Japanese URSI Commission H (Waves in Plasmas)
Activity Report
March- June, 2013

[1] Status of projects related with plasma wave observation

1. NICT Science Cloud

Major methodologies of Solar-Terrestrial Physics (STP) including space plasma data analysis so far are (1) theoretical, (2) experimental and observational, and (3) computer simulation approaches. Recently "informatics" is expected as a new (fourth) approach to the STP studies is a methodology to analyze large-scale data (observation data and computer simulation data) to obtain new findings using a variety of data processing techniques. What is the infrastructure required for the fourth methodology is “cloud computing system”. The cloud computing environments should play significant roles in the STP science. At NICT (National Institute of Information and Communications Technology) we are now developing a new research environment for the 4th methodology named “NICT Science Cloud”.

One of the advantages of the NICT Science Cloud to the legacy (traditional) data analysis environments is its integrated resources. The NICT Science Cloud provides the researchers with rich computational resources for research studies, such as super-computer, large-scale storage (disk) area, data processing parallel cluster workstations with GPGPUs, licensed applications, DB (database) and meta-DB, and communication devices. The background (backbone) network for the NICT Science Cloud is the JGN-X (Japan Gigabit Network), which connects many computer resources with as high-speed network as 1Gbps to 40Gbps.

For the large-scale data analysis for STP data files, we have implemented a distributed data analysis servers in the NICT Science Cloud. There are 23 servers with 276 CPUs distributed at five data centers. These 23 servers are clients of Gfarm/Pwrake, which is a middle-ware for both distributed data storage and parallel data processing. The Gfarm/Pwrake shows a great performance for large-scale data analysis on such a wide-area distributed cloud environment.

2. Akebono (EXOS-D)

The Akebono spacecraft has attained the 24 years of successful operation without any major troubles. The regular data acquisition of MGF, PWS, VLF, TED, and RDM is continued at stations in Japan and Sweden. The operation of the Akebono operation will be extended until March, 2015 (FY2014) in order to realize collaborative measurements with the Van Allen Probes, and further extension to the

end of FY2016 is expected as an optional mission. Detailed information on the Akebono dataset is available on the website of DARTS/AKEBONO (http://www.darts.isas.jaxa.jp/stp/akebono/).
[General information: http://www.jaxa.jp/projects/sat/akebono/index_e.html]

3. CRUX magnetometers

In order to study spatial structure of quarter-wave mode of field line resonances, Osaka Electro-Communication University operates magnetometer sites in New Zealand. Currently they are collecting data from Te Wharau (L-value 2.2 Re) and Middlemarch (2.8 Re) stations. For more information, see http://www1.osakac.ac.jp/crux/.

4. Special Issue of Earth, Planets and Space entitled "Physical Processes in Non-Uniform Finite Magnetospheric Systems -50 Years of Tamao's Resonant Mode Coupling Theory" (Earth Planets Space, Vol. 65, No. 5, 2013)

This special issue of Earth, Planets and Space is published to commemorate the Workshop on Physical Processes in Non-Uniform Finite Magnetospheric Systems, -50 Years of Tamao's Resonant Mode Coupling Theory -, held in Fukuoka, Japan, in 12-15, September, 2011. This international workshop was held on the occasion of the 50 years' anniversary of the publication of Professor Tamao's pioneering paper on the resonant mode coupling of magnetohydrodynamic waves in the magnetosphere. The workshop was proposed and organized by an international team of scientists who respected Prof. Tamao's great contribution. More than 60 participants from many countries discussed recent progress and future perspectives about the resonant mode coupling and other topics in which a non-uniform and finite system is essential. For example, the resonant mode coupling theory is applied to sounding of the Earth's magnetosphere, and the MHD waves in Herman and other planets' magnetospheres are studied in terms of this theory. In addition, the magnetosphere-ionosphere coupling study is now developed to research of the magnetosphere-ionosphere compound system in which many elementary processes are self-consistently coupled. The new method was also presented to separate upward and downward propagating Alfven waves from the wave signals observed above the ionosphere. 8 papers from the participants are published.

[2] Recent Meetings

1. Symposium on Electromagnetospheric Physics (Organizers: H. Kawano and

K. Shiokawa), Fukuoka, Japan, March 4-5, 2013.

2. JpGU (Japan Geoscience Uniton) Meeting 2013, Makuhari, Japan, May 19-24, 2013.
3. AOGS(Asia Oceania Geosciences Society) 2013, Brisbane, Australia, June 24-28, 2013.

[3] Future Meetings

1. 11th International School/Symposium for Space Simulations (ISSS-11), Jhongli City, Taiwan, July 21-27, 2013.
2. IAGA 2013, Mérida, Yucatán, México, August 26-31, 2013.
3. AP-RASC 2013, Taipei, Taiwan, September 3-7, 2013.
4. COSPAR Symposium on "Planetary Systems of our Sun and other Stars, and the Future of Space Astronomy", Bangkok, Thailand, November 11-15, 2013.
5. International CAWSES (Climate and Weather of the Sun-Earth System)-II Symposium, Nagoya, Japan, November 18-22, 2013.

[4] Recently Published Papers (March 2013 – June 2013)

1. **Kubota, Y., Yamamoto, K., Fukazawa, K., and Murata, K. T., Visualization of the Flux Rope Generation Process Using Large Quantities of MHD Simulation Data, Data Science Journal, Vol.12, pp.WDS134-WDS138, Apr., 2013.**

   We present a new concept of analysis using visualization of large quantities of simulation data. The time development of 3D objects with high temporal resolution provides the opportunity for scientific discovery. We visualize large quantities of simulation data using the visualization application 'Virtual Aurora' based on AVS (Advanced Visual Systems) and the parallel distributed processing at "Space Weather Cloud" in NICT based on Gfarm technology. We introduce two results of high temporal resolution visualization: the magnetic flux rope generation process and dayside reconnection using a system of magnetic field line tracing.

2. **Kunitake, M., Yamamoto, K., Watari, S., Ukawa, K., Kato, H., Kimura, E., Murayama, Y. and Murata, K. T., Solar-Terrestrial Data Analysis and Reference System (STARS) – Its High Potentiality for Collaborative Research, Data Science Journal, Vol.12, pp.WDS225-WDS228, Apr., 2013.**

   Cross-sectional studies have become important for an improved understanding of

various Solar-Terrestrial Physics (STP) fields, given the great variety and different types of observations from the Sun to the Earth. In order to better combine, compare, and analyze different types of data together, a system named STARS (Solar-Terrestrial data Analysis and Reference System) has been developed. Cross-sectional study requires cooperative work. STARS has two functions for cooperative work, the "Stars Project List (SPL)" and the "Event Listing". The SPL is used for exchanges of plotting information by cooperating persons. The event list database provides all users of STARS hints for recognizing typical occurrences of STP phenomena.

3. **Murata, K. T., Watari, S., Nagatsuma, T., Kunitake, M., Watanabe, H., Yamamoto, K., Kubota, Y., Kato, H., Tsugawa, T., Ukawa, K., Muranaga, K., Kimura, E., Tatebe, O., Fukazawa, K. and Murayama, Y., A Science Cloud for Data Intensive Sciences, Data Science Journal, Vol.12, pp.WDS139-WDS146, Apr., 2013.**

   It is often discussed that the fourth methodology for science research is "informatics". The first methodology is a theoretic approach, the second one is observation and/or experiment, and the third one is computer simulation. Informatics is a new methodology for data intensive science, which is a new concept based on the fact that most scientific data are digitalized and the amount of data is huge. The facilities to support informatics are cloud systems. Herein we propose a cloud system especially designed for science. The basic concepts, design, resources, implementation, and applications of the NICT science cloud are discussed.

4. **Watanabe, H., Yamamoto, K., Tsugawa, T., Nagatsuma, T., Watari, S., Murayama, Y. and Murata, K. T., An Integrated Management System of Multipoint Space Weather Observation, Data Science Journal, Vol.12, pp.WDS175-WDS178, Apr., 2013.**

   An outline of a planned system for the global space-weather monitoring network of NICT (National Institute of Information and Communications Technology) is given. This system can manage data collection much more easily than our current system by installations of autonomous recovery, periodical state monitoring, and dynamic warning procedures. According to a provisional experiment using a network simulator, the new system will work under limited network conditions, e.g., a 160 msec delay, a 10 % packet loss rate, and a 500 Kbps bandwidth.

5. **Watari, S., Kato, H., Murata, K. T., Yamamoto, K., Watanabe, H., Kubota, Y. and Kunitake, M., Research Environment and Information Service of Space Weather Cloud, Data Science Journal, Vol.12, pp.WDS209-WDS212, Apr., 2013.**

   To optimize space weather research and information services, it is important to establish a comprehensive system that enables us to analyze observation and simulation data in an integrated manner. For this, we recently constructed a new computing environment called the "Space Weather Cloud Computing System" of the National Institute of Information and Communications Technology (NICT). Currently, the Space Weather Cloud contains a high performance computer, a distributed mass storage system using the Grid Data Farm (Gfarm) technology, servers for analysis and visualization of data, a job service based on the RCM (R&D Chain Management) system, servers for Solar-Terrestrial data Analysis, and the Reference System (STARS).

6. **Murata, K. T., Watanabe, H., Yamamoto, K., Kubota, Y., Tatebe, O., Tanaka, M., Fukazawa, K., Kimura, E., Ukawa, K., Muranaga, K., Suzuki, Y., Isoda, F., A Parallel Processing Technique on the NICT Science Cloud via Gfarm/Pwrake (in Japanese), IPSJ HPC SIG Technical Reports, Vol.2013-HPC-139, No.9, pp.1-6, 2013.**

   For data intensive science on cloud systems, we need development of techniques for DIC (Data-Intensive Computing) as well as HTC (High-Through-put Computing), MTC (Many-Task Computing), and HPC (High-Performance Computing). The DIC is a new concept of large-scale data processing paying attentions to data distribution, data-parallel execution, and harnessing data locality by scheduling of computations close to the data. As the data file size is getting larger, I/O time to read and/or write data is not negligible compared with data processing time. We herein develop a DIC technique on a science cloud using Gfarm/Pwrak. The Gfarm/Pwrake has been developed as an integrated system of both distributed file system and parallel data processing system. With identifying file system nodes (FSN) and processing client node (CN) and giving higher priority to process files on the local disk than on remote disks, we succeeded in progress of total performance in processing large-scale data files.

7. **Watanabe, H., Kurosawa, T., Ichioka, S., Kimura, E., Murata, K. T., Tatebe, O., Parallel File Transfer using UDT (in Japanese), IPSJ HPC SIG Technical Reports, Vol.2013-HPC-139, No.8, pp.1-8, 2013.**

High-speed data migration remains one of problem in the high-performance distributed computing. There are researches to improve end-to-end data I/O performance in a LFN(Long Fat Network), but most of them have been developed for a one-to-one data transfer. In fact, they are not the easy technology to use in the case of a one-to-many data transfer because users such as science researchers are forced to develop a function to control parallel data transfer. We propose the parallel data transfer system using UDT, and confirmed about 7Gbps data I/O performance (download) of the proposed system in the both local evaluation experiment and global evaluation experiment.

8. **Isoda, F., Murata, K. T., Watanabe, H., Fukazawa, K., Yamamoto, K., Tatebe, O., Tanaka, M., Kimura, E., High Performance of Big Data Processing via NICT Science Cloud (in Japanese), IEICE-SC2013-4, Vol. IEICE-113, No.86, pp.19-24, 2013.**

   Science cloud is a cloud system designed for scientific researches, and expected as a new infrastructure for big data sciences. Not only parallelization of CPU as in super-computers, but I/O and network throughput parallelization are crucial for the big data science. One of the typical structures of science cloud is a scalable cluster in which multiple clusters in a cloud are connected with high-speed network. In the present study, we study a performance of parallelization of both CPU and I/O inside a cloud as a first step to the high performance scalable clusters. In case with few processes executed on each computational node (server), parallelization efficiency is almost 100%. This high efficiency is expected to maintain in larger-scale cluster systems such as those with 100 servers. On the other hand, under the condition of multi-processes on each node, the present parallelization does not show good performance due to the congestions of I/O. Parallelization efficiency is as low as 15.6. New techniques of decentralization of I/O within each node are required in the next step.

9. **Murata, K. T., Watanabe H.,, Ukawa, K., Muranaga, K., Suzuki, Y., Isoda, F., Yamamoto, K., Tatebe, O., Tanaka, M., Kimura, E., Satoh, S., The NICT Science Cloud -- A Proposal of Cloud System for Scientific Researches – (in Japanese), IEICE-SC2013-2, IEICE-113, No.86, pp.5-11, 2013.**

   This paper is to propose a cloud system for science, which has been developed at NICT (National Institute of Information and Communications Technology), Japan. The NICT science cloud is an open cloud system for scientists who are

going to carry out their informatics for their own science. The NICT science cloud is not for simple uses. Many functions are expected to the science cloud; such as data standardization, data collection and crawling, large and distributed data storage system, security and reliability, database and meta-database, data stewardship, long-term data preservation, data rescue and preservation, data mining, parallel processing, data publication and provision, semantic web, 3D and 4D visualization, out-reach and in-reach, and capacity buildings.

10. **Watanabe, H., Iwama, T., Murata, K. T., Ukawa, K., Muranaga, K., Suzuki, Y., Kimura, E., Tatebe, O., Takasugi, H., Kamezawa, Y., NICT Science Cloud -- An Extension of Security Functions in a Wide-Area Distribution File System -- (in Japanese), IEICE-SC2013-3, IEICE-113, No.86, pp.13-18, 2013.**

    The NICT Science Cloud is a cloud system specialized for scientific research activities. One of the important functions provided by the NICT Science Cloud is a wide-area distributed file system, as wide as over Japan. This file system is implemented by a middle-ware, named Gfarm (Grid datafarm). The wide-area storage system is operated on the cloud system, maintaining several tens of millions of scientific data files. For more reliable and safety operation of the file system, we need development of security system designed for such wide-area file systems. In the present study, we demonstrate our science cloud system focusing on the file system. Addressed are the issues for the secure and reliable wide-area file system in the present discussions.

11. **Fujita, S., and T. Tanaka, Possible generation mechanisms of the Pi2 pulsations estimated from a global MHD simulation, *Earth Planets Space*, 65, pp. 453-461, 2013.**

    The plasmaspheric virtual resonance (PVR) and the transient Alfven wave bouncing between the ionospheres in both hemispheres (the transient response, TR) are regarded as the possible generation mechanisms of the Pi2 pulsations. However, the global MHD simulation of a substorm [Tanaka et al., 2010] did not reproduce such wave modes because of insufficient ionospheric reflection of the Alfven wave, numerical transfer of the Alfven wave across the field lines, and no plasmasphere. Furthermore, it is noted that the substorm current wedge (SCW) which is a driver of the TR is not reproduced in the global MHD simulation. In this study, we search the sources of the Pi2 pulsations in the global MHD simulation, namely, the compressional wave in the inner magnetosphere for the PVR and the Alfven wave injected to the ionosphere for the TR. In conclusion, there appears a compressional signal in the inner

magnetosphere when the high-speed Earthward flow at the substorm onset surges in the inner edge of the plasma sheet.

12. **Kokubun, S., ULF waves in the outer magnetosphere: Geotail observation 1 transverse waves, *Earth Planets Space*, 65, pp. 411-433, 2013.**

A survey of ULF waves in the Pc 5 frequency range during the six year period (1995-2000) has been made for the field line resonance waves in the outer magnetosphere, using plasma flow and magnetic field measurements with the Geotail spacecraft. On the morning side a series of wave trains often appears during several hours. In contrast such a series of wave trains with a long duration is rarely observed in the afternoon to evening sector. Most of waves in the afternoon sector are isolated, of which duration is approximately one hour. The existence of a set of preferential frequencies and the pronounced dawn-dusk asymmetry of wave occurrence and wave features, which were found in ground-based and ionospheric measurements of geomagnetic ULF pulsations, were statistically confirmed. It is also noted that the background plasma flow is sunward in the evening sector without exception. Transverse waves are generally observed in the condition of plasma β below 1.5. High β cases are mostly associated with events on the dusk side. As for the relation to solar wind conditions, Pc 5 waves tend to occur under the condition of more radial than the average IMF spiral angle, or of low cone angle.

13. **Pilipenko, V. A., H. Kawano, and I. R. Mann, Hodograph method to estimate the latitudinal profile of the field-line resonance frequency using the data from two ground magnetometers, *Earth Planets Space*, 65, 435–446, 2013.**

The hodograph method enables estimating the latitudinal profile of the field-line resonance (FLR) frequency (f_R) using the data from two ground magnetometers. This paper provides the full details of this method for the first time, and uses a latitudinal chain of ground magnetometers to examine its validity and usefulness. The hodograph method merges the widely-used amplitude-ratio and cross-phase methods in a sense that the hodograph method uses both the amplitude ratio and the phase difference in a unified manner; further than that, the hodograph method provides f_R at any latitude near those of the two ground magnetometers. It is accomplished by (1) making a complex number by using the amplitude ratio (phase difference) as its real (imaginary) part; (2) drawing thus obtained complex numbers (one number for one frequency) in the complex plane to make a hodograph; and (3) fitting to thus obtained hodograph a model satisfying the FLR condition, which is a circle with the assumption that the resonance width is independent of the latitude.

14. **Grison, B., O. Santolik, N. Cornilleau-Wehrlin, A. Masson, M. J. Engebretson, J. S. Pickett, Y. Omura, P. Robert, R. Nomura, EMIC triggered chorus emissions in Cluster data, J. Geophys. Res., 118, doi:10.1002/jgra.50178, 2013.**

Electromagnetic ion cyclotron (EMIC) triggered chorus emissions have recently been a subject of several experimental, theoretical and simulation case studies, noting their similarities with whistler-mode chorus. We perform a survey of 8 years of Cluster data in order to increase the database of EMIC triggered emissions. The results of this is that EMIC triggered emissions have been unambiguously observed for only three different days. These three events are studied in detail. All cases have been observed at the plasmapause between 22 and 24 magnetic local time (MLT) and between –15 degrees and 15 degrees of magnetic latitude. Triggered emissions are also observed for the first time below the local helium gyrofrequency. The number of events is too low to produce statistical results, nevertheless we point out a variety of common properties of those waves.

15. **Y. Katoh, M. Kitahara, H. Kojima, Y. Omura, S. Kasahara, M. Hirahara, Y. Miyoshi, K. Seki, K. Asamura, T. Takashima, and T. Ono, Significance of Wave-Particle Interaction Analyzer for direct measurements of nonlinear wave-particle interactions, Ann. Geophys., 31, 503?512, 2013.**

In the upcoming JAXA/ERG satellite mission, Wave Particle Interaction Analyzer (WPIA) will be installed as an onboard software function. We study the statistical significance of the WPIA for measurement of the energy transfer process between energetic electrons and whistler-mode chorus emissions in the Earth's inner magnetosphere. The WPIA measures a relative phase angle between the wave vector E and velocity vector v of each electron and computes their inner product W, where W is the time variation of the kinetic energy of energetic electrons interacting with plasma waves. We evaluate the feasibility by applying the WPIA analysis to the simulation results of whistler-mode chorus generation. We compute W using both a wave electric field vector observed at a fixed point in the simulation system and a velocity vector of each energetic electron passing through this point. By summing up Wi of an individual particle i to give Wint, we obtain significant values of Wint as expected from the evolution of chorus emissions in the simulation result.

16. **K. Yamaguchi, T. Matsumuro, Y. Omura, and D. Nunn, Ray tracing of whistler-mode chorus elements: implications for generation mechanisms of rising and falling tone emissions, Ann. Geophys., 31, 665-673, 2013.**

Using a well-established magnetospheric verylow-frequency (VLF) ray tracing method, in this work we trace the propagation of individual rising- and fallingfrequency elements of

VLF chorus from their generation point in the equatorial region of the magnetosphere through to at least one reflection at the lower-hybrid resonance point. Unlike recent work by Bortnik and co-workers, whose emphasis was on demonstrating that magnetospheric hiss has its origins in chorus, we here track the motion in the equatorial plane of the whole chorus element, paying particular regard to movement across field lines, rotation, and compression or expansion of the wave pulse. With a generation point for rising chorus at the equator, it was found the element wave pulse remained largely field aligned in the generatin regions. However, for a falling tone generation point at 4000 km upstream from the equator, by the time the pulse crosses the equator the wavefield had substantial obliquity, displacement, and compression, which has substantial implications for the theory of falling chorus generation

17. **A. Kakad, Y. Omura, B. Kakad, Experimental evidence of ion acoustic soliton chain formation and validation of nonlinear fluid theory, Phys. Plasmas, 20, 062103, 2013.**

We perform one-dimensional fluid simulation of ion acoustic (IA) solitons propagating parallel to the magnetic field in electron-ion plasmas by assuming a large system length. To model the initial density perturbations (IDP), we employ a KdV soliton type solution. Our simulation demonstrates that the generation mechanism of IA solitons depends on the wavelength of the IDP. The short wavelength IDP evolve into two oppositely propagating identical IA solitons, whereas the long wavelength IDP develop into two indistinguishable chains of multiple IA solitons through a wave breaking process. The wave breaking occurs close to the time when electrostatic energy exceeds half of the kinetic energy of the electron fluid. The wave breaking amplitude and time of its initiation are found to be dependent on characteristics of the IDP. The strength of the IDP controls the number of IA solitons in the solitary chains. The speed, width, and amplitude of IA solitons estimated during their stable propagation in the simulation are in good agreement with the nonlinear fluid theory. This fluid simulation is the first to confirm the validity of the general nonlinear fluid theory, which is widely used in the study of solitary waves in laboratory and space plasmas.