

Heater-induced artificial ionospheric ion upflow

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We have investigated force balance associated with ion upflow, by using the EISCAT UHF radar and heating facility in Tromsø, northern Norway (69.6 deg N, 19.2 deg E). The heating facility enables us to induce not only enhanced electron temperature but also upward flowing ions in the F-region/topside ionosphere. The heater-induced artificial ion upflow is one of the most suitable events to estimate force balance of ionospheric ions quantitatively and also understand generation mechanisms of ion upflow. Furthermore, the heater-induced ionospheric data are potentially usable to estimate height profiles of ion-neutral collision frequency, neutral density, and horizontal neutral wind in the F-region/topside ionosphere.

We conducted the heater and radar observations as an EISCAT special program by UK and Japan between 17 and 20 November, 2011, and successfully obtained data including artificial ionospheric ion upflow. The UHF radar and heater beams were both pointed into the magnetic zenith, and pump cycle of the heater was 16 min on, and 12 min off. During heater on period electron temperature sometimes increased up to about 4000 K and upward ion velocity reached about 500 m/s at an altitude of 500 km.

In this paper, we show the detailed results of the heating experiment, and discuss quantitative force balance associated with ion upflow.

Keywords: polar ionosphere, ion upflow, ion outflow, EISCAT

Reimei observations on correlation of field-aligned current to precipitating electrons and accelerated ionospheric ions

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High-time and -spatial resolution data obtained by the low-altitude polar-orbiting micro satellite, Reimei, provide us with remarkable opportunities for revealing the characteristics of electrons and auroras based on the perfectly simultaneous and conjunction measurements of auroral emissions and particles.

The Reimei satellite has been making numerous notable observations in the nightside southern polar ionosphere during the winter seasons during 2005-2008. The first case shown in this paper is a comprehensive set of various fine-scale auroral activities, which shows four types of auroral forms and their variations taken by the multispectral auroral imaging camera (MAC): faint bands, streaming multiple arcs, shearing pair of arcs, and vortices/curls. The electron energy spectrum analyzer (ESA) covering a full pitch angle range observed various properties of electron energy-pitch angle distributions and their time variations, each of which is distinctive of the correspondent auroral activity. It is evident that the main energy fluxes responsible for the arc-type emissions are carried by the inverted-V electrons accelerated by (quasi-)electrostatic parallel potential structures above the satellite orbit. On the other hand, the rapidly rotating vortices are associated with the significant fluxes of spiky electron components with energy-time dispersions produced by dispersive Alfvén waves. The field-aligned current signatures are also affected by these relations between auroras and precipitating electrons, which are controlled by difference of the upward and downward electron fluxes.

Another case presents unique correlative features between streaming fireball-type auroral globs at the poleward edge of the auroral bands and sharply field-aligned sporadic electron precipitations with clear energy-time dispersions embedded in the inverted-V electrons. The peak energies of the dispersive electron signatures at the start are almost equal to the characteristic energies of the inverted-V components. This correlation obviously designates the fine modification of the auroral forms/emissions in the larger structure driven by the strong dispersive Alfvén waves at the similar altitudes with the parallel potential drop.

Keywords: auroral electron, ionospheric ion acceleration, field-aligned current, satellite observation, field-aligned potential, auroral dynamics

Spatial Variations of O⁺ Resonance Scattering Emission Estimated by the UPI-TEX on KAGUYA

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In 1980s, terrestrial Oxygen ion (O⁺) outflow was observed much more than expected amount in the polar region where the magnetic field connects to interplanetary space. However, it is not yet obvious when and how much O⁺ outflow are produced. In order to observe terrestrial O⁺ outflow, we use the Upper Atmosphere and Plasma Imager-Telescope of Extreme ultraviolet (UPI-TEX) on board the lunar orbiter, KAGUYA(SELENE). TEX imaging observations can detect both temporal and spatial variations of O⁺ resonance scattering emissions, which reflects to the O⁺ column density. However, O⁺ scattering light is too weak to see the spatial variations obviously. Therefore, this analysis is to estimate spatial variations of O⁺ scattering light that is removing filter support effects and spatial integrated it. In this study, we discussed about validity of its estimate and changing O⁺ scattering light associated with geomagnetic activity (AE).

Keywords: KAGUYA Satellite, UPI-TEX, Oxygen ion outflow, Solar wind, Geomagnetic activity

Ionospheric current patterns during the undershielding and overshielding deduced by a global ionospheric potential solve

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Toward the understanding of the magnetosphere-inner magnetosphere-ionosphere coupled system, we have developed a two-dimensional ionospheric global potential solver (GEMISIS-POT). Our model basically follows a methodology of the so-called "thin shell model." The important extension from previous studies is that our model covers the pole-to-pole ionosphere without placing any boundary at the equator. By using the solver, we investigated how the ionosphere changes from under-shielding condition to over-shielding condition as the FAC distribution changes. Calculations are performed by changing j_0 , $R2 / j_0$, $R1$ (the ratio of peak current density of R2 and R1-FAC) and moving R2-FAC toward the nightside with $dLTR2-R1$ (the local time deference between the R1 and R2-FAC peaks) relative to the fixed R1-FAC. In the previous talk, we reported the calculation results focusing on the electric field structure. In the present study, we analyze the ionospheric current and equivalent magnetic field perturbation of the calculation examples representing the undershielding and overshielding.

We separate the ionospheric current into the diagonal and non-diagonal components in terms of the thin shell approximation. In the polar region, where the dip angle of the geomagnetic field is close to zero, the diagonal and non-diagonal components are nearly equivalent to Pederson and Hall currents, respectively. However, in the low latitude region with the finite dip angle, they cannot be simply reduced to Pederson and Hall currents because of the mixture of Pederson, Hall and parallel conductivities in the conductivity tensor arising from the thin shell approximation of $J_z=0$ (vertical ionospheric current is assumed to be zero).

The calculation results show that the non-diagonal part is the major part of the ionospheric current in the polar region, whereas, in the equatorial region, the diagonal component becomes the major part. In this talk, we discuss how the current circuit from the polar to equatorial region is described by the pair of diagonal and non-diagonal components and also discuss the derived current circuit in relation to the pair of Pederson and Hall currents.

Detection of the ionospheric day/night terminator effect by SuperDARN radars

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It is well known that the non-uniform ionospheric conductivity has an effect to deform the ionospheric convection pattern. For example, it is deduced that the dawn-dusk asymmetry of the ionospheric convection pattern in the polar region is caused by the electric charges and the secondary electric field arisen from the non-uniform ionospheric conductivity around the day/night terminator.

We have tried to detect the sharp deformation of the ionospheric convection around the day/night terminator by using data from the SENSU Syowa East SuperDARN radar. We found a remarkable convection pattern during the intervals from February to March and from September to October when the day/night terminator crossed the field of view (FOV) of the radar. However, the direction of the convection was opposite to that expected from the day/night terminator effect and is rather explained by the line of sight (LOS) velocity expected when the ionospheric plasma flows anti-sunward across the FOV of the radar. In addition, it was difficult to interpret the obtained results, because the place where the day/night terminator crosses the FOV of the radar corresponds to the auroral zone around the midnight. In this study, therefore, we attempt to detect the day/night terminator effect by using data from the SuperDARN radars that observe the polar cap ionosphere.

Keywords: SuperDARN radars, ionosphere, conductivity, day/night terminator, convection

Walen Separation in the ionosphere

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Global ionospheric current and convection system couples to the magnetospheric dynamics. Transmission of electromagnetic energy, momentum and current from the magnetosphere to the ionosphere for driving and maintaining the ionospheric current system against to the Joule dissipation should be mediated via shear Alfvén wave. Fundamentally, the above fact won't be changed even for quasi-static state. This means that the ionospheric current and convection system is formed as a result of incident and reflection process of shear Alfvén wave at the ionosphere.

Applying the concept of Walén relation of incompressible MHD disturbances to the ionospheric current and convection system, we develop the methodology that describes the ionospheric current and convection system as a superposition of incident and reflected components of shear Alfvén wave. Extracted incident component corresponds to the driving force of ionospheric current system, while reflected component corresponds to the feedback component to the magnetosphere that is excited as a result of magnetosphere-ionosphere coupling process. The Walén separation also enables to extract the Cowling channel from the ionospheric current and convection system.

In this presentation we will discuss about how the Walén-separation technique can be applied to the realistic ionospheric data and show a specific result of separation analysis.

Keywords: magnetosphere-ionosphere coupling, Walén relation, Alfvén wave, ionospheric current, ionospheric convection

Ion-neutral collision frequency from EISCAT observations in the polar lower ionosphere during geomagnetic disturbances

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One of the fundamental processes in the thermosphere-ionosphere coupled system is collision between ions and neutral particles. The collisional process contributes to, for example, ion drag and Joule heating. Ion drag transfers momentum of ions to neutral particles, and may temporally modulate thermospheric dynamics, in particular, at F-region heights. The ion-drag process can also be defined as increasing flow velocity of a bulk motion of neutral gas along the mean ion velocity. Collisions also result in increases of thermal energy of both ions and neutral species. These processes are called frictional heating and Joule heating, which elevate the ion temperature first then the thermospheric temperature. The ion-neutral collision frequency is an essential parameter to represent equations related to the ion drag and frictional/Joule heating. Then the ion-neutral collision frequency was estimated using data from the European Incoherent Scatter (EISCAT) radar at Tromsø, Norway during the Dynamics and Energetics of the Lower Thermosphere in Aurora 2 (DELTA-2) campaign in 2009. Vertical component of the ion velocity in the lower ionosphere (106-135 km) and the ion momentum equation were applied to the calculation. The calculated ion-neutral collision frequency was approximately equivalent to that predicted using modeled density data. However, notable increases were found above 126.8 km during natural ionospheric heating events. An obvious depression in calculated values was also found between 114.6 km and 126.8 km just after cessation of another heating event. This paper discusses contributions of the vertical thermospheric motion to variations of the ion-neutral collision frequency.

Keywords: Ionosphere, Thermosphere, High latitude, ion-neutral collision frequency, EISCAT radar

The occurrence rate of THR emissions observed by the Akebono satellite

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This is a report on the occurrence rate of Terrestrial Hectometric Radiation (THR), auroral radio emissions emanating from the topside ionosphere in the MF and HF ranges. Data shown in this paper were obtained by the Plasma waves and sounder experiment (PWS) mounted on the Akebono satellite. The Akebono/PWS measurements show that THR emissions are sometimes observed in two frequency bands near 1.5-2.0 MHz and 3.0-4.0 MHz when the satellite passes over the auroral latitudes; however, their occurrence rate has not yet been investigated. Statistical studies using the Akebono/PWS data show the spatial distribution of THR occurrence; THR is detected at all magnetic local times and most often during pre-midnight hours (2100-2400 MLT) in a wide magnetic latitude range ($|\text{MLAT}| > 30\text{deg}$). During daytime hours (0600-1500 MLT), the distribution of its occurrence is confined in higher latitude ranges ($|\text{MLAT}| > 70\text{deg}$). The explanation of this spatial distribution is that THR is favorably generated in the night-side auroral latitudes near 1000-km altitude.

Keywords: auroral phenomena, auroral radio emissions, radio propagation, auroral ionosphere

Spatial distribution of the magnetic perturbation in the magnetosphere at the times of low-latitude round Pi 2's

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Pi 2 magnetic pulsations are damped magnetic oscillations having periods between 40 and 150 seconds; they are observed by ground-based magnetometers and satellites at the onset times of the expansion phase of substorms.

In this study, we use magnetometer data from the ETS-VIII geosynchronous satellite (M.Lat = -7.88deg, M.Lon = 218.56deg) [Koga and Obara, 2008], the THEMIS satellites [Angelopoulos, 2008], and a MAGDAS ground station YAP (M.Lat = 1.49, M.Lon = 209.09) [Yumoto et al., 2006]. We identified 100 isolated Pi 2 pulsations in the ground H (northward) component data from YAP in the period from 1 January 2009 to 31 May 2009; in this period, the apogees of the THEMIS satellites were located in the nighttime region at $5R_e < r < 30R_e$ (r : geocentric distance). We statistically investigated the maximum amplitude of the compressional magnetic field component observed by THEMIS in the interval of 5 min before and after the Pi 2 onset time observed at YAP. We found that large magnetic perturbations (>10 nT) were most frequently observed in the region of $r = 8-10R_e$ and $LT = 22-24$ hr. This location is the same as that of the Pi 2 source region deduced by Uozumi et al. [2007] from ground-based observations. Taking into account the decay of the fast-mode wave with distance from a source, the above result strongly suggests that the epicenter of the Pi 2-related compressional pulse is located in the region of $r = 8-10R_e$ and $LT = 22-24$ hr.

Keywords: Pi 2 magnetic pulsation, Pi 2 source, multi point observation, propagation

Magnetic conjugacy of northern and southern auroral beads

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Auroral beads, i.e. azimuthally arrayed small-scale bright spots resembling a pearl necklace, have recently drawn the attention of researchers as a possible precursor of explosive activation of the aurora. Here we used simultaneous, ground-based, all-sky camera observations from a geomagnetically conjugate Iceland-Syowa Station pair to demonstrate that small-scale auroral beads evolve synchronously in the northern and southern hemispheres and have good magnetic conjugacy for ~ 7 min before an auroral breakup. The synchronous conjugate auroral beads undergo a two-step evolution: in the first ~ 4 minutes, well-organized bead structures move eastward with an almost constant speed of 1 km/s or less, and subsequently they develop dramatically into brighter and larger auroral forms with faster propagation speed of 2-6 km/s. Our observations strongly suggest that, for the auroral beads, the magnetosphere plays a fundamental role in the determining their temporal evolution, while the ionospheric contribution that can induce asymmetric auroral behavior in the two hemispheres is minor or not significant.

Keywords: auroral beads, magnetic conjugacy, substorm

Stability analysis of auroral arc with magnetic shear effects

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The dynamics of auroral arcs in the magnetosphere-ionosphere coupling system has been vigorously studied on the basis of magnetohydrodynamic instabilities and their nonlinear evolution. The feedback instability was proposed for a mechanism [Sato, 1978; Lysak, 1991], where destabilization of shear Alfvén waves is induced through a resonant coupling with density waves propagating in the ionospheric convection electric field. Recently, two-dimensional simulations (along a field line and crossing arcs) with dipole magnetic fields demonstrated formation of small-scale arcs and ionospheric cavity modes [Streltsov and Lotko, 2004; Lu et al., 2008]. Treating nonlinear terms appropriately, a three-dimensional simulation in slab geometry showed that Kelvin-Helmholtz type vortex structures are spontaneously excited in the magnetosphere [Watanabe, 2010]. A linear analysis with non-uniformity of the Alfvén velocity clarified growth properties of the field-line resonances and cavity modes [Hiraki and Watanabe, 2011]. Furthermore, their relationship to the occurrence of auroral vortices has been investigated with nonlinear simulations.

In this study, we revisit linear stability of auroral arcs and shear Alfvén waves. Recent imaging observations revealed that, before substorm onset, arcs appear at high latitudes, propagate slowly, and suddenly destabilize to breakup at a low latitude region [Mende et al., 2009]. We examine this fact to be understood as a switching phenomenon where stability of arcs changes through changes of its direction relative to the convection electric field. Global two-cell convection fields at midnight point to the east-west direction, whereas strong north-south components are locally formed by the Harang discontinuities at low latitudes [e.g., Zou et al., 2009]. From analyses of feedback instability, it is found that the growth rates are mainly controlled by the amplitude of convection fields and are at the maximum for modes with wave numbers parallel to the ionospheric currents. However, we can analytically suggest that magnetic shear produced by the field-aligned current of arcs has a stabilizing effect on modes perpendicular to the shear; it can produce a strong directivity for growing modes. In this talk, we introduce results of this stability analysis with arc-induced magnetic shears as well as the dependences on convection field and conductivity.

Keywords: auroral arc, feedback instability, magnetic shear

Crater red aurora in the cusp

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A new high-resolution all-sky imager (Longyearbyen, Svalbard) detected the formation of "crater red aurora" in the cusp and the immediate ejection of the narrow auroral form from the crater during an interval of southward IMF on 29 December 2011. The crater red aurora can be defined as a circular-shaped region in which 630-nm dayside auroral emissions weaken. The emission data obtained continuously with an exposure time of 4 s show that the circular shape whose diameter was approximately 150 km at F region heights was formed for 2 min after the initial weakening at a smaller region. Immediately after the circular-shape was formed, a latitudinally-narrow (~40 km) auroral form was ejected from the inside wall of the crater in the azimuthal direction. The speed of the leading edge is estimated to be approximately 1.5 km/s. These observations strongly suggest that the crater red aurora is the ionospheric signature of a crater flux transfer event, which has been studied recently with data from spacecraft near the dayside magnetopause. Considering that the scale of a crater flux transfer event reflects the size of a flux transfer event itself, the present observation shows that the ionospheric signature of a flux transfer event is much larger than the ejected narrow auroral form. Such an auroral form, which has been regarded as a so-called poleward moving auroral form, would represent the structure inside a flux transfer event, not the whole structure of a flux transfer event.

Keywords: red aurora, F region, cusp, plasma flow

Simultaneous observation of polar cap patches with all-sky imager and EISCAT radars

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The airglow intensity of polar cap patches is related to the local electron density profile of the polar cap ionosphere as well as the profiles of neutral gases that contribute to optical emission. Concurrent operation of an all-sky imager and incoherent scatter radars enables simultaneous observations of optical intensity of polar cap airglow and ionosphere parameters. An all-sky airglow imager equipped with a high sensitivity EMCCD detector has been deployed in Longyearbyen, Svalbard (78.1 N, 16.0 E) since October 2011. The imager's fine time and 2D resolution and its proximity to the EISCAT Svalbard radar (ESR) provide opportunities to study the relationship between the optical intensity and electron density of polar cap patches. By virtue of the spatial resolution of approximately 2 km per pixel, it is possible to identify a fine structure of the electron density in the region where the ESR beam crosses at a particular altitude. A 4-second exposure time of the imager combined with its high spatial resolution allows us to detect rapid changes in patch structures which have not been possible to identify with radar-alone observations.

In this study we analyze a storm time polar cap patch event combining the data obtained by the all-sky imager and two radars, the ESR and mainland EISCAT UHF radar. An interval between 17 UT and 24 UT on 22 January 2012 is studied. The variations of optical intensity and electron density show a good agreement, which enables us to cross-calibrate the two parameters. Cross examination of optical intensity and electron density reveals steep gradients and sharp edges of patch structures as narrow as a few kilometers. Temporal variations obtained from the two EISCAT radars suggest that some patches were transported antisunward from the polar cap to lower latitudes, which is in good agreement with the all-sky imager observation. These facts suggest that electron density structures may travel across the polar cap from the cusp region to the night side auroral zone keeping their sharp density gradients.

Keywords: polar cap patches, high-latitude ionosphere, EISCAT, all-sky imager, ionospheric electron density structures, airglow

A coordinate analysis of dayside diffuse aurora: GEOTAIL, FAST, and South Pole auroral observations

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It has been thought that the source of diffuse auroral emissions is scattered plasma sheet electrons into the loss cone by some wave-particle interactions. Both ECH waves and whistler-mode chorus have been thought to be the contributors to the production of diffuse auroral electrons since they can resonate with plasma sheet electrons. A question which wave mode dominantly contributes to the production of diffuse auroral electrons has been discussed for more than four decades and there is still controversy. A recent study done by Thorne et al. [2010] reveals that whistler-mode chorus is dominantly responsible for the production of diffuse auroral electrons. While, there are some observational suggestions that ECH waves cause diffuse auroral electron precipitations. [e.g., Nishimura et al., 2010; Liang et al., 2010]. Multi-point observations along a field line using low altitude satellites and spacecraft around the magnetic equator are important to investigate the contributor to the generation of diffuse aurora since the properties of diffuse auroral electrons depend on the wave mode that causes electron pitch angle scattering.

This study shows a coordinate analysis of dayside diffuse auroras using the data obtained from a reliable ground-spacecraft conjunction event. During the event, diffuse auroras were observed by the South Pole all sky imager. At that time, GEOTAIL located in the dayside magnetosphere at a radial distance of $\sim 10R_e$, at 1000 MLT and its ionospheric footprint was inside the diffuse aurora. Furthermore, the FAST spacecraft passed over the footprint of GEOTAIL. The FAST observations showed the precipitating electrons in the energy range of 0.1 to 10 keV and the pitch angle distributions revealed that electron scattering rates reached strong diffusion limit in the energy range of 0.1 to 5 keV. PWI/SFA onboard GEOTAIL observed both whistler-mode waves and ECH waves around the conjunction event. More likely wave mode contributing to the electron precipitations was investigated by estimating resonant energies for whistler-mode waves and ECH waves, respectively. Based on the observed frequency distributions, minimum resonant energy for whistler-mode waves were too high to scatter the electrons in the energy range below 10 keV, while ECH waves can resonate with the electrons in the energy range of 0.1 to 10 keV. This result suggests that generation mechanism of diffuse aurora in this event was pitch angle scattering driven by ECH waves rather than whistler-mode waves.

Keywords: Diffuse aurora, wave-particle interaction, whistler-mode waves, ECH waves

Two satellite observations of precipitating electrons associated with auroral breakup

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We compare auroral electrons several minutes before and after an auroral breakup. The electrons were observed by the FAST and DMSP satellites near the breakup location. The breakup was identified in global images taken by the Polar satellite at 1957:50 UT on 10 November 1999. FAST passed the breakup location 6 min before the breakup and observed diffuse electrons with energy around 10 keV. The diffuse electrons were accompanied by broadband electrons below 1 keV, which are supposed to be associated with Alfvén waves. Seven min after the breakup, a DMSP satellite crossed the onset arc. DMSP observed inverted-V type electrons at the surge horn, which was 15 deg west of the initial breakup location. In summary, the onset arc corresponded to diffuse electrons with broadband electrons before breakup, and to inverted-V electrons after breakup. It is thus suggested that the evolution of diffuse electrons to inverted-V electrons is associated with waves.

Keywords: aurora, auroral breakup, substorm, field-aligned current

Photoelectron flows in the polar cap during geomagnetically quiet and weakly disturbed periods

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On the open magnetic field lines in the polar cap, downgoing electrons with energies lower than about 100 eV, which are considered to be photoelectrons reflected by a field-aligned potential drop above the satellite, had been identified in some case studies [e.g., Winningham and Gergiolò, 1982]. To examine the typical characteristics of the photoelectron flows and the field-aligned potential drop, we statistically investigated photoelectrons in the polar cap using the data obtained by the FAST satellite in an altitude range of 3000-3900 km in July 2002 (solar maximum) during geomagnetically quiet and weakly disturbed periods. In this period, the apogee of the FAST satellite located at high latitudes in the northern (summer) hemisphere. The geomagnetically quiet period is defined as the times when the *Kp* index is less than or equal to 2+ for the preceding 3 hours and when the *SYM-H* index ranges from -10 to 40 nT, while the weakly disturbed period is defined as the times when the *Kp* index ranged between 4- and 5. The polar cap is defined by the lack of energetic ions [Andersson et al., 2004]. We found counter-streaming photoelectrons of up to more than 10 eV, indicating existence of a field-aligned potential drop (reflection potential drop) above the satellite altitude. Such distributions were frequently (quiet: 83%, weakly disturbed: 65%) observed in the polar cap. The estimated typical reflection potential drop above the satellite is about 20 V. In respect of the presence of a field-aligned potential drop at high altitudes, this result is consistent with the modeling results by Wilson et al. [1997] and Su et al. [1998], although the field-aligned distribution of the potential (e.g., presence of a potential jump) cannot be investigated from only the photoelectron observations in the present study. The typical observed reflection potential drop during geomagnetically quiet periods (about 22 V) is smaller than these modeling results by a factor of 2-3, while the median of net escaping electron number fluxes during geomagnetically quiet periods ($1.7 * 10^8$ /cm²/s) is larger than these models by a factor of 2.8-3.5. During weakly disturbed periods, the net escaping electron number flux tends to increase (median: $2.8 * 10^8$ /cm²/s), while the magnitude of the reflection potential drop tends to decrease (median: about 17 V), compared to those during geomagnetically quiet periods.

The net escaping electron number flux negatively correlates with the reflection potential drop. This relation corresponds to the fact that only high-energy photoelectrons can overcome the potential drop and escape when the reflection potential drop becomes large. On the other hand, the net escaping electron number flux, which should be nearly equal to the flux of the polar wind ions under small FAC conditions, negatively correlates with the upward electron number flux. This relation is contrary to the modeling results by Khazanov et al. [1997] and Tam et al. [1998]. An increase in downgoing electrons and their backscatter in the ionosphere with increasing reflection potential drop may explain the negative correlation. A potential drop at high altitudes, which was not considered by Khazanov et al. [1997] and Tam et al. [1998], would provide a polar wind system regulated by a negative feedback, and the most appropriate balance for polar wind ions would be achieved near the median of the reflection potential drop.

Keywords: polar wind, ion outflow, polar ionosphere

In-situ measurement of cusp plasma irregularity by sounding rocket - ICI-3 campaign -

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The ICI-3 (Investigation of Cusp Irregularities-3) campaign was conducted in Svalbard, Norway on December 2011. Science objective of ICI-3 is to obtain a better physical description of instabilities and wave phenomena driven by the newly discovered Reversed Flow Events (RFEs) in the winter cusp ionosphere. In particular, we would like to elucidate the following unresolved problem: 1)whether the RFEs are associated with a tangential discontinuity or a rotational discontinuity, 2)if the RFE-Birkeland current sheets are related to inverted-Vs, and 3)Identification of wave phenomena and non-linear saturation. In-situ measurements by sounding rockets will be needed to understand inherent cause of such phenomena.

The ICI-3 sounding rocket was launched at 07:21:31 UT at Ny-Alesund in Svalbard on December 3, 2011, and it successfully intercepted the cusp aurora region. All onboard systems functioned flawlessly. Measurements of the electron density and its perturbation, low energy electron flux, AC and DC electric fields, and field-aligned currents were made to conduct a comprehensive study with the aim to exploit the potential role of the gradient drift instability versus the other suggested mechanisms for the cusp plasma irregularity. An independent attitude determination system was prepared to define the orientation of the payload in order to derive vector field measurements.

We present a result obtained from a fixed-bias Langmuir probe which was installed to measure fine-scale (~1 m) electron density perturbation.

Keywords: Ionospheric cusp, plasma irregularity, electron density, sounding rocket

Poleward-propagating magnetic perturbations in the cusp

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Poleward-propagating magnetic perturbations are often observed on the ground in the cusp latitudes. Some previous studies suggested that these phenomena are the ionospheric current signature of flux transfer events [e.g., Milan et al., 2000]. However, our recent study on the mesoscale plasma injection in the cusp, which is typical of a flux transfer event, has shown that poleward-propagating nature is not clear despite that a vortical feature is identified [Taguchi et al., 2010]. In this study, using large data set obtained from the Greenland magnetometer chain, we identify statistical characteristics of poleward-propagating magnetic perturbations in the daytime sector, and understand what produces this signature. We took poleward-propagating events using cross-correlation of data from different stations in the Greenland chain. Results from the statistical analysis of these events show that the occurrence frequency is high around 12 MLT, as is expected, and that a typical poleward propagation speed is 0.5-2 km/s, which is consistent with the convection velocity. What is interesting is that there are a significant number of events that occur both in the East and West chains with no time lag. This shows that the longitudinal extent is more than about 1,000 km, which is much larger than the extent of the typical scale size of the possible signature of a flux transfer event. The east-west component of the magnetic perturbations of these events is generally small, which suggests that the perturbations are not produced simply by the enhancement of the anti-sunward convection in the longitudinal wide extent. We will show the detailed characteristics of the poleward-propagating phenomena including the longitudinally wide events, and discuss what drives these phenomena.

Keywords: ground magnetic perturbations, ionospheric current, cusp, polar cap, IMF

Periodic structures of the electron density in the F region cusp

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Structured plasma density in the dayside cusp is known to be collocated with "soft" precipitating particles, that is, electrons with energy less than about roughly 500 eV. When the energy and flux change over time, the structured density becomes even more irregular. In this study, using high time resolution data from the EISCAT Svalbard radar, we understand whether or not some periodic features exist in the irregular density distribution in the cusp. First, we derived the raw electron density profile with the shortest time resolution (of 3.2/6.4 s) from the radar data. We then examined the electron density profile using wavelet analysis. The result of wavelet analysis shows that several periodic variations exist in the structured density, and that a variation of 40-80s is prominent. We will show the detailed result about this variation, and discuss why this is prominent.

Keywords: F region, electron density, cusp, plasma convection, IS radar observations

All-sky imaging polarimetry of OI 630 nm aurora

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Auroral polarimetry potentially contributes to bring us new information on electron collision with atmospheric particles and local process in the ionosphere. Recent ground-based measurement data showed that auroral emission at OI 630 nm probably polarized with a degree of 1-4 % [*Lilensten et al., Polarization in aurorae*, 2008], and the polarization is maximized in the magnetic perpendicular direction [*Barthelemy et al., Polarisation in the auroral red line during coordinated EISCAT Svalbard Radar/optical experiments*, 2011]. However, past experiments were carried out with a photometer mainly in the polar cap region, and examples were limited. To measure polarization degrees continuously from the magnetic perpendicular direction to the magnetic parallel direction, the all-sky imaging polarization observation combined with a fish-eye lens and 2-D CCD or CMOS detector is the most feasible.

We plan to carry out a campaign measurement of imaging polarimetry of auroral 630 nm emission at Poker Flat Research Range, Alaska during a new moon period of 2012-13 winter with a newly developed all-sky polarization imager. In addition, we will make a model to estimate atmospheric scattering along the line-of-sight path between aurora and the ground. The instrument will be precisely calibrated since its optical system may produce artificial polarization. All-sky imaging auroral polarization data bring us to examine the dependence of the polarization degree on the magnetic field angle. In this talk, we report our plan of the auroral polarimetry measurement, and the current status of the developments in detail.

Relationship between auroral curl/spiral and particle precipitation: Reimei observation

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One of the most attracted properties of the aurora is its wave-like structures and the various scales of its wave structures are observed, such as an auroral curl or spiral. In this study, we focused on the precipitated particle behaviors when the aurora curl or spirals are observed at its footprint. Statistical analysis, using Reimei observations, shows that the inverted-V structures, low-energy electron dispersion, and plasma sheet electron precipitations are closely associated with the well-developed auroral wave structures.

Electron properties of Inverted-V structures and their vicinities based on Reimei observations

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Electrons accelerated by the field-aligned potential difference are referred to as Inverted-V electrons. It is thought that fine structures of their energies and pitch angle distributions are due to electrostatic potential structures and their variations. Scientists have addressed outstanding problems such as how the potential difference is supported or how they are distributed along the magnetic field line. The purpose of this study is to understand how Inverted-V electrons are formed by focusing on not only Inverted-V regions but also their vicinities. The Reimei satellite for simultaneous observations of auroral particles and emissions with high temporal and spatial resolutions observed beam electrons at the edge of Inverted-V regions. At first their pitch angles are 0 to 20 degree. As Reimei moves toward the center of Inverted-V regions, their pitch angles broaden up to ~120 degree, and their characteristic energy becomes higher. This electron beam is observed with non-accelerated diffuse electrons. To investigate electron properties around and in Inverted-V regions, we estimated the density and temperature of the source electrons. To observed electron energy fluxes we fitted the Maxwellian distribution for diffuse electrons and the accelerated Maxwellian distribution for Inverted-V electrons and electron beams.

An event observed on February 2, 2006 shows Inverted-V electrons with the width of ~0.6 LAT at 73 ILAT and 0.4 MLT. At the high latitude of these electrons, diffuse electrons with energies of ~400 eV and the isotropic distribution were observed. The estimated temperature and density of source diffuse electrons are ~300 eV and ~0.6/cc, respectively. In addition, those of energetic Inverted-V electrons are ~300-400 eV and ~0.1 /cc, respectively. For beam electrons, on the other hand, they are <100 eV and <0.1 /cc, respectively. These results indicate that source regions of diffuse electrons and energetic Inverted-V electrons are the magnetosphere such as the plasma sheet, and source electrons of the electron beam exist at altitudes of the topside ionosphere consisted of lower temperature electrons. To form electron beams, we figure out that a small amount of electrons are needed to supply into the acceleration region. From observations of auroral emissions, the poleward motion of the auroral arc with a low speed (~0.5 km/s) was captured. Thus electron beams are likely explained by a drift of the electrostatic potential drop in the latitudinal direction. In other events, the similar signature of electron beams indicates that their source region is the topside ionosphere. Some static auroras, however, are also observed. In these cases, we consider that these ionospheric electrons are supplied into the potential drop due to the fallen bottom of equipotential planes toward lower altitudes. In this presentation, we will show some inverted-V events including diffuse electrons and electron beams and discuss about formations of electron beams.

A Study of ULF pulsations observed at a New Magnetometer Array in the Tasmania and New Zealand Region

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In order to observe ULF pulsations and its spatial distribution, we are constructing a new magnetometer array in New Zealand and Tasmania region. In February 2011 and March 2012, we installed (or will install) magnetometers in Middlemarch and Wairarapa, respectively. Some magnetometers have been operated by previous projects in Tasmania and its conjugate point. Coordination of their and our magnetometers will allow us to study temporal variations of frequency of field line resonances in the Tasmania and New Zealand meridian lines. In this paper, our latest results are introduced.

Keywords: ULF, plasmasphere, Inner Magnetosphere, Magnetosphere-Ionosphere coupling

Development of ULF wave database conjugately observed at Syowa and Iceland

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The Energization and Radiation in Geospace (ERG) satellite will be launched in 2014 or 2015 to observe the inner magnetosphere. In conjunction with this, the existing observation network on the ground is to be redeveloped. As part of these developments, observation data from induction magnetometers installed in Antarctica and Iceland have been arranged. There are three observation points in Iceland and one station in Antarctica. In Iceland the sampling frequency is 2 Hz; on the other hand, at Syowa station, the sampling frequency is 20 Hz. Induction magnetometers are installed along with fluxgate magnetometers and riometers. The data are sent to Japan in a quasi-real-time manner. By making dynamic spectra from these data, we are developing a database of ultralow-frequency (ULF) waves. In the future, we intend to create a database environment that can compare the ERG satellite data with the ULF observation data simultaneously in a quasi-real-time manner. Currently, dynamic spectra have been developed for the period from February 2003 to January 2011. This period is consistent with that of CDF data files from the Syowa station. The frequency ranges of the developed dynamic spectra are 0-1 Hz and the durations are 24 h. To remove the effects of DC and anti-aliasing filters whose cutoff is 1 Hz, the averaged background is deducted from the FFT spectra data from the Iceland stations. Frequency ranges of FFT spectra from Syowa station are 0-10 Hz. Therefore, frequency ranges of 0-1 Hz are extracted from these data in addition to the aforementioned deducting procedure. As a feature of the conjugate observations, differences in attenuations of received signals between the summer and winter hemispheres are indicated. The intensities of the observed phenomena in the dynamic spectra of the summer hemisphere are weaker than those observed in the winter hemisphere. These attenuations are considered to be related to propagating processes in the ionospheric waveguide. Development of the database is proceeding, and we intend to publish it on a website in the near future.

Keywords: conjugate observation, ultralow-frequency, database development

Wp index: A new substorm index derived from high-resolution geomagnetic field data at low latitude

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Geomagnetic field data with high time resolution (typically 1 s) have recently become more commonly acquired by ground stations. Such high time resolution data make it possible to identify Pi2 pulsations which have periods of 40-150 s and irregular (damped) waveforms. It is well-known that pulsations of this type are clearly observed at mid- and low-latitude ground stations on the nightside at substorm onset. Therefore, with 1-s data from multiple stations distributed in longitude around the Earth's circumference, substorm onset can be regularly monitored. In the present study we propose a new substorm index, the Wp index (Wave and planetary), which reflects Pi2 wave power at low-latitude, using the geomagnetic field data from 11 ground stations (Tucson, Honolulu, Canberra, Kakioka, Learmonth, Urumqi, Iznik, Fuerstenfeldbruck, Ebro, Tristan da Cunha, and San Juan). We compare the Wp index with the AE and ASY indices as well as the electron flux data and the magnetic field data at geosynchronous altitude for 11 March 2010. It is found that significant enhancements of the Wp index mostly coincide those of the other data. Thus the Wp index can be considered as a good indicator of substorm onset. The Wp index, other geomagnetic indices, and geosynchronous satellite data are plotted in a stack for quick and easy search of substorm onset. The stack plots and digital data of the Wp index are made available from the web site (<http://s-cubed.info>) for public use.

Long-term variations of quiet-time geomagnetic H components on the nightside at mid latitudes

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Magnetic H-component values for several mid-latitude observatories were analyzed using the principal component analysis. It was found that there exists a seasonal variation in the opposite sense between the northern and southern hemispheres. The amplitude of the seasonal variations is larger at higher latitudes. This fact possibly indicates that the seasonal variation is caused by a electric current system at high latitudes such as the Region-1 current system. It was also found that there exists an irregular variation in the same sense between the two hemispheres, which is likely to anti-correlate with solar-wind activity.

Keywords: geomagnetic variation, long-term variation, field-aligned current

Syowa SENSU SuperDARN imaging radar and the future perspective

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SENSU Syowa HF radars are important components of SuperDARN, the international HF radars network since 1995 and have significantly contributed to understanding not only magnetosphere ? ionosphere system and their couplings but also MLT region dynamics. As SuperDARN radars were originally designed to reveal global polar plasma convection patterns in both hemispheres in real time, its spatial resolution has been relatively low. As the number of new scientific targets like comparison with mid and small scale aurora phenomena and fine height profile of neutral wind distributions have been increasing, higher spatial (and temporal) resolution observations have been essentially desired. Imaging radar technique has been tried to be applied and developed to overcome this issue. We show the current status of our preparation of the SENSU imaging radar system, and will discuss particularly on the scientific targets and the future perspectives which can be revealed by this new technique using SuperDARN.

Keywords: SuperDARN, Syowa, imaging, MLT region dynamics, MI coupling, aurora