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PEM28-01 会場:302 時間:5 月 28 日 12:00-12:15

３次元磁気リコネクションにおけるアウトフロー構造
Outflow structure of 3D magnetic reconnection

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Magnetic reconnection is believed to be a key process in magnetospheric dynamics of the Earth, in particular, in magnetospheric substorms. Fast earthward flows are frequently observed in the near-Earth region of the magnetotail in association with substorms and are attributed to magnetic reconnection. The fast earthward flows are usually termed the bursty bulk flows (BBFs) and have a typical spatial scale in the y (GSM) direction with 2-3 Re (Re: Earth radii). The BBFs are considered to be the main transporter of the plasma momentum and energy in the magnetotail, and be responsible for the plasma heating at the depolarization fronts and aurora breakup in the polar ionosphere. However, the relation between the BBFs and magnetic reconnection is poorly understood yet. Main issue arises in the 3D characteristics. It is clear from the observations that the BBFs have a 3D structure, while the 3D dynamics of reconnection has not been revealed clearly, mainly because of the limitation of computer resources.

Since the BBFs have an MHD scale (much larger than the ion inertia length) in the y direction, the 3D MHD simulations have been carried out to investigate the generation mechanism in the course of magnetic reconnection. However, it has been suggested that the scale of the BBFs depends sensitively on the resistivity which is provided artificially at the x-line. Furthermore, for the case without the artificial resistivity, no BBFs arise in the system. These results from the MHD simulations imply that the BBF is an MHD-scale dynamics originated from kinetic physics, therefore the kinetic simulations are needed.

The 3D kinetic simulations of magnetic reconnection so far have focused on the dissipation mechanism at the x-line. Our previous particle-in-cell (PIC) simulations have found that the anomalous resistivity is generated due to a current sheet shear mode at the x-line and is enhanced significantly in association with plasmoid ejections. However, the system size in the y direction was only 10 ion inertia length in the previous simulations, so that the outflow structure was almost uniform along the y axis. The present study has challenged larger-scale PIC simulations in 3D with the help of the adaptive mesh refinement (AMR). The simulations are performed on the K, the state-of-the-art supercomputer of Japan. The system size is 40 ion inertia length in the y direction which is larger than the typical BBF scale. It is found that a larger-scale kink mode evolves around the x-line, in addition to the current sheet shear mode, and is enhanced due to plasmoid (flux lope) ejections. As a result, the thin current layer becomes more turbulent in the present simulations. The plasmoid ejections are three dimensional and have a scale of 10-20 ion inertia length in y, corresponding to the wavelength of the large-scale kink mode. This scale is roughly consistent with the BBFs scale. The ion outflow jets are also three dimensional and are regulated by the kink mode. The present results from large-scale 3D PIC simulation suggest that the outflow structure of 3D reconnection is determined by the large-scale kink mode arising along the x-line, which wavelength is comparable with the BBFs observed frequently in the near-Earth magnetotail.

Keywords: magnetic reconnection, particle-in-cell simulation, 3D dynamics, turbulence, outflow jet

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PEM28-02 会場:302 時間:5 月 28 日 12:15-12:30

地球磁気圏近尾部プラズマシート中のリコネクションアウトフロー
The Magnetic Reconnection Outflow in the Near-Earth Plasma Sheet

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In the near-Earth plasma sheet, earthward fast plasma flows over several hundred km/s are observed by in-situ satellites. These plasma flows are suddenly decelerated by the dominant dipolar magnetic field at around 10 Re. The following tailward rebound flows are also observed by them. In this paper, we studied the three dimensional evolution of these earthward and tailward flows using MHD simulation and analyses of GEOTAIL observation data during from 1995 to 2005.

キーワード: 地球磁気圏近尾部, 磁気リコネクション, プラズマ流, バウンスフロー
Keywords: Near Earth Plasma Sheet, Magnetic Reconnection, Plasma Flow, Bursty Bulk Flow, Bounce Flow

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PEM28-03 会場:302 時間:5 月 28 日 12:30-12:45

磁気流体シミュレーションで再現されたオーロラ爆発のエネルギー収支
Energy budget of the plasma sheet during auroral substorms

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Where is the magnetic energy for the expansion phase of auroral substorms accumulated? This question was raised by Akasofu (2013), and it was concluded that the magnetic energy must be accumulated in the plasma sheet within a distance of 10 Re to meet the large total energy consumption by the ionosphere. Many different features of substorms are reasonably reproduced by the new global MHD simulation (Tanaka et al., 2010), where high-pressure regions such as cusps and inner plasma sheet are essentially important to maintain the enhanced Region1 and Region2 field-aligned current systems. Both magnetic energy and thermal energy are therefore important to understand the energy budget during the substorm, and that is the motivation of the present study. The purpose of this paper is to evaluate the energy budget of the plasma sheet in a simulated substorm. Magnetic energy and thermal energy of the plasma sheet, as well as the energy consumption by the ionosphere are evaluated. Possible important role of dipolarization in the energy conversion is also discussed.

Using the global MHD simulation, it is found that magnetic energy release rate and thermal energy accumulation rate are balanced in the plasma sheet during the early expansion phase of the simulated substorm. Around the peak of the expansion phase, energy release rate in the plasma sheet does not meet the energy consumption rate in the ionosphere. External energy source from outside of the plasma sheet is needed to maintain the high auroral activity. The JxB force of the dipolarization does the work to increase the thermal energy inside. This is how the accumulated magnetic energy within a distance of 10 Re is converted into the thermal energy during the early expansion. The increase of the thermal energy is the source of enhanced Region-2 field-aligned current system. Region1 field-aligned current must be supplied from outside of the plasma sheet to maintain the high auroral activity in the ionosphere. The dynamo of Region1 is slow-mode expansion in the cusp-mantle region. The enhanced conductivity plays the essential role to introduce the large Region 1 field aligned current because the dynamo has the nature of voltage-generator.

キーワード: サブストーム, プラズマシート, オーロラ, 磁気流体力学
Keywords: Substorm, plasma sheet, aurora, Magnetohydrodynamics

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PEM28-04 会場:302 時間:5 月 28 日 14:15-14:30

AE および Dst の出現強度分布と太陽風パラメータ
Intensity distribution of AE and Dst and its relation to solar wind parameters

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Storm-substorm relationship and related solar wind-magnetosphere coupling process are studied on the basis of statistical analyses of AE, Dst, epsilon parameter and Em using OMNI data base from 1995 to 2013 and Wp index data from 2005. The statistical relationship between AE and Dst is examined to clarify the difference between CME storm and CIR storm. The intensity distribution of AE and Dst for a year is compared with that of epsilon and Em parameters in the solar wind.

The obtained major results are,

1). Relationship between AE at substorm and Dst is rather linear.

2). AE vs Dst relationship at CIR storm is different from that at CME storm.

3). Intensity distribution of AE and Dst for a year shows the exponential distribution.

4). Intensity distribution of epsilon parameter for a year shows the power low distribution.

5). Intensity distribution of Em for a year shows the exponential distribution.

6). The results 3) to 5) suggest that magnetospheric disturbances are mainly controlled by the solar wind electric field rather than by solar wind Poynting flux.

キーワード: サブストーム, 磁気嵐, 太陽風相互作用
Keywords: substorm, magnetic storm, solar wind interaction

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PEM28-05 会場:302 時間:5 月 28 日 14:30-14:45

シータオーロラの形成について
Possible Formation Scenario of Transpolar Aurora

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There might be two types of transpolar auroras, they say. 1) One type of the transpolar aurora appears in the pole ward edge of electron precipitations, which expanded from dawn side aurora oval or dusk side aurora oval depending on the IMF by polarity, as mentioned by Makita ea. al. (1991). The evidences were inferred from the satellite particle data together with aurora images taken by the low altitude polar satellites. This type of transpolar aurora, which is associated with relatively intense electron precipitations near the pole ward boundary, tends to become much more luminous, forming so-called theta aurora. 2) Another type of transpolar aurora is theta aurora, which appears under the conditions of strong northward IMF. This type of theta aurora is cause by a sign change of IMF By . (Tanaka et al, 2004) This transition includes a lobe field line replacement from old IMF originating fields to new IMF originating fields, rotation of plasma sheet to the opposite inclination, and reformation of ionospheric convection cell. In the midst of the reconfiguration, old and new convection systems must coexist in the magnetosphere-ionosphere system and the polar cap and tail lobes are continuously encroached by the new open field lines connected to the new IMF. Whereas magnetic field lines accumulated in new lobes tend to rotate the outer plasma sheet in the opposite direction, the old merging-cell convection still continues to generate closed field lines that must return to dayside against the new lobe formation. The growth of new lobes results in the blocking of the return path toward the dayside of closed field lines generated in the old merging cell to form the kink structure in the plasma sheet. Losing their return path, these closed field lines generated from old lobes accumulate on the nightside. The theta, then, appears at the foot points of these accumulated closed field lines. We have joined NASA IMAGE project, receiving real time telemetry data over Japan from 2000 to 2005. By investigating IMAGE data, we confirmed that two different processes actually exist. In the talk, we like to report our examination and discuss on the relationship between above mentioned two types of transpolar auroras.

キーワード: シータオーロラ, IMAGE 衛星, MHD シミュレーション
Keywords: Theta Aurora, IMAGE satellite, MHD simulation

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PEM28-06 会場:302 時間:5 月 28 日 14:45-15:00

極冠パッチと共存する極冠アークの発生
Coexistence of a polar cap arc and a polar cap patch

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極冠パッチの後縁に寄り添った極冠アークをスバールバルのロングイヤービエンに設置された全天イメージャ (ASI) で 2014 年 12 月 23 日に観測した。極冠パッチは惑星間空間磁場 (IMF) が南向きの場合に発生すること、また極冠アークは IMF が北向きの場合に発生することが知られている。さらに、IMF が南向きから北向きに反転した場合には極冠パッチと極冠アークが同時に出現することがあることが知られている。パッチとアークの同時出現についてこれまでの観測例では、両者は互いに遠く離れてはいない (すなわち、両者ともに観測機器の視野内にある) ものの、両者の位置には隔たりがあったことが知られている。それに対して、今回報告する観測例ではパッチとアークは近接していた。波長 630.0 nm の光の全天画像には、パッチがオーロラオーバルに進入する直前にパッチの後縁の輝度が突然上昇したことが記録されている。これらの画像はパッチのエッジに沿って細長い帯状のオーロラ発光があったことを示している。スバールバル・ダイナゾンデ（イオノゾンデ）の F 層臨界周波数 (foF2) 観測値から導出した F 層の最大電子密度 (NmF2) の時間変化は、天頂における 630.0 nm 光輝度の時間変化とよく一致しており、これは ASI で観測したパッチ状の像は確かにプラズマのパッチだったことを示している。また、ASI で観測した 557.7 nm 光輝度データは、パッチのエッジに沿った明るいアーク状の像がオーロラ発光によるものであることを示唆している。ACE 衛星による IMF 観測によると、このイベントの 1 時間前に IMF が南向きから北向きに反転していたことがわかっている。さらに、アークが現れたのとほぼ同じ時刻に F 層ドリフト速度の東西成分が反転したことがスバールバル・ダイナゾンデで観測されており、観測域の F 層に東西方向の速度シアが存在したことを示唆している。このことも、観測した明るいアークが確かにオーロラアークであったことを示している。このイベントの特異性は、これまで良く知られている南北に伸びた極冠アークとは異なり、アークが東西に伸びている点である。これらの観測事実をもとに、このアークの発生源についての考察を行う。

キーワード: 極冠パッチ, 極冠アーク, 極域電離圏, 磁気圏, アーク起源
Keywords: polar cap patch, polar cap arc, polar ionosphere, magnetosphere, arc origin

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PEM28-07 会場:302 時間:5 月 28 日 15:00-15:15

地磁気脈動 Pi2：伝搬性ループ電流が作る偏波分布
Substorm Pi2 pulsations: Polarization patterns caused by azimuthal propagation of ionospheric loop currents

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夜側オーロラ帯から中緯度に広がる Pi2 脈動の偏波特性（回転方向、主軸の向き）の分布の詳しい結果は Samson and Harrold によって 1983 年に公表された。Pi2 偏波分布はサブストームを背景にもつため複雑になる。

この複雑に見える偏波地図も一旦視点を変えてみるとその複雑さが消えてしまう事を報告する。さらに、この偏波地図から Pi2 に関する磁気圏エネルギー源やその振動モードに関する豊富な情報が得られることも報告する。

References:
Samson, J.C., and B. G. Harrold (1983), Maps of the polarizations of high latitude Pi2’s, J.Geophys.Res., 88, 5736-5744.

キーワード: 地磁気脈動 Pi2, オーロラ帯ループ電流
Keywords: Pi2 pulsation, Loop currents in auroral zone

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PEM28-08 会場:302 時間:5 月 28 日 15:15-15:30

地上及び磁気圏に於けるＰｉ磁気波動とサブムトームの発達
Comparisons of Pi pulsations and substorm developments observed on the ground and in the near-earth magnetotail

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We present unique results of recent work for comparisons of Pi pulsations and their relation to substorm developments observed on the ground and in the night-side magnetotail. The observations of Pi pulsations and aurora on the ground and of the magnetic field oscillations at the geosynchronous orbit and in the near-earth magnetotail are examined in detail. The expansion onset of a substorm examined was registered at 0512 UT on 4th April 2009. Pi pulsations appeared to oscillate from 0502 UT about 10 minutes earlier than the expansion onset. The Pi pulsations initiated with a small amplitude oscillation in association with faint appearance of auroral luminousity oscillations concurrently to the Pi 2 oscillations. The auroral luminousity oscillations became clear from 0506 UT in association with the clear appearance of the Pi 2 oscillations, particularly in the magnetic field D component oscillations. The large amplitude Pi 2 oscillations began to appear suddenly from 0509 UT accompanied with a slight poleward movement of the auroral activity, and then the aurora began to move suddenly poleward from 0512 UT with the auroral luminosity enhancement, which is the expansion onset. For about 3 minutes after the expansion onset the aurora continued to activate at the poleward site. Then the aurora became weak and moved gradually to the lower latitude side from 0515 UT, but the Pi 2 oscillations still continued to oscillate. During this substorm activity Pi 2 oscillations were clearly observed simultaneously at the geosynchronous orbit by GOES 11 and GOES 12 in the pre and post midnight sector, respectively, which provided very interesting oscillation signatures, i.e., the antiphase oscillations in the horizontal components of the magnetic field, implying that the polarization of the magnetic field horizontal components was opposite each other, suggesting the opposite flow direction of the field-aligned currents (FACs), that is upward and downward in the pre and postmidnight sector. Thus these observations at the synchronous orbit represent clear evidence of Pi 2 oscillations as substorm current wedge FAC oscillations. While, the observations by the THEMIS satellites located in the near-earth magnetotail at the radial distance from – 10 Re to – 13 Re provided a very important indication concerning to the growth of Pi oscillations and substorm processes in the near-earth magnetotail. For the most earthward satellite, THEMIS A (THA) observed small amplitude magnetic field perturbations from 0505 UT almost simultaneous to the clear appearance of the Pi 2 oscillations on the ground and at the geosynchronous orbit, and then the magnetic field perturbations became to oscillate gradually in the amplitude, which continued until 0513UT, when the dipolarization signature appeared at this site. While, the THEMIS E (THE) satellite located a little tailward nearest to the THA observed the gradual increase of the magnetic field intensity from 0504 UT and then observed the field decrease from 0507 UT associated with the plasma pressure increase. The dipolarization and associated plasma depression appeared at 0512UT. Thus, the dipolarizations observed at the THEMIS satellites was almost coincident to the expansion onset on the ground. These are summaries in this work, which indicate the close relation between Pi oscillations observed on the ground and substorm processes in the ionosphere, at the synchronous orbit and in the near-earth magnetotail.

キーワード: Ｐｉ　磁気波動, サブストーム, 磁気圏
Keywords: Pi oscillations, substorm, magnetosphere

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PEM28-09 会場:302 時間:5 月 28 日 15:30-15:45

サブストーム回復相のオーロラパッチ中に現れる下部熱圏風速変動
Lower-thermospheric wind variations in auroral patches at the substorm recovery phase

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ノルウェー・トロムソに設置したファブリペロー干渉計 (FPI; 557.7 nm) で下部熱圏風速を測定したところ、サブストーム回復相にオーロラパッチが出現するのに連動し、一晩の中で最大振幅の風速変動がとらえられた。サブストームの時間発展における磁気圏でのプラズマエネルギーの蓄積と放出過程（即ち、成長相にプラズマシート付近に蓄積されたエネルギーの主要部分が短時間の拡大相に放出）を考えると、活動後期の回復相に風速変動が最大になることは興味深い結果であり、磁気圏と極域超高層大気におけるエネルギー輸送過程と散逸過程を理解する上で、本現象の理解は非常に重要であると言える。

本研究では太陽風・地磁気・オーロラ画像・FPI 風速データを用いたサブストーム回復相の磁気圏－電離圏－熱圏結合の総合解析を初めて詳細に実施している。今回は 2010 年 11 月から 2012 年 1 月までの 5 イベントを取り上げ、特にオーロラ形態と風速変動領域との関係に着目することで、全てのイベントにおいて以下 3 点の特徴を見出した: (1) 風速変動はオーロラパッチの縁あるいは周辺より暗い部分に孤立して現れ、その振幅は鉛直風で最大 20 m/s 程度、時間スケールは約 10 分以下である、(2) 電離圏対流電場は 15 mV/m よりも小さい、(3) 脈動オーロラを伴う。これらの事実から風速変動を発生させるエネルギー散逸もパッチ状に局在していると考えられる。対流電場が小さいため、大気の加速機構としてジュール加熱やローレンツ力は考えにくい。これはサブストーム成長相や拡大相における風速変動の発生機構と異なる特徴である。風速変動がパッチの暗い部分に集中していることから粒子加熱も主要な発生機構とは考えられない。何かしら他の物理機構が主要な役割を担うと想像されるが、まだ特定には至っていない。

キーワード: オーロラ, サブストーム, ファブリペロー干渉計, 電離圏, 熱圏, 極域
Keywords: aurora, substorm, Fabry-Perot interferometer, ionosphere, thermosphere, polar region

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脈動オーロラの準周期的空間変調
Quasi-periodic spatial modulation of pulsating aurora

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A quasi-periodic intensity modulation of pulsating auroras has been considered to be formed by pitch-angle scattered electrons with whistler-mode chorus waves, because the intensity modulation is consistent with the time scale of chorus elements. A 2-D simulation study showed the latitudinal displacement of chorus elements from the magnetic field line, and the Cluster satellites observed oblique propagations of chorus waves close to the equator. These oblique chorus waves may be seen as the quasi-periodic spatial modulations of the pulsating aurora in the ionosphere. The purpose of this study is to examine the oblique propagation of chorus elements as a possible mechanism of the spatial modulations of the pulsating aurora. We used data obtained by a highly sensitive sCMOS camera installed at Poker Flat Research Range (PFRR) in Alaska from February to April 2014. The imaging sensor of 2048 x 2048 pixels and the narrow field of view of 15 x 15 degrees enable us to identify the smallest auroral structure ever observed. The field of view approximately corresponds to 27 km x 27 km at 100 km altitude, and the spatial resolution is ˜52 m when 4 by 4 binning is used. From the initial analysis of a magnetic storm event on February 19, 2014, we found several events of spatial variations of small-scale (5 km across on average) elongated patches during the ON-phase of the main pulsating patch. The typical propagation speed of the small elongated patches is an order of 50 km/s at the 100 km altitude, which corresponds to an order of 1000 km/s in the magnetosphere. In the presentation we add some more storm events to show statistical results of the propagation directions and the speed, the scale-size, and the periodicity of small-scale pulsating auroral patches to compare with the simulated results of chorus wave-electron interactions which may form the spatial variations of pulsating patches in the ionosphere.

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広視野偏光分光観測によるオーロラ発光の偏光特性
Characteristics of polarization in auroral emissions based on wide-field polarization spectroscopic observation

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近年のオーロラ偏光観測から、630nm 発光が最大で 17 %偏光する可能性が示唆されている (Bommier et al., 2011)。しかし、その特性や他の波長のオーロラ偏光はよくわかっていない。本研究では、630nm オーロラに加えて、557.7nm オーロラの直線偏光を世界で初めて同時測定し、磁気子午線に沿った偏光の仰角分布を長期間にわたって捉えることを目的とし、広視野偏光分光器と、大気の散乱による偏光を定量的に校正可能な変光望遠鏡を新たに開発した。

この広視野偏光分光器は、魚眼レンズ、回転ステージに装着したワイヤーグリッド型直線偏光子、VPH 透過型回折格子ならびに EMCCD 検出器から構成され、450nm から 710nm の波長範囲で波長分解能 2.0nm、視野角 130 度を有する。オーロラ偏光を 1%以下の高精度を測定するための鍵となるのは器械偏光の校正である。このために、既知の偏光状態を持つ光を視野 130 度内で 3 度毎に入射し、偏光子を回転させながら強度変化を測定する装置と解析方法を確立した。

観測は、2014 年の 11 月から 12 月にかけてアラスカ・ポーカーフラットにおいて行われた。一晩を通じてオーロラの活動が活発だった 2014 年 11 月 20 日晩の解析結果から、630nm オーロラの直線偏光度は磁気子午線に沿った磁北側の低仰角（～10 度）で 8%と大きい値を取り、仰角が上がるにつれて仰角～80 度で 1 %程度まで減少し、磁気天頂付近から磁南側の低仰角側で再度偏光度が上昇していくといった仰角依存性が確認された。その傾向は他の観測日でも確認された。一方で、理論的に偏光していないとされる 557.7nm オーロラについても、オーロラ活動が活発な場合では平均的に 10%以上の直線偏光を示す観測結果が得られた。

さらに、降り込み電子の平均エネルギーに対する直線偏光度の対応を捉えるために、磁気天頂付近における 557.7nm と 630nm の発光強度比と直線偏光度の関係性を調べた。その結果、630nm オーロラの直線偏光度は 630nm 発光強度の割合が大きくなるにつれて、つまり低エネルギーの降り込み電子の割合大きくなるにつれて、1%程度大きくなることが確認できた。この関係性にはばらつきが大きく、降下電子エネルギー以外の他の要因（ピッチ各分布等）を今後の研究では考慮する必要がある。

キーワード: オーロラ, 偏光, 装置開発
Keywords: aurora, polarization, development

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無人システムを利用したオーロラ現象の南極広域ネットワーク観測
Antarctic large area network observation of auroral phenomena using unmanned system

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国立極地研究所（極地研）の宙空圏研究グループは、平成 28 年度（2016 年度）から始まる次期南極観測計画期間中に、無人観測システムを利用した、オーロラ現象の地上ネットワーク観測を計画している。本講演では、その計画の概要紹介を行う。

同グループは、これまで、昭和基地周辺の磁気緯度 66 度～72 度、磁気経度 60 度～85 度の領域内の 8 か所に無人磁力計網を展開してきている。内陸のドームふじ基地までのルート沿いの 3 か所（みずほ、中継拠点、ドームふじ）には、英国調査所（British Antarctic Survey (BAS)）が開発した無人磁力計が、沿岸域の 5 か所（アムンゼン湾、H68、インホブデ、スカーレン、セールロンダーネ）には、極地研が開発した衛星通信機能を備えた無人磁力計が、それぞれ設置され、3 成分フラックスゲート磁力計による 1 秒値通年連続観測が行われている。現在実施中の第Ⅷ期南極観測計画では、新たに、磁力計に加えオーロラ全天カメラと GNSS/TEC 観測機も備えた「無人オーロラ観測装置」の開発が行われており、2015 年度には 1 式を、昭和基地から約 300km 東に位置するマラジョージナヤに設置する予定である。次期の第Ⅸ期南極観測計画では、新たに無人オーロラ観測装置 1 式を、昭和基地から約 800km 西に位置するセールロンダーネ地域に設置し、さらにその西側に位置するインドのマイトリ基地や南アフリカのサナエ基地とも共同して、磁気緯度 62 度～72 度、磁気経度 45 度～85 度の範囲のオーロラ帯からサブオーロラ帯までに及ぶ領域において、オーロラ現象の広域ネットワーク観測を行うことを計画している。このような観測点網により、以下のような目的の観測を行う：

1．サブストームオンセットメカニズムの解明：

オンセット領域の周囲にオンセット前後に現れる現象の時間・空間変化を 1 秒精度で観測し、ERG 衛星など磁気圏衛星との同時観測により、オンセットメカニズムの解明を目指す。具体的には以下のような課題に解答を与えるデータを得ることを目的とする。（1）高緯度側からの streamer は本当にオンセットに関係しているのか？（2）オンセット直前の beads 構造はオンセットに本質的なのか？（3）オンセット領域の局在化はどのように進行するのか？

2．オーロラ現象の共役性の時間空間変動の解明：

南北両極域での同時観測により、太陽風変動や磁気圏電離圏現象に伴う磁気圏構造の時間空間変化の解明を目指す。特に以下の課題に着目する。（1）サブストーム発達に伴う急激な磁気圏構造変化に対応した共役点位置やオーロラ形態の共役性の変化

3．サブストーム時、ストーム時に発生する波動－粒子相互作用過程の解明：

オーロラ、磁場、銀河雑音電波吸収（CNA）、VLF 波動、ULF 波動の同時観測により、粒子降下と波動現象に見られる相関関係とその時間空間変化の解明を目指す。特に以下の課題に着目する。（1）オンセット時の Pi2 や Pi1 周期の磁場変動と粒子降下変動との関係、（2）サブストーム時のインジェクションと、ＮＳオーロラ、脈動オーロラ、Pi1C 波動、VLF 波動発達との関係、（3）ストーム時のリングカレントや放射線帯の変動と、オーロラ粒子降下、高エネルギー粒子降下、VLF 波動、ULF 波動の発達との関係。

キーワード: 無人観測, 広域ネットワーク, オーロラ現象, 共役性
Keywords: unmanned observation, large area network, auroral phenomena, conjugacy

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磁気嵐時の高エネルギーイオンの位相空間密度特性
Properties of energetic ion PSD during magnetic storms observed by Van Allen Probes

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It is observationally known that the contribution of O+ ions to the ring current increases with increasing size of magnetic storms, while H+ is the main component of the ring current ions during small storms. Ion injection from the magnetotail caused by substorms is considered as one of the principal mechanisms that supply energetic ions to the ring current region. However, the dependence of the ion injection properties on ion species (such as the depth of ion injection into the inner magnetosphere) is far from well understood as is the role of injection itself. To characterize the ion supply to the ring current during magnetic storms, we investigate in this study the properties of energetic H+ and O+ phase space densities (PSDs) during geomagnetic substorms observed by the Van Allen Probes mission. We examine substorms that occurred during the periods of April 23, 2013 to April 28, 2013, April 29, 2013 to May 5, 2013, and March 15, 2013 to March 20, 2013. Using energetic ion (greater than 50 keV) and magnetic field data obtained by the RBSPICE and EMFISIS instruments onboard Van Allen Probes, we study the temporal variations of H+ and O+ PSD spatial distributions and compare their properties during each of the substorm events.

We calculated the first adiabatic invariant, mu, and PSD for ions within a pitch angle range from 70 to 110 degrees. PSDs for specific mu values (mu = 0.3, 0.5 and 1.0 keV/nT) were obtained as a function of L for each ion species for each orbit of Van Allen Probes during each substorm. We identified a sudden increase in each PSD spatial distribution as an injection boundary. The results for the period of April 23-28, 2013 show that both H+ and O+ ions penetrated directly down to L<5 during the main phase of the magnetic storm (minimum Dst greater than -65 nT). The penetration boundary of H+ ions was located at smaller L at dusk than at dawn. We also find that H+ ions with smaller mu values (mu = 0.3 and 0.5 keV/nT) penetrated earlier than those with larger mu values (mu = 1.0 keV/nT). In contrast, the timing of O+ penetrations is almost the same for all O+ ions regardless of the mu values. The results also show that O+ ions penetrated more deeply in L and earlier in time than do the H+ ions. These results taken together suggest that the source of the injected O+ ions is located closer to Earth than that of the protons (the inner edge of the plasma sheet) and therefore suggest the importance of the contribution of subauroral O+ ions to the storm-time ring current.

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Van Allen Probes 衛星を用いた磁気音波波動の統計解析
Statistical analysis of magnetosonic waves from the Van Allen Probes data

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Magnetosonic waves (MSWs) are X mode electromagnetic emissions seen at between the proton cyclotron frequency and the lower hybrid resonant frequency. Their magnetic field fluctuations have a linear polarization. It has been suggested that MSWs can contribute to the acceleration of relativistic electrons in the radiation belts. In this study, we statistically investigate plasmaspheric MSWs using data from the EMFISIS instrument onboard the Van Allen Probes. The MSWs occur at all local times but in this study we observe them mainly on the dayside and during both magnetically quiet and active periods. We also investigate the polarization of MSWs using the spectral matrix. At L<1.5, the polarization of at the lower frequency component of MSWs changes from R-mode to X-mode. At the same location, there are some L-mode waves that may be converted from the R-mode waves below the cross-over frequency. These L-mode waves may contribute to the plasmaspheric EMIC waves deep in the plasmasphere.

キーワード: 磁気音波, 内部磁気圏, Van Allen Probes, EMIC
Keywords: MSW, inner magnetosphere, Van Allen Probes, EMIC

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地球放射線帯電子の消失過程に関する研究: 磁気圏界面からの流出の評価
Loss processes of outer radiation belt electron: Contribution of magnetopause shadowing

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The Earth's radiation belts consist of the inner and outer radiation belts, and these regions are composed of highly energetic electrons. Especially in the outer radiation belt, the energetic electron fluxes are highly variable during magnetic storms. Energetic electrons in the radiation belts sometimes cause satellite charging, resulting in gradual degradation of instruments and devices onboard satellites. Therefore, it is important to understand basic physics of the energetic electron variation in the outer radiation belt from the point of view of space weather. It has been considered that the drastic change of the outer radiation belt is controlled by the delicate balance between transport, acceleration and loss processes. However, each process has complex physical mechanisms and there remain still much outstanding questions.

In this study, we particularly focused on the loss processes. As a possible loss process, (i) precipitation to the atmosphere, (ii) Dst-effect and (iii) direct loss from the magnetopause (magnetopause shadowing) have been considered. The correlation between the magnetopause location and the outer boundary of the outer radiation belt was reported by Matsumura et al. [2011]. Turner et al. [2012] suggested that a rapid depression of outer belt electrons is caused by the sudden inward shift of the magnetopause and subsequent enhancement of outward radial diffusion. However, the regions where electrons escape and how the magnetopause shadowing effect reaches smaller L-value are still open questions.

In order to understand the effect of magnetopause shadowing, we used the concept of the drift shell splitting. Due to the asymmetric configuration of Earth's magnetosphere, charged particles which have different pitch angles drift along the different drift shells. On the dayside, particles whose pitch angles are closer to 90 degrees have drift shells closer to the magnetopause. It is expected that, as a result of magnetopause shadowing, the pitch angle distribution will be the butterfly distribution. To investigate this hypothesis, we used Solid State Telescope (SST) onboard the THEMIS satellite and analyzed pitch angle distributions of energetic electrons.

Our result shows inward shift of dominant region of butterfly distribution when the magnetopause is compressed. We consider that this change is caused by the effect of inward shift of the magnetopause. However, the correlation coefficient between the magnetopause standoff distance and the shadowing region (the region where the effect of magnetopause shadowing is observed in the pitch angle distributions) is relatively low. It is because the effect of drift shell expansion due to the enhancement of the ring current. Then we calculate the largest $L*$ which has last closed drift shell, $L*max$ [Koller and Zaharia, 2011] and compared $L*max$ with shadowing regions. The result shows good correlation and it supports the scenario that the electron loss is caused by the magnetopause shadowing.

However, our result also shows a little difference between loss and shadowing region. It means that the other loss processes are necessary to explain the total loss of outer belt electrons. We investigate this difference of the two by calculating 1-D Fokker Planck radial diffusion model. The simulation result supports the Turner's scenario, magnetopause shadowing and subsequent enhancement of outward radial diffusion. However, strong radial diffusion coefficients are required to explain observation.

We also consider the precipitation loss to the atmosphere by using POES. POES can detect strong precipitation events. However, these precipitation events are not detected for all the events, there are some events which we can rarely detect strong precipitations. Thus, it is suggested that precipitation loss is not the main cause of loss but just the subsequent loss. However, we need to investigate further about precipitation loss.

キーワード: 放射線帯, 消失過程
Keywords: radiation belt, magnetopause shadowing, drift shell splitting, loss process

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あけぼの衛星搭載 PWS によるサウンダ観測：2015 年観測の初期結果
Topside sounding of upper ionosphere by EXOS-D/PWS in 2015

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We present initial results of sounder experiments by the Akebono (EXOS-D) satellite conducted in March-April 2015.

Plasma wave sounder experiments have been conducted by Stimulated Plasma Wave experiment (SPW) subsystem of Plasma Wave and Sounder experiments (PWS) on board the Akebono satellite in the topside ionosphere and plasmasphere [Oya et al., JGG 1990]. The sounder experiments have two main purposes: One is the remote sensing of the topside ionosphere including polar region and inner plasmasphere, and another is active experiments by the stimulation of plasma waves in space. Both of them have been successfully conducted by the SPW subsystem of Akebono/PWS.

During March-April 2015, we carry out sounder experiments by the Akebono satellite in both polar region and equatorial region of ionosphere/plasmasphere. In this paper we study echoes obtained by the experiments and derived altitude profile of the plasma density of the topside ionosphere. We also investigate plasma resonances appeared in ionograms and discuss their generation mechanism based on the weak turbulence theory of the sequence of diffuse plasma resonances [e.g., Oya, 1970].

キーワード: サウンダ観測, 上部電離圏
Keywords: topside sounding, upper ionosphere

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日本経度帯のプラズマ圏密度季節変化：地上磁場に FLR 同定 2 点法を適用した長期間連続測定
Seasonal dependence of the plasmaspheric density along the 210MM: Continuous observations by ground magnetometers

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In this paper we have applied the cross-phase method and the amplitude-ratio method to the MAGDAS/CPMN ground magnetometers MGD (Magadan) and PTK (Paratunka, Kamchatka), located in the Russian Far East along the 210MM (Magnetic Meridian), and identified FLR (field-line resonance) events. MGD is located at (53.6, 219.1) magnetic latitude and longitude [deg], and PTK is located at (46.2, 226.2). Their L values are 2.9 and 2.1. We have identified the FLR events by using both visual inspection and an automatic-identification computer code.

Although the two magnetometers are separated by about seven degrees in magnetic latitudes, which is larger than the typical separation (about 1-2 degrees) for which the cross-phase and amplitude-ratio methods are efficient, but we could identify more than a hundred FLR events a year from the MGD/PTK-pair data, and the FLR events had a fairly continuous coverage from January to December.

In this paper we estimate the plasmaspheric density from thus obtained FLR frequencies, and examine their seasonal dependence. The result suggests a weak, but marginally significant seasonal dependence with maxima in winter and minima in summer. More details will be discussed at the presentation.