Commission G: Ionospheric Radio and Propagation (November 2010 – October 2013)

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G1. Ionospheric irregularities

G1.1 Equatorial Spread F and Plasma Bubble

Simultaneous observations at Darwin of equatorial bubbles by ionosonde-based range/time displays and airglow i maging to explain satellite traces of the ionogram (Lynn et al., 2011; 2013). Post-midnight F-region field-aligned irregularities were investigated over Indonesia during solar minimum using a VHF radar [Otsuka et al., 2012, 2013; Nishioka et al., 2012].

The so-called large scale wave structure (LSWS) at the base of F-layer is the earliest manifestation of seed perturbation for the Rayleigh-Taylor (R-T) instability. It has been found to play deterministic role on the development of equatorial plasma bubbles (EPBs) [Tsunoda et al., 2011]. Except for a few case studies, a comprehensive investigation has not been conducted to determine the characteristics of LSWS. One reason is that it is not straightforward with existing sensors to detect LSWS, particularly, in the spatial domain. In this scenario, a comprehensive study was carried out, for the first time, on the spatial and temporal characteristics of LSWS. Observations were made over the African and Southeast Asian sectors during the year 2011. The observations confirm the findings from case studies, that these wave structures can occur a few degrees west of E-region sunset terminator, and can grow significantly in amplitude at longitudes east of sunset terminator [Sudarsanam et al., 2012; Thampi et al., 2012]. With the use of additional stations that are located on either side of dip equator, the phase fronts of these spatial structures are shown to be aligned with geomagnetic field lines over a wide latitudinal belt of 500 - 600 km centered on dip equator. The zonal wavelengths of these structures are found to vary from 100 to 700 km which is consistent with the earlier reports. Tsunoda et al. [2013] showed relationship between multi-trace of ionograms is related to the LSWS. Recently there is a statistical finding that EPBs are consistently observed when the amplitudes of LSWS are grown to sufficient strengths. These results provide better insights on the underlying physical processes involved in excitation of LSWS in terms of important roles being played by the E-region electrical loading and the polarization electric fields that are induced via spatially varying dynamo current due to neutral wind perturbations associated with Atmospheric Gravity Waves (AGWs).

The research project “Research Enhancement and System Establishment for Space Weather in Indonesia” is conducted during FY 2010-2012 under the framework of “Strategic Funds for the Promotion of Science and Technology” by MEXT (operation by Japan Science and Technology Agency (JST)). This is a joint project with RISH, Solar-Terrestrial Environmental Laboratory (STEL), Nagoya University, and National Insititute for Information and Communications Technology (NICT). The counterpart in Indonesia is LAPAN. Space weather is a program to observe, assess, and forecast the space environment, and regional observations and studies of the ionosphere are very important. Experiments for the project is not limited in Indonesia, but spread over southeast Asian countries. RISH and LAPAN started the EAR long-duration observation of the equatorial Spread-F (ESF) since July 2010 and archived huge amount of data for ESF occurrence and their spatial-time structures. They also expand observation network of dual-band satellite beacon receivers for the study of ionospheric structures. STEL started the Fabry-Perot interferometry experiment at the EAR site and Chiang Mai (Thailand) to measure thermospheric winds at the geomagnetically conjugate points. NICT keeps operation of SEALION ionosonde network, and collecting GPS-TEC data from the region of southeast Asia.

G2. Ionospheric Disturbance

G2.1 Ionospheric Storm

Sai et al. [2013] investigated the background magnetic field dependence of the saturated state of a magnetorotational instability (MRI) in an accretion disk by performing three-dimensional magnetohydrodynamic simulations. We assume an unstratified disk by employing the local shearing box approximation. Three different uniform background magnetic field configurations are treated for a wide range of field intensities. These simulations indicate that the time variations of the turbulent stress and the magnetic energy are altered by the presence of a poloidal component of the background field. We find that the saturation amplitude of the turbulent stress and the magnetic energy are determined by both the poloidal and azimuthal components of the field. In particular, when the poloidal component has the same intensity, the obtained turbulent stress for β y0 200 becomes smaller than those for a purely poloidal field case. Despite the fact that the background field affects the MRI turbulence, the correlation between the obtained turbulent stress and the magnetic energy in the nonlinear stage is independent of the field topology. Our results indicate that the saturated turbulent stress has a stronger correlation with the power of the perturbed component of the magnetic field than with the power of the total magnetic field. These results suggest that both the intensity and the direction of the background magnetic field significantly affect the turbulent motion of the MRI in accretion disks.

By a series of self-consistent electron hybrid code simulations, Katoh and Omura [2013] studied the effect of the background magnetic field inhomogeneity on the generation process of whistler-mode chorus emissions. Chorus with rising tones are generated through nonlinear wave-particle interactions occurring around the magnetic equator. The mirror force plays an important role in the nonlinear interactions, and the spatial inhomogeneity of the background magnetic field is a key parameter of the chorus generation process. We have conducted numerical experiments with different spatial inhomogeneities to understand properties of the chorus generation process. We assume the same initial condition of energetic electrons at the magnetic equator in all simulation runs. The simulation results reveal that the spectral characteristics of chorus significantly vary depending on the magnetic field inhomogeneity. Whistler-mode emissions are generated and propagate away from the equator in all simulation runs, but distinct chorus elements with rising tones are only reproduced in the cases of small inhomogeneities. In the simulation that had the smallest inhomogeneity, we find excitation of broadband hiss-like emission (BHE) whose amplitudes are comparable to discrete chorus elements found in other simulation runs. The BHE consists of many wave elements with rising tones nonlinearly triggered in the region close to the magnetic equator. We show that the small spatial inhomogeneity of the background magnetic field results in the small threshold amplitude for the nonlinear wave growth and allows the triggering process of rising tone elements to emerge easily in the equatorial region of the magnetosphere.

A campaign observation of auroras and VLF/ELF waves was carried out from January 28 to February 5, 2014 at Poker Flat, Alaska, in collaboration with an auroral rocket launch. Dual cameras were used to determine the height of auroras. A loop antenna with a 20kHz-sampling portable recorder was tested for VLF/ELF wave measurement at remote site without power line.

G2.2 Traveling Ionospheric Disturbances

First satellite-imaging observation of medium-scale traveling ionospheric disturbances were made by FORMOSAT-2/ISUAL [Adachi et al., 2011]. Interesting disappearance of equatorial plasma bubble was observed after interaction with mid-latitude medium-scale traveling ionospheric disturbance [Otsuka et al., 2012]. Observation of nighttime medium-scale traveling ionospheric disturbances in 630-nm airglow images over 7 years in equatorial latitudes at Kototabang, Indonesia [Fukushima et al., 2012]. Characteristic motion of high-latitude nighttime medium-scale traveling ionospheric disturbances were reported associated with auroral brightenings based on airglow-imaging observations at Tromsoe, Norway and Athabasca, Canada [Shiokawa et al., 2012, 2013] and based on GPS network over Europe [Otsuka et al., 2013].

Shiokawa et al. [2012] reported the rapid oscillating motion of nighttime medium-scale traveling ionospheric disturbances (MSTIDs) associated with an auroral brightening, based on airglow imaging observations at Tromso (magnetic latitude: 67.1N), Norway. This observation indicates that the MSTID oscillation was linked to auroral electric field in the ionosphere, implying that the observed MSTIDs are ionospheric plasma structures. They suggest that the observed MSTIDs were created by atmospheric gravity waves at the beginning, left as fossil plasma structures even after the gravity wave packet dissipated in the thermosphere.

Shiokawa et al. [2013] show statistical characteristics of occurrence rate, direction of motion, and wave parameters of high-latitude nighttime medium-scale traveling ionospheric disturbances (MSTIDs) were reported based on observations by all-sky airglow imagers at Tromsoe (magnetic latitude: 67.1N), Norway and at Athabasca (61.7N), Canada. The MSTIDs were observed mostly before midnight with an occurrence rate of more than 30-50% of clear observation hours. The average wavelengths, phase velocities, and periods of the observed MSTIDs were 150-200 km, 50-80 m/s, and 30-60 min, respectively. Some MSTIDs at Tromsoe tend to show eastward motion in addition to the typical westward and southwestward motion at middle latitudes. At both stations, some MSTIDs showed characteristic changes of their phase velocity and directions in association with auroral activity, suggesting that they are plasma structures affected by auroral electric field.

G3. Ionospheric Structure and Models

G3.1 Ionospheric Structure

There is a development of a new three-dimensional GPS ionospheric tomography technique that uses total electron content (TEC) data from the dense Global Position System (GPS) receiver network, GPS Earth Observation Network (GEONET) in Japan, and it will not require an ionospheric model as the initial guess that will bias the reconstruction of electron density. The GEONET is operated by Geospatial Information Authority of Japan and consists of more than 1200 receivers; this high density and wide coverage helps to reconstruct the electron density distribution in the ionosphere with high spatial resolution. This tomography technique uses a constrained least squares fit to reconstruct the three-dimensional electron density distributions. This method is different to most other techniques as they require a background ionospheric model as an initial guess that could bias the reconstructed electron density. It rather uses a prior condition that the electron density should not exceed a certain value that is determined by the restrain parameter, which is derived from the NeQuick model. Its independency of the initial guess from a model will make it useful even in disturbed conditions. This paper presents results that are obtained by using this new tomographic technique. The reconstruction of three-dimensional ionospheric tomograms is demonstrated using the GPS data, and the reliability and robustness are checked with simulated tomograms obtained using the synthetic GPS-TEC data produced using NeQuick model.

G3.2 Ionosphere –Thermosphere Models

Jin et al. [2011] show a new Earth's atmosphere-ionosphere coupled model that treats seamlessly the neutral atmospheric region from the troposphere to the thermosphere as well as the thermosphere-ionosphere interaction including the electrodynamics self-consistently. The model is especially useful for the study of vertical connection between the meteorological phenomena and the upper atmospheric behaviors. As an initial simulation using the coupled model, a 30-day consecutive run in September reveals that the longitudinal structure of the F-region ionosphere varies on a day-to-day basis in a highly complex way and that a four-peak structure of the daytime equatorial ionization anomaly (EIA) similar to the recent observations appears as an averaged feature. The simulation reproduces and thus confirms the vertical coupling processes proposed so far with respect to the formation of the averaged EIA longitudinal structure; the excitation of solar nonmigrating tides in the troposphere, their propagation through the middle atmosphere, and the modulation of ionospheric dynamo, which in turn affects EIA generation. The simulation result indicates that not only the ionospheric averaged longitudinal structure but also the day-to-day variation can be modulated significantly by the lower atmospheric effect. This new model is named as "GAIA (Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy)" and is now started for studies of various atmospheric/ionospheric phenomena. During this period of report, Pancheva et al. [2012] and Jin [2012] used for the study of atmospheric tides, while Liu et al. [2013b] use it for clarify vertical coupling process of the sudden stratospheric warming.

Model studies are also conducted for smaller-scale phenomena. Yokoyama [2013a] developed hemisphere-coupled modeling to show an intriguing aspect of nighttime medium-scale traveling ionospheric disturbances (MSTIDs) that they were simultaneously observed at magnetic conjugate locations in the Northern and Southern Hemispheres. In order to study the hemisphere-coupled electrodynamics, the numerical model has been upgraded to consist of two simulation domains for both hemispheres in which the electrostatic potential is solved by considering electrodynamics in both hemispheres. The simultaneous occurrence of MSTIDs at the magnetic conjugate stations has clearly been reproduced when the F-region neutral wind satisfies the unstable condition in both hemispheres and a sporadic-E layer is given only at the Northern (summer) Hemisphere. On the other hand, Yokoyama [2013b] studied scale dependence of nighttime medium-scale traveling ionospheric disturbances (MSTIDs) is studied with the midlatitude ionosphere electrodynamics coupling model by changing initial perturbation scales. It is shown that both sporadic E (Es)-layer and Perkins instabilities have the scale dependence that a shorter wavelength mode tends to stop growing within a shorter period, whereas a very long wavelength mode grows so slowly in the E region that it does not effectively seed the Perkins instability in the F region. As a result, the typical wavelength of MSTIDs (100-200 km) can be spontaneously generated without scale-dependent forcing. It is also shown that long frontal structures of MSTIDs can be formed by the Pedersen polarization process along the wavefront of MSTIDs by which the wavefront is forced to be uniformly distributed.

G4. Coupling with Atmosphere/Lithosphere

G4.1 Neutral Atmosphere-Ionosphere System

Nishioka et al [2013] detected clear concentric waves and short-period oscillations in the ionosphere after the EF5 tornado hit Moore, Oklahoma, USA, on 20 May 2013 using a dense wide-coverage ionospheric total electron content (TEC) observation in North America. These concentric waves were non-dispersive waves with a horizontal wavelength of ~120 km and a period of ~13 minutes. They were observed for more than seven hours throughout North America. TEC oscillations with a period of ~4 minutes were also observed in the south of Moore for more than eight hours. Comparison between the TEC observation and the infrared cloud image from the GOES satellite indicates that the concentric waves and the short-period oscillations are caused by supercell-induced atmospheric gravity waves and acoustic resonances, respectively. This observational result provides the first clear evidence of a severe meteorological event causing atmospheric waves propagating upward in the upper atmosphere and reaching the ionosphere.

Maruyama et al. [2013] studied that geomagnetic disturbances from 7 to 12 November 2004 were quite intense, and the maximum excursion of Dst reached –374 nT. Unusual ionospheric phenomena have been observed around the world that have been associated with successive magnetic storms during this period. The ionospheric total electron content (TEC) was increased at the longitudes of Japan within a short time after sunset on 8 November, from 20 TEC units at 1830 JST to 97 TEC units at 2015 JST (JST = UT + 9 h). The enhanced TEC was significant over Hokkaido (43 deg N), and the center of the enhanced region was well within the plasmasphere as an L value of approximately 1.5. The drift velocity of the plasma in the density-enhanced region measured by the Defense Meteorological Satellite Program (DMSP) satellite was westward with a peak value of 250 m/s in the Earth's frame, demonstrating a positive correlation between density and drift velocity. A similar TEC event was observed after sunset on 10 November: TEC was enhanced, from 15 TEC units at 1830 JST to 45 TEC units at 2030 JST. During the second event, the ionosphere was highly structured and the rate of the TEC index (ROTI) increased. The two-dimensional map of a ROTI-enhanced region exhibited the west to northwest transportation of plasma in which density irregularities were entrained. A physical mechanism is proposed to explain these disturbances, i.e., storm-induced plasma stream, which is different from a phenomenon called storm-enhanced density at midlatitudes.

The first comparison of the estimated meridional wind velocities with meridional wind observed with FPIs is conducted by the researchers at NICT. They analyzed data from the ionosondes and FPIs installed at Chiang Mai, Thailand, and Kototabang, Indonesia, from 2010, and found that the estimated and observed wind velocities were generally in good agreement on most nights, although on some nights, the wind velocities were different. The assumption that the meridional wind is equal anywhere between the two ionosonde stations would not be suitable for the days when the winds were not in good agreement. We also investigated the seasonal dependence of the correlation between the estimated and observed meridional winds. They were in good agreement from February to April and were not in good agreement from May to July.

G4.2 Effect of Thunderstorm and Meteorological Phenomenon

Schekotov et al. [2011] reported ULF impulsive magnetic response at mid-latitudes to lightning activity, explaining that a pair of impulse causes the spectral resonance structure in the frequency-time plots. Long-term variations in the tweek reflection height in the D- and lower E-region ionosphere has been firstly shown by Ohya et al. [2011]. Correlation between pulsating aurora and chorus waves at Syowa Station in Antarctica were reported for a case study by Ozaki et al. [2011].

Ohya et al. [2012] reported multi-point observations of daytime tweek atmospherics during the solar eclipse of 22 July 2009 at Moshiri and Kagoshima, Japan, where the magnitudes of the solar eclipse were only 0.458 and 0.966, respectively. The wide range of estimated tweek reflection heights at Kagoshima also suggests a difference in electron density in the D- and lower E-regions between total and partial solar eclipses.

Iyemori et al. [2013] showed that three rare occasions are introduced, where the excitation of vertical acoustic resonance between the ground and the ionosphere, and the resultant generation of a field-aligned current, just after earthquakes are observationally confirmed. In the case of two inland earthquakes, barometric observations very close to the epicenters (i.e., only 30 km apart) were available, and they showed a sharp spectral peak which appeared within one hour after the origin time and lasted a few hours. The observed periods of the spectral peaks around 260 seconds are close to the period of the theoretically-expected fundamental mode of the resonance. On the other hand, magnetic observations on the ground showed a dominant period at 220–230 seconds which corresponds to the first overtone among theoretically-expected major resonance peaks. In the third case, i.e., during the 2010 Chile earthquake, a long-period magnetic oscillation in the east-west direction, which has two major resonance periods at 265 and 190–195 seconds, was observed on the night-side magnetic dip equator in Peru, where the distance is more than 2600 km from the epicenter, under a very quiet geomagnetic condition. The oscillation was interpreted as the effect of field-aligned current generated through a dynamo process in the ionosphere over the epicenter caused by the resonance.

G4.3 Eathquake Effect on the Ionosphere

Ionospheric disturbances following the intense earthquake and tsunami such as the 2011 off the Pacific coast of Tohoku Earthquake (2011 Tohoku EQ) were studied by GPS-TEC and ionosonde observations in Japan and numerical simulations. All the details of post-seismic ionospheric disturbances were first observed by a high-resolution two-dimensional GPS-TEC observation in Japan [Tsugawa et al., 2011]. The initial ionospheric disturbance appeared as sudden TEC depletion about seven minutes after the earthquake onset near the epicenter [Saito et al., 2011; Kakinami et al., 2012]. In the vicinity of the epicenter, short-period oscillations with a period of about 4 minutes were also observed [Saito et al., 2011]. Off the epicenter, zonally-extended band-like structures and concentric wave trains appeared in the detrended TEC maps about 15 minutes after the earthquake onset. The former band-like structure traveled equatorward and also appeared in Taiwan [Chen et al., 2011]. The latter concentric waves with longer wavelengths and larger propagation velocities appeared earlier [Tsugawa et al., 2011]. The center of the TEC depletion and concentric waves, termed “ionospheric epicenter”, was located about 170 km from the epicenter in the southeast direction and consistent with estimated areas of the tsunami source. These ionospheric disturbances were reproduced by numerical simulation with a time-dependent, two-dimensional, nonlinear, non-hydrostatic, compressible and neutral numerical model [Matsumura et al., 2011]. Based on these observation and simulation results, it is considered that the first fast-propagating ionospheric concentric wave with the propagation velocity of about 3.5 km/s was caused by the acoustic wave generated from the propagating Rayleigh wave. The second and following concentric waves would correspond to the atmospheric gravity waves (AGWs) propagating in the ionosphere. These AGWs are considered to be generated at the tsunami wavefronts and at the lower ionosphere above the tsunami source. Unusual multiple-cusp signature (MCS) was observed in ionograms obtained by four ionosonde stations in Japan about 15 minutes after the earthquake onset [Maruyama et al., 2011]. The real height analysis of the MCS showed a vertical ionospheric structure with a scale size of 20~30 km, indicating acoustic wave generated from the propagating Rayleigh wave. The specific conditions of MCS appearance were statistically studied based on MCS events observed in 8 or 43 earthquakes with a seismic magnitude of 8.0 or greater during the period 1957 to 2011 [Maruyama et al., 2012]. Ogawa et al. [2012] reported giant ionospheric disturbances observed with the SuperDAN Hokkaido HF radar and GPS networrk after the 2011 Tohoku earthquake.

Shinagawa et al. [2013] showed that unusual ionospheric variations were observed in the M9.0 Tohoku-oki earthquake on 11 March 2011. Among various kinds of features in the ionosphere, significant depletion of TEC near the epicenter was observed after the earthquake. Although previous studies have suggested that the coseismic ionospheric variations are associated with atmospheric perturbation caused by vertical displacement of the sea surface, the mechanism of the TEC depletion has not been fully understood. In this paper, a two-dimensional nonlinear nonhydrostatic compressible atmosphere-ionosphere model is employed to investigate the ionospheric variations in the vicinity of the epicenter. The simulation results reveal that an impulsive pressure pulse produced by a sudden uplift of the sea surface leads to local atmospheric expansion in the thermosphere and that the expansion of the thermosphere combined with the effect of inclined magnetic field lines in the ionosphere causes the sudden TEC depletion above the epicenter region.

G5. Polar Atmosphere-Ionosphere

G5.1 Studies with optical imagers

Several studies on various phenomena in the polar cap ionosphere have been conducted by using an all-sky airglow imager (ASI) of OMTIs (Optical Mesosphere Thermosphere Imagers; operated by Nagoya University) at Resolute Bay (74.73N, 265.07E). Hosokawa et al. [2011a] observed an unusual event in which a polar cap ionization patch stopped its anti-sunward motion and stayed within the field-of-view for more than one hour. When the patch stagnated, its luminosity decreased gradually, which allows them to investigate how the patch plasma decayed in a quantitative manner. The decay of the patch can be quantitatively explained by the loss through recombinations of O^+ with ambient N_2 and O_2 molecules, if we assume the altitude of the optical patch to be around 295 km. The derived altitude of the patch around 295 km is much higher than the nominal value at 235 km obtained from the MSIS-E90/IRI2007 models, which suggests that we should employ higher emission altitude when we investigate optical patches transported deep into the nightside polar cap. Hosokawa et al. [2011b] carried out a statistics of motion of polar cap arcs (i.e., auroral arcs in the polar cap latitudes) by using 5 years of optical data from Resolute Bay. They identified 743 arcs by using an automated arc detection algorithm, and statistically examined their moving velocities. They showed that polar cap arcs fall into two distinct categories, the IMF-dependent and IMF-independent (IMF: Interplanetary Magnetic Field) arcs. This implies that the mechanism causing the arc motion is fundamentally different between these two types of arc. Thus, their magnetospheric source could also be different.

A highly sensitive all-sky EMCCD airglow imager has been operative in Longyearbyen, Norway (78.2N, 15.6E; AACGM latitude 75.3) since October 2011. The imager captures 630.0 nm all-sky images with an exposure time of 4 sec, which is about 10 times shorter than that achieved by conventional cooled CCD imagers. This allows us to visualize the structure of polar cap patches without blurring effects and better estimate their periodicities. Hosokawa et al. [2013] presented, as one of the first results from the imager, an event of successive appearance of patches on the night of December 21, 2011. A time-series of the optical intensity at zenith showed modulations having two distinguished periods, one at 40 min and the other at 5--12 min. One possible explanation is that such a coexistence of two different periodicities is a manifestation of simultaneous occurrence of patch generation processes on the dayside. Namely, the 40 min periodicity was created by large-scale reconfiguration of the dayside convection pattern while the 5-12 min modulations were closely associated with mechanisms driven by pulsed reconnection on the dayside magnetopause. Such a combined effect of multiple patch generation processes may play a role in structuring patches; thus, it would be of particular importance for evaluating the space weather effects in the trans-ionospheric communications environment in the polar cap.

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More recently, there are observations of regions of increased 630.0 nm airglow emission simultaneously by dual all-sky imagers in the polar cap, one at Longyearbyen, Norway and the other at Resolute Bay, Canada (74.7N, 265.1E). The Resolute Bay incoherent scatter radar observed clear enhancements of the F region electron density up to 1012 m-3 within these airglow structures, which indicates that these are optical manifestations of polar cap patches propagating across the polar cap. During this interval of simultaneous airglow imaging, the nightside/dawnside (dayside/duskside) half of the patches was captured by the imager at Longyearbyen (Resolute Bay). This unique situation enabled us to estimate the dawn-dusk extent of the patches to be around 1500 km, which was at least 60-70% of the width of the anti-sunward plasma stream seen in the SuperDARN convection maps. In contrast to the large extent in the dawn-dusk direction, the noon-midnight thickness of each patch was less than 500 km. These observations demonstrate that there exists a class of patches showing cigar-shaped structure. Such patches could be produced in a wide range of local time on the dayside nearly simultaneously and spread across many hours of local time soon after their generation.

High-latitude GPS TEC changes associated with a sudden magnetospheric compression and associated with polward-moving sun-aligned arcs were reported at high latitudes above the auroral zone [Jayachandran et al., 2011; 2012].

G5.2 Studies with EISCAT Radars

By using EISCAT radars as well as instruments operated in northern Scandinavia, we have conducted following studies: Nozawa et al. [2012] showed that lower thermosphere/Mesosphere wind was investigated by the new meteor radar at Bear Island (74.5ºN, 19.0ºE) that started operation on November 2007. Seasonal variations of mean wind, diurnal and semidiurnal tides, and quasi-two day wave are found to be similar to those at Tromsø (69.6ºN, 19.2ºN). Sato et al. [2012] studied first observations of auroral roar emissions near 4 times f_{ce} (electron cyclotron frequency) were conducted at Longyearbyen (78.2ºN, 16.0ºE). 4 f_{ce} roar emissions were detected from 5.27 to 5.70 MHz during moderate geomagnetic disturbances in 22 days between May and September 2011 only from noon to evening, while no event occurred during the winter season. The observations support the idea expanded from the most commonly accepted generation mechanism of 2 f_{ce} and 3 f_{ce} roar: the origin of 4 f_{ce} roar is upper hybrid waves favorably generated under the condition of f_{UH} (upper hybrid resonance frequency) equal to 4 f_{ce} in the auroral F-region. Fujiwara et al. [2012] showed that variations of ion temperatures at Longyearbyen were investigated using IPY long-run data obtained by EISCAT Svalbard radar and predictions by GCM. The ion temperatures show significant seasonal variations. The amplitudes of the local time and seasonal variations observed are much larger than the ones predicted by the IRI-2007 model. This study suggested significant heat sources in the polar cap region even under solar minimum and geomagnetically quiet conditions. Tsuda et al. [2011] showed that fine structure of a sporadic sodium layer (SSL) was observed by a new sodium LIDAR, which started operation on October 1, 2010, at Tromsø on January 11, 2011. The sodium lidar measurement with 5-sec time resolution revealed the details of dramatic sodium-density increase as well as short-period wavelike structure in the SSL. The calculated power spectral densities are well represented by power laws, implying the presence of the short-period waves and turbulence in the frequency range of 10^{-4} – 10^{-1} Hz.

Fujii et al. [2012] studied a physical process for the latitudinal motion of an auroral arc based on the four-side bound Cowling channel model is proposed. Assuming that an upward field-aligned current (FAC) is associated with the auroral arc that forms a Cowling channel with finite lengths not only latitudinally but also longitudinally and that the upward FAC region is primarily embedded in a purely northward electric field, the primary Hall current driven by the northward electric field accumulates positive excess charges at the eastern edge of the channel and negative charges at the western edge. The charges produce a westward secondary electric field. This secondary electric field moves the arc with its magnetospheric source drifting together with the magnetospheric plasmas equatorward and simultaneously produces the electric field outside the channel that moves the downward FAC equatorward of the upward FAC region equatorward together with the upward FAC. Thus, the whole 3-D current system is expected to move equatorward as often observed in the afternoon auroral zone.

Taguchi et al. [2012] showed that 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. We present initial results from a new high-sensitivity all-sky imager installed at Longyearbyen, Norway in October 2011. The 630.0-nm all-sky images taken with a time resolution of 4 s reveal that one of the PMAFs that occurred with such typical separation times on 29 December 2011 comprises two consecutive auroral bursts. This observation provides evidence that one PMAF could reflect double FTEs—there is not always a one-to-one correspondence between FTEs and PMAFs.

Using a simultaneous and common-volume observation by a European incoherent scatter (EISCAT) VHF radar and a sodium lidar at Tromso, Norway (69.6 deg N, 19.2 deg E), the effect of pure particle precipitation, excluding that of the electric field, on sodium density variations has been observed for the first time [Tsuda et al., 2013]. The observation on 24-25 January 2012 showed that sodium atom density decreased when there was no ion temperature enhancement (indicating a weak electric field) and the electron density increased (indicating strong particle precipitation). From the results we have concluded that auroral particle precipitation induced sodium atom density decrease in this event. Furthermore, a discussion is provided regarding the time response of the decrease in sodium density.

Ionospheric ion upflow during an auroral substorm has been investigated using simultaneous EISCAT radar and IMAGE satellite data [Ogawa et al., 2013]. Approximately 6 minutes after an initial brightening identified with data from the IMAGE WIC instrument, ion upflow was seen and the electron temperature became enhanced, too. The ion upflow, with a velocity of about 150 m/s, and the electron temperature enhancement lasted for about 25 minutes. During the poleward expansion phase surges of large upward ion velocity and flux, and high ion and electron temperatures occurred over Longyearbyen. The upward ion flux reached 2×10^14 m-2s-1. Naturally enhanced ion-acoustic lines (NEIALs) were seen near the poleward edge of the expanded auroral oval both near the end of expansion phase 17 minutes after onset and also later in the recovery phase. The NEIALs seemed to be accompanied by another type of enhanced echoes, obliquely to the local geomagnetic field. Data from the LENA instrument on the IMAGE satellite show that energetic neutral oxygen reaches the IMAGE satellite about 40 minutes after the initial brightening, and oxygen continues to get detected during the recovery phase. Ion upflow at the poleward edge of the auroral oval during the expansion phase was proved to be related to ion/neutral outflow with energy below 18-27 eV, whereas during the recovery phase of a substorm upward ions are accelerated up to about 60 eV and flow out in the entire polar region.

Updates on EISCAT results are found at http://polaris.nipr.ac.jp/~eiscat/results.html

G5.3 Other studies of the polar region

Frequency-dependent polarization characteristics of Pc1 geomagnetic pulsations were observed by multi-point ground stations at low latitudes [Nomura et al., 2011]. Polarization of Pc1/EMIC waves and related proton auroras were investigated in detail at subauroral latitudes [Nomura et al., 2012]. Sakaguchi et al. [2012] visualized ion cyclotron wave and particle interactions in the inner magnetosphere using THEMIS-ASI observations.

Morilka et al. [2012] examined AKR spectra using the long-term observation from the Polar satellite to prove the comprehensive features of field-aligned auroral acceleration and to give observational constraints to the theoretical mechanisms for acceleration at substorm. The remote observations of substorm phenomena through auroral radio waves from the high altitude polar magnetosphere disclosed some fundamental characteristics of the vertical auroral acceleration region and provided new information on the formation process for field-aligned electric field at substorm onset. Furthermore, we reveal new aspect of the relationship between the plasma state in the plasma sheet and the formation of auroral acceleration.

Morioka et al. [2013] studied that auroral kilometric radiation (AKR) is known to be transient emissions generated by rapidly accelerated electrons together with sudden auroral activation in the polar magnetosphere of the earth. In contrast, the characteristics and relationship with the auroral acceleration of rather continuous AKR emissions are not well understood. We examine the emission using long-term data and report that the continuous AKR emission frequency changes with universal time (UT) as the Earth rotates, indicating that the Earth is a spin-modulated variable radio source. The observed UT variation of AKR frequency means that the acceleration altitude changes periodically with planetary rotation. The observations indicate that the diurnal wobble of the tilted geomagnetic field in the solar wind flow alters the magnetosphere-ionosphere (M-I) coupling state in the polar magnetosphere, giving rise to periodic variation of auroral particle acceleration altitude. These observations of planetary radio wave properties provide insight into the physics of planetary particle acceleration

Nishiyama et al. [2012] carried out ground-based observations, optimized to temporal and spatial characteristics of pulsating auroras (PAs) in the micro/meso scale, using an electron multiplying charge coupled device (EMCCD) camera with a wide field of view corresponding to 100 × 100 km at an altitude of 110 km and a high sampling rate up to 100 frames per second. We focus on transient PAs propagating southward around 1100 UT, in the early recovery phase of the substorm, on 4th March 2011. Three independent patches (PA1–3) each with different periods between 4 and 7 s were observed, which means that the periodicity was not explained by the electron bounce motion and strongly depended on local plasma conditions in the magnetosphere or in the ionosphere. One more insight is that only PA1 had also a sharp peak of modulations around 1.5 Hz, with a narrow frequency width of 0.30 Hz, and the strong modulations existed as a small spot in the center of PA1. We have also conducted cross spectrum analysis and have obtained coherence and phase distributions for auroral variations between 0.1 and 3.0 Hz. The results indicated that low frequency variations from 0.2 to 0.5 Hz inside PA1–3 propagated as a collective motion in well-defined directions. The estimated horizontal propagation velocities ranged from 50 to 120 km/s at the auroral altitude. The velocities are almost consistent with the Alfven speed at the magnetic equator, which suggests that compressional waves have an effect on PA via modulations of the ambient plasma environment.

Sakanoi et al. [2012] studied that black aurora is a small-scale (typically a few to 10 km) black structure seen in diffuse aurora, and its generation process has been studied with immense interest. We report the precise characteristics of black aurora based on simultaneous image and particle measurement data and possible generation process. Thirteen black auroral events are identified from the Reimei satellite data, and the relationship between particle and auroral images around the satellite's magnetic footprints is investigated in detail. We found that a number of small-scale deficiencies were embedded in precipitating electrons from the central plasma sheet with energies greater than 2–7 keV and that each deficiency corresponded exactly to black arcs and black patches at the magnetic footprint. Therefore, black arcs and black patches are not associated with a field-aligned potential (such as a divergent potential structure) but probably originate from the suppression of pitch angle scattering. In the black auroral region, low-energy (2–5 keV) inverted-V-type downward electrons (spanning channels that are several tens of kilometers wide) often appear to overlap with high-energy (several keV) plasma sheet electrons.

G.6 Solar and planetary studies

Yoneda et al. [2013] studied that Jupiter’s sodium nebula showed an enhancement in late May through the beginning of June 2007. This means Io’s volcanic activity and the magnetosphere’s plasma content increased during this period. On the other hand, Jupiter’s radio emission called HOM became quiet after the sodium nebula enhancement. The HOM emission is considered to be related to the activity of aurorae on Jupiter. These observation results therefore suggest that the increase in plasma supply from Io into Jupiter’s magnetosphere weakens its field-aligned current, which generates the radio emissions and aurorae on Jupiter. By comparing our observation results to recent model and observation results, we add supporting evidence to the possibility that Io’s volcanism controls Jupiter’s magnetospheric activity.

Kodama et al. [2013] showed that observations of [OI] 630 nm emission in the Enceladus torus around Saturn have been made at the summit of Mt. Haleakala in Hawaii using a high-dispersion echelle spectrograph coupled to a 40 cm telescope in the period of 13 May through 19 June 2011. A slit of the spectrograph was aligned perpendicular to the equatorial plane of Saturn and placed at a distance of 4 Saturn's radii (Rs) from the planetary center in the dawn side to put the Enceladus torus within the field of view. As a result, [OI] 630 nm torus emission was detected with S/N ~ 7 for summed exposure of 20 h during the observing period. The observed brightness has a maximum value of 4.1 ± 0.6 Rayleighs (R) near the equator, and it extends to north-south (N-S) direction with a full width at half maximum of 0.8 Rs. We made estimation to explain mechanism of the observed brightness taking into account an excitation of [OI] 630 nm by electron impact and photodissociation of water group molecule (OH and H2O). Densities of electron, O, OH, and H2O and electron temperature derived from data taken by Cassini and Hubble telescope were used for the estimation. The observed brightness is reasonably explained, taking into account an uncertainty of estimation depending on N-S distributions of species and quiet solar activity conditions. The estimation also suggests that [OI] 630 nm emission is excited by photodissociation of OH and H2O and by electron impact of O with their contributions of 50%, 30%, and 20%, respectively, for quiet solar activity. We also note that the intensity due to photodissociation has considerable variability depending on the level of solar activity by a factor of 2.5.

Yagi et al. [2012] showed that a model of the martian exosphere is built for average solar conditions. A Chamberlain's approach (Chamberlain, J.W. [1963]. Planet. Space Sci. 11, 901) is used to describe the O, CO, CO2, and O2 thermal exospheric components. The average thermal oxygen density at 300 km in altitude varies by about one order of magnitude with seasons. A Monte-Carlo test particle simulation is also developed in order to estimate the non-thermal oxygen component of the exosphere. The seasonal variation of the non-thermal oxygen average density is much less than the thermal component but displays clear seasonal variations of its spatial distribution. The neutral oxygen atomic escaping flux varies from 2.9 to 5.3 x 1025 s—1 in good agreement with other studies. Mars's oxygen exosphere is thermal below 600 km and non-thermal above 700 km at all seasons. The typical scale height is ~45 km for thermal O and ~ 500 km for the non-thermal oxygen density. The total photoionization rate above 300 km corresponds to a CO•2 /O+ total production ratio between 0.004 and 0.02. When compared to the composition of the escaping flux measured by ASPERA-3/Mars Express, this suggests that ions formed below 300 km should significantly contribute to the escaping ion flux and/or that a significant part of the newly O+ ions reimpacts Mars. The simulated oxygen density profile is also compared to the recent observed profile by Alice/Rosetta (Feldman, P.D. et al. [2011]. Icarus 214, 394-399). Although the scale height of our simulated non-thermal oxygen exosphere and the transition from thermal to non-thermal dominated exospheres are slightly higher than suggested by Feldman et al. [2011], a good agreement is found when taking into account the uncertainties of Alice/Rosetta observations.

Io-Jupiter interaction leads to auroral emissions and Jovian decametric radiations (Io-DAM) [Matsuda et al., 2013]. The longitudinal distribution of the Io-DAM occurrence probability has been considered to be controlled by the footprint magnetic intensity of each hemisphere. Recent observations revealed that the brightness of the main auroral spot is mainly modulated by Io's magnetic latitude. In the present study, we propose that the Io-DAM occurrence probability is controlled by the north-south asymmetry of the footprint magnetic intensity, in addition to Io's magnetic latitude. Hall magnetohydrodynamic equations are solved in the corotating meridional plane, which includes the Jovian ionosphere of finite thickness. We assume that the ionospheric Pedersen conductance is inversely proportional to the footprint magnetic intensity; the conductance is nearly the same for both ionospheres at a longitude of 290°, while twice higher for the south than for the north at a longitude of 110°. Above the northern ionosphere, the parallel current density further than 20° downstream of the main spot is estimated to be 1.5–2.0 times larger for 290° than for 110°. This indicates that if the Io-DAM lead angle is large, the suppressed Io-DAM occurrence probability for the northern hemisphere around 110° would be caused by the north-south asymmetry of the footprint magnetic intensity. A large current density conducted into the south around 110° would be the source of the Io-D component, radiated from the southern hemisphere. The observed brightness of the Io-related auroras is discussed in the context of the intensity of the parallel current density.

Ishiyama et al. [2013] investigated the geological conditions below two lava flow units through determining the bulk permittivity and porosity in the uppermost basalt layer to depths of a few hundred meters. We use a newly developed method based on three data sets obtained by the Lunar Radar Sounder (LRS), Multiband Imager (MI), and Terrain Camera (TC) onboard the Selenological and Engineering

Explorer (SELENE; Kaguya) spacecraft. The bulk permittivity of the uppermost basalt layer is calculated as the ratio of the apparent radar depth to the thickness of the uppermost basalt layer. Its thickness can be constrained from the excavation depths of two types of craters (haloed and nonhaloed craters). These craters are identified on the basis of FeO and/or TiO2 maps created from the MI data. These excavation depths are determined based on the measurement of the crater diameter using the TC data. The apparent radar depth is derived from the time delay between the surface echo and subsurface echo measured by LRS near the craters. The bulk permittivities are estimated to be 2.8–5.5 in a lava flow unit of Mare Humorum and 4.2–18.0 in a lava flow unit of Mare Serenitatis. These bulk permittivities are indicative of porous basalt layers with the porosities of 19%–51% in the unit of Humorum and 0%–33% in the unit of Serenitatis. The estimated porosities would be mainly explained by two different sources: intrinsic voids of lava and impact-induced cracks.

A new radio spectropolarimeter for solar radio observation has been developed at Tohoku University and installed on the Iitate Planetary Radio Telescope (IPRT) at the Iitate observatory in Fukushima prefecture, Japan [Iwai et al., 2012a]. This system, named AMATERAS (the Assembly of Metric-band Aperture TElescope and Real-time Analysis System), enables us to observe solar radio bursts in the frequency range between 150 and 500 MHz. The minimum detectable flux in the observation frequency range is less than 0.7 SFU with an integration time of 10 ms and a bandwidth of 61 kHz. Both left and right polarization components are simultaneously observed in this system. These specifications are accomplished by combining the large aperture of IPRT with a high-speed digital receiver. Observational data are calibrated and archived soon after the daily observation. The database is available online. The high-sensitivity observational data with the high time and frequency resolutions from AMATERAS will be used to analyze spectral fine structures of solar radio bursts.

Iwai et al. [2012b] showed that the first coordinated observations of an active region using ground-based radio telescopes and the Solar Terrestrial Relations Observatory (STEREO) satellites from different heliocentric longitudes were performed to study solar radio type-I noise storms. A type-I noise storm was observed between 100 and 300 MHz during a period from 2010 February 6 to 7. During this period the two STEREO satellites were located approximately 65° (ahead) and –70° (behind) from the Sun-Earth line, which is well suited to observe the earthward propagating coronal mass ejections (CMEs). The radio flux of the type-I noise storm was enhanced after the preceding CME and began to decrease before the subsequent CME. This time variation of the type-I noise storm was directly related to the change of the particle acceleration processes around its source region. Potential-field source-surface extrapolation from the Solar and Heliospheric Observatory/Michelson Doppler Imager (SOHO/MDI) magnetograms suggested that there was a multipolar magnetic system around the active region from which the CMEs occurred around the magnetic neutral line of the system. From our observational results, we suggest that the type-I noise storm was activated at a side-lobe reconnection region that was formed after eruption of the preceding CME. This magnetic structure was deformed by a loop expansion that led to the subsequent CME, which then suppressed the radio burst emission.

Iwai et al. [2012c] showed that the relationships between solar radio type-I bursts and soft X-ray activities were investigated using Hinode/XRT and a ground-based radio telescope belonging to Tohoku University. Although a type-I burst is thought to be generated by high energy non-thermal electrons in the solar corona, the counterpart of this radio burst in X-rays or EUV have yet to be identified. In this study, we found some small scale soft X-ray activities on the XRT images around the onset time of the type-I burst when 10 percent of the soft X-ray flux enhancement around the onset time of the radio burst is defined as a burst-related activity. However, the causal relationship between the observed soft X-ray activities and the onset of the type-I burst are unclear, and more simultaneous observations of radio bursts and X-rays are needed to investigate the coronal counterpart of the type-I burst.

Iwai et al. [2013] showed that Solar radio type-I bursts were observed on 2011 January 26 by high resolution observations with the radio telescope AMATERAS in order to derive their peak flux distributions. We have developed a two-dimensional auto burst detection algorithm that can distinguish each type-I burst element from complex noise storm spectra that include numerous instances of radio frequency interference (RFI). This algorithm removes RFI from the observed radio spectra by applying a moving median filter along the frequency axis. Burst and continuum components are distinguished by a two-dimensional maximum and minimum search of the radio dynamic spectra. The analysis result shows that each type-I burst element has one peak flux without double counts or missed counts. The peak flux distribution of type-I bursts derived using this algorithm follows a power law with a spectral index between 4 and 5.

G.7 Instruments and experiments

G7.1 PANSY

PANSY (Program of the Antarctic Syowa MST/IS Radar) is a project which was started in 2000 to comprehensively study the polar atmosphere with a large aperture atmospheric radar as the main instrument combined with complementary observation techniques and also with numerical modeling and theoretical works.

The PANSY project has been supported internationally by resolutions from international scientific bodies such as IUGG, URSI, SPARC, SCOSTEP, and SCAR. The scientific research objectives and technical developments have been frequently discussed at international and domestic conferences. The project was authorized in 2008 as one of the main observation plans for the 6 year period of Japanese Antarctic Research Expedition program (2011-2016), and funded by Japanese government in 2009. The PANSY radar is the first Mesosphere-Stratosphere-Troposphere/Incoherent Scatter (MST/IS) radar in the Antarctic region. It is a large VHF monostatic pulse Doppler radar operating at 47 MHz, consisting of an active phased array of 1,045 Yagi antennas and an equivalent number of transmit-receive modules with a total peak output power of 500 kW. Its first stage has been installed at Syowa Station (69°00'S, 39°35'E) in early 2011, and is currently operating with 228 antennas and modules.

The radar aims to clarify the role of atmospheric gravity waves at high latitudes in the momentum budget of the global circulation in the troposphere, stratosphere and mesosphere and the dynamical aspects of unique polar phenomena such as polar mesospheric clouds (PMC) and polar stratospheric clouds (PSC). The katabatic winds as a branch of Antarctic tropospheric circulation and as an important source of gravity waves are also of special interest. Moreover, strong and sporadic energy inputs from the magnetosphere by energetic particles and field-aligned currents can be quantitatively assessed by the broad height coverage of the radar extending from the lower troposphere to the upper ionosphere. Currently the radar is operating with about a quarter of the full system. Nevertheless, we have already obtained interesting results on the Antarctic troposphere, stratosphere and mesosphere, such as observation of gravity waves and multiple tropopauses associated with a severe snow storm in the troposphere and stratosphere, and polar mesosphere summer echoes. The first paper of these initial results was recently accepted and is now online [Sato et al., JASTP, 2013].

G7.2 Equatorial Atmosphere Radar

A receiver system for radars were developed based on the general-purpose software-defined radio receiver referred to as Universal Software Radio Peripheral 2 (USRP2) under control of a PC. The receiver is able to collect received signals at intermediate frequency (IF) of 130 MHz with a sample rate of 10 MHz. USRP2 digitizes IF received signals, produces IQ time series, and then transfers the IQ time series to PC through the Gigabit Ethernet. PC receives the IQ time series, executes range sampling, carries out filtering in the range direction, decodes phase-modulated received signals, integrates the received signals in time, and finally stores processed data to the hard disk drive (HDD). Because only sequential data transfer from USRP2 to PC is available, the range sampling is triggered by transmitted pulse leaked to the receiver. In order to perform range imaging with multiple frequencies, the digital receiver executes real-time signal processing for each of the time series collected at different frequencies. Further, in order to implement oversampling, the receiver is able to decode phase-modulated oversampled signals by interleaving oversampled signals in the range direction. Because program codes for real-time signal processing at PC is written in C++ language, the signal processing executed by the digital receiver is easy to be implemented, reconfigured, and reused. Using the measurement result from a 1.3-GHz range imaging atmospheric radar, we demonstrate that the digital receiver, which is capable of executing real-time signal processing for range imaging and oversampling, is useful for resolving fine-scale structure of atmospheric turbulence with a vertical scale as small as 100 m.

Equatorial Atmosphere Radar (EAR) is a big atmospheric radar located in West Sumatra, Indonesia. The EAR was established in June 2001, and has continued long-term observations. Research Institute for Sustainable Humanosphere (RISH), Kyoto University and National Institute of Aeronautics and Space (LAPAN) of Indonesia hold the 10^{th} anniversary ceremony and symposium on September 22-23, 2011, at Jakarta. The ceremony was attended by the Minister of Research and Technology of Indonesia, the Minister of the Embassy of Japan, and the representative from the Ministry of Education, Culture, Sports, Science Technology (MEXT), and the Vice President of Kyoto University.

G7.3 Rocket experiments

Ionospheric Radio Wave: S-310-40 sounding rocket experiment was carried out at Uchinoura Space Center (USC) at 23:48 JST on 19 December, 2011. The purpose of this experiment is the investigation of characteristics of radio wave propagation in the ionosphere and the estimation of electron density structure in the lower ionosphere, when the intensity of radio wave measured on the ground was attenuate at nighttime. In order to measure the radio waves, a LF/MF band radio receiver (LMR) is installed on the sounding rocket. The LMR measured the propagation characteristics of four radio waves at frequencies of 60 kHz, 405 kHz, 666 kHz and 873 kHz in the region from the ground to the lower ionosphere. The LMR could measure the relative attenuation of radio waves from the ground up to the ionosphere. Furthermore the loop antenna consists of three loop antennas in order to measure three components of four radio waves. Although the attenuation of intensity is seen near an altitude of 100 km, the amount of attenuation is less than usual. 100 dB or more is decreased in usual. Such observations are not obtained by past rocket experiments. We investigate the unusual propagation characteristic of radio waves in the ionosphere at winter nighttime. Then we will obtain the 3-dimensional structure of electron density in the lower ionosphere by measuring the intensity of radio waves that propagate from the three different directions.

Electric field measurement with double probe: S-520-26 sounding rocket experiment was carried out at Uchinoura Space Center (USC) in Japan at 5:51 JST on 12 January, 2012. The purpose of this experiment is the investigation of the bonding process between the atmospheres and the plasma in the thermosphere. S-520-26 sounding rocket reached to an altitude of 298 km at 278 seconds after the launch. The S-520-26 payload was equipped with Electric Field Detector (EFD) with a two set of orthogonal double probes to measure both DC and AC less than 200 Hz electric fields in the spin plane of the payload by using the double probe method. Results of DC electric fields measured by the EFD have the large sine waves that result from the payload rotation at the spin period. The largest contribution to the electric field measurements by double probes moving through the ionosphere at mid-latitudes is that due to the $\boldsymbol{v}\mathrm{x}\boldsymbol{B}$ fields created by their motion across the ambient magnetic field, where $\boldsymbol{v}$ is the rocket velocity in the Earth-fixed reference frame and $\boldsymbol{B}$ is the ambient magnetic field. The sum of the squares of the two components represents the magnitude of the DC electric field in the spin plane of the payload. These data reveal abrupt, large-scale variations which can immediately be attributed to changes in the geophysical electric field since the $\boldsymbol{v}\mathrm{x}\boldsymbol{B}$ fields are slowly varying. The sum of the squares data also reveals contributions at the spin frequency and its harmonics. These contributions result primarily from distortions of the waveforms in the raw data.

There are number of waves in the mid-latitude ionosphere. One interesting phenomenon is medium-scale traveling ionospheric disturbance (MSTID) in the F-region. The MSTID is the wave structure with a wavelength of 100-200 km. These horizontal structures can be observed by using the total electron content (TEC) from GEONET, Japanese dense network of GPS receivers. We conducted an intensive experiment to study generation mechanism of the MSTID by the combination of sounding rockets and ground observations. We monitored horizontal structures of the MSTID by using GPS-TEC real-time monitor system. While active MSTID region appeared over south Kyushu, Institute of Space and Aeronautical Science of JAXA (JAXA/ISAS) launched sounding rockets S-310-42 and S-520-27 from Uchinoura Space Center (USC) at 23:00 JST and 23:57 JST, respectively. Ionospheric parameters, i.e., plasma density, electric field, density fluctuations, were measured by in-situ instruments on board of the S-520-27 rocket. TMA (Tri-Methyl Aluminum) and Lithium were released from the S-31-42 and S-520-27 rockets, respectively, for measurement of the neutral winds. Their luminescent clouds were imaged from the JAXA experimental jet “Hisho” and from three ground sites. The Lithium experiment under the moonlight was the world first trial, and was successful. Both rockets transmitted dual-band beacon signal which was received at five ground sites. Preliminary analysis of from the experiment show that strong wind shear and sporadic-E layers co-existed at around 100 km. Also the results infer large horizontal inhomogeneity of F-region plasma density as well. Electric-field detector (EFD) on board of the rocket S-520-27 measured a waveform of electric field at the frequency less than 6.4 kHz. Intensity from 4 kHz to 6 kHz are increased at the apex region during the period from 210 sec to 350 s. In the low frequency components, we sound enhanced intensity of 40 Hz or less is clearly seen during the time of most of rocket flight.

G7.3 MAGDAS

MAGDAS is the world network of magnetometer developed and maintained by International Center for Space Weather Science and Education (ICSWSE), Kyushu University. MAGDAS network and its observations are well maintained during this period. New installation of fluxgate magnetometer (MAGDAS 9) in 2012 is listed as follows.

- Jayapura, Indonesia. - Sicincin, Sumatra, Indonesia
- Bengkulu, Sumatra, Indonesia
- Liwa, Sumatra, Indonesia
  (Above three are for earthquake investigations in Sumatra).
- Jerusalem, Ecuador.

Many studies of atmospheric tides, sudden stratospheric warming, various ionospheric phenomena, and thermosphere-ionosphere coupling are published in international journals.

G7.4 VLF

The Solar-Terrestrial Environment Laboratory (STEL), Nagoya University, started routine observation of VLF waves at Athabasca (54.72N, 246.69E, MLAT=61.3), Canada, using a loop antenna since February 16, 2012. The loop antennas measure east-west and north-south magnetic field variations with a sampling rate of 100 kHz. Quick-look spectra are available at http://stdb2.stelab.nagoya-u.ac.jp/vlf/index.html

G7.5 GNSS receivers

Electronic Navigation Research Institute (ENRI) and National Institute of Information and Communications Technology (NICT) developed a system to monitor ionospheric disturbances in realtime. Observed data of 200 GPS receivers selected from the Japanese nationwide GPS reference network (GEONET) are transferred to ENRI in realtime with a sampling rate of 1 Hz. The data are processed to produce a map of perturbation component of ionospheric total electron content (TEC) every 5 minutes with a typical time delay of 1-2 minutes. The realtime monitor will be utilized in the JAXA/ISAS sounding rocket experiment for medium-scale traveling ionospheric disturbances to monitor occurrence of the target phenomenon. (http://www.enri.go.jp/cnspub/susaito/rocket/recent_mstid.html).

The two-dimensional maps of absolute TEC, rate of TEC change index (ROTI), and loss of lock on GPS signals (LOL) with 10-30 minutes delay are also available from NICT at the following URL;
http://seg-web.nict.go.jp/GPS/RT_GEONET/index_e.html

Several 100 km to 1,000 km scale ionospheric variations caused by equatorial plasma bubble and/or travelling ionospheric disturbances can degrade single-frequency GNSS positioning and differential GNSS positioning. However, these ionospheric disturbances have not been monitored enough due to the lack of dense wide-coverage ionospheric observations. One of the most effective methods for such dense and wide-coverage ionospheric observations is two-dimensional TEC observations using a dense GNSS receiver network. Dense GNSS receiver networks are now available only limited areas such as Japan, North America, and Europe. It is needed to expand the GNSS-TEC observation area using all the available GNSS receiver networks with international collaboration of ionosphere and space weather researchers in the world. We propose a new data format, GNSS-TEC Exchange format (GTEX), to promote international exchange and share of GNSS-TEC data. The main concept of the GTEX is to include slant TEC data from each GNSS receiver. By sharing slant TEC data which are not converted to vertical TEC, various ionospheric studies may be possible without affected by specific analysis procedures such as satellite/receiver bias estimation, or different mapping heights. The structure of GTEX is designed to be as close to the format of GNSS observation data (RINEX) as possible, because RINEX is a de facto standard in exchanging GNSS observation data and potential users of GTEX would be familiar with RINEX. Since the 1st Asia-Oceania Space Weather Alliance (AOSWA) workshop held at Chiang Mai, Thailand during 22-24 February, 2012 (AOSWA, 2013), we have collaborated with several organizations researching ionosphere and space weather in Korea, Thailand, Indonesia, Malaysia, and China to share the GTEX data of each country and to develop dense wide-coverage TEC maps in the Asia-Oceania region. The GTEX has been adopted as the basis of ionospheric data sharing by Ionospheric Studies Task Force (ISTF) established in the Asia-Pacific Region of International Civil Aviation Organization (ICAO), which is working on ionospheric characterization for facilitation of GNSS implementation for aviation (ICAO/ISTF, 2012).

NICT, a delegate of Japan, proposed "GNSS-TEC exchange format (GTEX)" as a format to promote international exchange and sharing of GNSS-TEC data in an input document to the meeting of Working Group 3L-3 (trans-ionospheric propagation) of ITU-R held in Geneva from 19 to 26 June 2013. The document was discussed in the larger context of the need to incorporate new digital products and SG3DB databanks. As a result, the GTEX was included in a Chairman's report towards the definition of new digital products for transionospheric propagation.

In order to investigate drift velocities of the ionospheric irregularities at high-latitudes, three dual-frequency GNSS receivers with mutual distances of 172-242 m have been operated at EISCAT Tromso radar site since September 2012. The receivers sample GNSS signals at a rate of 50 Hz. We observed the ionospheric scintillation associated with aurora activities.

G7.6 Airglow imagers

The Solar-Terrestrial Environment Laboratory (STEL), Nagoya University is conducting various optical and radio measurements of ionosphere and thermosphere at 13 ground-based stations over the world. The STEL have started new routine measurements of VLF/ELF waves at Athabasca (54.7°N, 246.7°E), Canada since September 25, 2012, in collaboration with Kanazawa University and Athabasca University. STEL also started routine measurements of ionospheric airglow emssions at 630-nm at Haleakala, Hawai (20.7°N, 203.7°E) in March 2013 in collaboration with Kyoto University and Tohoku University. These ground-based data are available from STEL web site.

Quick-look spectra are available at http://stdb2.stelab.nagoya-u.ac.jp/vlf/index.html

Another all-sky airglow imager has been operational in Longyeabyen, Norway (78.2N, 15.6E; AACGM latitude 75.3) since October 2011 by University of Electro-Communications. The ASI is equipped with an EMCCD camera whose imaging part has 512x512 pixels. The imager has two different passband interference filters for airglow measurements, one at 630.0 nm and the other at 557.7 nm, which enables us to study various phenomena in the polar cap ionosphere, such as cusp aurora, polar cap aurora and polar cap patches. The exposure time for 630.0 nm emissions is 4.0 s. Every 56 s (= 14 x 4 s) 557.7 nm emissions are observed with an exposure time of 1.0 s by rotating the filter turret. Background continuum emission from the sky is sampled every 10 min at a wavelength of 572.5 nm and is used to derive the absolute intensity of the airglow lines. Optical images obtained by this ASI will be used for better understanding the dynamic nature of polar cap ionospheric phenomena such as polar cap patches and polar cap arcs in near future.

G7.7 Satellite observations

Airglow emissions at the lower-thermosphere (O_2 762 nm, 95km alt.) and the upper-thermosphere (O 630 nm, 250 km alt.) are measured with IMAP/VISI on the international space station. We find many concentric gravity wave event in the O_2 emission, and equatorial anomaly and plasma bubbles in O630 nm emission. We are also conducting the ground-based all-sky imaging measurement at the summit of Haleakala, Maui, Hawaii to carry out simultaneous measurement of airglow emissions with IMAP/VISI.

In order to monitor space environment and its temporal variations, JAXA Space Environment Group has been developing space radiation detectors as well as magnetometers and installing them on Low Earth Orbit (LEO) satellites, Geostationary Orbit (GEO) satellites, Geostationary Transfer Orbit (GTO) satellite, Quasi Zenith Orbit (QZO) satellite and Japanese Experimental Module (JEM) of the International Space Station (ISS). We are using these space environment data to know the situation of space environment and to provide warning messages to the satellite operators as well as ISS/JEM manager, when the space environment will be harmful. Based on our observation data, we also have constructed an advanced electron belt model for the use in satellite manufacturing. With space radiation data obtained by JAXA satellites and ISS, some findings related to the space radiation environment have been obtained. We will review our activities related to the space environment research and development in JAXA. [Obara, 2012a]

The Space Environment Data Acquisition equipment (SEDA), which was mounted on the Exposed Facility (EF) of the Japanese Experiment Module (JEM, also known as "Kibo") on the International Space Station (ISS), was developed to measure the space environment along the orbit of the ISS. This payload module, called the SEDA-Attached Payload (AP), began to measure the space environment in August 2009. This paper reports the mission objectives, instrumentation, and current status of the SEDA-AP. [Obara, 2012b]

G7.8 Instruments for planetary sciences

IPRT (Iitate Planetary Radio Telescope) is a ground-based VHF-UHF radio telescope developed by Tohoku University, which has been developed at the Iitate observatory in Fukushima prefecture Japan since 2000 and dedicated for the observations of solar and planetary radio emissions. IPRT has two distinctive radio receivers; one is a low noise and quite stable receiver tuned at 325MHz and 785MHz, and another one is a 100-500MHz spectro-polarimeter, named AMATERAS (the Assembly of Metric-band Aperture TElescope and Real-time Analysis System). The former is mainly used for observing Jupiter's synchrotron emission with the sensitivity of 0.1Jy, and enables us to investigate dynamical variations of Jupiter's deep inner magnetosphere. The latter is used for observing solar radio bursts with 10ms accumulation time and 61 KHz bandwidth, and enables us to clarify various micro structure of wave-particle or wave-wave interactions generated in the solar corona region.

The Jovian and solar radio wave receiver system in HF range (15-40MHz) was continuously operated at Iitate Observatory of Tohoku University. Spectrograms of Jovian and solar radio wave with a time resolution of 0.5 sec were automatically archived and provided to the researchers through the internet. The discussion on combining this data archive with that of Nancay observatory has started between the researches of Paris Astronomical Observatory and Tohoku University. In addition, the operation of RF waveform recording receiver system for the observation of Jovian decametric S-bursts was started at Iitate Observatory since October 2013. The data will be useful for the analysis of the repetition of S-bursts, which is caused by Jovian Ionospheric Alfven Resonator (IAR).

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