2022年度 02)ISEE International Joint Research Program 目次詳細

2022 02)ISEE / CICR International Joint Research Program List

23 件

＊所属・職名は2023年3月現在
＊Affiliation and Department displayed are current as of March 2023.

(注1):新型コロナウイルスの影響で中止／Cancelled due to COVID-19
(注2):中止／Cancelled

研究代表者 Principal Investigator	所属機関* Affiliation	職名* Job title	研究課題名 Project Title	頁 Page	備考 Remarks
Wai-Leong The	Universiti Kebangsaan, Malaysia	Senior Lecturer	Understanding the Role of Magnetic Island in Plasma Acceleration and Energy Conversion during Magnetic Reconnection	53	
Hermann J. Opgenoorth	University of Umea, Sweden	Professor Emeritus	Study of sub-auroral storm time magnetic and convection disturbances and their effects for GIC and GNSS impacts.	54	
Dedong Wang	GFZ Potsdam, Germany	Researcher	Analytical Chorus Wave Models Derived from Van Allen Probe and Arase Observations	56	
Sudarsanam Tulasiram	Indian Institute of Geomagnetism, India	Professor	Geomagnetically Induced Currents at equator due to IP shocks and solar wind discontinuities	58	(注2)
Shibaji Chakraborty	Virginia Tech, USA	Postdoctoral Associate	Influence of Solar Flare-Driven Changes in the Ionospheric Conductance and Electric Fields on HF Radar Observed Doppler Flash	59	
Ondrej Santolik	Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague, Czechia	Head of the Department	Investigation of electromagnetic waves in space plasmas	61	
Takuya Hara	Space Sciences Laboratory, University of California, Berkeley, CA, USA	Assistant Research Physicist	Multi-point spacecraft investigations on the solar erupted magnetic flux ropes propagating through the inner heliosphere	63	
Viktor Fedun	The University of Sheffield, ACSE department, UK	Professor	Analysis of solar active regions based on Lagrangian methodology	64	
Lazzara Matthew	University of Wisconsin-Madison, Space Science and Engineering Center, USA	Senior Scientist	Creation of a new high-quality long-term temperature dataset of East Antarctic meteorological observations	66	(注2)

研究代表者 Principal Investigator	所属機関* Affiliation	職名* Job title	研究課題名 Project Title	頁 Page	備考 Remarks
Sam Krucker	FHNW, Switzerland	Professor	The NoRH/RHESSI flare catalogue: time-dependent analysis	67	
Brian Welsch	University of Wisconsin - Green Bay, USA	Associate Professor	Exploring Magnetic Energies to Understand and Predict CME Onset	69	
Sae Aizawa	University of Pisa, Italy	Researcher	Investigation of the solar wind propagation and its characteristics in the inner heliosphere using multi-spacecraft, ground-based observations and numerical simulations	71	
Matthias Förster	GFZ German Research Centre for Geosciences, Germany	Senior Scientist (Retired)	Subauroral phenomena observed by SuperDARN and the Swarm satellite constellation	73	
Berger Thomas	University of Colorado at Boulder, USA	Research Staff	Investigation of Solar Polar Magnetic Fields using Hinode/SP and SDO/HMI Data	75	(注2)
Andrzej Rakowski	Silesian University of Technology, Poland	Professor	Establishment of master dendrochronological calibration curve around 660 BC using annual tree ring samples from Poland	76	
Tobias Spiegl	Free University of Berlin, Germany	Researcher	Modelling the transport and deposition of ^{14}C produced by extreme solar proton events and ^{7}Be produced by galactic cosmic rays during the satellite era	78	

(Form 2-2)

Project Title: Solar X-ray Irradiance, Temperature & Magnetic Field Variabilities of the Spatially Resolved Coronal Features

Principal Investigator Name (Affiliation): Rangaiah Kariyappa, Former Professor of Indian Institute of Astrophysics, Bangalore 560034, INDIA, kari.hemi@gmail.com

Summary of Research Report:

The main focus of this research at ISEE is to understand the solar soft X-ray irradiance variability - *Sun as a Star* - using the spatially resolved full-disk images of the Sun. We have used the observations of the full-disk images from Hinode/XRT and X-ray irradiance flux from GOES instruments. The final goal is to determine the impacts of EUV, UV & X-ray irradiance variations on Earth's Climate and space weather.

A careful study has been done to identify, track, monitor and segment the different coronal features from the full-disk images of the corona. Studied the variability of solar soft X-ray irradiance for a period of 13 years (February 2007–March 2020, covers Solar Cycle 24), using the X-Ray Telescope on board the Hinode (Hinode/XRT) and GOES (1 – 8 Å). The full-disk X-ray images observed in Al_mesh filter from XRT are used, *for the first time*, to understand the solar X-ray irradiance variability measured by GOES instrument. An algorithm has been developed in Python and applied to identify and segment the different coronal X-ray features from the full-disk images. The segmentation process has been carried out automatically based on the intensity level, morphology and sizes of the X-ray features. The total intensity, area, and contribution of all the features (active regions, coronal holes, background regions and X-ray bright points) were estimated and compared with the full-disk integrated intensity (FDI) and GOES (1 – 8 Å) X-ray irradiance measurements. It is found that the total intensity of all the features are well correlated with GOES X-ray flux. The contributions of the segmented X-ray features to FDI and X-ray irradiance variations showed that the background and active regions have a greater impact on the X-ray irradiance fluctuations. It is observed that the area and contribution of ARs and CHs varies with the phase of the solar cycle, whereas the BGs and XBPs show an anti-correlation. The area of the coronal features is highly variable suggesting that their area has to be taken into account in irradiance models, in addition to their intensity variations. The X-ray bright points (XBPs) have been identified and counted automatically over the full-disk to investigate their relation to solar magnetic cycle. The number variation of XBPs suggest for an existence of anti-correlation with the sunspot numbers. Both the number variation and the contribution of XBPs need to be considered in the reconstruction of total solar X-ray irradiance variability.

A new initiative has been done to study the temperature variability of coronal segmented features using two filters observations from Hinode/XRT by filter ratio method. Studying the variation of the temperature of the full-disk corona and of individual feature's temperature along with the solar cycle will be of interest and important to understand the Physics of the Corona.

Although an attempt has been made earlier to measure the temperature of coronal XBPs, but the variation in temperature of the full-disk image and of individual features over the solar cycle is not measured yet. Since Hinode/XRT allows capturing images of the Sun in 8 different filters, it has got a unique feature that, using 2 different filters, the temperature map of the Sun can be generated. To study the temperature variations, the Al_mesh and Ti_poly filters of full-disk composite, level-2, X-ray images of the Sun are used. Derived the integrated intensity of all the segmented features in both the filters, and generated the temperature maps of the corona using the filter ratio method. Because of the XRT straylight issue and unavailability of a good pair of images we have restricted our analysis for the

period of 4 years (February 01, 2008 - May 08, 2012, covering the starting part of the solar cycle 24).

It is a *first analysis* in using direct energy values of the coronal features from segmented solar disk to determine the temperature values of the features. It is found that the average temperature of the full-disk and of all the features show temperature fluctuations and they vary in phase with the solar activity. Although the temperature of all the features varies but the mean temperature estimated for the whole observed period of the full-disk, active regions, background regions, coronal holes, and XBPs are about 1.39 MK, 1.98 MK, 1.37 MK, 1.34 MK, and 1.52 MK respectively. The temperature values and their variations of all the features suggest that the features show a high variability in their temperature and that the heating rate of the emission features may be highly variable on solar cycle timescales.

Publication:

H. N. Adithya, R. Kariyappa, Shinsuke Imada, Kanya Kusano, J. J. Zender, L. Dame, G. Giono, Mark Weber and E. E. DeLuca, 2021, Solar Soft X-ray Irradiance Variability, I: Segmentation of Hinode/XRT Full-Disk Images & Comparison with GOES (1-8) X-ray Flux, Sol. Phys. 296, 71.

Paper submitted/under review:

H. N. Adithya, R. Kariyappa, Kanya Kusano, Satoshi Masuda, Shinsuke Imada, J. J. Zender, L. Dame, Mark Weber and E. E. DeLuca, 2022, Solar Soft X-ray Irradiance Variability, II: Temperature Variations of Coronal X-ray Features, Sol. Phys. (Under review).

Posters presented in conference:

1. Astronomical Society of India (ASI) conference, Roorkee, India (25-29 March 2022): Study of temperature variability of coronal features using filter ratio method of spatially resolved images from Hinode XRT, H.N. Adithya, Rangaiah Kariyappa, Satoshi Masuda, Kanya Kusano, Shinsuke Imada, Joe Zender, Luc Dame, Mark Weber, Edward DeLuca, Data presented: Preliminary analysis of XRT temperature maps 2008-12.
2. Hinode 15/IRIS 12 Meeting, Prague, Czech Republic, (Sep 19-23, 2022) :Number Variation of XBPs with Solar Cycle 24, Rangaiah Kariyappa, H.N. Adithya, Satoshi Masuda, Kanya Kusano, Shinsuke Imada, Joe Zender, Luc Dam´e, Mark Weber, Edward DeLuca, Data presented: Preliminary analysis of XRT xbp number variation 2008-21.
3. The 5th ISEE Symposium: Toward the Future of Space – Earth Environmental Research (Nov 15-17, 2022):Comparison of the Solar Soft X-ray Images from Hinode/XRT with SOHO/MDI & SDO/HMI Magnetograms, Rangaiah Kariyappa, H.N. Adithya, Satoshi Masuda, Kanya Kusano, Shinsuke Imada, Joe Zender, Luc Dame, Mark Weber, Edward DeLuca, Data presented: Preliminary analysis XRT - HMI comparison study for the period: 2008-12

Visits to ISEE & Other Institutions in Japan:

1. ISEE Visit under Visiting Professorship Program (Kariyappa) and SCOSTEP/SVS program (Adithya); April 16 - July 14 2022 (to work on XRT Temperature variability);
2. ISEE Visit (by Kariyappa, Joe Zender & Adithya) under International Joint Research program; Nov 28 - Dec 4 2022 (to work and discuss on Magnetic field analysis and XRT database);
3. During the visit period at ISEE, Kariyappa had visited Kyoto University (June 5-7, 2022) and Hida Observatory (June 13-15, 2022).
4. During the visits Seminars and Colloquium are given at ISEE & Kyoto University.

(Form 2-2)

Investigation of Extreme Global Total Electron Content using Statistical and Fractal Methods

Dr. D. Venkata Ratnam (KLEF Deemed to be university)

Summary:

Satellite based radio communication and navigation systems rely mostly on trans-ionospheric propagation of radio signals concerning changes by the total electron content (TEC). Therefore, it is necessary to understand the changing behavior of structural variations of ionospheric TEC for high-frequency applications besides mitigating the risks associated with the space weather impacts for navigation and aviation applications. The reference thresholds identified for moderate and severe level of threshold activity for TEC by International Civil Aviation Organization (ICAO) are 125 and 175 TECU respectively. In view of this, statistical analysis of long-term ground based Global Navigation Satellite System TEC data of 25 years (1997-2021) using extreme value theory (EVT) is performed for both quiet and disturbed day conditions for four different regions – India (5-45°N), Japan low (20-30°N), Japan mid-latitudes (30-50°N), and global regions to identify the extreme ionospheric TEC events that take place once in 11, 22, 44, 66, 88, and 110 years with 95% confidence intervals. In the present work, both generalized extreme value (GEV) using annual maxima and generalized pareto distribution (GPD) using peak-over-threshold (PoT) analysis are performed for the time series of all regions. The results illustrate that GPD works better than GEV to identify the return periods of extreme events. The moderate and severe threshold levels of TEC for different return periods are discussed according to the guidelines provided by International Civil Aviation Organization (ICAO). The analysis would be helpful in developing risk assessment and mitigation strategies for critical GNSS space weather systems.

Methods:

- Generalized Extreme Value Theory (Annual Maxima Method)
- Generalized Pareto Distributions (Block maxima method using PoT)

Results:

In the present work, both generalized extreme value distribution (GEV) using block maxima method and generalized pareto distribution (GPD) using peak-over-threshold (PoT) method are analyzed to understand the extreme behavior from the tails of distribution for both quiet and disturbed conditions of four different regions – India (5-45°N), Japan low (20-30°N), Japan mid-latitudes (30-50°N), and global regions to identify the extreme ionospheric TEC events that take place once in 11, 22, 44, 66, 88, and 110 years with 95% confidence intervals. Figs.1 and 2 and Figs. 3 and 4 illustrate the time series of quiet and disturbed data set, estimated return levels, and uncertainty plot of India and Japan mid latitude regions respectively.

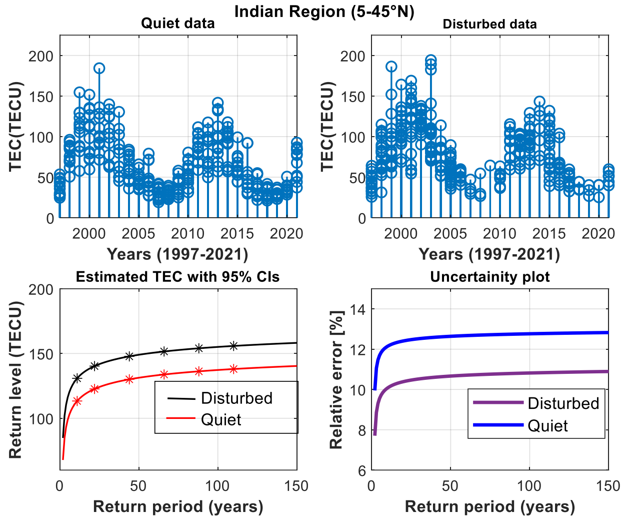

Fig.1. GEV return levels Indian region

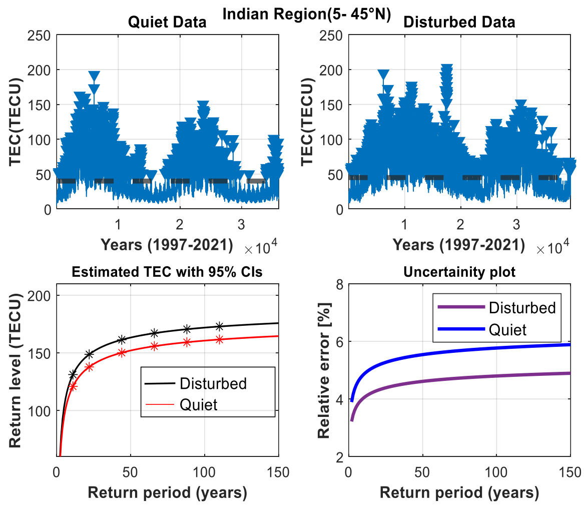

Fig.2 GPD return levels in Indian region

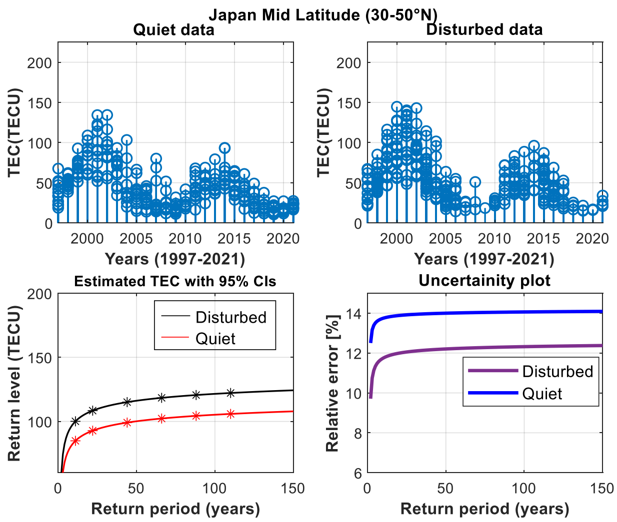

Fig.3. GEV return levels in Japan mid latitude region

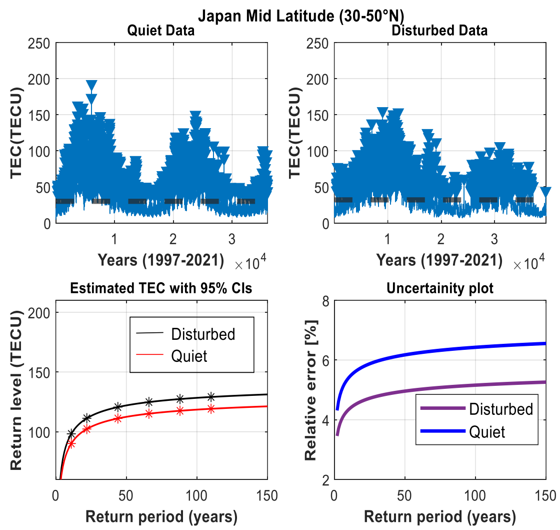

Fig.4 GPD return levels in Japan mid latitude region

Periods of stay in ISEE: The stay duration (12 October 2022 - 07 Dec 2022)

List of Publications:

1. Suneetha Emmela, D.Venkata Ratnam, Yuichi Otsuka, Atsuki Shinbori, Takuya Sori, Michi Nishioka, and Septi Perwitasari,"An Extreme Value Analysis of Long-term GNSS Ionospheric Total Electron Content Data Observed at Japan Grid point Location (34.95ºN and 134.05ºE)" (Communicated to IEEE Geoscience and Remote Sensong Letters- Under Revision).
2. Suneetha Emmela, D.Venkata Ratnam, Yuichi Otsuka, Atsuki Shinbori, Takuya Sori, Michi Nishioka, and Septi Perwitasari, "Statistical Analysis of Global and Regional Ionospheric total Electron Content (TEC) using Extreme Value Distributions" (Manuscript Under Preparation)

List of Presentations:

1. D.Venkata Ratnam, Suneetha Emmela, Yuichi Otsuka, Takuya Tsugawa, Michi Nishioka, Atsuki Shinbori, Takuya Sori, "Extreme Value Analysis of GPS Ionospheric TEC using Long-term Data", Poster presentation at ISEE Nagoya University, Japan during Nov 9-10, 2022.

(Form 2-2)

Investigation of the responses of global equatorial/low-latitude ionosphere to CIR-driven and CME-driven intense geomagnetic storms during solar cycle 24

PI: **Andrew Akala** (University of Lagos, Nigeria)

Research Summary

Purpose of Project

This study investigated solar-magnetospheric-ionospheric coupling processes that are associated with CIR-driven and CME-driven intense geomagnetic storms of solar cycle 24 and the responses of global equatorial/low-latitude ionosphere to the storms. The study diagnosed the drivers of the intense geomagnetic storms, grouping them into CIR-driven and CME-driven storms. Thereafter, the responses of TEC and irregularities over the global equatorial and low-latitude ionosphere to the CIR-driven and CME-driven storms were investigated.

2. Methods

We considered the solar and interplanetary events that are associated with the geomagnetic storms studied. We obtained solar events from the Solar Dynamics Observatory. Afterward, we derived ionospheric electric current disturbance (Diono) from ground-based magnetometer data and SYMmetric Horizontal magnetic field (SYMH) data (Akala et al., 2020). The GNSS observatory data were obtained from UNAVCO; SONEL; and International GNSS Service within the low-latitude GNSS stations. The GNSS observational data were processed by Gopi TEC processing software (Seemala, 2010). Multipath effects were eliminated by employing an elevation cut-off angle of 30°. We used the Rate Of change of TEC Index (ROTI) as a proxy for ionospheric irregularities. Finally, to characterize the thermospheric behavior during the period of investigation, we obtained and analyzed O/N_2 data from Global Ultraviolet Imager (GUVI)

4. Results

CIR-driven storms caused plasma density build-up at the interface of stream interaction regions. High-speed streams with characteristic lower density overtook slow-speed streams and compressed it to increase the magnetic field and dynamic pressure, and ultimately increased the plasma temperature and entropy, but these high responses in the interplanetary events did not translate to enhancement in the geoeffectiveness of the resultant geomagnetic storms. We also observed semi-annual-peak periodicity in the geoeffectiveness of the geomagnetic storms' occurrences, with clear highest geoeffectiveness at March equinox and least at June solstice. At night, the westward electric field caused a decrease in TEC, leading to a contraction of the EIA crests. Strong nighttime westward electric fields leads to a total coalition of the EIA structure to form a single strip of plasma density around the equator by a reversed fountain process (Arowolo et al., 2021). Storm-induced suppression in irregularities was consistently recorded over the South American, African, and Indian Ocean/Asia longitudinal sectors. Longitudinal effects of higher ionospheric dynamics over the South American sector was based on global geomagnetic field configuration with a comparatively weaker geomagnetic field in the sector (Idolor et al., 2022). At storm-time, manifestations of increased O/N_2 ratios are evident over the low-latitude ionosphere after many hours of storm onset. At storm-time, the upwelling transports heavier species from the lower thermosphere to higher altitudes leading to a relative abundance of heavier species at higher altitudes of the thermosphere and lighter species at the lower thermosphere.

References

Akala, A. O., Oyeyemi, E. O., Amaechi, P. O., Radicella, S. M., Nava, B., & Amory-Mazaudier, C. (2020). Longitudinal responses of the equatorial/low-latitude ionosphere over the oceanic regions to geomagnetic storms of May and September 2017. Journal of Geophysical Research: Space Physics, 125, e2020JA027963. https://doi.org/10.1029/2020JA027963

Arowolo, O. A., Akala, A. O., & Oyeyemi, E. O. (2021). Interplanetary Origins of Some Intense Geomagnetic Storms During Solar Cycle 24 and the Responses of African Equatorial/Low-Latitude Ionosphere to Them. Journal of Geophysical Research: Space Physics, 126(2), e2020JA027929.

Idolor, O. R., Akala, A. O., & Bolaji, O. S. (2022). African and American Equatorial Ionization Anomaly (EIA) responses to 2013 SSW event. Journal of Geophysical Research: Space Physics, 127, e2021JA029848. https://doi. org/10.1029/2021JA029848

Seemala, G. K. (2010). Rinex GPS-TEC program, version 1.45. satellite navig. sci and tech for Africa. In Presentation at a workshop held from 23rd March–9th April, 2009 at ICTP. Trieste.

Period of stay in ISEE

6 Weeks: 2 Days, 14th June 2022 – 29th July 2022.

List of Publications

1. Akala, A. O., R. O. Afolabi Y. Otsuka (2022), Responses of the African-European equatorial-, low-, mid-, and high-latitude ionosphere to geomagnetic storms of 2013, 2015 St Patrick's Days, 1 June 2013, and 7 October 2015, Advances in Space Research, https://doi.org/10.1016/j.asr.2022.10.029; 2. Manuscript #2 is ready for resubmission to Space Weather journal.

(Form 2-2)

SSW influence on the MLT dynamics, temperature, and meridional circulation

Dr. Ravindra Pratap Singh

Physical research Laboratory, Navrangpura, Ahmedabad, India, 380009

This research work was carried out in collaboration with Dr. Satonori Nozawa of ISEE, Nagoya University, Japan. Here we report the summery of the study conducted in the fiscal year of 2022.

1. Purpose

It is known that the sudden stratospheric warming (SSW) events influences the mesosphere lower thermosphere (MLT) region at different latitudes. During major SSW events it has been shown that the zonal mean zonal wind in the mid and high latitude MLT region reverses from westward to eastward preceding SSW. The mean meridional winds on these latitudes show altitude dependent changes before, during, and after major SSW events. There have been several studies to investigate the characteristics of the atmospheric waves during SSW events. It is shown that the atmospheric tides play an important role in coupling the SSW related influences to the MLT region. The sodium Doppler wind-temperature lidar observations show significant cooling and substantial depletion of the sodium layer during major SSW events. Despite the influences of SSW events on MLT region dynamics, temperature, and meridional circulation their effects remains poorly understood, primarily due to involvement of different timescale waves in the dynamical coupling of the stratosphere and MLT region. Hence, the purpose of this joint research program is to investigate MLT changes in terms of tidal variabilities, temperatures, and densities of the sodium atom during the SSW in February 2018 and January 2019.

2. Methods

In the present work we use following data sets for the two major SSW events of February 2018 and January 2019:

a. Tromso (69.6 ^{o}N, 19.2 ^{o}E) Sodium LIDAR data for February 2018 SSW event
b. Tromso: (69.6 ^{o}N, 19.2 ^{o}E) MF radar data for February 2018 and January 2019 SSW event
c. Alta (69.9 ^{o}N, 23.2 ^{o}E) Meteor radar (MR) data for February 2018 and January 2019 SSW event

3. Results

The major SSW event was observed in February 2018 with the onset date on 12 Feb 2018 defined as the first date when zonal mean zonal wind (ZMZW) at 10 hPa and 60 ^{o}N reverses from eastward to west ward with a value of -13.78 m s^{-1}. The peak temperature at 10 hPa between 60 to 90 ^{o}N with a value of 242.38 was observed on 16 Feb 2018. The 2019 SSW is also a major SSW event because the ZMZW at 60°N and 10 hPa reversed from eastward to westward on 2 Jan 2019 which is defined as the central date of this SSW event.

We have started data analysis using Na lidar obtained temperatures and column density during SSW event of February 2018. We have found contrasting behavior in Na densities and mesospheric temperature behavior during 2018 SSW event. The Na densities are found to increase accompanied by temperature increase at around 90 km altitude on 15 to 18 Feb 2018. These observations need to be further investigated using complimentary satellite/reanalysis database.

We have analyzed MR and MF wind radar data to investigate dynamical changes observed in the MLT region during Feb 2018 and Jan 2019 SSW events. The amplitudes of the diurnal tide (DT), semidiurnal tide (SDT), terdiurnal tide (TDT), and quarterdiurnal tide (QDT) has been calculated for each day and altitude region. We have found that the average zonal wind speeds reversed from westward to eastward during 12-13 Feb 2018 then remains westward during 14 to 16 Feb 2018 at the altitude region of 70 to 100 km altitude. This is followed by positive strong eastward wind from 70 to 85 km altitude and westward wind from 90 to 105 km altitude. The meridional wind remains southward during 13-14 Feb 2018 followed by northward wind during 15-18 Feb 2018. Zonal wind shows no change in DT amplitudes, SDT amplitudes are enhanced during 13-19 Feb 2018, QDT amplitudes increased during 13-19 Feb 2018 and reduced thereafter, QDT amplitude are enhanced during 13-19 Feb 2018 but above 90 km altitude and remain low below 90 km altitude.

In summary, the Na densities and temperatures at 80-90 km altitude show increase which may be due to the upward extent of the anomaly below 80 km showing cooling during Feb 2018 SSW event, which can be confirmed using further datasets (satellite/reanalysis). The tidal influences and the variation in the amplitudes of SDT, TDT, and SDT during SSW events need to be further interpreted based on the current understanding.

The efforts initiated during ISEE international joint research program in the FY 2022 is ongoing. Overall this was a very enjoyable and productive collaboration. I sincerely hope that my visit to ISEE hopefully will initiate long-term collaboration between PRL and ISEE researchers.

4. Periods of stay in ISEE

The PI have travelled to ISEE during 12 October 2022 to 15 November 2022. The work started with the proposal discussion on 14 October 2014 with Dr. Satonori and his PhD student Mr. Koyama. I have made a presentation explaining SSW influences on the meridional circulation in the MLT region and discussed about the aim of the proposal. Mr. Koyama presented his ongoing work on semidiurnal tidal variations in the high latitude MLT region. I have delivered a division seminar in the Ionospheric and Magnetospheric Research on 27 October 2022.

5. List of publications

None so far. Work is still in progress.

Estimation of solar wind speed using the multi-station IPS telescope

Linjie Chen (National Space Science Center, Chinese Academy of Sciences)

The upcoming Chinese IPS telescope at Mingantu, Inner Mongolia, China, comprising of multi-station IPS stations with one station having cylinder antennas of larger aperture sizes than the ISEE stations and two other sub stations having parabolic dishes of comparable sizes similar to the ISEE stations provides an unique opportunity to study the unrevealed details of the three dimensional structure of solar wind in the inner heliosphere. In this project, we propose to use this Chinese IPS system (one large + 2 small stations) operating at dual frequencies at 327 and 635 MHz for estimating the solar wind speed based on the computer assisted tomography (CAT) analysis and Magneto hydrodynamic (MHD) supported tomography methods developed at ISEE and compare them with the solar wind speeds estimated at ISEE and other single site IPS stations like Ooty Wide Field Array (OWFA) in India. The larger collecting area of the cylindrical antenna of Chinese IPS telescope would enable to observe many IPS radio sources, which would be used to de-convolve the LOS integration data and to retrieve the detailed intrinsic solar wind distribution. The better estimates of solar wind speed targeted using this IPS system would also be crucial for providing the link between solar magnetic field and the fast solar wind speed evolution at high solar latitudes during the upcoming solar minimum of cycle 24.

In order to carry out the studies in this project, I firstly investigated the methods of estimating the solar wind with IPS telescope, especially studied the method that is used for ISEE IPS stations. Due to the COVID-19, it is not possible to make the travel to ISEE in the first half period of this project. Both I and Dr. Kazumasa Iwai decided to make the joint studies online. I have discussed with these studies with Iwai every month via Zoom meeting. During the last year, I have tested the IPS observing data of the radio source 3C119 and 3C147 that was produced by ISEE IPS telescope, and processed the data to get the scintillation index of the signals. The results look fine, and agree with what we expected. In this way, I have understood how to process the IPS data of ISEE. Furthermore, I also processed the observed data by FAST in China, the data include several different radio source such as 3C84, CTA21, NVSS_J020346+113445, and so on. Although, I cannot confirm the scintillation index in the data that I have processed, these experiences will be quite helpful to process the upcoming new Chinese IPS system.

In the schedule, I have planned to travel to ISEE from Mar. 17 to Mar. 31, 2023, and work with Iwai together to process more IPS data observed by the ISEE multi-station telescope, as well as the FAST data, we hope some scientific results can be obtained during the periods of stay in ISEE, however, it's a pity that the travel didn't happen. Here, I have to say that the joint Research funding is really not friendly to be used for the foreign researcher. I guess the aim of this funding is to encourage the foreign researcher to travel to Japan and collaborate with the Japanese researcher, but the strict funding policy make it difficult to realize this aim. Anyway, thanks for the approval of this joint research program, and many thanks Dr. Kazumasa Iwai for the collaborations and efforts in this joint program.

ISEE joint research project, Nagoya University, Japan: Project report

Understanding vertical atmosphere-ionosphere (AI) coupling through atmospheric gravity waves

Principal Investigator Name (Affiliation)
Dr. Ajeet Kumar Maurya,
Department of Physics, Babasaheb Bhimrao Ambedkar University, Lucknow, India

Research summary,

Purpose: The proposed work is focused on the new understanding of the atmosphere-ionosphere (AI) coupling process through atmospheric waves (AWs) (gravity and acoustic waves). The sources of AWs considered in this work are of meteorological origin. These waves play a consequential role in controlling processes within the AI system by transporting energy and momentum. Despite their important role, these waves remain poorly understood, mainly because of absence of continuous monitoring technique and propagation models. The main purpose of the work is to develop continuous monitoring technique using radio remote sensing method and determine propagation and dissipation mechanism of AWs in different regions of AI system.

Method: The present work employs radio signals from Global positioning system derived total electron content detrended grided data with 15 minutes running average and plotted for every 5 minutes. The very low frequency/low frequency (3-30kHz/40-70 kHz) navigational transmitter signals from various JJI, JJY40, JJY60 and BPC transmitter. WWLLN Lightning location data is used for identification of lightning activity across the Japan region is used.

Results: We have first selected strong convection/lightning region using the WWLLN data plotted over Japan region. We have selected four days from January 2019 (low solar activity time) when lightning was over the main land Japan and analyzed VLF/LF and detrended GPS TEC data. The analysis of the VLF data on three out of four days reveals presence of short period (~1-3 minutes) wave like fluctuations during local night time over Japan.

The example of the wave fluctuations on 23rd January 2019 on JJY40 amplitude is shown below

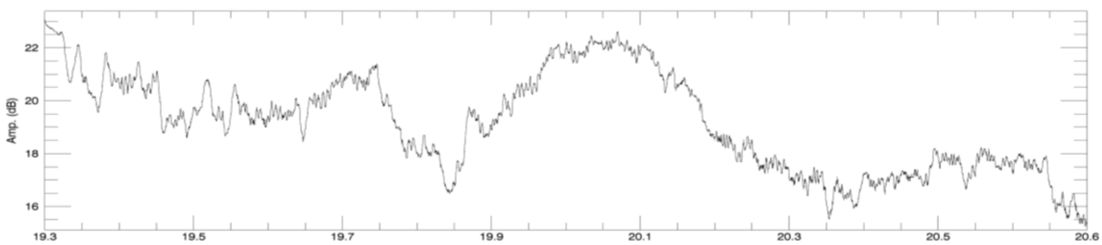

Figure 1: Showing JJY40 amplitude variation on 23 January 2019 during 19-20UT. The signal

recorded at RKB VLF station operated by OCTAVE VLF group.

A short period waves can be clearly seen and the period is substantially less than the Brunt-Vaisala period at those heights (~5 minutes). Thus, these waves are most probably acoustic waves. Further, in order to understand atmosphere-ionosphere coupling and upward propagation of these waves, we have analyzed TEC data from various GPS stations located across the Japan region. The example of detrended VTEC on 23rd January 2019 at 20 UT is shown below.

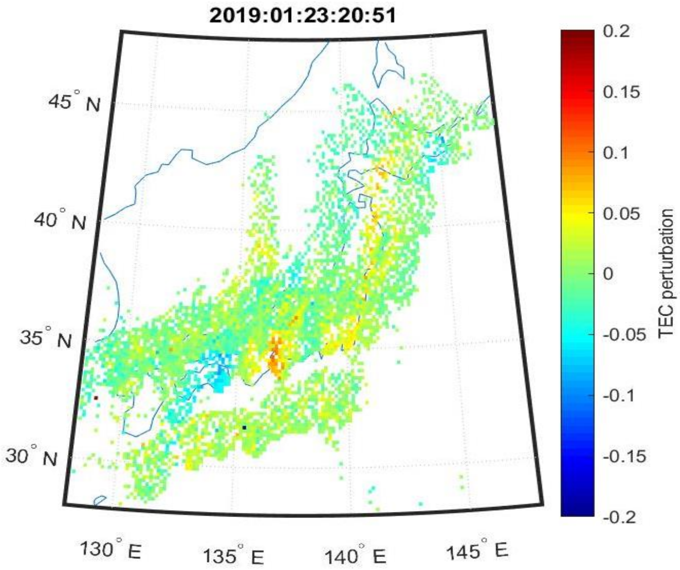

Figure 1: Showing detrended VTEC at 19UT over Japan region.

The TEC data show significant perturbation during this time. The comparison with all four days of analysis data of VLF/LF and detrended TEC does not leads to any significant correlation. Thus, it is suggested to analyze one year of VLF/LF data and further comparisons with GPS detrended TEC data.

Periods of stay in ISEE: I stayed at ISEE during 9th December 2022 to 12th January 2023. I would like to thank the Host researcher Prof. Yuichi Otsuka for all the support provided by him. He completed all the formalities for my visit and stay at Nagoya University.

List of publications: None, manuscript preparation is underway

(Form 02-2)

Developing a nowcasting capability for the occurrence of post-sunset equatorial plasma bubble in Southeast Asia

Prayitno Abadi
Research Center for Climate and Atmosphere,
Indonesian National Research and Innovation Agency (BRIN)

1. Purpose

The presence of equatorial plasma bubbles (EPBs) after sunset can significantly disrupt trans-ionospheric radio wave propagation, which is essential for modern communication systems. However, the day-to-day variability in EPB occurrence presents a significant challenge, and researchers have been investigating the factors that influence EPB generation. To provide effective space weather services, a reliable and straightforward nowcasting model is necessary to accurately predict post-sunset EPB occurrence. This nowcasting model involves forecasting EPB occurrence a few hours in advance by analyzing its controlling factors. The goal of this study is to develop a model to nowcast EPB occurrence using ground observations in Southeast Asia.

2. Methods

The simple model of EPB occurrence developed in this study is based on observations collected from ionosondes located in the equatorial region, specifically in Chumphon (CPN, 99.4°E, 10.7°N, dip lat.: 1.3°N) in Thailand, Bac Lieu (BCL; 105.7°E, 9.3°N, dip lat.: 1.5°N) in Vietnam, Cebu (CEB; 123.9°E, 10.4°N, dip lat.: 3.0°N) in the Philippines, and Guam (GUM; 144.86°E, 13.62°N, dip lat.: 5.6°N). CPN, BCL, and CEB ionosondes belong to Southeast Asian Low-latitude Ionospheric Network (SEALION), whereas GUM ionosonde belong to Global Ionosphere Radio Observatory (GIRO). The simple model of EPB used in this study is a statistical model that connects the controlling factors of EPB occurrence to the probability of its occurrence. We identified the daily changes in evening upward plasma drift (hereafter denoted as *v*) in the equatorial F region as a prominent factor that controls the probability of post-sunset EPB occurrence. This factor is caused by the pre-reversal enhancement (PRE) phenomenon. The observation of *v* is derived from the time derivative of virtual height (*h'*) at 3 MHz around sunset observed by ionosondes, while the occurrence of EPBs is identified by the occurrence of spread-F (SF) from the ionosonde observation. To build a model of the EPB occurrence probability, we implement logistic regression, which can be expressed by $y = \frac{1}{1+\exp(-z)}$ and $z = \beta_0 + \beta_1 v$, where *y* is the logistic regression that represents the probability of EPB occurrence, *z* is a linear function consisting of *v*, and β_j (j = 0 and 1) are regression coefficients. The β_j can be solved by the gradient descent technique from data observation. The parameter of *v* in the *z-function* is also defined as a predictor for plasma bubble occurrence. The dataset used in this study contains 2690 data points, where each data point consists of *v* and the EPB occurrence. The data was collected during equinox seasons (March–April and September–October) from 2003 to 2020.

3. Results

After obtaining the *z*-function $z = -2.80 + 0.16v$, logistic regression was applied to classify nights with or without EPB occurrence. A *y*-value of ≥0.5 indicated EPB occurrence, while a *y*-value of <0.5 indicated its absence (see Figure 1). The model achieved an accuracy of 0.8 and a true skill score (TSS) of 0.6. This *z*-function and corresponding y-values can be used as a reliable statistical model for daily nowcasting of EPB occurrence or non-occurrence by simply adding new input values of *v*. Technical details on the development of this nowcasting EPB model have been reported in Abadi et al. (2022).

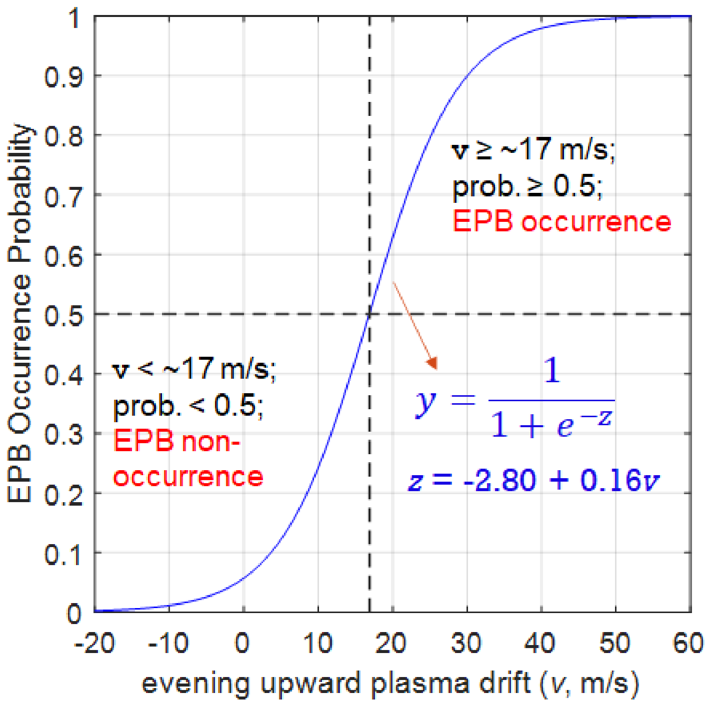

Figure 1: Logistic regression model depicting the probability of EPB occurrence as a function of the evening upward plasma drift.

4. Period of Stay in ISEE

1–31 December 2022

5. List of Publications

Abadi, P.; Ahmad, U. A.; Otsuka, Y.; Jamjareegulgarn, P.; Martiningrum, D. R.; Faturahman, A.; S. Perwitasari; Saputra, R. E.; Septiawan, R. R. (2022) Modeling post-sunset equatorial spread-F occurrence as a function of evening upward plasma drift using logistic regression, deduced from ionosondes in Southeast Asia. Remote Sens., 14, 1896, https://doi.org/10.3390/rs14081896.

6. Future work

Assessing the use of the ionosonde network in Southeast Asia for forecasting equatorial plasma bubble occurrence in the region. (Under preparation)

(Form 2-2)

Understanding the Role of Magnetic Island in Plasma Acceleration and Energy Conversion during Magnetic Reconnection

Wai-Leong Teh (Universiti Kebangsaan Malaysia)

This research project aimed to investigate the roles of magnetic islands/flux ropes in plasma heating and energy conversion during magnetic reconnection. We have performed a large-scale 2-D fully kinetic simulation of multiple island coalescence with a small reconnection guide field. Our main findings are that (1) the spatial scaling of coalescing islands plays a significant role in the plasma heating and that (2) significant energy dynamo is found at a secondary magnetic island. Results have been published in Physics of Plasmas and The Astrophysical Journal.

Periods of stay in ISEE: 28 Nov 2022 – 30 Nov 2022

Publications:

1. T. K. M. Nakamura, W.-L. Teh, S. Zenitani, T. Umeda, et al. (2023), Spatial and time scaling of coalescing multiple magnetic islands, Physics of Plasmas, 30, doi: 10.1063/5.0127107.
2. W.-L. Teh, T. K. M. Nakamura, S. Zenitani, T. Umeda, & R. Nakamura (2023), New aspects of energy conversion in magnetic island dynamics: particle-in-cell simulation of multiple island coalescence and MMS observations, The Astrophysical Journal, accepted.

(Form 2-2)

Study of sub-auroral storm time magnetic and convection disturbances

Hermann J. Opgenoorth, Umeå University, Umeå Sweden

After many COVID-enforced re-plannings and shifts of my visit to ISEE at Nagoya University, which was originally planned and applied for in late 2019, it was finally possible to carry out my research visit for the Study of sub-auroral storm time magnetic and convection disturbances, in February and March of 2023.

I arrived at ISEE on Monday February 13, 2023. The forst days I was busy with acquainting myself with the facilities ISEE, to discuss my science plans with Prof. Nishitani and other members of his group, also also with other visitors at ISEE like Prof. P. Ponomarenko, Prof. K. D. Leka, and Dr. M Förster.
I also prepared my 1 hour long colloquium lecture with the title:

The Origins and Characteristics of Three-Dimensional Current Systems in Near-Earth Space and Their Implications for Space Weather.

This colloquium, which was given in the afternoon of February 20, did set the scene for my later research activities and explained my intent in more detail to other members of the group.

In the second week of my stay, I analysed a list of 26 events of Sub-Auroral Polarisation Streams as seen in the Hokkaido-East SuperDARN radar, learned how to present and understand lin -of-sight and FoV data from the various Super-Darn radars. In this work frequent discussions with Prof. Ponomarenko were very helpful. I also requested magnetic data from suitable and valuable Japanese magnetometers along the 210 meridian chain network from Prof Yoshikawa and Dr. Uozumi (Kyushu University), which I promptly received (for all 26 events) only a few days later.

Investigating these data, and also other data from the global SuperMAG magnetometer network and Iridium satellite data from the AMPERA project on ionospheric and field-aligned currents, it became very clear that most of these SAPS event in Prof. Nishitani's list were indeed related to fast activations of ionospheric currents over stations nearby the location of SAPS in the Hokkaido radar. I also could see that many of the SAPS events were rather short-lived (much like the magnetic disturbances) and often they were restricted to only one radar FoV. I decided to concentrate my investigations to the best example, a set of SAPS observation around magnetic midnight during the well-studied St Patrick's storm on 17.3. 2015.

I interrupted my work at ISEE for a few days for a visit to the University of Kyoto, where I discussed - on February 27 and 28 respectively - Sudden Storm Commencements (SSC) and general SWx issues concerning geomagnetically induced currents (GICs) with Profs Araki and Kikuchi. The rest of the week I spent preparing and analyzing more data, a.o. new magnetograms in the same scale as the SuperDARN Hokkaido data to present initial results of my work at the ISAR-7 meeting at NIPR in Tokyo on Monday, March 6, and at the national SuperDARN Meeting (also at NIPR) on March 9.

The titles of my two presentations introducing my work at ISEE were:
The Origins and Characteristics of Three-Dimensional Current Systems at Auroral and Sub-auroral Latitudes and their Potential Impacts on The Arctic Upper Atmosphere,
Hermann J. Opgenoorth, Audrey Schillings, and Anna Naemi-Willer
and
Strong electric fields adjacent to auroral electro-jects and sub-auroral storm time electro-jets - implications of ionosphere / magnetosphere coupling on Space Weather impacts
Hermann J. Opgenoorth, Audrey Schillings, Anna Naemi-Willer N. Nishitani, P. Ponomarenko, A. Yoshikawa and T. Uozumi.

My results were discussed at several ISEE group meetings and put into context of other, wider, and longer lasting observations of SAPS. After my return to Sweden on March 12, I have begun to discuss the work achieved at ISEE with my colleagues in Sweden, Denmark, the UK and the US, in order improve on our datasets and to advance our knowledge on SAPS.

I expect to continue my studies that I began at ISEE here in Sweden and stay in close contact with Prof. Nishitani and his colleagues about my progress. I intend to make a more detailed research plan and apply for a longer period as Visiting Professor at ISEE in the autumn of 2024, in order to continue and finalise my work, but then for a visit of at least 3 months duration. I am very satisfied with the working conditions, data access and discussion opportunities provided by Prof Nishitani and his group. Even if it has not been possible to prepare any publications during this short stay, it has been very successful and it laid the ground for future continued work with several potential future publications emerging from it.

(Form02-2)

Analytical Chorus Wave Models Derived from Van Allen Probe and Arase Observations

Dedong Wang (GFZ Potsdam, Germany)

Purpose

By performing long-term radiation belt simulations, our recent paper [*Wang and Shprits*, 2019] showed that the outcome of interactions between energetic electrons and chorus waves (acceleration or loss) depends on the latitudinal distribution of the waves. This paper showed that high-latitude chorus waves can tip the balance between acceleration and loss. A decrease in high-latitude chorus waves can tip the balance between acceleration and loss toward acceleration, or alternatively, the increase in high-latitude waves can result in a net loss of MeV electrons. This study demonstrated that it is critical to include the effects of high-latitude chorus waves into terrestrial and outer planet radiation belt models. In order to extend our previous chorus wave model [*Wang et al.*, 2019] developed by using Van Allen Probe data to higher latitude, we aim to combine observations from Van Allen Probes and Arase.

Methods

We analyze the statistical characteristics of the measurements from different satellites and see whether there is systematic bias of them in the same long-term interval. We first compare the statistical root mean square Bw (magnetic intensity) from Van Allen Probes and Arase during the years when both satellites were operating. There are two years overlap between the Van Allen Probe mission and the ERG (Arase) mission. While the Van Allen Probes mainly cover the low-latitude environment, the Arase satellite covers both low- and high-latitude wave environments. We first compare the statistical characters from each mission in these two years in the latitude range covered by both satellites. Figure 1 shows an example about how to select these time periods. By doing these comparisons, we can see whether there is a systematic bias. If there is, we will find to which extent the statistical features agree with each other.

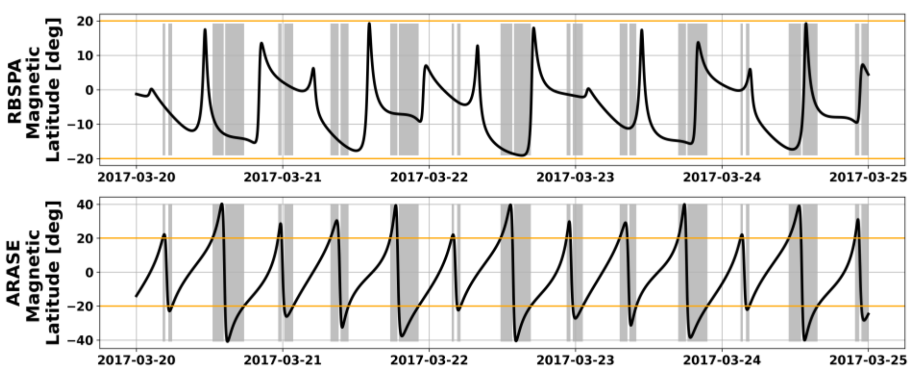

Figure 1. An example showing how we select time period to compare statistical characters of waves from RBSP-A and Arase. Data in those time intervals shaded with grey color are removed in the database to be compared.

Results

We compared the statistical root mean square Bw (magnetic intensity) from Van Allen Probes and Arase during the years from March of 2017 to October of 2018. After October of 2018, the magnetic field measurements have some problem in one component (*personal communication with Prof. Miyoshi and Dr. Nakamura*). The results are shown in figure 2.

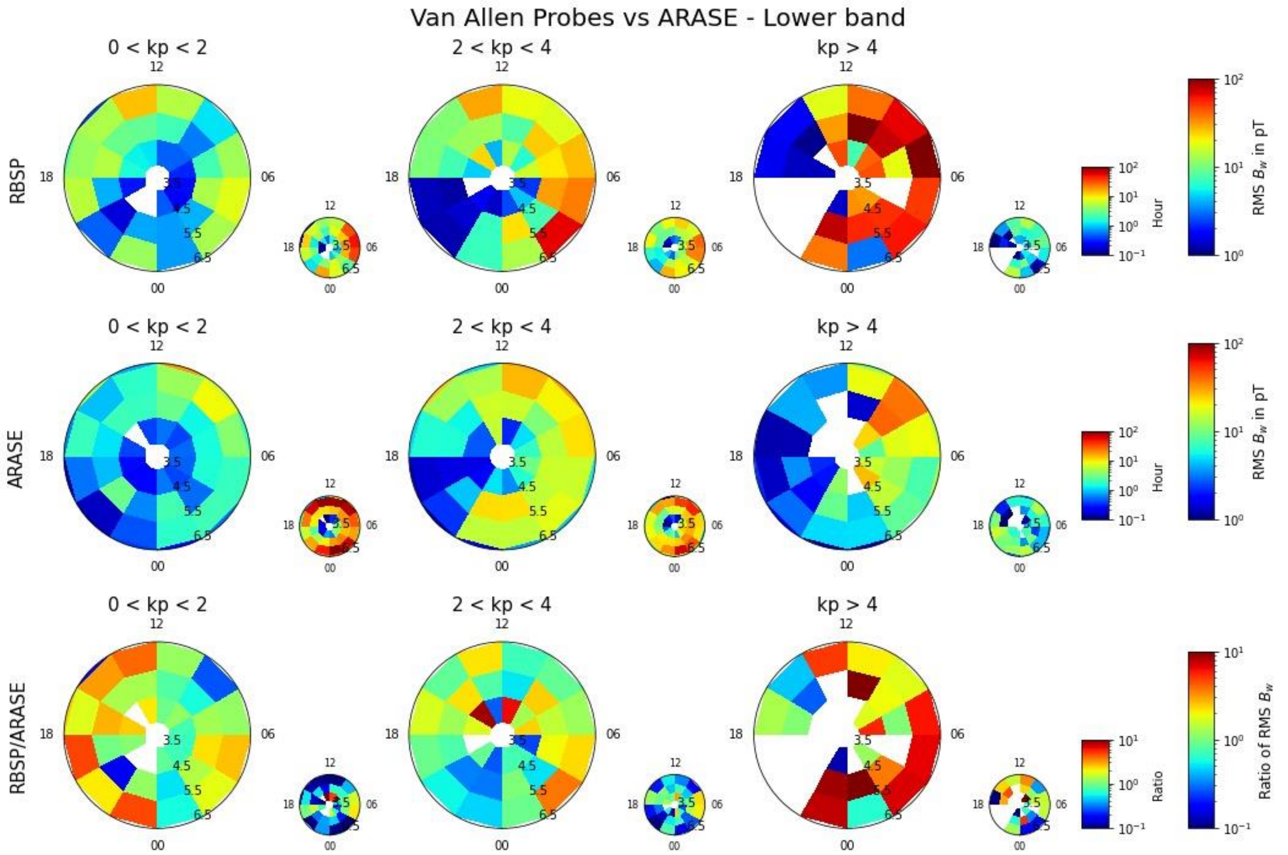

Figure 2. Different columns show statistical characteristics (RMS Bw in big panels and sampling time in small panels) of chorus waves in different geomagnetic conditions. Panels in first (second) row show results from Van Allen Probes (Arase). Panels in the third row show the ratio of RMS Bw and sampling time between RBSP and Arase.

Then we developed analytical chorus wave model by using the combination of the data from these two satellites and currently we are improving the models.

Periods of stay in ISEE

From 14 February 2023 to 17 February 2023.

List of publications

A paper about the statistical characters of chorus waves from RBSP and Arase and improved chorus wave model from this project is in preparation, to be submitted in this year

References:

Wang, D., and Shprits, Y. Y. (2019). On how high-latitude chorus waves tip the balance between acceleration and loss of relativistic electrons, *Geophys. Res. Lett., 46*.

Wang, D., et al. (2019) Analytical chorus wave model derived from Van Allen Probe observations, *J. Geophys. Res. Space Physics, 124*.

(Form 2-2)

Geomagnetically Induced Currents at equator due to IP shocks and solar wind discontinuities

Sudarsanam Tulasiram
Indian Institute of Geomagnetism, India

Cancelled

(Form 2-2)

Influence of Solar Flare-Driven Changes in the Ionospheric Conductance and Electric Fields on HF Radar Observed Doppler Flash

Shibaji Chakraborty (Virginia Tech)

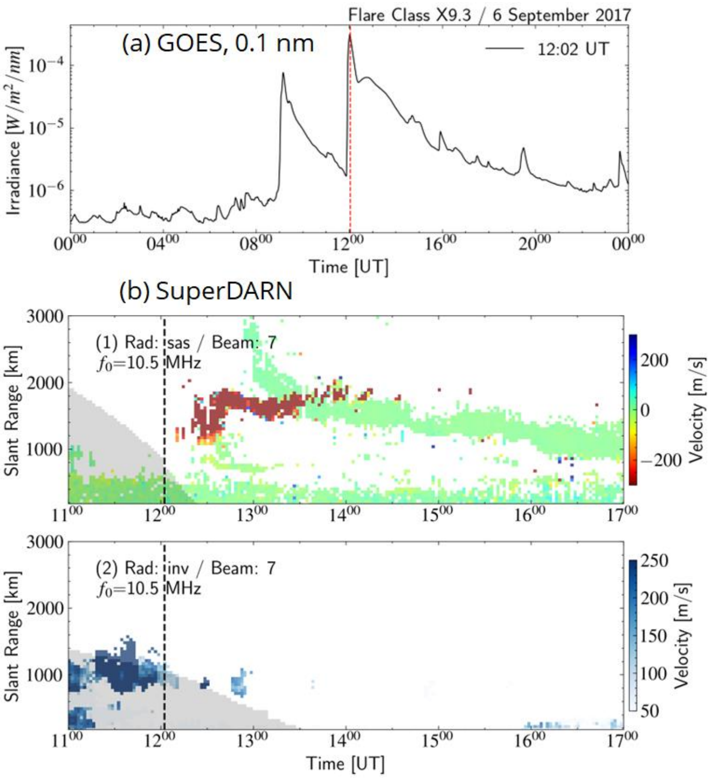

Figure 1. Solar flare irradiance and its impact on the ionosphere recorded by SuperFARN HF radars on 6 September 2017: (a) GOES flare irradiance at 0.15 nm; (b) range-time plots showing LoS Doppler velocity recorded by (b-1) Saskatoon and (b-2) Inuvik radars color coded by the color bar on left of each panel. The vertical dashed lines represent flare peak, and the gray shaded region indicates solar zenith angle greater than 90º.

A solar flare is a space weather event that causes a transient in the dayside ionospheric system by enhancing plasma density. A solar flare effect (SFE) is typically a transient in sub-auroral, middle, and low latitudes dayside ionospheric currents due to changes in the ionospheric electric field and conductivity caused by flare-enhanced photoionization [1]. However, the largest X-class flares can impact current systems at auroral and polar latitudes as well. Using ground-based radars and GNSS TEC receivers located in at high and middle latitudes in the North American sector, we analyzed an X9.3 flare on 6 September 2017. We found: (i) the SuperDARN radar located at Saskatoon (at dawn sector) observed a sudden appearance of ionospheric scatter following the flare; (ii) the SuperDARN Inuvik radar, located in the polar cap, recorded a sudden reduction in plasma flow velocity. Near the day-night terminator SuperDARN radars observed an intensification of irregularities due to the Gradient Drift Instability, GDI [2]. We speculate that flare-enhanced density gradients intensified the conditions for GDI at the day-night terminator. Reduction in plasma flow velocity observed by the Inuvik radar is likely driven by a reduction in the efficiency of mechanical energy conversion in the dayside solar wind-magnetosphere-ionosphere (SW-M-I) interaction.

References

[1] J. J. Curto, S. Marsal, E. Blanch, and D. Altadill, “Analysis of the solar flare effects of 6 september 2017 in the ionosphere and in the earth’s magnetic field using spherical elementary current systems,” Space Weather, vol. 16, no. 11, pp. 1709–1720, 2018.

[2] K. Hosokawa and et al., “Characteristics of solar flare effect in the high-latitude ionosphere as observed by the SuperDARN radars,” Advances in Polar Upper Atmosphere Research, 2000.

(Form 2-2)

Investigation of electromagnetic waves in space plasmas

Ondrej Santolik, IAP Czech Academy of Sciences, Prague, Czechia

Project period : Start date : 2022/4/1 End date : 2023/3/31

ISEE researcher : Dr.Yoshizumi Miyoshi

This project aimed at innovative joint research of electromagnetic waves in the plasma environment of the Earth. We focused on the analysis of the Japanese Arase (ERG) spacecraft mission complemented with data from other spacecraft missions and with ground based measurements. The proposed investigation was devoted to research of electromagnetic waves generated in space plasmas in a direct connection with wave particle interactions in the region of Van Allen radiation belts and electromagnetic waves generated by lightning discharges. This research not only contributed to fundamental understanding of the physics of radiation belts, but also to improvements of their models, with Space Weather applications, including radiation protection of spacecraft on the geostationary orbit.

The travel of Dr. Kolmasova and Dr. Santolik to the University of Nagoya was organized from January 30th 2023 to February 4th 2023. The ISEE International Joint Research Program funded the accommodation of the two foreign researchers on the University of Nagoya campus and on-site expenses. Owing to insufficient funding from the program both return flight tickets were purchased with funding from the Czech sources. This brief 4 day visit was consecrated to seminars with University of Nagoya students, analysis and interpretation of Arase data with a special attention to chorus waves, equatorial noise waves, and lightning whistlers, comparison with measurements of CLUSTER and Van Allen Probes, and discussions about a common publication.

List of publications in journals with referees

1. Hajoš, M., Němec, F., Demekhov, A., Santolík, O., Parrot, M., Raita, T., & Bezděková, B. (2023). Quasiperiodic ELF/VLF emissions associated with corresponding pulsations of the geomagnetic field. *Journal of Geophysical Research: Space Physics*, 128, e2022JA031103. https://doi.org/10.1029/2022JA031103
2. Bezdeková, B., Nemec, F., Manninen, J., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2023). Very low frequency whistler mode wave events observed simultaneously by the Kannuslehto station and Van Allen Probes. Journal of Geophysical Research: Space Physics, 128, e2022JA031078. https://doi.org/10.1029/2022JA031078
3. Miyoshi, Y. , I. Shinohara, S. Ukhorskiy, S.G. Claudepierre, T. Mitani, T. Takashima, T. Hori, O. Santolik, I. Kolmasova, S. Matsuda et al. (2022). Collaborative Research Activities of the Arase and Van Allen Probes, Space Science Reviews (2022) 218:38 https://doi.org/10.1007/s11214-022-00885-4
4. Dahmen, N., Sicard, A., Brunet, A., Santolik, O., Pierrard, V., Botek, E., et al. (2022). FARWEST: Efficient computation of wave-particle interactions for a dynamic description of the electron radiation belt diffusion. Journal of Geophysical Research: Space Physics, 127, e2022JA030518. https://doi. org/10.1029/2022JA030518

5. Hanzelka, M., & Santolík, O. (2022). Effects of field-aligned cold plasma density filaments on the fine structure of chorus. Geophysical Research Letters, 49, e2022GL101654. https://doi.org/10.1029/2022GL101654
6. Kaspar, P., Kolmasová, I., & Santolík, O. (2022). Model of the first lightning return stroke using bidirectional leader concept. Journal of Geophysical Research: Atmospheres, 127, e2022JD037459. https://doi.org/10.1029/2022JD037459
7. Nemec, F., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2022). Alpha transmitter signals observed by the Van Allen Probes: Ducted versus nonducted propagation. Geophysical Research Letters, 49, e2022GL098328. https://doi. org/10.1029/2022GL098328
8. Kolmasová, I., Santolík, O., Slegl, J., Popová, J., Sokol, Z., Zacharov, P., Ploc, O., Diendorfer, G., Langer, R., Lán, R., and Strhárský, I.: Continental thunderstorm ground enhancement observed at an exceptionally low altitude, Atmos. Chem. Phys., 22, 7959– 7973. https://doi.org/10.5194/acp-22-7959-2022, 2022
9. Hanzelka, M., Nemec, F., Santolík, O., & Parrot, M. (2022). Statistical analysis of wave propagation properties of equatorial noise observed at low altitudes. Journal of Geophysical Research: Space Physics, 127, e2022JA030416. https://doi.org/10.1029/2022JA030416
10. Parrot, M., Němec, F., & Santolík, O. (2022). Properties of AKR-like emissions recorded by the low altitude satellite DEMETER during 6.5 years. Journal of Geophysical Research: Space Physics, 127, e2022JA030495. https://doi.org/10.1029/2022JA030495
11. Hartley, D. P., Chen, L., Christopher, I. W., Kletzing, C. A., Santolik, O., Li, W., & Shi, R. (2022). The angular distribution of lower band chorus waves near plasmaspheric plumes. Geophysical Research Letters, 49, e2022GL098710. https://doi.org/10.1029/2022GL098710
12. Nemec, F., Santolík, O., Hospodarsky, G. B., Kurth, W. S., & Kletzing, C. (2022). Power Line Harmonic Radiation observed by the Van Allen Probes spacecraft. Journal of Geophysical Research: Space Physics, 127, e2022JA030320. https://doi.org/10.1029/2022JA030320
13. Hartley, D. P., Christopher, I. W., Kletzing, C. A., Kurth, W. S., Santolik, O., Kolmasova, I., et al. (2022). Quantifying the sheath impedance of the electric double probe instrument on the Van Allen Probes. Journal of Geophysical Research: Space Physics, 127, e2022JA030369. https://doi.org/10.1029/2022JA030369
14. Kolmašová, I., Santolík, O., and Rosická, K.: Lightning activity in northern Europe during a stormy winter: disruptions of weather patterns originating in global climate phenomena, Atmos. Chem. Phys., 22, 3379-3389, https://doi.org/10.5194/acp-22-3379-2022, 2022.

(Form 2-2)

Multi-point spacecraft investigations on the solar erupted magnetic flux ropes propagating through the inner heliosphere

Takuya Hara (Space Sciences Laboratory, University of California, Berkeley, CA, USA)

Purpose of Project:

This project is to investigate the multi-point *in-situ* spacecraft plasma and magnetic field measurements at the different heliospheric radial distances and longitudes, in order to understand a global morphology of the solar erupted magnetic flux ropes propagating through the inner heliosphere. Based on the spacecraft observations, we especially aim to address the following 3 scientific issues: the spatiotemporal evolution of the solar erupted magnetic flux rope propagating (1) radially and (2) longitudinally through the inner heliosphere, and (3) the geometrical relationship of the solar erupted magnetic flux rope observed between on the solar surface and in the interplanetary space (i.e., inner heliosphere).

Methods:

We fist investigated the physical processes responsible for the formation and eruption of the magnetic flux rope using the solar data observed by either SDO or HINODE satellites. Based on the *in-situ* spacecraft observations, we next applied the model fitting technique under the assumption that a magnetic flux rope is a cylindrical shape with a force-free, and self-similar expansion (e.g., *Marubashi and Lepping*, 2007) to estimate the flux rope geometrical axial orientation as it propagates through the inner heliosphere.

Results:

At that time when we submitted our proposal in FY2022, we were planning to investigate the ICME event erupted in April 2014, because it had been likely detected by several *in-situ* spacecraft, such as, Venus Express (at Venus), near-Earth spacecraft, and MAVEN (at ~1.28 AU *en route* to Mars). However, owing to some limitations in the *in-situ* spacecraft data, we decided to change the ICME event and the associated solar erupted magnetic flux rope in October 2021. This event was simultaneously observed by BepiColombo (at ~0.33 AU *en route* to Mercury), Solar Orbiter (at ~0.68 AU), near-Earth spacecraft, and STEREO-A (at ~0.96 AU). We succeeded in estimating the axial orientation of the solar erupted flux rope both on the solar surface and in the inner heliosphere, enabling us to discuss how it evolved through the inner heliosphere.

Periods of Stay in ISEE, Nagoya University:

I was able to overcome the COVID-19 pandemic and to visit at ISEE/Nagoya University twice in FY2022. I stayed Nagoya for 2 weeks in July 2022 and a week in January 2023, and had several in-person meetings with colleagues to discuss the ICME event erupted in October 2021.

Publications:

As of March 2023, we are now finalizing a manuscript to summarize the ICME event erupted in October 2021. Our manuscript is anticipated to be submitted to the special issue on the Earth, Planets and Space (EPS) journal. The call for papers will be announced in early FY2023.

(Form 2-2)

Analysis of solar active regions based on Lagrangian methodology

Principal Investigator
Prof Viktor Fedun
Plasma Dynamics Group
Department of Automatic Control and Systems Engineering
The University of Sheffield, Mappin Street
Sheffield, S1 3JD

The collaborative ISEE project between members of Plasma Dynamics Group, the University of Sheffield and colleagues from the Institute for Space-Earth Environmental Research is devoted to the possibility to identify the change in the topology of solar plasma flows prior appearance of the active regions (AR). This is an extensive task that requires the analysis of large data volumes of numerical and observational data with the use of velocity field identification methods e.g., DeepVel (Asensio Ramos et al., ApJ, 2017) and flow analysis (Finite-Time Lyapunov Exponents (FTLE), Shadden, S., et al., Phys. D: Nonlinear Phenomena, 2005). The flow plasma trajectories are organised by coherent structures, i.e., temporal and spatial material lines/surfaces, which provide a 'skeleton' of plasma motions. It has been shown that there is a correlation between the material surfaces and the structuring of the magnetic field. Therefore, it is possible not only to observe and understand the evolution of these lines/surfaces but also to determine the restructuring of the magnetic field. With the use of numerical simulation data of the rising of magnetic flux tube and the formation of sunspots [R2D2 code] obtained from ISEE colleagues (Dr. Haruhisa Iijima), in the framework of this project, we were able to show the presence of considerable global disturbances in the dynamics of the mesogranular cells due to the intense magnetic flux rising below the surface (i.e., prior appearance of AR). Our findings suggest that the Lagrangian analysis is a powerful tool to describe the changes in the photospheric flows due to magnetic flux emergence and this approach can be used for the prediction of AR appearance. This work was the core of the submitted research paper 'Novel approach to forecasting photospheric emergence of active regions, ApJL, 2022' and form the basis for the new study which is related to the identification of the velocity field within AR in the observational data ('Using machine learning tools to estimate photospheric velocity fields prior to the formation of active regions', MNRAS, 2023 [under final stage of preparation]). During my visit (26.11- 08.12.2022) I had a number of useful discussions with ISEE colleagues and established new research connections within and outside of ISEE (Drs. Hotta and Kaneko). During the time of the project, together with Dr. Iijima, I successfully applied for AOGS 2023 session 'ST04: Modelling Magnetohydrodynamic Processes in the Solar Atmosphere'. The research undertaken during the term of the project went beyond its main scope, i.e., the results and developed methodologies are also important to the study of collective vortical motions and energy transfer in the solar atmosphere. During my stay in ISEE I have got CIDAS account which will grant me access to the numerical data to continue our joint research work.

Publications with acknowledgment to ISEE (2022-2023)

1. Silva, S.S.A., Lennard, M., Verth, G., Ballai, I., Rempel, E., Warnecke, J., Hotta, H., Ilijima, H., Park,

S.-H., Kusano, K. and Fedun, V., Novel approach to forecasting photospheric emergence of active regions, ApJ Letters, 2022, (submitted, under review)

2. Yuyang Yuan, Y., Fedun, V., Verth, G., Silva, S.S.A., Vortex detection by Advanced Γ Method in solar plasma, ApJ Supplement, 2023 (accepted)
3. Lennard, M., Tremblay, B., Asensio Ramos, A., Hotta, H., Iijima, H., Sung-Hong Park, Silva, S.S.A., Verth, G., Fedun, V., Using machine learning tools to estimate photospheric velocity fields prior to the formation of active regions, Monthly Notices of the Royal Astronomical Society, 2023 (under final stage of preparation)
4. Tziotziou, K., Scullion, E., Shelyag, S., Steiner, O., Khomenko, E., Tsiropoula, G., Canivete Cuissa, J. R., Wedemeyer, S., Kontogiannis, I., Yadav, N., Kitiashvili, I., Skirvin, S., Dakanalis, I., Kosovichev, A., Fedun, V., Vortex Motions in the Solar Atmosphere Definitions, Theory, Observations, and Modelling, Space Science Reviews, 219, 1, 2023
5. Skirvin, S., Fedun, V., Silva, S.,Van Doorsselaere, T., Claes, N., Goossens, M., Verth, G. The effect of linear background rotational flows on magnetoacoustic modes of a photospheric magnetic flux tube, Monthly Notices of the Royal Astronomical Society, 518, 4, 6355-6366, 2023
6. Solar Vortex Tubes III: Vorticity and Energy Transport, Silva, S.S.A., Verth, G., Ballai, I., Rempel, E., Shelyag, S., Schiavo, L., Fedun, V., ApJ, 2023 (under final stage of preparation)
7. A. B. Albidah, A., Fedun, V., Aldhafeeri, A., Ballai, I., Jess, D., Brevis, W., Higham, J., Stangalini, M., Silva, S.S.A., MacBride, C., Verth, G., ApJ, 2023 (under review)

(Form 2-2)

Creation of a new high-quality long-term temperature dataset of East Antarctic meteorological observations

Lazzara Matthew
University of Wisconsin-Madison, Space Science and Engineering Center, USA

Cancelled

(Form 2-2)

The NoRH/RHESSI flare catalogue: time-dependent analysis

Säm Krucker, UC Berkeley & University of Applied Sciences Northwestern Switzerland (FHNW)

Solar flares give us a unique opportunity to make spatially resolved observations to study magnetic energy release and particle acceleration in space plasmas. The most direct diagnostics of electron acceleration are provided through radio and hard X-ray observations where we observe synchrotron emissions in the GHz range and non-thermal bremsstrahlung emissions above typically 10 keV. Observations at these two different wavelength ranges are highly complementary as synchrotron emission heavily depends on the magnetic field along which the electrons spiral, while bremsstrahlung is weighted by the ambient density where the electrons suffer collisions. The two leading solar dedicated observatories of the past decades are the Nobeyama Radioheliograph (NoRH) and the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). Starting in 2021, the STIX hard X-ray imaging spectrometer has become operational. All these observatories apply indirect imaging techniques heavily relying on sophisticated imaging reconstruction algorithms to achieve the best possible results.

During my research stay at University of Nagoya in February 2023, we worked on one of the most prominent solar radio flares observed to date, SOL2014-02-25, an X5 GOES class flare. In collaboration with Stephen White, we analyzed the morphology of this event, and we investigated the consistency of the extremely high brightness temperature with theoretical models. We concluded that this flare is at the upper limit of brightness temperature possible from theoretical consideration for solar flares. A publication is in preparation (White, Krucker, Masuda et al. 2023).

In a second part of my stay, I compiled a list of NoRP and STIX jointly observed flare to date. There are currently only 8 jointly observed flares (flares larger than GOES M class), but I will continue to update this list. The correlation between hard X-ray and microwave peak fluxes found during our earlier research stay in 2019 between NoRP and RHESSI data is also found the NoRP and STIX catalogue (see Figure 1). It is notable that extremely large flares have not yet occurred in the recent solar cycle (cycle 25), i.e. there no flares with a 17 GHz peak flux above 3000 sfu.
The NoRH/RHESSI flare catalogue: time-dependent analysis

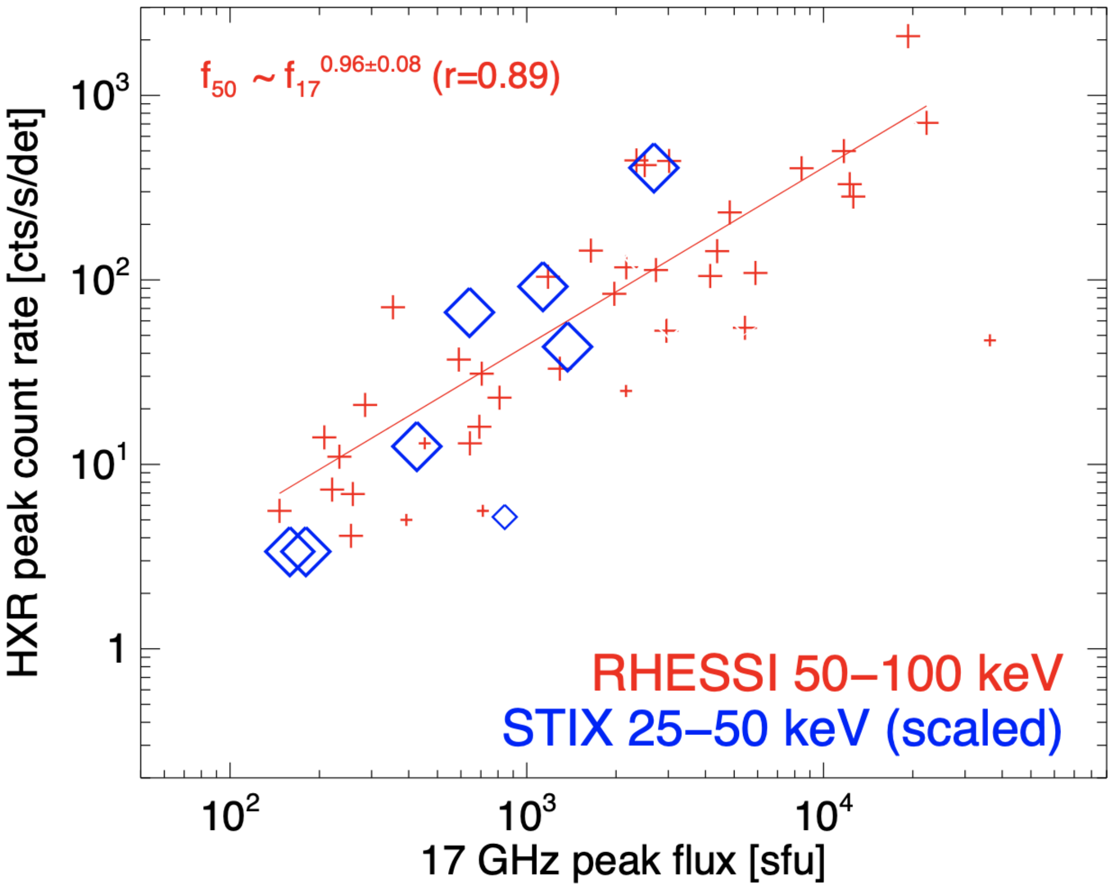

Figure 1: Correlation plot between the 17 GHz peak flux and the 50-100 keV peak count rate from NoRP and RHESSI from Krucker, White, & Masuda 2022, with the new events jointly observed by NoRP and STIX added in blue. The correlation also holds for STIX observations, as expected.

(Form 2-2)

Exploring Magnetic Energies to Understand and Predict CME Onset

Prof. Brian Welsch (University of Wisconsin – Green Bay)

Purpose: *To determine if a magnetic flux system in a region of the solar corona that possesses energy in excess of that system's partially open field energy (POFE) should erupt to produce a coronal mass ejection (CME).* In a CME, solar magnetic fields that initially close in the low corona suddenly open into the heliosphere, which can drive severe space weather disturbances at Earth. The trigger mechanisms of CMEs, however, remain unclear. At conferences from 2018 to 2021, J. Linker and collaborators argued that, based upon results of numerical simulations (which remain unpublished), CME onset occurs when the magnetic energy of a closed-field region exceeds the POFE for that flux system. The POFEs in their models, however, could only be roughly estimated, because their models' fields lack the symmetry required to determine the POFE. Our aim was to investigate idealized magnetic systems, for which the POFE can be precisely calculated, to seek out any physical mechanism(s) that might trigger dynamic evolution near the POFE limit.

Period of stay in ISEE: 14-25 November 2022

Methods: We explored magnetic structure and energy in an axisymmetric (2.5D) model of delta-spot active region (AR), comprised of a central spot and opposite-polarity moat, encircled by a disconnected, bipolar surrounding-flux (SF) system. This configuration's symmetry enables computing the POFE, by changing the boundary condition to make the AR system unipolar. An advantage in analyzing axisymmetric systems like this is that a flux function can be employed to determine equilibrium states. For this purpose, we assume the coronal field obeys the force-free Grad-Shafranov equation. Energy would be added to the either the AR or SF flux systems through shearing flows applied to the footpoints of magnetic fields within each system. Due to the free boundary between the AR and SF systems, which will evolve as magnetic shear is varied in each, determining the equilibrium state is a non-linear problem, and an analytic solution in terms of eigenfunctions of the Grad-Shafranov operator does not exist. Eigenfunction expansions can still be used, in principle, to compute a given configuration's current-free initial state (its "potential" field) and the POFE: either Bessel functions in cylindrical geometry or spherical Bessel functions in spherical geometry. Unfortunately, because these eigenfunctions are oscillatory on small scales, numerical accuracy of estimated quantities can suffer. This motivated considerable effort to identify either analytic or numerically robust solutions for the magnetic field's current-free initial state, and for that boundary condition's POFE.

Results: Three primary insights were made: two significant gains in scientific understanding, and identification of one significant difficulty. The first insight regards the non-uniqueness of coronal magnetic fields for a given normal-field boundary condition (BC), i.e., with specified B_n, subject to different additional constraints. It was suggested by Grad & Rubin (1958) and Bineau (1972) that a force-free magnetic field was uniquely determined when B_n and the normal current density J_n were both specified. Counterexamples have been reported (e.g., Kusano et al. 1996, Hu 2004); in these cases, the different fields that match the common BCs on both B_n and J_n differ in relative magnetic helicity content, H. The proposed spontaneous evolution of a flux system toward the open state at the POFE threshold would also involve non-uniqueness, but with altered constraints: B_n is again assumed fixed, but in this case the coronal field's relative helicity would be the same in the pre- and post-opening field, but the BC on vertical current J_n would not be preserved. This is expected for an ideal instability.

The second insight regards the nature of the field energy as the POFE for a given flux system is approached. Sturrock (1991) argued that magnetic energy of a field becomes stationary as the field is completely opened, and that this completely open field energy (COFE) is the maximum possible energy for a given B_n . The numerical experiments of Hu (2004) suggest that a field's magnetic energy when opening a single flux system was also stationary, though not an extremum. This logic can be applied to multi-system, global configuration, in which different flux systems can be opened individually and in different order. In such a configuration, the global configuration's energy generally exhibits hysteresis. When two flux systems' fields both possess substantial energy above their current-free minimum energies – i.e., they are evolving toward the open state – but neither has reached its POFE, they could, in principle, exchange energy (with magnetic pressure or tension in one system doing work against the other), possibly enabling one of the closed systems to open. This possibility has not yet been explored.

The third insight was the recognition of a fundamental difficulty in modeling coronal magnetic evolution toward the POFE: based on recent work by Schuck et al. (2022), increasing magnetic shear within a flux system should, because it corresponds to an increasing horizontal current in the corona, alter B_n at the base of the corona. This, however, would violate the fixed-normal-field BC assumed above. In fact, B_n at the base of the corona can only be kept fixed if one assumes that evolution in coronal currents is exactly mirrored by currents in the interior, which is unrealistic. It remains unclear how magnetic field boundary conditions should be handled when modeling evolution of coronal currents without assuming mirror currents in the interior also evolve to exactly offset the contribution of coronal currents to B_n .

These three insights have not yet been written up for publication in a scientific journal, but are expected to contribute to additional progress in understanding magnetic evolution in the lead up to CME onset.

Publications: None yet.

(Form 2-2)

Investigation of the solar wind propagation and its characteristics in the inner heliosphere using multi-spacecraft, ground-based observations and numerical simulations

Sae Aizawa

(Department of Physics, University of Pisa)

Introduction and Purpose of the project

Solar wind propagates approximately radially through interplanetary space, defining the extent of the heliosphere. During its propagation, the solar wind interacts with the planetary bodies it encounters, resulting in the creation of distinct environments at each planetary body. Thus, it is important to understand its behavior and Sun's activity as its origin. To investigate the characteristics of the solar wind from the Sun, many space missions are available to study the Solar and heliospheric physics. It allows us to combine them and get a more complete picture of plasma processes. In addition, recent observations by BepiColombo, which is Mercury exploration mission by ESA and JAXA and currently en route to Mercury, show that they are capable of detecting all the manner of solar events certifying this as another excellent probe in the inner heliosphere. However, correctly interpret the multipoint measurements and connect these data, comprehensive modelling is necessary.

In this project, we first examine the solar wind propagation in a global MHD simulation, called SUSANOO with the magnetic field data obtained by BepiColombo during its cruse phase to understand the error in arrival time of heliospheric current sheet crossings as a proxy of normal solar wind propagation. Then we expand it to longer time period and comparison of plasma measurements. It is an important step to understand the features of SUSANOO simulation so that we can discuss the interpretation of multipoint measurements with it in future.

Method

In SUSANOO, it is possible to extract the solar wind information such as the magnetic field, plasma parameters as a time series at any objects in space. We have first extracted the magnetic field data at BepiColombo, and compared it with the magnetic field obtained by BepiColombo. We have derived the cone and clock angle of the magnetic field, compared them, and identified the difference in time between BepiColombo and outputs from SUSANOO. The cone angle corresponds to the change in x-component, thus it is a proxy to identify the heliospheric current sheet (HCS) crossings, thus it represents the large structure of the solar wind from the Sun in the inner heliosphere.

Results

Figure 1 shows an example of comparison between BepiColombo and SUSANOO in June 2021. At the time, BepiColombo was in the distance of ~ 0.8 AU. Overall, it looks consistent for the magnetic field data, however the magnetic field magnitude seems to be low in SUSANOO, and sometimes small variation does not correspond. When we zoom in several time periods, we can clearly identify HCS crossing detected by BepiColombo, which is not consistent with the result by SUSANOO (see Figure 2). Since actual observation has better temporal resolution, we mainly focus on the large structure by checking the clock angle together. As a result, we have discussed HCS crossings in June 2021, and identified the time difference between SUSANOO and BepiColombo.

SUSANOO always predicts it earlier than actual observations, and so far, the range is 16 ~ 55 hours, which is sometimes better than the mean time differences using another global MHD simulation, 33.4 hours for magnetic field polarity, investigated by Wang et al., 2020. As for the plasma density variation, we have found that SUSANOO does not show any variations as BepiColombo shows. However, the electron analyzer onboard BepiColombo is still inside a sunshield, thus, it is difficult to justify if electron density obtained by BepiColombo shows the actual variation of ambient solar wind. The instrument team has hardly worked on it and it is still under investigation. With assumptions implemented in MHD simulations, and temporal and spatial resolutions, it is necessary to collect more data in the heliosphere with various heliospheric distance to identify the characteristics of SUSANOO simulation and how much differences in time we have between background solar wind propagation and extreme solar event such as coronal mass ejections. This will be the next step by using more data from other space missions such as Solar Orbiter and Parker Solar Probe.

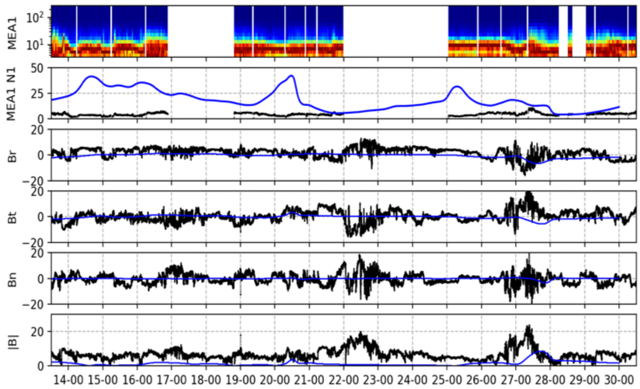

Figure 1. Overview of BepiColombo observation and outputs from SUSANOO simulation. From top to bottom, electron spectrum from BepiColombo, electron density, and magnetic field from both BepiColombo (in black) and SUSANOO (in blue).

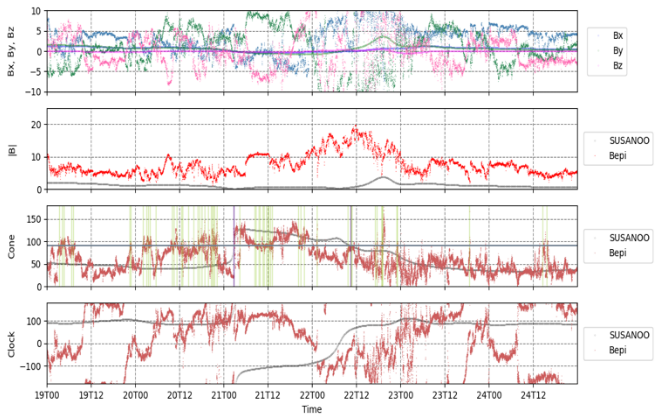

Figure 2. Zoom-in of comparison between BepiColombo observation and outputs from SUSANOO simulation. From top to bottom, three components of the magnetic field, magnitude, and the cone and clock angle from both BepiColombo (dots) and SUSANOO (lines). Green lines represents the crossing of BepiColombo data at the cone angle of 90 degree.

Ref: Wang et al., 2020, MHD modeling of the background Solar Wind in the inner heliosphere from 0.1 to 5.5 AU: Comparison with in situ observations, Space Weather, 18, e2019SW002262. https://doi.org/10.1029/2019SW002262

Periods of stay in ISEE: Nov 28th – Dec 2nd, 2022

Publications:

A manuscript is in preparation. Once it is ready, it will be submitted to a peer-reviewed journal. Furthermore, I am in constant discussion with my collaborators to continuously work on this project.

(Form 2-2)

Project Title

Subauroral phenomena observed by SuperDARN and the Swarm satellite constellation

Matthias Förster
GFZ German Research Centre for Geosciences,
Section 1.1, Telegrafenberg, 14473 Potsdam, Germany

Purpose:

Our study aimed on subauroral processes of particle and energy input, which result in so-called subauroral polarisation streams (SAPS) that are longitudinally elongated structures of high-speed plasma flow together with plasma density depletion and temperature enhancements. Swarm satellite observations of various plasma parameters and SuperDARN ground-based ion drift measurements, focusing on the Japanese radar facilities of the SuperDARN network, Hokkaido East ("hok") and West ("hkw"), were used for event studies of individual geomagnetic storms in comparison with quiet time periods. The main idea was, that a synoptic view of satellite and ground-based observations provides some insights for a better understanding of the relation between larger- and smaller-scale ion drift structures and the physical coupling processes within the magnetosphere-ionosphere-thermosphere (M-I-T) system.

Methods:

The Swarm satellites on their near-polar orbits are equipped with electric field instruments (EFI) that comprise two Thermal Ion Imager (TII) sensor heads at the front side of the satellites as well as two spherical Langmuir probes (LPs) at the front bottomside. The EFI instruments allow in principle full 3-D vector records of the ion drift with the vertical and horizontal cross-track components from the TII sensor heads and the along-track component from a closer LP data analysis. These high-resolution ion drift observations can be used in comparison with the larger-scale ion drift patterns obtained from criss-crossed SuperDARN line-of-sight drift measurements for comparisons during overflights together with LP measurements of plasma density, temperature, and effective ion masses. For the data extraction and visualization of SuperDARN data we used the SPEDAS software, provided from ISEE.

Results:

The goal of direct comparisons of ion drift measurements from EFI/TII on the one hand side and of the l.-o.-s. SuperDARN observations on the other necessitated some further development of the IDL software for reading and mapping the data accordingly. The 2-Hz EFI Swarm satellite data are given as daily cdf-files; the SuperDARN drift values were deduced using the SPEDAS software package. As shown already previously, the in-situ satellite drift component measurements appear to have generally larger magnitudes, probably due to the higher spatial and temporal resolution. They can sometimes reach even considerable values up to a factor of more than two (cf., e.g., Koustov et al., 2019, doi: 10.1029/2018JA026245). Large subauroral plasma streams are essentially co-located with plasma density troughs and temperature enhancements. This has been investigated for some storm periods as, e.g., the so-called "Surprise Ionospheric Storm" of August 25-26, 2018 (Astafyeva et al., 2020, 10.1029/2019JA027261) or the major geomagnetic storm of February 26-27, 2023, that occurred just during the time of the visit. These observations have been contrasted with quiet-time intervals. Structures of subauroral polarization streams (SAPS) could be identified without doubt during geomagnetically disturbed periods with variable intensity depending on the strength of the disturbance. It is intended to submit at least one publication on the analysis of a storm interval.

Period(s) of stay in ISEE:

19 February till 04 March 2023

Publications:

None yet, only first draft ideas.

Presentations:

"Estimation of the effective ion masses M_{eff} by Langmuir probes onboard the Swarm satellites", Matthias Förster, 68th Colloquium of CICR at ISEE, Nagoya, February 27, 2023.

(Form 2-2)

Investigation of Solar Polar Magnetic Fields using Hinode/SP and SDO/HMI Data

Berger Thomas
University of Colorado at Boulder, USA

Cancelled

Establishment of master dendrochronological calibration curve around 660 BC using annual tree ring samples from Poland

Andrzej Rakowski- Silesian University of Technology, Poland

Radiocarbon measurements in annual tree rings reported in Miyake et al. (2012), was the first to confirm the occurrence of event (henceforth M12) of rapid increase in its concentration, occurring within one year. Between 774–775 CE, a significant increase of 12‰ in $\Delta^{14}C$ value has been noted (Miyake et al. 2012). To explain the causes of the M12 event, the four-box carbon cycle model has been used, yielding the estimated production rate of $6 \cdot 10^8$ atoms$\cdot$cm$^{-2}\cdot$s^{-1}. According to the authors, this value may suggest a giant SEPs or SNe as a possible cause of this event. However, considering no evidence of SNe in this time frame, the SEPs is most possible reason of this increase. The production value has been recalculated by Usoskin et al. (2013), using five-box carbon cycle model, and the obtained result is around 4 times smaller than what was presented by Miyake et al. (2012), i.e. $1.3 \pm 0.2 \cdot 10^8$ atoms$\cdot$cm$^{-2}\cdot$s^{-1}. The assumption of SEPs as a possible cause of M12 was confirmed by the Mekhaldi et al. 2015, who recorded a comparable rapid increase in ^{10}Be and ^{36}Cl in ice cores from Antarctica and Greenland around 775 CE and 994 CE. GRBs with typical energy spectra and fluxes could produce significant amounts of ^{14}C and ^{36}Cl, however, the ^{10}Be production rate would not be significantly affected (Pavlov et al. 2013; Mekhaldi et al. 2015). That said, a large SEP, or series of SEPs, are a cause of the discussed Miyake events.

Such sudden and intense increase in the concentration of radiocarbon found application in the precise radiocarbon dating with one-year resolution. This method was used by Wacker et al. (2014) to precisely date the cutting year of a timber in the historical Holy Cross chapel of the convent St. John the Baptist in Val Münstair in Switzerland. Also, in the works of Hakozaki et al. (2018), Krąpiec et al. (2020) and Philipsen et al. (2022), such event was used to precisely determine the age based on changes in the concentration of radiocarbon in the sequence of annual tree rings.

For the study, sub-fossil oaks (*Quercus robur* L.) were recovered from a gravel pit near Vistula River in the village of Grabie, near Kraków (southern Poland, Fig. 1). Around 100 slices of oak trunks were taken and after preparation were used for dendrochronological study. Measurements were made with 0.01 mm accuracy using a DENDROLAB 1.0 apparatus, then the ring-width sequence were processed with a set of software TREE-RINGS (Krawczyk and Krąpiec 1995), TSAP (Rinn 2005) and DLP (Holmes 1999).

Standard chemical pretreatment of samples of annual tree rings has been extended to step aimed at obtaining α-cellulose, which should ensure the elimination of any contamination. Measurements ware performed for samples of oak and pine, in order to determine possible differences in the magnitude of increase of radiocarbon concentrations, depending on the tree species. The concentration of radiocarbon in annual tree rings has been determined based on measurement with accelerator mass spectrometry (AMS). This technique allows to perform precise measurement using samples with a carbon content of ≥ 1 mg.

The sub-annual data from the Grabie core 68 EW and LW rings show a prolonged increase in the $\Delta^{14}C$ values of 20.4±1.0‰ between 665 (data from Rakowski et al. 2019) and EW 661 BCE. The radiocarbon concentration in this period raised from **-1.3±2.3‰** in 665 BCE to **19.1±2.2‰** in EW from 661 BCE showing high value of radiocarbon concentration during the rest of measured period. Similar as in the literature the $\Delta^{14}C$

curve shows first the rapid increase of about 8.3±2.8‰ between 665 and 664 BCE, and then gradual increase to the maximum value of 19.1±2.2‰ in EW in 661 BCE. Park et al. (2017) and Sakurai et al. (2020) reported increase in $\Delta^{14}C$ value of 14.3±1.5‰ in German oak series within 4 years, and 13.3±2.1‰ in Choukai-Jindai cedar within 6 years respectively. The rapid increase between 665 BCE. The difference in radiocarbon concentration ($\Delta^{14}C$) in LW from 665 BCE and 664 BCE presented in literature is 8.9±0.4‰ (Park et al. 2017), and 9.8±2.2‰ (Sakurai et al. 2020) and is similar to the value obtained in this study.

The $\Delta^{14}C$ values measured in LW from 664 BCE (5.6±2.2‰), and in EW from 663 BCE (6.0±2.1‰), show no significant differences. This is because, to a significant extent, the EW is formed from the material accumulated in the previous year and a much lesser amount of it derives from the material created by photosynthesis in the year of growth (Speer 2010). Olsson and Possnert (1992) observed that there is no delay between the radiocarbon concentration in the atmospheric sample in comparison with its concentration in the EW and LW during the maximum bomb effect (1962–1963). According Ermich (1959), EW formation in this climatic zone occurs from April to mid-June, and LW formations ends in mid-September. This limits the beginning of the phenomenon to the period before formation of the LW, as there is no significant difference between $\Delta^{14}C$ values in LW1 and LW2 in year 664 BCE. The most probable period of occurrence may be in **April ± 2 months**.

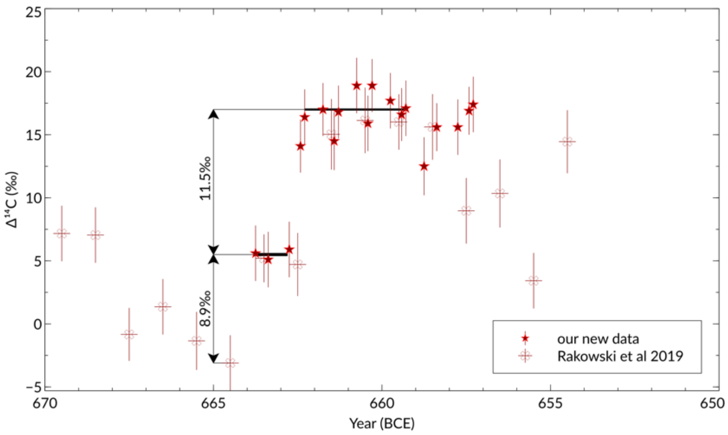

Figure 1. Results of $\Delta^{14}C$ determination in Grabie site tree. New results are shown as stars. Results from Rakowski et al. (2019) are shown as empty crosses.

Articles:

Rakowski A, Pawlyta J, Miyahara H, Krąpiec M, Molnal M, Wiktorowski D, Minami M. Radiocarbon concentration in sub-annual tree rings from Poland around 660 BCE. Radiocarbon - in review.

Successive publication of articles is planned after the elaboration of the measurement results. The results will be presented during the MACh 14th Conference in Gliwice (mach2023.polsl.pl) May 2023, 2nd CLARA Conference in Mexico September 2023, and during 4th Radiocarbon and the Environment Conference in Italy, September 2024.

Period of stay in ISEE:

11.11.2022 – 6.12.2022 – Nagoya University

(Form 2-2)

Modelling the transport and deposition of 14C produced by extreme solar proton events and 7Be produced by galactic cosmic rays during the satellite era

Dr. Tobias Christian Spiegl (Free University of Berlin)

Scientific background

Cosmogenic isotopes (such as 10Be, 7Be, 36Cl or 14C) are a product of spallation, when galactic cosmic rays (GCR) or solar energetic particles (SEP), produced by solar proton events (SPE), interact with atmospheric molecules in the higher atmosphere. The abundances of these isotopes in natural archives are widely used to gain understanding about the solar-climate interactions spanning from geological time scales (e.g. Milankovic cycles) to historical (e.g., Miyake events of the $8^{th}/10^{th}$ century) or more recent solar events (e.g. the 2003 "Halloween" solar storm).

Current appropriation period

During the current appropriation period of the "ISEE International Joint Research Program" (2022/2023) we modelled the transport and deposition of cosmogenic 10Be produced by historical extreme SPE and GCR during the 8th and 10th. To this effect the EMAC model has been extended by a GCR-source based on WASAVIES calculations. This is an extension of our initial work, where we investigated the cosmogenic surface signatures of historical extreme SPE events without a GCR background. By the aid of these simulations the influence of tropospheric weather dynamics on SEP and GCR signatures can be analyzed. The results of these analysis will be presented at the IUGG General Assembly **(session A06 - Energetic Particle Precipitation Impacts on the Ionosphere, Upper Atmosphere, and Climate System) in July (Berlin).** Furthermore, a publication summarizing the main scientific outcome is in preparation:

Schaar, K., Spiegl, T.C., Langematz U., Miyake, F., Sato, T., Mekhaldi, F., Yoden, S. and Kusano K.: Preindustrial Be-10 signatures shaped by GCR, SEP and weather dynamics. JGR-Atmospheres (in preparation).

Additionally, EMAC has been extended by a simple carbon cycle parameterization in cooperation with our partners at ISEE. To this effect our Phd candidate, Mr. Konstantin Schaar, had the opportunity to stay two weeks at ISEE under the guidance of Prof. Miyake to discuss the first results of our 14C transport and deposition experiments in October 2022. These new simulations will put us in the position to evaluate our modelled deposition pattern for extra-polar latitudes, which is conserved in tree rings worldwide. From these experiments, we expect a more accurate estimation regarding the seasonal timing of the extreme SPEs and hope to set new impulses for future high-resolution geochronologies. The carbon cycle parameterization is still in test stage and currently under revision, we expect a first comprehensive version of the code in late 2023.

Workshop at ISEE in October 2022

To strengthen the collaboration between Free University of Berlin, ISEE and other project partners a 2-day meeting (03.10 to 04.10.22) was hosted by Prof. Fusa Miyake at ISEE. Here, the project partners presented individual work in progress and future directions of the collaboration were discussed. The workshop was attended by Prof. Fusa Miyake (corresponding ISEE researcher), Dr. Tobias Spiegl (FU-Berlin, PI), Konstantin Schaar (FU-Berlin), Dr. Tatsuhiko Sato (JAEA), Prof. Ulrike Langematz (FU-Berlin) and Prof. Shigeo Yoden (Kyoto University). Below, a summary of the main scientific highlights of this meeting is given.

Prof. Fusa Miyake gave an update on the current status of studying past extreme solar events based on cosmogenic nuclides (14C in tree rings and 10Be & 36Cl in ice cores). Since the last meeting several new events have been reported, e.g., 5259 BCE and 7176 BCE events (Brehm et al. 2022, Paleari et al. 2022). The causes of regional differences in 14C concentrations during extreme SEP events have been discussed. New 14C data of Japanese cedar for the 993 CE event show a delayed signal of 14C spike, which is consistent with the previous studies (Miyake et al. 2022). It is possible that such a difference in the 14C data may be explained by atmospheric transport processes or a difference of fixation period of carbon in trees.

Konstantin Schaar presented new modelling results concerning the deposition and transport of 7Be produced by GCR during the contemporary satellite era. It shows that the general dynamics of the global ground level concentration of Be-7 (e.g. production modulation due to Schwabe cycle and annual periodicity) is captured quite well in the EMAC. In a next step, historical ensemble simulations will be conducted to assess the influence of climate change on the transport and deposition of cosmogenic nuclides.

Dr. Tatsuhiko Sato emphasized that the initial cosmogenic nuclide yield is the fundamental information to be provided for climate model simulations. about monthly yields of ^{10}Be and ^{14}C produced during 2001-2020 using the PHITS-based Analytical Radiation Model in the Atmosphere (PARMA) coupled with their production cross sections from atmospheric constitutions (^{14}N and ^{16}O) evaluated by Particle and Heavy Ion Transport code System PHITS.

Prof. Ulrike Langematz gave a presentation on the influence of energetic particle precipitation on the ozone layer in different epochs.

Prof. Shigeo Yoden talked about possible future collaborative research on coordinated observations and analysis of the time-space variations of the GCR-related isotopes in past and future events.

Dr. Tobias Spiegl gave a presentation on new ideas concerning the possible impact of interannual variability and long-term climate shifts during the Holocene era on the signatures of cosmogenic nuclides produced by extreme SEP events.