Commission H (Waves in Plasmas) Activity Report

December 7th, 2006

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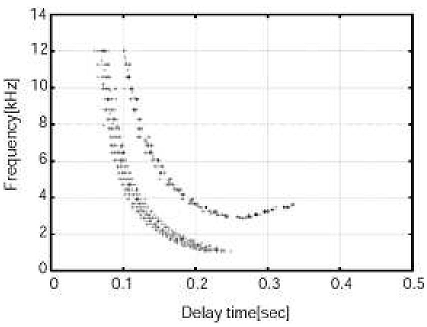
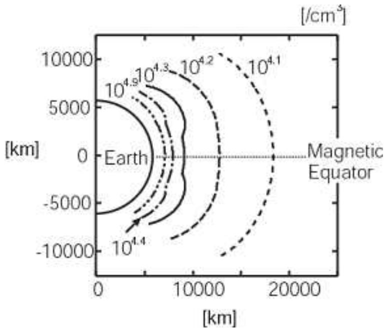
Research Topics

AKEBONO and **GEOTAIL** has been making observations since 1989, and 1992, respectively. Detailed status of these satellites are shown in the previous Commission H (Waves in Plasmas) Activity Report on August 3rd 2006.

<Magnetospheric Plasma Waves and related Phenomena>

The investigation of the earth's plasmasphere should be advanced 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. As direct observations from the ground cannot be performed caused by the disturbance of the ionosphere, the electron density in the plasmasphere is generally observed from spacecraft. Goto et al. (2006) proposed an estimation method of the plasmaspheric electron density profile using the information from natural VLF waves observed on the scientific satellites in the plasmasphere. They demonstrated that the electron density profile in the plasmasphere can be successfully reconstructed based on the wave normal angles and spectrum of the whistler mode waves observed in the plasmasphere. The validity of the estimation method was verified in many simulations.

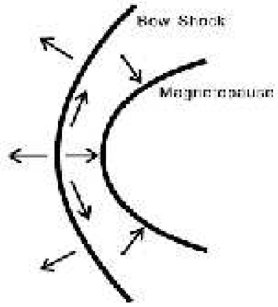




The upper left figure shows a scatter plot of the delay times of whistler waves as a function of frequency at an observation point in the plasmasphere, and the left figure shows the electron density profile of the plasmasphere.

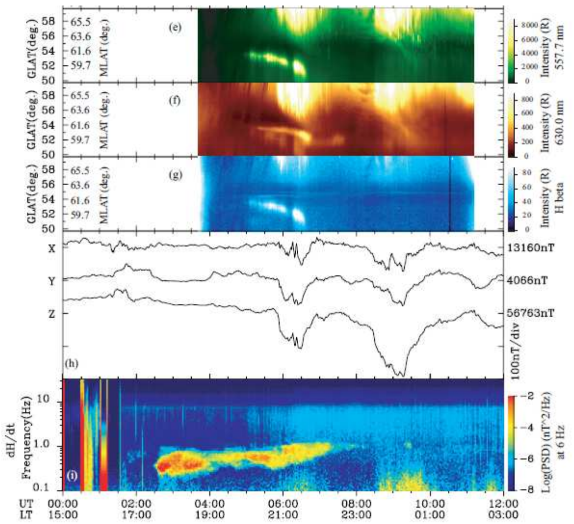
Narita extensively studies low-frequency waves both in the upstream and down stream regions of the Earth’s bow shock with the four-point measurements by the **Cluster spacecraft**. The right-hand polarized magnetosonic/whistler mode and the ion beam resonant mode and the ion beam resonant mode exit in the upstream region. These waves show a transition to the mirror mode in the downstream region. The upstream waves propagate nearly parallel to the background magnetic field, while the waves propagate nearly perpendicular in the downstream region. Hence, the propagation pattern is outward divergent and aligned with the shock normal direction in the upstream region, away from the solar wind direction toward the flank region and aligned with the plasma flow direction in the magnetosheath, and inward convergent toward the magnetopause. Near the foreshock region, wave spectra have the
Kolmogorov’s slope of -5/3, and show energy injection, inertial, and

dissipation. These results have added significantly to our present knowledge of low-frequency waves in the bow sock region. Figure shows a simplified sketch of the propagation pattern. Arrows represent wave phase velocities. The outer and inner solid curved lines represent the bow shock and the magnetopause, respectively.



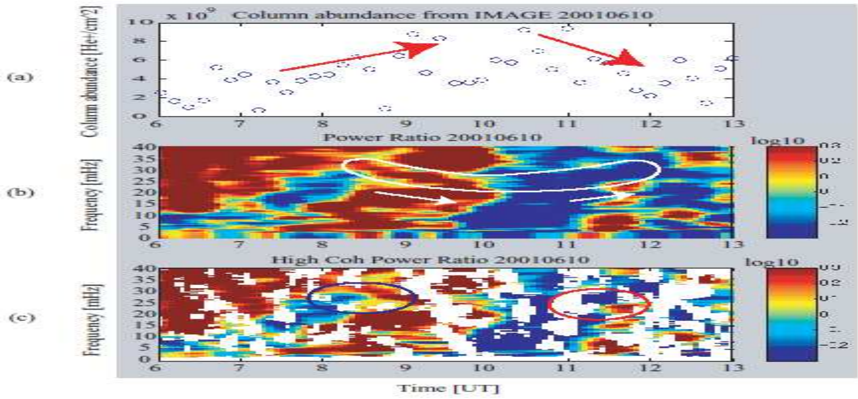
Using high-sensitive all-sky imager, Sakaguchi et al. (2006) reported isolated proton arcs observed in the subauroral region at Athabasca, Canada (54.7N, 246.7E, MLAT=62.0N). Their appearance clearly coincides with intense Pc 1 geomagnetic pulsations observed by an induction magnetometer. Using simultaneous polar-orbiting satellite data, Sakaguchi et al. concluded that the observed isolated arc were driven by the EMIC waves, which were generated near the plasmapause and scattered the ring current protons resonantly into the loss cone.

Figure shows the Keograms of 557.7nm, 630.0nm, H-beta (from top to bottom) obtained at Athabasca, Canada, magnetic field variations obtained at Meanook near Athabasca, and dynamic spectrum of H component geomagnetic field variations at Athabasca on September 5, 2005.



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. Kawano et al. presented an invited talk at the "Mesosphere-Themosphere-Ionosphere Workshop" about the progress on theestimation of plasmaspheric O+ ratio by comparing the mass density estimated using the ground-observed ULF waves with the He+ intensity measured by IMAGE/EUV.

The following figure is from Abe et al. [2006]:(a) The IMAGE/EUV He+ column abundance [He+/cm2] corresponding to the point (called "mapped TIK-CHD midpoint" below) where the field line running through the midpoint between the two ground magnetometers, placed at stations named TIK and CHD, intersects the equatorial plane. The horizontal axis shows time (UT). The column abundance increases (decreases) as the "mapped TIK-CHD midpoint" enters (exits) the plume. (b) H-component power ratio dynamic spectra on the ground (TIK/CHD). The vertical axis shows frequency [mHz], and the horizontal axis shows time (UT). There exists a red band with decreasing frequency with time, and a blue band with increasing frequency with time, as marked by a white loop and arrows. (c) Same as (b), but pixels with coherence < 0.83 are set blank. Just below the red (blue) band marked by the white loop of Figure 5b, one can identify a blue (red) band. These are the features of the field-line resonance (FLR). The FLR frequency is inversely proportional to the plasma density at the "mapped TIK-CHD midpoint"; thus, the decrease-then-increase of the frequency (Panel b) is consistent with the simultaneous increase-then-decrease of the He+ column abundance (Panel a).



<Solar Radio Bursts and related Phenomena>

Morioka et al. (2006) 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. The occurrence distribution of these bursts with respect to the emitted power flux is different from that of ordinary type III bursts, indicating that they are not just the weaker components of the ordinary bursts. 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.

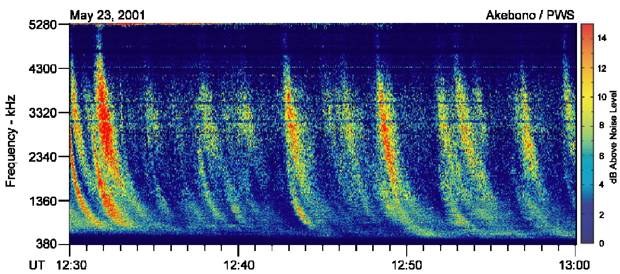
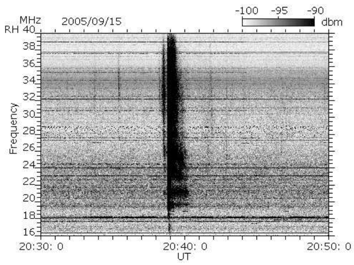


Figure: High time-resolution dynamic spectrogram of micro-type III bursts observed by the Akebono satellite on May 23, 2001.

Magnetohydrodynamic (MHD) waves which are thought to play an important role in acceleration of the solar wind are detected in the decametric type III solar radio bursts obtained at Tohoku University Iitate observatory (Nakagawa and Iizima,2006). The power spectrum (Figure) shows several peaks in the frequency range from 16 to 40 MHz, indicating that the energy conversion from the plasma wave into the radio wave is enhanced locally at several altitudes of about 0.3 to 1.0 solar radius from the Sun. At these altitudes the waveforms of the MHD waves are supposed to become steepened (Suzuki and Inutsuka, 2005), and the steep gradients of the plasma density enhance the conversion rate to the radio waves. Figure: An example of a type III solar burst (the right-hand polarized component of the radio wave) observed at Iitate observatory of Tohoku University, Japan, on September 15, 2005.



<Antenna Analysis>

Nagai et al. [2006] have tried to evaluate the impedance of wire antennas onboard Geotail spacecraft, by using the waveforms of chorus emissions observed in the magnetosphere. Since the propagation characteristics of chorus emissions are well-known, it is possible to calculate the theoretical values of the wave electric fields, only from the wave magnetic fields measured by search coil magnetometers. By comparing the theoretical electric fields with those actually observed by the wire antennas, the antenna impedances can be inversely estimated. Treating the antenna sheath to be the parallel circuit of R (resistance) and C (capacitance), they have found that the antenna impedance varies with the spin of the spacecraft, indicating the variation of the antenna sheath with respect to the angle between the antenna and the ambient geomagnetic field line.

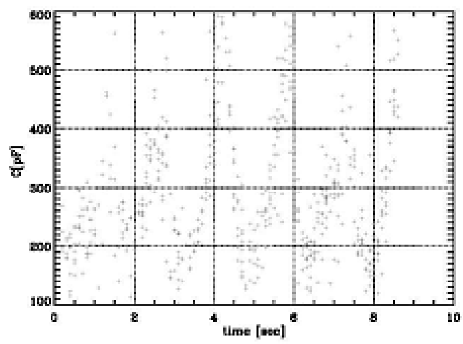


Figure: An example of the antenna sheath capacitance estimated from the Geotail observations of chorus emissions. The capacitance varies with almost the half of the spin period of Geotail (3 sec).

Yamashita et al. [2006] have investigated the characteristics of wire antennas at low frequencies by theoretical calculations and numerical simulations. With the previous experimental measurements called “Rheometry,” which measures the output voltages of a scale-model antenna immersed in the quasi-static electric field generated in a water tank, they had found an interesting frequency dependence of antenna sensitivity (here evaluated as the antenna “effective lengths”). For a wire dipole antenna covered by the thin insulators except for its tips, the 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 based on an equivalent electric circuit model. They have also confirmed the frequency dependence by using numerical electromagnetic simulations, which have revealed the detailed spatial distributions of ambient electric fields and potentials deformed under the influence of the antenna wires.

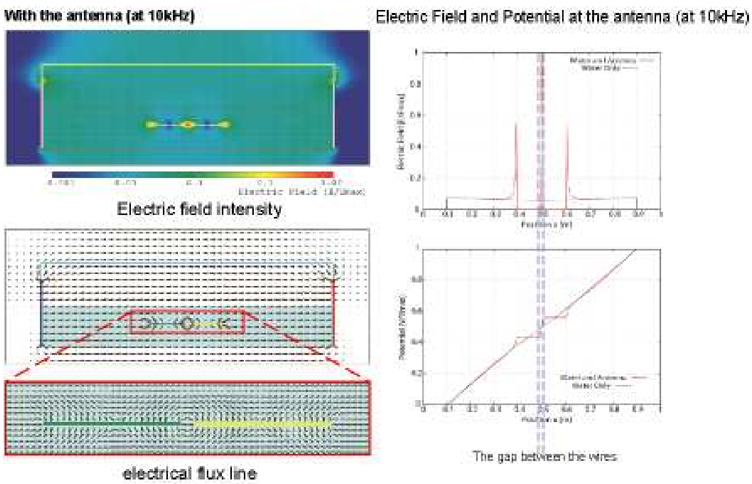


Figure: Electric field and potential distributions around a wire dipole antenna.

<Single Probe Application onboard Satellite>

Ishisaka et al. [2006] have investigated the relationship between the Geotail spacecraft potential, the electron density and the electron temperature in the near tail regions during the period from November 1994 to March 1997, and obtained the empirical formula shown the relationship between the spacecraft potential and electron density considering the electron temperature. The amount of scatter of the measured value from the empirical formula was about +/-20%. Therefore the electron density in the solar wind and the magnetosphere could be estimated by the spacecraft potential and the empirical formula. The electron density obtained from the spacecraft potential was determined by the electrons in wider energy range includes cold components that are not measured by the particle detectors. Using the spacecraft potential and the plasma particle density obtained by the low energy particle instrument (LEP) onboard Geotail, we investigated the distribution of low energy plasma in the magnetosphere. They have obtained the map shown the spatial distribution of low energy plasma and have clearly seen a large amount of low energy plasma existed near the magnetopause in the magnetosphere.

<Polar Region Experiments>

Ozaki et al. [2006] have been observing 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: "West Ongul," "Skallen," and "H100." Each system has a crossed loop antenna to pick up the north-south and east-west components of ELF/VLF magnetic fields, whose intensities and polarizations are measured at 4 spaced frequency bands (500, 1 k, 2 k and 6 kHz), with less than 1 minute resolution. 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 ground-based ELF/VLF observations will be compared with "riometer" observations at Syowa Station, as well as with 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.

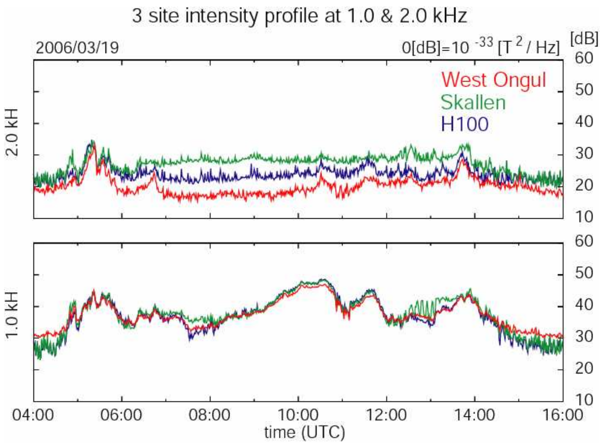


Figure: An example of ELF/VLF wave intensities measured at three unmanned stations near Syowa Station on March 19, 2006. The difference in intensities observed at 2 kHz gives the information on their ionospheric exit points.

<Lightning Location>

Yagitani et al. [2006] have developed a lightning detection system to determine the lightning locations by observing the sferic waveforms at a single station. By receiving two horizontal magnetic components and one vertical electric component at VLF frequencies, this system measures a series of sequential pulses on each of the observed sferics, which are used to compute both the direction and distance to the corresponding lightning stroke. 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.

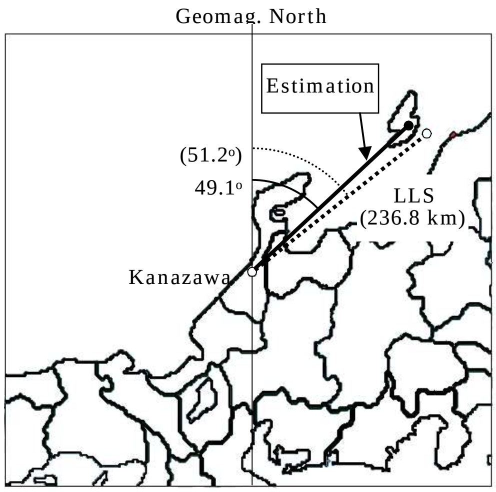


Figure: An example of the lightning location estimated by the developed system (solid line), compared with that identified by a conventional lightning location system (LLS) (dotted line).

<SELENE>

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

<BepiColombo>

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

<Ionospheric Sounding by Plasama Wave Observation>

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

<New Technology>

Development of the analogue chip for plasma wave receivers

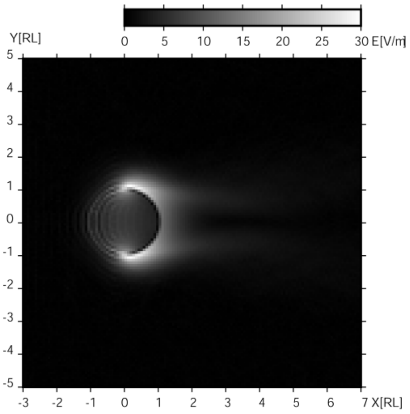
The development of analogue chips for plasma wave receivers has been started in Research Institute for Sustainable Humanosphere of Kyoto University. The development is based upon the ASIC technology (ASIC: Application-Specific Integrated Circuit). This development leads to realizing lightweight plasma wave receivers, which can be used in multiple spacecraft missions or deep space missions.

They designed the analogue circuits and their layouts to be realized inside a chip. At the first step, they incorporated the first stage differential amplifier and low pass filter with the cutoff frequency of 100kHz into chips. The first prototype they developed is shown in the figure. The performance tests for the developed chips have been conducted in Kyoto University.

The picture shows the first prototype of the analogue chip designed in Kyoto University. The chip contains the differential amplifiers, filters and main amplifiers which are essential to plasma wave receivers.

<Space Plasma Wave Simulation>

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. Figure shows the magnitude of the electric field around the moon in the solar wind flowing from the left.



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.

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.

By using full electromagnetic particle simulation, Hikishima et al. [2006] have been investigating the generation and propagation mechanisms of chorus emissions and VLF emissions, through the cyclotron resonant interaction between whistler mode waves and anisotropic electrons. With a one-dimensional simulation model along a nonuniform magnetic field line in the dayside outer magnetosphere, they have found that a whistler mode wave generated around the magnetic equator exhibits the rising-tone-like frequency-time structure when observed at a fixed location away from the equator. Detailed analyses of wave-particle interactions involved are under way.

In the science session of "space plasma theories and simulations, **SGEPSS** (Society of Geomagnetism and Earth, Planetary and Space Sciences) Fall meeting, Sagamihara, 4-7 November 2006, 24 oral and 9 poster papers were presented:

MHD and fluid-type simulations associated with Kelvin-Helmholtz instability and the resulting plasma mixing process are presented by Matsumoto and Seki (2006), Nakamura and Fujimoto (2006), and Takagi et al. (2006). Particle simulations associated with tearing instability occurring in the magnetic reconnection at the current sheet were conducted in order to analyze the electron acceleration and heating by Haijima et al. (2006), Shinohara et al.(2006), Fujimoto et al.(2006), and Hayakawa (2006).

Advanced techniques of MHD, Vlasov and interlocked PIC-MHD simulations are also presented by Yagi et al.(2006), Miyoshi and Kusano (2006), Umeda (2006), Sugiyama and Kusano (2006), and Ouki and Shinohara (2006). A simulation project for spacecraft environment was introduced by Usui et al. (2006).

From a view point of space engineering, PIC simulations on interaction of intense electromagnetic waves such as SPS microwave beam with the ionospheric electrons were conducted by Nakamoto et al. (2006). Antenna characteristics in the photoelectron environment were also investigated with 3D PIC-EM simulations by Miyake et al. (2006).

Other research results were presented such as Whistler-electron nonlinear interactions by Katoh and Omura (2006), Furuya et al. (2006) and Hikishima et al. (2006), moon-plasma interactions by Kimura and Nakagawa (2006), Alfven wave nonlinear interactions by Nariyuki and Hada (2006) and Tanaka et al. (2006), and Show waves by Amano and Hoshino (2006) and Matsukiyo (2006).

Reconnection process has effects on large scales and quite often our interest is in this aspect. However, electron dynamics at the X-line needs to be treated appropriately at the same time. It is a clever idea to include kinetic effects only in the close proximity of the X-line but coarse-grain the physics to MHD approximation or at remote locations. Sugiyama et al [SGEPSS, 2006] is developing a code (multi-scale code) in this direction. One-dimensional Alfven wave propagation has been successfully tested. As a similar but different approach, one may think of including high resolution treatment only in the X-line proximity. Fujimoto et al [SGEPSS, 2006] has introduced the AMR scheme together with particle splitting scheme into a full particle code, whereby higher resolution is attained whenever and wherever it is needed. This enables the authors to run long time simulations and observe the elongation of the X-line and the associated decline in the reconnection rate.

Conferences and Meetings (July 2006 ～ December 2006)

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 Fall meeting, Sagamihara, Nov. 4-7, 2006, http://www.stp.isas.jaxa.jp/STP/sgepss/
8) CAWSES Workshop on Space Weather Modeling (CSWM), Nov. 14-17, 2006

Future Conferences and Meetings

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/

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