽放射強度の変動として日々の F10.7 を入力する以外に、モデルの下層大気領域に気象再解析データをナッジング手法により取り込み、現実の気象活動の影響による超高層大気変動を再現する試みを行ってきた。特に、2009 年 1 月に発生した成層圏昇温とその影響による熱圏・電離圏の変動については、観測と同様に再現されることが解り、大気上下結合過程の解析に利用された（Jin et al, 2012; Liu et al., 2013, 2014）。

本発表では、1996 年から 2013 年末まで行った気象再解析データを取り入れた大気圏電離圏シミュレーションのデータベースについて紹介する。現時点では未だモデルの改良余地が多く残るが、大気上下結合や長期変動の研究のほか、ある程度は観測された現象の解析や、領域・要素モデルの背景場、観測計画の参考などに利用しうる。また、現在進んでいるモデルの改良や数値予測に向けたデータ同化などの開発状況についても紹介する。

太陽極端紫外線および彩層画像データに基づく、太陽紫外線放射量の活動周期変動

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Long-Term Variation in Full-Disk Solar EUV 304A and H-alpha Images

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We estimated the long-term variations of solar UV/EUV emissions, which affect on the thermosphere and ionosphere, by using full-disk solar images. The Extreme-Ultraviolet Imaging Telescope (EIT) on board Solar and Heliospheric Observatory (SOHO) has shown us full-disk features of the sun in EUVs over 15 years, and the data enable us to derive the spatially resolved, long-term variation. In this work we examined the EUV 304 A emission in different latitudes by using full-disk images taken by SOHO/EIT. On the other hand, the solar UV radiation is mainly emitted by the chromospheric height, where bright plages are seen. We also tried to derive a proper index of solar UV radiation by analyzing the H-alpha images obtained by the Flare Monitoring Telescope (FMT) at Hida Observatory in Japan and National Ica University in Peru.

太陽紫外線放射の変動は、地球の超高層大気変動を引き起こす要因の一つである。近年では、人工衛星などにより太陽の紫外線分光データが得られ、太陽活動周期にわたる紫外線放射量の波長ごとの推定も行われている。しかし紫外線域では、太陽全面撮像での長期観測データがなく、紫外線放射の変動が太陽面のどの構造に起因するものなのか、詳しくわかっていない。一方、極端紫外線や X 線においては太陽活動周期にわたる撮像観測データが蓄積されており、活動領域・コロナホールといった、太陽表面の領域ごとで太陽活動周期にわたる長期変動が調査可能となっている。また、太陽紫外線が主に放射される彩層については、H-alpha 線やカルシウム線といった波長での長期にわたる全面撮像観測データが蓄積されており、これらを代用することで、太陽紫外線放射量を推定する試みもなされている。
私たちは、SOHO 衛星搭載の極端紫外線撮像望遠鏡 (EIT) による太陽全面極端紫外線や、京都大学飛騨天文台フレア監視望遠鏡 (FMT) による彩層撮像データを解析することで、コロナホールや活動領域の明るさや面積の長期変動を詳しく調べている。また、それらと超高層大気変動（地磁気静穏日変動場; Sq 場）などとを比較することで、超高層大気への影響を及ぼす要因を空間分解された太陽面構造の中に求めている。本講演では、これらの解析結果について紹介する。

地磁気シールドは気候を変えるか？　スベンスマルク仮説の地質学的検証と新展開

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Does the geomagnetic field change climate? - Geological assessment of the Svensmark hypothesis

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The correlation between galactic cosmic ray flux and global cloud cover suggests that the cosmic rays may affect the Earth's climate. Cosmic ray flux is strongly modulated by the geomagnetic field. During a geomagnetic polarity reversal, the decline of field intensity causes an increase of cosmic ray flux, which would result in increased cloud cover. This may cause climate change. This hypothesis, however, is not backed up by the robust geological evidence. In order to test this hypothesis, we examined this effect from the past two geomagnetic polarity reversals. These geomagnetic events are encompassed in interglacial periods and have periods of unusually weak geomagnetic field. The increased cloud impact on climate is most easily detectable at those times. We collected high-resolution climate, sea-level and paleomagnetic records using a sediment core from Osaka Bay, Japan. Comparing the global sea-level changes and the palynological warm proxy, the thermal maximum coincides with the sea-level highstand in Stages 17, 21 and 25. However, in Stages 19 and 31, the thermal maximum clearly lagged behind the sea-level peak, and the connection between orbital forcing and climate was disrupted. In these stages, there is a geomagnetic polarity reversal. The relatively cool phase is shown by the higher cool and lower warm palynological proxies. During the Matuyama-Brunhes polarity reversal, this phase coincide with the period during which geomagnetic field intensity was lower than 40% of its normal value and cosmic ray flux accordingly increased by more than 40%. The temperature decrease was about 3 deg. C based on the palynological data. The same cooling is also observed during the Lower Jaramillo reversal. Does this cooling effect affect the precipitation and/or East Asian monsoon system? In Japan, the temperature in summer is controlled by the temperature of Pacific air mass. On the other hand, the winter temperature is controlled by the Siberian air mass. The precipitations in summer and winter reflect the temperature gradient between the land and ocean in each season and hence are good indicators of summer and winter monsoon strengths. During the cooling events, annual temperature variability became larger and the summer precipitation decreased. If the cooling levels over land and sea are the same, then the temperature gradient would not change, either and hence the strength of the monsoon would never change. Cooler Japanese summers and winters, and a weaker summer monsoon could be caused by the temperature over land being lower than the temperature over the ocean. Then, the annual temperature variability becomes larger, and the summer monsoon becomes weaker. The cooling effect would be larger over the land than the sea. These evidence may suggest that the Earth's climate can be affected by the geomagnetic field.

日本における地磁気誘導電流災害ハザードマップ

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A hazard map for the geomagnetically induced current disaster in Japan

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Recently, potential risk of the geomagnetically induced currents (GICs) which happen to cause large-area power line failure has been reported frequently by Japanese mass media. Japanese government (Ministry of Economy, Industry and Trade) also reported importance of GIC risk assessment in Japan. Responding to the circumstances, scientists of SGEPSS should work out to meet such demand from Japanese society. To perform the risk assessment, we need to investigate two issues at the same time. The first is to estimate magnitude of extremely severe space weather events and the second is to evaluate in a realistic way the GICs in Japan. The first issue is pursued by many scientists all over the world (e.g., Tsubouchi and Omura, 2007). Recently, Baker et al. (2013) reported an extremely large solar flare in 2012 which possibly causes geomagnetic disturbances comparative to the Carrington storm in 1859. On the other hand, the second issue has not been studied so intensively yet. In the talk, we present a map of the geomagnetically induced electric field (GIE) induced by the circular source current with unit intensity in the magnetosphere based on a 3D resistivity distribution estimated from the bathymetry data and sediment layer data. As the GIE depends on inclination of the current circle in the magnetosphere, we obtain local maximum of the GIC by changing inclination of the source current. Thus, by superposing the local maximums, we obtain a map indicating the regions with high risk of the GIC accident. Thus, this map is so-called the hazard map for disasters caused by GICs.

We also obtain the geomagnetic variations on the ground with a realistic resistivity distribution. The geomagnetic variations consist of direct magnetic signatures from the magnetospheric current and the induced magnetic variations by a heterogeneous Earth's resistivity. This information will be useful to investigation of the surface geomagnetic variations.

References

Tsubouchi, K., and Y. Omura (2007), Space Weather, 5, S12003, doi:10.1029/2007SW000329.

Baker, D. N., X. Li, A. Pulkkinen, C. M. Ngwira, M. L. Mays, A. B. Galvin, and K. D. C. Simunac (2013), Space Weather, 11, 585-591, doi:10.1002/swe.20097.

R010-07　　**会場: C**　　**時間: 11月3日 11:40-11:55**

地磁気急始変化（SC）の統計的性質

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Statistical properties of geomagnetic sudden commencements.

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We summarize properties of geomagnetic sudden commencement (SC) derived from statistical analysis of the list of SCs observed at Kakioka (gm latitude = 26deg) for 1924-2013 and Colaba/Alibag (16deg) for 1871-1968.

1. [total No. of SC, maximum H-amplitude, No. of SC larger than 50 nT, No. of SC larger than 100 nT] is [2306, 310nT, 136(5.9%), 18(0.78%)] for Colaba/Alibag and [1805, 273 nT, 135(7.5%), 17(0.94%)] for Kakioka.
2. Occurrence frequency (F) and amplitude (A) of SC show a similar time variation with SSN. The peak of A tends to shift to the declining phase.
3. SCs larger than 100 nT occur at the maximum SSN and the declining phase.
4. SC occurred in March 24, 1940 at 15:38 UT seems to the largest SC since 1871.
5. The LT variation of the SC(H) amplitude at Kakioka shows the maximum at midnight, the second maximum near noon and the minimum around 8h LT. The separate plots of the LT variation for summer and winter season show similar LT variations, although the size of it is different (larger in summer). The LT variations are consistent with those calculated by Kikuchi et al. (2001) separately for summer and winter season. We interpret that the midnight maximum of SC(H) is caused by a pair of field aligned currents (FAC) responsible for the main impulse (MI) of SC and the second maximum near noon is due to FAC and FAC-induced IC.
6. The LT variation of the amplitude of SC(D) takes the maximum around 8h LT when SC(H) takes the minimum. A caluculation of global distribution of ICs produced by a pair of high latitude FACs (Tsunomura & Araki; 1984) shows that the current flows in north-south direction near 8h LT. It means that SC(H) is not affected by ICs. Geomagnetic fields due to FACs for MI of SCs is dominant at noon and midnight and weak at the dawn and dusk side. Therefore, we can consider the main source current for SC(H) is the magnetopause current (MC) causing the DL part of SC.
7. Since Siscoe et al. (1968), several workers have been studied the linear relationship between the SC amplitude and the square root of the solar wind dynamic pressure (Pd). The LT variation of SC amplitude, however, is not taken into consideration. Hereafter, we should use SC(H) around 8h LT which is directly related with Pd.
8. The time variation of MC induces currents in the ionosphere and the earth. Although the induced earth current enhances the magnetic field variation on the surface, the current induced in the ionosphere reduces it. Therefore, induction effects may be reduced for SC(H) observed around 8h LT..

Colaba-Alibag (10deg Gm Latitude；1871-1968) と，Kakioka (27deg； 1924-2013) の SC(地磁気急始変化) リストの解析から判る SC の統計的性質をまとめる．

1.　[SC 全数，最大振幅，振幅 50nT 以上の SC 数，の振幅 100nT 以上の SC 数] は，Colaba-Alibag が [2306，310nT，136（5.9 %），18(0.78 %)]，Kakioka が [1805，273nT，135（7.5%），17(0.94%)]
2. 発生頻度 (F），振幅 (A) 共に，太陽黒点数 (SSN) と同様の 11 年周期変化を示す．A のピークは，SSN の下降期にずれる傾向がある．
3. 100nT 以上の大振幅 SC は，SSN 極大期からそれ以後の下降期に発生する．
4.　1940 年 3 月 24 日 15:38 の SC が，1871 年以降の最大振幅 SC（Alibag:310nT,　Kakioka：273nT 以上）と推定できる．
5.　Kakioka の SC(H）の振幅日変化は，0h 頃に極大，12h 頃に第 2 極大，8h 頃に極小になる．夏冬の季節に分けても，日変化量は変わる（夏が大きい）が，極大・極小の LT は，ほぼ同じである．これは，Kikuchi-Tsunomura（2001）の沿磁力線電流 (FAC) と FAC による電離層電流 (IC）の磁場で，季節変化も含めて説明できる．夜の極大は FAC が，昼の第２極大は FAC ＋ IC が作る．
6. Kakioka の SC(D) 振幅は 8h 頃に極大になる．一方，FAC が作る IC の緯度-LT 分布（Tsunomura & Araki；1884）は，8h 頃に IC の方向が南北になることを示す．これより，8h 頃の SC(H) の極小には IC が寄与していないと解釈できる．FAC の寄与は，0h-12h で最大になり，朝夕では小さいと考えられるから，8h 頃の SC(H) は，主に DL 成分（磁気圏界面電流；MPC）が作ると考えて良い．
７．SC(H) 振幅と（太陽風動圧）**0.5 に線形関係があるとして，その係数を求めた例は，Siscoe et al. (1968) 以来，幾つかあるが，SC(H) の LT 変化は無視されている．8h 頃の SC(H) は，IC・FAC による変形を受けず，直接に太陽風動圧効果を表すから，今後は，これを用いるべきである．
8.　SC の誘導電流効果の考察には，源電流として，MPC と IC を考える必要がある．

IC の誘導電流は地球内部に流れて地上磁場を強める．MPC は，電離層と地球内部に誘導電流を流す．地上磁場は地下誘導電流によって強められ，電離層誘導電流によっては弱められる．したがって，電離層源電流の小さい 8h 頃の SC(H) への誘導電流効果は小さいと考えられる．

全球地磁気データを用いた磁気嵐時のグローバルな電離圏電流分布

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Global distributions of storm-time ionospheric currents using the ground-based geomagnetic field observation data

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It has been well-known that two-cell ionospheric convection in the polar ionosphere driven by a dawn-to-dusk electric field which carries the region-1 field-aligned currents (R1 FACs) are significantly intensified and expand to middle-low latitudes during the main phase of geomagnetic storms. The two-cell ionospheric currents produce negative and positive disturbances of the H-component of geomagnetic field in the morning and afternoon sectors of sub-auroral and middle- latitudes, respectively. The geomagnetic field variations are revesed in high latitude above the footprint of R1 FACs. The dawn-to-dusk polar electric field penetrates to the magnetic equator, and cases a significait ehnahcement of the eastward equatorial electrojet current (eEJ). During the recovery phase which is caused by the northward turning of the IMF, the two-cell ionospheric currents in the polar ionosphere are abruptly reduced and the equatorward boundary of auroral electrojet currents (AEJ) move to high latitude. In this case, the geomagnetic field variations at the magnetic equator show a reduction or reversal of the eEJ in the daytime sector associated with an enhancement of the westward equatorial electrojet current (wEJ) component driven by the dusk-to-dawn electric field originating from the R-2 FACs. However, due to the lack of geomagnetic field data in the middle-low latitudes, detailed relationship between the magnetic field variations of high-middle latitudes and at the equator during geomagnetic storms has not been clarified yet. In this talk, we investigated time and spatial evolutions of global geomagnetic field variations from high-latitude to the magnetic equator during geomagnetic storms, using 1-miniute geomagnetic field data obtained from the CARISMA, GIMA, IMAGE, MACCS, and NSWM networks, and provided by WDC geomagnetism in Kyoto.

In the present analysis, we first subtracted 10-day average solar quiet (Sq) daily variaion from the disturbed field during the geomagnetic storm for H and D components observed at each station. The 10 quiet days were idenfitied from the list of quiet and disturbed days provided by WDC geomagnetism in Kyoto. As a next step, we excluded the magnetic effects produced by magnetospheric currents by subtracting the low-latitude geomagnetic field variation of the northward component.

The equivalent current system showed that two-cell ionospheric currents are significantly enhanced in the daytime together with a strong enhancement of the eEJ at the daytime equator during the main phase of geomagnetic storms. The centers of these vortices were located at 70 degrees and 65 degrees in the morning and afternoon sector, respectively. The two-cell ionospheric currents expanded to the low-latitude region of less than 30 degrees (GMLAT). In the nighttime of middle-low latitudes, the arrows of the equivalent current were directed in the northward direction. This signature indicates that the nighttime magnetic field signatures are produced by the magnetic effect of the R-1 FACs. On the other hand, during the recovery phase associated with strong northward turning of the IMF, the equivalent current system showed that the two new vortices different from two-cell ionospheric currents driven by the R-1 FACs system appear in the polar cap and middle latitude. The former led to the enhanced NBz current driven by the lobe reconnection due to the strong northward IMF, while the latter was generated by the enhanced R-2 FACs produced by the strongly asymmetric ring current flowing westward in the inner magnetosphere. In this case, the equatorial magnetic field variation showed a strongly negative signature produced by the wEJ current due to the dusk-to-dawn electric field. Therefore, it seems that the enhanced NBz current system plays an important role in the intensification of the dusk-to-dawn electric field from the middle-latitudes to the magnetic equator.

磁気嵐主相時に領域 1 沿磁力線電流によって極域電離圏に持ち込まれた電場によって駆動される 2 セル型の電離圏対流が強められ、中・低緯度側へ拡大することがよく知られている。その 2 セル型の電離圏対流は、サブオーロラ帯および中緯度の午前と午後側において、それぞれ地磁気の水平成分の負と正の変動を引き起こす。その変動の極性は、領域 1 沿磁力線電流の電離圏における足元を境に逆転する。そして、極域の朝-夕方向の電場は磁気赤道まで伝搬し、昼間側の磁気赤道において東向きのジェット電流が増大する。惑星間磁場 (IMF) の磁場が北向きに変化することに伴って磁気嵐回復相に移行するが、その期間において、2 セル型の極域電離圏対流が急激に弱まり、オーロラエレクトロジェット電流の位置が高緯度側へ移動する。このとき、磁気赤道の磁場変動は、東向きのジェット電流が急激に衰退し、西向きのジェット電流へと変化する。これは、内部磁気圏を流れる非対称管電流に接続する領域 2 型沿磁力線電流によって持ち込まれた通常の対流電場とは逆向きの電場によって駆動されたものと考えられている。しかしながら、中低緯度における地磁気データの不足によって高緯度-中緯度における地磁気変化と赤道域の磁場変動との詳細な対応関係がまだよく明らかにされていない。そこで本研究では、CARISMA, GIMA, IMAGE, MACCS と NSWM の地磁気観測ネットワーク、および京都大学地磁気センターから提供された全球をカバーする地磁気 1 分値データを用いて磁気嵐時における高緯度から磁気

赤道に至るまでのグローバルな地磁気の時間と空間変動を明らかにする。

本解析ではまず、各観測点で得られた地磁気の H と D 成分に対して磁気嵐時におけるデータから各月の地磁気静穏日に当たる 10 日分のデータを平均したものを差し引いた。ここで用いた地磁気静穏日は、京都大学地磁気センターから提供された地磁気静穏日リストから同定した。次に、磁気圏界面電流や環電流の作る磁場の影響を極力抑えるために、上で求めた各観測点の擾乱場から緯度補正を加えた低緯度の地磁気水平成分を差し引いた。

解析の結果、磁気嵐主相時における等価電流系は、昼間側の磁気赤道において東向きのジェット電流の増大とともに 2 セル型の電離圏電流の発達を示した。これらの渦電流の中心は、朝側と午後側でそれぞれ 70 度と 65 度に位置していた。また、その 2 セル型の電離圏電流は、磁気緯度 30 度以下の低緯度領域まで拡大していた。また、中低緯度の夜側において等価電流ベクトルの方向が北を向いていた。この領域における夜側の電離圏電気伝導度がかなり低いことを考えると、これは、領域 1 型の沿磁力線電流の作る磁場効果を見ていると考えられる。一方、IMF の北向きに伴って磁気嵐回復相が始まると同時に、領域 1 型の沿磁力線電流が作る 2 セル型の電離圏電流が急激に弱まり、極冠域と中緯度に新たな渦電流が出現した。これらの渦電流の極性は、領域 1 型の沿磁力線電流の作る渦電流の極性とは逆であった。これらの渦電流の出現に呼応して昼間側の赤道域では、西向きのジェット電流が増大していた。極冠域に出来た渦電流は、ローブ理コネクションによって発生した NBz 電流が作る渦で、中緯度の渦電流は、内部磁気圏を流れる非対称管電流に接続する領域 2 型沿磁力線電流が作る渦であると考えられる。これらの 2 つの沿磁力線電流が持ち込む夕-朝方向の遮蔽電場が昼間側の西向きのジェット電流の駆動に関与していると考えられる。

大規模磁気嵐の 3 次元 MHD シミュレーション

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Three dimensional MHD simulation of super magnetic storms

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It is important to study super magnetic storms like the Carrington storm in 1859 for good understandings of space weather. As the solar wind and IMF becomes abnormal conditions, plasma turbulence are strongly excited near boundary layers in the magnetosphere. In the plasma sheet magnetic reconnection occurs in patchy and intermittent manner to produce streamer-like structure. At the magnetopause, more regular vortex train is formed for northward IMF. It is because velocity shear created between the magnetosheath fast flow and magnetopause slow flow. On the other hand, sunward fast flow is produced by tail reconnection for southward IMF. Therefore two types of velocity shears created outside and inside of the magnetopause to strongly excite Kelvin-Helmholtz instabilities in both sides. Moreover dayside reconnection occurs in patchy and intermittent manner to give seeds of plasma turbulence. As the results, complicated and strong vortex turbulence appears in flank magnetopause.

We will demonstrate those phenomena from 3-dimensional global MHD simulation of interaction between the solar wind and magnetosphere to discuss relationship between the currents and vortices in boundary layers for extreme conditions on the solar wind and IMF. In particular we will stress relationship among parallel and perpendicular components of vorticity and current, their influence to the global structure of magnetosphere and also compressibility in order to understand the fundamental picture of super magnetic storms in the magnetosphere.

サイクル 24 における地磁気嵐とその原因となった現象について

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Geomagnetic storms and their solar sources in cycle 24

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Solar activity of cycle 24 is low comparing with recent several cycles. Geomagnetic activity is also low because of the low solar activity. To examine characteristics of geomagnetic storms of this cycle, we pick up geomagnetic storms with Dst index less than or equal to -100 nT and analyze their solar sources. No geomagnetic storm with Dst index less than -200 nT is observed until now. Main cause of the geomagnetic storms is coronal mass ejections (CMEs) because of rising and maximum phases of the solar cycle now. Relatively slow CMEs contribute to the geomagnetic storms. Solar counter parts tend to be unclear on the slow CME. This is a problem from a view of space weather forecast. We report several examples of geomagnetic storms and their solar sources in cycle 24 comparing with those in previous cycles.

サイクル 24 の太陽活動は、最近の数サイクルに比べて低く、地磁気活動も低い状態となっている。そこで地磁気嵐について、これまでのサイクルとの違いを調べるため、サイクル 24 に発生した Dst 指数が-100nT 以下の地磁気嵐について、その太陽面での関連現象を調べた。サイクル 24 では、これまでのところ、Dst 指数が-200nT を下回るような地磁気嵐は発生していない。太陽活動の立ち上がりから極大の時期であるため、地磁気嵐の原因としては、CME による地磁気嵐の発生が多くなっている。しかし、地磁気嵐の原因となった CME は比較的速度の遅いものが多い。遅い CME の場合、太陽面での関連現象があまりはっきりとしないことが多い。これまでのサイクルとの比較やサイクル 24 で地磁気嵐の原因となった現象について、いくつかの例を取り上げて報告する予定である。

宇宙環境変動による人工衛星への影響（レビュー）

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Space Environment Effect on Satellite (Review)

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The orbit of the satellite is divided, for convenience' sake, 1) Low-altitude orbit, 2) Mid-altitude orbit, 3) Geosynchronous orbit and 4) beyond (including interplanetary space). The space environment is classified, A) Neutral atmosphere, B) High-energy radiation environment, C) Plasma, and D) Dust and debris. When we classify the influence, it reads to (i) attitude and orbital changes, (ii) surface deterioration, (iii) contamination, and (iv) charging and discharging and (v) semiconductor damage. Measures against the influence from the space environment are extensively taken in recent years, and the research and development of the technology is also advanced. Moreover, for the International Space Station (ISS), measures against the influence from the space environment in the very low altitude have been developed. It greatly contributes to safe use of space when it is achieved to be able to forecast the space environment changes in advance. In that sense, international space environmental information service (ISES) has been started on the world scale since 1996. It is so-called space weather forecast, and the forecast accuracy has improved greatly by the development of the computer simulation, too. In the talk, the space environment effect on the satellite is reviewed.

人工衛星の飛翔する宇宙空間は、太陽活動の影響を大きく受けて激しく変動する事が、これまでの宇宙空間の科学研究から明らかにされている。人工衛星の軌道を便宜上区分すると１）低高度軌道、２）中高度軌道、３）静止軌道、そして４）静止移動以遠（含む惑星間空間）になり、それぞれの領域で固有の宇宙環境の変動が見られる。

宇宙環境変動を分類すると、A）中性大気、B）高エネルギー放射線、C）プラズマ、D）宇宙塵・デブリ（人工破片）に区分され、一方、影響で分類すると、ア）姿勢・軌道への影響、イ）表面劣化・コンタミネーション、ウ）衛星帯電・放電（表面、深部）、エ）半導体損傷、になる。人工衛星本体ではないが、衛星電波が途中の電離層などの変動で、地上局にて受信できなくなる事や、宇宙空間で活動している宇宙飛行士への被曝も含めると、多岐にわたる影響が識別できる。

宇宙環境からの影響に対する対策が、近年、積極的にとられていて、対策技術の研究開発も進んでいる。具体例を挙げると、衛星表面の導電コーティング、帯電を緩和する中和装置の開発、半導体異常の発生時に自己復旧する回路の設計、放射線に強い半導体の製造、コンタミネーションを受けないセンサーの開発、などの要素技術の開発が行われている。また、超低高度を飛翔する国際宇宙ステーション（ＩＳＳ）に特化した対策として、表面を原子状酸素から護る素材の開発、大気の急激な膨張による軌道高度の急降下を防ぐ推進系の開発、デブリ（人工破片）からＩＳＳを守る防護バンパーの開発、さらに宇宙服の高度化なども、広い意味の宇宙環境対策と言える。

宇宙環境の悪化が正確に事前に予報出来ることが実現すると、宇宙空間の安全な利用に大きく貢献する。その意味で、1996年から、国際宇宙環境情報サービス（ＩＳＥＳ）が世界規模で始められている。いわゆる宇宙天気予報であるが、予報精度も、コンピュータシミュレーションの発展で、近年大きく向上している。そして、衛星帯電の予測や被曝量の計算も、シミュレーションできるようになっている。講演では、以上の流れで、宇宙環境変動による人工衛星への影響をレビューする。

Super constellation of micro-satellites as a platform for space weather monitoring

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It is expected that micro-satellites with a weight less than 100 kg will play important roles in space development in the near future due to extreme low cost and the rapid down-sizing. Adding to Surrey Satellite Technology Ltd., a former venture company of Surrey University in UK and one of the pioneers of microsatellite, not a few institutes or companies started entering the international race of micro-satellite development. Micro-satellite had been considered as an educational or experimental tool, but it is not any more at present. Google bought US company, Skybox Imaging, which may launch several tens of, even hundreds of 100 kg-class micro-satellites in the near future for commercial services as a part of Google businesses. Recently, with telescopic camera on board RISING-2, our second 50 kg-class satellite we succeeded in acquiring the color of the earth color, RGB, images with 5 m resolution, which is the best performance in the world as 50 kg satellite. Low cost of the micro-satellite enables institutes or university of developing countries to launch their own spacecraft. Actually many ASEAN countries show very strong interest in fabricating and operating satellites and few have already some experiences. However, generally speaking, their ability of satellite development and utilization is just a beginner level at this moment. And no standardized satellite BUS or scientific sensors exist in the world. One of the fascinating ideas to realize super multipoint measurement for space weather monitoring might be installing a standardized scientific plasma sensor package at every micro-satellite as a part of the BUS instruments. In the near future we may have an opportunity to realize the super constellation with more than several tens of micro-satellites, organizing ASEAN and other developing countries. Here we would like to discuss how to implement our conception.

Spatial-temporal response of space debris distribution to geomagnetic fluctuations

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Growing population of space debris due to increasing payload launches and explosions/collisions of orbiting space objects is a big concern for sustainable future space exploration. In the context of space weather science, space debris issues have been regarded as a part of space environmental mitigation/remediation studies.

In this study, we introduce a different viewpoint into this background. We utilize archived orbital data of thousands of space debris in the thermospheric altitude region as multiple in-situ sensors that respond to atmospheric density fluctuation induced by Joule heating in the ionosphere.

As initial study, we analyze correlations between geomagnetic indices data and time deviations of space debris orbit data to evaluate spatial-temporal response of the space debris distribution to geomagnetic storms. The initial result suggests that 1) there is high correlation between Kp-index and the 1st-order time deviation of orbit mean motion (dn/dt) at a certain time delay from Kp to dn/dt, and 2) trends of the time delay mapped into orbital elements space have characteristic patterns that may supply evidences to mechanisms of the thermosphere-ionosphere system.

Autoregressive model for time series prediction of the outer radiation belt electron flux variations observed by Van Allen Probes

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The outer radiation belt in the Earth's inner magnetosphere is consisted of relativistic energy electrons in MeV range. The electron flux is highly variable depending on both solar wind and magnetospheric conditions. Enhanced fluxes sometimes cause deep dielectric charging on spacecraft and in the worst case satellite anomaly will happen after discharge. Prediction of the electron flux is important for safety operation of the satellite in the near Earth's orbit, but the physical processes of relativistic electrons acceleration, loss, and transport are not fully understood, so far. Because first principal calculation is not available for prediction now, Japan space weather information center at NICT has developed a multivariate autoregressive (AR) model for the prediction of electron flux at geostationary orbit. The model is based on the statistical time series analysis method using Akaike Information Criterion (AIC), which can estimates future flux variations by a few days lagging response of solar wind parameter changes [Sakaguchi et al., 2013]. Recently, the Van Allen Probes have provided observation data throughout the radiation belts. We analyze the 2.3 MeV electron flux time series data obtained from Relativistic Electron Proton Telescope (REPT), which is sorted by L-star of 3, 4, and 5 in the outer radiation belt in a year of 2013. The AR analysis reveals the cross-correlation of fluxes between L-star, and their responses to solar wind parameters and geostationary flux. In the presentation, we show the AR analysis results and also validation results of 2.3 MeV electron flux prediction by using latest data in 2014.

磁気圏圧縮に対する非圧縮性電離圏の応答－ HF Doppler 観測－

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Response of the incompressible ionosphere to the compression of the magnetosphere as observed with the HF Doppler sounder

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The ionospheric plasma in mid latitude is moved by the geomagnetic sudden commencement (SC), ULF pulsations, storm and substorms as observed with the HF Doppler sounders. The motion of the ionospheric plasma has often been considered to be caused by the fast mode or compressional magnetohydrodynamic (MHD) waves radiated by the solar wind magnetosphere interaction. Conversely, the ionosphere has been believed to be incompressible. In other words, the compressional MHD waves never cause the motion of the ionospheric plasma. This paper addresses the compressibility/incompressibility issue of the ionosphere by examining the motion of the ionospheric plasma observed with the HF Doppler sounder in mid latitude during the SC which is definitely caused by the compressional waves from the magnetosphere. We show that the daytime ionosphere moves upward toward the sun during the main impulse (MI) of SC, in opposite direction to the earthward motion of the magnetosphere. The ionospheric motion is well correlated with the enhancement in the equatorial electrojet, which implies that the electric field responsible for the ionospheric motion in mid latitude is a potential field associated with the ionospheric currents flowing from the high latitude to the equator. We note that the upward motion is preceded by the transient (<1 min) downward motion, but it is well correlated with the negative impulse in the equatorial electrojet. Therefore, even the transient electric field is a potential field associated with the ionospheric currents. We conclude that the ionosphere never responds to the compressional MHD waves but moves due to the potential electric field associated with the ionospheric currents transmitted from the high latitude. Since the electric field and currents are transmitted at the speed of light by the TM0 (TEM) mode waves in the Earth-ionosphere waveguide (transmission line), the ionospheric plasma moves simultaneously everywhere in the global ionosphere. The simultaneous motion is expressed as the incompressibility of the ionosphere.

太陽風動圧急増に伴って励起されたPc5-6 波動の観測

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Observation of Pc5-6 excited by sudden increase of solar wind dynamic pressure

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Geomagnetic pulsations excited by the solar-wind - magnetosphere interaction is one of the important phenomena of magnetospheric dynamics. Understanding the excitation and propagation mechanism contribute not only to the basic understanding of magnetospheric dynamics, but also to upgrading forecast model of relativistic electron flux because Pc5 is one of the significant contributor of electron acceleration.

We have been studied a Pc5-6 geomagnetic pulsation event on Jan. 06, 2013, excited by sudden increase of the solar wind dynamic pressure, using ground-based magnetometer and HF radar (SuperDARN) networks and satellite (GOES, Van-Allen Probes).Around 14:25UT, sudden increase of geomagnetic field is observed on the ground. After this increase, almost coherent Pc5-6 pulsations (Period; about 600sec.) are observed almost all the local time from high latitude to the low latitude except for noon local time sector. The solar wind velocity and IMF Bz are 315km/s and positive(northward), respectively. HF radar at King Salmon, Kodiak, and Hokkaido also observes the same frequency ranges of drift velocity variations. However, the phase difference between ionospheric drift velocity and magnetic field on the ground suggests that the magnetic field variations on the ground is not produced by the ionospheric Hall current. Van Allen Probes, which footprint is located near the FOV of King Salmon, also observed the Pc5-6 event. The results and interpretation of this event based on the coordinated observations between ground and satellite will be shown in our presentation.

太陽風ー磁気圏相互作用によって励起される Pc5-6 帯の地磁気脈動現象は、励起・伝播のメカニズムの解明を通じて磁気圏ダイナミクスの理解に貢献する。同時に、同現象は、放射線帯外帯電子加速・加熱の原因と一つと考えられており、現象の理解を通じて宇宙天気予報の精度向上に貢献することが期待されている。

今回は、2013 年 1 月 6 日の太陽風動圧増加に伴って観測された Pc5-6 帯の地磁気脈動に着目し、同現象を地磁気・HF レーダネットワークの地上観測や、衛星観測データを用いて総合解析を行った。地磁気において同日 14:25UT 頃に太陽風動圧の増加に伴う磁場強度の増加が観測され、その後、昼間付近を除く広いローカルタイムにおいて、高緯度から低緯度までほぼ位相のそろった Pc5-6 地磁気脈動（周期約 600 秒程度）が 40 分間にわたって観測された。この時の太陽風の速度 315km/s と低速であり、IMF は北向きであった。同現象の際には、SuperDARN と Van Allen Probes 衛星との同時観測のための特別観測モード (ST-APOG) が運用されており、King Salmon, Kodiak, Hokkaido レーダー等で同現象に対応する電離圏のドリフト速度変動が検出されている。興味深いのは、King Salmon のドリフト速度変動と、地上磁場変動との間で、位相のずれが見られるという点である。このことは、地上で観測されている磁場変動が Hall 電離層電流の結果ではないことを示唆している。これは、観測点が冬半球の夜側に位置することから考えると矛盾は無い。また、同期間には King Salmon HF レーダー付近に Footprint を持つ Van Allen Probes 衛星でも同様の現象が検出されている。講演では地上ー衛星の同時観測結果を総合的に解析した結果について報告する予定である。

あけぼの太陽電池劣化に基づく放射線帯プロトン分布のモデル化

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Modeling L-shell distribution of the trapped protons from solar cell degradation of the Akebono satellite

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Output current of silicon solar cells of Akebono satellite orbiting in the inner magnetosphere decreased from 13 A in 1989 to about 7 A in 2009, due to accumulated damage by energetic particles. Annual decrease from the same month in the previous year shows a clear oscillation due to orbit precession correlated with trapped energetic proton flux up to 1996. Although phase of the oscillation in annual variation shows a clear correlation, the amplitude tends to be larger than that expected from a degradation model based on energetic proton distribution of the NASA's AP8 model. The larger amplitude of oscillation suggests that the proton radiation belt was more sharply localized than given by the AP8 model throughout the early half of 1990s.

We have been further working on modelling of the L-shell distribution of trapped energetic protons which provides best-fit for the degradation of solar cells. The results by assuming Gaussian distribution of proton flux for L value are as follows.

(1) If we assume a steady state before 1996, the best-fitted distribution has a peak around L=1.6 and a width of dL=0.2 (i.e., half width of 1/e decrease from the peak).

(2) If we employ a dynamic model with temporal variation and introduce a different distribution between April 1991 and June 1992, RMSE is further improved from the steady model. Modeled distribution has a peak around L=1.9, suggesting outward shift or expansion of the proton radiation belt during the interval.

Our modeling gives narrower distribution than given by the AP8 model, but is more consistent with the CRRES model based on the observation before November 1991 including the dynamic variation in 1991.

SuperDARN 北海道-陸別第一レーダーの現況報告 (2014.08)

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[1] 名大 STE 研; [2] 名大 STE 研; [3] -

Status report on the SuperDARN Hokkaido East radar

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Latest status of the SuperDARN Hokkaido East radar, which has been in operation since November 2006, will be reported.

2006 年 11 月に稼働を開始した SuperDARN 北海道-陸別第一レーダー (以降、第一レーダー) の最新状況について報告する。同レーダーは稼働開始から約 8 年が経過し、ほぼ順調に運用を継続している。これを用いて電離圏各パラメータの太陽活動依存性等長期変動の特性に関する研究が可能となりつつある。一方、2014 年 10 月には SuperDARN 北海道-陸別第二レーダー (以降、第二レーダー) が運用を開始する予定であり、視野を隣接する第一レーダーと同時に観測を実施することにより幅広い視野を確保し、今までは困難であった研究テーマ、例えば ULF 波動や伝搬性電離圏擾乱の経度依存性等に取り組むことが可能となる。一方で、第一・第二レーダー間の電波干渉についてはその影響がデータの質の低下を引き起こすことが懸念される。両者間で光ケーブルによりブランキング信号をやり取りし、直接お互いの電波が他方の受信機に入り込むことを防ぐ処置を施しているが、このブランキングにより受信パルスに歯抜けが起きるという影響がある。講演においては第一レーダーの現況および、第二レーダー稼働開始後の運用体制について詳細な報告を行う予定である。

航空機被ばくの危険性と太陽活動との相関

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Radiation hazard at aircraf altitude and the correlation with solar activities

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Understanding the solar cycle variation of the radiation dose at aircraft altitude is one of the most important topics of space weather research. We applied Sato et al. (2013) air-shower model to calculate the radiation dose rate in the stratosphere and in the troposphere during solar cycle 23, using GOES energetic particle sensor data as the input. As a result, it is found that the seasonal variation of dose rate at the tropopause is relatively enhanced during the solar maximum, and longer-time trend of ˜10 year shows monochromatic increase from the solar maximum to the solar minimum. We report the mechanisms of the seasonal variation and the longer time trend of dose rate at the tropopause in this presentation.

航空機高度における被ばく線量の太陽活動による変動を知ることは宇宙天気の重要なトピックの一つである。我々は Sato et al.(2013) の空気シャワーシミュレーションを適応し、GOES energetic particle sensor データを入力データとして、23 太陽周期における成層圏と対流圏での被ばく線量を計算した。結果として、太陽極大期での成層圏と対流圏の境界での被ばく線量の季節変動が、太陽極小期と比べて相対的に増加していることがわかった。また、およそ 10 年の長期的間隔で見ると、太陽極小期から極大期に向かって単調増加していることがわかった。今回の発表では、この被ばく線量の季節変動と単調増加のメカニズムについて報告する。

The relationship among relativistic electron flux in the radiation belt, solar wind and Pc 5 at the dip equator

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To clarify the mechanism of relativistic electron (>2MeV) flux increase in the outer radiation belt, we investigated the relationship among relativistic electron flux, solar wind parameters and Pc 5 pulsation at the dayside dip equator.

As the first step, we counted the number of electron flux increase events which occurred during 2005/01/01˜2013/12/31 and checked whether magnetic storm occurred or not before electron flux increased by using the Dst index (WDC for Geomagnetism, Kyoto University). As a result, we found that storm events (Dst <-50nT) are 44% and storm-free events (Dst >-50nT) are 56%. Most of the previous studies investigated storm events, while storm-free events received little attention.

We selected storm-free events and investigated the variation of solar wind parameters (data of the ACE satellite, NASA GSFC) and Pc 5 at the dayside dip equator (data of the MAGDAS/CPMN, Kyushu University) before the electron flux (data of the GOES satellite, NOAA SEC) increased. As a result, we can see large increases of solar wind velocity (at least 300km/s) before relativistic electron flux increase. We can also see enhancement of Pc 5 activity at the dayside dip equator during relativistic electron flux is increasing. Enhancement of Pc 5 activity at the dayside dip equator means that convection electric field penetrated to the dip equator. This result suggests that monitoring of Pc 5 activity at the dayside dip equator can be good clue to clarify the mechanism of relativistic electron flux increases in the outer radiation belt. (i.e. Identification the type of Pc 5 which can cause radial diffusion.)

次世代M-I結合シミュレーションを用いたKH不安定が引き起こすULF波動の研究

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[1] NICT; [2] 九大・宙空センター; [3] 気象大

The study of ULF pulsation driven by KH instability using a next generation M-I coupling simulation model

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ULF pulsation plays an important role in relativistic electron acceleration of outer radiation belt. One of the ULF generation mechanisms is an excitation due to KH instability at the magnetopause. Claudepierre et al. [2008] reported the ULF pulsation following the KH instability using a global MHD simulation model. Our next generation magnetosphere-ionosphere coupling global MHD simulation model reproduced the ULF pulsation at the magnetosphere and the ground following the KH instability because the resolution is improved. In this study, we have done the spectral analysis to ULF pulsation at the magnetosphere and ground. We drove the simulation changing the solar wind velocity of 800 km/s, 600 km/s, and 400 km/s. we made the spatial distribution of the integrated ULF wave power at the equatorial plane. In the results, we found that the integrated ULF wave power and the peak frequency depend on the solar wind velocity. The integrated ULF wave power is distributed lying on 2-3 layers at the magnetopause. These features are consistent with the results of Claudepierre et al. [2008]. We also found that there is the region of the strong ULF power, which seems to propagate form KH instability, at L= 8 Re in the night side in the case of northward IMF and the solar wind velocity of 800 km/s. In this lecture we will report the results of the detail analysis.

ULF波動は放射線外帯電子の加速に大きな役割を果たすと考えられている。ULF波動生成の要因の一つとして磁気圏境界における KH 不安定が考えられる。Claudepierre et al. [2008] では高解像度のグローバル MHD シミュレーションコードを用い、太陽風と磁気圏の境界層で KH 不安定に伴う ULF 波動の励起を報告している。我々が開発を行っている次世代磁気圏-電離圏結合シミュレーションでは、解像度が向上したため磁気圏境界で KH 不安定が再現され、それに伴い地上や磁気圏の磁場変動において ULF 波動も励起されている。

本講演ではシミュレーションから KH 不安定で引き起こされる磁気圏-電離圏の ULF 波動についてスペクトル解析を行った。太陽風パラメータの速度について 800 km/s, 600 km/s, 400 km/s と変化させシミュレーションを行い、赤道面における ULF 帯で積分した磁場変動と電場変動の強度分布を作成し比較した。その結果、ピーク周波数と ULF 強度は太陽風速度に依存し、ピーク周波数は速度が大きいほど高くなり、ULF 強度は速度が大きいほど強くなる。赤道面の ULF 強度分布をみると磁気圏境界で 2-3 層の強度分布を示す。これは Claudepierre et al. [2008] と同様の結果となっている。また、IMF が北向きの場合に太陽風速度 800 km/s で夜側領域の L=8 Re 付近に KH 不安定の変動から伝搬してきたと考えられる ULF 強度が強い領域が見られる。講演ではこれらの解析結果を報告する。

The IUGONET and its contributions for space weather study from the past to the future

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Space weather is an exciting research field on the complex system between Sun and Earth region. In order to investigate the mechanism of long-term variations on space weather, it is crucially important to make cross-cutting studies with various kinds of data observed at various regions and methods. Thus, it is needed to combine databases which maintained by each institute and to accelerate to make data-sharing network in our community. One of our approaches to solve the above problem is "The IUGONET" (Inter-university Upper atmosphere Global Observation NETwork) project. It was established in 2009 as a research project supported from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, and will be closed at the end of this fiscal year. It was launched by only five Japanese universities and institutes (NIPR, Tohoku University, Nagoya University, Kyoto University, and Kyushu University), that have been leading ground-based observations of the upper atmosphere for decades. And now, the IUGONET built much collaboration with both domestic and international institutes/projects.

The IUGONET project has two main products. One of our data management frameworks is the IUGONET metadata database (MDB). As previously explained, researchers for space weather need various kinds of archived data observed by many instruments, for example radars, magnetometers, photometers, radio telescopes, helioscopes, and so on. The IUGONET MDB can help them because it treats all kind of data belonging to IUGONET institutes, and have flexibility to other type of data including the satellites and the numerical simulation which are used in our community.

Other product of the IUGONET is analysis software which can use for scientific research and publication. The iUgonet Data Analysis Software (UDAS) is a plug-in software of Themis Data Analysis Software (TDAS), which is upgraded to Space Physics Environment Data Analysis System (SPEDAS). The UDAS provides many routines for loading the ground-based observational data from various types of instruments, and performing scientific data analysis. This platform made it easier for space weather researchers to analyze a various kind of data in a unified way.

We held 7 workshops for our products approximately every six months to spread the use of them across many researchers to make contribution to space weather study. 25 reviewed journals related to the IUGONET products and their scientific applications are published. On the other hands, some problems are exposed throughout our six years activities. We plan to deal with them on our follow-up project in near future. In this presentation, we will summarize the achievements, problems, and suggestions of the IUGONET project related to space weather research.

NICT サイエンスクラウドを用いた磁気圏グローバル MHD シミュレーションデータと LANL 衛星粒子データの比較

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Comparison between particle environment around GEO from global MHD simulation and that from LANL based on the NICT Science Cloud

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http://www.seg.nict.go.jp/

Substorm injection is one of the important element of magnetospheric substorm, like auroral break up. Studying substorm injection is important to understand the physics of substorms. Also, substorm injection temporaly changes the particle environment around satellites at GEO. And dynamical variations of particle environment around GEO is one of the causes of satellite anomaly due to surface charging. We try to evaluate our magnetospheric global MHD simulation code by comparing output from global MHD code and LANL satellite particle data.

We have built a large-scale environment for the statistical analysis where the data obtained through satellites observations and computer simulation are used to construct a uniform, integrated dataset. In this environment, plenty of data are integrated in the following manner: (1)Archiving large quantities of data files, (2)Resampling time series and convert coordinates, (3)Extracting parameters from simulation data, and (4)Merging both data into one file.

(1)Archiving large quantities of data files: Using the STARS (Solar-Terrestrial data Analysis and Reference System) meta-database that provides meta-information of observation data files managed at distributed observation data sites over the internet, users download data files without knowing where the data files are managed. On the other hand, simulation data is saved from supercomputer to petabyte-scale distributed storage that is connected to 10GbE (JGN-X).

(2)Resampling time series and convert coordinates: We developed an original data class (SEDOC class) to support our reading of data files and converting them into a common data format. The data class defines schemata for several types of data. Since this class encapsulates data files, users easily read any data files without paying attention to their data formats. The SEDOC class supports a function of resampling time series through linear interpolations and converting them into major coordinates systems.

(3)Extracting parameter from simulation data: We have developed a 3-D visualization system that visualizes both of these data simultaneously and extract parameters from simulation data in the arbitrary coordinate value.

(4)Merging both data into a single file: Time scale and coordinate are regularized over data files.

We found a practical problem of the system, especially in case of long durational data analyses. It is the problem of the computational load on the processes two to four. It is necessary to solve this problem in order to achieve data-intensive processing for plenty of data files with non-negligible file I/O and CPU utilization.

To overcome this problem, we developed a parallel and distributed data analysis system using the Gfarm and Pwrake based on the NICT Science Cloud. The Gfarm shares both computational resources and perform parallel distributed processing. In addition, the Gfarm provides the Gfarm file system which behaves as a virtual directory tree among nodes. The Pwrake throws a job for each Gfarm node that has a target data file in the local disk. It utilizes local disk I/O to achieve effective load balance.

Detailed comparison between simulation and observation will be shown in our presentation.

サブストームインジェクションはオーロラブレークアップ等と同様、磁気圏サブストームの典型的な現象の一つであり、これを研究することはサブストームの物理を理解する上で重要である。同時に、サブストームインジェクションは静止軌道の粒子環境を急激に変化させることから、人工衛星の表面帯電等のリスク要因にもつながる。

我々は、過去に蓄積した膨大な磁気圏グローバル MHD シミュレーションの計算結果と、LANL 衛星の粒子データを比較することで、シミュレーションの計算結果の評価を試みると共に、シミュレーションの計算結果を用いてサブストームインジェクションによる静止軌道の粒子フラックス増大の推定を試みる。

本研究では両データの比較を行うために、NICT サイエンスクラウド（以下、サイエンスクラウド）が提供している計算機リソースおよびデータ処理システムをマッシュアップし、両データのデータフォーマットを統一したデータセットを作成する環境を構築した。データセットを作成するプロセスは、データアーカイブ、時間軸・座標系の統一、物理量の抽出、両データのマージの 4 つからなる。

データアーカイブ

分散管理された衛星観測データの収集には、NiCTy+Download Agent を利用することにより、分散管理情報をメタデータベース化した STARSDB を参照して定常的にデータを収集できる。また、サイエンスクラウドではスパコンをハウジングできる環境を提供しており、スパコンから出力された大規模データは、基幹ネットワークが 10GbE で接続された分散ストレージ（Gfarm）に出力することができる。

時間軸・座標系の統一

衛星観測データの時間分解能と座標系をシミュレーションデータに合わせる。サイエンスクラウドが提供する SEDOC を利用することで、衛星観測データのデータフォーマットの差異や時間単位で出力されたファイル群を意識することなく、指定した時間分解能にサンプリングして配列に格納される。また、衛星軌道データについては、主な座標系に変換することができる。

物理量の抽出

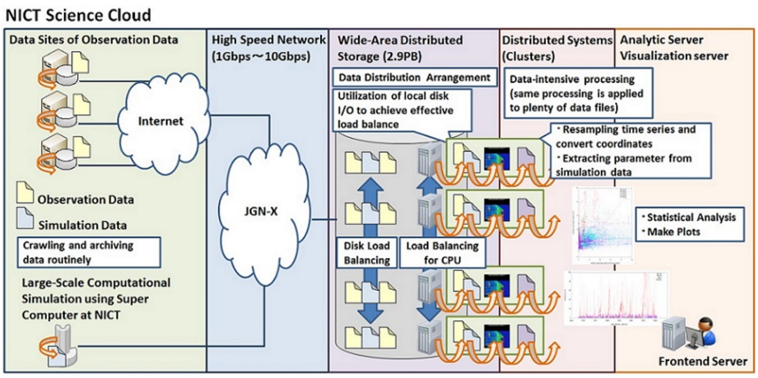
座標系が統一された衛星軌道の任意の座標値に該当する、シミュレーションデータの物理量を抽出する。サイエンスクラウドが提供する V_Aurora は、衛星観測データとシミュレーションデータの融合表示および指定した座標値の物理量の抽出が可能である。

両データのマージ

時間軸・座標系が統一された両データを１つのファイルにマージする。

データアーカイブされた大量のデータファイルに対して、上記の一連の処理を行った場合、データ読み込み時のディスク I/O およびデータ補間時の CPU の処理性能がボトルネックになる。本研究では、この問題を解決するため Pwrake によるワークフローを作成した。Pwrake は分散配置されたファイルがあるノード上でプロセスを起動するようにジョブ管理するため、ローカルディスク I/O を活用したデータ処理が行える。

本発表では、過去に蓄積した LANL シリーズの衛星データと Global MHD シミュレーションデータを用いて比較を行った結果について紹介する。



東北大学における地上観測ネットワークのデータベース開発

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Development of database of ground-based observation network of Tohoku University

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Planetary Plasma and Atmospheric Research Center (PPARC) of Tohoku University have been developed an upper atmosphere, planetary, and space physics database under collaboration with the Inter-university Upper atmosphere Global Observation NETwork (IUGONET). The database consists of planetary and solar radio observation by Iitate Planetary Radio Telescope (IPRT) and Jupiter/galaxy decameter radio receiver working in Iitate observatory, that is one of the observatory of Tohoku University. Development of database of LF/VLF wave observation at Athabasca, Ny-Alesund, and Asia VLF Observation Network (AVON) are also undergoing collaborated with Chiba University. These data can be accessed by IUGONET metadata database as well as IUGONET analysis software "UDAS".

年輪中炭素 14 濃度の高精度分析による宇宙線の 22 年周期変動および太陽圏環境の復元

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Reconstruction of cosmic-ray 22-year cycles and the heliospheric environment based on carbon-14 in tree rings

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It has been revealed by the meausrement of beryllium-10 content in ice core layers that the cosmic ray variation associated with the Hale solar magnetic reversal cycles was amplified during the Maunder minimum in the 17th century. It was suggested that the variability of the heliospheric current sheet was changed during the time. It has been also found that the amplified 22-year cosmic-ray cycles (actual cycle length was 28 years due to the lengthened solar cycles) might have been playing important role in climate multi-decadal variations. Associated with the annual-scale 40 percent increase in cosmic ray flux every 28 years, temperatures and precipitations were changed over the northern hemisphere.

We are conducting high resolution measurement of carbon-14 in tree rings from the Maunder Minimum in order to determine the absolute ages of the events. We report the preliminary results of the measurement.

IUGONET プロジェクト期間に構築された極地研超高層大気データベース

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Upper atmosphere database at NIPR constructed during the IUGONET project

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Space and Upper Atmospheric Sciences Group in the National Institute of Polar Research has been observing the upper atmosphere in the polar region with various instruments, such as imagers, radars, magnetometers, and riometers since the International Geophysical Year in 1957-1958. However, databases of the observed data have been constructed and maintained separately for each instrument or project, and thus the current situation of the database was quite different from each other. In addition, since the format of data files is different for each instrument and observation period, it was necessary to provide users with many varieties of routines for reading the files or ascii files converted from the original data.

We constructed a new database of the upper atmosphere during the Inter-university Upper atmosphere Global Observation NETwork (IUGONET) project. We decided to convert almost all kinds of data files to the Common Data Format (CDF), which is self-describing data format and widely used in the field of solar-terrestrial physics. The format can easily be read in various language, for example, C, Fortran, Java, Perl, IDL, and MATLAB with libraries provided by NASA. In particular, a set of IDL routines, UDAS, developed by the IUGONET team allows users to download, load, and visualize our data. The data conversion was carried out in collaboration with the ERG Science Center. At present, we are developing the system that automatically creates the CDF files, metadata files, and quick-look plots from data transferred from observatories in the polar region. In the presentation, we will show the current status and future prospects of the database.

国立極地研究所宙空圏研究グループでは、1957〜1958 年の国際地球観測年から長期にわたって、極域においてイメージャ、レーダー、磁力計、リオメータ等の多種多様な観測装置により超高層大気データを取得している。しかし、これらのデータのデータベースは観測装置、あるいは、プロジェクト毎に別々に構築されており、その整備・公開・利用状況に大きな差があった。また、データの種類や観測時期毎にファイルフォーマットが異なっており、ユーザーに複数の読み込みプログラムを提供する、または、一度アスキーファイルに変換してから提供する等の必要があった。

そこで、我々は大学間連携プロジェクト「超高層大気長期変動の全球地上ネットワーク観測・研究」（略称 IUGONET）の実施期間に、新たな超高層大気データベースを構築した。ここで、ファイルフォーマットは、ほぼ全ての種類のデータについて、太陽地球系物理学の分野で広く使われている自己記述型の Common Data Format（CDF）に統一することにした。このフォーマットは、NASA が提供するライブラリを利用することにより、C、Fortran、Java、Perl、IDL、MATLAB 等、様々な言語で読み込むことが可能である。特に、IUGONET プロジェクトで開発された IDL のライブラリ「UDAS」を利用すれば、容易にデータファイルのダウンロード、読み込み、描画が可能となる。このフォーマット変換は、同じく多様なデータの CDF 変換を行っている ERG サイエンスセンターと協力しながら行った。現在は、極域の観測点から転送されてくるデータファイルから自動で CDF ファイル、メタデータ、クイックルックプロットを生成するシステムの構築を行っている。講演では、極地研超高層大気データベースの現状と将来の展望について紹介する。

Capon法を用いた波数解析

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Wave vector determination using the Capon method

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Temporal and spatial variations cannot be separated using a dataset obtained by a single spacecraft. This issue can be resolved using datasets obtained by multi-point measurement, but we should keep in mind that, while the number of data points in the time domain can be quite large, that in the spatial domain is simply the number of spacecraft, which is only a few, typically. Usual data analysis techniques, such as Fourier decomposition, cannot be directly applied to such data.

One of the more sophisticated techniques to deal with data with small number of data points is Capon's method. In this presentation we study some of its fundamental properties (which are not well known at least to the knowledge of the present authors). Accuracy and sensitivity in determination of the wave numbers will be discussed, taking number of data points, number of waves included in the data, and the number of events for taking the event average, as external parameters. Influence of external noise will be presented also. Based on these results, we argue plausibility of analyzing wave number spectra of MHD turbulence, when it is expressed as superposition of many waves with different wave numbers.

単一衛星により得られたデータからは、空間と時間変化の分離が出来ない。これを解決するためには、複数衛星による多点データの取得が必要である。この際、時間に関しては観測継続時間とサンプリング時間の比に対応したデータ点が取得できるが、空間に関しては衛星数（通常は数基程度）だけのデータ点しか取得できないため、通常のフーリエ解析などの方法は空間データに対してはほとんど無力である。

データ点が少数である場合の解析法として様々な手法が提案されている。本研究ではその中でも比較的よく使われている Capon 法に着目し、まず、意外にも良く知られていないその基本的性質と雑音に対するロバストネスを検証する。観測点の数、データとして与える波の数、さらにイベント平均をとるためのイベント数を外部パラメータとして、Capon 法による解析が妥当であるための条件を呈示する。特に、磁気流体乱流のように多くのモードが混在する場合の波数同定の妥当性について検証した結果を報告する。