Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-01 Room:311 Time:April 28 11:00-11:15

ERG project

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The ERG (Exploration of energization and Radiation in Geospace) is Japanese geospace exploration project. The project focuses on relativistic electron acceleration mechanism of the outer belt in the context of the cross-energy coupling via wave-particle interactions. The project consists of the satellite observation team, the ground-based network observation team, and integrated-data analysis/simulation team. The ERG satellite will be launched in FY2015. Comprehensive instruments for plasma/particles, and field/waves are installed in the ERG satellite to understand the cross-energy coupling system. In the ERG project, several ground-network teams join; magnetometer networks, radar networks, optical imager networks, etc. Cooperative observations between the in-situ satellite and ground-based observations are important. Some simulation codes including both macro-scale phenomena and micro-physics are developed in Japan, which are very helpful quantitatively to understand the observational results and to incorporate the observations. In this presentation, the overview of the projects will be presented and possible collaborations with other geospace satellite missions as well as the ground-based observations will be discussed.

Keywords: ERG project, inner magnetosphere, future mission

PEM04-02 Room:311 Time:April 28 11:15-11:35

Upper Atmosphere phenomena in Geomagnetic Anomaly Region in association with Magnetosphere Disturbances

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Since 1999, we continuously study/observe upper atmosphere phenomena in Geomagnetic Anomaly Region (South Atlantic Anomaly: SAA) by using several equipments and obtained several interesting results. We show several remarkable phenomena in SAA on the basis of imaging riometer data and CCD imager data obtained at Southern Space Observatory (SSO; 29.4S, 307E) in Brazil and other stations.

(1) Particle precipitation in SAA seems to be related with polar disturbances. From imaging riometer data, enhancement of Cosmic Noise Absorption (CNA) occurs simultaneously with magnetic disturbances in polar region. On the other hand, CNA at Kakioka imaging riometer can be also seen during polar disturbance (not so frequently observed). It may suggest that particle precipitations are occurred in association with substorm at Kakioka as well as SAA.

(2) In sometimes, strong CNA is observed in association with sharply decreasing of electron flux (GOES satellite data) after moderate polar disturbance period. It may indicate that injection and drifting of electrons after polar disturbances precipitate in SAA during this period.

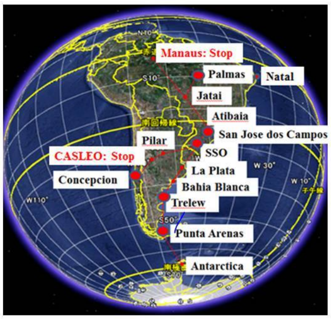
(3) It is well known that VLF waves trigger precipitation of radiation belt particles.

Although the longitudinal difference is 94 degrees (6 hours local times) between Syowa Station, Antarctica and SSO, CNA at SSO is nearly simultaneously observed with VLF emissions at Syowa Station. It may suggest that particles are more easily precipitating and observed in SAA through the wave particle interactions in radiation belt.

(4) Static multiple bands are singularly observed at SSO. The characteristics of static multiple bands are different from atmospheric gravity waves. They are fixed at the ground and rotate with earth rotation. This phenomena is very seldom and looks like occurs in winter season. The luminosity of these phenomena are not clear but less than 150R like airglow level..

We almost finished to construct South America Riometer Network (SARINET; 7 stations) and hope to collect data continuously during one solar cycle.

Keywords: South Atlantic Geomagnetic Anomaly, Cosmic noise absorption, Imaging riometer, Radiation belt, Airglow



South America Riometer Net work (SARINET)

PEM04-03 Room:311 Time:April 28 11:35-11:55

Loss of geosynchronous relativistic electrons by EMIC waves during quiet geomagnetic conditions

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We have examined relativistic electron flux losses at geosynchronous orbit under quiet geomagnetic conditions. Two 3-day periods, from 11 to 13 October and from 29 November to 1 December, in 2007 were chosen for analysis because geomagnetic conditions were very quiet (3-day average of Kp <1) and significant losses of geosynchronous relativistic electrons were observed. During both intervals, there were no geomagnetic storm activities. Thus, the loss processes associated with geomagnetic field modulations caused by ring current buildup can be excluded. The flux of geosynchronous relativistic electrons with energy >2 Mev shows typical diurnal variations with a maximum near noon and a minimum near midnight for each day. The flux level of the daily variation gradually decreased from first day to third day for each 3-day period. The total magnetic field strength (Bt), however, is relatively constant for each day. Unlike electron flux decreases, the flux of protons with energy between 0.8 and 4 MeV adiabatically responses to the daily variation of Bt. That is, there is no significant decrease of the proton flux when the electron flux decreases. During both 3-day periods, well-defined electromagnetic ion cyclotron (EMIC) waves were detected at geosynchronous spacecraft. Low-altitude polar orbiting spacecraft observed the precipitation of energetic electrons and protons in the interval of EMIC waves enhancement. From these observations, we suggest that the EMIC waves are a major factor to control the electron flux decrease under quiet geomagnetic conditions.

Keywords: Relativistic electron flux, geosynchronous orbit, EMIC waves

PEM04-04 Room:311 Time:April 28 11:55-12:10

Characteristics of dayside SAPS structures observed by the SuperDARN Hokkaido radar

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Sub-Auroral Polarization Streams (SAPS) are intense westward ionospheric flows in the subauroral ionosphere, and considered to be generated as a result of magnetosphere-ionosphere coupling during relatively disturbed periods. SAPSs are usually located in the evening to midnight sector, but occasionally it extends to earlier magnetic local times close to local noon. Owing to limitation of the observation techniques, no detailed studies of its local time extent have been made so far. In this study we use the data from the SuperDARN Hokkaido radar, one of the midlatitude SuperDARN radars located at the lowest geomagnetic latitude, to discuss the detailed characteristics of dayside SAPS, with focus on their relation to solar wind and geomagnetic parameters.

Keywords: dayside, SAPS, SuperDARN, Hokkaido radar, magnetosphere, ionosphere

PEM04-05 Room:311 Time:April 28 12:10-12:25

Amplification of EMIC waves by Pc3-4 waves

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Electromagnetic ion cyclotron (EMIC) wave is one of the key phenomena for the dynamics of high energy electrons in the radiation belt, since EMIC waves can scatter particles and make them precipitate into the ionosphere from the inner magnetosphere. The EMFSIS of Van Allen Probes observed the proton-band EMIC wave with the frequencies 2-6Hz at ~3RE in the GSM coordinates at 1110-1140UT on 29 June 2013. It was during the recovery phase of the magnetic storm started on 27 June. This event has significant enhancements of wave amplitudes up to ~10nT at 1123 and 1130UT. At these times, the magnetic field variations in the Pc3-4 range are also observed. We present the relation between amplitudes of EMIC waves and Pc3-4 wave occurrences, and discuss the amplification mechanism of EMIC waves by ULF waves with longer periods.

Keywords: EMIC waves, Pc3-4

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-06 Room:311 Time:April 28 12:25-12:40

Study of Pc1 pearl structures observed at multi-point ground stations at Russia, Japan and Canada

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We have investigated possible generation mechanisms of pearl structures of Pc1 geomagnetic pulsations using ground-based multi-point induction magnetometers at Athabasca in Canada, at Magadan in Russia and at Moshiri in Japan. During 3-years of observation (January 1, 2009 to December 31, 2011), we found two Pc1 pulsations with similar dynamic spectrum shapes at three stations simultaneously. For the case 1, which occurred on April 8, 2010, Pc1 pulsations were clearly identified at the three stations in the frequency range of 0.4 to 1.2 Hz. Coherence between the two stations was high ($r > 0.8$). The cross-correlation of the upper envelope of Pc1 waves between the ATH and the MGD, which indicates amplitude modulation of Pc1 due to pearl structures, was also high ($r > 0.8$). In some time interval during the case 1, however, correlation decreased down to 0.5. The case 2 occurred on April 11, 2010 in the frequency range of 0.2 to 0.8 Hz showed that the coherence and cross-correlation between ATH and MGD were both high ($r > 0.8$) throughout the event. The high coherence indicates that the Pc1 pulsations observed at these different stations were propagated from the same source region. However, in case 1, the Pc1 pearl structures were slightly different for different stations. The case 1 showed polarization angle variation depending on frequencies, while the case 2 does not show such dependence, suggesting that the case 1 has a spatially-distributed ionospheric source at high latitudes. In order to understand these different features of Pc1 pearl structures, we made two model calculations of Pc1 peal structures under the different conditions. One model is that the Pc1 waves come from a north-south extended ionospheric source region with slightly different frequencies at different latitudes. This source distribution, causes the Pc1 pearl structure by beating during the duct propagation in the ionosphere. The other model is that the Pc1 waves with different frequencies are mixed at the point source in the ionosphere, assuming that the pearl structures were already made in the magnetosphere. The Pc1 from the point source shows an identical waveform among the different stations. On the other hand, the Pc1 from distributed source region shows slightly different waveforms at different stations. This result suggests that the distributed source region is able to create the different Pc1 pearl structures at different stations through the beating, as observed for the case 1. We conclude that the Pc1 pearl structures are created by both magnetospheric processes and ionospheric beating processes before they reach the ground-based magnetometer at low latitudes.

Keywords: Pc1 pulsation, Pearl structures, multi-point ground observations

PEM04-07 Room:311 Time:April 28 14:15-14:35

Gradual Diffusion and Punctuated Enhancements of Highly Relativistic Electrons: Van Allen Probes Observations

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The dual-spacecraft Van Allen Probes mission has provided a new window into megaelectron Volt (MeV) particle dynamics in the Earth′ s radiation belts. Observations (up to E ˜10 MeV) show clearly the behavior of the outer electron radiation belt at different time scales: months-long periods of gradual inward radial diffusive transport and weak loss being punctuated by dramatic flux changes driven by strong solar wind transient events. Analysis of multi-MeV electron flux and phase space density (PSD) changes during March 2013 are presented in the context of the first year of Van Allen Probes operation. This March period demonstrates the classic signatures both of inward radial diffusive energization as well as abrupt localized acceleration deep within the outer Van Allen zone (L ˜4.0$\pm$0.5). This reveals graphically that both ″ competing ″ mechanisms of multi-MeV electron energization are at play in the radiation belts, often acting almost concurrently or at least in very rapid succession. It also shows in remarkable ways how the coldest plasmas in the magnetosphere intimately control the most highly energetic particles.

Keywords: Van Allen Probes, Radiation belts, Solar wind, Electron energization

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-08 Room:311 Time:April 28 14:35-14:55

Particle Acceleration in Kinetic Eigenmodes from the Van Allen Probes

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The Van Allen Probes have revealed the presence of a broad spectrum of narrow scale Alfvén eigenmodes in the inner magnetosphere during geomagnetic storms. Here we use observations from the Van Allen Probes to build a reduced MHD model for these waves in a dipolar geomagnetic field. This model is then used to explore the manner through which particles may be accelerated in these wavefields. Test particle simulations show that the narrow perpendicular scale and parallel electric fields carried by these waves lead to the violation of the 1st and 2nd adiabatic invariants for ions. This can drive the heating of the thermal ion population to multi-keV temperatures and the acceleration of a small fraction of these particles to energies exceeding 100 keV. This process has obvious implications for the storm time ring current, but also for the acceleration/loss of radiation belt electrons.

Keywords: Particle acceleration, Alfven waves, van allen probes, field lines resonances, ring current, radiation belts

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-09 Room:311 Time:April 28 14:55-15:10

Van Allen Probes observations of oxygen torus in the inner magnetosphere

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The oxygen torus is found in the deep inner magnetosphere as enhancements of O^+ ion density in a limited L range. It was first reported by Chappell [1982] who used the DE-1/RIMS instrument. Horwitz et al. [1984, 1986] showed that the O^+ density sometimes becomes comparable to or exceeds the H^+ density at L=3-4. Following studies revealed that the oxygen torus is observed just inside the plasmasphere at all local time with higher occurrence frequency in the late evening and morning sectors. A recent study by Nosé et al. [2010] cast a new light on the oxygen torus as a one of essential factors of O^+-rich ring current generation. They proposed that thermal O^+ ions preexisting in the oxygen torus are locally and nonadiabatically accelerated by fluctuations associated with dipolarization in the deep inner magnetosphere and contribute to ring current O^+ ions. Therefore investigation of the oxygen torus is important to understand the dynamics of ions of ionospheric origin in the inner magnetosphere.

We study the oxygen torus, using the magnetic field and plasma wave data obtained by the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) instrument onboard the Van Allen Probes. We examine a few events on the dawnside in which toroidal standing Alfven waves appear clearly. From the frequency of the toroidal waves, the magnetospheric local mass density (ρ) is estimated by solving the MHD wave equation for realistic models of the magnetic field and the field line mass distribution. We also estimate the local electron number density (n_e) from the plasma wave spectrograms by identifying narrow-band emission at the upper-hybrid resonance frequency. Assuming the quasi-neutral condition of plasma, we infer the local average ion mass (M) by ρ/n_e. It is found that M is generally less than 4 amu in the plasma trough, while it shows an enhancement of $>$6 amu near the plasmapause. This indicates an existence of the oxygen torus in the vicinity of the plasmapause. We will present the result and discuss possible formation mechanisms of the oxygen torus. Possible contribution of the oxygen torus to the formation of the O^+-rich ring current will be also discussed.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-10 Room:311 Time:April 28 15:10-15:25

Akebono observations of EMIC waves in the slot region of the radiation belts

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We present a unique observation of electromagnetic ion cyclotron (EMIC) waves in the deep inner magnetosphere at L = 2.5-5 made by the Akebono satellite at altitudes of 3,300-8,700 km. The mode conversion, i.e., L mode (He+ band)→R mode (He+ band)→L mode (O+ band) was clearly identified from the equator to high latitudes. In addition, we found rising tone structures, recently identified as EMIC triggered emissions, which could lead to bursty precipitation of relativistic electrons. First, we estimated the ion composition ratio (H+, He+, O+) = (83%, 16%, 1%) from polarization analysis. Second, we estimated minimum resonant electron energies with the observed EMIC waves and triggered emissions to be 1?10 MeV. The satellite trajectory during the wave observation was primarily through the slot region of electron radiation belts. The collocation implies possible contribution of EMIC waves to formation of the slot region of radiation belts after a magnetic storm.

Keywords: EMIC wave, slot region of the radiation belt, mode conversion, triggered emission, ion compotision ratio, Akebono satellite

PEM04-11 Room:311 Time:April 28 15:25-15:40

Oxygen ion acceleration and transport in the near-Earth plasma sheet during an isolated substorm

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Rapid enhancements of energetic ions during a substorm are one of the unsolved issues in the inner magnetospheric research (<7 Re). Previously, two distinct processes have been suggested to explain the enhancements. The first one is transport from the near-earth plasma sheet, and the other one is local acceleration. To test the both process, we performed test particle simulation under the electric and magnetic fields that are self-consistently obtained by the global MHD simulation developed by Tanaka et al. (2010, JGR). Oxygen ions are released in the lobe region with an interval of 1 minutes. The distribution function in the lobe is assumed to be drifting Maxwellian. The temperature is assumed to be 20 eV, the density is 105 cm-3, and the parallel velocity is given by the MHD simulation. In total, a few hundreds of millions of particles are traced. Each test particle carries the real number of particles in accordance with the Liouville theorem. After tracing particles, we reconstruct 6-dimensional phase space density of the oxygen ions, as well as the directional differential number flux so as to be able to make a direct comparison with in-situ satellite observations. Just after a substorm onset, the differential flux of the ions is rapidly enhanced in the energy range from 50 to 150 keV at radial distance R greater than 7 on the nightside in the equatorial plane. The region of the enhanced flux propagates duskward, then to dayside because of grad-B and curvature drift of the ions. We also plotted energy versus time spectrograms of the differential flux at a fixed position to make a direct comparison with the CRRES satellite observation. At 7.2 Re and at 22.4 MLT, the ion flux is suddenly enhanced about 10 minutes after the onset. The enhancement appears first at 120 keV, followed by lower energy as time proceeds. The energy-time dispersion is similar to that observed by CRRES [Fu et al., 2002]. The steepness of the energy-time dispersion depends on the source location of the ions. After a while, a high energy ion flux appears first, followed by that at lower energies. This is a called a drift echo, arising from the ions that encircled the Earth by the grad-B and curvature drift. We will discuss the acceleration processes in more detail, the role of pre-existing ions, and the total kinetic energy of the oxygen ions and its dependence on the source distribution function in terms of the ring current development.

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

PEM04-12 Room:311 Time:April 28 15:40-15:55

On the formation of overshielding triggered by a substorm onset: Global MHD simulation study

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The dawn-dusk convection electric field is a significant driver of transport of charged particles in the inner magnetosphere. When the dawn-disk convection electric field is enhanced, the ring current is developed, and the plasmasphere is shrunk. Ground-based observations have shown that, sometimes, the polarity of the convection electric field is reversed after a substorm onset. The presence of the dusk-dawn electric field is called an overshielding condition. Here, we demonstrate that the overshielding condition can appear after a substorm onset on the basis of a global MHD simulation. Immediately after the substorm onset manifested by a sudden decrease in the AL index and auroral brightening, the plasma pressure is enhanced in the inner magnetosphere. The simulated magnetic field on the ground shows a negative excursion in the polar cap, a positive excursion at auroral latitudes, and a negative excursion at sub-auroral latitudes at dusk. At noon and at equator (0 MLAT), the eastward electrojet starts to decrease just after the onset, and the westward electrojet appears about 10 min after the onset. All these variations are consistent with the observations. We discuss generation mechanisms, evolution of the overshielding condition in the ionosphere and the magnetosphere, and the redistribution of the charged particles trapped in the inner magnetosphere during the overshielding condition on the basis of the simulation solving drift transport equations.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-13 Room:311 Time:April 28 16:15-16:30

Nonlinear wave particle interactions in oblique whistler-mode chorus emissions

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The highly nonlinear phenomena of VLF chorus and triggered VLF emissions are of great interest due to their role in electron heating and precipitation, and are widely believed to be due to nonlinear cyclotron resonance between the narrow band wavefield and the anisotropic energetic electron population (~keV), the dominant mechanism being identified as nonlinear phase trapping. Considerable advances have been made in the theory and numerical simulation by assuming parallel (ducted) propagation [Nunn et al., 1997, 2009;Omura et al., 2008, 2009; Omura and Nunn, 2011]. Here we address the important issue of nonlinear wave particle interaction in oblique VLF wavefields. The treatment is of necessity non self-consistent. The narrow band wavefield is arbitrarily, but here chosen to be a CW field or a sophisticated model of a VLF chorus element based upon the theory of Omura et al.[2008, 2009]. We develop the electron equations of motion and then by backward trajectory integration compute resonant particle distribution function , resonant currents and thus local nonlinear growth rates. This may be done for any resonance order n and any field. As shown in Omura et al. [2008] nonlinear trapping for n=1 cyclotron resonance gives rise to a phase space hole in distribution function at the trap. Such a hole is also noted at higher order resonances (e.g. n=2) for sufficient wave amplitude and obliquity. For n=1 we find a marked saturation effect due to adiabatic effects, growth maximising at about 25pT and 2000km from the equator. For moderate obliquity $\vartheta<20$ degrees the n=1 resonance is relatively unaffected but growth rolls off sharply at high obliquity. For the n=0 resonance for obliquity $\vartheta>20$ degrees nonlinear trapping may occur giving a peak in phase space density. As trapped electrons are moving away from the equator adiabatic effects do not occur and maximum damping rates are at ~6000kms and at obliquities ~55 degrees. For the lower band rising chorus element model maximum n=1 growth is close to the equator, but maximum n=0 damping is found at the top of the frequency band at ~10000km downstream. Due to the coincidence of group and resonance velocities particles may be trapped near the equator and dragged a long way before detrapping.

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Keywords: whistler wave, wave-particle interaction, simulation, nonlinear, inner magnetosphere, chorus emissions

Japan Geoscience Union Meeting 2014
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PEM04-14 Room:311 Time:April 28 16:30-16:45

Relativistic electron microbursts induced by EMIC triggered emissions in the dipole magnetic field

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We perform test particle simulations of relativistic electrons interacting with electromagnetic ion cyclotron (EMIC) triggered emissions with rising-tone frequencies. We assume that the geomagnetic field is dipole because EMIC triggered emissions and radiation belt electrons are observed in the inner magnetosphere [1]. EMIC triggered emissions are generated by energetic protons injected into the inner magnetosphere and drifting westwards in the longitudinal direction. We study trajectories of relativistic electrons drifting eastwards interacting with EMIC triggered emissions over different longitudinal ranges. When relativistic electrons in the radiation belt interact with EMIC triggered emissions, some of them are trapped by a wave potential and efficiently guided down to lower pitch angles. Repeated interactions result in scattering of relativistic electrons into the loss cone [2]. Counting relativistic electrons which fall into the polar region, we find that half of the relativistic electrons interacting with EMIC triggered emissions are precipitated. We derive conditions of kinetic energies and pitch angles for efficient precipitation of relativistic electrons.

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Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM04-15 Room:311 Time:April 28 16:45-17:00

Investigating the upper and lower energy cutoffs of EMIC-wave driven precipitation events

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For some time theoretical modelling has shown that electromagnetic ion cyclotron (EMIC) waves should play an important role in the loss of relativistic electrons from the radiation belts, through precipitation of the electrons into the polar ionosphere. However, there are limited direct experimental observations of relativistic electron precipitation occurring, despite the indirect evidence for its importance.

Relativistic electron resonance takes place through "anomalous resonance" where the electron overtakes the wave. Until recently, it was through that EMIC wave scattering interactions were limited to electrons with energies greater than 1-2 MeV. Recent theoretical modelling [Omura et al., JGR, 2012] has suggested that this lower limit may be as small as 100 keV when considering EMIC waves more like those experimentally observed (i.e. non-constant frequency which ramps with time on one second timescales). Using data from the POES satellites we confirm the presence of lower energy (<1 MeV) electron precipitation most likely driven by EMIC waves.

We report on a continuing study that determines the typical flux impacting the ionospheric D-region during EMIC-driven precipitation events, and the effect this has on ionospheric conditions. We examine a very large set of EMIC-driven electron precipitation events detected using data from the POES satellite constellation [Carson et al., JGR, 2013] and determine the typical precipitating electron and proton fluxes.

As part of this study, we investigate the response of the MEPED instruments on-board the POES satellites to better characterise the EMIC-driven precipitation. Using the results of a previously reported Monte-Carlo simulation of the MEPED electron and proton telescopes [Yando et al., JGR, 2011], we characterise the typical energy range and flux for both the precipitating electrons and protons observed in these events. We go on to show that such events will produce very significant D-region changes detectable using the ground-based Antarctic-Arctic Radiation-belt (Dynamic) Deposition - VLF Atmospheric Research Konsortium (AARDDVARK) worldwide VLF receiver network.

Keywords: EMIC waves, electron precipitation, POES spacecraft, AARDDVARK, radiation belts, particle precipitation

PEM04-16 Room:311 Time:April 28 17:00-17:15

Plasmaspheric Content as Revealed by Spaceborne GPS Observations

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The FORMOSAT-3/COSMIC (F3/C) mission has been operating for more than seven years. The F3/C low earth orbit (LEO) satellites receive the signals from the global positioning system (GPS) for sounding of the atmosphere and the ionosphere of the earth, including the plasmasphere. The plasmasphere above ionosphere acts like a reservoir; it takes plasma from the ionosphere by day, stores it in a loss-free environment, and returns it to the ionosphere at night. For the non-radio occultation observation of the F3/C, we study the morphology of the plasmaspheric electron content (PEC) derived from F3/C raw observation data, which includes the diurnal variations of the time-series PEC, two-dimensional distribution and the interaction with the ionosphere.

Keywords: plasmasphere, FORMOSAT-3/COSMIC, GPS

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Polarization and occurrence statistics of VLF/ELF chorus waves at sub-auroral latitudes at Athabasca, Canada.

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Chorus waves are whistler-mode emissions in the very low frequency (VLF) range that are one of the most intense and common natural emissions. They are generated in the inner magnetosphere at the geomagnetic equator and follow the geomagnetic field lines into the ionosphere and the ground. They are believed to be *one of the major contributions to the acceleration and scattering of radiation belt particles* (e.g., Inan et al., 1982; Omura et al., 2007). Consequently we are interested in the *spatial and temporal motion of the acceleration region of radiation belt electrons*, which might be directly linked to the motion of the Ionospheric footprints of VLF/ELF waves.

For a period of 9 days, from February 17 to 25, 2012, the VLF-CHAIN campaign observed VLF/ELF emissions at sub-auroral latitudes using two loop antennas at Athabasca (MLAT=61.31, L=4.3) and Fort Vermillion (MLAT=64.51, L=5.4), Canada.

Several interesting features of chorus emissions have been observed such as quasi-periodic emissions, falling-tone and rising-tone chorus, as well as *Bursty-Patch* emissions. We have applied polarization and spectral analysis to make **the first comprehensive study of the physical properties of VLF/ELF chorus waves at sub-auroral latitudes**. Combining these analyses with a triangulation method we have also identified the location and motion of the Ionospheric exit points of these various types of chorus waves.

Furthermore, after September 24, 2012, continuous measurements of VLF/ELF waves with a sampling rate of 100 kHz have been made at Athabasca. Based on this data we show in this presentation the preliminary results of a one-year statistical analysis of frequency and occurrence rate of VLF/ELF chorus waves at sub-auroral latitudes.

Keywords: VLF, Chorus Waves, Polarization analysis, Ionospheric exit point, Sub-auroral latitudes

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Nonlinear analysis of magnetospheric wave-particle interactions

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The dynamics of the Earth's radiation belts are largely controlled by wave-particle interactions. Gyro-resonant whistler-mode chorus - electron interactions can generate relativistic (MeV) electrons in the outer zone during magnetic storms. Whistler-mode waves can pitch-angle scatter electrons and induce precipitation loss from the inner magnetosphere. Here we analyze the growth of magnetospheric whistler mode waves with particular emphasis on the nonlinear growth phase. We show that nonlinear wave growth can only take place over a restricted parameter space. We examine the conditions under which chorus wave growth can take place,and discuss how the results can be compared with computer simulations and experimental observations.

Keywords: wave-particle interactions, whistler-mode waves, radiation belts, nonlinear cyclotron resonance, chorus wave growth