Commission H (Waves in Plasmas) Activity Report

March 8th, 2007

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Research Topics

<AKEBONO and **GEOTAIL>**

Both satellites have been making observations since 1989, and 1992, respectively. Detailed status of these satellites were presented in the previous Commission H (Waves in Plasmas) Activity Report on August 3rd 2006.

<SELENE>

Plasma Wave Observation using Waveform Capture (WFC) on LRS/SELENE

Introduction

The moon-orbiter SELENE will be launched this summer. The waveform capture (WFC) instrument, which is a subsystem of the Lunar Radar Sounder (LRS) instrument onboard the SELENE satellite, is a high-performance and multi-functional receiver for the measurement of plasma waves and radio emissions. The WFC is designed to measure the plasma waves and radio emissions below 1MHz.

The instrument is a kind of software receiver in which most of the functions are realized by a DSP on the WFC board. 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, kilometric radiation originated from the Earth, solar radio emissions, and many kinds of plasma waves in the Earth's magnetosphere.

(Moon on 30th Jan..2007
by T. Okada)

Overview of the WFC instrument

The electric wave signals detected by the two orthogonal 15m tip-to-tip antennas are received by the two kinds of passive receivers: WFC-H and WFC-L. These antennas are nominally used as dipole antennas, but those on y-axis can also be used as a pair of monopole antennas for the WFC-L data. The WFC-H is a digital sweep frequency analyzer which covers the frequency range below 1MHz. On the other hand, the WFC-L captures waveforms below 100kHz. The data from both receivers are processed by the DSP on the WFC board and sent to the ground with the other LRS mission data. The WFC works intermittently when the radar sounder (SDR) is working in order to avoid the interference from the SDR pulse signal.

The WFC-H archives very high time and frequency resolution on spectral observation by using hybrid ICs called PDCs (Programmable down converters). The PDCs convert the wideband input signals from antennas sampled at 2.5MHz into narrow band signals and down-sample the data. Finally, the output data from the PDCs are converted into the spectral data by the DSP using the FFT. The frequency resolution of WFC-H is about 300Hz at 10kHz and 5kHz at 1MHz, respectively. The sweep time is a few hundred milliseconds.

The WFC-L captures a few seconds of continuous waveforms intermittently. The duration of the waveforms depends on the observational mode. Several kinds of maximum frequency of the waveforms can be selected by changing the sampling frequency of the A/D converters and digital filters installed in the DSP software. In order to obtain maximum scientific output, a lossless data compression technique and an automatic data selection algorithm are introduced in the DSP software.

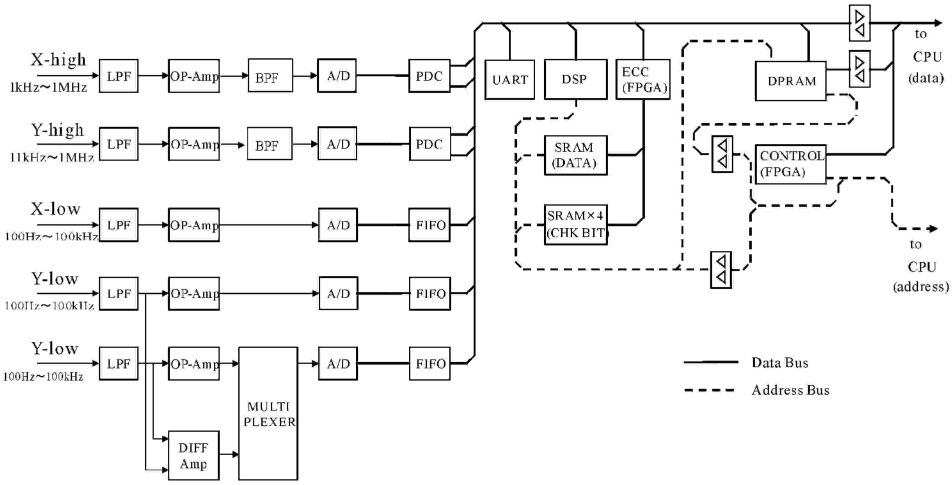
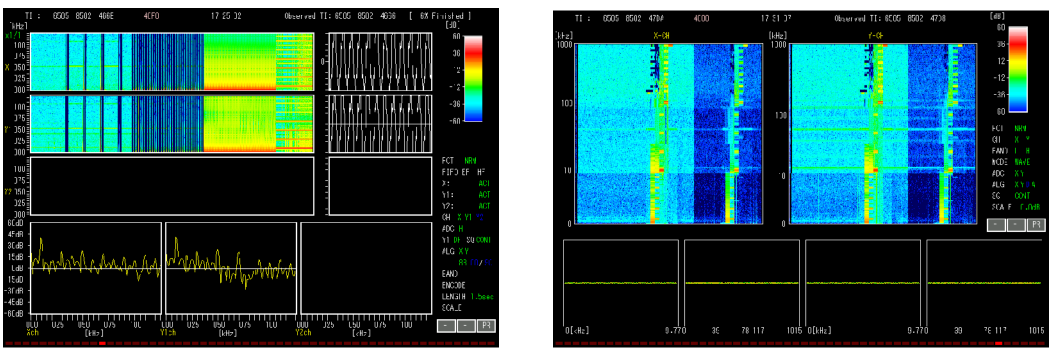


Figure 1. Block diagram of the LRS/WFC onboard SELENE.

Summary

The basic data for the calibration were cautiously obtained and the function test for the instrument was also successfully performed. Because of the flexibility of the instruments, various kinds of observation mode can be achieved and we expect the WFC to bring a lot of scientific outputs.

For more information, refer to Kasahara et al., 2007)



(a) WFC-L (b) WFC-H

Figure 2. Quick Look System for (a) WFC-L and (b) WFC-H.

<BepiColombo>

Refer to the previous Commission H (Waves in Plasmas) Activity Report on August 3rd 2006 for details.

<ERG :Energization and Radiation in Geospace>

For the purpose to study the unresolved major problems underlying in Geospace, a small satellite mission named as **ERG (Energization and Radiation in Geospace)** has been proposed being focused on the formation of radiation belt associated with magnetic storms. A comprehensive measurement of particles and fields on-board a small satellite is planned based on the heritage of the achievement of previous and undergoing Japanese scientific satellite missions. The on-board scientific instruments are arranged to make definitive evaluation of possible mechanisms for the formation of radiation belt and dynamic behaviour of plasma and plasma waves in Geospace.

The on-board instruments are planned to measure following terms as;

(1) Distribution functions of electrons and ions in wide energy range such as 10eV to 10MeV for electrons and 10eV to 1MeV for ions.
(2) DC electric and magnetic fields with resolution of 0.1mV/m and 0.1nT.
(3) Electric and magnetic components of plasma waves in a frequency range from 1Hz to 5MHz.

Main objectives of plasma waves and electric field observation of ERG are set as follows: (I) Examination of the theories of relativistic particle acceleration by plasma waves, (II) Identification of the origin of storm-time electric fields in the inner magnetosphere, (III) Diagnosis of plasma density, temperature and composition in the plasmasphere by waves, and (IV) Investigation of wave-particle interaction and mode conversion processes in the inner magnetosphere. The on-board plasma wave and electric field instrumentation consists of 3-axis search coil magnetometer, 4 sets of long-deployed wire antennas and other optional sensors such as loop antenna and z-axis inflatable antenna to determine the Poynting vectors and wave-forms of electric and magnetic components of the plasma waves. A wave-particle correlater is under study to realize the direct verification of wave-particle interactions in the geospace plasma.

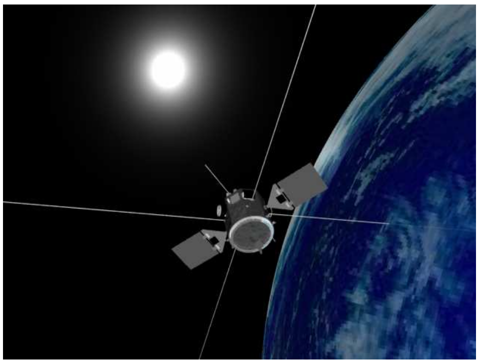


Figure 3. An artistic view of the ERG satellite.

Aiming at understanding the complex regional interactions during magnetic storms, the satellite data will be compared with ground-based network observations from the ERG ground network team utilizing numerical model/simulation from the ERG modeling team. The ERG modeling/data center team will also develop necessary software for the comparative studies. The activity of the ERG ground network and modeling/data center has already started. Various Japanese ground network groups such as HF radars, magnetometers, and optical imagers have joined the project. The new SuperDARN radar in Hokkaido, Japan started operation since November 2006. Several ground magnetometers and optical imagers will be installed in the eastern Russia in 2007-2008. These ground networks at subauroral latitudes are a powerful tool for remote sensing of the inner magnetosphere. The GEMSIS (Geospace Environment Modeling System for the Integrated Studies) project at STEL, which is planned to be the kernel of the ERG modeling team, will start concept design of the comprehensive data analysis system combined with the numerical modeling within 2007.

In order to enhance science outputs, simultaneous observations with RBSP and ORBITALS under international collaborations of the ILWS program is highly desirable for the ERG project. Collaborative observations between ERG and the extended THEMIS mission will also provide unique opportunity of comprehensive investigation of geospace storms during the next solar maximum.

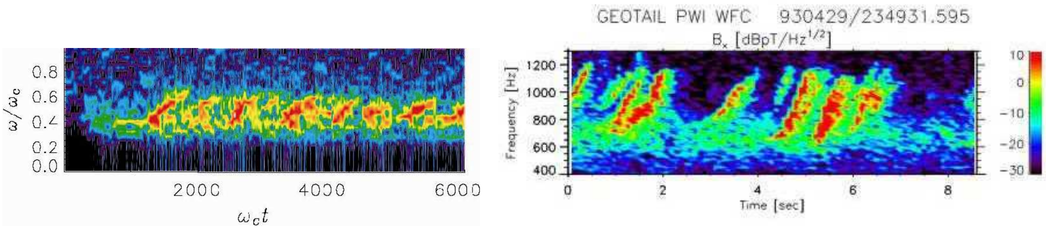
ERG in-situ observes particles and fields. When one interprets the data acquired by ERG, it is important to have an idea on the background macro-scale fields. As one of such macro-scale fields, magnetospheric plasma mass density distribution can be estimated by using data from ground magnetometer arrays. That is, the magnetic field-line eigenfrequency (in the ULF range) can be identified in the ground magnetometer data, and the eigenfrequency depends on the plasma mass density along the field line on which the ground station resides; thus, from the observed eigenfrequency one can estimate the plasma mass density along the field line. Data from MAGDAS/CPMN (MAGnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network), mainly run by Space Environment Research Center (SERC), Kyushu University, Japan, are appropriate for this purpose.

Magnetic storms are a target of ERG, and an important feature of magnetic storms is the energization of particles in the radiation belt during the storm recovery phase. Suggested mechanisms for the energization include the energization by magnetospheric ULF waves. By using ULF data from ground magnetometer arrays (such as MAGDAS/CPMN mainly run by SERC, Kyushu University) and ground-based radars. (such as the SuperDARN Hokkaido radar mainly run by STEL and NIPR, and FM-CW radars mainly run by SERC, Kyushu University), one can estimate the spatial distribution of the ULF wave activities in space.

IMAP satellite is another small satellite mission which is currently proposed; the "IMAP satellite" is the abbreviation for "Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping Satellite." The IMAP satellite will take two-dimensional images of the ionosphere, mesosphere, thermosphere, and plasmasphere from above the sky at the height of 24,000km, for the purpose of clarifying the latitudinal coupling, altitudinal coupling, and the inter-region coupling of the above-mentioned regions. The IMAP satellite is related to ULF waves where the plasmaspheric plasma mass density, estimated from the field-line eigenfrequency (in the ULF range) identified in the ground magnetometer data, are compared with the images taken by IMAP. That is, the EUVI (Extreme Ultra Violet Imager) on-board IMAP will take images of the plasmasphere by using 30.4nm (83.4nm) light, backscattered from He+ (O+) ions within the plasmasphere; the EUVI images thus provide information on the distributions of He+ and O+ within the plasmasphere, and if the information is merged with the field-aligned mass density information coming from ground magnetometer data, one can estimate the three-dimensional distributions of ions within the plasmasphere. To merge the two pieces of information, the methodology of tomography is useful.

<Space Plasma Wave Simulation>

Hikishima et al. [2007] have been investigating the generation and propagation mechanisms of chorus emissions by using full electromagnetic simulation. With a one-dimensional anisotropic plasma model along a nonuniform magnetic field, they have reproduced a series of frequency-rising whistler-mode wave packets as shown in Figure (a). Such a frequency-time structure looks quite similar to chorus emissions actually observed by Geotail in the dayside outer magnetosphere as in Figure (b). Detailed analyses of wave-particle interactions involved are under way.



(a) (b)

Figure 4 (a). Frequency-time diagram of whistler-mode waves observed in simulation.
Figure 4(b). Frequency-time diagram of chorus emissions observed by Geotail spacecraft.

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. In the simulation result 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 generation process simulated in the present paper is explained by roles of resonant currents in association with an electromagnetic electron hole in the phase space produced through the nonlinear interaction. On the basis of the simulation result, they found that these resonant currents are formed by untrapped electrons through the nonlinear wave-particle interaction and suggested that the resonant current formation by untrapped electrons plays an essential role in the triggering mechanism.

Katoh and Omura [2006c] studied a combined effect of wave trapping due to oppositely propagating narrow band whistler mode waves and discussed its dependence on the background plasma density. In the case where forward and backward traveling whistler mode waves coexist, rapid scattering of resonant electrons occurs owing to the overlapping of diffusion curves of both waves. Simulation results showed that the low-density plasma condition, where the electron plasma frequency is close to the electron gyrofrequency, is favorable for the significant resonant scattering of high energetic electrons. These results suggest that the combined effect plays an important role in energizing relativistic electrons in the equatorial region of the Earth's inner magnetosphere during the recovery phase of geomagnetic storms.

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, 2007].

Katoh and Omura (2007) 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. No initial wave was assumed except for electromagnetic thermal noise induced by the energetic electrons. 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. The trailing edge of NEWNFG was continuously created at increasing frequencies in the region close to the equator. Observed at a fixed point, the NEWNFG showed a frequency variation of a typical chorus emission.

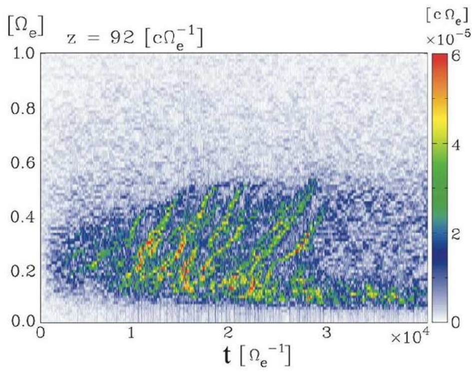
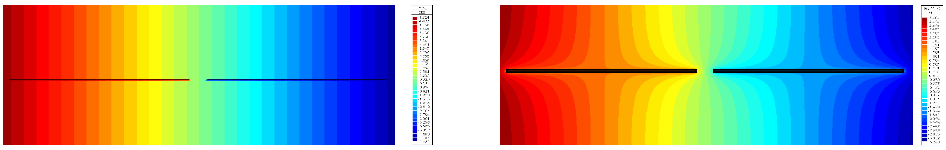


Figure 5. Chorus emissions reproduced in the simulation result [Katoh and Omura, 2007]. The lower cutoff frequency of the emissions is attributed to the lower limit of the linear growth of whistler-mode waves under the assumed parameters. The generation of chorus emissions is gradually quenched because the anisotropic distribution of energetic electrons is relaxed through repeated generation processes of whistler-mode waves.

<Antenna in Space Plasma>

Yamashita et al. [2006] and Yagitani et al. [2007] have investigated the low-frequency characteristics of wire antennas onboard spacecraft. With previous ground-based “Rheometry Experiment” using an antenna scale model to pick up an electric field generated inside a water tank, they had 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. Such a frequency dependence of the effective length has been explained by theoretical calculations as well as by numerical electromagnetic simulations. 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 as shown in Figures 6 (a) and 6 (b), which can quantitatively explain the frequency dependence of the antenna’s effective length.



(a) at 10 Hz (b) at 10 kHz

Figure 6. Electric potential structures around a wire dipole antenna covered with an insulator except for its tips.

<Ionospheric Sounding by Rocket Experiments>

Electric field measurements by EFD onboard S-310-37 Sounding Rocket

The S-310-37 sounding rocket experiments were carried out at Uchinoura Space Center (USC) on January 16, 2007 at 11:20 LT. The purpose of S-310-37 rocket experiment is an integrated observation of the high electron temperature layer in the Sq current focus during the winter daytime over USC [Abe et al., 2007; Ishisaka et al., 2007].

In the S-310-37 rocket experiment, the double probe technique was employed to determine vector along the rocket trajectory. Figure 7 (a) shows the 3 pair of antenna extended from the rocket during the spin test. Figure 7 (b) shows components of electric field measured by the EFD.

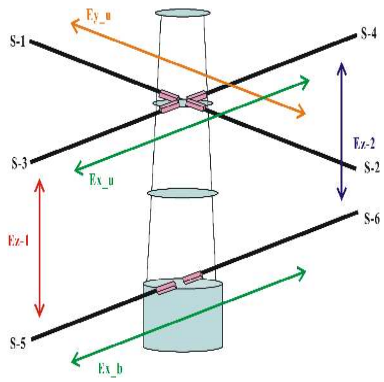


Figure 7a (Left). Three pairs of probe antennas extended onboard S-310-37 rocket, and 7b (Right). Definition of electric field in three dimensions.

Three components (Ex_u, Ey_u and Ex_b) in the spin plane of the payload and two components (Ez-1 and Ez-2) parallel to the spin axis were measured by EFD. Antenna length is 2m tip-to-tip. The antenna was deployed at 61.5 sec (Ey_u), 62.0 sec (Ex_u) and 62.5 sec (Ex_b) after liftoff. Raw electric field data from the EFD during the ascent are shown in the Figure 8.

The waveforms are modulated at the spin period of 1.2 sec. The Ex_u and Ey_u data are 90 degree out of phase, because the double probes are orthogonal. The largest contribution to electric field measurements by such probes moving through the ionosphere at mid-latitudes is that due to the VxB fields created by their motion across the ambient magnetic field. It is clearly seen the amplitude of Ex_u and Ey_u data increase at the altitude from 90km to 116km. But amplitude of Ex_b increases at the altitude from 84km to 104km. Incidentally the high electron temperature region is found at altitude from 95km to 102km, according to the Fast Langmuir Probe measurement (Abe et al. private communication).

These electric field data may be related with the high electron temperature region in the Sq current focus during the winter daytime.

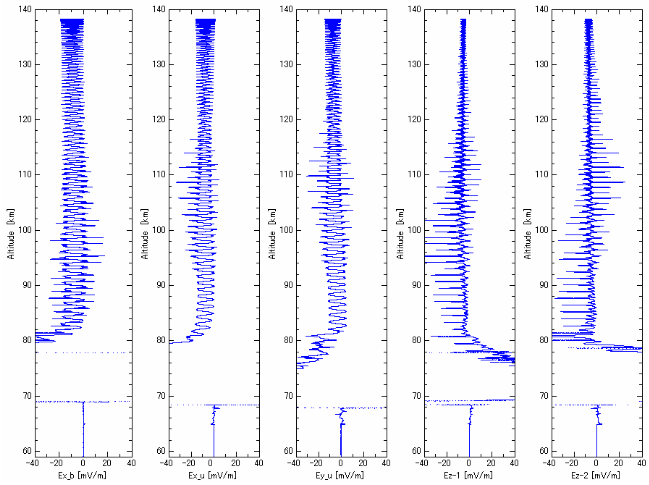


Figure 8. Electric field intensity measured by EFD onboard S-310-37 sounding rocket. The vertical axis is altitude and horizontal axis is electric field intensity.

<Ground Observations of Magnetospheric Plasma waves and related Phenomena>

Low-latitude observations

From the observed frequency of the field-line resonance (FLR), one can estimate the plasma mass density along the field line being observed. 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.

Polar Region Experiments

Ozaki et al. observed natural ELF/VLF waves (chorus and hiss) in Antarctica from December 2005 to December 2006, by using three low-power magnetometer systems placed at three sites near Showa Station, which measured intensities and polarizations of ELF/VLF magnetic fields in 4 frequency bands (500, 1 k, 2 k and 6 kHz). A preliminary analysis has suggested that the difference in observed ELF/VLF intensities at the three stations can be used to estimate the ionospheric exit points of the ELF/VLF waves, which will be compared with “Riometer” images of cosmic noise absorption (CNA) by the ionosphere over Antarctica. Such a comparison will provide a quantitative clue to the stereoscopic structures of the ELF/VLF propagation in the polar ionosphere and magnetosphere.

ULTIMA

ULTIMA is the official abbreviation for "Ultra Large Terrestrial International Magnetometer Array". ULTIMA is an international consortium that aims at promoting collaborating research on the magnetosphere, ionosphere, and upper atmosphere through the use of ground-based magnetic field observations. ULTIMA is composed of individual magnetometer arrays in different countries/regions. The official webpage of ULTIMA is at: http://www.serc.kyushu-u.ac.jp/ultima/ultima.html

The ULTIMA kick-off meeting was held at UCLA on November 17, 2006; at the meeting the Bylaws of ULTIMA were signed by members including the PIs of major magnetometer arrays: Drs. K. Yumoto, C. T. Russell, B. J. Fraser, V. Angelopoulos, I. R. Mann, P. J. Chi, and M. B. Moldwin. At the kick-off meeting, the aforementioned persons elected Professor Yumoto to be the first Chair of ULTIMA. He in turn appointed Dr. Peter Chi to be the Secretary of ULTIMA. Professor Yumoto also appointed Mr. George Maeda to be Assistant Secretary for ULTIMA.

The Bylaws state that ULTIMA provides a platform for each array to easily and efficiently collaborate with other arrays in order to expand observational coverage. ULTIMA also helps identify the importance and need of individual arrays to continue operation or establish new stations in their host countries. The Bylaws of ULTIMA can be viewed at the aforementioned webpage of ULTIMA. ULTIMA activity seeks new members and the Bylaws were crafted with this in mind.

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Conferences and Meetings (December 2006 〜 March 2007)

1) AGU fall meeting, San Fransisco, Dec. 11-15, 2006, http://www.agu.org/meetings/fm06/
2) Chapman Conference on Midlatitude Ionospheric Dynamics and Disturbances, Yosemite National Park, California, Jan. 3-6, 2007, http://www.agu.org/meetings/cc07acall.html
3) 8th International School/Symposium for Space Simulations (ISSS-8), 25 February - 3 March 2007, Kauai, Hawaii http://www.isss8.ucla.edu/

Future Conferences and Meetings

1) International Symposium on Coupling Processes in the Equatorial Atmosphere (CPEA Symposium), Kyoto, 20-23, March, http://www.rish.Kyoto-u.ac.jp/cpea-sympo
2) EGU, Vienna, 15-20 April, http://www.cosis.net/members/meetings/programme
3) Greenland IPY 2007 Space Science Symposium, "Transport in the Coupled Solar Wind - Geospace System seen from a High-Latitude Vantage Point" (GSSS-2007), Kangerlussuaq, Greenland, 4-9 May
4) SuperDARN Workshop 2007, Abashiri, Japan, 4-8 June, http://center.stelab.nagoya-u.ac.jp/sd2007/
5) Japan Geoscience Union Meeting, Makuhari, Japan, 19-24 May, 2007, http://www.jpgu.org/meeting/
6) IUGG at Perugia (Italy), July 2-13, http://www.iugg2007perugia.it/
7) Asia Oceanic Geoscience Society 4th Annual Assembly (AOGS-2007), Bangkok , 30 July – 4 August 2007.：http://www.asiaoceania.org/aogs2007/
8) IPELS2007, International Workshop on the Interrelationship between Plasma Experiments in Laboratory and Space, TNQ Novotel Palm Beach near Cairns, Australia, 5-10 August
9) 2007 INTERNATIONAL SYMPOSIUM ON ANTENNAS AND PROPAGATION, Niigata, 20-24 August, http://www.isap07.org/
10) International CAWSES meeting, Kyoto, 22-27 October, http://www.stelab.nagoya-u.ac.jp/cawses/

Acknowlegement

The editors thank to Dr. Y. Kasahara, Dr. H. Kojima, Dr. H. Usui, Dr. T. Miyake, Dr. H. Kawano, Dr. Y. Miyosi, and Dr. K. Ishisaka for their contribution to this report.