COMMISSION H: Waves in Plasmas (November 2004 – October 2007)

Edited by Toshimi Okada and Yoshiharu Omura

Based on the papers published from November of 2004 to October of 2007, we compiled major achievements in the field of plasma waves and related studies made by Japanese scientists and their collaborators. We categorize the studies into three groups as shown in Contents. Each section provides a specific summary of important scientific achievements rather than a comprehensive report of the whole research activities of Japanese Commission H. On the other hand, the reference list attached at the end is intended to be used as a database of all papers we have collected from the Japanese Commission H members.

Contents

H1. Space Observation and Experiment of Plasma Waves
- H1.1 Magnetospheric Plasma Waves
  - < AKEBONO, GEOTAIL and related Satellite >
  - < Jovian Radio Emission >
- H1.2 Ionospheric Radio Waves
  - < Rocket Experiment >
- H1.3 Ground Observation and Experiment of Plasma Waves
  - < Solar Radio Burst >
  - < ULF Wave >
  - < Polar Region Experiment >
  - < Sub-Ionospheric Radio Waves including Seismic and Lightning Emissions >

H2. Theory and Computer Experiment on Plasma Waves
- H2.1 Wave Propagation and Wave-Particle Interaction
- H2.2 Antenna in Space Plasma

H3. New Projects for Lunar and Planetary Plasma Wave Study
- < KAGUYA >
- < BepiColombo >
- < ERG >
- < Jupiter Mission >

References

Acknowledgement

H1. Space Observation and Experiment of Plasma Waves

H1.1 Magnetospheric Plasma Waves

<AKEBONO , GEOTAIL and related Satellite>

Nineteen years has past since Akebono was launched in 1989. The instruments onboard Akebono is still successfully working and enormous dataset has been stored. The total amount of the digital (PCM) data is about 2 tera-bytes, and the analogue data will amount to 20 tera-bytes if we digitize all of them, which are recorded in 20,000 tapes of DAT. In order to manage the huge datasets effectively, a database system on the VLF/ELF waves observed by Akebono is now under construction [Takata et al., 2006; 2007].

Goto et al., [2004] introduced an inversion technique to estimate electron density profile in the plasmasphere based on the propagation characteristics of whistler mode wave. As lightning whistlers were frequently observed by the wideband receiver (WBA) onboard Akebono, this technique is a quite useful method not only for scientific interests but also for engineering applications since the plasmaspheric plasma cannot be ignored for high-precision navigation and positioning from artificial satellites [Goto et al, 2006].

Kasahara et al. [2004] have studied chorus emissions observed by Akebono in the vicinity of the outer radiation belt associated with magnetic storms. They estimated the energies of whistler mode wave and relativistic electrons during recovery phase of magnetic storms, and the total energy of chorus generated during magnetic storm is large enough to accelerate relativistic electrons.

Miyoshi et al. [2007] studied evolution of energetic electron fluxes, related solar wind conditions, and relevant plasma waves in the inner magnetosphere during the two corotating interaction region (CIR)-driven magnetic storms in November 1993. They reported that the flux of the outer radiation belt electrons increased significantly during the 3 November storm, while it did not increase above the prestorm level during the 18 November storm. They concluded that these differences can be related to the southward offset of interplanetary magnetic field (IMF) in the high-speed coronal hole stream, which is influenced by the IMF sector polarity via the Russell-McPherron effect.

Kumamoto et al. [2004] investigated long-term variations of ambient electron number density in the nightside auroral region based on auroral hiss data observed by the PWS. The electron number density in the nightside auroral region shows clear dependence on solar activity.

Morioka et al. [2007] identified two sources of auroral kilometric radiation (AKR) and their development prior to and during substorms. One source is a low-altitude source region corresponding to middle-frequency AKR and the other is a high-altitude source region corresponding to low-frequency AKR.

Seasonal and solar cycle dependences of the correlation between auroral kilometric radiation (AKR) and the auroral electrojet (AE) index have been investigated based on the plasma wave data obtained by the Akebono satellite [Kumamoto et al., 2005, 2006]. AKR power flux increases as about the 1.2 power of AE index in all seasonal and solar activity conditions. However, even for the same AE index, AKR power flux during solar minimum is 5 dB larger than that during solar maximum.

The behavior of AKR during magnetically quiet periods is investigated by Morioka et al. [2005a]. Features of quiet-time AKR indicated that the onset of AKR is one of the elementary components of the contracted substorm. Unexpected features showing that AKR spectra do not always depend on the substorm magnitude are also presented.

Seki et al. [2005] presented a paper concerning the magnetosphere-ionosphere coupling (M-I coupling) process in the upward field aligned region during magnetic storm, using AKR observations. The paper found that the auroral precipitation during the main phase of magnetic storms is not characterized by the inverted-V type electron precipitation but by the Maxwellian type precipitation, indicating the missing of the field aligned potential in the M-I coupling region during the main phase.

LHR band emissions observed at mid-latitude were investigated using data from the EXOS-C (Ohzora) satellite by Morioka et al. [2005b]. The results are, (1) LHR propagates in the LHR duct formed horizontally in the mid-latitude upper-ionosphere, (2) The emission is closely related to the occurrence of ionospheric ELF hiss, and (3) LHR emissions are commonly observed in the slot region of the radiation belt.

Electric fields in the inner magnetosphere associated with sudden commencements (SCs) are investigated using the data measured by the Akebono satellite [Shinbori et al., 2006]. After a passage of a bi-polar waveform associated with fast-mode hydromagnetic waves, the increase of the convection electric field takes place in the entire magnetic local time sector in the inner magnetosphere. The origin of the convection electric field in the inner magnetosphere is a plasma motion caused by the compression of the magnetosphere due to the solar wind shock.

Shinbori et al. [2007] investigated electrostatic electron cyclotron harmonic (ESCH) waves in the low-latitude plasmasphere (MLAT$<45^{\circ}$) by using the long-term plasma wave observation data obtained from the plasma wave and sounder experiment (PWS) onboard the Akebono satellite.

Nishimura et al. [2006, 2007a] revealed the generathin mechanism of the so-called "equatorial enhancement of the plasma wave turbulence (EPWAT)". From the Akebono PWS measurements theyshowed that the Z-mode waves are excited directly through a wave-particle interaction rather than the mode conversion from electrostatic waves. The ring-current electrons originating in the premidnight tail region are accelerated perpendicular to the ambient magnetic field and confined around the geomagnetic equator because of the conservation of the first and second adiabatic invariants.

Plasma Wave Instrument (PWI) onboard Geotail spacecraft continues to survey plasma waves in the terrestrial magnetosphere as well as in the magnetosheath and solar wind regions at the distance of 10Re to 30Re from the earth for more than 15years since the launch in 1992.

Shin et al. [2005] reported the electrostatic quasi-monochromatic (EQM) waves in the frequency range near 1 kHz. Geotail spacecraft observations show good correlation of EQM wave activities with the existence of cold electron beam-like component which correspond to the electrons accelerated in the bow shock. They show that under the existence of the cold beam-like component and background electrons with different temperatures, most plausible wave mode of the EQM waves is electron acoustic wave.

Shiokawa et al. [2005] examined the rapid decrease in Bz just before dipolarizations observed by the GEOTAIL satellite in the near-Earth plasma sheet. The magnetic Bz component suddenly decreased 2-4 s prior to the dipolarization. Characteristic waves with frequencies of 5-20 Hz and amplitudes of 1-3 mV/m and 5-15 nT/s were observed in the electric and magnetic field data at the time of the sudden decreases in Bz. They argue that the observed sudden decreases in Bz prior to the dipolarizations are possibly the explosive growth phase and subsequent disruption of the tail current caused by the observed characteristic field oscillations in the lower hybrid frequency range.

Oka et al. [2006] discuss a possible relationship between the Whistler critical Mach number(M-crit(w)) and the electron acceleration based on Geotail observations. They report that M-crit(w) seems to regulate the electron acceleration efficiency at the shocks. At the shock transition layer it is found that the spectral index Gamma of electron energy spectra defined by f(E) proportional to E-Gamma G is distributed between 3.5 and 5.0 in the sub-critical regime, while the hardest energy spectra with Gamma = 3-3.5 are detected in the super-critical regime.

In the study on the electromagnetic waves radiated in the upstream region of the bow shock, Kasaba et al. [2005] summarized the generation mechanism of electrostatic and electromagnetic 2fp emissions based on the Geotail observations and computer simulations. They also discuss the electron acceleration in the quasi-perpendicular shock region comparing with intensities of 2fp emissions and shock normal angles.

Kasaba et al. [2005] summarize the characteristics of the DC electric field measurement by the double probe system, PANT and EFD-P, aboard Geotail. In better conditions, accuracy of Ey is 0.2 mV/m. The potential accuracy would be better because those values are limited by the accuracy of the particle measurement especially in low density conditions. In practical use, the corrections by long-term variation and spacecraft potential are effective to refine the electric field data.

Hori et al. [2005] studied the electric field by the Geotail spacecraft in the near-Earth magnetotail during magnetic storms. The observed electric field properties in the near-Earth plasma sheet are basically classified into the two categories: one is characterized by intermittent bursts of fluctuating duskward electric fields associated with substorm expansions, and the other is dominated by a relatively steady, weak duskward electric field. The weak strength of the convection electric field in the latter category is seen even during storm main phase.

Lobe trapped continuum radiation (LTCR) has been observed onboard the Geotail spacecraft, at frequencies as low as 1 kHz in the distant geomagnetic tail region. By comparing the waveform observations of the LTCR with the 3-d ray-tracing analysis, the possible source regions of the LTCR is identified as the plasma sheet boundary layer away from the nominal tail axis and the low latitude boundary layer (Takano et al., 2005).

Morioka et al. [2007] studied detailed features of micro-type-III radio bursts, which are elements of the so-called type III storm, by using long-term observations made by the Geotail and Akebono satellites. Micro-type-III radio bursts are characterized by short-lived, continuous, and weak emissions. It was found that both micro and ordinary type-III bursts emanated from the same active region without interference, indicating the coexistence of independent electron acceleration processes.

Hashimoto et al.[2005] showed new sources of the Kilometric continuum radiation, which was first identified with the Geotail Plasma Wave Instrument (PWI) and has been observed with various satellites. Using the multiple satellite data, they revealed that the kilometric continuum can be radiated at the equatorial density irregularities inside the plasmasphere as well as at the plasmapause. Further, IMAGE and Geotail simultaneous kilometric continuum observations measure a very broad emission cone of up to about +/- 30 degrees.

The auroral kilometric radiation is the intense emissions radiated in the polar region in the relation to auroral activities. Murata et al. [2005] examined the simultaneous observation data of Geotail and Polar spacecraft. They found the two distinct regions where the AKR is osculated. One is the night side region at lower region less than 60MLAT and the other is the vicinity of the plasma pause regions of the MLAT between 30 and 50 degrees in the day side and between 10 and 30 degrees in the night side.

An empirical formula correlating the Geotail spacecraft potential measured by the single probe and the electron number density as determined by the plasma wave observations in the solar wind and broader magnetosphere have been obtained. Using this formula and plasma particle measurements, the problem how much and how the low-energy plasma exist in the magnetosphere is investigated [Ishisaka et al., 2005].

The extensive collaboration of the Geotail observations and computer simulations was conducted on the modulated Langmuir waves observed by Geotail. Usui et al. [2005] studied the amplitude modulation of Langmuir waves using fill particle electromagnetic computer simulations. They succeeded on explaining it by the nonlinear trapping theory instead of the conventional theories such as the decay instability and the modulational instability.

By using a test-particle simulation, Nakagawa and M. Iizima [2005, 2006] studied velocity distribution of the solar wind electrons injected into the lunar wake boundary. They showed that the pitch angle of the electrons are largely diffused by the electric field at the wake boundary. The component perpendicular to the backgoround magnetic field became large enough to excite whistler mode wave as observed by GEOTAIL in the solar wind upstream of the lunar wake.

<Jovian Radio Emission>

Morioka et al. [2004] investigated the characteristics of the Jovian Anomalous Continuum (JAC) in interplanetary space, using Ulysses observation. Some new source characteristics of JAC were obtained: (1) JAC tends to occur when the solar-wind dynamic pressure decreases after a rapid increase, (2) JAC appears most likely when the System III longitude of the sub-solar point is near 270°, and (3) the periodic appearance of JAC is not due to its intensity modulation but its repeated individual excitation.

Morioka et al. [2006] investigated the occurrence characteristics of Jovian multiple quasi-periodic bursts based on Galileo spacecraft observations. They showed that Multiple QP bursts recurrently appeared in a group with a planetary spin period of 10 hr, i.e., they were preferably excited when Jupiter had a particular spin phase angle with respect to the sun (at a sub-solar longitude of System III around 260-320º).

H1.2 Ionospheric Radio Wave

<Rocket Experiment>

Ashihara et al. [2005] studied the mid-latitude D-region ionosphere by measuring, onboard rocket S-310-33, the intensities of radio waves at 238 kHz and 873 kHz transmitted from the ground stations. The electron density profile was estimated from absorption of these radio waves and it is found that there was a thin layer of high electron density of 2.4×10^3 cm^{-3} at the altitude of 89 km. The thickness of its layer is about 0.9～1.0 km.

Ishisaka et al. [2005] studied the ionosphere in the auroral region by the MF radio absorption method. The SRP-4 rocket was launched at Poker Flat in Alaska on 18 March 2002. The Low frequency and Medium frequency band radio Receiver (LMR) and the DC Probe System (DPS) were installed on-board the rocket to estimate the electron density in the D-region as low as 50 km altitude.

The number density of electrons by impedance probe (NEI) instrument provided high-quality data of the electron density in the midlatitude and auroral ionosphere in the SEEK-2 and DELTA campaigns, respectively [Wakabayashi et al., 2005a; Wakabayashi et al., 2005b; Wakabayashi and Ono, 2006]. It measured multi-layered sporadic E layer (Es) and enhancements of the electron density associated with precipitations of auroral electrons.

The occurrence character of the ionization ledge was investigated by using the topside sounder experiments on-board Ohzora and ISIS-2 [Uemoto et al., 2006, 2007a]. The ionization ledge tends to align along the geomagnetic field line, and to appear within local time sectors from morning (9 LT) to slightly after midnight (2 LT). The occurrence of ionization ledges is correlated with eastward electric fields applied in the equatorial ionosphere, which cause upward plasma drifts.

Simultaneous magnetic conjugate observations of the F3 layer have been performed by using the meridional ionosonde network located in Southeast Asia (SEALION) between November 16, 2004 and March 31, 2005 [Uemoto et al., 2007b]. A clear dependence of the F3 layer on the magnetic latitude is found. The magnetic latitude dependence can be explained by the plasma diffusion effects along the magnetic field lines in the magnetic low-latitude region.

For precise measurements of the electron density in the ionosphere, Wakabayashi et al. [2005a] and Wakabayashi and Ono [2006] developed impedance probes using the direct digital synthesizer (DDS) and logarithmic amplifier. It allows measuring the electron density with an accuracy of less than 3%. The impedance probes were mounted on the S310-31 and S310-32 (SEEK-2 campaign, without log amp), and S310-35 (DELTA campaign, with log amp) rockets. See below for the results.

H1.3 Ground observation and Experiment of Plasma Waves

<Solar Radio Bursts>

A new solar radio spectrograph covering frequency ranges from 18 to 38 MHz and 190 to 350 MHz has been installed at the Husafell station in Iceland [Hiyama et al., 2006]. Thirty solar bursts have been measured since September 2004. They compared our ground measurement with solar bursts simultaneously detected by the WIND spacecraft.

<ULF Wave>

From the observed frequency (in the ULF range) of the field-line resonance (FLR), one can estimate the plasma mass density along the field line being observed. Kawano et al. [2006] compared the L profile (at L>2.3) of the electron density during a magnetic storm, observed by Akebono/PWS, with simultaneous ion density at L=2.07, estimated by Chi et al. [2000] by using FLR identified in ground magnetometer data. As a result, Kawano et al. suggested that the plasmapause remained outside L=2.07 during the storm but the density within the plasmasphere decreased.

Takasaki et al. [2006] observed FLR at L~1.4, from which they reported an increase in the equatorial plasma density at L~1.4 during a large storm. This is surprising, because it is usually thought that the plasmasphere shrinks during a storm; Takasaki et al. interpreted the increase in terms of an outflow of heavy ions (e.g., O+) from the ionosphere to the plasmasphere.

Uozumi et al. [2007] studied the generation and propagation of Pi 2 waves in the magnetosphere by comparing the ground-based signatures of Pi 2, observed by the Circum-pan Pacific Magnetometer Network (CPMN), with their model calculations. They suggested that the source region of Pi 2 is located at 9 Re and 22.5 MLT on the equatorial plane. They also suggested that, to successfully explain the observations, Pi 2 has to start from the source region as fast mode waves.

Kawano and Lee [2007] applied, for the first time, the so-called gradient methods to simulated ground magnetic field data (simulated by an MHD code). They reported that there do exist cases in which the gradient methods successfully identify FLR. They then went further and reported a case in which a non-FLR wave component biases the gradient-method output; the non-FLR component appears to have arisen from the coupling of an FLR component and a cavity-mode component where the two frequencies match.

Tokunaga et al. [2007] applied, for the first time, the Independent Component Analysis (ICA) method to a Pi 2 event observed by CPMN. As a result, they found that the Pi 2 had two components; the one component looked, at low latitudes, similar to previously reported cavity mode, but it had a common waveform even outside the nominal plasmasphere. The other component was localized at nightside high latitudes, suggesting its relevance to substorm current systems; it is also to be noted that this component was also observed near the dayside dip equator.

Abe et al. [2006] identified the plume from the ground for the first time by using ULF waves measured by ground magnetometers. They confirmed the identification by comparisons with the data from the EUV imager on board the IMAGE satellite.

Iyemori et al. [2005] reported a long-period Pc5 pulsation in Thailand shortly after the onset time of the Sumatra earthquake on December 26, 2004. They suggested that the Pc5 was generated by dynamo action in the lower ionosphere, set up by an atmospheric pressure pulse which propagated vertically as an acoustic wave when the ocean floor suddenly moved vertically. This study was followed by the study of Shinagawa et al. [2007], who used a time-dependent two-dimensional nonhydrostatic compressible atmosphere-ionosphere model, ran numerical simulations, and successfully reproduced the atmospheric pressure pulse.

Tsurutani et al. [2006] reviewed geomagnetic activity due to corotating solar wind streams. They demonstrated that geomagnetic storms associated with high-speed streams/CIRs (corotating interaction regions) have the same initial, main, and “recovery” phases as those associated with ICME (interplanetary coronal mass ejections)-related magnetic storms but that the interplanetary causes are considerably different. They showed that elongated storm “recovery” phases are caused by nonlinear Alfven waves within the high streams proper, and the acceleration of relativistic electrons occurs during these magnetic storm “recovery” phases.

Sakaguchi et al. [2007] reported very good correspondence between 13 isolated auroral arc events at subauroral latitudes and Pc 1 geomagnetic pulsations using one-year data from Athabasca, Canada (magnetic latitude: 62 deg, L=4.6). The observed Pc 1 frequencies were almost the same as the frequencies of He+ electromagnetic ion cyclotron (EMIC) waves at the equatorial plane connected to observed isolated arcs. These results indicate that interactions of spatially-localized EMIC waves with ring current ions cause high-energy ion precipitation and associated isolated auroras at subauroral latitudes.

<Polar Region Experiment>

Miyake et al. [2004] carried out successfully the PPB experiment in Antarctica in January 2003, and recently reported the observational results such as the Pc1 pulsations, ELF hiss, polar chorus and auroral hiss. In the PPB experiment, two challenging techniques for the data transmission were carried out. First, all the observed data were transmitted directly from the balloons to National Institute of Polar Research in Japan, by way of the IRIDIUM satellites for the world-wide mobile telephone.

Ozaki et al. [2007] observed natural ELF/VLF waves (chorus and hiss) in Antarctica from December 2005 to December 2006 at three sites near Showa Station, which measured intensities and polarizations of ELF/VLF magnetic fields. With the preliminary analysis they have confirmed that the intensities and polarizations of the observed waves could be used to calculate their ionospheric exit points, during substorms as well as in quiet times. Such information will provide a quantitative clue to the stereoscopic structures of the ELF/VLF propagation in the polar ionosphere and magnetosphere.

Optical observations of flickering aurora by a high-speed imaging photometer system were carried out at Syowa Station in 1998 [Sakanoi et al., 2005]. They made a comparison study between observed parameters of flickering aurora and theoretical values of dispersive Alfven waves and demonstrated that observed flickering aurora would be produced by electron flux modulations by electromagnetic ion cyclotron waves or inertial Alfven waves in the auroral acceleration region located over the altitude range of about 2000–5000 km.

<Sub-Ionopsheric Radio Waves including Seismic and lightning Emissions>

Ionospheric Alfven Resonances (IARs) as a kind of resonance phenomenon in the ionosphere and mangetosphere, were observed in Kamchaktka, Russia (L = 2.1) by Hayakawa et al. [2004], who have reported its statistical results on the spectral resonance structures in the ULF /ELF range from 0.1 to 5.0 Hz on the basis of the long-term observation during 2.5 years. Then, Surkov et al. [2006] have presented a theory for mid-latitude IARs excitation due to electromagnetic waves radiated from the lightning discharges, and have found that nearby thunderstorms in a range of 1000 - 2000 km make a main contribution to IARs.

ELF wave phenomena in the Earth-ionosphere cavity, known as Schumann resonance, have been studied in order to monitor the lower ionosphere and global lightning activity. Ando et al. [2005] have developed an algorithm to deduce the global lightning activity map as an inverse problem to the ELF data observed at a few stations in the world. Anomalous Schumann resonance effects have been found for earthquakes by Hayakawa et al. [2005], who have found an anomaly in Schumann resonance (e.g., enhancement in the fourth harmonic etc.) in Japan, in possible association with a large earthquakes in Taiwan. They have interpreted that this anomaly is due to the interference between the direct signal from a major lightning source in America and the signal scattered from the Seismo-ionospheric perturbation over Taiwan.

Nickolaenko and Hayakawa [2007] have reviewed the latest works on Schumann resonances and related ELF transient events during the last several years, including ionospheric non-uniformities, the use as a global thermometer, new objects for studies, and new results in old problems.

Nickolaenko et al. [2004] have developed a computer algorithm for accelerating the convergence of the time series computations of the ELF pulsed waveforms propagated in the Earth-ionosphere waveguide.

Hayakawa [2007] has reviewed the subionospheric VLF/LF propagation during earthquakes, and have presented event and statistical studies on the correlation of ionospheric perturbations as seen by VLF/LF and earthquakes with large magnitudes, say with magnitude larger than 6.0. Also, a few possible mechanisms have been suggested and discussed.

By using the full-wave method, Ozaki et al. [2004] have calculated the ionospheric penetration of the ELF/VLF electromagnetic field radiated from a dipole source on the ground. The results have shown a clear difference in day and night wave propagation characteristics.

They have examined the possibility of detecting the electromagnetic wave radiated by an earthquake, directly onboard a satellite.

Higashi et al. [2005] studied the anomalous electromagnetic signals onboard satellite in the ionosphere and the lower magnetosphere over seismic areas. In order to estimate the wave intensities related with seismic activity, they performed a numerical analysis of the electromagnetic waves in the lower ionosphere radiated from an underground transient dipole source.

Tsutsui [2005] detected an EM pulse just when an earthquake occurred on January 6 in 2004, and found that the arrival direction of the pulse pointed toward the earthquake epicenter. And by examining dispersion characteristic curve seen in frequency dynamic spectra (f-t diagram) of the detected EM pulse, the propagation distance was determined.Recently, he developed new analysis method to determine arrival directions of the EM pulses. [Tsutsui et al. 2007].

Seismogenic ULF emissions were detected prior to some large earthquakes ; for example, 2004 Niigata-Chuetsu earthquake [Ohta et al., 2005; Hayakawa et al., 2006] and 2004 Indonesia Sumatra earthquake [Ohta et al., 2007]. Ohta et al. [2005] performed the direction finding from Nakatsugawa, Japan and found that the observed azimuthal directions are consistent with the epicentral directions of both earthquakes, giving a strong evidence on the precursory ULF emissions.

Some sophisticated signal processings were developed and utilized to detect any weak seismogenic ULF emissions [Serita et al., 2005; Hattori et al., 2006; Ida et al., 2006; Ida and Hayakawa, 2006]. Ida et al. [2006] and Ida and Hayakawa [2006] have applied the fractal (mono- and multi-) analyses to ground-based ULF data to suggest that those fractal analysis are very useful in examining the nonlinear process (self-organized criticality) taking place in the lithosphere.

Hayakawa et al. [2007] have reviewed seismogenic ULF emissions, starting from earlier to the latest results. The most important conclusion from all ULF events reported before, is that there must be a threshold of the possible detection of seismogenic ULF emissions as functions of earthquake magnitude and epicentral distantce. Also, the generation mechanisms of ULF emissions (microfracturing, electro-kinetic effects etc.) are also discussed.

Nagano et al. [2006] and Yagitani et al. [2006] have developed a lightning detection system to determine the lightning locations by observing the sferic waveforms at a single station. Compared with the lightning locations identified by a conventional lightning location system (LLS) with multiple stations, it has been confirmed that the developed system could locate the lightnings within the distance of several hundred km with the location errors of about 10%, for the VLF sferics measured with distinguishable pulse trains.

H2. Theory and Computer Experiment on Plasma Waves

H2.1 Wave Propagation and Wave-Particle Interaction

In order to explain the solar wind transport across the low latitude magnetopause, Matsumoto and Hoshino [2004, 2006] and Matsumoto and Seki [2007] proposed new turbulent transport mechanisms by the secondary instabilities excited by the primal Kelvin-Helmholtz instability (KHI). It was found by 2-D MHD and full particle simulations that the secondary Rayleigh-Taylor instability greatly contributed to the formation of a broad mixing layer by exciting large amplitude electrostatic fields. 3-D MHD simulations also found a new secondary Magneto-Rotational instability excited inside a vortex. This type of 3-D secondary instability not only enhances a mixing process (in the magnetosphere) but also transports the kinetic energy in the direction of the ambient magnetic field (ionosphere).

Nonlinear evolution of the electron two-stream instability is systematically studied by a series of two-dimensional particle-in-cell simulations [Umeda et al., 2006a]. Detailed stability conditions of electron phase-space holes and electrostatic wave emission mechanism from phase-space holes are revealed.

A numerical method for solving linear dispersion equation for Maxwellian ring velocity distribution function is developed [Umeda, 2007a]. Generation and competition processes and electrostatic electron cyclotron harmonic (ECH) waves and electromagnetic whistler mode waves are examined by a two-dimensional particle-in-cell simulation [Umeda et al., 2007].

A robust numerical interpolation scheme for Vlasov code simulations is developed by Umeda et al. [2006]. The code is applied for generation mechanism of Langmuir wave packets in space plasmas. It is shown that Langmuir waves are spatially modulated by highly nonlinear processes involving both coherent trapping and incoherent turbulent mechanisms [Umeda, 2006, 2007b].

A parametric decay process of Alfven waves into ion acoustic waves is examined by a high-resolution magneto-hydro-dynamic (MHD) simulation [Tanaka et al., 2007]. It is shown that sinusoidal Alfven waves propagating in a radially expanding plasma exceed an amplitude threshold of the decay instability, exiting forward density fluctuations and backward-scattered Alfven waves. The density fluctuations also generate shocks and discontinuities, which may lead to turbulence of Alfven waves. Diffusion of energetic particles in such turbulence is studied by a test particle simulation by Otsuka et al. [2007].

A new model to excite collsionless shocks in computer simulations is developed by Umeda and Yamazaki [2006]. The new model allows us to follow full-kinetic dynamics of collisionless shocks in the shock rest frame, which is useful to perform a long-time simulation run.

Resonant diffusion processes of high energy electrons are studied numerically by using an original simulation scheme with hot electrons including fully relativistic effects and a fluid of cold electrons [Katoh et al., 2005]. A difference between results from their simulation and the quasi-linear diffusion is identified, indicating the importance of the nonlinearity which is not included in the quasi-linear theory.

A mode conversion process from slow X-mode waves to fast X-mode waves by the tunneling effect has been studied by solving Maxwell equations numerically [Katoh and Iizima, 2006]. The mode conversion is effective where the width of the evanescent layer between the local UHR frequency and the local fast X-mode cut-off frequency, is of the order of the wavelength of the incident slow X-mode waves. The result indicates the importance of the mode conversion in the auroral zone and magnetopause.

The electric field structure around the moon is studied by using a 2-dimensional, electromagnetic full particle simulation [Kimura and Nakagawa, 2006]. A plasma wake is formed behind the moon in the solar wind flow, and more intense electric field is produced at the terminator region of the moon due to the absorption of the plasma particles at the surface of the moon.

Katoh and Iizima [2006] studied the mode conversion process from slow X-mode waves to fast X-mode waves by the tunneling effect by means of the computer simulation. On the basis of the new approach by the simulation, they have confirmed that the mode conversion to the fast X-mode waves is especially effective in a case where the width of the evanescent layer which exists between the local UHR frequency and the local fast X-mode cut off frequency is of the order of the wave length of the incident slow X-mode waves.

Triggering process of VLF triggered emissions is studied by a self-consistent electron hybrid simulation with a homogeneous [Katoh and Omura, 2006a] and a dipole magnetic field model [Katoh and Omura, 2006b].

Katoh and Omura [2006a] studied frequency variation of a coherent whistler-mode wave in a homogeneous magnetic field. Simulation results show that an injected whistler-mode wave packet grows due to an instability driven by temperature anisotropy and the amplified wave packet triggers emissions with frequency shift during its propagation. They clarified that the resonant currents due to the nonlinear wave-particle interaction play significant roles in both wave growth and frequency variation. Based on the simulation results, we show that the range of the frequency shift in a homogeneous system is quantitatively estimated by the trapping frequency of trapped electrons.

Katoh and Omura [2006b] studied the generation mechanism of VLF triggered emissions in a dipole magnetic field. The evolution of a wave packet propagating along a reference magnetic field line is solved by Maxwell's equations, while the bounce motion of energetic electrons in the nonuniform magnetic field is taken into account. They found that a triggered emission with a rising tone is generated near the equatorial region after the wave packet passes through the magnetic equator, and 26% rising from the original frequency of the injected wave packet is reproduced.

The simulation model with a dipole magnetic field used in Katoh and Omura [2006b] has been applied to the study of the generation mechanism of whistler-mode chorus emissions [Katoh and Omura, 2007a]. Katoh and Omura [2007a] reproduced chorus emissions with rising tones by the electron hybrid simulation. They assumed energetic electrons forming a highly anisotropic velocity distribution in the equatorial region. In the early stage of the simulation, coherent whistler-mode waves were generated from the equator through an instability driven by the temperature anisotropy of the energetic electrons. During the propagation of the whistler-mode waves, they found formation of a narrowband emission with negative frequency gradient (NEWNFG) in the spatial distribution of the frequency spectrum in the simulation system.

Dynamics of energetic resonant electrons interacting with whistler-mode waves has been studied by a test-particle simulation with a dipole magnetic field and a coherent whistler mode wave [Omura and Summers, 2006]. A very efficient acceleration mechanism called relativistic turning acceleration (RTA) has been found in the test particle simulation, and it is analyzed theoretically [Omura et al., 2007], The RTA process has also been found in the self-consistent simulation of chorus wave generation [Katoh and Omura, 2007b].

Sugiyama and Kusano [2007] developed a new simulation model to interlock the fluid simulation and kinetic simulation with particle-in-cell model, and confirmed smooth propagation of Alfven wave through boundaries of small-scale and MHD domain. Parametric instabilities of incoherent Alfven waves are intensively studied by Nariyuki and Hada [2005, 2006a, 2006b, 2007a,2007b,2007c].

Katoh et al. [2006] studied generation of ion cyclotron waves through the ion pickup process surrounding Io by hybrid simulation. They simulated the excitation of ion cyclotron waves and discuss the modification of the velocity distribution of picked-up ions due to the wave-particle interaction.

2.2 Antenna in space plasma

The characteristics of dipole antenna or probe antenna have been studied in two ways; one is the construction of electrical equivalent circuit using the AKEBONO and GEOTAIL observation data. Another approach is the computer simulation using the particle code. Usui et al. [2006] have been studying the antenna properties of a dipole antenna immersed in magnetized plasma by performing PIC (Particle-In-Cell) electromagnetic simulations.

Higashi et al. [2005] studied the effective length and the impedance of the wire dipole antennas onboard the Akebono satellite. The effective length of each wire dipole antenna is estimated to be nearly the half of its tip-to-tip length of 60 m, which is consistent with the conventional assumption of the effective lengths of the dipole. On the other hand, the estimated capacitance and resistance exhibit specific spin variation, which would be caused by the plasma sheath formation around the antenna wires, depending on the angle between the antenna direction and the geomagnetic field line.

Imachi et al. [2006] have investigated the low-frequency characteristics of wire antennas onboard spacecraft like Geotail. With the ground-based “Rheometry Experiment” using an antenna scale model to pick up an electric field generated inside a water tank, they have found that for a wire dipole antenna covered with a thin insulator except for its tips, the antenna's effective length is almost equal to its tip-to-tip length at very low frequencies (less than hundreds of Hz), while it becomes half of it at higher frequencies.

The frequency dependence of the effective length has been explained by theoretical calculations as well as by numerical electromagnetic simulations [Imachi et al., 2007]. Especially the simulations have revealed the detailed spatial structures of ambient electric fields and potentials deformed under the influence of the antenna wires. The structure of deformed electric fields and potentials varies with frequency, which can quantitatively explain the frequency dependence of the antenna's effective length.

H3. New Projects for Lunar and Planeatary Plasma Wave Study

< KAGUYA >

KAGUYA was launched at 10:31:01 a.m. on September 14, 2007 (JST) from Tanegashima Space Center by JAXA. KAGUYA consists of a main orbiting satellite at about 100km altitude and two small satellites (Relay Satellite and VRAD Satellite) in polar orbit. The orbiters will carry instruments for scientific investigation of the Moon, on the Moon, and from the Moon.

The Lunar Radar Sounder (LRS) on-board KAGUYA has been planned to provide the data of subsurface stratification and tectonic features in the shallow part (several km depths) of the lunar crust, by using an FM/CW radar technique in HF (~5MHz) frequency range. The LRS consists of three subsystems: the sounder observation (SDR), the natural plasma wave receiver (NPW), and the waveform capture (WFC). Knowledge of the subsurface structure is crucial to better understanding not only of the geologic history of the moon, but also of the regional and global thermal history of the Moon, and also of the origin of the Earth-Moon system. In addition to the subsurface radar experiment, LRS will provide the spectrum of plasma waves, and solar and planetary radio waves in wide frequency range covering from 10 Hz to 30 MHz.

In order to achieve the lunar subsurface sounding and planetary radio wave observations by the LRS, strict electromagnetic compatibility (EMC) requirements were applied for all instruments and whole system of the spacecraft. The EMC performance of the spacecraft was finally evaluated in the system EMC test. In the EMC test, following new techniques were introduced: (1) Systematic control and evaluation of common-mode current noises were first performed to improve the spacecraft EMC performance. (2) Onboard battery operation was utilized for reduction of ambient broadband noises during EMC measurements.

The WFC, which is a subsystem of the LRS onboard KAGUYA, is a high-performance and multi-functional receiver for the measurement of plasma waves and radio emissions. Specific wave phenomena of interest to be obtained from the WFC data are dynamics of lunar wake as a result of solar wind-moon interaction, physics of mini-magnetosphere caused by the magnetic anomaly of the moon, kilometric radiation originated from the Earth, solar radio emissions, and many kinds of plasma waves in the Earth's magnetosphere.

Kobayashi and Ono [2006, 2007] propose a technique to estimate a detectability of subsurface echoes and a roughness parameter of a planetary surface by means of a sounder experiment. The technique was examined by simulations of planetary sounding observations which is based on physical optics, and demonstrated to estimate the RMS gradient of the planetary surface in the range from some fraction of degrees to about ten degrees. The technique can be applied to the radio sounder observation of Mars as well as that of the Moon by KAGUYA/LRS.

<BepiColombo>

The BepiColombo is the science mission to Mercury. It is the first collaborative space program of JAXA and ESA. The BepiColombo mission consists of two individual spacecraft called MPO (Mercury Planetary Orbiter) and MMO (Mercury Magnetospheric Orbiter). Two spacecraft of the BepiColombo will be launched in 2013.

Plasma Wave Investigation (PWI) was proposed in collaboration of the Japanese and European science teams. The targets of the PWI are plasma/radio waves in and around the Mercury magnetosphere. The MMO Payload Review Committee in JAXA selected the PWI for the science payload onboard MMO spacecraft in 2005.

The PWI investigates plasma/radio waves and DC electric field in Mercury magnetosphere. The detailed science objectives of the PWI are described by Matsumoto et al. [2006]. The PWI consists of two components of receivers (EWO: Electric Field Detector/Wave-Form Capture/Onboard Frequency Analyzer, and SORBET: Spectroscopie Ondes Radio & Bruit Electrostatique Thermique), two sets of electric field sensors (WPT: Wire-Probe antenna, and MEFISTO: Mercury Electric Field In-Situ Tool), two kinds of magnetic field sensors (LF-SC: Low Frequency Search Coil, and DB-SC: Dual-Band Search Coil), and the antenna impedance measurement system (AM^2P: Active Measurement of Mercury's Plasma).

After the Preliminary Requirements Review by JAXA in 2005, the PWI team started to design the receiver system and sensors. The specifications and designs of the PWI are described by Matsumoto et al. [2006] (whole PWI system), Blomberg et al.[2006a, 2006b](MEFISTO), Moncuquet et al. [2006](SORBET), and Trotignon et al.[2006](AM^2P).

<ERG Mission>

The Earth's inner magnetosphere (inside 10 Re) is a region where particle energy increases to the relativistic energy range. This region is very important as a laboratory where high-energy particle acceleration can be directly measured in a dipolar field configuration, as well as for human activities in space. Shiokawa et al. [2006] reviewed unsolved scientific problems of the inner magnetosphere and proposed a new project name ERG that will provide new insights into the dynamics of the inner magnetosphere. They made a rough assessment of possible instruments and options for various scientific objectives for the ERG project.

<Jupiter Mission>

The Solar-Sail Project has been investigated by JAXA as an engineering mission with a small orbiter into the Jovian orbit [Kasaba et al., 2007]. This paper summarizes the basic design of this project and possible Jovian system studies by this opportunity. The small Jovian orbiter acompanied with the Solar-Sail Project will try to establish the technical feasibility of such future outer planet missions in Japan. The main objective is the second target, the Jovian magnetospheric and auroral studies with its limited payload resources. Radio and plasma wave instruments are considered as one of base instruments.

References

Abe, S., H. Kawano, J. Goldstein, S. Ohtani, S. I. Solovyev, D. G. Baishev, and K. Yumoto, Simultaneous identification of a plasmaspheric plume by a ground magnetometer pair and IMAGE Extreme Ultraviolet Imager, J. Geophys. Res., 111, No. A11, A11202, doi:10.1029/2006JA011653, 2006

Anderson, R. R., H. Matsumoto, K. Hashimoto, H. Kojima, Y. Kasaba, M. L. Kiaser, J.-L. Bougeret, J.-L. Steinberg, and G. Rostoker, Geotail, Polar, and Wind observations of auroral kilometric radiation, COSPAR Colloquia Series, 16, 205-219, 2005.

Ando, Y., M. Hayakawa, A. V. Shvets and A. P. Nickolaenko, Finite difference analysis of Schumann resonance and reconstruction of lightning discharge, Radio Sci., vol. 40, RS2002, doi:10.1029/2004RS003153, 2005.

Ashihara Y., K. Ishisaka, T. Okada, T. Miyake, and Y. Murayama, “Estimation of electron density with MF radio receiver (MFR)”, JAXA Special Report SP-04-007, 2005.

Bernhardt, P. A., Selcher, C. A., Siefling, C., Wilkens, M., Compton, C., Bust, G., Yamamoto, M., Fukao, S., Ono, T., Wakabayashi, M., and Mori, H., Radio tomographic imaging of sporadic-E layers during SEEK-2, Ann. Geophys., 23, 2357-2368, 2005.

Blomberg, L. G., J. A. Cumnock, Y. Kasaba, H. Matsumoto, H. Kojima, Y. Omura, M. Moncuquet, J-E. Wahlund, Electric fields in the Hermean environment, Adv. in Space Res., 38, 627-631, 2006a.

Blomberg, J. G., H. Matsumoto, J.-L. Bougeret, H. Kojima, S. Yagitani, J.A. Cumnock, A. I. Eriksson, G. T. Marklund, J.-E. Wahlund, L. Bylander, L. Ahlen, J. A. Holtet, K. Ishisaka, E. Kallio, Y. Kasaba, A. Matsuoka, M. Moncuquet, K. Mursula, Y. Omura, and J. G. Trotignon, MEFISTO-An electric field instrument for BepiColombo/MMO, Adv. in Space Res., 38, 672-679, 2006b.

Deng, X. H., R. X. Tang, H. Matsumoto, J. S. Pickett, A. Fazakerley, H. Kojima, W. Baunjohann, A. Coates, R. Nakamura, D. A. Gurnett, and Z. X. Liu, Observations of electrostatic solitary waves associated with reconnection with Geotail and Cluster, Advances in Space Research, 37, 3, 1373-1381, 2006.

Dmitriev, A. V., J.-K. Chao, A. V. Suvarova, K. Ackerson, K. Ishisaka, Y. Kasaba, H. Kojima, and H. Matsumoto, Indirect estimation of the solar wind conditions in 29 October 2003, J. Geophys. Res., 110, A09S02, doi:10.1029/2004JA010806., 2005.

Goto, Y., Y. Kasahara, and T. Sato, An Inversion Technique of the Plasmaspheric Electron Density Estimation Based on Propagation Characteristics of Whistler Mode Wave, Proc.of the 2004 International Symposium on Antennas and Propagation, 1E2-2, pp.245-248, 2004.

Goto, Y., Y. Sakai, Y. Kasahara, and T. Sato, Passive Remote Sensing of the Earth’s Plasmashpere Using Whistler Mode Waves (in Japanese), IEICE Trans. Commun, J89-B(7), pp.1188-1197 2006.

Hashimoto, K., R. R. Anderson, J. L. Green, and H. Matsumoto, Source and propagation characteristics of kilometric continuum observed with multiple satellites, J. Geophys. Res., 110, A09229, doi:10.1029/2004JA010729, 2005.

Hashimoto, K., J. L. Green, R. R. Anderson, and H. Matsumoto, Review of Kilometric Continuum, Lect. Notes Phys. 687, 37-54, 2006.

Hattori, K., A. Serita, C. Yoshino, M. Hayakawa and N. Isezaki, Singular spectral analysis and principal component analysis for signal discrimination of ULF geomagnetic data associated with 2000 Izu Island earthquake swarm, Phys. Chem. Earth, vol. 31, 281-291, 2006.

Hayakawa, M., O. A. Molchanov, A. Y. Schekotov, and E. Fedorov, Observation of ionospheric, Alfven resonance at a middle latitude station, Adv. Polar Upper. Atmos. Res., No. 18, 65-76, 2004.

Hayakawa, M., K. Ohta, A.P. Nickolaenko, and Y. Ando, Anomalous effect in Schumann resonance phenomena observed in Japan, possibly associated with the Chi-chi earthquake in Taiwan, Ann. Geophysicae, vol. 23, 1335-1346, 2005.

Hayakawa, M., VLF/LF radio sounding of ionospheric perturbations associated with earthquakes, Sensors, 7, 1141-1158, 2007.

Hayakawa, M., K. Ohta, S. Maekawa, T. Yamauchi, Y. Ida, T. Gotoh, N. Yonaiguchi, H. Sasaki and T. Nakamura, Electromagnetic precursors to the 2004 Mid Niigata Prefecture earthquake, Phys. Chem. Earth, vol. 31, 356-364, 2006.

Hayakawa, M., K. Hattori, and K. Ohta, Monitoring of ULF (ultra-low-frequency) geomagnetic variations associated with earthquakes, Sensors, 7, 1108-1122, 2007.

Higashi R., T. Imachi, S. Yagitani, I. Nagano, and I. Kimura, The characteristics of crossed wire antennas onboard the Akebono satellite, IEICE Trans. Commun, (in Japanese), J88-B, 2, 442-450, 2005.

Hiyama, Y., T. Ono, M. Iizima, H. Misawa, F. Tsuchiya, A. Morioka, and N. Sato, Initial results of Husafell solar radio spectrograph, Adv. Polar Upper Atmos. Res., 20, 76-85, 2006.

Hori, T., A.T.Y. Lui, S. Ohtani, P. Cason Crandt, B.H. Mauk, R.W. McEntire, K. Maezawa, T. Mukai, Y. Kasaba, and H. Hayakawa, Storm-time convection electric field in the near-Earth plasma sheet, J. Geophys. Res., 110, 4, 13, 2005.

Imachi, T., S. Yagitani, R. Higashi, and I. Nagano, Rheometry experiment for a wire antenna aboard spacecraft at low frequencies, IEICE Trans. Commun. (in Japanese), J89-B, 4, 552-559, 2006.

Imachi, T., S. Yagitani, K. Yamashita, R. Higashi, and I. Nagano, Low frequency characteristics of electric wire antenna onboard scientific spacecrafts, 2007 International Symposium on Antennas and Propagation (ISAP2007), 696-699, 2007.

Ida, Y., and M. Hayakawa, Fractal analysis for the ULF data during the 1993 Guam earthquake to study prefracture criticality, Nonlinear Processes Geophys., vol. 13, 409-412, 2006.

Ida, Y., M. Hayakawa, and K. Gotoh, Multifractal Analysis for the ULF Geomagnetic Data during the Guam Earthquake, IEEJ Trans. Fundamentals and Materials, vol. 126, No.4, 215-219, 2006.

Ishisaka K.，T. Okada，H. Hayakawa，T. Mukai，and H. Matsumoto，“Application of spacecraft potential to investigate the distribution of low energy plasma in magnetosphere”，COSPAR COLLOQUIA SERIES Vol.16, Frontiers in Magnetospheric Plasma Physics, 75-78, 2005.

Ishisaka K., T. Okada, J. Hawkins, S. Murakami, T. Miyake, Y. Murayama, I. Nagano, and H. Matsumoto, “ Investigation of Electron Density Profile in the Lower Ionosphere by SRP-4 Rocket Experiment”, Earth, Planets and Space, Vol. 57, 879-884, 2005.

Iyemori, T, M. Nose, D. S. Han, Y. F. Gao, M. Hashizume, N. Choosakul, H. Shinagawa, Y. Tanaka, M. Utsugi, A. Saito, H. McCreadie, Y. Odagi, and F. X. Yang, Geomagnetic pulsations caused by the Sumatra earthquake on December 26, 2004, Geophys. Res. Lett., 32, L20807, doi:10.1029/2005GL024083, 2005.

Kasaba, Y., H. Matusmoto, Y. Omura, and T. Mukai, 2fp radio source in Geotail observations and numerical simulations: Microscopic view, COSPAR Colloquia Series, 16, 247-250, 2005.

Kasaba, Y., H. Hayakawa, K. Ishisaka, T. Okada, A. Matsuoka, T. Mukai, and Y. Takei, Evaluation of DC electric field measurement by the double probe system aboard the GEOTAIL spacecraft, Advances in Space Research, 37, 3, 604-609, 2005.

Kasaba, Y., T. Takashima, and H. Misawa, Jovian Small Orbiter sub-WG with J. Kawaguchi and Solar-Sail WG, Jovian Small Orbiter for Magnetospheric and Auroral Studies Associated with Solar Sail, Advances in Geosciences 2006, 45, 2007.

Kasahara, Y., H. Uchiyama, and Y. Goto, Whistler Mode Chorus Observed around the Plasmapause during Magnetic Storms, *Frontiers of Magnetospheric Physics, COSPAR Colloquia Series, Elsevier*, 16, pp.228-234, 2004.

Katoh, Y., T. Ono, and M. Iizima, Numerical experiment of resonant scattering process of high energetic electrons in the outer radiation belt, Earth Planets Space, 57, 117-124, 2005.

Katoh, Y., and M. Iizima, A computer simulation study on the mode conversion process from slow X-mode to fast X-mode by the tunneling effect, Earth Planets Space, 58, e53-e56, 2006a.

Katoh, Y. and Y. Omura, Parametric study of resonant scattering process by narrow band whistler mode waves driven by temperature anisotropy, J. Plasma Physics, 72, 935-939, 2006b.

Katoh, Y. and Y. Omura, A study of generation mechanism of VLF triggered emission by self-consistent particle code, J. Geophys. Res., 111, A12207, doi:10.1029/2006JA011704, 2006c.

Katoh, Y. and Y. Omura, Computer simulation of chorus wave generation in the Earth's inner magnetosphere, Geophys. Res. Lett., 34, L03102, doi:10.1029/2006GL028594, 2007a.

Katoh, Y. and Y. Omura, Relativistic particle acceleration in the process of whistler-mode chorus wave generation, Geophys. Res. Lett., 34, L13102, doi:10.1029/2007GL029758, 2007b.

Kawano, H., P. J. Chi, A. Kumamoto, and A. Morioka, In situ observation at L = 2.3-5 by the Akebono satellite of the plasmaspheric depletion during the September 1998 magnetic storm, J. Geophys. Res., J. Geophys. Res., 111, A04204, 2006.

Kawano, H., and D.-H. Lee, Gradient methods applied to simulated ULF data: The effects of the ionospheric damping factor, J. Geophys. Res., 112, A07212, doi:10.1029/2006JA011849, 2007.

Kobayashi T., and T. Ono, Estimation of planetary surface roughness using radio sounder A-scope data, J. Geophys. Res., 111, E06S10, doi:10.1029/2005JE002575, 2006.

Kobayashi, T., and T. Ono, SAR/InSAR observation by an HF sounder, 112, E03S90, J. Geophys. Res., doi:10.1029/2005JE002576, 2007.

Kumamoto, A., T. Ono, and M. Iizima, "Seasonal and solar cycle dependences of ambient plasma density in the polar magnetosphere", 35th COSPAR Scientific Assembly, Paris, France., p.3398, 2004.

Kumamoto, A., T. Ono, and M. Iizima, Seasonal and solar cycle dependences of the correlation between auroral kilometric radiation and the AE index, Adv. Polar Upper Atmos. Res., 19, 10-20, 2005.

Kumamoto, A., T. Ono, and M. Iizima, Solar zenith angle and solar activity dependences of vertical profile of electron number density in the nightside auroral region, Adv. Polar Upper Atmos. Res., 20, 27, 2006.

Matsumoto, Y. and M. Hoshino, Onset of turbulence induced by a Kelvin-Helmholtz vortex, Geophys. Res. Lett., 31, L02807, doi:10.1029/2003GL018195, 2004.

Matsumoto, H., J.-L. Bougeret, L. G. Blomberg, H. Kojima, S. Yagitani, Y. Omura, M. Moncuquet, G. Chanteur, Y. Kasaba, J.-G. Trotignon, Y. Kasahara, BepiColombo MMO PWI Team, PLASMA/RADIO WAVE OBSERVATIONS AT MERCURY BY THE BEPICOLOMBO MMO SPACECRAFT, Advances in Geosciences 2005, vol.3, 71, 2006.

Matsumoto, Y. and M. Hoshino, Turbulent Mixing and Transport of collision-less plasmas across a stratified velocity shear layer, J. Geophys. Res., 111, A05213, doi:10.1029/2004JA010988, 2006.

Matsumoto, Y. and K. Seki, The secondary instability initiated by the three-dimensional nonlinear evolution of the Kelvin-Helmholtzinstability, J.Geophys.Res., 112, A06223, doi:10.1029/2006JA012114, 2007.

Miyoshi, Y., A. Morioka, R. Kataoka, Y. Kasahara, and T. Mukai, Evolution of the outer radiation belt during the November 1993 storms driven by corotating interaction regions, J. Geophys. Res., 112, A05210, doi:10.1029/2006JA012148, 2007.

Miyake, T., T. Okada, H. Yamagishi, A. Chino, K. Ishisaka, T. Yamagami, "Development of ELF/VLF band wave receiver onboard Polar Patrol Balloon",IEICE Trans. on Communication B, vol.J87-B, No.5, pp.741-745, 2004.

Miyoshi, Y., A. Morioka, R. Kataoka, Y. Kasahara, and T. Mukai, Evolution of the outer radiation belt during the November 1993 storms driven by corotating interaction regions, J. Geophys. Res., 112(A05210), doi:10.1029/2006JA012148, 2007.

Moncuquet, M., H. Matsumoto, J. L. Bougeret, L. G. Blomberg, K. Issautier, Y. Kasaba, H. Kojima, M. Maksimovic, N. Meyer-Vernet, and P. Zarka, The radio waves and thermal electrostatic noise spectroscopy (SORBET) experiment on BEPICOLOMBO/MMO/PWI: Scientific objectives and performance, Adv. in Space Res., 38, 680-685, 2006.

Morioka, A., T. Yuasa, Y. S. Miyoshi, F. Tsuchiya, and H. Misawa, Source characteristics and radiation mechanism of Jovian anomalous continuum, J. Geophys. Res., 109, A06206, doi: 10.1029/2004JA010409, 2004.

Morioka, A., Y. Miyoshi, F. Tsuchiya, H. Misawa, A. Kumamoto, H. Oya, H. Matsumoto, K. Hashimoto, and T. Mukai, Auroral kilometric radiation activity during magnetically quiet periods, J. Geophys. Res., 110, A11223, 2005a.

Morioka, A., H. Oya, T. Obara, Y. S. Miyoshi, K. Nagata, K.-I. Oyama, and T. Abe, LHR band emissions at mid-latitude and their relationship to ionospheric ELF hiss and relativistic electrons, Ann. Geophys., 23, 723-732, 2005b.

Morioka, A., H. Nozawa, H. Misawa, F. Tsuchiya, Y. Miyoshi, T. Kimura, and W. Kurth, Rotationally driven quasi-periodic radio emissions in the Jovian magnetosphere, J. Geophys. Res., 111, A04223, doi: 10.1029/2005JA011563, 2006.

Morioka, A., Y. Miyoshi, F. Tsuchiya , H. Misawa , T. Sakanoi , K. Yumoto, R. R. Anderson, J. D. Menietti , E. F. Donovan, Dual structure of auroral acceleration regions at substorm onsets as derived from AKR spectra, J. Geophys. Res., 112, A06245, doi 10.1029/2006JA012186, 2007.

Morioka, A., Y. Miyoshi, S. Masuda, F. Tsuchiya, H. Misawa, H. Matsumoto, K. Hashimoto, and H. Oya, Micro-type-III radio bursts, Astrophys. J., 657, 567-576, 2007.

Morioka, A., Y. Miyoshi, F. Tsuchiya , H. Misawa , T. Sakanoi , K. Yumoto, R. R. Anderson, J. D. Menietti , E. F. Donovan, Dual structure of auroral acceleration regions at substorm onsets as derived from AKR spectra, J. Geophys. Res., 112, A06245, doi 10.1029/2006JA012186, 2007.

Murata, K. T., W. Kurth, K. Hashimoto, and H. Matsumoto, Occultations of auroral kilometric radiation in the vicinity of the earth, COSPAR Colloquia Series, 16, 220-223, 2005.

Nagano, I., S. Yagitani, M. Ozaki, Y. Nakamura, and K. Miyamura, Estimation of lightning location from single station observations of sferics, IEICE Trans. Commun. B (in Japanese), J89-B, 1, 22-29, 2006.

Nakagawa,T. and M. Iizima, Pitch angle diffusion of electrons at the boundary of the lunar wake, Earth Planets Space, 57, pp.885-894, 2005.

Nakagawa, T., and M. Iizima, A reexamination of pitch angle diffusion of electrons at the boundary of the lunar wake, Earth Planets Space, 58, e17-e20, 2006.

Nariyuki, Y. and T. Hada, Self-generation of phase coherence in parallel Alfven turburence, Earth, Planets and Space, 57, e9-e12, 2005.

Nariyuki, Y. and T. Hada, Remarks on nonlinear relation among phases and frequencies in modulational instabilities of parallel propagating Alfven waves, Nonlinear Processes in Geophysics, 13, 425-441, 2006a.

Nariyuki, Y. and T. Hada, Kinetically modified parametric instabilities of circularly-polarized Alfven waves: Ion kinetic effects, Phys. Plasmas., 13, 124501, 2006b.

Nariyuki, Y., and T. Hada, Magnetohydrodynamic parametric instabilities of parallel propagating incoherent Alfven waves, Earth, Planets and Space, 59, e13-e17, 2007a.

Nariyuki, Y. and T. Hada, Density fluctuations induced by modulational instability of parallel propagating Alfven waves with beta ～1, J. Phys. Soc. Japan, 76(7), 074901, 2007b.

Nariyuki, Y. and T. Hada, Consequences of finite ion temperature effects on parametric instabilities of circularly polarized Alfven waves, J. Geophys. Res., 112(A10), A10107, 2007c.

Nickolaenko, A. P., L. M. Rabinowicz, and M. Hayakawa, Time domain presentation for ELF pulses with accelerated convergence, Geophys. Res. Lett., vol. 31, L05808, doi:

10.1029/2003GL018700, 2004.

Nickolaenko, A P., and M. Hayakawa, Recent studies of Schumann resonance and ELF transients, J. Atmos. Electr., 27, No. 1, 19-39, 2007.

Nishimura, Y., T. Ono, M. Iizima, A. Shinbori, A. Kumamoto, and H. Oya, Statistical studies of fast and slow Z-mode plasma waves in and beyond the equatorial plasmasphere based on long-term Akebono observations, Earth Planets Space, 58, pp. 343-346, 2006.

Nishimura, Y., T. Ono, M. Iizima, A. Shinbori, and A. Kumamoto, Generation mechanism of Z-mode waves in the equatorial plasmasphere, Earth Planets Space, 59, 1027-1034, 2007.

Nishimura, Y., A. Shinbori, T. Ono, M. Iizima, and A. Kumamoto, Storm-time electric field distribution in the inner magnetosphere, Geophys. Res. Lett., 33, L22102, 2006.

Nishimura, Y., T. Ono, M. Iizima, A. Shinbori, A. Kumamoto, and H. Oya, Statistical studies of fast and slow Z-mode plasma waves in and beyond the equatorial plasmasphere based on long-term Akebono observations, Earth Planets Space, 58, 343-346, 2006.

Nishimura, Y., T. Ono, M. Iizima, A. Shinbori, and A. Kumamoto, Generation Mechanism of Z-mode Waves in the Equatorial Plasmasphere, Earth Planets Space, 59, 1027-1034, 2007a.

Nishimura, Y., A. Shinbori, T. Ono, M. Iizima, and A. Kumamoto, Evolution of ring current and radiation belt particles under the influence of storm-time electric fields, J. Geophys. Res. 112, A06241, 2007b.

Ohta, K., N. Watanabe, and M. Hayakawa, The observation of ULF emissions at Nakatsugawa in possible association with the 2004 Mid Niigata Prefecture earthquake, Earth Planets Space, vol. 57, 1003-1008, 2005.

Ohta, K., N. Watahabe, and M. Hayakawa, The obserbation of ultra-low frequency emissions at Nakatsugawa, Japan, in possible association with the Sumatra, Indonesia, earthquake, Int'l J. of Remote Sensing, 28: 13, 3121-3131, 2007.

Otsuka, F., Y. Omura, and O. Verkhoglyadova, Energetic particle parallel diffusion in a cascading wave turbulence in the foreshock region, Nonlin. Processes Geophys., Vol. 14, pp. 587?601, 2007.

Oka, M., T. Terasawa, Y. Seki, M. Fujimoto, Y. Kasaba, H. Kojima, I. Shinohara, H. Matsui, H. Matsumoto, Y. Saito, and T. Mukai, Whistler critical Mach number and electron acceleration at the bow shock: Geotail observation, Geophys. Res. Lett., 33, L24104, doi:10.1029/2006GL028156, 2006.

Omura Y., and D. Summers, Dynamics of high-energy electrons interacting with whistler mode chorus emissions in the magnetosphere, J. Geophys. Res., Vol. 111, A09222, doi:10.1029/2006JA011600, 2006.

Omura Y., N. Furuya, D. Summers, Relativistic turning acceleration ofresonant electrons by coherent whistler-mode waves in a dipole magnetic field, J. Geophys. Res., Vol. 112, A06236, doi:10.1029/2006JA012243, 2007.

Ozaki, M., I. Nagano, S. Yagitani, and K. Miyamura, The ionospheric penetration characteristics of ELF/VLF waves radiated from a dipole source on the ground, Trans. IEE of Japan A, 124, 12, 1239-1244, 2004.

Ozaki, M., I. Nagano, S. Yagitani, H. Yamagishi, N. Sato, and A. Kadokura, First report of multipoint observation to study the propagation mechanism of natural ELF/VLF waves in Antarctica, IEICE Trans. Commun. (in Japanese), J90-B, 12, 1340-1344, 2007.

Sakaguchi, K., K. Shiokawa, A. Ieda, Y. Miyoshi, Y. Otsuka, T. Ogawa, M. G. Connors, E. Donovan, and F. Rich, Simultaneous ground and satellite observations of an isolated proton arc at subauroral latitudes, J. Geophys. Res., 112, A04202, doi:10.1029/2006JA012135, 2007.

Sakaguchi, K., K. Shiokawa, Y. Miyoshi, Y. Otsuka, T. Ogawa, K. Asamura, and M. Connors, Simultaneous appearance of isolated auroral arcs and Pc 1 geomagnetic pulsations at subauroral latitudes, J. Geophys. Res., in press, doi:10.1029/2007JA012888, 2008.

Seki, T., A. Morioka, Y. S. Miyoshi, F. Tsuchiya, H. Misawa, W. Gonzalez, T. Sakanoi, H. Oya, H. Matsumoto, K. Hashimoto, and T. Mukai, Auroral kilometric radiation and magnetosphere-ionosphere coupling process during magnetic storms, J. Geophys. Res., 110, A0506, doi: 10.1029/2004JA010961, 2005.

Sakanoi, K., H. Fukunishi, and Y. Kasahara A Possible Generation Mechanism of Temporal and Spatial Structures of Flickering Aurora, J. Geophys. Res., 110(A3), 10.1029/2004JA010549, 2005.

Serita, A., K. Hattori, C. Yoshino, M. Hayakawa, and N. Isezaki, Principal component analysis and singular spectrum analysis of ULF geomagnetic data associated with earthquakes, Natural Hazards Earth System Sci., vol. 5, 685-689, 2005.

Shin K., H. Kojima, H. Matsumoto, and T. Mukai , "Electrostatic quasi-monochromatic waves downstream of the bow shock: Geotail observations", COSPAR COLLOQUIA SERIES Vol.16, Frontiers in Magnetospheric Plasma Physics, pp. 293-296, 2005.

Shinagawa, H, T. Iyemori, S. Saito, and T. Maruyama, A numerical simulation of ionospheric and atmospheric variations associated with the Sumatra earthquake on December 26, 2004, Earth Planets And Space, 59, 1015-1026, 2007.

Shinbori, A., Y. Nishimura, T. Ono, M. Iizima, A. Kumamoto, and H. Oya, Electrodynamics in the duskside inner magnetosphere and plasmasphere during a super magnetic storm on March 13-15, 1989, Earth Planets Space, 57, 643-659, 2005.

Shinbori, A., T. Ono, M. Iizima, and A. Kumamoto, Enhancements of magnetospheric convection electric field in the inner magnetosphere associated with sudden commencements Enhancements of magnetospheric convection electric field associated with sudden commencements in the inner magnetosphere and plasmasphere regions, Adv. Space Res., 38, 1595-1607, 2006.

Shinbori A., T. Ono, M. Iizima, A. Kumamoto, K. Okamoto, F. Hanaoka, S. Shirai, M. Ohashi, and H. Oya, Electrostatic electron cyclotron harmonic waves observed by the equatorial region of the plasmasphere, Earth Planets Space, 59, 613-629, 2007.

Shiokawa, K., Y. Miyashita, I. Shinohara, and A. Matsuoka, Decrease in Bz prior to the dipolarization in the near-Earth plasma sheet, J. Geophys. Res., 110, A09219, doi:10.1029/2005JA011144, 2005.

Shiokawa, K., K. Seki, Y. Miyoshi, A. Ieda, T. Ono, M. Iizima, T. Nagatsuma, T. Obara, T. Takashima, K. Asamura, Y. Kasaba, A. Matsuoka, Y. Saito, H. Saito, M. Hirahara, Y. Tonegawa, F. Toyama, M. Tanaka, M. Nose, Y. Kasahara, K. Yumoto, H. Kawano, A. Yoshikawa, Y. Ebihara, A. Yukimatsu, N. Sato, S. Watanabe, and Subgroup of Inner Magnetosphere in SGEPSS, ERG - A small-satellite mission to investigate the dynamics of the inner magnetosphere, Adv. Space Res., 38(8), pp.1861-1869, 2006.

Sugiyama, T. and K. Kusano, Multi-scale plasma simulation by the interlocking of magnetohydrodynamic model and particle-in-cell kinetic model, J. Computational Phys., 227, pp.1340-1352, 2007.

Surkov, V.V., M. Hayakawa, A. Y.Schekotov, E.N.Fedorov and O.A.Molchanov, Ionospheric Alfven resonator excitation due to nearby thunderstorms, J.Geophys.Res.,vol.111, A01303,doi:10.1029/2005 JA011320, 2006.

Takano, H., I. Nagano, S. Yagitani, H. Matsumoto, Lobe trapped continuum radiation generated in the distant magnetotail, COSPAR Colloquia Series, 16, 224-227, 2005.

Takasaki, S., H. Kawano, Y. Tanaka, A. Yoshikawa, M. Seto, M. Iizima, Y. Obana, N. Sato, and K. Yumoto, A significant mass density increase during a large magnetic storm in October 2003 obtained by ground-based ULF observations at L~1.4, Earth Planets And Space, 58, 617-622, 2006.

Takata, Y., Y. Kasahara, and Y. Ozaki, Development of Scientific Data Archives System Using General-Purpose Data Format (in Japanese), J. Acad. Computing and Networking, Vol.10, pp.5-14, 2006.

Takata, Y., Y. Kasahara, N. Mouri, and T. Matsuhira, Development of Science Database System Applicable to Various Access Restrictions (in Japanese), J. Acad. Computing and Networking, Vol.11, pp.50-59, 2007.

Tanaka, S., T. Ogino, and T. Umeda, Parametric decay of circularly polarized Alfven waves in the radially expanding solar wind, Journal of Geophysical Research, Vol. 112, No. A10, A10110, doi:10.1029/2007JA012513, 2007.

Terasawa, T., K. Nakata, M. Oka, Y. Saito, T. Mukai, H. Hayakawa, A. Matsuoka, K. Tsuruda, K. Ishisaka, K. Kasaba, H. Kojima, and H. Matsumoto, Determination of shock parameters for the very fast interplanetary shock on 29 October 2003, J. Geophys. Res., 110, A09S12, doi:10.1029/2004JA010941, 2005.

Tokunaga, T., H. Kohta, A. Yoshikawa, T. Uozumi, and K. Yumoto, Global features of Pi 2 pulsations obtained by independent component analysis, Geophys. Res. Lett., 34, L14106, doi:10.1029/2007GL030174, 2007.

Trotignon , J.G., C. Beghin, D. Lagoutte, J.L. Michau, H. Matsumoto, H. Kojima, K. Hashimoto, Y. Kasaba, L.G. Blomberg, J.P. Lebreton, A. Masson, M. Hamelin, R. Pottelette, Active measurement of the thermal electron density and temperature on the Mercury Magnetospheric

Orbiter of the BepiColombo mission, Adv. Space Res., 38, 686-692, 2006.

Tsurutani, B., W. Gonzalez, A. Gonzalez, F. Guarnieri, N. Gopalswamy, M. Grande, Y. Kamide, Y. Kasahara, G. Lu, I. Mann, R. McPherron, F. Soraas, and V. Vasyliunas, Corotating Solar Wind Streams and Recurrent Geomagnetic Activity: A Review J. Geophys. Res., 111(A7), 10.1029/2005JA011273, 2006.

Tsutsui, M, Identification of Earthquake Epicenter from Measurements of Electromagnetic Pulses in the Earth, *Geophys. Res. Lett.*, Vol. 32, L20303, doi:10.1029/2005GL023691, 2005.

Tsutsui, M, Konagaya, S and Kagawa, T., A Method of Direction Finding for Dispersive Electromagnetic Pulses, Electronics and Communication in Japan, Part 1, Vol. 90, No. 5, 23-32, 2007.

Uemoto, J., T. Ono, A. Kumamoto, and M. Iizima, Statistical analysis of the ionization ledge in the equatorial ionosphere observed from topside sounder satellites, Journal of Atmospheric and Solar-Terrestrial Physics, 68, 1340-1351, 2006.

Uemoto, J., T. Ono, A. Kumamoto, and M. Iizima, Comparison of the IRI 2001 model with electron density profiles observed from topside sounder on-board the Ohzora (EXOS-C) and the Akebono (EXOS-D) satellites, Advances in Space Research, 34, 750-754, doi:10.1016/j.asr.2006.10.019, 2007a.

Uemoto, J., T. Ono, T. Maruyama, S. Saito, M. Iizima, and A. Kumamoto, Magnetic conjugate observation of the F3 layer using the SEALION ionosonde network, VOL. 34, L02110, doi:10.1029/2006GL028783, 2007b.

Umeda, T., Vlasov simulation of amplitude-modulated Langmuir waves, Physics of Plasmas, 13, 9, 092304, 2006.

Umeda, T., and R. Yamazaki, Particle simulation of a perpendicular collisionless shock: A shock-rest-frame model, Earth, Planets and Space, 58, 10, e41-e43, 2006.

Umeda, T., Y. Omura, T. Miyake, H. Matsumoto, and M. Ashour-Abdalla, Nonlinear evolution of the electron two-stream instability: Two-dimensional particle simulations, Journal of Geophysical Research, 111, A10, A10206, doi:10.1029/2006JA011762, 2006a.

Umeda, T., M. Ashour-Abdalla, and D. Schriver, Comparison of numerical interpolation schemes for one-dimensional electrostatic Vlasov code, Journal of Plasma Physics, 72, 6, 1057-1060, 2006b.

Umeda, T., M. Ashour-Abdalla, D. Schriver, R. L. Richard, and F. V. Coroniti, Particle-in-cell simulation of Maxwellian ring velocity distribution, Journal of Geophysical Research, 112, A4, A04212, doi:10.1029/2006JA012124, 2007.

Umeda, T., Numerical study of electrostatic electron cyclotron harmonic wave due to Maxwellian ring velocity distributions, Earth, Planets and Space, 59, 11, 1205-1210, 2007a.

Umeda, T., Vlasov simulation of Langmuir wave packets, Nonlinear Processes in Geophysics, 14, 5, 671-679, 2007b.

Uozumi, T., H. Kawano, A. Yoshikawa, M. Itonaga, and K. Yumoto, Pi 2 source region in the magnetosphere deduced from CPMN data, Planetary and Space Science, 55(6), 849-857, 2007.

Usui, H., H. Furuya, H. Kojima, H. Matsumoto, and Y. Omura, Computer experiments of amplitude-modulated Langmuir waves: Application to the Geotail observation, J. Geophys. Res., 110, A06203, doi:10.1029/2004JA010703, 2005.

Usui, H., Y. Miyake, M. Okada, Y. Omura, T. Sugiyama, K. T. Murata, D. Matsuoka, H. O. Ueda, Development and Application of Geospace Environment Simulator for the Analysis of Spacecraft-Plasma Interactions, IEEE Transactions on plasma science, Volume 34, Issue 5, part2, Oct, 2006, Page(s): 2094- 2102, Digital Object Identifier 10.1109/TPS.2006.883290, 2006.

Wakabayashi, M., T. Ono, H. Mori, and P. A. Bernhardt, Electron density and plasma waves measurement in mid-latitude sporadic-E layer observed during the SEEK-2 campaign, Ann. Geophys., 23, 2335-2345, 2005a.

Wakabayashi, M., and T. Ono, Multi layer structure of mid-latitude sporadic-E observed during the SEEK-2 campaign, Ann. Geophys., 23, 2347-2355, 2005b.

Wakabayashi, M., and T. Ono, Electron density measurement under the influence of auroral precipitation and electron beam injection during the DELTA campaign, Earth, Planets and Space, 58, 1147-1154, 2006.

Yagitani, S., I. Nagano, and M. Ozaki, Lightning detection system with sferics observation at a single station, 28th International Conference on Lightning Protection (ICLP 2006), Vol.1, II-11, 434-437, Kanazawa, Japan, 2006.

Yumoto, K., A significant mass density increase during a large magnetic storm in October 2003 obtained by ground-based ULF observations at L~1.4, Earth, Planets and Space, 58, 617-622, 2006.

Acknowledgments

The editors thank Prof. M. Hayakawa, Drs. H. Kojima, H. Usui, T. Nakagawa, Y. Kasahara, S. Yagitani, H. Kawano, and Y. Miyoshi for their collaboration in editing the report.