Commission H (Waves in Plasmas) Activity Report (Ver.2.0)

August 3rd, 2006

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Research Topics

AKEBONO and **GEOTAIL** has been making observations since 1989, and 1992, respectively. The followings are the recent topics based on these satellite data and the related research results.

<Antenna in Space Plasma>

Yagitani et al. [2006] studied the variation of antenna impedance and effective length using the Chorus events in the dayside magnetopause region. They compared the observed electric field strength with the theoretical values, which can be calculated using the whistler mode dispersion relation and magnetic field components of Chorus observed by the onboard search coil magnetometers. They found the fluctuations of the difference of observed electric field strengths and theoretical in very short time scales less than one second. They will conduct further analyses how the antenna impedance and effective length vary in short time scales.

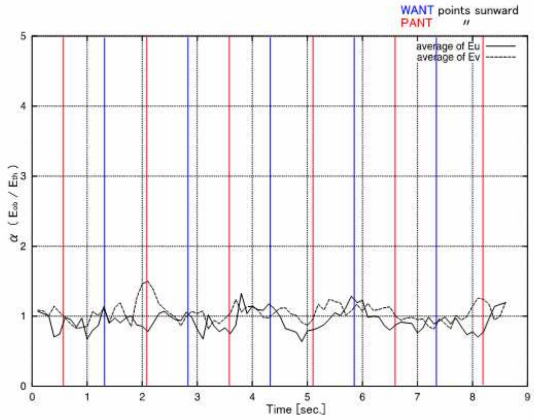


Figure 1. Time variation of the difference of the observed electric field strength and theoretical values.

Imachi et al. [2006] investigated the characteristics of wire antennas at low frequencies by experimental measurements and theoretical calculations. In the experimental measurements, called “Rheometry€, 35hey have measured the output voltages of the scale-model antennas immersed in the quasi-static electric field

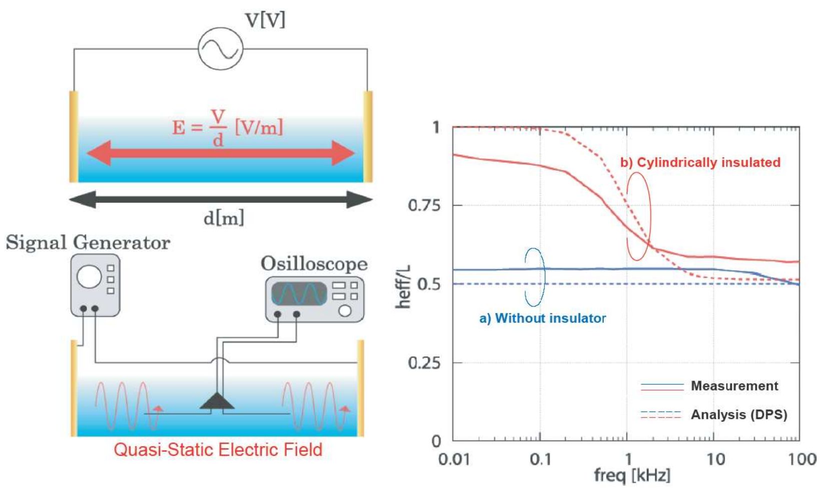


Figure 2. The configuration of “Rheometry” experiment (left), and the frequency dependence of the antenna sensitivity (shown as the “effective lengths”) (right) .

The result has shown that the insulators which cover the antenna wires have large impedances and degrade the sensitivity of the antennas at very low frequencies (less than hundreds of Hz). Such a frequency dependence of the antenna sensitivity (here evaluated as the antenna "effective lengths") has also been confirmed by theoretical calculations.

Kasaba et al. (2006a) summarizes the characteristics of the DC electric field measurement by the double probe system, PANT and EFD-P, aboard Geotail. The accuracy and correction factors for the gain (effective length) and off-set, which depends on ambient plasma conditions, are provided. They concluded that the Geotail electric field measurement by the double probe system has the accuracy 0.4 mV/m for Ex and 0.3 mV/m for Ey, after the correction of the gain and offset. 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.

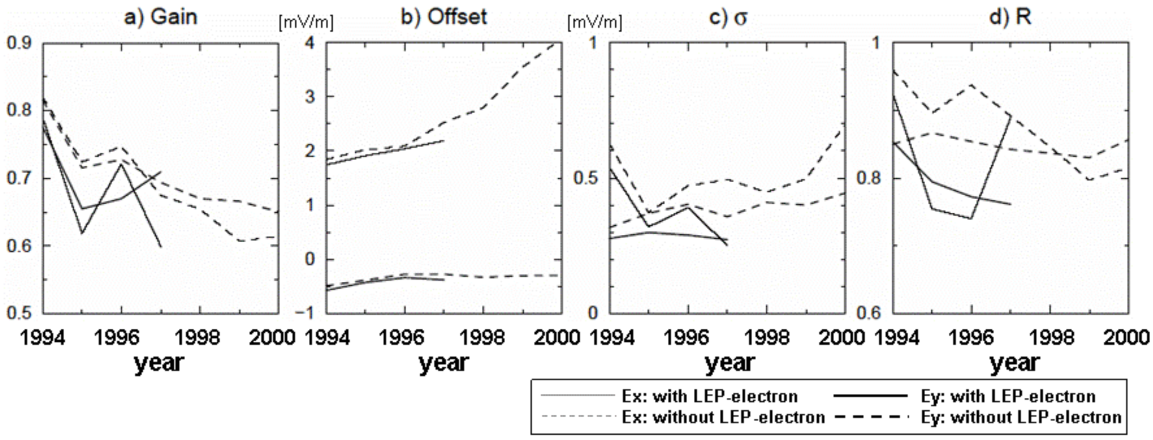


Figure 3. Time variation of (a) gain, (b) offset, and (c) error, (d) correlation coefficient in 1994-2000.

<Magnetospheric Plasma Waves>

Kasaba et al. (2005a) has studied several topics related to the 2fp radiation generated in the terrestrial electron foreshock. The investigation started from the macroscopic geometry of the radio source, and is expanding to the microscopic processes. This paper was a summary of latter studies, especially about the generation mechanism of electrostatic and electromagnetic 2fp waves and the electron acceleration at the quasi-perpendicular shock.

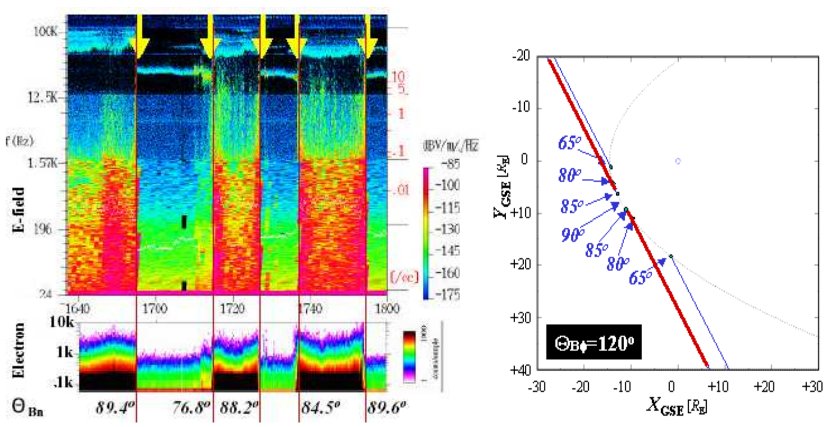


Figure 4. Foreshock electric field spectrum and electron energy distribution at shock crossings (Yellow arrow) observed by GEOTAIL on 5 Apr. 1995 (left).

A schematic view of the electron foreshock. Red line is the region with strong electron beams connected to quasi-perpendicular shocks with Θ_{Bn} = 80°~85° (right).

Hashimoto et al. [2005] studied the kilometric continuum radiation by IMAGE and GEOTAIL simultaneous observations.

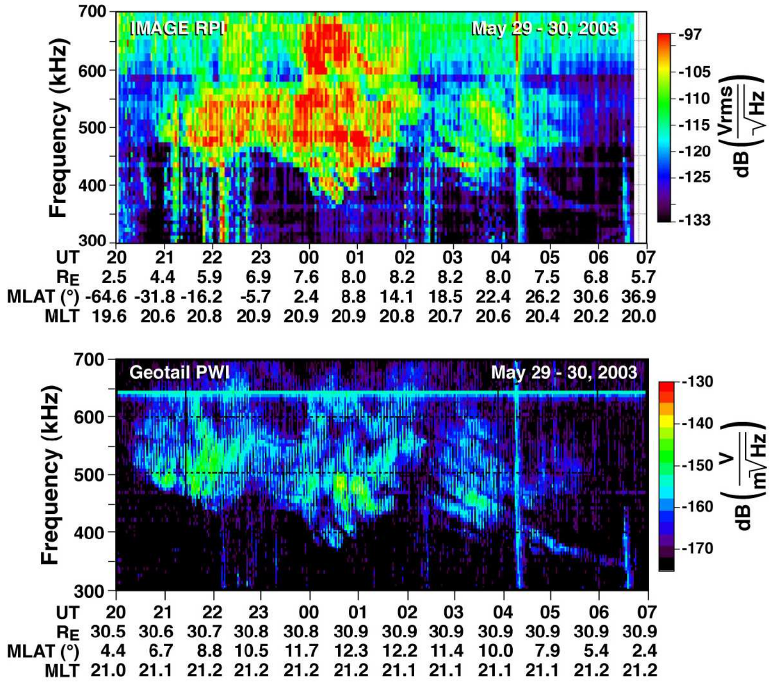


Figure 5 IMAGE and GEOTAIL observations on May 29--30, 2003. Note the similarity of the spectra.

The frequency-versus-time spectrogram with a frequency range of 300 - 800 kHz of kilometric continuum by IMAGE RPI are displayed in a in the top of Fig. 5. The kilometric continuum with quite good similarity in both spectra including the fine structures can be seen from 21 UT to 06 UT.

Hashimoto et al. [2006] reviewed kilometric continuum. The non-thermal continuum (NTC) NTC is generated in the free space L-O mode above the local electron plasma frequency, from sources at or very near the plasmapause. The strong electrostatic bands occur at frequencies where the frequency of the electrostatic upper hybrid resonance is equal to the frequency of the electrostatic (n+1/2)fg resonance, where fg is the local electron cyclotron frequency. Kilometric continuum is not merely a high frequency extension and has triggered new investigations since this range is higher than the maximum plasma frequencies of a few hundred kHz observed at the plasmapause. This is believed to be generated in events separate from the lower frequency non-thermal continuum. Recent NTC research has focused on improving thier understanding of the source location, emission cone characteristics, propagation characteristics, and detailed spectral measurements primarily in the kilometric frequency range.

Non-thermal continuum radiation is one of the fundamental electromagnetic emissions in planetary magnetospheres. It has been observed in every planetary magnetosphere visited by spacecraft with wave instruments and even found to be generated in the magnetosphere of the Galilean moon Ganymede. Although this emission has been observed and studied for more than 35 years, there are still several unverified theories on how this emission is generated and much more we do not know about this emission and its relationship to plasmaspheric dynamics. Recently there is a renewed interest in studying the high frequency extension of this emission (the escaping component) especially into the kilometric frequency range. Kilometric continuum has been reported to be observed by Polar and Cluster and INTERBALL-1 in addition to Geotail, IMAGE, and CRRES.

<Single Probe Application>

Ishisaka, et al. (2005) investigated the relationship between the Geotail spacecraft potential, the electron number density and the electron temperature in the near tail regions, and obtained the empirical formula shown the relationship between the spacecraft potential and electron number density considering the electron temperature. Using the spacecraft potential and the plasma particle density obtained by the low energy particle instrument (LEP) onboard Geotail, they investigated the distribution of low energy plasma in the magnetosphere. The left panel of Fig. 6 shows the approximate formula of relationship between spacecraft potential and electron density in the range of electron density less than 2.0 cm^{-3} each electron temperature. The color lines in the right panel indicate the electron temperature, for example the blue line is the electron temperature less than 100 eV and the red line is the temperature range more than 3000 eV.

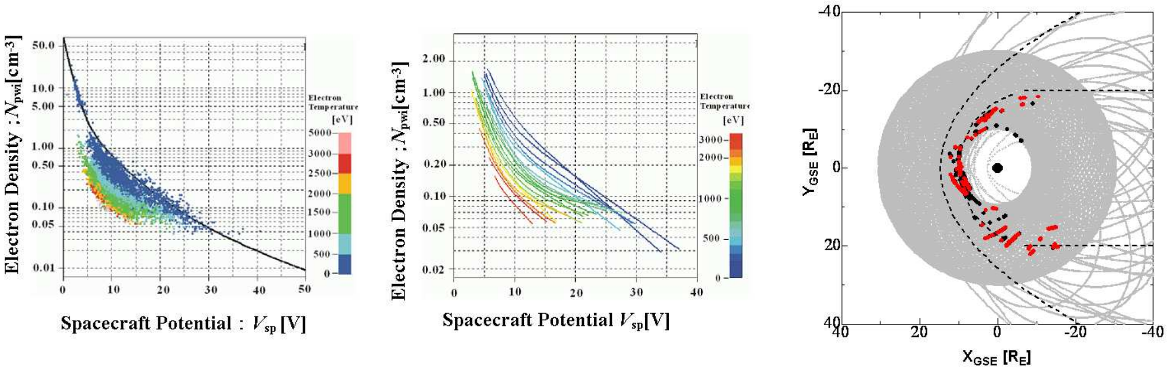


Figure 6. (Left) Experimental result, (Middle) Theoretical relation, and
(Right) Distribution of low energy plasma in the magnetosphere

The right panel shows spatial distribution of low energy plasma in the magnetosphere plotted on the X-Y plane of the GSE coordinate system. The dotted line in plate indicates the mean position of bowshock and magnetopause. The grey lines are the Geotail orbits that we investigated during the period from September 1993 to December 1997. The black dots indicate the positions of the low energy plasma density more than 1cm^{-3}, while the red color dots, 5 cm^{-3}. Thus it is shown that a large amount of low energy plasma exists near the magnetopause in the magnetosphere.

<Coordination of spacecraft and ground observations>

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 field-line resonance (FLR, in the ULF frequency range) identified in the **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. This work was also presented at the JPGU 2006 meeting in Japan and the GEM 2006 Summer Workshop in the USA.

Kawano, H. and D.-H. Lee have been using an MHD simulation to test the "gradient method," a method to identify FLR in the ground magnetometer data. They presented the work in the "Korea-Japan Workshop on ULF Waves and other Geospace Phenomena."

Kawano, H. et al. talked at the "Second workshop on the dynamics of the ionosphere-origin heavy ions" about the estimation of the plasmaspheric O+ ratio by comparing the mass density estimated from the ground magnetometer data with the He+ column abundance measured by IMAGE/EUV.

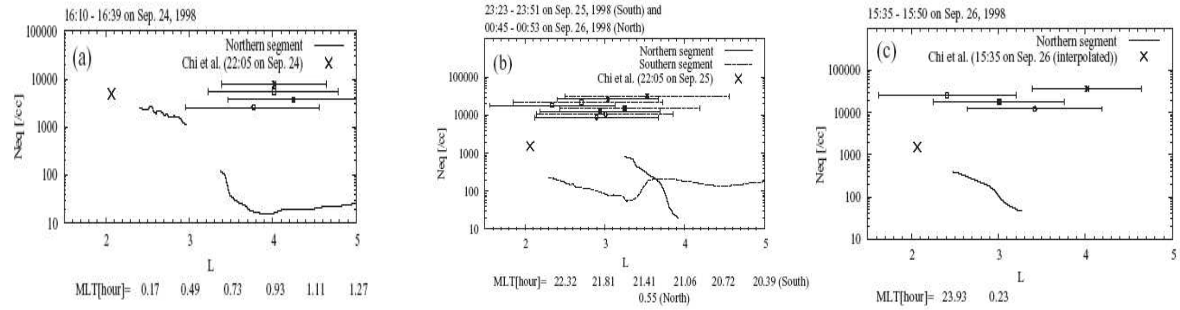
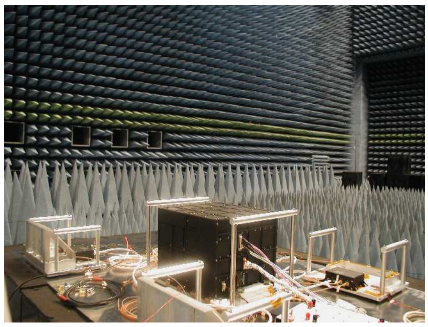


Figure 7. Horizontal axis shows the L value, and the vertical axis shows the density. Lines show electron densities from Akebono/PWS, and crosses show ion densities estimated from ground magnetometer data. Panel (a) shows data before the storm, (b) shows data in the midst of the storm recovery phase, and (c) and (d) show data in the late recovery phase. For more details, refer to Kawano et al.[2006].

Moon and Planetary Exploration

<SELENE>



Selene is scheduled to be launched in 2007. The Lunar Radar Sounder (LRS) experiment onboard the SELENE consists of three subsystems; SDR (sounder), NPW (natural plasma wave) and WFC (waveform capture). SDR will provide subsurface stratification and tectonic features in the shallow part (several km depth) of the lunar crust, by using an FM/CW radar technique in HF frequency range. NPW and WFC will observe planetary radio waves and natural plasma waves in the frequency range from 20kHz to 30MHz and from 100Hz to 1MHz, respectively.

The photo is a snapshot of the function tests and test of the LRS instrument in the RF test at the Tsukuba Space Center in December 2004 (reported by Ono and Kumamto).

<BepiColombo>

The BepiColombo is the science mission to Mercury. It is the first collaborative science mission between JAXA and ESA. The BepiColombo mission consists of two individual spacecrafts called MPO (Mercury Planetary Orbiter) and MMO (Mercury Magnetospheric Orbiter). Scientists in Japan and Europe jointly proposed the plasma wave observation system called PWI (Plasma Wave Investigation) in the response to the AO (Announce of Opportunity) for MMO. The Principal Investigator of PWI is Prof. Hiroshi Matsumoto in Kyoto University, Japan. After reviewing the PWI proposal, the MMO Payload Review Committee in JAXA selected the PWI for the science payload onboard MMO spacecraft. The MMO launch is scheduled in 2012.The PWI investigates plasma/radio waves and DC electric field in Mercury magnetosphere. It consists of two components of receivers, two sets of electric field sensors, two kinds of magnetic field sensors, and the antenna impedance measurement system. The stage for developing the onboard instruments is now in the Phase B (development of prototype model).

MMO is one of the spacecrafts which explore Mercury. The main target of the MMO is Mercury's magnetosphere, and the project is a collaborative project between Japan and Europe. Yamawaki et al. [2006] reported the current status of the onboard software design of PWI (Plasma Wave Investigation) onboard MMO, especially related to data compression algorithm. They estimated the compression ratio from the spectrum data of the GEOTAIL SFA data. For the purpose of examining the proper parameter for the efficient lossless compression, they also investigated the optimum parameter for the adaptive range coder.

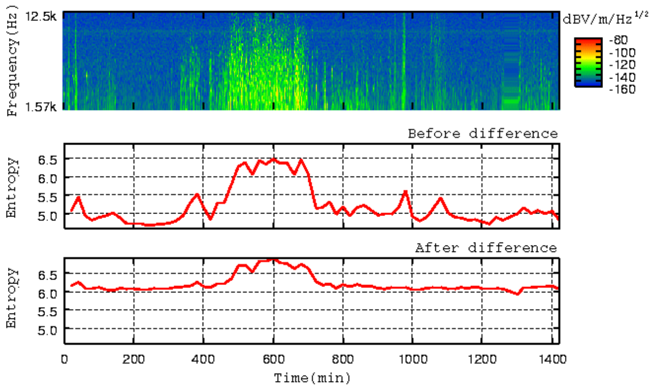


Figure 8. An example of spectrum of GEOTAIL SFA and the entropy of the data.

Itou et al [2006] studied several problems for the development of a direction finding system onboard spacecraft. The most critical problem to realize the onboard system is to determine wave normal directions on the condition that the in-situ plasma parameters cannot be properly obtained. They discussed errors in direction finding onboard spacecraft and proposed a novel technique based on the WDF method to derive wave normal directions.

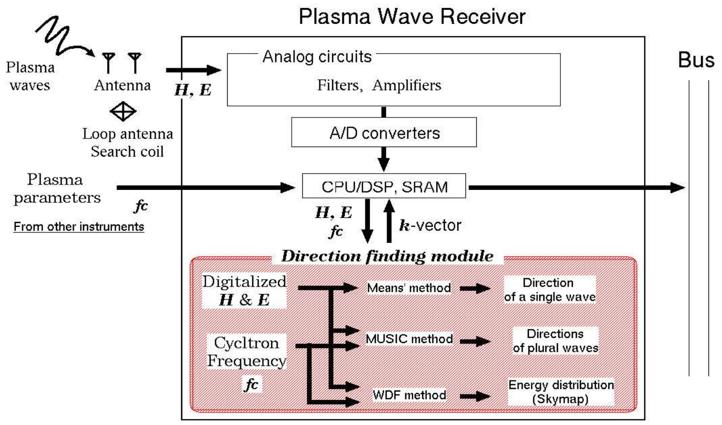


Figure 9. Overview of the onboard direction finding system

Ionospheric Sounding

Ashihara et al. (2006) measured the electron number density in the mid-latitude D-regeon ionosphere and found an thin layer of enhanced electron density by using the MF radio absorption method. The S-310-33 rocket was launched at 0:30 JST on 18th January, 2004.

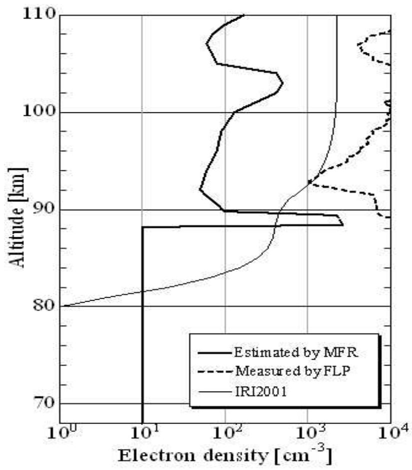


Figure 10. Estimated electron density profile in the ionosphere.

The Medium Frequency Receiver (MFR) was installed to measure 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. 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.

Figure 10 shows the electron density profiles estimated by three different methods: The thick line indictes the one estimated by the rocket experiment using MFR, the broken line by probe method, and the thin line is by the IRI 2001 model. The MFR rocket experiment gives the existence of thin layer of high electron density. Electrons in ionospheric D region are closely related to neutral dynamic meteorology and chemistry including such as hydrated ion and NOx, though the electron density is very small, from ten to several thousands /cc. Therefore it has the possibility to find a new physical knowledge in mesosphere and lower ionosphere.

Sakai et al. [2006] studied the influence of the total electron content (TEC) in the plasmasphere on the GPS signals quantitatively depending on solar cycle, season, sunspot numbers and local time. They suggested that the contribution of the delay times caused by the TEC in the plasmasphere can be as much as 80% of the total delay time from GPS satellite to the ground at the solar activity maximum period.

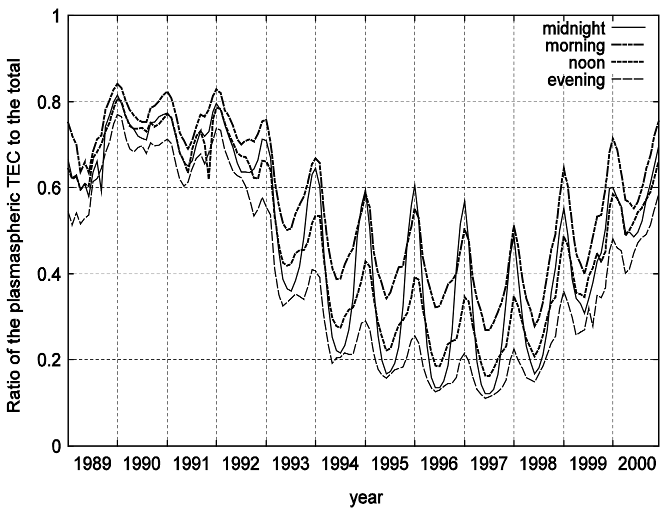
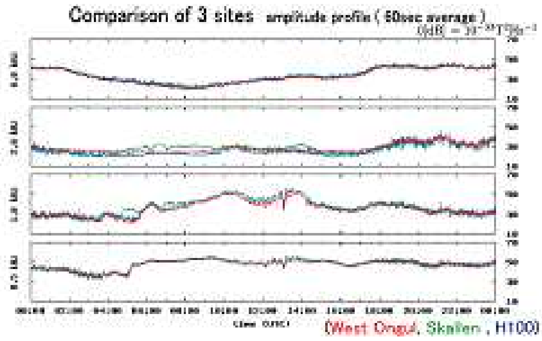


Figure 11 Ratio of the TEC in the plasmasphere depending on the solar cycle.

Polar Region Experiments

Ozaki et al. [2006] are conducting the multipoint observations of natural ELF/VLF waves (chorus and hiss) in Antarctica from December 2005 to December 2006. Three low-power magnetometer systems have been placed at three sites near Showa Station: “West Ongul,” “Skallen,” and “H100” unmanned stations, which form a triangle with side length of about 100 km. Each system consists of two crossed vertical loop antennas with a multi-channel analyzer which measures continuously with less than 1 minute resolution the mean intensity and polarization of NS and EW magnetic components in 4 spaced frequency bands (500, 1 k, 2 k and 6 kHz). With the preliminary analysis of the intensities and polarizations of ELF/VLF waves so far observed, they have confirmed that they could estimate the dynamic structure of the ground-based ELF/VLF observations will be compared with the Akebono satellite observations of the ELF/VLF waves above Antarctica, for the study of the stereoscopic structure of the ELF/VLF propagation over the polar ionosphere and magnetosphere.



(a) (b)

Figure 12. (a) A crossed loop antenna installed at West Ongul, and (b) an example of ELF/VLF intensities measured at the three sites on February 27, 2006.

Lightning and Seismic-related Radio Emissions

Surkov et al. (2006) developed a theory of midlatitude Ionospheric Alfvén Resonator (IAR) excitation due to random cloud-to-ground lightning discharges. Electromagnetic wave radiated from the lightning discharges penetrates into the ionosphere, thereby exciting the shear Alfvén and magnetosonic waves in the *F* region of ionosphere. The IAR arises due to wave reflection from the Alfvén velocity gradients in the topside ionosphere. Model calculations of the IAR spectrum due to nearby thunderstorm activity were applied to interpret ULF observation made at Karimshino station (52.94ºN, 158.25ºE) in Kamchatka peninsula. It is shown that the sharp impulses which are in one-to one correspondence with the appearance of the spectral resonance structure (SRS) in dynamic spectrograms can be the result from nearby lightning discharges followed by impulse IAR excitation.

Hayakawa et al. (2006) reviewed the previous direction finding (DF) systems including goniometer, field-analysis method and also we demonstrate how important these DF techniques are in the general studies of VLF/ELF sferics and whistlers. They presented some latest findings such as new results on ELF transients (charge moment change) and convincing evidence on the ducted propagation of low-latitude whistlers.

Hayakawa et al. (2005) examined our Schumann resonance data at Nakatsugawa during the period of a severe earthquake (so-called Chi-chi earthquake on 21 September, 1999). They found a very anomalous effect in the Schumann resonance, possibly associated with two large land earthquakes (one is the Chi-chi earthquake and another one on 2 November 1999 (Chia-yi earthquake) with a magnitude again greater than 6.0). The anomaly is characterized mainly bay the unusual increase in amplitude of the fourth Schumann resonance mode and a significant frequency shift of its peak frequency (~1.0Hz) from the conventional value on the *By* magnetic field component which is sensitive to the wave propagation in the NS meridian plane. Anomalous Schumann resonance signals appeared from about one week to a few days before the main shock

Space Plasma Simulation

1. Nonlinear interaction between whistler waves and electrons

Katoh and Omura [2005a, 2005b, 2006] have been intensively studying the whistler-electron interaction in the radiation belt. Particularly, they focus on the resonant scattering process of relativistic electrons by whistler mode waves. They also started a self-consistent particle simulation of VLF triggered emissions. Figure 10 shows the wave spectrum observed at the off-equator location in the simulation system.

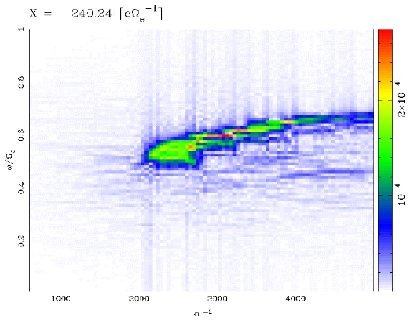


Figure 13. Simulation result of triggered emission.

Hikishima et al. [2006] have investigated the generation and propagation mechanisms of the chorus emissions through the cyclotron resonant interaction between the whistler mode waves and anisotropic electrons by full electromagnetic particle simulation. The simulation model is one-dimensional with a nonuniform magnetic field of a dipole type. They have confirmed that the whistler mode waves are generated from the region corresponding to the magnetic equator, and propagate toward high latitudes. The frequency-time (f-t) structure of the whistler mode waves generated in the simulation is consistent with that of the "structureless" type of chorus emissions actually observed by Geotail spacecraft.

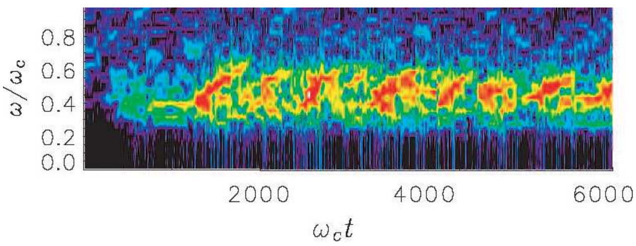


Figure 14. Simulated structureless emission

2. Microscopic wave-particle interactions

Omura [2005], Umeda et al.[2005], Matsukiyo et al. [2005], Shinohara et al. [2005], and Usui et al. [2005] studied microscopic wave-particle interactions in various plasma phenomena such as electrostatic solitary waves, collisionless shock, magnetic reconnection, and amplitude modulation of Langmuir waves.

3. PIC simulations for space engineering

Miyake et al. [2005] has been investigating antenna characteristics in space plasma via three-dimensional PIC-EM simulations. The recent study focuses on the effects of photoelectrons around the antenna and spacecraft body. The development of PIC simulation tool called Geospace Environment Simulator (GES) has been proceeding for the analysis of spacecraft environment (Usui et al. [2006]). The core engine for the GES is developed by Okada [2005] and called NuSPACE which is three-dimensional EM PIC simulation code of domain decomposition model.

New Technology

Murata et al. (2005) has developed the "Virtual Earth's Magnetosphere System (VEMS)", with which one can reproduce the Earth magnetosphere in the past time. One first assigns time and data to visualize observation data in the 4-D domain (3-D space and 1-D time) as shown in Figure. The VEMS allows us to visualize 3-D MHD simulation results in the same 4-D work frame. This provides an environment to directly compare both observation data and simulation results.

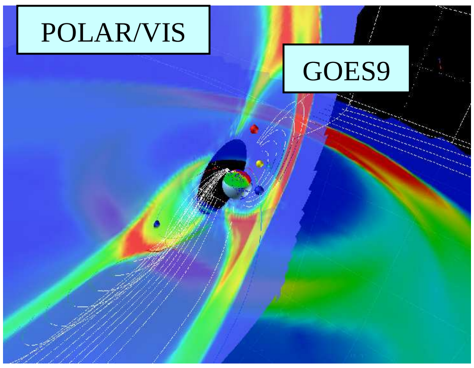


Figure 15. Global MHD simulation and satellite observations. Only the magnetic field lines which pass along the X-axis are extracted. Pressure (Global MHD simulation) is expressed as a cross section. The coordinate system is GSM.

Kimura and Murata (2006) extended their work to construct the STARS (Solar-Terrestrial data Analysis and Reference System). The system is now working based on the XML web service, for the XML web service overcomes firewall problems and allows users to access to the meta-data and observation data files over the recent Internet. The meta-data for observation data are collected based on RSS technology, which is recently one of the popular methods to collect meta-data on the Internet. We have customized the STARS data plot functions so that we can interactively analyze GEOTAIL/PWI/SFA and GEOTAIL/PWI/MCA .

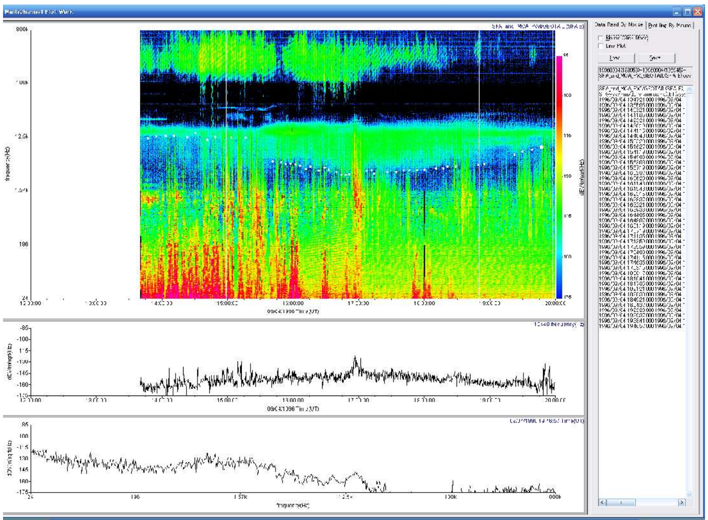


Figure 16. A dialog to analyze GEOTAIL/PWI/SFA data. With mouse click one gets a time, frequency and intensity of SFA data. The bottom two panels correspond to time variation at a certain frequency and spectrum at a time.

Murata and his co-workers challenged high-speed data transfer contest held at Super Computing 2005 (Seattle Nov. 2005). In this challenging contest, they transfer 3-D simulation data in quasi-realtime using extremely high-speed network (10Gbps). They succeeded in transferring 3-D observation data from Japan to USA within 1 minute, which are visualized on a Virtual Reality (VR) system at the SC 2005 conference hall. The challenging results are reported in the following two papers; Matsuoka et al. (2005) and Watari et al. (2005).

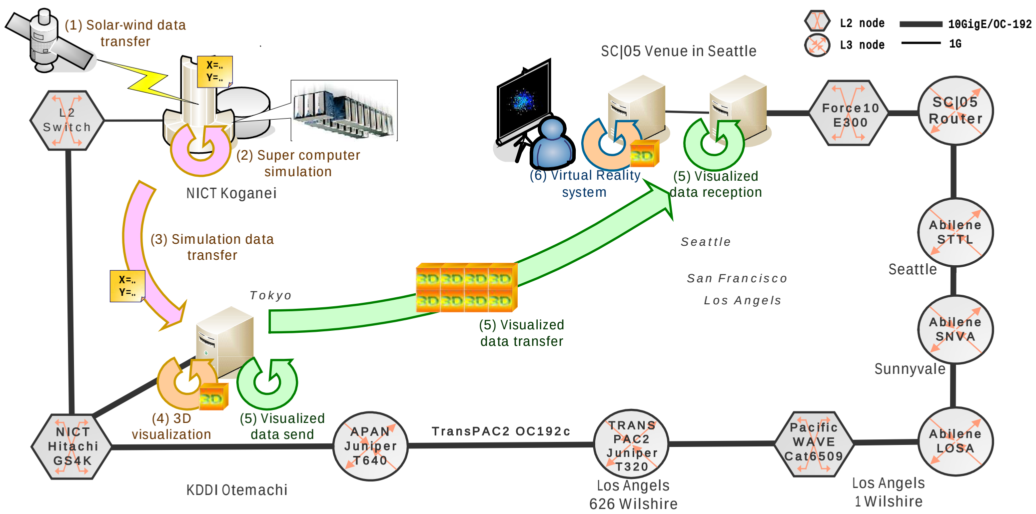


Figure 17. Coordinated data network

Future Project

Nakamura et al. (2006) reviews the proposal of future solar system sciences by JAXA and Japanese science communities, based on the discussion associated with the proposal for the future space programs, “JAXA Vision – JAXA 2025 –”, released in March 2005. This paper includes the mission developed in these days, like Selene to Moon, Planet-C to Venus, and BepiColombo to Mercury. And some missions which is in investigation as pre-phase-A study are also described. Those will cover the scientific and technological challenges in the URSI fields.

The main targets for the Sun and the Sun-Earth system in the next decade will be advanced studies of energetic processes in the magnetosphere related to the basis of space weather and of physical process in the magnetosphere that are common cosmic processes. For these objectives, two new solar terrestrial missions are proposed: SCOPE (cross Scale COupling in Plasma universE), a mission to study the cross-scale coupling in the plasma universe, and ERG (Energization and Radiation in Geospace), a mission to investigate energization and radiation in geospace.

Conferences and Meetings (February 2006～July 2006)

1) Korea-Japan Workshop on ULF Waves and other Geospace Phenomena, Feb. 16-17, 2006, Fukuoka, Japan.
2) Second workshop on the dynamics of the ionosphere-origin heavy ions, Feb. 20-21, 2006, Tokyo, Japan. http://swdcft49.kugi.kyoto-u.ac.jp/heavyion2/
3) Workshop on Space Plasma, March 16-17, 2006 , ISAS/JAXA, Japan

4) Radio Science Symposium for Sustainable Humanosphere, March 20-21, 2006, Clock Tower Centennial Hall, Kyoto University
5) 2nd Kanazawa Workshop on Waves in Plasmas and Electromagnetic Application, March 23-24, 2006, Kanazawa University, Japan
6) International Conference on Substorms -8, March 27-31, 2006, Banff, Canada
7) European Geosciences Union General Assembly, April 2-7, 2006, Vienna
8) Japan Geoscience Union Meeting 2006, May 14-18, 2006, Makuhari Messe, Japan
9) JPGU 2006 Spring meeting, May 14-18, 2006, Makuhari, Japan. http://www.jpgu.org/
10) International Symposium on Space Technology and Science, June 4-11, Kanazawa, Japan http://www.ists.or.jp/index.html
11) GEM 2006 Summer Workshop, June 25-30, 2006, Snowmass, CO., U.S.A. http://spacsun.rice.edu/~gem/gem2006/index.html
12) Asia Oceania Geosciences Society (AOGS) 3rd Annual Meeting (AOGS 2006), July 10-14, 2006, Singapore
13) 36th COSPAR, July 16-23, 2006 Beijing, http://www.copernicus.org/COSPAR/COSPAR.html
14) Western Pacific Geophysics Meeting, July 24-28, 2006, Beijing, http://www.agu.org/meetings/wp06/

Future Conferences and Meetings

1) The 30th Symposium on Space and Upper Atmospheric Sciences in the Polar Regions, Aug. 3-4, 2006, NIPR, Tokyo
2) Advanced School in Space Environment-2006: Solar-Terrestrial Physics, Italia L'aquila, Sept. 10-16, 2006, http://www.cifs-isss.org/
1) International Symposium on Recent Observations and Simulations of the Sun-Earth System (ISROSES), Varna, Bulgaria, Sept. 17-22, 2006, http://www.isroses.org/
2) The XXIInd International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV2006), Sept. 25-29, 2006, http://isdeiv.eee.u-ryukyu.ac.jp/
3) BepiColombo SWT #3 Sept. 25-28, Padova, Italy
4) The XXIInd International Symposium on Discharges and Electrical Insulation in Vacuum (ISDEIV2006) Sept. 25-29, Matsue.
5) Scientific Data and Knowledge within the Information Society, Beijing, China, Oct. 23-25, 2006, http://www.codataweb.org/06conf/index.html
6) Future perspectives of space plasma and particle instrumentation and international collaborations, Nov., 1-3,2006, Rikkyo Univ., Tokyo, Japan
7) SGEPSS, Sagamihara, Nov. 4-7, 2006, http://www.stp.isas.jaxa.jp/STP/sgepss/
8) CAWSES Workshop on Space WeatherModeling(CSWM), Nov. 14-17, 2006
9) AGU fall meeting, San Fransisco, Dec. 11-15, 2006, http://www.agu.org/meetings/fm06/
10) Chapman Conference on Midlatitude Ionospheric Dynamics and Disturbances, Yosemite National Park, California, Jan. 3-6, 2007, http://www.agu.org/meetings/cc07acall.html

Reference

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