Latitudinal distribution of the Field Aligned Current estimated from SWARM constellation

*Mohammed FathyAbdelmoneam Adel[1], Essam Ghamry[2]

1.Physics Department, Faculty of Science, Fayoum University, Fayoum, Egypt., 2.National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt.

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 subaurotral 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^{o} latitude in the northern geographic hemisphere 0^{o}-80^{o} showed that; close to the equator [0^{o},40^{o}] latitude] the mean absolute FAC increases within [1000-1600] MLT increases. This daytime enhancement decreases at latitudes >40^{o}, and reverses its signature at the sub-auroral region [50^{o}, 60^{o}] where the nightside FAC intensity increases dramatically in comparison to dayside FAC. Again Dayside FAC intensity maintains its strength at latitudes >70^{o}. The largest FAC intensity is observed at latitudes larger than 60^{o} 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^{o}, 50^{o}], but dramatically jumps at latitudes larger than 50^{o} . 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^{o} -50^{o}] and >70^{o} and nightside FAC intensity is stronger than dayside FAC within latitudes [50^{o}-70^{o}], while the duskside and dwanside FAC showed a parallel correlation.

Keywords: Ionosphere, Field Aligned Current (FAC)

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

*NOWADA MOTOHARU[1], Quan-Qi Shi[1], Robert C. Fear[2], Chun-Feng Zhang[1], Yong Wei[4], Zhong-Hua Yao[3], Andrew Fazakerley[3], Sui-Yan Fu[5], Zu-Yin Pu[5]

1.Center for Space Weather Sciences, Institute of Space Science, School of Space Science and Physics, Shandong University at Weihai, 2.Space Environment Physics Group/Astronomy Group, Department of Physics and Astronomy, University of Southampton, 3.Mullard Space Science Laboratory, University College London, 4.Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Science, 5.Institute of Space Physics and Applied Technology, School of Earth and Space Sciences, Peking University

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 SuparDARN 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

*Geng Wang[1], Zhenpeng Su[1], Zhonglei Gao[1]

1.University of Science and Technology of China

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

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

*Mariko Teramoto[1], Akiko Fujimoto[2], Kaori Sakaguchi[3], Masahito Nose[4], Yoshizumi Miyoshi[5], Craig Kletzing[6], Howard Singer[7], Ayako Matsuoka[1]

1.Japan Aerospace Exploration Agency, 2.Kyushu University, 3.National Institute of Information and Communications Technology, 4.Graduate School of Science, Kyoto University, 5.Institute for Space-Earth Environmental Research, Nagoya University, 6.Department of Physics and Astronomy, University of Iowa, 7.NOAA Space Weather Prediction Center

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 weather Pc5 pulsations accelerate the energetic electron via the drift resonant interaction.

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

*Masakazu Watanabe[1,2], Takashi Tanaka[1], Shigeru Fujita[3], Yusuke Aoyagi[4]

1.International Center for Space Weather Science and Education, 2.Faculty of Science, Kyushu University, 3.Meteorological College, 4.School of Science, Kyushu University

The importance of field-aligned currents connecting the magnetosphere and ionosphere is widely recognized. In order to stimulate steady-state plasma convection in the ionosphere, energy must be supplied continuously from the magnetosphere to the ionosphere by field-aligned currents. In the magnetosphere side of the current system, there exists a "dynamo" in which electromagnetic energy is produced from other sources. In spite of this recognition, it was not until the advent of global magnetohydrodynamic (MHD) simulation that we started to gradually understand the physical processes of the magnetospheric dynamo. Global numerical simulations revealed that in the magnetosphere plasma thermal energy is much higher than flow kinetic energy, indicating that the energy source of the field-aligned currents is mainly plasma thermal energy. Recently, we have learned that one dynamo process is the "expanding slow mode" disturbances (Watanabe et al., 2014), and we now have a consensus that the Region 1 field-aligned current system can be interpreted in terms of the expanding slow mode. However, this mechanism seems not applicable to the nightside Region 2 FAC system. The purpose of this study is, using MHD formulation, to interpret the physical processes of the Region 2 dynamo on the nightside, in prospect of generalizing the theory of the magnetospheric dynamo. The magnetospheric dynamo is defined as the region in which the dot product of the current density vector (J) and the electric field vector (E) is negative (J.E < 0). Using Poynting's law, Faraday's law, and Ohm's law (with no use of equation of motion), the dynamo condition can be expressed in terms of the spatial variation of the magnetic field. Keeping in mind that we are considering a high beta region in which the magnetic field is relatively strong, the spatial structure of the magnetic field is assumed to determine the physics in the system. For formation of a dynamo, either (1) the magnetic pressure increases in the convection frame, or (2) the magnetic tension and plasma convection are in opposite directions. By considering the equation of motion separately, condition (1) indicates that the plasma pressure is sustained by the magnetic pressure, which is interpreted by the expanding slow mode disturbances mentioned above. This mechanism applies to the Region 1 system. Meanwhile, condition (2) indicates that the plasma pressure is sustained by the magnetic tension, which is considered to be applicable to the nightside Region 2 system. The latter process has never been focused in the past, and in this study we describe physical processes of this tension-driven dynamo.

Keywords: field-aligned current, dynamo, Region 2

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

Kaoru Sawai[1], *Mitsunori Ozaki[2], Satoshi Yagitani[2], Kazuo Shiokawa[3], Yoshizumi Miyoshi[3], Ryuho Kataoka[4], Yusuke Ebihara[5], Akimasa Ieda[3], Martin Connors[6]

1.Graduate School of Natural Science and Technology, Kanazawa University, 2.Institute of Science and Engineering, Kanazawa University, 3.ISEE, Nagoya University, 4.NIPR, 5.RISH, Kyoto University, 6.Athabasca University

Pulsating aurora is a kind of luminous phenomena, which shows a luminous modulation on timescales from several hundred milliseconds to tens of seconds. It is generated by interaction between high-energy electrons and chorus waves. It is expected that spatial and temporal variations of pulsating aurora show a close relationship with those for chorus waves. In order to investigate their relationships, we have been analyzing simultaneous ground observations of pulsating aurora and chorus waves at Athabasca in Canada (L=4.3). VLF waveform is sampled at 100 kHz and all-sky EMCCD camera for pulsating aurora is sampled at 110 Hz. In this study, we analyzed 11 events of simultaneously observed pulsating aurora and chorus waves from Dec., 2014 to May, 2015. In each event, the auroral luminosity had a correlation with the chorus intensity, which also showed a correlation with AE index. These results show that high-energy electrons resonate efficiently with the chorus waves during a high auroral activity. Next, we have performed a statistical analysis of internal modulations of the pulsating aurora observed at different latitudes in the FOV of the all-sky EMCCD camera. The occurrence distributions of the internal modulation showed different trends above and below a modulation frequency of 4 Hz. In the case of less than 4 Hz, the internal modulation frequency had a correlation with its luminosity. This is the same result reported by Nishiyama et al. [2014] based on the nonlinear wave growth theory. Pulsating aurora having the internal modulation below 4 Hz frequently appeared at low latitudes. This would be caused by the effect of a small geomagnetic inhomogeneity at the equatorial region based on the nonlinear wave growth theory. On the other hand, pulsating aurora exhibiting internal modulations above 4 Hz had a weak intensity in comparison with that with less than 4 Hz. This would suggest that the flux of energetic electrons causing the high modulation frequency was low, or the internal modulation above 4 Hz was generated by high-energy electrons, which could not contribute to the auroral emissions. The occurrence of pulsating aurora showing a high modulation frequency (4~10 Hz) was mainly distributed at high latitudes. This would be caused by the effect of hiss-like emissions generated with a high ratio of plasma frequency and electron cyclotron frequency. Thus, the spatial and temporal features of pulsating aurora can be expected to vary with the conditions of chorus generation depending on the L-value.
In this presentation, we will discuss the relationship between high-energy electrons causing pulsating aurora and chorus waves in detail.

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

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

*Shoya Matsuda[1], Yoshiya Kasahara[1], Craig Kletzing[2]

1.Information and Media Center, Kanazawa University, 2.Department of Physics & Astronomy, University of Iowa

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 ($n(He^+)/n(H^+)$) and proton-oxygen ion ratio ($n(O^+)/n(H^+)$) 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.

Keywords: Ion cyclotron whistler, EMIC wave, heavy ion

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

*Yuka Sato[1], Atsushi Kumamoto[2], Yuto Katoh[2]

1.National Institute of Polar Research, 2.Tohoku University

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 (Δf/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.

Cowling conductance estimated from the equatorial electrojet and midlatitude ionospheric drift velocity during the Halloween storm PC5 events

*Kumiko Hashimoto[1], Takashi Kikuchi[2], Ichiro Tomizawa[3], Tsutomu Nagatsuma[4]

1.Kibi International University, 2.Nagoya University, 3.University of Electro-Communications, 4.National Institute of Information and Communications Technology

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.

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

*Aoi Nakamizo[1], Akimasa Yoshikawa[2,3]

1.Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology, 2.Faculty of Science, Kyushu University, 3.International Center for Space Weather Science and Education, Kyushu University

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 (Φ0, including the background and Pedersen polarization field) and secondary field (δΦHall, the polarization field generated by Hall current divergence).
In the previous meetings [Nakamizo et al., SGEPSS, 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 (δΦHall,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 (δΦHall,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 (δΦHall,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].

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

