Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-01 Room:302 Time:May 23 09:00-09:15

Structuring and nonlinear dynamics of auroral arc

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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 Alfven waves is induced through a resonant coupling with density waves propagating in the ionospheric convection electric field. Recently, two-dimensional simulations 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 showed that Kelvin-Helmholtz type vortex structures are spontaneously excited in the magnetosphere [Watanabe, 2010]. A linear analysis with non-uniformity of the Alfven velocity clarified eigenmode properties of the field-line and cavity resonances [Hiraki and Watanabe, 2011; 2012]. Furthermore, their relationship to the occurrence of auroral vortices has been investigated with nonlinear simulations.

In this study, the magnetospheric plasma is described by the reduced-MHD equations, and nonlinearity of Alfven wave appears in the convective derivatives with Poisson brackets terms. The field-aligned current of the Alfven wave flows into the ionosphere, producing an internal uniformity of plasma density or conductivity. The ionospheric plasma motion is described by the compressible two-fluid equations and is characterized by the Pedersen and Hall currents; nonlinearity appears in the divergence of these currents. The purpose of this study is to understand effects of the above nonlinearities on the development of feedback unstable modes. Auroral structuring as a result of these instabilities could be related to observing phenomena: splitting of arc and spiral or vortex (bead) structures. Properties of cavity modes and field line resonances associated with auroral structuring can be understood in the nonuniform flux-tube system. Furthermore, the relationship between long-lived auroral arcs and feedback-unstable modes that grow up in a strong convection is investigated. Characteristics of vortex structures appearing in auroral break-up would be pursued.

Keywords: auroral arc, Alfven wave, nonlinear simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-02 Room:302 Time:May 23 09:15-09:30

Observation of aurora polarimetry at OI 630 nm

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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., 2008]., and the polarization is maximized in the magnetic perpendicular direction [Barthelemy et al., 2011]. However, past experiments were carried out with a photometer mainly in the polar cap region, and examples were limited and there are no observation of circular polarization like all-sky imager.

We carried out observation of aurora polarimetry at OI 630 nm at Poker Flat Research Range in Alaska from 6 to 19 January 2013 with a newly developed all-sky polarization imager and meridian scanning photometer. We developed all-sky imager what measures polarization component (stokes vector) consists of fish-eye lens, the liquid crystal variable retarder difference which controls polarization electrically, polarization beam splitter, and CCD camera by joint development with the Institute for Astronomy, University of Hawaii. The photometer consists of wave plate on rotating stage, polarization beam splitter and measures polarization components.

In this talk, we report our result of this auroral polarimetry measurement, and the design of the observational instrument in detail. We will analyze and compare with geomagnetic data and precipitation particles data observed by the satellite and explore the application of aurora polarization measurement.

Keywords: aurora, polarimetry

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-03 Room:302 Time:May 23 09:30-09:45

Spatial distribution of the plasmaspheric ions estimated by assimilation of IMAGE/EUV data

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The IMAGE satellite observed EUV radiation at 30.4 nm which is scattered by helium ions in the plasmasphere. The imaging data of extreme ultra-violet (EUV) from the IMAGE satellite provides the information about the global structure of the plasmasphere. We are developing a data assimilation technique which incorporates the IMAGE/EUV data into a two-dimensional fluid model of the plasmasphere. Our approach consists of two steps. First, we estimate the initial state of the plasmasphere by the linear inversion. Second, we estimate the temporal evolution of the plasmasphere from a sequence of EUV images by using the ensemble transform Kalman filter, which is one of sequential data assimilation algorithms. By combining a sequence of EUV images and the dynamic model the plasmasphere, we estimate the spatial distribution of the plasmaspheric herium ions and the electric potential. We will show the structure of the plasmasphere for some events, which are estimated with the data assimilation technique.

Keywords: plasmasphere, data assimilation

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(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-04 Room:302 Time:May 23 09:45-10:00

Solar activity dependence of quiet-time photoelectron outflows and the field-aligned potential drop in the polar cap

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Counter-streaming photoelectrons with energies of about a few tens of electron volts are present on the open field lines in the polar cap, and the precipitating component is reflected photoelectrons by a field-aligned potential drop above the satellite [e.g., Kitamura et al., 2012]. To examine solar activity dependence of the photoelectron flows and the magnitude of the field-aligned potential drop, we statistically investigate photoelectrons in the polar cap using the data obtained by the FAST satellite in an altitude range of 3000-4200 km during geomagnetically quiet periods under small field-aligned current conditions. We selected 30 months when the apogee of the FAST satellite was located in the summer hemisphere from the months between July 1997 and January 2009. 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. The polar cap is defined by the lack of energetic ions [Andersson et al., 2004]. The typical magnitude of the field-aligned potential drop during geomagnetically quiet periods tends to decrease with decreasing solar activity (F10.7). Near the solar maximum, the typical magnitude of the field-aligned potential drop is 20-30 V, while it is about 10 V or smaller near the solar minimum. The flux of upgoing photoelectrons increases with increasing solar activity. In contrast, the median of the net escaping electron number flux in each month during geomagnetically quiet periods is almost unaffected by solar activity. This relation suggests that larger field-aligned potential drop prevents most of them from escaping.

Keywords: Polar wind, Ion outflow

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PEM28-05 Room:302 Time:May 23 10:00-10:15

A Parametric Sensitivity Study for Magnetosphere-Ionosphere Coupling Process in a Global MHD Simulation

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We present a parameter study of simulated processes of the magnetosphere-ionosphere (M-I) coupling using the global MHD simulation code developed by Tanaka (2010).

The boundary conditions for the M-I coupling include some scaling factors. These factors are adjustable and are determined through trial and error. The main goal of this study is optimization of these scaling factors in the boundary condition by use of a data assimilation technique.

In this paper, we examine the effects of varying the scaling factors to the ionospheric electric field potential map using a global MHD simulation.

References:

Tanaka, T., A. Nakamizo, A. Yoshikawa, S. Fujita, H. Shinagawa, H. Shimazu, T. Kikuchi, and K. K. Hashimoto (2010), Substorm convection and current system deduced from the global simulation, J. Geophys. Res., 115, A05220, doi:10.1029/2009JA014676

Keywords: global MHD simulation, sensitivity analysis, ionospheric electric field potential map, aurora, ionospheric conductivity, field-aligned current

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-06 Room:302 Time:May 23 10:15-10:30

Seasonal variation of the amplitude of geomagnetic sudden commencements from low latitude to the magnetic equator

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Seasonal dependence of diurnal variation of the main impulse (MI) of geomagnetic sudden commencements (SCs) has been investigated using the long-tern geomagnetic field data with high time resolution of 1 sec within a period from 1996 to 2008 provided from the NSWM [Kikuchi et al., 2008] and CPMN [Yumoto and the CPMN group, 2001] chains and the WDC for Geomagnetism, Kyoto. In the present analysis, we used the geomagnetic field data obtained from the 6 stations: Pohnpei (geomagnetic latitude, MLAT = 0.27 degree), Yap (MLAT = 0.38 degree), Cebu (MLAT = 0.85 degree), Guam (MLAT = 5.22 degree), Okinawa (MLAT = 16.54 degree), Kakioka (MLAT = 27.18 degree). In this study, the SC events have been defined as a rapid increase with its amplitude of more than 5 nT within 10 minutes in the SYM-H index. In this case, 4158 events of the magnetic field disturbance are found in a long period from January 1996 to October 2012, which has no Pi 2 signature around 10 minutes at the SC onset. Details of the analysis method have been described in the paper of Shinbori et al. [2009]. Moreover, the SC amplitude obtained at the above 6 stations has been normalized by that in the SYM-H index with latitude correction in order to minimize the different contribution of the rapid change in solar wind dynamic pressure. We also used solar wind data obtained from the IMP-8, Geotail, Wind and ACE satellites within the same period. As a result, the diurnal variation of SC amplitude in the equatorial region (0.27-5.22 degree) showed an equatorial enhancement in the daytime (6-18 h) with its maximum around 11 h produced by the enhanced eastward ionospheric currents due to the Cowling effect. The local time showing the peak amplitude tends to shift from the noon to the morning side by 1 hour. The equatorial enhancement was observed in an off-dip equatorial region (dip latitude: ˜15 degrees). The seasonal variation of the equatorial enhancement of SC amplitude shows that the SC amplitude tends to become relatively smaller in the summer than in the equinox or winter. This variation is different from that in the middle latitudes reported by Shinbori et al. [2012], and suggests that the intensity of the equatorial electrojet current does not simply depend on the solar zenith angle. One of the implications of the equatorial seasonal dependence is that the penetration polar electric field tends to become weak in the summer, compared with that in the winter and that there exists a contribution of ionosphere current flowing in the lower F-region. In future, in order to verify this feature, we will need to perform a comparable analysis between the SC amplitude and ionospheric conductivity calculated with the IRI-2007 and NRLMSIS-00 models.

Keywords: Sudden commencement, Magnetic equator, Seasonal variation, Ionospheric conductivity, Solar zenith angle, Cowling effect

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-07 Room:302 Time:May 23 10:30-10:45

Relationship between low latitude electric field and global currents during geomagnetic pulsations

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The PC5 is often observed at low latitude with enhanced amplitude at the dayside dip equator, consistent with the DP2 currents driven by the dawn-dusk electric field [Motoba et al., 2002]. The electric field associated with the DP2 currents has been observed by the HF Doppler measurements at low latitude [Motoba et al., 2004]. In the present study, we show that the HF Doppler frequency deviations at low latitude are out of phase with the equatorial PC5 in the same meridian in the period range of 1-10 min. The PC5 at the nightside low latitude shows little latitudinal change, implying major contribution of the compressional MHD waves propagated from the magnetosphere. However, appreciable currents were found to be driven by the dawn-dusk electric field in the nightside equatorial ionosphere. These results raise an issue on the dynamo for the PC5 which supplies the electric field and currents in the ionosphere.

Keywords: PC5 pulsation, HF Doppler frequency, ionospheric electric field and current, PC5 dynamo

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-08 Room:302 Time:May 23 11:00-11:15

Seasonal variation of equivalent current in the polar ionosphere

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We have statistically studied an equivalent current system in the polar ionosphere derived from ground-based magnetometer network. It is well known that the ionospheric current system forms a twin-vortex pattern with flow cells on the dawn and dusk sides. The anti-sunward current flow in the polar cap region tends to be tilted toward dawn even during negative IMF-By condition. This deformation of the current pattern is generally interpreted to be caused by non-uniform ionospheric conductivity.

Our results show that the current intensity is greater in summer than in winter and the tilt angle of the current flow is greater in winter than in summer. Furthermore, we found that diurnal variation of the magnetic field in the polar cap region averaged during the geomagnetically quiet condition is similar to the solar quiet (Sq) variation observed at low to middle latitudes. These results imply a possibility that the ionospheric current system in the polar region may be affected by the Sq current system.

Keywords: ionospheric current system, polar ionosphere, Sq current system, magnetometer network

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-09 Room:302 Time:May 23 11:15-11:30

Solar zenith angle dependence of tweek reflection height during magnetically quiet time and magnetic storms

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Reflection height of tweek atmospherics is an indicator of the height of the ionospheric D-layer. Variations in tweek reflection height through the day-night boundary at Antarctic station were reported by Saini and Gwal (2010). The tweek reflection height gradually varied from 64 km to 79 km at Indian Maitri station in Antarctica through three months (January-March) in both 2003 and 2005, showing variations of the tweek reflection height under the midnight sun at polar region. The descent (rise) of the reflection height corresponds to increase (decrease) in electron density in the ionospheric D- and lower E-regions. Singh et al. (2011) reported the variations of the tweek reflection height observed in India during a solar eclipse of 22 July, 2009, which occurred just after sunrise. The tweek reflection height decreased from about 94 km to 90 km during the sunrise. However, solar zenith angle dependence of the tweek reflection height has not been studied statistically. In this study, we statistically investigate the solar zenith angle dependence of the tweek reflection height, using long-term tweek data of 1976-2010 during magnetically quiet time, and for 7 major magnetic storms occurred in 1978 - 1999. We pick up major magnetic storms with the Dst minimum of less than -200 nT to know the difference between the storm time and quiet time. The tweek reflection height in the magnetically quiet time rises from about 88 km to 96 km with increasing the solar zenith angle from 80 degrees to 105 degrees. In the solar zenith angle range of 105 - 170 degrees, the tweek reflection height keeps at the height of 96 km. This shows that the tweek reflection height under the sunset/sunrise condition is lower than that in complete nighttime, indicating the increase in the electron density in the lower ionosphere due to the sunset/sunrise. The tweek reflection height during the magnetic storms also shows similar solar zenith angle dependence with that in magnetically quiet time. However, the tweek reflection height during magnetic storms is systematically entirely lower by about 2 km than that during magnetically quiet time. This shows the electron density increase during magnetic storms.

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-10 Room:302 Time:May 23 11:30-11:45

Current conservation of Equatorial Electrojet coupling to R1 current system

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Possible mechanism for current closure from polar to equatorial ionosphere via global Cowling channel is discussed. In our model, a global (primary) Hall current accompanied by two-cell type ionospheric convection induces polarization chargee at the conductivity gradient region of dawn-dusk conductivity terminator and magnetic dip-equator. The secondary electric field accompanied by this induced charge generates the secondary Hall current flows along the dawn-side terminator line to the magnetic dip-equator. Resultantly, the global Cowling channel from polar to equatorial ionosphere via the terminator-line and magnetic-dip equator could be formed. Our model shows that growing of equatorial electrojet (EEJ) is due to the converging Hall current from polar region to the dawn side dip-equator and decaying of EEJ is due to the diverging Pedersen current from dusk-side dip-equator to the polar region. This mechanism can be applied to the EEJ disturbances accompanied by the solar wind variations such as DP2-type magnetic field disturbances and many phenomena associate the equatorial enhancement and/or depression of the geomagnetic field disturbances.

Keywords: Equatorial electrojet, Field aligned current, Magnetosphere-Ionosphere coupling

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-11 Room:302 Time:May 23 11:45-12:00

Overshielding Electric Fields at Low Latitude as Observed with the HF Doppler Measurements

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The convection electric field penetrates from the polar ionosphere to low latitude and drives the DP2 currents in the global ionosphere with an intensified equatorial electrojet (EEJ). The electric field often reverses its direction, that is, the overshielding occurs and causes the equatorial counterelectrojet (CEJ) during storm and substorms. The overshielding electric field has been observed at the equator with the incoherent scatter radar in Jicamarca and SuperDARN radars in mid latitude. In low latitude, on the other hand, the HF Doppler measurements have been used to detect the electric field associated with the short-period disturbances such as the sudden commencements and geomagnetic pulsations (1-10min), but the overshielding electric field with time scales of several 10s of min have not been reported. To detect the overshielding electric field in the low latitude ionosphere, we analyzed the Doppler frequency of the HF radio signals propagated over 120 km in Japan at frequencies of 5 and 8 MHz. We compared the Doppler frequency deviations with the equatorial EEJ/CEJ and found that the overshielding electric field is comparable to or even stronger than the convection electric field. These results suggest that the overshielding electric field would play an important role in the ionospheric disturbances at low latitude.

Keywords: ionospheric convection, overshielding electric field, equatorial counter electrojet, HF doppler, low latitude ionosphere

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-12 Room:302 Time:May 23 12:00-12:15

Characteristics of azimuthally polarized Pi 2 pulsations on the morning side

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Pi 2 pulsations are globally observed on the ground at the onsets of substorms. On the morning side, the amplitude of the D-component Pi 2 pulsation increases due to the sunrise effect (Saka et al., [1980]). However, there are few studies about this phenomenon, and its mechanism is still unknown. We analyzed azimuthally polarized Pi 2s on the morning side using data from the MAGDAS global magnetometers network. The following results are found; (1) D-component oscillations at low-latitude station were synchronized among D-component high-latitude oscillations and H-component dip-equator oscillations. (2) The amplitude of the D-component oscillation increases with latitude. (3) The oscillations in the D-component shows the out-of-phase relationship between postmidnight and morning side. (4) The oscillations in the D-component shows the out-of-phase relationship between the southern and northern hemispheres. From the result (3), the D-component oscillations on the morning side are deferent from magnetic fluctuations caused by the downward FAC oscillation of a substorm current wedge. We suggest that the north-south ionospheric current controls the azimuthal oscillation on the morning side.

Keywords: Pi 2 pulstaions, ULF waves, ionospheric current, substorm current wedge, multipoint ground-based observation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-13 Room:302 Time:May 23 12:15-12:30

Relationships between auroral beads evolution and Pi pulsations at substorm onset

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Auroral beads often appeared during presubstorm onset phase, which has been considered as one of important auroral phenomena relating to substorm expansion onset. Recently Motoba et al.,(2012) have reported optical signatures of auroral beads evolution in all ? sky images observed at a conjugate pair ? station, Syowa in Antarctica and Tjornes in Iceland, in which auroral beads appeared almost at the same time, as an inter ? hemispheric signature and the evolution was stable in the first stage, and then developed to a larger scale spiral form (undulations), at the same time at both the conjugate stations. These interhemispheric similarities suggest that there must be a common driver in the magnetotail equatorial region. On the other hand, it has been well known that Pi pulsation is another important signature at substorm onset. In this paper we examined relationships between auroral beads evolution and Pi pulsation onsets during a few minutes before the substorm expansion onset for the 30 September 2012 substorm event. Results show that there exist very good relationships between Pi pulsation onsets and auroral beads evolutions, particularly on the signatures for auroral beads sudden evolution to spiral structures and/or undulations, which was coincident to appearance of Pi 2 pulsation, and auroral beads brightness enhancement, which accompanied Pi 1 pulsation onset. The appearances of these Pi 1 and Pi 2 pulsations show a good conjugacy. These results show very good one-to-one correspondence between auroral beads dynamics and Pi 1 and 2 onsets, suggesting a common physical mechanism controlling their dynamics in the magnetotail equatorial region.

Keywords: substorm, aurora, pulsations

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-14 Room:302 Time:May 23 12:30-12:45

Convection and Birkeland currents associated with theta auroras: MHD modeling

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When the interplanetary magnetic field (IMF) is northward, there occasionally occurs a peculiar auroral configuration which is called the theta aurora. The theta aurora consists of a ring of auroral luminosity (auroral oval) and the transpolar arc that crosses the polar cap from the nightside to the dayside. One mechanism that describes the theta aurora formation is the IMF By (dawn-dusk component) variation. When the IMF By polarity switches, the theta aurora is formed during the reconfiguration of the magnetosphere-ionosphere system. There are many observational studies that supports this idea, and global magnetohydrodynamic (MHD) simulations do reproduce the theta aurora configuration. However, details of the magnetosphere-ionosphere coupling process are not well known. Also, because of the observational constraints, it is not straightforward to advance the research deductively from observations. The purpose of this paper is, using numerical MHD simulations, to investigate the detailed processes of the magnetosphere-ionosphere coupling associated with the theta aurora formation and to show the evolution of convection and field-aligned currents (FACs) in a form to permit comparison with observations.

We set the IMF magnitude to 10 nT and switched the IMF clock angle from -45 to +45 degrees and vice versa. In this paper we define the theta aurora as the ionospheric projection of the closed field line region in the magnetotail (i.e., the plasma sheet). When IMF By switches from negative to positive, in the northern ionosphere, the theta aurora is detached from the dawnside auroral oval and drifts duskward in the polar cap. In the southern hemisphere, the dawn-dusk relation reverses. The characteristics of ionospheric convection and FACs are summarized as follows.

(1) In general, when IMF By is significant, quasi-stationary ionospheric convection exhibits the basic round/crescent cell pattern. In the theta aurora formation, the round cell plays a crucial role. Twenty minutes after the IMF By switch, the new round cell associated with the new IMF By is established. The theta aurora drifts with this round cell. The convection speed is faster in the rear side of the theta aurora motion (the new-lobe side) than the foreside (the old-lobe side). After the full development of the theta aurora, sunward convection occurs only at the dayside tip of the theta aurora (the theta crossbar is not connected to the dayside auroral oval). In the nightside part of the theta aurora, the round cell flow turns its direction from antisunward to sunward, so both sunward and antisunward convection coexist. The theta is often attributed to sunward convection; however this picture is not necessarily correct.

(2) The FAC reconfiguration precedes the convection reconfiguration. Fifteen minutes after the IMF By switch, the NBZ system associated with the new IMF By is already established. An FAC system with the same current polarity as the NBZ system extends antisunward along the rear side (with respect to the drift motion) portion of the theta aurora. If we trace the current lines to the magnetosphere, the FAC region is mapped to the foreside part of the protruded plasma sheet boundary (the old-lobe side). There the dot product of the current vector and the electric field vector is negative, meaning that that region is (part of) the dynamo of the FAC system. In addition, in the plasma sheet boundary on the old-lobe side, Dungey-type reconnection associated with the old IMF still continues to supply closed magnetic flux, which is one factor of the theta aurora growth. In the ionosphere, on the other hand, the FAC associated with the theta aurora largely closes with the region 1 FAC associated with the new crescent cell. This ionospheric closure of FACs drives the fast flow in the rear side of the theta aurora drift motion. That is, in the ionosphere, the theta aurora is ”pushed” from the rear side by the round cell convection.

Keywords: theta aurora, field-aligned current, ionospheric convection, MHD simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-15 Room:302 Time:May 23 14:15-14:30

Production of polar cap patches

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A highly sensitive all-sky EMCCD airglow imager has been operative in Longyearbyen, Norway (78.1N, 15.5E) since October 2011. One of the primary targets of this optical observation is a polar cap patch which is defined as an island of enhanced plasma density in the F region drifting anti-sunward across the central polar cap. Since the electron density within patches is often increased by a factor of 2?10 above that in the surrounding region, all-sky airglow measurements at 630.0 nm wavelength are capable of visualizing their spatial distribution in 2D fashion.

Although, in the last two decades, several efforts were made to capture the birth of patches in their generation region near the dayside cusp, it has been very difficult to directly image such an instant because the dayside part of the polar cap ionosphere is mostly illuminated by the Sun even in winter. In Longyearbyen, however, it is well-known that daytime aurorae can be observed using ground-based optical instruments in a limited period near the winter solstice. This enables us to directly image how polar cap patches are born near the dayside cusp region.

We present an event of polar cap patches on November 24, 2012, in which patches were generated within the field-of-view of the all-sky camera located on the dayside. During a 4-h interval from 0500 to 0900 UT on this day, we identified several signatures of poleward moving auroral forms (PMAF) in the equatorward half of the field-of-view, which are known as ionospheric manifestations of dayside reconnection. Interestingly, patches were directly produced from such poleward moving auroral signatures and propagated poleward along the anti-sunward convection near the cusp. From this observation, we strongly suggest that polar cap patches can be directly produced by poleward moving aurora forms, i.e., the periodic occurrence of dayside equatorial reconnection process.

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM28-16 Room:302 Time:May 23 14:30-14:45

Accelerated motion of a poleward-moving auroral form in the cusp

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Poleward-moving auroral forms (PMAF), the ionospheric signatures of flux transfer events (FTEs), are intermittent phenomena observed in the cusp during negative interplanetary magnetic field intervals. Previous observations from ground-based optics showed that PMAFs emerge from the poleward boundary of the stable cusp precipitation region, and move poleward, often having a strong azimuthal component. In this paper, taking the advantage of a high-sensitivity all-sky imager, which is situated at Longyearbyen, Svalbard, Norway, we present observations in which PMAFs can be distinguished inside the stable cusp precipitation region. The 630.0-nm all-sky images taken with a time resolution of 4 s reveal that one of the PMAFs that occurred at ~1100 MLT on 17 December 2012 moves poleward quasi-steadily inside the stable cusp region during approximately 3 min after its appearance near the equatorward edge, and then accelerates eastward immediately after it exits from its poleward boundary. Prominent acceleration is seen during approximately 2 min, suggesting that the duration in which the tension force works on the newly opened field lines is a few minutes.

Keywords: aurora, cusp, particle precipitation, magnetic reconnection, all-sky imager