ERG搭載中間エネルギー粒子分析器(MEPs)の地上較正試験結果

Ground calibration results of Medium-Energy Particle analysers (MEPs) for ERG

*笠原 慧[1]、横田 勝一郎[1]、三谷 烈史[1]、浅村 和史[1]、平原 聖文[2]、高島 健[1]、山本 和弘[3]
*Satoshi Kasahara[1], Shoichiro Yokota[1], Takefumi Mitani[1], Kazushi Asamura[1], Masafumi Hirahara[2], Takeshi Takashima[1], Kazuhiro Yamamoto[3]

1.宇宙航空研究開発機構宇宙科学研究所、2.名古屋大学、3.京都大学
1.Institute of Space and Astronautical Science/ Japan Aerospace Exploration Agency, 2.Nagoya University, 3.Kyoto University

ERG (Exploration of energization and Radiation in Geospace) is the geospace exploration spacecraft, which is planned to be launched in FY2016. The mission goal is to unveil the physics behind the drastic radiation belt variability during space storms. One of key observations is the measurement of ions and electrons in the medium-energy range (10-200 keV), since these particles excite EMIC, magnetosonic, and whistler waves, which are theoretically suggested to play significant roles in the relativistic electron acceleration and loss. In previous space missions, however, the medium-energy range has been the missing region due to the limitation of conventional particle instruments. We present unique techniques, which are essential to challenge this difficult energy range, and report the ground calibration results of the instruments.

キーワード：ERGミッション、中間エネルギー粒子分析器
Keywords: ERG mission, Medium-Energy Particle analysers

First observation of whistler-mode chorus with wavy tones

*Zhonglei Gao[1]

1.University of Science and Technology of China

Whistler-mode chorus emissions usually appear as rising tones, falling tones, constant tones, hooks and hiss-like band. Here we report a new type of chorus with “wavy tones” observed by Van Allen Probes. The frequency of chorus rose by up to 500 Hz within ~0.5s and then fell back within ~0.7s. This behavior repeated to give a wavy pattern and the continuous wavy structure lasted for ~10s. At the same time, rising tones and hiss-like band occurred above and below the wavy tones. The generation mechanism of chorus with wavy tones need to be further investigated.

ELF/VLF wave generation associated with magnetospheric compression: conjugated observations from satellite- and subauroral ground-based instruments.

*Claudia Martinez Calderon[1], Kazuo Shiokawa[1], Kunihiro Keika[1], Mitsunori Ozaki[2], Ian Schofield[3], Martin Connors[3], Craig Kletzing[4], Ondrej Santolik[5]

1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University, 3.Athabasca University Observatories, Athabasca, Alberta, Canada, 4.Department of Physics and Astronomy, University of Iowa, Iowa, USA, 5.Institute of Atmospheric Physics, Prague, Czech Republic

On February 2012, during the VLF-CHAIN campaign a VLF loop antenna was installed at the Athabasca University Geophysical Observatory in Alberta, Canada. The receiver, located at subauroral latitudes (ATH, 54.7N, 246.7E, L=4.3), has continuously monitored ELF/VLF emissions since September 2012. We found a rare conjugate event of ELF/VLF waves between ATH and the RBSP-B satellite, which was associated with strong magnetic compression.
On December 23, 2014 at 11:17 UT (03:17 MLT), both ATH and RBSP-B observed a chorus-like burst centered at ~2.5 kHz showing discrete elements and lasting approximately 3 minutes. This emission was observed 2 to 3 minutes after an intense sudden commencement (SYM-H amplitude ~63 nT) caused by the enhancement of solar wind speed (~330 to ~420 km/s) and dynamic pressure (~2 to 6 nPa) during northward IMF. The increasing magnetic field on the dayside, caused by the compression of the magnetosphere, lead to betatron acceleration of plasma-sheet electrons and thus enhancement of the temperature anisotropy. This anisotropy regulates electron cyclotron instability and in turn, generates whistler-mode plasma waves.
We use survey and burst mode electric and magnetic field data from RBSP-B, combined with electron fluxes and density, to discuss the characteristics of the waves. We found that wave vectors are highly oblique and frequency dependent (lower k-vector with higher frequencies). We also found that the Poynting vector was anti-parallel to the field line, directed southwards, away from the magnetic equator. Even though this emission was associated with a slight increase of the electron fluxes between 75 to 743 keV (due to the adiabatic compression), it did not cause local relativistic electron acceleration.
All-sky and horizon imagers located at ATH allow investigation of the relationship of the compression with auroras.

Keywords: ELF/VLF, magnetospheric compression, conjugate event, subauroral latitudes

Statistical characteristics of quasi-periodic Pc1/EMIC waves in the magnetosphere and the ionosphere

*Chae-Woo Jun[1], Kazuo Shiokawa[1], Kazue Takahashi[2], Kristoff Paulson[3], Martin Connors[4], Ian Schofield[4], Igor Poddelsky[5], Boris Shevtsov[5], Craig Kletzing[6], John Wygant[7]

1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Space Physics Group (SRP), Johns Hopkins University Applied Physics Laboratory, USA, 3.Space Science Center, University of New Hampshire, Durham, NH, USA, 4.Athabasca University Observatories, Athabasca, Alberta, Canada, 5.Institute of Cosmophysical Research and Radiowave Propagation, Far Eastern Branch of the Russian Academy of Sciences, Russian Federation, 6.Department of Physics and Astronomy, University of Iowa, Iowa, USA, 7.School of Physics and Astronomy, University of Minnesota, Minnesota, USA

Pc1 pearl structure is a quasi-periodic amplitude modulation of Pc1 pulsations with repetition periods of several tens of seconds. In previous studies, Pc1 pearl structures have been frequently observed on the ground, but only sparsely in space. In order to understand the generation and propagation mechanisms of the pearl Pc1 waves, we investigated the statistical characteristics of quasi-periodic (QP) and randomly structured (RS) EMIC/Pc1 waves in the magnetosphere and in the ionosphere, using ground induction magnetometers located at Athabasca (ATH, L = 4.3) in Canada and Magadan (MGD, L = 2.7) in Russia and the Van Allen Probes (RBSP-A and B) satellites located in the inner magnetosphere. From data covering a one-year period from August 2012 to August 2013, we found a total of 590 hours of Pc1 events at ATH, 295.4 hours at MGD, and 73 hours at RBSP-A, 75.8 hours at RBSP-B. By comparing the observations at ATH and MGD, we found that the occurrence of RS Pc1 waves is independent of UT and that QP Pc1 waves occur concurrently with typical Pc1 waves detected at subauroral latitudes. We also found that on the ground QP Pc1 waves are observed more often than RS Pc1 waves (69 % at ATH, and 68 % at MGD). At RBSP-A and B, EMIC waves exhibit a peak occurrence at L~6 and in the morning sector. In space, the QP and RS EMIC waves occurred at similar rates. QP EMIC waves are observed most often in the He^+ band, at L~4.5, and in the morning and dusk sectors. RS EMIC are frequently observed at L~5 from the midnight to morning sector. From these observations we conclude that the L and local time occurrence pattern of QP/RS EMIC differs between space and ground. To understand the source of the difference, we examined the propagation and polarization characteristics of pearl Pc1 waves that were simultaneously detected at magnetically conjugate locations on the ground and in space.

Keywords: Pc1 pearl structures, ground and space observations, conjugate events

THEMIS衛星を用いたEMIC rising tone の統計的解析
A statistical study of EMIC rising and falling tone emissions observed by THEMIS.

*中村 紗都子[1,2]、大村 善治[2]、Vassilis Angelopoulos[3]
*Satoko Nakamura[1,2], Yoshiharu Omura[2], Vassilis Angelopoulos[3]

1.京都大学大学院理学研究科地球惑星科学専攻 地球物理学分野、2.京都大学生存圏研究所、3.UCLA
1.Department of Geophysics, Graduate School of Science, Kyoto University, 2.RISH, 3.UCLA

Electromagnetic ion cyclotron (EMIC) waves with rising or falling frequency variations have been studied intensively because of their effects on energetic particles in the Earth’s magnetosphere. We develop an automated classification method of EMIC events based on the characteristics of frequency variations. We report some basic statistical properties of frequency variations in EMIC waves observed by three Time History of Events and Macroscale Interactions during Substorms (THEMIS) probes from January 2012 to December 2014. We clarify whether rising-tones or falling tones are observed in each 20-minute time segment. In the present analysis, we find that the occurrence rate of EMIC rising- or falling tone events is more than 30 % of the total EMIC wave events. The dayside magnetosphere is a preferential region for the EMIC frequency variations. The occurrence rate of rising tone events is slightly greater than that of falling tone events. We examine the relation between the frequency characteristics and the magnetospheric conditions. The solar wind pressure strongly controls the occurrence rates of frequency variations. We also calculate ranges of frequency variations. Large amplitude EMIC waves tend to have wider frequency variations and the range of frequency variation is largest around the pre-noon region. In addition, the fine-structures in wave amplitudes called “sub-packet structures” are found in 70 % of EMIC rising- or falling- tone events in the dayside region. Sub-packet structures appear mainly in large amplitude EMIC rising or falling tones. These features are consistent with nonlinear wave growth theory.

キーワード：電磁イオンサイクロトロン波、非線形
Keywords: EMIC, nonlinear

レイトレーシング法によるプラズマ圏内における磁気音波からEMIC波動へのモード変換過程の解析
Ray tracing of mode conversion process from magnetosonic mode waves to EMIC waves inside plasmasphere

*野村 浩司[1]、三好 由純[1]、桂華 邦裕[1]、小路 真史[1]、栗田 怜[1]、町田 忍[1]、北村 成寿[2]、Santolik Ondrej[3,4]、Kletzing Craig[5]、Boardsen Scott[6,7]、笠原 禎也[8]
*koji nomura[1], Yoshizumi Miyoshi[1], Kunihiro Keika[1], Masafumi Shoji[1], Satoshi Kurita[1], Shinobu Machida[1], Naritoshi Kitamura[2], Ondrej Santolik[3,4], Craig Kletzing[5], Scott A Boardsen[6,7], Yoshiya Kasahara[8]

1.名古屋大学宇宙地球環境研究所、2.ISAS/JAXA、3.Institute of Atmospheric Physics CAS, Prague, Czech Republic、4.Charles University in Prague, Czech Republic、5.The University of Iowa, Iowa City, USA、6.Goddard Planetary Heliophysics Institute, University of Maryland, Baltimore Country, Baltimore, Maryland, USA、7.Division, NASA/GSFC, Greenbelt, Maryland, USA more, Maryland, USA、8.金沢大学
1.Institute for Space-Earth Environmental Research, Nagoya University, 2.ISAS/JAXA, 3.Institute of Atmospheric Physics CAS, Prague, Czech Republic, 4.Charles University in Prague, Czech Republic, 5.The University of Iowa, Iowa City, USA, 6.Goddard Planetary Heliophysics Institute, University of Maryland, Baltimore Country, Baltimore, Maryland, USA, 7. Division, NASA/GSFC, Greenbelt, Maryland, USA more, Maryland, USA, 8.Kanazawa University

Magnetosonic waves (MSWs) are electromagnetic emissions of X-mode waves, which are typically generated at frequencies between the proton cyclotron frequency and the lower hybrid resonant frequency. Our previous studies using the Van Allen Probes EMFISIS data indicated that MSWs converts to EMIC waves inside the plasmasphere when the frequency of MSWs corresponds to the cross over frequency, so that plasmaspheric MSWs can be an origin of plasmaspheric EMIC waves. In order to investigate the mode conversion process from MSWs to EMIC waves inside the plasmasphere in more detail, we perform the ray tracing simulation for MSWs generated inside plasmaspshere, using the code developed by Kanazawa University. In this simulation, the initial wave normal angle is almost 90 deg. The ray of waves depends on wave frequency if the initial wave azimuthal angle is almost 0 deg, i.e., earthward direction. On the other hand, the ray of waves does not depend on the frequency if the initial wave azimuthal angle is larger than 10 deg. Additionally, we confirm the mode conversion from R-mode to L-mode at lower frequency components of MSWs, while higher frequency components of MSWs remain R-mode. The simulation results are consistent with the Van Allen Probes observations which show the conversion of plasmaspheric MSW to EMIC waves.

キーワード：磁気音波、Van Allen Probes、モード変換
Keywords: magnetosonic waves, Van Allen Probes, mode conversion

Energetic Particle Hybrid Simulations on Geomagnetic Pulsations

Energetic Particle Hybrid Simulations on Geomagnetic Pulsations

*天野 孝伸[1]、三好 由純[2]、関 華奈子[1]
*Takanobu Amano[1], Yoshizumi Miyoshi[2], Kanako Seki[1]

1.東京大学 地球惑星科学専攻、2.名古屋大学 宇宙地球環境研究所
1.Department of Earth and Planetary Science, University of Tokyo, 2.Institute for Space-Earth Environmental Research

It has long been known that geomagnetic pulsations in mHz frequency range may be generated either by the field line resonance mechanism [Southwood, 1974, Chen and Hasegawa, 1974], or by local plasma instabilities [Southwood et al., 1969]. The former is essentially due to mode conversion from fast mode waves into local Alfven eigenmodes. The source of the waves are believed to be external, such as fluctuations in the solar wind and/or waves emitted by the Kelvin-Helmholtz instability at the magnetopause. Generally speaking, such externally driven waves are thought to generate pulsations with small azimuthal wavenumbers m ~ a few, which have been observed on the ground magnetometers. On the other hand, those generated by internal plasma instabilities may have high mode number m ~ 100. Such large wavenumber modes have been primarily observed by satellite measurements during storm times, associated with enhanced injection of ring current ions into the inner magnetosphere. The low-frequency geomagnetic pulsations can be an efficient driver for the radial transport of radiation-belt electrons. The classical drift resonance theory indicates that, despite relatively larger amplitude of internally driven modes, only externally driven modes can contribute to the radial diffusion [Elkington et al., 2003]. However, recent studies have suggested that the internally driven pulsations may also play a role [Ukhorskiy et al., 2009].
It is well known that the so-called drift-bounce resonance of energetic ring-current particles may be responsible for the generation of high mode number ULF waves. Although the idea of drift-bounce resonance is intuitively quite easy to understand, analysis of the instability in reality is much more complicated than this simple picture [Chen and Hasegawa, 1991, Cheng, 1991]. Earlier theoretical studies indicated that it is the inward ring-current pressure gradient that drives the instability via drift-bounce resonance between the fast energetic particles and MHD waves. To the authors knowledge, however, nonlinear simulations of this instability have not been performed so far.
According to the theoretical analysis, kinetic dynamics of the energetic ring current particles is essential for the instability, including finite Larmor radius effect, fast bounce motion along the magnetic field line, as well as finite drift across the magnetic field. On the other hand, a cold dense thermal population that dominates the total mass density but with negligible thermal pressure may well be approximated by MHD. This motivates us to adopt a new simulation model called the energetic particle hybrid simulation, in which the cold ions and electrons are approximated by fluids whereas the energetic population is treated as kinetic particles. By using this newly developed simulation model, we will discuss the internal generation mechanism of geomagnetic pulsations.
We have constructed a two-dimensional pressure-balanced equilibrium by iteratively solving a Grad-Shafranov-like equation for an anisotropic bounce-averaged ring-current pressure distribution in a dipole-like background magnetic field. We adopt this equilibrium as the initial condition for nonlinear simulations. Preliminary three-dimensional simulation results will be presented, focusing on, in particular, the dependence on the plasma beta, the scale length of the pressure gradient, and the temperature anisotropy.

キーワード：磁気圏、環電流、磁気流体波動
Keywords: magnetosphere, ring current, MHD waves

GEMSIS-RC及びRBシミュレーションに基づく放射線帯外帯電子と単色Pc5波動のドリフト共鳴の特徴に関する研究

Study on characteristics of drift resonance between outer radiation belt electrons and a monochromatic Pc5 wave based on GEMSIS-RC and RB simulations

*神谷 慶[1]、関 華奈子[2]、齊藤 慎司[1]、天野 孝伸[3]、三好 由純[1]、松本 洋介[4]、梅田 隆行[1]
*Kei Kamiya[1], Kanako Seki[2], Shinji Saito[1], Takanobu Amano[3], Yoshizumi Miyoshi[1], Yosuke Matsumoto[4], Takayuki Umeda[1]

1.名古屋大学宇宙地球環境研究所、2.東京大学理学研究科、3.東京大学地球惑星科学専攻、4.千葉大学理学研究科
1.Institute for Space-Earth Environmental Laboratory, Nagoya University, 2.Graduate School of Science, University of Tokyo, 3.Department of Earth and Planetary Science, University of Tokyo, 4.Graduate School of Science, Chiba University

地球内部磁気圏の電子放射線帯外帯には、磁気圏内で加速されたと考えられる相対論的電子が捕捉されている。こうした増減を引き起こす放射線帯電子の加速機構には、大別して外部供給説と内部加速説がある。このうち外部供給説は、Pc5帯 (周期5 - 10 分)のULF波動と地球磁場中での電子のドリフト運動の共鳴が引き起こす動径方向輸送による加速機構であり、電子の第1, 2断熱不変量が保存された状態で、第3断熱不変量が破られることにより、電子が磁場の強い地球方向へ輸送され断熱的にエネルギーを得るメカニズムである。従来、外部供給説は拡散的に電子を輸送すると考えられていたため、特定の第一断熱不変量を持つ電子の位相空間密度の動径方向分布がピークを持たないことが外部供給説の同定と内部加速説との観測的な切り分けに使われてきた(Reeves et al., 2013)。一方で、Pc5波動の性質によってはドリフト共鳴による電子の動径方向への輸送が、電子の位相空間密度の動径方向分布に局所的なピークを生成しうることが指摘されている(Degeling et al., 2008)。これは、従来の放射線帯電子加速機構の観測的な切り分けに疑問を投げかけており、Pc5波動と相対論的電子の相互作用の基本的性質を理解する必要性を示している。これらを踏まえ、本研究の目的は、独自の数値シミュレーションモデルに基づき、単色ポロイダルPc5波動と電子の相互作用に着目して、ドリフト共鳴とそれによって引き起こされる動径方向輸送の基本的な性質を明らかにすることである。
本研究では、内部磁気圏の2つのシミュレーションモデル : GEMSIS-RC(Ring Current : 環電流)とRB(Radiation Belt : 放射線帯)モデルを組み合わせている。GEMSIS-RCは、第1断熱不変量保存を仮定した5次元位相空間において、環電流イオンのドリフト運動論近似したボルツマン方程式と電磁場の時間発展を記述するマクスウェル方程式を同時に解くことができる、内部磁気圏のグローバル数値シミュレーションモデルである(Amano et al., 2011)。GEMSIS-RBは、任意の電磁場構造において相対論的電子の旋回中心近似した運動方程式を解くテスト粒子シミュレーションコードである(Saito et al., 2010)。本研究では、GEMSIS-RCコードで単色Pc5波動のシミュレーションを行い、得られた内部磁気圏内のグローバルな電磁場変動をGEMSIS-RBコードの背景電磁場としてインプットすることで多数の相対論的電子の軌道を計算した。このことにより、Pc5波動による放射線帯電子の動径方向輸送が電子のエネルギー、ピッチ角などにどのように依存するかを定量的に評価することができるのが本研究の特徴である。具体的には、周期が300秒の典型的な単色Pc5波動に対するシミュレーションを行い、電子が共鳴する位置やその動径方向への輸送量、また電子のエネルギーやピッチ角といったパラメータ依存性を解析し、定量的な考察を行った。その結果、ドリフト共鳴による動径方向への輸送は、非線形効果による有限共鳴幅を持ち、ピッチ角が90°の電子よりもバウンス運動を伴うピッチ角の小さい電子の方が高い輸送効率を持つことが明らかとなった。これは、電子が第1, 2断熱不変量の保存下で動径方向に輸送された場合、それに伴ってピッチ角が90°に近づくことによって、動径方向輸送に対する電子のドリフト周期の変化率が緩やかになり、単色Pc5波動との共鳴幅に入る時間が長くなることが原因であると考えられる。

キーワード：電子放射線帯、ドリフト共鳴、GEMSIS-RC及びRB
Keywords: Radiation belt electrons, Drift resonance, GEMSIS-RC and RB

Wave-driven gradual loss of energetic electrons in the slot region

*Zhaoguo He[1]

1.Harbin Institute of Technology Shenzhen Graduate School, Shenzhen, China

Resonant pitch angle scattering by plasma waves is one of the important mechanism to the loss of the radiation belt electrons. Based on the observations and simulations, we investigate the detailed variations of the energetic electrons(>100 keV) in the slot region driven by hiss waves and lightning generated whistlers (LGW) during the recovery phase of the magnetic storm on 1 July 2013. The spacecrafts simultaneously detected substantial decreases in fluxes of energetic electrons and intense hiss waves and weak LGW at the region L~3. Correspondingly, using the time-variant wave parameters of those waves, we calculate bounce-averaged diffusion coefficients and solve a 2-D Fokker-Planck diffusion equation, and the hiss-driven simulations of energetic electron evolution show reasonable agreement with the observation data. The results provides further support that the plasmaspheric hiss can be mainly responsible for the loss of the energetic electron in the slot region.

Keywords: slot region, hiss wave, energetic electron

Test particle simulation of energetic electrons interacting with sub-packet chorus emissions in the inner magnetosphere

*Ryoko Hiragra[1], Yoshiharu Omura[1]

1.Research Institute for Sustainable Humanosphere, Kyoto University

A whistler-mode chorus emission is known as a rising tone wave with a smooth amplitude growth in the magnetosphere. Recently there has been a discovery about a new feature of the chorus wave amplitude. When a chorus wave is generated at the equator, the wave amplitude does not show a smooth growth but a gradual growth with multiple peaks. Waves with this feature are called sub-packet waves. The present study includes two attempts. The first attempt is to simulate the generation and development process of the sub-packet wave over the magnetosphere. The sub-packet's unsmooth amplitude growth at the equator is reproduced by suppressing the amplitude growth with the possible maximum amplitude defined as the optimum amplitude, which is calculated by other geophysical factors. Secondly it is aimed to simulate interaction between the sub-packet wave and energetic electrons under the dipole magnetic field. In the simulation results, a distinct wave form of sub-packet is successfully simulated at the equator as theoretically expected, and it has been also verified that the sub-packet's wave form evolves through propagation to higher latitudes depending on the related geophysical factors such as the inhomogeneity of the magnetic field. By simulating the interactions of sub-packet chorus emissions and resonant electrons, we have found notable features in the energetic electron dynamics in the magnetosphere. The details of these effects on electron dynamics are discussed under the various conditions of physical parameters such as particle initial energy and pitch angle.

Void structure of O^+ ion observed by the Van Allen Probes in the inner magnetoshpere

*Yohei Nakayama[1], Yusuke Ebihara[1], Takashi Tanaka[2], Shinichi Ohtani[3], Kazue Takahashi[3], Matina Gkioulidou[3], Lynn Kistler[4]

1.RISH, Kyoto University, 2.SERC, Kyushu University, 3.The Johns Hopkins University Applied Physics Laboratory, 4.University of New Hampshire

The Van Allen Probes Helium Oxygen Proton Electron (HOPE) instrument measures charged particles with an energy range from ~eV to ~50 keV. The observation shows that the energy flux of the particles increases inside the geosynchronous orbit during substorms. For some night-side events, the observed H^+ flux and O^+ flux spectrogram showed injections of energetic ions (tens of keV), but only the O^+ flux spectrum has a gap in the low energy range at high-L shells. The purpose of this study is to investigate the generation mechanism of the structure by using numerical simulations. By applying the same simulation model introduced by Nakayama et al. (2015, JGR), we simulated the substorm-time injection of O^+ ions in the global MHD electromagnetic fields and reconstructed the flux in the inner magnetosphere. Our simulation successfully reconstructs the structure of O^+ flux observed by Van Allen Probes. After analysis of test particle simulation, we concluded that the generation mechanisms of the structure are (1) the longitudinally and radially confined flow channel of O^+ ions and (2) the intensive non-adiabatic acceleration of O^+ ions in the nightside tail region.

Keywords: Van Allen Probes Observation, Substorm, Non-adiabatic Acceleration

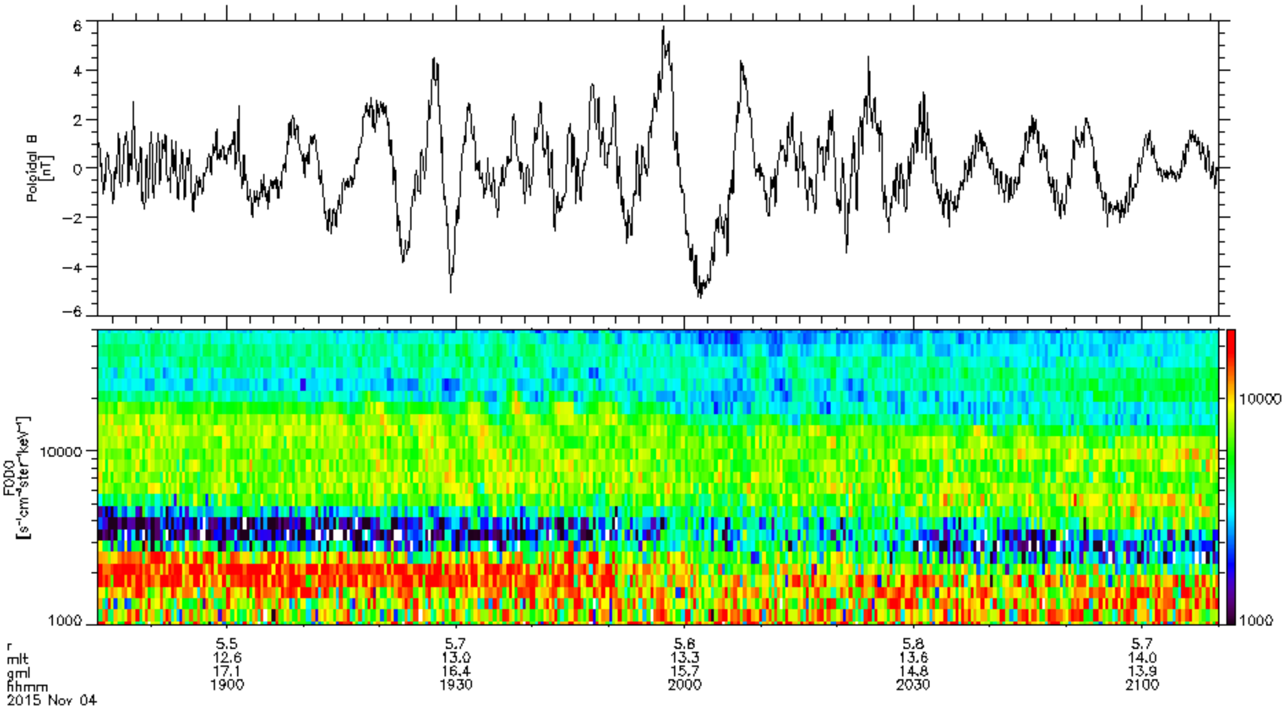
Van Allen Probes によってリングカレント領域で観測された周期的なイオンフラックスの変動
Periodic Ion Flux Modulation observed by Van Allen Probes in Ring Current Region

*山本 和弘[1]、能勢 正仁[2]、Kletzing Craig[3]、Smith Charles[4]、MacDowall Robert[5]、Spence Harlan[4]、Reeves Geoff[6,7]、Larsen Brian[6,7]
*Kazuhiro Yamamoto[1], Masahito Nose[2], Craig Kletzing[3], Charles Smith[4], Robert MacDowall[5], Harlan Spence[4], Geoff Reeves[6,7], Brian Larsen[6,7]

1.京都大学大学院理学研究科、2.京都大学大学院理学研究科附属地磁気世界資料解析センター、3.アイオワ大学、4.ニューハンプシャー大学、5.ゴダード宇宙飛行センター、6.ロスアラモス国立研究所、7.ニューメキシココンソーシアム
1.Graduate School of Science, Kyoto University, 2.Data Analysis Center for Geomagnetism and Space Magnetism, Graduate School of Science, Kyoto University, 3.Department of Physics and Astronomy, University of Iowa, 4.Institute for the Study of Earth, Oceans and Space, University of New Hampshire, 5.Solar System Exploration Division, Goddard Space Flight Center, 6.Space Sciences and Applications Group, Los Alamos National Laboratory, 7.Space Sciences Division, The New Mexico Consortium

In the drift-bounce resonance that was theoretically introduced by *Southwood et al.* [1969], the interaction is expected between ULF waves and electrons or ions. Through the interaction, charged particles in the ring current can be accelerated or deaccelerated and the population of ring current particles can be changed. There are many observations of drift-bounce resonance for protons [e.g., *Kokubun et al.*, 1977; *Takahashi et al.*, 1990; *Dai et al.*, 2013], whereas only a few observations of drift-bounce resonance are reported for O^+ ions [*Yang et al.*, 2010, 2011].
In this study, we report several events of periodic flux modulation of protons and O^+ ions observed by Van Allen Probes in 2012-2016. We find periodic flux modulation of O^+ ions and Pc5 waves on November 4, 2015 (event A) and November 30, 2015 (event B). In event A, the flux modulation is recognized at 1-50 keV and dispersed in energy. In event B, however, the flux modulation is limited at ~10 keV. We will examine dependence of the flux variations on pitch angles and energies, and discuss if the variations are due to drift-bounce resonance.

キーワード：波動粒子相互作用、ドリフトバウンスレゾナンス、地磁気脈動、酸素イオン、リングカレント、Van Allen Probes
Keywords: wave-particle interaction, drift-bounce resonance, geomagnetic pulsations, oxygen ions, ring current, Van Allen Probes


Poloidal B [nT]
FODO [s⁻¹cm⁻²ster⁻¹keV⁻¹]
10000
1000
r
mlt
gml
hhmm
2015 Nov 04
5.5 12.6 17.1 1900
5.7 13.0 16.4 1930
5.8 13.3 15.7 2000
5.8 13.6 14.8 2030
5.7 14.0 13.9 2100

磁気嵐中の水素、酸素イオンの内部磁気圏への供給に関する比較研究
Comparative study of proton and oxygen ion supply into the inner magnetosphere during a geomagnetic storm

*三谷 憲司[1]、関 華奈子[2]、桂華 邦裕[1]、Lanzerotti Louis[3]、Gkioulidou Matina[4]、Mitchell Donald[4]
、Kletzing Craig[5]
*Kenji Mitani[1], Kanako Seki[2], Kunihiro Keika[1], Louis J Lanzerotti[3], Matina Gkioulidou[4], Donald G Mitchell[4], Craig Kletzing[5]

1.名古屋大学　宇宙地球環境研究所（ISEE)、2.東京大学大学院　理学系研究科、3.New Jersey Institute of Technology、4.Applied Physics Laboratory, Johns Hopkins University、5.Department of Physics and Astronomy, University of Iowa
1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Graduate School of Science, University of Tokyo, 3.New Jersey Institute of Technology, 4.Applied Physics Laboratory, Johns Hopkins University, 5.Department of Physics and Astronomy, University of Iowa

It is observationally known that the contribution of oxygen ions to the ring current increases with increasing size of magnetic storms, although protons are the main component of the ring current ions during small storms. The protons and oxygen ions are considered to have different source and supply mechanisms. The protons mainly come from the solar wind through the plasma sheet, and oxygen ions originate from the terrestrial ionosphere. However, detailed properties of the ion supply and their dependence on ion species (such as depth and timing of ion penetration into the inner magnetosphere) are far from well understood. To characterize the ion supply to the ring current during magnetic storms, here we investigate the properties of energetic proton and oxygen phase space densities (PSDs) during a geomagnetic storm observed by the Van Allen Probes mission. We examine a magnetic storm that occurred during the period from April 23 to 25, 2013. Using energetic ion and magnetic field data obtained by the RBSPICE and EMFISIS instruments onboard Van Allen Probes, we studied the temporal variations of protons and oxygen ions PSD radial profiles.
We calculated the first adiabatic invariant, mu, and PSD for ions with a pitch angle of about 90 degrees (We selected data of a telescope with a pitch angle which is the nearest 90 degrees in all telescopes and is in range of 70 -110 degrees for each time.). Proton and oxygen PSDs for specific mu values (mu= 0.3, 0.5, 0.8, 1.0 keV/nT for proton, mu= 0.5, 0.8, 1.0 keV/nT for oxygen) were obtained as a function of L for each orbit of Van Allen Probes during the storm. The results show that both proton and oxygen 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 protons were located at smaller L at dusk than at dawn. Protons with smaller mu values (mu= 0.3 and 0.5 keV/nT) penetrated earlier than those with larger mu values (mu= 0.8, 1.0 keV/nT). It seems consistent with the energy dependence of the Alfven layer. In contrast, the timing of O+ penetration is almost the same for all mu values (mu= 0.5, 0.8 and 1.0 keV/nT). The observations also show that O+ ions penetrated more deeply in L and earlier in time than H+ ions.
These results suggest that the source of the transported oxygen ions is located closer to the Earth than that of the protons (i.e., the inner edge of the plasma sheet).
Variations of the oxygen E-t diagram during the second main phase of the storm show enhancement of flux in energy over ~100 keV closer to the Earth than protons inner edges. The magnetic fluctuation with about 0.01 Hz is also enhanced during the second main phase of the storm closer to the Earth than protons inner edges. We suggest that deeper penetrations of oxygen ions are caused by interaction between oxygen ions and Pc5 magnetic fluctuations.
Our results thus demonstrate the importance of the contribution from high energy oxygen ions to the

storm-time ring current.

キーワード：Van Allen Probes、酸素イオン
Keywords: Van Allen Probes, Oxygen ion

惑星間空間衝撃波到来時における内部磁気圏水素イオンのダイナミクス
The impact of interplanetary shock on hydrogen ions in the inner magnetosphere

*辻 浩季[1]、海老原 祐輔[1]、大村 善治[1]、田中 高史[2]
*Hiroki Tsuji[1], Yusuke Ebihara[1], Yoshiharu Omura[1], Takashi Tanaka[2]

1.京都大学生存圏研究所、2.九州大学宙空環境研究センター
1.Research Institute for Sustainable Humanosphere, Kyoto University, 2.SERC, kyushu university

An interplanetary (IP) shock is known to redistribute phase space density of magnetosphereic ions. Cluster satellite observations have shown that, soon after arrival of the IP shock, overall intensity of the ions rapidly increases and multiple energy dispersion appears in an energy-time spectrogram of the ions [Zong et al., 2012]. We have performed test particle simulation under the electric and magnetic fields provided by the global magnetohydrodynamics (MHD) simulation. The solar wind speed is increased from 372 to 500 km/s in order to reproduce the IP shock. The number density in the solar wind was set to a constant to be 5 cm-3, and the Z component of the interplanetary magnetic field (IMF) was turned from +5 to -5 nT. Just after the arrival of the IP shock, a fast mode wave propagates tailward in the magnetosphere. The amplitude of the electric field exceeds 20 mV/m. To reconstruct an energy-time spectrogram of the H+ ions at all MLTs at L = 5 ~ 10, we traced trajectories of the ions backward in time. The ions are accelerated nonadiabatically just after arrival of IP shock. Thus, the guiding center approximation is no longer valid. Knowing initial and final positions in 6-dimensional space, we mapped the phase space density, according to Liouville’s theorem. We assumed that the phase space density of the ions is isotropic Maxwellian before the shock arrival. The calculated temperature anisotropy A (=Pperp/Ppara –1) is increased 0.3, which may favor the excitation of electromagnetic ion cyclotron (EMIC) waves. We will discuss the evolution of the temperature anisotropy and possible growth of the EMIC waves.

キーワード：惑星間空間衝撃波、内部磁気圏、水素イオン
Keywords: interplanetary shock, inner magnetosphere, hydrogen ion

A pilot study for reconstruction of the inner-magnetosphere by data assimilation of global ENA and EUV measurements

A pilot study for reconstruction of the inner-magnetosphere by data assimilation of global ENA and EUV measurements

*中野 慎也[1]、Brandt Pontus[2]、Fok Mei-Ching[3]
*Shin'ya Nakano[1], Pontus Brandt[2], Mei-Ching Fok[3]

1.情報・システム研究機構　統計数理研究所、2.The Johns Hopkins University, Applied Physics Laboratory、3.NASA Goddard Space Flight Center
1.The Institute of Statistical Mathematics, 2.The Johns Hopkins University, Applied Physics Laboratory, 3.NASA Goddard Space Flight Center

During these several years, we have developed two data assimilation techniques for the inner magnetosphere. One is for reproducing the temporal evolution of the ring current by assimilation of energetic neutral atom (ENA) imaging data from the IMAGE satellite. The other is for reproducing the evolution of the plasmasphere by assimilation of extreme ultra-violet (EUV) imaging data from the IMAGE satellite. Both of the two techniques uses the data from the same satellite, and both are based on similar frameworks in which the electric field is treated as an unknown quantity. Therefore, it is expected that these two techniques are unified to obtain a comprehensive picture of the evolution of the ring current, the plasmasphere, and the electric field. Since the ring current is located in a different region from the plasmasphere, the ENA and EUV data would provide the information on different regions in the inner magnetosphere. Thus, the use of both the ENA and EUV data could remarkably improve the estimate of the electric field.
We are developing the unified data assimilation technique which incorporates ENA and EUV data into a model of the inner magnetosphere, the comprehensive inner magnetosphere ionosphere model (Fok et al., 2014). We have conducted a pilot study using synthetic ENA and EUV data sets generated from a simulation run under a certain condition. In this study, the distributions of the electric field, the ring current, and the plasmasphere were successfully estimated. The current status of the development of our data assimilation technique will be reported.

キーワード：リングカレント、プラズマ圏、データ同化
Keywords: ring current, plasmasphere, data assimilation

Longitudinally-propagating ionospheric flow structures observed by SuperDARN during March 17-18, 2015 storm

Longitudinally-propagating ionospheric flow structures observed by SuperDARN during March 17-18, 2015 storm

*堀 智昭[1]、西谷 望[1]、桂華 邦裕[1]、Ruohoniemi J. Michael[2]
*Tomoaki Hori[1], Nozomu Nishitani[1], Kunihiro Keika[1], J. Michael Ruohoniemi[2]

1.名古屋大学宇宙地球環境研究所、2.バージニア工科大学
1.Institute for Space-Earth Environmental Research, Nagoya Univ., 2.Bradley Department of Electrical and Computer Engineering, Virginia Tech

We study an interesting wavy structure of ionosphere flow at sub-auroral latitudes observed by SuperDARN during a magnetic storm on March 17-18, 2015. The main phase of the storm shows at least two step development in Dst and apparently those two steps are associated with an more or less isolated substorm followed by a series of more intense substorms, respectively. The wavy modulation of ionospheric flow actually occurs during the relatively stagnant period between the two substorms. At sub-auroral latitude, the fast eastward flow prevailing from midnight to early morning during the first substorm ceases and subsequently the mid-latitude SuperDARN radars start to see a series of alternate flow reversals of toward-radar flows and away-from-radar flows. Each of the flow reversal structures has a longitudinal wave length of roughly ~1h magnetic local time (MLT) and fairly large peak-to-peak amplitude of several hundreds of m/s. Interestingly, those flow structures pass by the fields of view of the radars one after another, showing a clear westward propagation over a wide MLT range from early morning all the way to midnight. From the radar observation, the propagation velocity is roughly estimated to be ~2-3 km/s. The large propagation speed with the relatively stagnant background flow (less than ~200 m/s) indicates that the corresponding westward-eastward electric field is not of the ionospheric origin, but is imposed by the magnetosphere. The speed of ~2-3 km/s in the ionosphere corresponds to ~ a few thousands of km/s in the equatorial magnetosphere, comparable with the Alfven velocity. Thus we infer that the westward-traveling modulation of ionospheric electric field could be the footprint of ULF waves propagating in the anti-sunward direction through the dawnside magnetosphere. Further comparison with in situ observations by inner magnetospheric satellites will be made to test this hypothesis as well as to examine how these propagating structure of ionospheric electric field is generated.

磁気嵐時のサブオーロラ帯孤立状発光現象のIMAP/VISI観測
Isolated subauroral emissions during a magnetic storm obtained with IMAP/VISI

*坂野井 健[1]、坂口 歌織[4]、三好 由純[5]、齊藤 昭則[3]、穂積 裕太[3]、山崎 敦[2]、Perwitasari Septi[1]、塩川 和夫[5]
*Takeshi Sakanoi[1], Kaori Sakaguchi[4], Yoshizumi Miyoshi[5], Akinori Saito[3], Yuta Hozumi[3], Atsushi Yamazaki[2], Septi Perwitasari[1], Kazuo Shiokawa[5]

1.東北大学大学院理学研究科惑星プラズマ・大気研究センター、2.宇宙航空研究開発機構宇宙科学研究所、3.京都大学大学院理学研究科、4.情報通信研究機構、5.名古屋大学宇宙地球環境研究所
1.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 2.JAXA, ISAS, 3.Graduate School of Science, Kyoto University, 4.NICT, 5.ISEE, Nagoya University

We report the SAR arc emission and isolated proton auroral event in the sub-auroral region obtained with IMAP/VISI in a big storm during the period from 21 to 26 July 2015. IMAP/VISI is a visible imaging spectrometer which aims to measures nightglow emissions from ISS (~400 km altitude) covering the wide range from +51 deg. to -50 deg. in geographical latitude. Two slits of VISI point to +45 deg. and -45 deg. to nadir with a scan width (mapped to the E-region altitude) of ~600 km to achieve a stereoscopic measurement of the airglow and aurora emission. In the nominal operation mode, VISI continuously measures airglow and auroral emissions at O2 762 nm, OH or N2 1PG 730 nm and O 630 nm simultaneously with a spatial resolution (plate scale) of ~10 km x 14 km and scan width of ~600 km perpendicular to the orbital track.
A big storm started on June 21, 2015 and Dst index decreased to 195 nT at 5UT on June 23. In the expansion and main phase from 1650 UT on July 22 to 1255 UT on July 23, we identified SAR arc emission at the magnetic latitude of ~50 deg. We will try to estimate the emission height of this SAR arc using the triangulation method with IMAP/VISI data. The dominant emission of SAR arc was O 630 nm with intensity of ~200R. On the other hand, during the recovery phase from 1656 UT on July 24 to 0025 UT on July 25, isolated tail-like or spot-shaped emissions occurred the sub-auroral latitudes, separately from the main auroral oval. These auroral structures are seen in all of the emission data at O630 nm, O2 762 nm and also in N2 1PG. This fact suggests that high-energy (more than 10 keV) particles probably produce these auroral emissions. These appeared almost the same magnetic latitude of ~58 deg, and likely to move with a co-rotation speed in the MLT range of 23-3 MLT. In addition, from 15 -19 UT on July 24 magnetic search coil data at Moshiri showed the Pc1 pulsation at ~2 - 3Hz, which is close to the ion cyclotron frequency in the magnetosphere. Further, POES 19 measured proton precipitation with energy of 30-250 keV existed associated with these isolated auroras. Therefore, these isolated auroras are suggested to be generated by high-energy proton precipitation that is produced by the pitch-angle scattering of ring-current protons by EMIC wave at equator.

キーワード：オーロラ、内部磁気圏、IMAP
Keywords: aurora, inner magnetosphere, IMAP

Transient time scale of poloidal Alfven waves in dipole geometry

*Jiwon Choi[1], Dong-Hun Lee[1], Khan-Hyuk Kim[1], Ensang Lee[1]

1.Kyung Hee Univ.

Standing poloidal Alfven waves with high azimuthal wave number (m >> 1) are of interest since they can be excited via bounce-drift resonance with ring current particles of the Earth’s magnetosphere. However, the temporal behavior of these transient poloidal waves in realistic dipole geometry has not been demonstrated in detail. We have conducted 2.5-D MHD simulations in a dipole coordinate system that are suited to model high-m ULF waves with high grid resolution. To investigate the time-dependent behavior of local wave fields, we impose fundamental and second harmonic standing poloidal Alfven waves with different azimuthal wave number and follow their evolution in time at different locations. Our results show that the wave energy is initially poloidal and asymptotically transferred to the toroidal mode energy. Such transit time is dependent on the azimuthal wave number; the poloidal mode remains for a longer period of time when the wave has larger mode number. Although our results agree with the tendency from previous theoretical studies that the poloidal mode with higher azimuthal wave number has longer lifetime than that with lower wave number, it is shown that the transit time in dipole geometry is much shorter than that from box models. It suggests that the observations of prolonged poloidal mode waves are likely due to the continuous excitation via wave-particle interaction.

Keywords: Wave particle interaction, Poloidal Alfven wave, MHD simulation

Effects of conductivity asymmetry between the northern and southern latitudes on quarter waves

*JaeJin Jang[1], Jiwon Choi[1], Dong-Hun Lee[1]

1.Kyung Hee Univ.

Quarter-wave modes are standing shear Alfvén waves in geomagnetic field lines and are generated when the ionosphere has very different conductances between the northern and southern ionosphere. Difference between two conductances is most large when one end of the field line is exposed by sun and the other is in Earth's optical shadow. We study how quarter waves are affected by such north-south asymmetry using three-dimensional dipole wave model. Unlike the previous studies mainly showing resonant frequency of the wave, we consider dipole effect on time histories of electric and magnetic fields at different locations including the equatorial region. To compare with the observation in a realistic manner, we study simulations of time histories and mode structure of quarter-wave mode for various conditions. It is found that dipole effect on time histories is very important in determining amplitude and phase at different locations. In addition, we discuss time-dependent feature of fundamental and second harmonics of quarter-wave mode.

Keywords: Quarter-wave, MHD simulation

