

Latitudinal distribution of the Field Aligned Current estimated from SWARM constellation

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We make use of the estimated Field Aligned Current (FAC) data provided by SWARM constellation A/B/C, we study the FAC footprint and strength in the northern hemisphere region. Through 398 day of good FAC data of SWARM-A, we got a profile not only of the FAC intensity footprint at the subauroral region but also a profile of the FAC intensity in the northern geographic from the equator until the polar cap region at different Magnetic Local Time (MLT).

Results showed that the maximum and minimum dayside FAC intensities shifted to higher latitudes, while the nightside FAC shifted to lower latitudes. The latitudinal difference between the dayside and nightside FAC intensity is approximately 3 degrees. Near the duskside the minimum FAC intensity is stronger than the maximum FAC intensity.

The mean absolute FAC value each 10° latitude in the northern geographic hemisphere 0° - 80° showed that; close to the equator [0° , 40°] latitude] the mean absolute FAC increases within [1000-1600] MLT increases. This daytime enhancement decreases at latitudes $>40^\circ$, and reverses its signature at the sub-auroral region [50° , 60°] where the nightside FAC intensity increases dramatically in comparison to dayside FAC. Again Dayside FAC intensity maintains its strength at latitudes $>70^\circ$. The largest FAC intensity is observed at latitudes larger than 60° which is comparable at all longitudes. The seasonal FAC variations showed the same behavior as the longitudinal variations. It has small amplitude within latitudes [20° , 50°], but dramatically jumps at latitudes larger than 50° . The seasonal FAC showed two crests at spring and autumn. The latitudinal profile of the FAC at different MLT showed that dayside FAC is stronger than nightside FAC intensity within latitude [0° - 50°] and $>70^\circ$ and nightside FAC intensity is stronger than dayside FAC within latitudes [50° - 70°], while the duskside and dawnside FAC showed a parallel correlation.

Keywords: Ionosphere, Field Aligned Current (FAC)

Stagnant Transpolar Arc and Its Intensification during Dual Cusp and Magnetotail Magnetic Reconnections

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We present that TransPolar Arc (TPA), which was observed during magnetic reconnections at the cusp regions in northern/southern hemispheres and in the magnetotail, intensified when the magnetic flux at geosynchronous altitudes slightly piled up. The B_y component of Interplanetary Magnetic Field (IMF) during this TPA interval was dominantly negative (dawnward), and associated IMF- B_z component turned from negative (southward) to positive (northward) directions. We refer to the solar wind conditions four hours before the TPA interval because they correlate with the TPA's location and motion stronger than "current condition" which is estimated with the time delay between the solar wind and magnetospheric observational time. In this presentation, we also show how "current condition" IMF and associated plasmas were changing. Further discussion on the relation between the TPA brightening, intensification and two cases ("current"/"four hours before") of IMF condition will be made. One of the most interesting points in this event was that TPA's location has been biased and stagnant in post-midnight and dawn region for one hour of its duration.

On September 16th, 2001, Cluster made in-situ observation of the cusp reconnection in northern hemisphere, and detected strong acceleration of the solar wind electrons at the electron edge as formed by this cusp reconnection during TPA's appearance (On the details of this northern cusp reconnection event, see Nowada et al. "Cluster Observation of Electron Accelerations at the Electron Edges Formed by Localized Magnetic Reconnection at Cusp/Entry Region", submitted to J. Geophys. Res., 2016). On the ground, SuperDARN radar in the southern hemisphere simultaneously observed the ionospheric plasma flows whose velocity was faster than 0.6 km/s around the cusp footpoint region. These flows, which were faster than the background plasma velocity, suggest that magnetic reconnection occurred also at the cusp in the southern hemisphere. Adding these dual cusp magnetic reconnections, east-westward and west-eastward flows faster than 0.5 km/s were also observed over the region from pre- to post-midnight along the main auroral oval. These fast ionospheric flows support that the magnetotail reconnection also would occur. During this TPA's appearance, we found that the TPA's luminosity had intensified for 23 minutes, when GOES 10 observed slight enhancements of the B_z component and associated magnetic inclination angle between B_x and B_z components at geosynchronous altitudes. These magnetic field variations seen by the geosynchronous satellite suggest that the magnetic flux pileup in near-earth magnetotail plays a significant role in the intensification of the TPA's luminosity even though its amount is small. In this presentation, we will discuss further feasibility of the constellation study including the MMS fleet under this topic. In-situ magnetic reconnection signatures at northern cusp can be observed by Cluster in this event, but no satellites detected direct evidence for simultaneous reconnection process in the magnetotail, which was estimated and speculated by the ionospheric plasma flow patterns by SuperDARN radars on the ground.

In general, it has been believed that high energy source electrons for which TPA was formed are

generated by magnetic reconnection in the magnetotail or “twisted” plasma sheet due to an influence of the IMF- B_y component. However, the observations of TPA during which simultaneous magnetotail reconnection evidently occurs and/or those of the whole TPA formation process from the stage of energetic electron generation by the magnetotail reconnection to the transport process of the TPA’s source electrons to the ionosphere has not been conducted. We can understand the TPA’s physics more, if we could reveal a global view of TPA’s formation from both space- and ground-based observations.

Keywords: Transpolar Arc, Cusp and Tail Reconnections, Ionospheric Flows

Nonlinear resonant scattering of radiation belt relativistic electrons by oblique EMIC waves

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Resonant scattering by EMIC waves has long been proposed as a candidate loss mechanisms for radiation belt relativistic electrons. Such resonant interaction process has been found to be in the nonlinear (rather than quasi-linear) regime. However, previous works are usually limited to the parallel EMIC waves, and the nonlinear scattering process by oblique EMIC waves remains to be investigated in detail. In this study, we perform test-particle simulations to examine the dependence of nonlinear characteristics on wave normal angle and resonance order. Our results provide in-depth understanding of the nonlinear loss of radiation belt relativistic electrons induced by EMIC waves.

Keywords: EMIC wave, non-linear, resonant

磁気嵐回復相に内部磁気圏におきるlow-m Pc5脈動と高エネルギー電子の関係

Interactions of energetic electrons with low-m number ULF waves in the inner magnetosphere during a storm recovery phase

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A number of previous studies have suggested that ULF waves, which occur during a recovery phase of a geomagnetic storm, are associated with the enhancement of electron flux in the outer radiation belt. ULF waves accelerate electrons whose drift velocities match the azimuthal phase velocities of ULF waves via drift resonance. Elkington et al., (1999 and 2003) proposed a simple model for the drift resonance effect on energetic electrons due to ULF toroidal and poloidal modes with large azimuthal wavelengths (low m numbers). Although some observational studies (Tan et al., 2004 and 2011) reported effects of low-m number ULF waves on electron acceleration, the interaction between low-m number ULF waves and energetic electrons is still incompletely understood.

In this study, we investigate interaction between low-m number ULF and energetic electron observed in the inner magnetosphere, using data from the multiple satellites, GOES 13, 15 and Van Allen probes. A Pc5 pulsation occurring at 6:00-8:00 UT on 13 September 2014 during a storm recovery phase are focused on. These Pc5 pulsations are dominated by the toroidal component with the frequency of a 3 mHz and a large amplitude of 30 nT when Van Allen Probes were located on the morning side (MLT~5) at L~6. Estimating m number from the phase difference of Pc5 pulsations and azimuthal separation between Van Allen Probes A and B, the Pc5 has an m number of 3 with westward propagation. Perturbations corresponding to the Pc5 pulsation are observed in the electron flux data. In this presentation, we discuss whether Pc5 pulsations accelerate the energetic electron via the drift resonant interaction.

夜側Region 2沿磁力線電流系を駆動する磁気圏ダイナモ

Magnetospheric dynamo driving the nightside Region 2 field-aligned current system

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磁気圏と電離圏をつなぐ沿磁力線電流の重要性は広く認識されている。電離圏に定常プラズマ対流を駆動するためには、沿磁力線電流により磁気圏から電離圏へエネルギーを供給し続けなければならない。電流回路の磁気圏側では電磁エネルギーを生み出す「ダイナモ」過程が存在する。しかしこの磁気圏ダイナモの理解が進んだのはごく最近である。グローバル数値シミュレーションにより、磁気圏においてはプラズマの熱エネルギーが流れの運動エネルギーよりずっと大きく、沿磁力線電流のエネルギー源になっていることが理解された。また、Region 1沿磁力線電流系のダイナモ過程は「膨張する磁気遅進波擾乱」で解釈されることが明らかになってきた。しかし同様の解釈を夜側Region 2に適用することはできないこともわかってきた。本研究の目的は、電磁流体近似を用いて夜側Region 2ダイナモ過程を物理的に解釈するとともに、磁気圏ダイナモ過程の理論を一般化することである。磁気圏ダイナモは電流密度ベクトル (J) と電場ベクトル (E) の内積が負 ($J \cdot E < 0$) の領域として定義される。この条件をPoyntingの法則、Faradayの法則、Ohmの法則を用いて(運動方程式を用いずに)磁場の空間変動に関する条件で書くことができる。磁場が比較的強い高ベータ領域を念頭に、磁場構造が物理を決めると考えると、ダイナモを形成するには(1)磁気圧がプラズマ対流に沿って増加するか(2)磁気張力とプラズマ対流が逆向きである、ことが必要である。運動方程式を加えて考察すると、前者はプラズマ圧が磁気圧で支えられていることを意味し、膨張する磁気遅進波擾乱で解釈される。これはRegion 1に適用される。一方後者はプラズマ圧が張力で支えられていることを意味し夜側Region 2に適用されると考えられる。後者についてはこれまで注目されたことがなく、本研究ではこの磁気張力によるダイナモについて議論する。

キーワード：沿磁力線電流、ダイナモ、リージョン2

Keywords: field-aligned current, dynamo, Region 2

サブオーロラ帯における脈動オーロラとコーラス波動の複数イベント解析

Multi-event analysis for chorus waves and pulsating aurora at sub-auroral latitudes

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脈動オーロラは高エネルギー電子がコーラス波動と相互作用することによって起こる現象といわれ、広い時間スケールの変調をもつ(数百 msec~数十sec)。脈動オーロラの時空間変動はコーラス波動と深い関連性を示すと考えられている。両者の関係性を調べるために、地上同時観測された脈動オーロラとコーラス波動について解析を行った。使用したデータはVLF波動(100 kHz sampling)と全天高速EMCCDカメラ(110 Hz sampling)であり、カナダのアサバスカ(L=4.3)で観測されている。本研究では、2014年12月から2015年4月に観測された11イベントの脈動オーロラとコーラス波動に対して解析を行った。結果、両者の強度に正相関の傾向が得られた。同時に、両者の強度はAE指数とも正相関の傾向にあった。これは高エネルギー電子が効率よく波動と共鳴し、降下電子のfluxが増加した結果と考えられる。次に、全天カメラ視野内の異なる緯度(55.6N, 54.7N, 53.8N)で観測された脈動オーロラの発光強度と内部変調の統計解析を行った。解析の結果、内部変調の発生分布は4 Hzを境界に異なる傾向を見せた。4 Hz以下の内部変調は発光強度と正相関を示した。この結果は非線形成長理論に基づいて西山ら(2014)によって説明されている結果と同じと考えている。また、4 Hz以下の内部変調は低緯度側のほうが高い変調周波数を持つ頻度が高かった。これは、非線形成長理論に基づく背景磁場の不均一性が関連していると考えられる。一方で、一般的な内部変調よりも高い4 Hz以上の変調周波数に対して発光強度は低い値をとった。速い内部変調を引き起こす高エネルギー電子のfluxが少ない影響、もしくは発光に寄与しづらい高エネルギー電子の降下による発生が考えられる。また、高緯度側では4 Hz以上の内部変調の発生頻度が高い傾向にあった。これはプラズマ周波数と電子サイクロトロン周波数の比が大きくなり、ヒスライクなコーラス波動の発生によるものと考えられる。このように、L値に依存した磁気圏の環境によって脈動オーロラの時間的特徴は変化すると考えられる。

本発表では、脈動オーロラを発生させる高エネルギー電子とコーラス波動の関連性について詳細に報告する予定である。

キーワード：脈動オーロラ、コーラス波動、内部変調

Keywords: Pulsating aurora, Chorus waves, A few Hz modulation

雷起源EMIC波動解析によるプラズマ圏下部の重イオン組成比推定

Cold heavy ion composition in the lower plasmasphere estimated from lightning induced EMIC waves

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Ion cyclotron whistler waves are electromagnetic ion cyclotron (EMIC) mode waves induced by lightning discharge. Propagation properties of ion cyclotron whistler waves strongly depend on the local cold heavy-ion composition. Crossover frequency is an important frequency for the ion cyclotron whistlers, which is a function of the ion composition. In this study, we examine the variation in the crossover frequency of heavy ion band ion cyclotron whistler waves observed by the Van Allen probes and the Akebono satellites. We found that the crossover frequencies of the observed events decreased with increasing altitude. This suggests the total heavy-ion composition is high at low altitudes and decreases with increasing altitude around lower plasmasphere. We can determine the composition of three species of ions by measuring two crossover frequencies. We focus on H⁺ band and He⁺ band ion cyclotron whistler waves, and estimate proton-helium ion ratio ($n(\text{He}^+)/n(\text{H}^+)$) and proton-oxygen ion ratio ($n(\text{O}^+)/n(\text{H}^+)$) in the lower plasmasphere. This wave-based approach used in this study can also be a useful means of estimating unknown cold-ion distributions in the inner magnetosphere.

キーワード：イオンサイクロトロンホイッスラ、EMIC波動、重イオン

Keywords: Ion cyclotron whistler, EMIC wave, heavy ion

上部電離圏で観測されるMF/HF帯オーロラ電波の周波数構造と偏波特性

Frequency structure and polarization of MF/HF auroral radio emissions observed in the topside ionosphere

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Auroral radio emissions are generated at ionospheric F-region altitudes in the medium and high frequency bands (MF/HF) and propagate towards the ground and outward into space. Satellite-level MF/HF auroral radio emissions, which were termed terrestrial hectometric radiation (THR), are band-limited signals like ground-level auroral roar. We report on the statistical properties of frequency structure and polarization of THR emissions using a long-term data set obtained from the Plasma Waves and Sounder (PWS) experiment mounted on the Akebono satellite in the polarization (PL) mode operation. The PL mode observation provides the power spectra of right- and left-handed polarized components (I_R and I_L), whose rotation is viewed from the normal direction of the antenna plane. We analyzed multi events where THR emissions appeared simultaneously in two discrete frequency ranges (THR-L and THR-H). THR-H was about twice the frequency of THR-L, as in the case of minor ground-level event of simultaneous $2f_{ce}$ and $4f_{ce}$ roars. The sign of axial ratio $(I_L - I_R)/(I_L + I_R)$ of THR-L was opposite to that of the simultaneously detected THR-H. The axial ratio is applied to identify the propagation mode of the electromagnetic waves with the assumption that the source of the waves is in an altitude region lower than the satellite position in the night-side auroral latitude. The observed axial ratio is consistent with the hypothesis that THR-L and THR-H respectively correspond to O- and X-mode electromagnetic waves. The observed harmonic frequency structure and polarization feature support the idea that O-mode THR-L results from linear conversion of upper hybrid waves generated under the condition of $f_{UH} \sim 2f_{ce}$, and harmonic X-mode THR-H is attributed to the nonlinear wave-wave coalescence of two upper hybrid waves generated under the same matching condition. However, we also found that the upper limit frequency of THR-H was slightly higher than twice the upper limit frequency of THR-L, and the normalized frequency bandwidth of THR ($\Delta f/f$) was often more than 0.1, unlike ground-level auroral roar. The explanation of these observed features should involve other factors related to the excitation of upper hybrid waves and mode conversion processes.

PC5地磁気脈動にともなう赤道ジェット電流と中緯度電場観測によるCowling電気伝導度
Cowling conductance estimated from the equatorial electrojet and midlatitude ionospheric
drift velocity during the Halloween storm PC5 events

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During the stormtime PC5 magnetic pulsations on 31 October 2003, we detected large amplitude oscillations in the ionospheric drift velocity with the HF Doppler sounder at midlatitude for 10 hours from 11 to 21 MLT. We estimated the electric field (E) from the HF Doppler frequency (HFD) under an assumption that the vertical motion of the reflection height is caused by the ExB drift of the ionospheric plasma. Similar oscillations were recorded on the magnetometer data at high-to-equatorial latitudes with significant amplitude enhancement at the dayside equator. We estimated the equatorial electrojet (EEJ) as a deflection of the equatorial PC5 from the low latitude PC5 and found that the midlatitude E is well correlated with the EEJ with correlation coefficients (0.80-0.95) calculated in each 60-min time interval over the 10 hour period, suggesting that the midlatitude E is associated with the ionospheric currents transmitted from high latitude to the equator. Taking the geometrical attenuation of the transmitted electric field into the estimation of the electric field at the equator, we estimated the ionospheric conductance enhanced by the Cowling effect at the equator as ranging from 140 mho at 11 MLT, 50 mho at 16 MLT, and 3 mho in the night after 18 MLT. The conductance depends on the solar zenith angle in a function of $\cos^{0.6}$ (zenith angle), roughly matching the Chapman layer formation due to the solar radiation. It is remarkable that the nighttime Cowling conductance is large enough to drive the EEJ with the transmitted electric field, although the magnetic effects of the nighttime EEJ are overcome by the PC5 propagated directly from the magnetosphere. We point out that the usage of the PC5 enables us to obtain the LT/solar zenith angle dependence of the ionospheric conductivity and to improve the capability of the HFD which would be less sensitive to longer period disturbances such as the DP2, substorms and so on.

キーワード：カウリング電気伝導度、PC5地磁気脈動、赤道ジェット電流、電離圏電場、ハロウィーン磁気嵐イベント

Keywords: Cowling conductance, PC5 magnetic pulsation, equatorial electrojet, ionospheric electric field, Halloween storm event

The Harang Reversal Generated by Ionospheric Polarization Field by Hall Current Divergence
 The Harang Reversal Generated by Ionospheric Polarization Field by Hall Current Divergence

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The ionospheric electric potential shows various asymmetries, localized structures, and so on. Whereas these structures have been mainly interpreted by the IMF polarity and/or magnetospheric convection structure, we have proposed that they can be also recognized purely by the ionospheric effect, the generation of polarization field due to conductivity inhomogeneities. Our study has been based on a part of the M-I coupling theory [e.g., Yoshikawa et al, JGR, 2013a, b] including the idea of Pedersen/Hall divergence/polarization effect [e.g., Yoshikawa et al., JpGU, 2009]. Although the possibility of ionospheric effect had been reported [Wolf, 1970; Atkinson and Hutchison, 1978], we have for the first time addressed and visualized the underlying physics. By applying a simplified version of 'Hall-conjugate method [Yoshikawa et al., JpGU, 2008]' to a 2D ionospheric potential solver (so-called thin shell model), we separate the total field (Φ , ionospheric total potential) into the primary field (Φ_0 , including the background and Pedersen polarization field) and secondary field ($\delta\Phi_{Hall}$, the polarization field generated by Hall current divergence).

In the previous meetings [Nakamizo et al., SGPSS, 2012-2014], we have specified one-to-one correspondence between characteristic spatial gradients of conductivity and characteristic deformations of potential, as follows; (a) For simplicity we consider dawn-dusk symmetric R1-FAC as the driving source. As the reference field, we calculate the potential with the uniform conductivity distribution. This reference field is symmetric with respect to both the noon-midnight and dawn-dusk axes. From this condition we gradually add spatial structures on the conductivity distribution. (b) Equatorward latitudinal conductivity gradient generates positive/negative Hall polarization field ($\delta\Phi_{Hall,eq}$) around pre-noon/pre-midnight sectors. As the result the total field (Φ) rotates clockwise. (c) Day-night conductivity difference not only shifts the potential centers toward night due to Pedersen polarization effect (in other words, current continuity), but also generates Hall polarization fields ($\delta\Phi_{Hall,t}$) along day-night terminators due to sharp conductivity gradients there, resulting in the convex/concave of total field (Φ) along terminators. (d) Auroral conductivity enhancement generates Hall polarization fields ($\delta\Phi_{Hall,a}$) around edges of conductivity band. Thus in the total field (Φ) a conspicuous structure appears around the midnight oval, resembling 'Harang reversal.'

This presentation mainly discusses the point (d). Important point is that we get Harang-like structure with simplified distribution of FAC (dawn-dusk symmetric R1-FAC) noted above. Moreover Harang-like structure located in pre-midnight sector, as the same as the observations, where we placed no input FAC. We suggest the possibility of two-ways of the ionospheric control of magnetosphere-ionosphere convection based on the characteristics of the solver used in this study (physically it can be called as 'perfect current confinement solver') and the advanced M-I coupling theory [Yoshikawa et al., JGR, 2013a,b].

キーワード：ホール電流発散とホール分極場、電気伝導度勾配、電離圏ポテンシャル変形、Harang reversal、磁気圏電離圏結合、電離圏コントロール

Keywords: Hall current divergence and Hall polarization field, Conductivity gradient, Deformation of ionospheric potential, Harang reversal, Magnetosphere-Ionosphere coupling, Ionospheric control on magnetosphere-ionosphere convection