２. ISEE International Joint Research Program 目次詳細

（所属・職名は平成30年3月現在）
(Affiliation and Department displayed are current as of March 2018.)

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Investigation of Plasma Bubble Propagations using the All-Sky Airglow Images and GNSS Data

Dr. Daniel Okoh (Space Environment Research Laboratory, Centre for Atmospheric Research, Nigeria)

This research is the first to report the occurrence frequency of equatorial plasma bubbles and their dependences of local time, season, and geomagnetic activity based on airglow imaging observations at West Africa.

The airglow image data used were obtained from the all-sky optical imager No. 5 of the Optical Mesosphere Thermosphere Imagers (OMTIs) provided by ISEE, and operated by the Space Environment Research Laboratory, Centre for Atmospheric Research. The imager is installed at the laboratory in Abuja (Geographic: 8.99°N, 7.38°E; Geomagnetic: 1.60°S, 79.39°E), it has a 180° fish-eye view covering almost the entire airspace of Nigeria. Plasma bubble visibility on the all-sky imager observations was enhanced by constructing percentage intensity deviations of the images from 1 h running averages of the images.

GNSS data used were obtained from seven GNSS receivers on the Nigerian Permanent GNSS Network, and the GNSS receivers used were selected such that the receiver stations fell within the region covered by the airglow imager. Differences between night-time and day-time ROTIs were computed as a proxy of plasma bubbles using the GNSS data.

Plasma bubbles are observed for 70 nights of the 147 clear-sky nights from 9 June 2015 to 31 January 2017. Most plasma bubble occurrences are found during equinoxes and least occurrences during solstices.

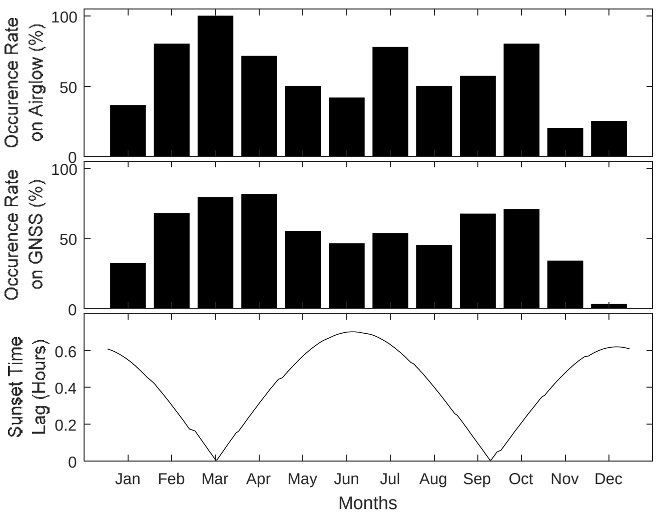

Figure 1. Percentage Occurrence of Plasma Bubbles as observed on the Airglow and GNSS data for the period from June 2015 to January 2017. The bottom panel represents sunset lag time between geomagnetic conjugate points on the same meridian as the all-sky camera station.

The occurrence rate of plasma bubbles was highest around local midnight and lower for hours farther away. On investigating the local time occurrence of plasma bubbles as a function of season, it was found that more post-sunset plasma bubbles occurred around the months of June–September while more post-midnight plasma bubbles occurred around the months of December–March. The post-sunset irregularities were attributed to electrical processes in the evening time equatorial ionosphere, while the post-midnight irregularities were proposed to be connected to tropospheric sources like the dusty harmattan winds which occur between the months of November and March in Nigeria.
In a total of 768 h for which there were clear sky airglow observations as well as GNSS ROTI data, the on/off status of plasma bubble in airglow and GNSS observations were in agreement for 67.2% of the hours. There were 65 h for which plasma bubbles were observed on the airglow images but not on the GNSS data, possibly due to the adopted ROTI threshold for the bubble identification and because GNSS radio paths can miss the plasma bubbles. On the other hand, another 187 h show that plasma bubbles were observed on the GNSS data but not on the airglow images, possibly because high ROTI can be caused by other sources, such as equatorial anomaly. A majority of the plasma bubbles were observed under relatively quiet geomagnetic conditions (Dst $\geq$ -40 and Kp $\leq$ 3), but there was no significant pattern observed in the occurrence rate of plasma bubbles as a function of geomagnetic activity. We suggest that geomagnetic activities could have either suppressed or promoted the occurrence of plasma bubbles.

My period of stay in ISEE was from 1 June to 31 August 2017. I appreciate the generous support I received during this period, and the warm disposition of staff and students I worked and stayed with at ISEE.

Publication:

Okoh, D., Rabiu, B., Shiokawa, K., Otsuka, Y., Segun, B., Falayi, E., Onwuneme, S., Kaka, R. First study on the occurrence frequency of equatorial plasma bubbles over West Africa using an all-sky airglow imager and GNSS receivers. Journal of Geophysical Research: Space Physics, 122, 12430–12444, doi: 10.1002/2017JA024602, 2017

Presentation:

Okoh, D. Occurrence Frequency of Equatorial Plasma Bubbles over West Africa using an All-Sky Aiglow Imager and GNSS Receivers. Weekly Seminar of ISEE, Institute for Space-Earth Environmental Research (ISEE), Nagoya University, 07/July/2017

Comparative Study of NoRH microwaves and SDO/AIA EUV DEM

Jeongwoo Lee (Seoul National University)

1. Purpose

We aimed to address one of the most important issues in solar physics: understanding how plasma heating and nonthermal particle acceleration occur during solar flares. For this purpose, we designed a new method that utilizes the microwave data obtained with the Nobeyama Radioheliograph (NoRH) along with the differential emission measure (DEM) derived from the Solar Dynamics Observatory/Atmospheric Imaging Assembly (SDO/AIA). The main idea is that we may use the plasma density derived from SDO/AIA for calculation of thermal microwave flux and subtracting it from the observed NoRH flux will yield the information on the nonthermal particles accelerated during solar flares.

2. Method

(1) Select targets. A composite microwave bursts observed with the NoRH is ideal for this study. (2) Calculate the EUV emission measure using the AIA DEM package developed by Mark Cheung on the simultaneous SDO/AIA six images at 94 A,131 A, 171 A, 193 A, 211 A, and 335 A. The output is n^2L, per given coronal temperature range, where n is the electron density and L is the line of sight. The temperature range will be set to (log T) = [5.7, 7.7] in the interval of d(log T) = 0.1. (3) Calculate the microwave free-free emission maps based on the AIA DEM maps derived from the emission measure, n^2L. Compare the DEM-based microwave maps with the simultaneous NoRH maps to identify the regions where free-free or gyrosynchrotron emission dominates. (4) Study the magnetic characteristics of each source using either nonlinear force-free field extrapolation or direct modeling based on EUV images. Use this information to provide magnetic context of the eruptions.

3. Result

We have derived the EM information from the SDO/AIA (E)UV lines of the composite solar flare, SOL2015-06-21T01:42 and SOL2015-06-21T02:36. Using the above method, we were able to identify three distinctive sources: the first one is the main flare source located within the bipolar spot, which consists of both thermal and nonthermal sources. While the nonthermal source expands in width across the polarization inversion line (PIL), the middle part of the nonthermal source weakens and turns into thermal source. As a result, the nonthermal source appears to split into two peaks moving away from the PIL with time, consistent with standard solar flare reconnection model. Second source is another impulsive microwave source, which is also magnetically confined source and entirely nonthermal. This source is very weak in EUV emission suggesting that thermal particles are depleted, allowing nonthermal electrons to survive longer against Coulomb collisions. Such behavior reminds us of the so-called *cold flares* that emit hard X-rays without accompanying soft X-rays, regarded as evidence for electron acceleration without thermal heating. We also found a thermal source rich in EUV and poor in microwaves. This may be a rare example of a passive receiver of thermal energy from a thermal reservoir through a magnetic channel as identified from EUV images and DEM analysis. In addition, we have explored the magnetic characteristics of each source using a noble method of calculating so-called quasi-separatrix layer, which enables identification of the location of magnetic reconnection during these flares. Finally, we combined these results to address the onset problem of solar eruption due to the double-arc instability (DAI).

4. Scientific Merit

This is the first study that microwave and EUV data are synthesized to serve as a tool for identifying the thermal and nonthermal components. We could implement such capability thanks to the excellent sensitivity of the NoRH (image quality of better than 20 dB) and spatial resolution of the SDO/AIA (0.6 arc sec per pixel). It is remarkable that these two independent instruments, one in space and the other in the ground, could simultaneously detect the subtle interplay between the thermal heating and nonthermal electron acceleration within a complex active region. This demonstrates how the combination of SDO/AIA and NoRH observation can help understanding the nonthermal particle acceleration and thermal heating in solar flares. In addition, we have found the importance of a composite flare in resolving the onset problem of solar eruption.

5. Publications

Main part of the above study was published in a paper titled: *Thermal and Nonthermal Emissions of a Composite Flare Derived from NoRH and SDO Observations* (Lee, J., White, S. M., Jing, J., Liu, C., Masuda, S., & Chae, J. 2017 ApJ, 850, 124). Another study made in collaboration, *Witnessing a Large-scale Slipping Magnetic Reconnection along a Dimming Channel during a Solar Flare* (Jing, J., Liu, R., Cheung, M. C. M., Lee, J., Xu, Y., Liu, C., Zhu, C., & Wang, H. 2017 ApJ Letters, 842, 18) is more focused on the DEM only. As related studies, we also identified magnetic structure for hosting these three sources in a paper, *Magnetic Structure of a Composite Solar Microwave Burst* (Lee, J., White, S. M., Liu, C., Kliem, B. & Masuda, S. 2018 ApJ in press). Another important collaboration has been made that identifies the condition for the eruption produced during this event in a *Flux Rope Formation By A Confined Solar Flare Preceding A Coronal Mass Ejection* (Kliem, B. , Lee, J., White, S. M., Liu, C., & Masuda, S. 2018 ApJ under review) has been favorably reviewed, and now in revision.

6. Period of Stay: total of 30 days in FY2017 at ISEE.

Development of PM2.5 instruments and observation in Mongolia and Japan

Sonomdagva Chonokhuu (National University of Mongolia)

Air pollution is a major environmental issue affecting people across the world. According to the World Health Organization (WHO), more than 2 million people worldwide die every year from air pollution. Of all the air pollutants, fine particulate matter (PM) is one of the most hazardous pollution for the human health. The particulate matter causes about 9% of lung cancer deaths worldwide, 5% of cardiopulmonary deaths and about 1% of respiratory infection deaths. According to the WHO, there is mounting evidence that concentration of particulate matter is increasing in Asia. Particulate matter mostly originates from dust storms, grassland fires, burning of fossil fuels in vehicles, power plants, but also various industrial plants generate significant amounts of particulates.

As standard instruments for the continuous monitoring of $PM_{2.5}$ mass concentrations, tapered element oscillating microbalance, beta attenuation, and a hybrid of beta attenuation and light scattering, have been widely used in conjunction with an impactor or cyclone. The $PM_{2.5}$ is expected to be heterogeneously distributed in both indoor and outdoor atmospheres because of its many direct emission sources and secondary formation processes. High-density multi-point observations are needed to understand the source, transport, and sink of $PM_{2.5}$ and its effects on climate, air quality, and human health. However, the above standard instruments are not suitable for these observations because of their relatively high cost, large size, high power consumption, and low temporal resolution (typically >1 h). The development and application of a low-cost palmtop-sized $PM_{2.5}$ sensor, which can measure $PM_{2.5}$ mass concentrations precisely and accurately, is important to achieve high-density multi-point observations. A palmtop-sized $PM_{2.5}$ sensor with low power consumption and high temporal resolution can also be applied to mobile measurements for personal exposure studies.

In this study we have developed PM2.5 instruments which is suitable for the observation in Mongolia. For accurate measurement of $PM_{2.5}$ mass concentrations, the sensor is designed to be able to estimate particle sizes from the distributions of light scattering intensities from single particles and to detect small particles with diameter as small as ~0.3 μm by reducing background noise. The performance of the sensor is evaluated based on laboratory and field tests. The validation of the compact PM2.5 sensors was performed by simultaneous measurements with large beta-attenuation monitor (BAM) instruments in Nagoya. Good correlation factors were obtained. Even when the PM2.5 concentrations were high than 1000 μg m^{-3} in New Delhi, India, good correlation was obtained.

We (Sonomdagva and Matsumi) have installed a small PM2.5 instrument in National University of Mongolia in Ulaanbaatar and have measured the PM2.5 concentration since August, 2016 (Fig. 2). This time we have installed the instruments in more three sites in in Ulaanbaatar, Mongolia. Figure 1 shows the new observation site in the ger area. Very high concentrations of PM2.5 have been observed by our instrument (Fig. 2). Now we are analyzing the observation results.

Figure 1　New observation site in the ger area in Ulaanbaatar, Mongolia.

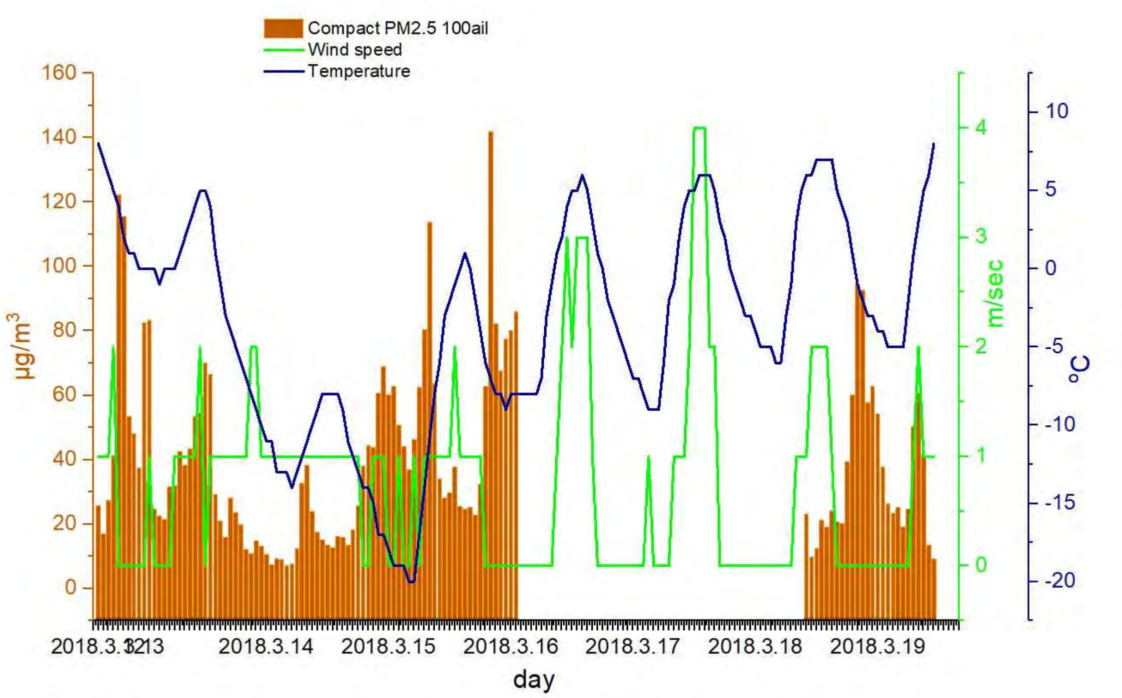

Figure 2　Observation result of PM2.5 in the Ger area site in Ulaanbaatar in March 2018.

Study on the formation of small-scale magnetic flux ropes in the reconnection diffusion region

Wai-Leong Teh
(Space Science Centre, Institute of Climate Change, Universiti Kebangsaan Malaysia)

Objectives

Magnetic reconnection is a prime mechanism for rapid energy conversion from magnetic field to kinetic energy in the form of plasma heating and acceleration. Magnetic flux ropes, which are of a helical and twisted magnetic field structure, are formed during magnetic reconnection. Recent in-situ spacecraft observations, for example, Magnetospheric Multiscale Mission (MMS), have found small-scale flux ropes (few ion inertial lengths) near the reconnection ion diffusion region, which is believed to be a prime region for energy conversion. Such small-scale magnetic flux ropes were found to have a significant core field at the center of the flux rope during a small guide-field reconnection, and their flux rope axis is tilted toward the reconnecting magnetic field direction. Yet, the formation of such small-scale flux ropes is not fully understood. Our primary objectives are to investigate the generation mechanism of small-scale flux ropes using a three-dimensional (3-D) particle-in-cell (PIC) simulation of magnetic reconnection with a small guide field and to compare the simulated flux ropes with observations.

Methods

Using supercomputer facilities at the Nagoya University to perform a 3-D PIC simulation of magnetic reconnection with a small guide field (~0.1). The 3-D PIC code is provided by T.K.M. Nakamura, who is one of our team members of this joint research program and is responsible for the simulation setup. The initial magnetic field and plasma profiles for the simulation are similar to the previous works by T.K.M. Nakamura, except that a larger simulation domain and a larger ion-to-electron mass ratio are implemented.

Results

Due to the security issues concerned by the Japanese government, the official approval for the access to the supercomputer facilities at the Nagoya University has been unexpectedly delayed and finally granted in January 2018. As a result, the 3-D PIC simulation setup is in progress yet. We have analyzed a magnetotail reconnection event seen by MMS spacecraft, where three ion-scale magnetic flux ropes were observed right after crossing a magnetic X-line. Two of which have the tilted flux rope axis toward the reconnecting magnetic field direction, a result similar to the recent MMS finding at the Earth’s magnetopause. The tilted angle more or less agrees with the prediction from the theory of the tearing instability.

Periods of stay

12 – 16 November, 2017

Publications

In progress.

Joint observations of travelling ionospheric disturbances using radar and GPS techniques

Sergii Panasenko (Department of Ionosphere Physics, Institute of ionosphere, Kharkiv, Ukraine)

1. Purpose

Coordinated investigations of traveling ionospheric disturbances (TIDs) are very important for better understanding coupled dynamics of atmosphere and ionosphere. TIDs and acoustic-gravity waves (AGWs) play crucial role in energy and momentum transfer, contribute to their budget and effect on the satellite orbits and radio propagation characteristics. The comprehensive joint study of such wave processes enables to improve atmospheric and ionospheric models, provide new insights into mechanisms and channels of Earth – atmosphere – ionosphere interactions and draw up recommendations to mitigate the TID negative influence on satellite and telecommunication systems.

This project aimed to detect and estimate the characteristics of TIDs using two complementary incoherent scatter (IS) and GPS receiver techniques providing three-dimensional structure of wave processes in electron density. In addition, IS technique yields altitude profiles of TIDs in electron and ion temperatures and vertical plasma drift velocity. The main attention was paid to study of large- and medium-scale TIDs induced by the total solar eclipse of 20 March 2015. For result obtaining, we used the data of Kharkiv IS radar and GPS networks deployed in Western and Northern Europe. The methods and software for joint IS and GPS data analysis were developed which gave possibility to assure consistency and correct interpretation of results.

2. Facilities and methods

We used the data of Kharkiv IS radar (49.6 N, 36.3 E) located in Ukraine which is the only one at middle latitudes of the Central Europe. GPS / TEC data over Europe were acquired with dense European and Finnish GPS networks. The developed method includes four stages allowing characterization of altitude and spatial TID characteristics. The noise and interference removal procedures as well as interpolation of GPS data gaps are made at first. At second stage, we evaluate and extract long term trends to obtain temporal fluctuations in the ionospheric parameters falling into AGW / TID period range (5 – 120 min). Further, spectral analysis is performed to detect prevailing TID periods. It followed by band-pass filtration in time domain and separation of large- and medium-scale TIDs by applying two-dimensional least-squares method to differential TEC variations. Finally, statistical analysis is made for estimation of the amplitudes and propagation characteristics of TIDs.

3. Results

The main results obtained within collaborative project can be summarized as follows.

1. We conducted coordinated measuring campaigns including Kharkiv and Millstone Hill IS radars, Shigaraki MU radar during magnetically quiet and disturbed time intervals. Radar data will be analyzed together with world GPS /TEC data for TID investigations.

2. During solar eclipse of 20 March 2015, we detected both large- and medium-scale TIDs having similar periods about 50 – 60 min. Large-scale TIDs have prevailing north-east and south-east direction over Central and Northern Europe, respectively. Medium-scale TIDs propagated southeastward over both regions. The TIDs with such periods were observed over Ukraine too. The downward phase progression indicates the sources of waves to be located in the lower atmosphere.

3. The map of LSTID horizontal phase velocity vectors is created to demonstrate the main features of large-scale wave propagation.

4. Period of stay in ISEE and activities

I have visited ISEE and worked with Dr. Otsuka during August – September, 2017. During staying in Japan, I took part in seminar, symposium and conference, participated in MU radar observations and met with team members for discussion of methods and obtained results. I would like to express my gratitude to ISEE staff for hospitality and creating excellent conditions for my work as well as to all team members for assistance in method development and result obtaining and interpretation. I hope for continuation of such fruitful collaborative work.

5. Sustainability

The applied approach and developed methods provide sustainable progress in the study of TIDs observed during high energy natural and artificial processes. We plan to investigate such disturbances in the periods of geomagnetic storms, solar terminator moving, meteorological front passage, sudden stratospheric warmings, etc. For cooperation extension, the follow-up project was submitted. It devoted to joint study of TIDs driven by artificial sources, namely, ionospheric heater operation and rocket launches as well as evaluation of similarities and differences of naturally and artificially induced TIDs.

6. List of publications and presentations

1. Sergii V. Panasenko, Yuichi Otsuka, Max Van de Kamp, Leonid F. Chernogor, Takuya Tsugawa, Michi Nishioka. Observation and Characterization of Traveling Ionospheric Disturbances Induced by Solar Eclipse Using Incoherent Scatter Radars and GPS Networks. Journal of Atmospheric and Solar-Terrestrial Physics. (**in progress**)

2. S. Panasenko, Y. Otsuka, M. Yamamoto, I.F. Domnin. Study of travelling ionospheric disturbances in the European and Japanese longitudinal sectors with Kharkiv incoherent scatter and MU radars. 11-th MU Radar / Equator Atmospheric Radar Symposium. RISH, Kyoto University, Uji Campus, Uji, Kyoto, Japan. 07 – 08/09/ 2017.

3. S.V. Panasenko, Y. Otsuka, T. Tsugawa, M. Nishioka. AGW / TID events over Europe during solar eclipse of 20 March 2015. Mesosphere-Thermosphere-Ionosphere (MTI) Research Conference. NICT, Tokyo, Japan. 12 – 13/09/2017.

4. S.V. Panasenko, D.V. Kotov, L.Ya. Emelyanov, L.F. Chernogor, O.V. Bogomaz, S.V. Katsko, A.E. Miroshnikov, I.F. Domnin. Ionospheric research in Ukraine using Kharkiv incoherent scatter facility. Ionospheric and Magnetospheric Research Seminar. ISEE, Nagoya University, Nagoya, Japan. 01/09/2017.

5. Sergii V. Panasenko, Yuichi Otsuka, Max van de Kamp, Takuya Tsugawa, Michi Nishioka. Large- and medium-scale traveling ionospheric disturbances over Europe induced by solar eclipse as inferred from dense GPS network data. JpGU Meeting 2018. Makuhari Messe, Chiba, Japan. 21/05/2018.

6. Sergii V. Panasenko, Leonid F. Chernogor, Oleg V. Lazorenko, Yuichi Otsuka, Max Van de Kamp. Observations of ultrawideband signals in GPS TEC variations over Europe during solar eclipse. 9th International Conference on ULTRAWIDEBAND AND ULTRASHORT IMPULSE SIGNALS. O. S. Popov Odessa National Academy of Telecommunications, Odessa, Ukraine. 4-9/09/2018.

Joint study of particle acceleration in solar flares with MUSER and NoRH

Jing Huang (National Astronomical Observatories, Chinese Academy of Sciences)

Purpose:

In solar flares, plenty of particles are accelerated in reconnection region and they transport in solar atmosphere to produce HXR, microwave and cm-dm wavelength bursts. These bursts could be recorded by based-spaced telescope. From the observations and proposed mechanism for these bursts, we could deduce the parameters of the source regions and find more diagnose for particle acceleration, which could be helpful to understand the physical process of particle acceleration. Prof. Yihua Yan is the member of ICCON (The International Consortium for the Continued Operation of Nobeyama Radioheliograph), which began in April 2015 for continued operation of NoRH. The National Astronomical Observatories, Chinese Academy of Science (NAOC) contributes to the continued operation of NoRH (about 50 thousand per year). Jing Huang and Yin Zhang the members of NoRH Chief Observer to check the status of operation of NoRH. The joint study of the observations of both MUSER and NoRH would find new results on acceleration.

Method:

MUSER (Ming'antu Spectral Radio Heliograph) has the capability of acquiring high temporal, spatial, and spectral resolution over a wide frequency range simultaneously, which could record the bursts processes in a wide region above sunspot. It has two antenna arrays: the low frequency array at 0.4-2 GHz consists of forty 4.5-meter antenna and the high frequency array at 2-15 GHz has sixty 2.0-meter antenna. It recorded both right and left polarization signals of radio emission by spectra and image. NoRH (Nobeyama Radio Heliograph) has operated for more than twenty years, which have recorded lots of new features of solar activities and quiet sun from the images at 17 (I and V) and 34 GHz. The joint observations of MUSER and NoRH would provide us the most whole process of transportation of electrons from chromosphere to high corona. We could deduce the conditions of local plasma, magnetic field and the distribution of energetic electrons, which help us to understand the physical mechanism for acceleration and energy transfer. Radio Fine structures, like type III bursts, zebra pattern, pulsation, fiber and so on are proposed to be related with various of dynamical process in solar atmosphere. Based on the spectral structures from radio spectrometers and the locations from MUSER, we could fine more information related with acceleration and transportation of energetic electrons.

Results:

(1) We have analyzed a flare event with MUSER and NoRH data in 2014-12-17. The active region has a circular ribbon and the emission density has oscillations at about 200s before the M class flare. After the onset of the flare, the oscillations disappeared and the emission from flare region has no obvious oscillations. The microwave emission at 17 GHz and HXR emission at 25-50 Kev is located on the two parallel ribbons of the main flare region. The emission at 1.7 GHz is deviated a bit from the main flare region. All the emission related with M class flare has no oscillations. We conclude that the 200-s oscillation of active regions ribbon could be the leakage of wave of the sunspot. The reconnection of the flare may destroy the link between the circular ribbon and the sunspot, which would be the reason for the disappearance of the oscillation. And the main acceleration sites is located in the flare region.

(2) We have analyzed a prominence in the solar limb, which accompanied with a C class flare and an CME. The evolution of prominence could be divided into three phases: slow raise, fast eruption and partial ejection. The microwave emission of prominence showed that there are several local enhancements along the structure of prominence. The bright temperature of the bright spot is about 2 times higher of that of the prominence. The microwave emission at 17 and 34 GHz had equal value of bright Temperature. It may suggest that the emission of these local bright spot is optical thick. High density could be the main reason for this feature. After comparing the emission at microwave and EUV bands, it is found that both emission along the prominence has the local enhancement. It may indicate the localized heating in the flux rope. Hence, we proposed that in the prominence/ flux rope, local reconnection would take place and heat the local plasma which produce high value of bright temperature.

Main list of publications:

Proposed schedule:

From 2018/01/22-2018/02/10, Chen Xinyao visit ISEE

From 2018/02/04-2018/02/20, Huang Jing and Zhang Yin visit ISEE

Combining PMSE and wind observations to study coupling processes in the mesosphere

Ingrid Mann (UiT the Arctic University of Norway)

From February 19th until February 28th 2018 a group of two researchers from the UiT Space Physics Group visited the Institute of Space – Earth Environmental Research (ISEE) at Nagoya University. UiT's Dorota Jozwicki (PhD) and Carsten Baumann (Postdoc) were hosted by Associate Professor Satonori Nozawa from Division Ionospheric and Magnetospheric Research at ISEE.

Scientific Background:

Among the coupling processes in the solar-terrestrial system the Earth atmosphere at altitudes around 60 to 120 km is of special interest, because it is governed by solar radiative forcing from above and from below by atmospheric waves. The atmospheric waves, notably gravity, tidal, and planetary waves influence the spatial pattern of noctilucent clouds (NLC) observed optically and polar mesospheric summer echoes (PMSE) observed with radar. Both phenomena are observed during the polar summer, similar radar echoes are however also observed during the rest of the year (called PMWE, for winter echoes). The PMSE, PMWE and NLC form in the presence of mesospheric dust, but the mesospheric dust formation and its link to meteors is still an open question. Other local phenomena with wavy spatial structure are sporadic E layers and sporadic sodium layers. The goal of the collaboration is to combine PMSE observations with EISCAT VHF and with observational studies using the other instruments that are at present located at the EISCAT Tromsø site, and in particular the sodium LIDAR that is located there and used for studies of the mesosphere by Dr Satonori Nozawa. Since at present the sodium LIDAR studies are restricted to darkness, we intended to start by comparing the sodium LIDAR and PMWE observations.

Course of the visit:

In order to find a good starting point the visit started with two talks given by both visitors regarding their ongoing research. That was a presentation by Dorota Jozwicki on the radar characteristics of PMSE/PMWE and an overview of the influence of meteoric smoke on the ion chemistry of the lower ionosphere given by Carsten Baumann. These talks were followed by a presentation given by Dr Nozawa recapitulating the technical details of ISEE's LIDAR system in Tromsø as well as the scientific fields of the connection of sporadic sodium layers with ionospheric sporadic E-layers and the difficulties of the sodium ion chemistry in general.

We were introduced to the ISEE's LIDAR database and are now able to go through the different observation periods and search for common EISCAT PMWE measurements. During the research stay Dorota Jozwicki actually already started to go through the LIDAR database to identify temperature measurements during the same time of EISCAT PMWE measurements. The temperature information within the LIDAR and common PMWE volume pin down a parameter within the advanced spectral analysis of the EISCAT radar spectrum. By doing so one would get a deeper insight into the nature of the PMWE phenomenon.

The discussions on the connection between sporadic sodium layers (SSL) and sporadic E-layers (Es-layers) revealed two possible ways for collaboration. Firstly, extension of existing modeling capabilities of the Na/Na^+ chemistry and secondly investigations on the role of auroral precipitation on the SSL/Es connection. Carsten Baumann contacted researchers from the Sodankyla Geophysical Observatory to eventually include the Sodium ion chemistry into the Sodankyla Ion and Neutral Chemistry model (SIC). This model can be used in order to understand both, the connection between SSL and Es layers and the influence of auroral precipitation. However, a final decision on this way has yet to be made.

Furthermore the visitors were engaged in the institute's scientific colloquium on the hot topic of Sudden Stratospheric warmings (SSW) and the link to their influence on the equatorial ionosphere. The visit ended with more hands-on work with the EISCAT data analysis software guisdap introduced by Dr Nozawa to Dorota Jozwicki.

In the end we want to thank Satonori Nozawa and his colleagues for giving us a warm welcome at the ISEE, for enabling an enjoyable stay in Nagoya and for opening the door for fruitful collaborations now and in the future.

ISEE Work Report

Title of the Proposal: The Role of flow angle in determining geo-effectiveness of non-radial solar wind outflows associated with Co-rotating Interaction Region (CIR) like events

Principal Researchers: P. Janardhan[1], and D. Chakrabarty[1] D. Rout[1]

and

Ken'ichi FUJIKI[2]

Institutions: [1]Physical Research Laboratory, Ahmedabad, India,
[2]Institute for Space-Earth Environmental Research, Nagoya University, Japan

Schedule of the stay at ISEE

Under this proposal two researchers from PRL, India visited ISEE for interactions and discussions with ISEE researchers.

1. Janardhan P (15 May 2017 to 04 June 2017)
2. Rout D (29 October 2017 to 22 November 2017)

Aim of the Proposal:

The solar wind is primarily radial in nature with the azimuthal component of the flow typically being between 10-30 km/sec. On some occasions however, solar wind flows have been observed to be non-radial. A few studies also reveal non-radial solar wind flows associated with interplanetary coronal mass ejections (ICME's). It has been shown (Owens and Cargill, 2004) that the average non-radial or azimuthal component of the solar wind flow is ~30 km s^{-1}. It is also suggested by Pizzo, (1989) that for a co-rotating solar wind structure, the interface acts like a wall and the impinging solar wind gets deflected making it non-radial. Such non-radial solar wind flows arise as fast-moving ICMEs push solar wind plasma aside. In a CIR, the stream interface is defined by rise in solar wind velocity, sharp drop in proton density, sharp rise in proton temperature, and shear in solar wind flow and it is believed that it acts as a boundary or a transition region where the slow solar wind interacts with the fast solar wind (Forsyth and Mars, 1999). During CIR driven storm, the solar wind flow also becomes more non radial for a few hours.

Another class of highly non-radial solar wind outflows, lasting over 24 hours, are the so called solar wind disappearance events (Balasubramanian et al., 2003, Janardhan et al., 2005, 2008a, 2008b). These unusual and unique events are typically characterised by highly non-radial, low density (< 0.1 cm^{-3}), low velocity (< 350 km s^{-1}) solar wind outflows whose solar sources are small mid-latitude coronal holes located at central meridian and lying adjacent to large active regions. The degree of deviation from the radial direction also has consequences on geo-effectiveness and space weather (Rout et al, 2017). The geo-effectiveness during various solar phenomena (Interplanetary shocks, solar flares, CMEs and CIRs) have been investigated by several researchers by considering the Dst, Kp and AE indices (Alves et al., 2006, Yermolaev et al., 2012). It is also shown that IP shocks with similar upstream conditions, such as magnetic field, speed, density, and Mach number can have different geo-effectiveness, depending on their shock normal orientation and it can also reduce the ionospheric convection during nighttime (Oliveira and Raeder, 2015). It shows that the geo-effectiveness of an event can be controlled by the impact angle. It is to be noted that the merging electric field decides the magnetosphere-ionosphere coupling processes (Fejer et al., 2007). Therefore, it will be very interesting to study whether the solar wind non-radial flow influence the merging electric field and hence, the penetration of the merging electric field into the ionosphere. In addition, the aim of this proposed investigation is to address the solar origin of the non-radial flows which are not associated with any CME and CIR and how it affects the magnetosphere-ionospheric coupling. Based on an extensive study (Rout et al., 2017) of 43 CIR events during the deep solar minima of solar cycle of 23 (2006-2010), our recent result shows that the prompt penetration electric field over low latitude ionosphere can be significantly influenced by the solar wind azimuthal flow angle during CIR-induced geomagnetic storms. Further this study revealed that Z component of the interplanetary magnetic field (IMF Bz) and the equatorial electrojet (EEJ) strength are causally related to each other when the average solar wind flow being radial to within 6^0 at L1. This investigation elicits the important role of average solar wind azimuthal flowangle in determining the geoeffectiveness of CIR events and it can control the space weather impact on terrestrial atmosphere. Therefore, this study raised the question about the causes and solar sources of such extreme non-radial outflows (where the azimuthal flow angle is more than 6 degree) the in the solar wind. The aim of the present proposal is to find out such extreme events and identify the solar and the interplanetary origins associated to these events. In this investigation, the interplanetary solar wind data was taken from ACE and WIND satellites. To study the photospheric magnetic field distribution, synoptic magnetogram data from the Michelson-Doppler-Interferometer (MDI) instrument on board the Solar and Heliospheric Observatory (SOHO) is utilised. Further, using measurements of photospheric magnetic fields and potential field computations, the flows are mapped back to the Sun. This work is carried out in collaboration with Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Japan**.**

Summary of this investigation

In order to find out the origin of the extreme non-radial events, the cases of where the azimuthal flow angle of solar wind flow exceeded more 6^o for a period of 1 day or more in absence of any solar phenomena such as coronal mass ejection (CME) and/or co-rotating interaction regions (CIRs) were taken. For most of the events, the solar wind density at 1 AU was < $5cm^{-3}$ for periods of more than 1 day, similar to the well-known ''solar wind disappearance events'', which show unusual drops in solar wind density at 1 AU (<1 cm^{-3}) for prolonged periods (> 1 day). It is well known that the isotopic ratio of O^{7+}/O^{6+} can be used as a good proxy for associating solar wind outflows to either AR or CH (Liewer et al. 2004). It was shown that the solar source of this event could not be pinned down to either an AR or a CH (Janardhan et al. 2008a), as the O^{7+}/O^{6+} ratios were sometimes indicative of a CH origin and at other times indicative of an AR origin. It is seen that the O^{7+}/O^{6+} ratio is above 0.2 when the low-density flows began, suggesting thatthe solar source was an active region open field (Schrijver and Derosa, 2003). If the ratio, O^{7+}/O^{6+} = 0.2 change then there is a transition of a coronal hole (CH) source and an active region (AR) source. Sometimes it is also observed that a reverse transitionoccurs in between the CH and AR and it oscillates. The CH-AR-CH-AR type of oscillations implies that there is a constantly evolving and dynamic boundary interface. The charge state ratio O^{7+}/O^{6+} thus provides evidence that these flow periods at 1 AU represent the dynamic evolution of an open-closed field coronal hole to active region boundary and also suggests that a fast and dynamical evolutions taking place at the source regions. We thus traced back the events to the Sun, using a velocity trace back technique combined with a potential field source surface extrapolation, to pin point their solar sources. Strikingly, this exercise reveals that the events are all associated with characteristic pairing of an active regions (AR) and coronal holes (CH) located at the central meridian. Further, the dynamical evolution taking place at AR-CH complex regions were examined, using the Extreme Ultraviolet Imaging Telescope and the Michelson Doppler Imager images, that shows new emerging magnetic flux regions and coronal loops, during the trace back dates, disturbing the stable CH configurations and leading to the extreme non-radial events. Therefore, this investigation for the first time, throws light on the causative mechanism of non-radial solar wind flows not associated with CME and CIR. Based on the combined observations, it was found that a rapid evolution takes place in the CH and AR due to a process of interchange reconnection. The exact magnetic topology of the AR-CH region is complicated and it is very difficult to pinpointthe reconnection sites and locations of the opposing polarities involved (Janardhan et al. 2008a).

The manuscript (**On the origin of extremely non-radial solar wind outflows** by D. Rout, P. Janardhan, K. Fujiki, and D. Chakrabarty) is now under preparation. It will be submitted to Astronomy & Astrophysics shortly.

Solar polar fields during cycle 24 An unusual polar field reversal

It is important to mention here that this proposal also brought out another research paper while addressing the above mentioned problem. This manuscript (**Solar polar fields during cycle 24 An unusual polar field reversal by** P. Janardhan, K. Fujiki, M. Ingale, Susanta Kumar Bisoi, and Diptiranjan Rout) is undergoing minor revisions in Astronomy & Astrophysics and on the verge of acceptance. The summary of this manuscript is explained below.

It is well known that the polarity of the Sun's magnetic field reverses or flips around the maximum of each 11-year solar cycle. This is commonly known as polar field reversal and plays a key role in deciding the polar field strength at the end of a cycle, which is crucial for the prediction of the upcoming cycle. The aim of this investigation was to report a prolonged and unusual hemispheric asymmetry in the polar field reversal pattern in solar cycle 24.

We have examined the polar field reversal process from solar cycles 21–24, spanning the period between Jan. 1975 and Dec. 2016, using magnetic field measurements from NSO/KP and the constructed magnetic butterfly diagram which clearly depicts the field reversal during each solar cycle. Our study highlights the unusual nature and the significant hemispheric asymmetry of the field reversal pattern in solar cycle 24 by examining high latitude solar magnetic fields, poleward of 45^0 and 78^0. The current study shows that the field reversal in the Northern solar hemisphere was completed only by November 2014 as opposed to a recent study by Gopalswamy et al. (2016), which suggested that this process was completed by the end of 2015. It is to be noted that these authors used 17 GHz microwave images to show the absence of microwave brightness enhancement in the polar region during the prolonged zero-field polar field conditions in the Northern hemisphere following 2012 until late 2015. The difference in completion of polar field reversal in the Northern hemisphere is understood from the fact that the 17 GHz microwave emission is generally observed in the lower corona or at best in the chromospheric region, but not at the photospheric level. However, our study of the polar reversal is at the photosphere and is therefore better in pinpointing the time of completion of the polar reversal in the solar Northern hemisphere. This study also shows that the reversal occurred much earlier, in late 2014. The heliospheric signatures of this unusual polar reversal pattern, studied using synoptic maps of solar wind velocities, has shown the development of polar coronal holes in the

Northern hemisphere as late as in October 2016. Since the heliospheric measurements of solar wind velocities are made in the corona at a height higher than that of the 17 GHz microwave emission, it is, thus, expected that the time of the polar reversal pattern could be later than thetime of polar reversal known from the 17 GHz microwave brightness enhancement.

The unusual polar reversal pattern, in cycle 24, in the solar Northern hemisphere showed at least two field reversals or zero crossings of the magnetic field while the Southern hemisphere showed only a single unambiguous zero crossing or field reversal. The hemispheric asymmetry of polar field reversal is well known and well discussed by Svalgaard & Kamide (2013) wherein, the authors attributed such hemispheric asymmetry to the asymmetry in solar activity in both the hemispheres. Our study of the variation of toroidal magnetic fields showing a hemispheric asymmetry in solar activity in the sunspot belt regions lends support to the report by Svalgaard & Kamide (2013). The unusual pattern of field reversals in the Northern hemisphere in Cycle 24 can be attributed to multiple surges of solar activity after 2012 that carried the wrong magnetic flux to the solar northpole. It is to be noted that the present study veryclearly shows the occurrence of such multiple surge activity forthe solar Northern hemisphere during cycle 24.

From our study, we have seen a lower polar flux for cycle 24 as compared to cycle 23, which itself had a comparatively weaker polar field strength than the earlier cycles. The variation of polar cap fields in the latitude range 78^0-90^0 in Cycle 24 has a similar profile like in Cycle 23 which showed a very good correlation with the meridional flow speed. From the correlation of meridional flow speed and the polar cap fields, it is clear that presumably the meridional flow speed during the declining phase of Cycle 24 was much faster than the earlier Cycle 23 leading to the observed weakness of polar field strengths in cycle 24. Further, the weaker polar field strength noticed in the Northern hemisphere as compared to the Southern hemisphere can be attributed to the multiple surge activities noticed in the Northern hemisphere, which resulted in the reduced field strength due to multiple flux cancellations.

It is known that the strength of the polar field can be used as precursor for predicting the strength of the upcoming cycle. The weaker polar field strength of cycle 24 implies a weaker cycle25 in keeping with the flux transport dynamo model prediction of (Choudhuri et al. 2007) wherein, the authors used the axial dipole moments of the previous cycle to successfully predict theamplitude of the next cycle. Using the long term variations inunsigned high-latitude (45^0–78^0) solar magnetic fields (Janardhan et al. 2015), a prediction of $\sim$62 ±12 has been made for the maximum sunspot number for solar cycle 25 in the old unmodified sunspot number scale indicating a weaker cycle 25 than cycle 24. This study lends support to the prediction that the amplitude of the next cycle 25 will be weaker than the current cycle 24.

Earlier studies (Bisoi et al. 2014; Janardhan et al. 2015) have reported a steady $\sim$20 year decline, starting from the mid-1990's to the end of 2014 of solar photospheric fields in the latitude ranges 45^0-78^0. It is evident that the photospheric fields continuing to decline in the Northern hemisphere while the field strength in the Southern hemisphere has at least partially recovered and shown an increase since June 2014. It is observed that the photospheric fields in the Southern hemispherehave already approached the minimum in cycle 24, while the Northern hemisphere is still declining and has yet to approach the minimum as of the end of 2017. This asymmetry in the decline in both hemispheres and the continuation of photosphericfield decline in the north explain the prolonged zero-field condition and delayed polar reversal of the northern hemisphere. Due to the overall trend is still that of a decline and one would expect that this would continue at least until 2020, the expected minimum of the current cycle 24.

The study of solar photospheric fields and a continuation of the study of solar polar field reversal process is, therefore, of utmost importance in understanding the sun, the solar dynamo process, the solar wind and space weather, more so because of the fact that such a situation on the sun, when solar photospheric fields have been steadily declining for nearly 25 years now and there is speculation that we are probably on the verge of a grand minimum akin to the Maunder minimum (Janardhan et al. 2015; Sánchez-Sesma 2016), is unique and probably unprecedented since systematic solar observations began four centuries ago.

Publications:

1. **Solar polar fields during cycle 24 An unusual polar field reversal.**
   P. Janardhan, K. Fujiki, M. Ingale, Susanta Kumar Bisoi, and Diptiranjan Rout ***[Under minor revision, nearly accepted, 2018, A&A]***

2. **On the origin of extremely non-radial solar wind outflows** by D. Rout, P. Janardhan, K. Fujiki, and D. Chakrabarty **[Under Prepration]**

Talks:

1. **Declining solar activity: Is the sun going into hibernation? – Janardhan, P. May 2017**
2. **Magnetosphere-Ionosphere-Thermosphere System Under Varying Space Weather Conditions – Rout D., 10 November 2017**

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We are very thankful to ISEE International Collaborative Research Program for support in executing this work. We are extremely thankful to Dr. K. Fujiki for all his kind support in this collaborative work. We would also like to express our sincere thanks and appreciation to Dr. Tokumaru, Dr. Iwai and Dr. Shiokawa for the scientific discussion during the stay at Nagoya University.

Investigating Heliospheric Data Assimilation to Improve CME Arrival Predictions of MHD Codes

Dr. Angelos Vourlidas JHU/APL

I visited ISEE on Oct 12- Nov 2, 2017. My host was Dr. Kanya Kusano and my collaborators were Drs. Daikou Shiota (NICT) and Neel Savani (UMBC).

The general purpose of the visit was to investigate whether the prediction of the coronal mass ejection (CME) time of arrival (ToA) provided by MHD models can be improved by updating the model with observational data as the CME propagates into the heliosphere. Such data assimilation has never been attempted with solar/heliospheric models although it is a stable of terrestrial weather modeling.

Because of the relative short duration of this exploratory visit, we decided to focus on two specific objectives: (1) assimilate the STEREO/HI-1 data to SUSANO model for a single event to check whether it improves the ToA accuracy and (2) produce synthetic white light images from the SUSANO model.

Our initial idea to use data from the Sept 6, 2017 CME did not work because the SECCHI/HI observations were corrupted between Sep 6-7 due to onboard compression errors (all SECCHI telescopes were affected actually). We had only 2-3 images, all within 30 Rs, to work with. We decided to go after the events on March 10-13, 2017, where we have observations from both HI-1s in almost quadrature w/ Earth. We also decide to use the j-map approach for the initial comparisons with the SUSANO model.

Progress on objective 1: Unfortunately, I did not have the March 2017 SECCHI data with me. It took some time to download (we need both COR2 and HI) but I had trouble with the software to produce the j-maps. Many of the routines seems to be wired for internal NRL directories. I was not able to resolve the bugs. Also, the online j-maps from JPL archive were also missing for the exact period. So we decided to wait on this until I got better j-maps.

Progress on Objective 2: We accomplished this objective Dr. Shiota produced synthitc white light images for the March 2012 period that look quite reasonable. We did not proceed with a detailed comparison of the observations until I am able to obtain better HI images.

A considerable amount of my time was devoted in preparing and giving seminars on various CME issues at NAOJ, NICT, and ISEE. In addition, I presented information on the upcoming Parker Solar Probe mission to inform the Japanese Heliophysics community about this exciting mission to be launch on July 31, 2018.

I also advised ISEE students on the use of the data analysis software for STEREO observations.

However, our collaboration with my ISEE and NICT colleagues is ongoing. We have agree on the following steps:

* Dr. Vourlidas: provide high-quality j-maps for March 10-14, 2012 and measure CME height-time for all events. Note: there are multiple CMEs during this period.
* Dr. Vourlidas: provide the h-t data, for both CME shock and front, along the Earth direction to Dr. Shiota.
* Dr. Shiota: Check Lugaz et al. (2009) for an early example of comparing model and observed j-maps and assess whether/how the method could be improved.
* Team: discuss methods for comparing/incorporating model/obs j-maps.

These effort is ongoing. I plan to provide the j-maps and associated information by mid-april. The delay is wholly my own due to my commitments to the preparations for the Parker Solar Probe mission simulations (Feb) and the science planning for the first orbit.

Overall, it was a very enjoyable and productive visit. The administrative support and working environments were excellent. I sincerely hope that my visit marks the beginning of a hopefully long-term collaboration among the ISSE, NICT and JHUAPL groups. I am looking forward interacting my colleagues soon!

Diagnostics of mechanism of quasi-periodic pulsations in the multi-wavelength emission of solar flares

Elena Kupriyanova (Central Astronomical Observatory at Pulkovo of RAS)

The processes of primary energy release of solar flares are one of the widely discussed problems of solar physics. One reason for the slow progress in this field is the lack of observations that could provide information directly from the primary energy release site. Quasi-periodic pulsations (QPPs) observed in the broadband emission of solar flares are known as one of the tools for diagnosing energy release processes, in particular, processes associated with the electron acceleration. For example, the analysis of QPPs makes it possible to determine whether the observed brightness variations are the result of modulation of the acceleration process itself or by modulating the emission of already accelerated particles. Therefore, the purpose of the project is to identify the mechanism of QPPs during the primary flare energy release.

According the proposed work plan during my stay in ISEE from 09/05/2018 to 11/07/2018, the following studies were performed and following results were obtained.

We found a weak solar flare (GOES class C2.3) occurred on December 21, 2015 at the East limb with the unusual QPPs observed at the beginning of the impulsive phase. We analyzed data of the Broadband Microwave Spectropolarimeter (BBMS) in the range 4-8 GHz (radio astrophysical observatory of Badary), Radioheliograph (NoRH) and Radio Polarimeters (NoRP) of the Nobeyama Observatory at 17 GHz, as well as X-ray data from the RHESSI and FERMI satellites.

Analyzing the spectra of the microwave and X-ray emissions the following estimations of the parameters both thermal (3-10 keV) and non-thermal (both 26-55 keV and 4-8 GHz) emissions were obtained: temperature $T \approx 20$ MK, emission measure EM = [2−6]*10^(46) cm^(−3), source size r ≈ 10'', electron spectral index $\delta \approx 3$, peak frequency of microwave spectrum $f_{\rm peak} \approx 6$ GHz.

The following results were obtained. In-phase pulsations with a similar period of 12-15 s are found in both microwave and hard X-ray emissions. This is the signature of that the X-ray and microwave emissions are related to the same population of accelerated electrons. Moreover, the pulsations were in phase in the optically thin, and in the optically thick parts of the gyrosynchrotron spectrum. Checking the QPPs through the microwave spectrum allows to find frequency-dependent behavior of the amplitude of the QPPs: the frequency increases, the amplitude decreases. Besides, the rise time of the time profiles at higher frequencies is longer than that at the lower frequencies and that for the non-thermal component of the X-ray emission.

We compared the results of observations with parameters and characteristics of the emissions associated with various pulsation mechanisms. We suggested and tested an empirical self-consistent model of the microwave response on the injections of electrons for this event. The modeling was performed under assumptions: (i) the acceleration of electrons is the continuous process; (ii) the injection at each time is delta-function with the subsequent decay; (iii) the life-time of the electrons is defined by Coulomb collisions only. The comparison of the results of the modeling with the results of analysis of observations allowed to connect the properties of the QPPs with the quasi-periodic energy release.

The suggested empirical model is a good tool for diagnostics of energy release processes in more powerful flares.

The results of the project were presented at the conferences and seminars:

1. Kupriyanova, Kashapova, Reid, Masuda, Xu, Myagkova “Multi-wavelength observations of solar flares as basement of diagnostics of mechanism of quasi-periodic pulsations”, Fall meeting of the Astronomical Society of Japan, Hokkadio University, Japan, 11-13 September 2018
2. Kupriyanova, Masuda, Kashapova, Zhdanov «A role of the co-phased quasi-periodic pulsations in the energy release of the weak solar flare»: The 4th Asia-Pacific Solar Physics Meeting (APSPM 2017), 7–10 November 2017, Kyoto University, Kyoto, Japan
3. Kupriyanova, Kashapova, Masuda, Zhdanov «In-phased quasi-periodic pulsations as an indicator of the processes of the energy release of weak solar flares», XIII annual meeting “Plasma Physics in the Solar System”, Institute of Cosmic Researches, Moscow, Russia, 12-16 February 2018
4. Kupriyanova, Masuda, Kashapova, Zhdanov “In-phase QPPs as a tester of processes of energy release in a weak solar flare” Second Workshop “Quasi-periodic Pulsations in Stellar Flares: a Tool for Studying the Solar-Stellar Connection” ISSI, Bers, Switzerland, 26 Feb - 2 March 2018
5. Kupriyanova, Masuda, Kashapova, Xu, Reid, Myagkova “Diagnostics of mechanism of quasi-periodic pulsations in the multi-wavelength emission of solar flares”, Seminar at ISEE, Nagoya University, 12.06.2017
6. Kupriyanova, Masuda, Kashapova, Xu, Reid, Myagkova “Diagnostics of mechanism of quasi-periodic pulsations in the multi-wavelength emission of solar flares”, Seminar at ISEE, Nagoya University, 19.06.2017
7. Kupriyanova, Kashapova, Masuda, Reid, Xu, Myagkova “Multi-wavelength observations of solar flares as basement of diagnostics of mechanism of quasi-periodic pulsations”, seminar at KASI, Republic of Korea, 17.11.2017
8. Kupriyanova, Masuda, Kashapova, Zhdznov “About in-phase QPPs in broadband emission of a weak solar flare”, seminar at ISTP, Irkutsk, Russia, 23.11.2017

The paper Kupriyanova, Masuda, Kashapova, Zhdanov “In-phase quasi-periodic pulsations as a tester of processes of energy release in a weak solar flare” is preparing for publishing in a high-score scientific journal in 2019.

Data-driven magnetofrictional and MHD simulations of space-weather-effective quiet-sun filament eruptions

Antonia Savcheva (Harvard-Smithsonian Center for Astrophysics)

As the title suggests, and as outlined in my proposal, the original purpose of the joint research was to perform magnetofrcitional (MF), i.e. reduced MHD, and MHD data-constrained and data-driven simulations of large quiet-sun filaments erupting to cause major space weather events. For this purpose, before arriving at ISEE, for her first visit in May 2017, Savcheva had prepared non-linear force-free field (NLFFF) and unstable models produced with the flux rope insertion method (Savcheva et al. 2012) of the AR/QS filament observed with AIA between Aug 4-8, 2012. The models were of the two eruptions on Aug 6 and 8, 2012. Savcheva had equilibrium NLFFF models to be used as I.C. with boundary driving in data-driven MF and MHD simulations that follow the build-up of free energy towards eruption. And unstable magnetic field models, obtained by adding slightly more axial flux to the best-fit NLFFF model, to be used as I.Cs. to data-constrained MHD simulations that concentrate on the dynamics of the eruption, starting from non-equilibrium.

However, when the details of the capabilities of Inoue-san's MHD simulation were discussed when Savcheva first arrived at ISEE, it turned out that the fact that the simulation is Cartesian precludes us from studying large quiet sun filaments that extend over large portions of the solar disk, where curvature effects cannot be ignored (until the simulation is extended to the spherical domain). So, the team decided that we will keep the same methodology and goals, but instead focus on active-region-size eruptions. In particular, we were interested in quickly choosing an event that occurred in a relatively weak-field region, because this is the advantage of the flux rope insertion method - that it can be applied in regions of any field strength and still find a flux rope as long as the existence of one is supported by the observations, while Inoue-san's NLFFF code works best in strong field regions. This is how the idea of the collaboration originated.

At the time Savcheva was working on a series of NLFFFs with her students of the sigmoid that produced several eruptions in Feb 13-18, 2009 and was very well observed by Hinode/XRT and EIS and STEREO. Savcheva produced larger FOV stable NLFFF and unstable models of the Feb-13 eruption. The incorporation of the two codes was done during Savcheva's first visit in May 2017, and a stable I.C. was tested in the MHD code for relaxation.

A successful eruption from an unstable model was achieved in Inoue's MHD code during Savcheva's second visit in September 2017. During that visit we tried different FOVs and started the twist and current analysis of the simulation. This analysis on the original simulation was almost completed during Savcheva's third visit in March 2018. During that visit, Savcvheva also worked on a code for cleaning the photospheric boundary condition for the flux rope insertion method, so that the influence of noise could be reduced, as we suspected initially that could be causing some artefacts. Subsequently an analysis of the **J**x**B** forces in the box and different cross-sections showed that the simulation was adequate for further analysis. Example maps of different quantities from one time step computed with the tools implemented in Inoue-san's MHD code are shown in Fig. 1.

During that visit Savcheva also recomputed and relaxed the best-fit stable and unstable models onto larger grids for the eruptions on Feb 17 and 18, so that those eruptions can be simulated and analyzed in the same way. Inoue-san has also exported all time steps of his simulation of the Feb 13 event and a 3D QSL and twist analysis will be performed with the tools that Savcheva and Tassev have developed at the CfA (Tassev & Savcheva 2017, Tassev 2018).

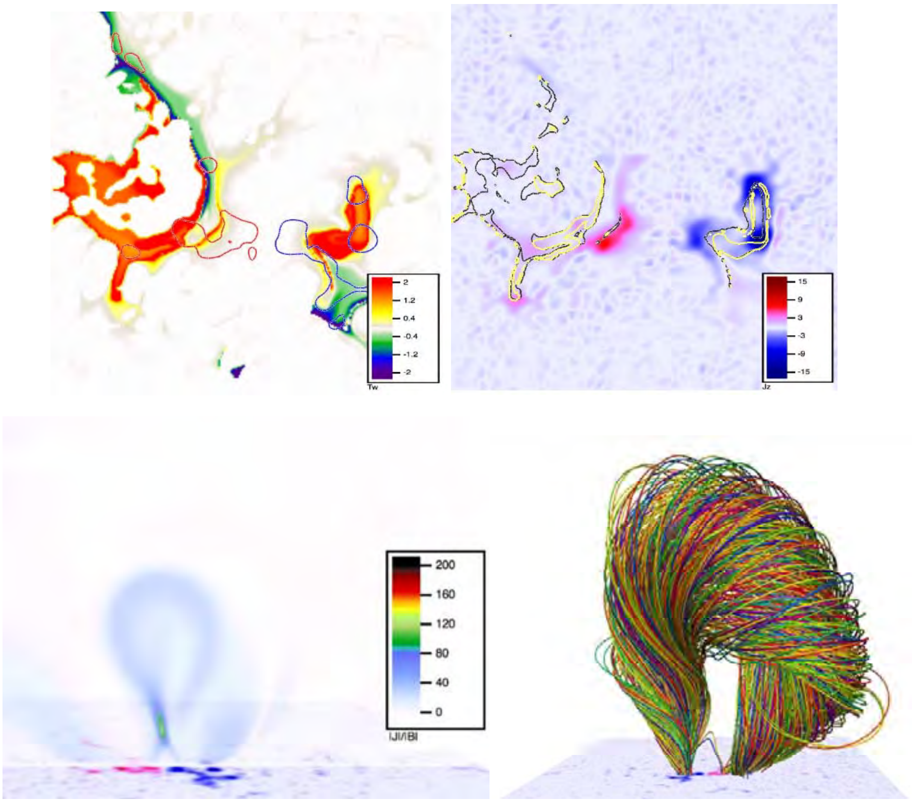

Fig.1 Top left: Twist distribution. Blue and red lines correspond to contours of negative and positive polarities (t=32.5 Alfven time). Top right: Jz distribution. Black and yellow contours correspond to contours of Tw=1.5 and Tw=2.0, respectively. Bottom left: cross section through the flux rope showing the current sheet underneath. Bottom right: Field lines of the erupting flux rope.

Project Title

Principal Investigator Name (Affiliation)
Geeta Vichare
Indian Institute of Geomagnetism
Navi Mumbai, India

Title:

Study of the propagation of substorm associated Pi2 pulsations in different local time sectors.

Objective:

To understand the magnetospheric- ionospheric dynamics using ground and topside ionospheric observations of substorm associated Pi2s at low latitudes.

Rationale/Background of study:

Pi2 pulsations are a class of ultra-low frequency oscillations of the Earth's magnetic field which are impulsive in nature. These damped oscillations have frequency between 6.6 – 25 mHz, and are generated by a source residing in the night side of the magnetosphere. Pi2s are well known for their occurrence at the time of substorm onset and intensification [Saito et al., *Planet. Space Sci* 1976]. During substorm onset, transient hydromagnetic waves are launched in the near Earth plasma sheet, due to sudden changes in the state of the magnetosphere [Southwood and Stuart, 1979], which are caused by a short circuiting of the cross-tail current to the auroral ionosphere via field-aligned currents at the time of tail current disruption. Pi2 pulsations are the manifestation of these transient hydromagnetic signals generated in the magnetosphere during substom. As Pi2 is one of the signatures of the substorm phenomena, which can be observed at ground as well as in ionosphere and magnetosphere, it can be considered as an important proxy for understanding the complex electrodynamic processes taking place in the magnetosphere during substorm and the coupling process between magnetosphere and ionosphere.

Although Pi2 is a well observed phenomenon during substorm, its origin in the magnetosphere and its propagation to ionosphere and to ground is still not completely understood. The observation of Pi2 signatures in the daytime low latitude ground stations is another interesting feature. The mechanism through which these oscillations propagate to daytime low latitudes is still an unsettled issue. Through proposed study we intent to address these key issues.

Methodology:

To investigate the spatial features of the low-latitude Pi2 oscillations, the present study combines the three-component magnetic field measurements from a dense network of low-latitude ground stations (Magnetic latitudes ≤ 50°) distributed around the globe and the Swarm multi-satellites located at day and night local times. The Swarm mission is a constellation of three satellites (Swarm-A: Alpha, Swarm-B: Bravo and Swarm-C: Charlie) of which two satellites Swarm-A and Swarm-C orbits side by side at an altitude of ∼460 km, whereas Swarm-B moves at a higher altitude of ∼520 km with its orbit shifted in longitude. This provides a unique opportunity to have simultaneous observations from the topside ionosphere at different local times.

The substorm associated Pi2 pulsations are firstly identified using magnetic field measurements (1 second resolution) from ISEE ground magnetometer data, together with AL and Wp indices. The oscillations in the compressional, toroidal, and poloidal components at satellite and H, D, and Z components at ground are characterized by estimating their coherence, amplitude, and cross-phase angle with respect to H at midnight ground observation. We identified coherent Pi2 oscillations in all the three magnetic field components at satellite and ground. The variation of these characteristic features with longitude and latitude is useful to understand the longitudinal/latitudinal extent of these waves.

Results:

The investigations of the characteristics of the Pi2 oscillations from space and ground platforms in different local times, in all the three magnetic field components at satellite and ground can provide insight into the mechanisms responsible for the observed Pi2s.

The analogous pairs of magnetic field components above and below the ionosphere (satellite compressional with ground H and satellite toroidal with ground D) found to have identical phase during night and opposite phase during day.

Poloidal component above the ionosphere is found to oscillate in-phase (out-of-phase) with the midnight ground H in the southern (northern) hemisphere at night, suggesting field aligned currents associated with substorm current wedge (SCW) as a source at night.

The phase and amplitude of H on ground undergo significant change near the dawn terminator, whereas H oscillates mostly in-phase with respect to midnight ground H at other LTs.

The oscillations in D component have phase reversal near midnight, dawn, dusk, and noon meridians with opposite hemispheres having opposite phase.

These Pi2 characteristics observed globally above and below the ionosphere suggest that the source for nighttime and daytime Pi2s are oscillating field aligned currents and ionospheric currents, respectively.

Periods of stay in ISEE:

First Visit of Dr. Geeta Vichare: 24-29 October 2017

Second Visit of Dr. Geeta Vichare: 11-13 March 2018**;** 14-16 March 2018- attended Space weather conference at Kyushu University

Visit of Dr. Neethal Thomas: 27-30 September 2017

List of Publications:

(1) "Study of low-latitude Pi2 pulsations using conjugate observations from the Swarm satellites and globally distributed ground network", Neethal Thomas, K. Shiokawa, G. Vichare (Manuscript ready for submission)

(2) "Study of storm-time currents using Swarm multi-satellite mission", G. Vichare, N. Thomas, K. Shiokawa, A.K. Sinha, A. Bhaskar (Manuscript under preparation)

List of Presentations:

Following papers presented at Space weather meeting held at Kyushu University during 14-15 March 2018

(1) Conjugate observations of the low-latitude Pi2 pulsations from longitudinally distributed ground network and Swarm satellites, N. Thomas, K. Shiokawa, G. Vichare

(2) Ring current studies using swarm measurements, G. Vichare, n. Thomas, K. Shiokawa, A.K. Sinha, A. Bhaskar

Development of Ionospheric Weather Forecasting Algorithms for GNSS Users

Dr. D. Venkata Ratnam

Professor, ECE, K L University., Guntur,India

Summary:

The Space weather refers to the conditions on the sun and thermosphere, magnetosphere, and ionosphere that can affect the performance and reliability of Global Navigation Satellite Systems (GNSS) and can endanger the human health and life (National Space Weather Programme Strategic Plan). Efficient real-time modelling of the ionospheric effects on GNSS observations is a key goal of the growing number of operational GNSS constellations. However, the most accountable errors for GNSS based technology due to space weather are Total Electron Content (TEC) induced-GNSS signal delays, scintillations and solar bursts. However, the TEC time series derived from GPS measurements is useful and provides an opportunity for developing a ionospheric forecasting tool to alert about threats due to ionospheric irregularities on their position computation. Moreover, identifying an effective multivariate forecasting technique is very essential to alert the Global Navigation Satellite System (GNSS) users under various space weather conditions. The major factors, namely, geomagnetic activity (Ap), solar Extreme Ultraviolet (EUV) irradiance (F10.7p), periodic oscillations (annual, semi-annual, terannual and biennial oscillations) and long-term trend are considered in multivariate ARMA model as input parameters along with real time TEC observations. The proposed model is twofold: first, the impact of solar, geomagnetic, trend and periodic factors on TEC has been investigated from linear model. Second, ARMA method is applied for forecasting each factor. Later, a novel ionospheric forecasting algorithm based on the fusion of Principal Component Analysis and Artificial Neural Networks (PCA – NN) method to forecast the ionospheric TEC values. Solar index (F10.7), geomagnetic index (Ap), TEC data over the span of 20 years (1997-2016) over Japan Grid Point (134.05°E and 34.95°N) are used to apply artificial intelligence methodologies.Hence, in this joint research project, a novel forecasting tool for ionospheric variations due to space weather conditions is intended for early warning messages to GNSS users and GNSS receiver designers. For this, wehave implemented the principal component analysis (PCA) to extract the most regular TEC patterns from the TEC time series to build a regionalionospheric TEC climatological model.

Methods:

- Principal Component Analysis (PCA) method, and Neural Networks (NN).
- Multivariate Singular Spectrum Analysis With Kernel-based Extreme Learning Machine Approach.
- Multivariate TEC Forecast model based on Linear time series model and Auto Regressive Moving Average Model (ARMA)

Results: Figure 1 shows the GPS measured TEC values along with the VTEC values plot obtained using NN model, PCA-NN model and IRI model for 1997-2008. The plot in blue is the TEC values plot during the training data period (1997-2007) and the plots in black, red, green and pink are the testing data periods in case of GPS measured TEC, NN model, PCA-NN model and IRI models respectively. It can be inferred from Figure1 that the TEC values forecasted using the NN algorithm does not accurately match the measured values unlike the PCA-NN model.

Figure 2 represents the annual, semi-annual, biennial and terannual components of ionospheric periodic TEC variations and trend component in 1st-5th panels of Figure 2 for training period (2009-2015) and their corresponding forecasted VTEC values using multivariate ARMA model are shown in red color during test period (2016 year) over Bengaluru GNSS station, India. Similarly, the VTEC values of solar and geomagnetic components during the training period are also given as inputs for ARMA model to forecast (1-hour ahead) their future contributions for the test period.

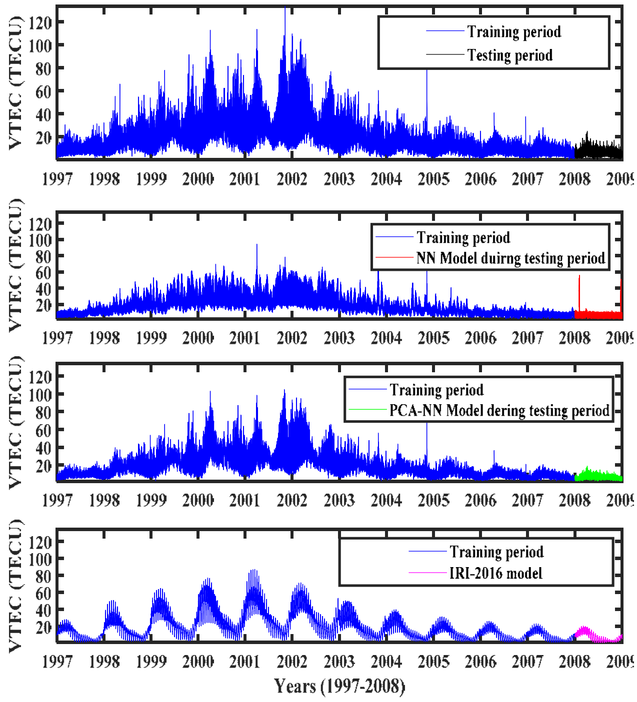

Fig.1. PCA-NN TEC forecasting results

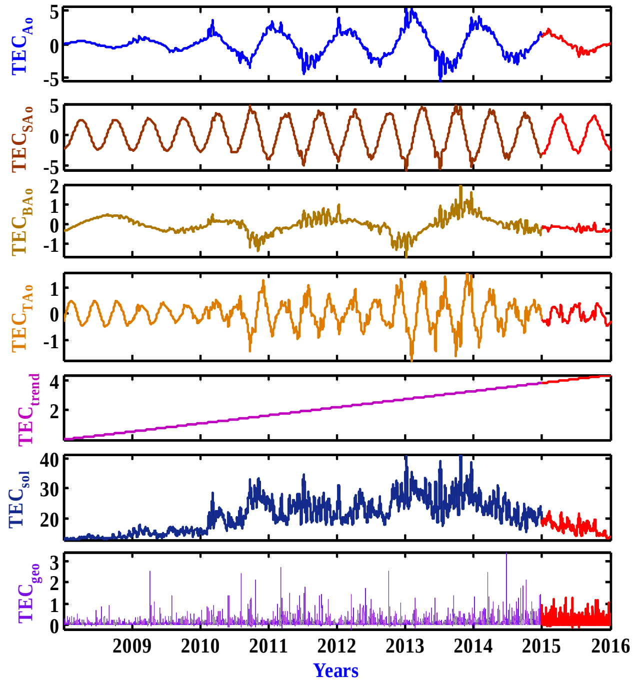

Fig.2. Forecast results using multivariate ARMA model

Periods of stay in ISEE: The stay duration (20 July 2017-20 Oct 2017)

List of Publications:1. Sivavaraprasad G, D.Venkata Ratnam, and Ostuka. Y, “Multicomponent Analysis of Ionospheric Scintillation Effects using Synchrosqueezing Technique for Monitoring and Mitigating their Impact on GNSS Signals” Journal of Navigation, 2018 (Minor Revison). (Impact Factor: 1.6)

2. D.Venkata Ratnam, Yuichi. Otsuka, G.Sivavaraprasad, and. J R K Kumar Dabbakuti, “Development of Multivariate Ionospheric TEC Forecasting Algorithm using Linear Time Series Model and ARMA over Low-latitude GNSS Station”, Advances in Space Research (Elsevier), 2018.doi.org/10.1016/j.asr.2018.03.024 (**In press**) (Impact Factor: 1.5)

3. I.Lakshmi Mallika, D. Venkata Ratnam, Y. Ostuka, G.Sivavaraprasad, Saravana Raman, “A New Hybrid Ionospheric Total Electron Content Forecasting Algorithm Based on PCA NN Method Using GEONET TEC Maps Data over Japan”, IEEE JSTARS, 2018. (Under preparation) (Impact Factor: 2.9)

4. G Sivavaraprasad, Yuichi Otsuka, Nitin Kumar Tripathi, V Rajesh Chowdhary, and D.Venkata Ratnam, Mohammed Afzal Khan“Spatial and Temporal Characteristics of Ionospheric Total Electron Content over Indian Equatorial and Low-Latitude GNSS Stations”, IEEE International Conference on Signal Processing and Communication Systems, 4-5 January-2018, K L University, Guntur, India. Published in the IEEE digital explorer (Scopus Indexed).doi.10.1109/SPACES.2018.8316326

5. J R K Kumar Dabbakuti, Otsuka Yuichi, Sahithi K and D. Venkata Ratnam, ""Modeling and Forecasting of Ionospheric TEC Variations based on Multivariate Singular Spectrum Analysis With Kernel-based Extreme Learning Machine Approach"", (Under Preparation)

List of Presentations:

D.Venkata Ratnam, Yuichi. Otsuka, J R K Kumar Dabbakuti, and Sivavaraprasad G, "Ionospheric TEC forecasting model based on linear time-series and ARMA methods over a Low latitude GNSS Station", SGEPSS fall meeting in 2017, Kyoto, Japan, 16-19. October, 2017.

Study of the causes of post-midnight field-aligned irregularity at magnetically low latitudes using simulations

Dao Ngoc Hanh Tam (Ho Chi Minh City Institute of Physics)

I. Objectives

We aim to find the generating mechanisms of post-midnight FAIs at low latitudes in the solar minimum. In this study, we use Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy (GAIA) model to investigate the relationship of plasma bubble or irregularity generation at post-midnight with midnight temperature maximum (MTM) and tidal waves. We compare GAIA model with the observational data to reveal the physical mechanism of post-midnight plasma irregularities in equatorial and low-latitude regions.

II. Methodology

Based on GAIA model, we examined the Growth rate of Rayleigh-Taylor instability (GRT) at magnetic equator. The factors contributing to the GRT around midnight at magnetic equator have been estimated considering the upward ExB drift caused by the eastward electric field (E) and magnetic field (B), with the g/υ_{in} drift driven by gravitational acceleration where υ_{in} is the ion-neutral collision frequency. It is found that the enhancement of GRT around midnight caused by the ascent of the altitude of bottom-side of F-layer (h'F) through increasing g/υ_{in}, and that the ascent of h'F is attributed to the relatively weak westward electric fields. The enhancement of h'F related to the neutral winds contributes to the generation of plasma bubbles at around midnight. We tried to examine the effect of neutral wind, temperature and the occurrence of irregularities to propose the cause of FAIs around midnight in low-latitude regions.

Based on the midnight FAIs observed in Southeast Asia, we found that post-midnight FAIs related to plasma bubble and generated around midnight. These results also show the equatorward neutral winds related to MTM possibly driven by tidal waves near magnetic equator. The equatorward winds also can uplift the bottomside of F-layer and cause the enhancement of growth rate of Rayleigh-Taylor instability. This growth rate increase causes plasma bubble as well as post-midnight FAIs inside. We use data from GAIA model to have the picture in the relation of h'F, neutral wind, and MTM.

III. Results

We found that the GRT simulated by the GAIA model enhanced at midnight during June solstice and low solar activities. The local time and seasonal variations of GRT are consistent with the occurrence rate of post-midnight FAIs observed with VHF radar in Kototabang [*Otsuka et al*., 2012]. Consequently, the GAIA model can reproduce the condition that the Rayleigh-Taylor instability likely occur. The increase of h'F causes the enhancement of g/υ_{in}, the decrease of westward electric field causes the enhancement of E/B around midnight. They could contribute to the R-T Instability around magnetic equator.

In order to investigate the relationship between neutral temperature and meridional neutral wind, we investigated the latitudinal variation of h'F, the divergence of neutral wind and temperature around midnight along 100^o longitude in summer solstices in five years. We found that the neutral wind convergence coincides with the peak of the neutral temperature e.g. MTM. In June solstices, the altitude h'F increasing at around 10^o

N near magnetic equator could relate to the convergence of neutral wind and MTM at equatorial latitude in the northern hemisphere. In other seasons of solar minimum years, MTM is also associated with the convergence of the neutral wind. We can see that the peak of MTM in June solstice occurs around 10°N of the northern hemisphere, however, locations of MTM in other seasons are near magnetic equator of the southern hemisphere. Therefore, convergence of neutral wind in June solstice can increase h'F near magnetic equator and enhance GRT. This is the reason why FAIs appear more frequent in June solstices in the solar minimum. The seasonal variation in the location of the thermospheric temperature related to the MTM corresponds to the seasonal variation of the occurrence of post-midnight FAIs.

Regarding the longitudinal variations, *Dao et al*. [2011] investigated the post-midnight irregularities observed with C/NOFS and found that the four-wave structure of ΔN/N enhancement is obvious in June and July of 2008-2009. This four-wave pattern could result from a propagating wavenumber-3, non-migrating diurnal tides. They also found that during equinoxes, the four peaks are present with more disturbed peak amplitudes but not as strong during June and July. This four-wave pattern is not evident during December. Based on the longitudinal variation of divergence of the thermospheric wind in 4 seasons taken from GAIA model, we found that the convergence of the neutral winds related to MTM also shows the four-wave structure in June solstices and equinoxes before midnight. Location of MTM in June solstice near magnetic equator in Northern hemisphere could cause the occurrence of irregularities in the low latitude regions.

For a brief summary, we found that in June solstices the increase of bottomside F-layer contributes the enhancement of GRT. The upturn of altitude h'F near magnetic equator could have resulted of convergence of equatorward neutral winds from both hemispheres, which is associated with an MTM occurring around the magnetic equator. These results suggest that the equatorward neutral winds can uplift the F layer at low latitudes and increase GRT causing irregularities around midnight. The equatorward thermospheric winds in both hemispheres could also intensify the eastward current that generates the large polarization electric field. A case study of plasma bubble in Southeast Asia [*Dao et al.,* 2017] is an observational evidence for the role of the equatorward thermospheric winds at low latitudes in the generation of post-midnight FAIs in June 2011. Theoretically, data estimated form GAIA model a suitable support for this event.

*** Reference**

1. Otsuka, Y., K. Shiokawa, M. Nishioka, and Effedy (2012), ***VHF radar observations of post-midnight F-region field-aligned irregularities over Indonesia during solar minimum***, Indian J. Radio Space Phys., 41, 199–207.

2. Dao, E., M. C. Kelley, P. Roddy, and others (2011), ***Longitudinal and seasonal dependence of nighttime equatorial plasma density irregularities during solar minimum detected on the C/NOFS satellite***, Geophys. Res. Lett., 38, doi:10.1029/2011GL047046.

3. Dao, T., Y. Otsuka, K. Shiokawa, and others (2017), ***Coordinated observations of post-midnight irregularities and thermospheric neutral winds and temperatures at low latitudes***, J. Geophys. Res. Space Physics, 122, doi:10.1002/2017JA024048.

IV. Periods of stay in ISEE

May 12 - August 5: stayed at Division 2, ISEE, Nagoya University.

V. List of publications

Not yet.

The intercalibration of IPS data sets from ISEE and Ooty Observatories

P K Manoharan, NCRA-TIFR

It is well known to the heliophysics community that the significant studies on the physical properties of the solar wind and on understanding of space weather events are being carried out based on interplanetary scintillation measurements at the Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Japan and Radio Astronomy Centre, National Centre for Radio Astrophysics (NCRA), TIFR, India. The active collaboration between the solar wind groups of ISEE and Ooty, NCRA has have provided several successful and important results on the understandings of the physical properties of the solar wind as well as the propagation characteristics of space weather events in the inner heliosphere. The IPS measurements from these institutions have provided an impressive data base for nearly four solar cycles.

The important advantage among the ISEE and Ooty IPS observations is the same observing frequency of 327 MHz, which is best suited to probe solar wind density structures at heliocentric distances in the range of ~20–250 solar radii. The main purpose of my visit was to combine the ISEE and Ooty IPS data sets and to determine the 'scintillation-distance' curve for ISEE measurements. Such curves are extremely important to determine the normalized scintillation indices, which are crucial in tracking space weather events in the Sun-Earth distance. For IPS data sets available between Ooty and ISEE, the comparison of scintillation indices could be made for several strong sources and the standardization of scintillation-distance curves could be achieved.

The trackability of the Ooty Radio Telescope is useful to get simultaneous scintillation observations between Ooty and ISEE. The comparison of a large number of simultaneous measurements available between Ooty and ISEE yielded several interesting results. Some of them are listed below:

- Scintillation index curves have been established for ISEE observations.

- For a given source, when the time difference between Ooty and ISEE observations is less than 30-min of time, the IPS power spectra from these observatories are compared and they look identical, which has been confirmed on more than one source. In excess of 90% of the simultaneous power spectra, which in fact exceed couple of hundreds, compare excellently well and the sensitivity difference between the telescopes has also been evidently shown. This result is a phenomenal one that two independent observatories separated by a large geographical position provide the identical results. It essentially validates the importance of single station IPS measurements in space weather monitoring studies.

- Despite the fact that more 90% of the simultaneous spectra match identically, few spectra between Ooty and ISEE show some remarkable difference, which has some comprehensive information on the solar wind structures passing along the individual line of sight to the radio source. More analysis will be taken up to explore the physical properties.

- This visit has also been useful for discussions with other Japanese astrophysical groups (e.g., pulsar group) to initiate more collaborative studies.

It was a scientifically fruitful visit. We plan to publish collaborative paper(s) on the above studies.