# 2024年度　02）ISEE International Joint Research Program　目次詳細

## 2024　02）ISEE / CICR International Joint Research Program List

23　件

＊所属・職名は2025年3月現在

＊Affiliation and Department displayed are current as of March 2025.

| 研究代表者 Principal Investigator | 所属機関* Affiliation | 所属部局* Department | 職名* Job title | 研究課題名 Project Title | 頁 Page | 備考 Remarks |
|---|---|---|---|---|---|---|
| HajiHossein AZIZI | University of Kurdistan, Iran | Mining Engineering | Professor | Dating and chemical analysis of garnet in S-type granites for discriminating magma sources in western Iran | 45 | |
| Andrzej Rakowski | Silesian University of Technology, Poland | Institute of Physics - CSE | Professor | Reconstruction of intense ENSO variability from dendrochronological records from Peru | 47 | |
| Kazue Takahashi | The Johns Hopkins University Applied Physics Laboratory, USA | Space Exploration Sector | Principal Professional Staff | Magnetoseismic investigation of heavy ions in the inner magnetosphere | 49 | |
| Rangaiah Kariyappa | Indian Institute of Astrophysics, India | Solar & Space Physics | Retired Professor | Dynamics & Heating of the Solar Corona at the Sites of Small Scale Features(Campfires and Bright Points) Observed from Solar Orbiter/EUI and SDO/HMI | 51 | |
| Chih-Chien Tsai | National Science and Technology Center for Disaster Reduction (NCDR) , Taiwan | Meteorology Division | Associate Researcher | Evaluation of different techniques for deriving 3D wind fields from the PAWR observations and deriving precipitation from satellite observations | 54 | |
| Xueqiang Lu | Nankai University, China | College of Environmental Science and Engineering | Professor | Identification of Avian Dietary Change and Its Implications Using Isotopic Technology | 56 | |
| Jih-Hong Shue | National Central University, Taiwan | Department of Space Science and Engineering | Professor | Comparative studies on Earth's and Mercury's dynamic magnetospheres | 58 | |
| Prayitno Abadi | Indonesian National Research and Innovation Agency (BRIN) , Indonesia | Research Center for Climate and Atmosphere | Senior Researcher | Effects of Ionospheric Scintillation on the Precision of GNSS Precise Point Positioning (PPP) Technique at Low-latitude region | 60 | |

| 研究代表者<br>Principal Investigator | 所属機関*<br>Affiliation | 所属部局*<br>Department | 職名*<br>Job title | 研究課題名<br>Project Title | 頁<br>Page | 備考<br>Remarks |
|---|---|---|---|---|---|---|
| Gary Verth | The University of Sheffield (TUoS) , United Kingdom | School of Mathematics and Statistics | Senior Lecturer | Vortical plasma and magnetic structures in the solar atmosphere and beyond | 62 | |
| Grandhi Kishore Kumar | University of Hyderabad, India | Centre for Earth, Ocean and Atmospheric Sciences (CEOAS) | Assistant Professor | Estimation of quasi 2-day wave Momentum flux in the high latitude middle atmosphere | 64 | |
| Jing Liao | University of New Hampshire, USA | Space Science Center | Research Scientist | Nightside auroral outflows as source of the warm plasma cloak | 68 | |
| Stepan Poluianov | University of Oulu, Finland | Sodankylä Geophysical Observatory and Space Physics and Astronomy Research Unit | Senior Researcher | Solar and terrestrial effects in the 70-year long tritium and beryllium-10 record from the Dome Fuji in East Antarctica | 70 | |
| Seiji Yashiro | The Catholic University of America, USA | Physics Department | Researcher | Relationship between Gamma-Ray Flares and White Light Flares | 73 | |
| Yukinaga Miyashita | Korea Astronomy and Space Science Institute, Korea | Heliophysics Research Center | Principal Researcher | Feasibility study of in situ and remote observations of the heliosphere and the Sun at the L4 point | 75 | |
| Ondrej Santolik | Institute of Atmospheric Physics of the Czech Academy of Sciences (IAP) , Czech Republic | Department of Space Physics | Professor | Investigation of electromagnetic waves in the Earth's magnetosphere using spacecraft and ground-based measurements | 77 | |
| VISWANATHAN Lakshmi Narayanan | Krea University, India | Environmental Studies | Assistant Professor and Discipline Coordinator | On the impact of geomagnetic disturbances in the gravity wave and tidal dynamics of the mesosphere in the auroral region | 79 | |
| Jyrki Manninen | University of Oulu, Finland | Sodankyla Geophysical Observatory | Deputy Director | Conjugate observations of magnetospheric whistler-mode waves by KAN, PWING, and ERG/ARASE | 81 | |
| Noé Lugaz | University of New Hampshire, USA | Space Science Center | Research Professor | Comparing Remote Observations, In-Situ Measurements and Simulations of the Variation of the Properties of Coronal Mass Ejections Over 1-10° in Longitude. | 83 | |

| 研究代表者 Principal Investigator | 所属機関* Affiliation | 所属部局* Department | 職名* Job title | 研究課題名 Project Title | 頁 Page | 備考 Remarks |
|---|---|---|---|---|---|---|
| Sergey Koldobskiy | University of Oulu, Finland | Sodankylä Geophysical Observatory & Space Physics and Astronomy RU | Postdoc | Reconstruction of physical properties of historical solar energetic particle events | 85 | |
| Neethal Thomas | University of Oulu, Finland | Sodankylä Geophysical Observatory | Postdoctoral Researcher | EISCAT - Arase study of energetic electron precipitation | 87 | |
| Nada Al-Haddad | University of New Hampshire, USA | Space Science Center | Research Associate Professor | Investigating Helicity Transformation in Coronal Mass Ejections using Numerical Simulations | 89 | |
| Nariaki Nitta | Lockheed Martin Solar and Astrophysics Laboratory, USA | Solar and Astrophysics Laboratory | Senior Staff Physicist | Linking Coronal Mass Ejections Observed Near the Sun and at 1 AU | 91 | |
| Sae Aizawa | LPP, CNRS, France | Space Plasma Group | CNRS researcher | Analysis of radial propagation of the solar wind in the inner heliosphere with multi space missions and SUSANOO propagation model. | 92 | |

(Form02-2)

# Dating and chemical analysis of garnet in S-type granites for discriminating magma sources in western Iran

**HajiHossein AZIZI (University of Kurdistan, Iran)**

Firstly, I would like to express my deep gratitude to the ISEE members during my two-month stay at ISEE in the summer of 2024.

The genesis of S-type granites is one of the most important processes involved in the continental crust evolution of the Earth. In this research, we focused on chronological and geochemical analysis on S-type granites and their minerals in western Iran, which is a plate boundary. During my stay at ISEE, we did the following:

1. Study on the thin sections for the metamorphic rocks and the granites in western Iran.
2. Separation of garnet and minerals related to both granite and metamorphic rocks.
3. Sampling from different parts of a single garnet grains using the microdrill.
4. Digestion of the garnet grains in HF and $HNO_3$ for quantitative analysis of trace elements and Sr-Nd isotope analysis.
5. Discriminating the inclusions in the garnet grains using XRD.
6. Measuring the whole rock major oxides by XRF.
7. Measuring trace elements for 56 whole rock samples by ICP-MS.
8. Chemical separation of Sr-Nd isotope fractions for 56 samples (analysis in progress).
9. Zircon U-Pb dating for the granitic rocks using the LA-ICP-MS.
10. Discussion on our preliminary data and manuscript.
11. One-day field trip with ISEE members to see the Precambrian Rock Museum.

Furthermore, during my stay, we continued our ongoing collaboration to complete our papers and to start writing some new ones. This year, two of our papers were published in high-quality journals (First Quarter): ***Lithos and International Geology Review.*** These papers mainly focus on the whole-rock chemistry and isotope ratios to elucidate the magma sources in western Iran. The abstracts of our papers, supported by ISEE 2022−2024, are listed below.

1. **Azizi, H.,** Nouri, F., **Asahara, Y., Minami, M.,** Tsuboi, M., Takahashi, H. A. and Whattam, S. A. (2024). *Ultrapotassic rocks in the Saray Peninsula, Northwest Iran: An example of carbonate peridotite melts in a post-collision system in the late Miocene.* ***Lithos,*** *488, 107788*. With this abstract; Late Miocene ultrapotassic rocks are widely exposed in the Saray Peninsula of northwestern Iran. These rocks are mainly classified as tephrite-tephritic phonolite with some trachyte and lamprophyre dikes with porphyritic textures. Ca-rich pyroxene and leucite are the main phenocrysts. Olivine and phlogopite with some sodic amphiboles occur locally as phenocrysts. Chemically, the rocks are characterized by low contents of $SiO_2$ (45.4–47.3 wt%), with high contents of $K_2O$ (3.4–6.6 wt%), $K_2O/Na_2O$ (1.2–5.7), MgO (5.6–9.1 wt%), CaO (10.3–12.7 wt%) and Sr (826–2020 ppm) with low $P_2O_5/Al_2O_3$ (0.08–0.14). Chondrite normalized REE and primitive mantle-normalized patterns indicate the involvement of a LREE (La, Ce)

and LILE (Cs, Ba, Pb) enriched mantle, and weak negative Ti-Nb-Ta anomalies are observed. Isotopically, the rocks show high $^{87}Sr/^{86}Sr$ ratios (0.7071–0.7084) and low εNd(t) values (–3.8 to –1.8). Their $\delta^{13}C$ values show a variation from –13.4‰ to –6.5‰, confirming some organic carbon recycling in the subduction zone, and the absence of Ce/Ce* and Eu/Eu* negative anomalies confirm the redox system melting. The Sr-Nd isotopic values, higher contents of incompatible elements, and lower $\delta^{13}C$ values suggest a continental crustal material involvement for the sources of these rocks. The presence of calcite in the matrix, the inclusion of melt droplets with some calcite, and the carbonation of leucite and pyroxene grains confirm the high $CO_2$ content during magmatic evolution and/or the late stages of reaction of $CO_2$-fluid rocks with earlier minerals. Due to the situation of the Saray ultrapotassic rocks near the junction of the Van microplate and the NW Iran block, dragging of the Van microplate beneath NW Iran is likely to have transported some carbonate rocks and biogenetic organic carbon into the mantle and converted the primitive mantle to carbonate peridotite. A very low rate of partial melting at a pressure of less than 3 GPa around the garnet-spinel stable zone produced ultrapotassic melts. The correlation with some neighboring ultrapotassic rocks shows that this process is a dominant factor to generate the kamafugite and/or interval of kamafugite-Roman type ultrapotassic series in a collision system, without considering the role of mantle phlogopite present in the deep metasomatized mantle. This work shows why most of the ultrapotassic rocks in Iran have developed near the suture zone after the closure of Neotethys.

2. **Azizi, H.,** Nouri, F., **Asahara, Y., Minami, M.** and Whattam, S. A. (in press). *Continental crust variance between post-collisional compressional and extensional domains controlled magmatic activity at Damavand volcano, Northern Iran.* ***International Geology Review***, pp.1-23. With this abstract; The Quaternary Damavand stratovolcano, with an elevation of 5670 m, is the highest mountain in Iran and is the subject of this study. The main rocks are trachyandesite and trachybasalt, and Sr-Nd isotope ratios of whole rock samples show small variations in εSr (+3.2 to + 6.4) and εNd (−1 to + 1). Overall, rock chemistry and Sr-Nd isotope ratios support a metasomatic asthenospheric mantle with minor pelagic sediments from the oceanic subducted slab and/or carbonatite melts from the deep mantle as sources. Collision of the Arabian and Eurasian plates compressed the Iranian plateau between them, resulting in compressional and extensional domains in different regions. As a result of continuous pressure from the Arabian plate, thrusting and folding in compressional domains increased crustal thickness while thinning occurred in extensional areas. These processes cause thermal gradient perturbations at the boundaries between the two, leading to the melting of the mantle and/or lower crustal mafic rocks and production of alkaline rocks. Damavand volcano is located at the junction of compressional and extensional regimes, and its activity has been influenced by the variation of crustal thickness along the Alborz Mountain in the southern Caspian Sea. Therefore, the variation of crustal thickness can be suggested as a main mechanism for the generation of magmatic activity along the entire Iranian plateau in a post-collision system.

We are also eager to continue our research in 2025, focusing specifically on xenoliths and enclaves within granite, and correlating them with some of our ongoing projects (ISEE) such as apatite chemistry in granite and the results of the present project on garnet in granite. We believe the combination of these research would be much useful for the understanding of S-type granites in Iran. Ultimately, we aim to develop a model for S-type granites, which are the main components of continental crusts.

## Reconstruction of intense ENSO variability from dendrochronological records from Peru

Andrzej Rakowski (Silesian University of Technology, Poland)

The aim of our study was to compile a floating chronology for algaroba from the Casma Region of Peru and to establish absolute dating based on radiocarbon analyses of single annual growth rings that had been relatively dated dendrochronologically (wiggle-matching). In doing so, we sought to create a chronological framework for the ancient civilisation that once colonised this area and inhabited the Cerro Laguna archaeological site. The Cerro Laguna archaeological complex is in the Ancash region of Peru, characterised by semiarid climatic conditions. The maximum temperature reaches 34°C in summer and 15°C in winter. Annual precipitation totals range from 48 to 208 mm, with rainfall concentrated in the summer months (January to April), followed by a long, cool, dry period for the remainder of the year. Preliminary archaeological studies suggest that Cerro Laguna dates to the Late Intermediate Period, approximately 600 to 1300 CE (Ghezzi, pers. comm.). From the Cerro Laguna archaeological complex (Fig. 1), ten cross-sections were collected from different trunks. The relatively small number of samples analysed was due to conservation guidelines aimed at protecting the remains of historical settlements. For absolute dating, five tree rings were selected from sample CL9. α-cellulose was extracted from the wood following the protocol of Green (1963). This method was modified by employing an ultrasonic bath (Pazdur et al. 2005) and using HCl instead of acetic acid to avoid any potential acetylation (Nemec et al. 2010). After pretreatment, approximately 4 mg of α-cellulose extracted from each sample (one ring per trunk) was combusted to $CO_2$ and subsequently reduced to graphite (Krąpiec et al. 2018; Wiktorowski et al. 2020). The resulting graphite–iron mixture was then pressed into a target holder for AMS $^{14}C$ measurements. Because the wood, initially dated using dendrochronological methods, needed an independent age verification, the wiggle-matching method was applied. Wiggle-matching, together with its underlying mathematical assumptions, is described by Bronk Ramsey et al. (2001). In this study, the wiggle-matching analysis was carried out using OxCal v4.4 (Bronk Ramsey 2009) and the calibration curve SHCal20 (Hogg et al. 2020). This finding suggests that **the CLAA1** sequence covers the period **1253–1322 (±8) CE**, thereby confirming Cerro Laguna's designation within the Late Intermediate Period. Importantly, it may also facilitate the creation of a multi-decade calibration curve with annual resolution. This is particularly relevant for the Southern Hemisphere, where calibration curves still contain uncertainties due to limited data, and the findings here could help refine those curves. Statistical dendrochronological analyses of the Neltuma spp. samples showed promising results for a tropical archaeological context, given their distinctly recognisable ring boundaries (Ferrero et al., 2014). Despite the relatively small number of samples (10 trees), our results align with earlier studies of modern populations, particularly in terms of mean sensitivity (0.62), autocorrelation (−0.13), and mean correlation (0.42) (López et al., 2006; Rodríguez et al., 2005). This suggests that even a limited archaeological dataset can capture a dendrochronological signal reflecting climatic information. The high standard deviation was expected and mirrors the findings of other algaroba studies, where growth is influenced by **ENSO** (López et al., 2006). Recording these events can help validate dates in dendrochronological sequences, especially those of shorter duration. The presence of pronounced ENSO events suggests that the Cerro Laguna site was established around 1300 CE, coinciding with climatic shifts in the Pacific region noted in several archaeological studies. At least four **ENSO events** are recognisable across the Cerro Laguna sequences due to a significant (2.5-fold) increase in tree-ring width relative to normal years. This points to a notably dry period, with low rainfall occurring both during ENSO and non-ENSO seasons, which may explain the relatively narrow mean tree-ring widths compared with other algaroba records. Constructing the **CLAA1** chronology for the Cerro Laguna site, spanning **1253–1322 CE**, confirms its affiliation with the Late Intermediate Period, strengthening the historical narrative of the region. Despite a relatively small sample (10 trees), Neltuma spp. provided robust dendrochronological signals, indicating that these trees can reliably reflect climatic variations. Comparable mean sensitivity and autocorrelation values to previous research underscore this method's validity in tropical archaeological settings. Significant increases in tree-ring width point to strong **ENSO events around 1300 CE**, revealing marked climate shifts that likely affected both vegetation and human settlement. These results offer a pathway towards creating a multi-decade calibration curve with annual resolution in the Southern Hemisphere, addressing existing data gaps and improving understanding of regional climate trends. The identified **ENSO** events and associated climate conditions shed light on how ancient communities at Cerro Laguna may have responded to environmental stresses, highlighting the interplay between climate variability and human development. The findings encourage expanded dendrochronological studies using a wider array of species and sites in the region, enabling further exploration of past climate fluctuations and their implications for historical societies. These conclusions underscore the central insights gained from the research, underscoring the importance of dendrochronological methods for reconstructing historical climatic conditions, and elucidating their influence on human civilisation.

**Articles:**

M. Krąpiec, P. Salazar, A. Rakowski, J. Pawlyta, I. Gezzi, R. Rodriguez, A. R. M. Navarro Cerrillo, A. Mabres, D. Wiktorowski, M Minami - **Annual rings of algaroba (Neltuma pallida) tree from northern Peru. Radiocarbon - in review.**

Successive publication of articles is planned after the elaboration of the measurement results. The results will be presented during the **25th Radiocarbon** Conference in Kraków June 2025, **3rd CLARA** Conference in Chile August 2026, and during **Radiocarbon and Archaeology** Conference in Brazil, August 2026.

**Period of stay in ISEE:**

22.02.2025 – 21.03.2025 – Nagoya University

(Form02-2)

**Magnetoseismic investigation of heavy ions in the inner magnetosphere**

Kazue Takahashi (The Johns Hopkins University Applied Physics Laboratory)

**Objective:** The objective of the research project is to understand how and where ionospheric $O^+$ feeding (outflow) to the magnetosphere occurs. $O^+$ ions control various magnetospheric processes such as reconnection and wave-particle interactions, and it is necessary to know their density in quantitatively understanding the processes. The problem is that the total $O^+$ number density is largely determined by the low energy ( < 10 eV) population, which is difficult to directly measure with particle instrument. We use an alternative approach, magnetoseismology, to evaluate the $O^+$ density.

**Method:** In magnetoseismology, we estimate the total ion mass density from the observed frequencies of standing Alfven waves. The waves are driven by disturbances in the solar wind and are ubiquitous in the magnetosphere. The frequencies depend on the background magnetic field and the mass density. Because we have good magnetic field models, we can solve the standing Alfven wave equation using the magnetic field models to estimate the mass density. The mass density can be combined with the electron density determined from plasma wave spectra to derive the $O^+$ density when we make an assumption on the $He^+$ to $H^+$ density ratio, which is fairly small and stable.

**Results:** We have applied magnetoseismology to data from the Van Allen Probes spacecraft covering 2012-2019. The spacecraft had apogees at $L \sim 6$ and their elliptical orbits completed four rotations in magnetic local time (MLT). This enabled us to statistically generate *L*-MT maps of the $O^+$ density using observations made during 102 storms. The main result is that the $O^+$ density in the plasmatrough is enhanced during the main and early recovery phases of the storms (see Figure 1). The density is higher on the morning side during the main phase, but this morning/afternoon asymmetry disappears during the early recovery phase. The joint research activity occurred when this work was in the final stage. The participants discussed the significance of the data analysis results.

**Period of stay:** 7-11 October 2024

**Publication:**

Takahashi, K., Denton, R. E., & Chi, P. (2025). Stormtime Evolution of the O+ Density: Magnetoseismic Analysis of Van Allen Probes Data. *Journal of Geophysical Resaerch: Space Physics*. doi:10.1029/2024JA033657

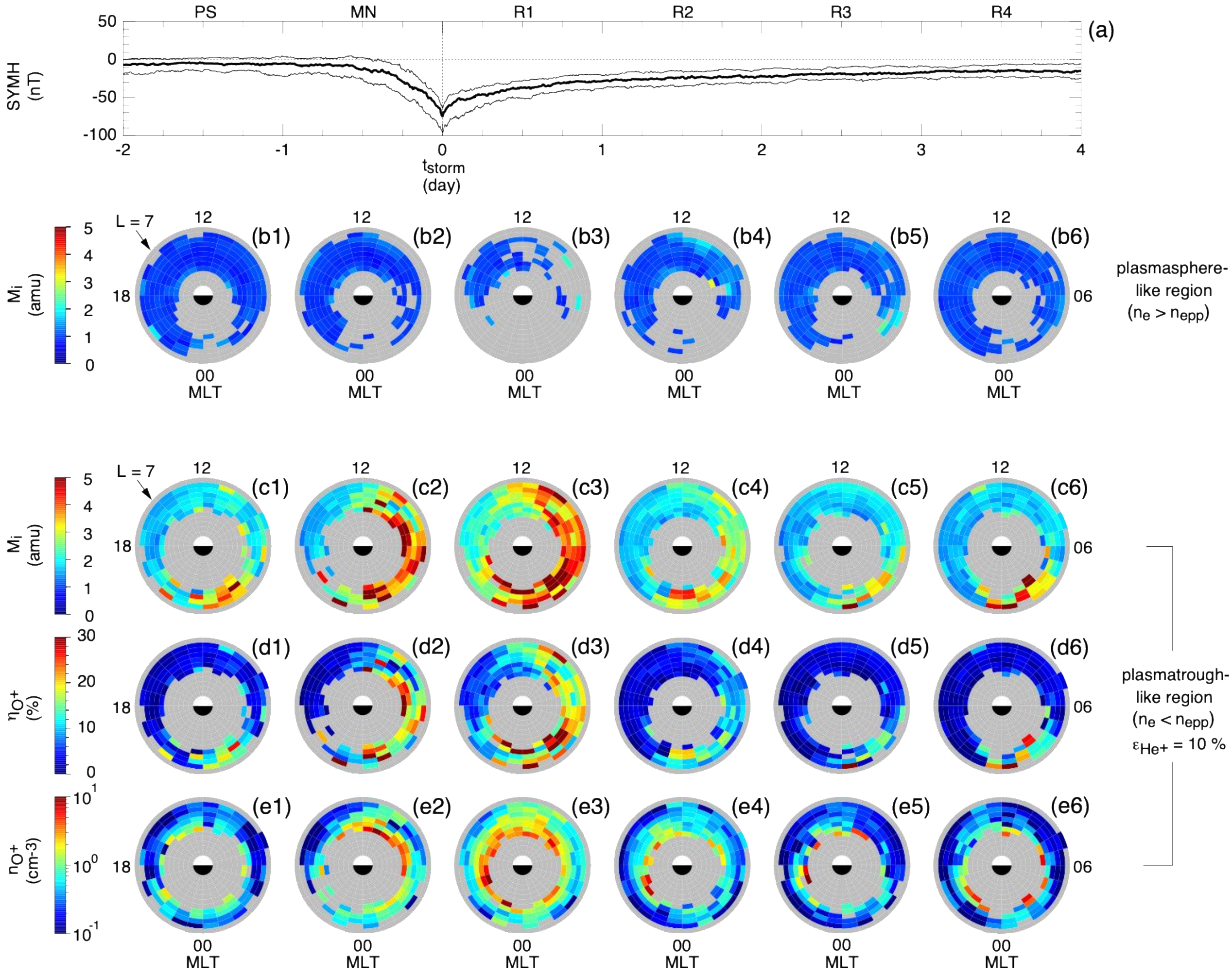



**Figure 1.** Figure 9 of Takahashi et al. (2025). (a) Superposition of SYMH for the selected 102 storms plotted versus $t_{storm}$, where $t_{storm}$ = 0 corresponds to the SYMH minimum of each storm. The heavy and light black lines indicate the median and the upper and lower quartiles, respectively. (b1-b6) *L*-MLT maps of the average ion mass in the plasmasphere-like region. (c1-c6, d1-d6, e1-e6) *L*-MLT maps of the average ion mass, the $O^+$ concentration, and the $O^+$ number density in the plasmatrough-like region.

(Form02-2)

## Project Title:

*Dynamics & Heating of the Solar Corona at the Sites of Small Scale Features (Campfires and Bright Points) Observed from Solar Orbiter/EUI and SDO/HMI*

**Principal Investigator Name (Affiliation):**

*Rangaiah Kariyappa, Indian Institute of Astrophysics, Bangalore 560034, INDIA, kari.hemi@gmail.com*

**Co-Investigators:**

*S. Masuda (ISEE/NU), J. Zender (ESA/ESTEC), T. Matsumoto (ISEE/NU)*

Under this approved project, Kariyappa had visited ISEE/NU from July 11 - 30, 2024 and had a detailed discussion with Masuda and Matsumoto and done preliminary results. During this period he had also attended the COSPAR meeting in South Korea to present a paper on Solar X-ray Irradiance Variability. The preliminary results of the approved research project are presented below.

## Preliminary Results:

We have conducted a preliminary analysis on a sample of time sequence observations made on March 17, 2022 with ***EUI/HRI*** of Solar Orbiter observed in 174A & 1216A. The time series plots are shown below:

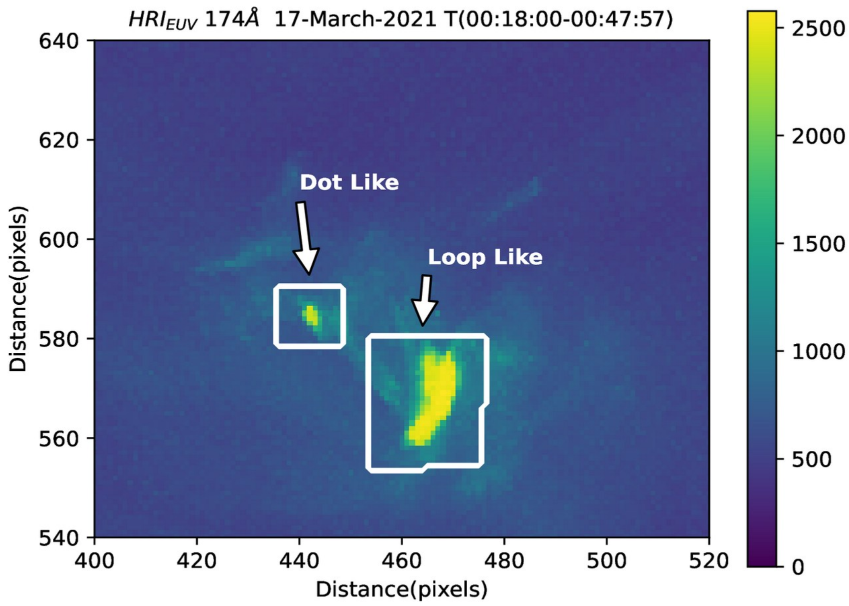



**Figure 1:** A sample i*mage showing campfires (roundish - dot like & loop like structures) observed on March 17, 2022 with EUI/HRI of SolO (174A).*

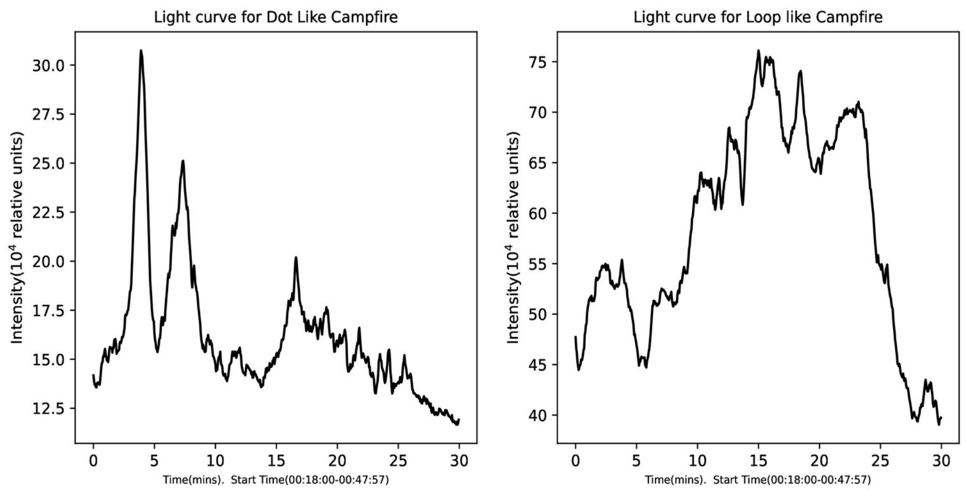



**Figure 2:** *Showing brightness oscillations of Campfires 1 (roundish - dot like structure) and 2 (loop like structure (174A).*

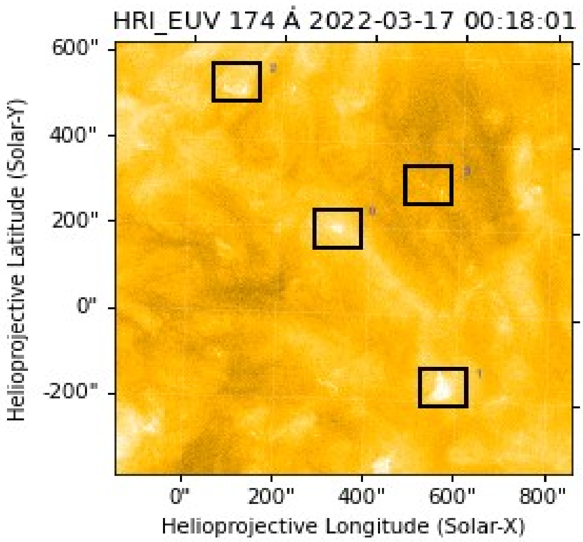
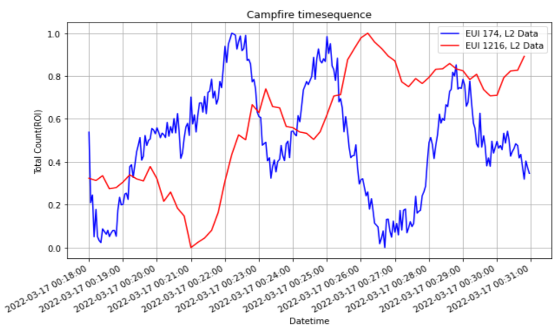
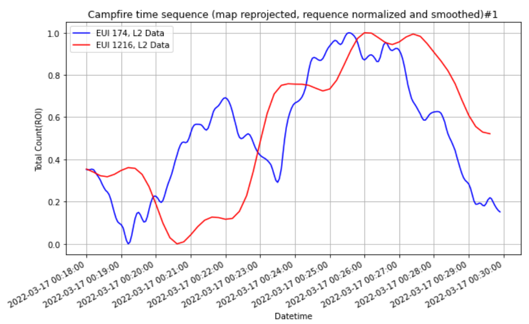
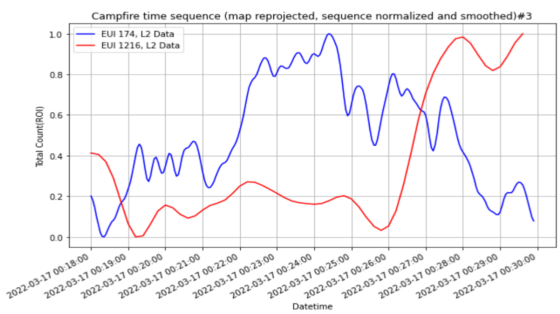
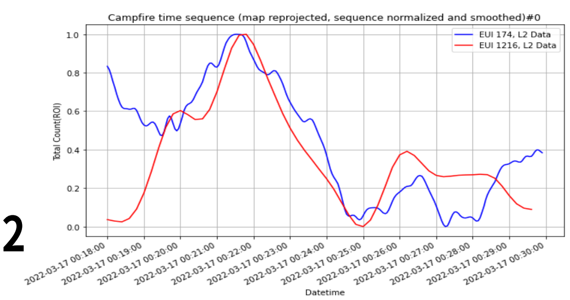



**Figure 3:** *A sample of an image observed on 17-3-2022 in 174 A (EUI) showing Campfires*



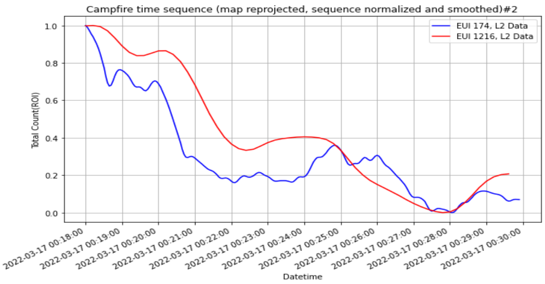



**Figure 4:** *Intensity variations (time series) in 5 campfire locations observed* ***in 174 A & 1216 A*** *from Solar Orbiter, EUI on March 17, 2022.*

In addition we analyzed the time sequence images observed by SO/EUI on March 17, 2022 in 174 A & 1216A. We derived the intensity values in all the five campfire locations (shown the campfires in Figure 3) observed on March 17, 2022 in 174 A and 1216 A – Lyman Alpha. Their time series plots are shown in Figure 4. It is seen that the intensity variations in all the campfires over the total observed period. We noticed a phase delay (time shift) of around 2-min between 174 A and 1216 A in campfire time series. It looks from these five samples that the campfires are more diverse and dynamic in nature. It is difficult to come to any conclusion from these samples, hence we propose to select a large number of campfires and bright points observed simultaneously in SO/EUI, Hinode/XRT and SDO/HMI to study their intensity oscillations, their periods, to bring out the differences among the campfires, the phase delay/time shift, heating mechanism in all the cases, energy budget, determine the role magnetic field in the heating of these features etc.

*Paper presented at the COSPAR meeting:*

R. Kariyappa, H.N. Adithya, S. Masuda et al. EUV, UV & X-ray Irradiance Variability over the Solar Cycle 24 and their Impacts on Earth's Climate & Space Weather, July 13-21, 2024, Busan, South Korea

(Form02-2)

# Evaluation of Different Techniques for Deriving 3D Wind Fields from the PAWR Observations and Deriving Precipitation from Satellite Observations

Chih-Chien Tsai (National Science and Technology Center for Disaster Reduction)

## 1. Purpose

Following the successful technical exchange in 2023, Prof. Nobuhiro Takahashi extended a second invitation to the National Science and Technology Center for Disaster Reduction (NCDR) in Taiwan to apply for the 2024 Institute for Space-Earth Environmental Research (ISEE) International Joint Research Program. This continued collaboration aims to strengthen international cooperation between the two institutions. The NCDR delegation consists of five members: Drs. C.-C. Tsai, Y.-C. Chen, H.-H. Lin, S.-C. Huang, and Ms. D.-R. Chen. In addition to the previous year's focus on phased array radar data processing, this year's exchange expanded to include satellite data applications, heterogeneous disaster prevention data visualization, and disaster prevention product applications. Through this ongoing international exchange, NCDR staff can absorb the latest research capabilities from abroad and further explore potential future collaborative projects between the two organizations.

## 2. Methods (five topics)

The NCDR delegation embarked on a seven-day academic exchange visit to Nagoya University on October 20, 2024. Japanese scholars participating in the discussions included Profs. N. Takahashi, K. Tsuboki, T. Shinoda, and Dr. S. Lestari from ISEE, Prof. T. Ushio from Osaka University, and Dr. N. Yoshida from the Japan Aerospace Exploration Agency (JAXA). The exchange covered the following five topics:

(a) Dual-polarization phased array radar hardware, data processing, product demonstration, and severe weather diagnostic analysis.

(b) Satellite data processing, product development, and visualization.

(c) Visualization techniques and disaster prevention product applications.

(d) Visits to Kyoto University's Middle and Upper Atmosphere (MU) radar and Osaka University's Multi-Parameter Phased Array Weather Radar (MP-PAWR).

(e) Discussion of Memorandum of Understanding (MoU) for future collaboration.

## 3. Results (of the five topics)

(a) Dr. Tsai delivered a lecture on "An Update of Radar-related Research Progress in NCDR", with key achievements on dual-polarization radar quantitative precipitation estimation and severe weather monitoring applications. Prof. Takahashi delivered an introduction to Japan's MP-PAWR systems. Following the 2023 exchange, NCDR successfully conducted Wind Synthesis System Using Doppler Measurements (WISSDOM) three-dimensional (3D) wind field retrieval tests using the MP-PAWR data, establishing a solid foundation for future collaboration. Prof. Takahashi provided clarification on technical issues and committed to sharing additional data for comparative analysis.

(b) Dr. Yoshida presented on Global Satellite Mapping of Precipitation (GSMaP) algorithms and products. NCDR delegation members successfully registered as GSMaP members and downloaded valuable rainfall data for drought response and severe weather analysis. Dr. Chen delivered a lecture on "Applications of Meteorological Satellite Data in Disaster Prevention by NCDR," with key achievements on real-time monitoring systems, cloud parameter retrieval, and 3D satellite cloud visualization platform development.

(c) Prof. Takahashi presented MP-PAWR observations of severe rainfall events, demonstrating how integrating radar, lightning, and camera data enhanced understanding of convective storm lifecycles. Dr. Lestari shared findings on Typhoon Jongdari (2018), revealing how convective rainfall proportion increased as the typhoon approached. Dr. Lin delivered a lecture on "Application of Big Data and Visualization Technique on Disaster Warning System," showcasing NCDR's meteorological database and visualization products. Both parties exchanged views on developing 3D radar echo profile visualization modules using the MP-PAWR data and discussed animation capabilities.

(d) During the visit to Kyoto University's MU radar facility, the NCDR delegation observed one of the world's largest atmospheric radar systems, featuring 475 Yagi antenna modules that enable continuous 3D wind monitoring. The delegation also toured Osaka University's MP-PAWR, upgraded in 2023. This advanced system achieves 10–30 second temporal resolution through 12 transmitting and 128 receiving antennas, significantly enhancing monitoring of small-scale severe weather phenomena.

(e) The NCDR delegation actively discussed establishing an MoU with Profs. Takahashi and Tsuboki. The proposed collaboration framework focuses on natural disaster prevention cooperation, data exchange, visualization tool sharing, and professional development opportunities. ISEE agreed to the partnership but suggested expanding beyond visualization tools to include other technologies. Rather than annual alternating symposiums, both parties agreed to emphasize exchanges between young scientists. NCDR has drafted the MoU, and coordination for a signing ceremony is currently underway.

## 4. Periods of stay

Oct. 21 (Mon) @617 bldg. I
10:30-12:00 Lecture by Dr. Tsai (in "Radar Meteorology" class)
12:00-13:30 Lunch
13:30-17:00 MP-PAWR/WISSDOM discussion (I)
17:00-19:30 MoU discussion

Oct. 22 (Tue) @617 bldg. I
09:00-12:00 GSMaP discussion (I)
12:00-13:30 Lunch
13:30-15:00 Lecture by Dr. Chen
15:30-17:00 GSMaP discussion (II) including wrap-up

Oct. 23 (Wed) @617 bldg. I
09:00-12:00 (not decided yet because ISEE's Faculty meeting)
12:00-13:30 Lunch
13:30-17:00 Lecture by Dr. Lin

Oct. 24 (Thu) Visit to MU radar (Kyoto U.) and MP-PAWR (Osaka U.) sites
08:00 Nagoya (pick you up at the hotel)
10:00 MU radar site
11:30 Lunch at Shigaraki
14:30 MP-PAWR radar site (Osaka U.)
16:00 leave MP-PAWR site
18:30 Nagoya

Oct. 25 (Fri) @409 bldg. II
09:00-12:00 MP-PAWR/WISSDOM discussion (II) and wrap-up
12:00-13:30 Lunch
13:30-17:00 Wrap-up the meeting.

## 5. Publication

Hsu, L.-H., Chiang, C.-C., Lin, K.-L., Lin, H.-H., Chu, J.-L., Yu, Y.-C. and Fahn C.-S. (2024) Downscaling Taiwan precipitation with a residual deep learning approach. *Geoscience Letters*, 11, 23.

(Form02-2)

# Identification of Avian Dietary Change and Its Implications Using Isotopic Technology

Xueqiang Lu (Nankai University)

## 1) Purpose

Evaluating the composition of avian diets has been a focus of ornithological inquiry for over a century. Understanding the dietary niche of a species allows researchers to quickly describe important life-history traits as well as the complex interactions that birds have with their environments and, in turn, provides essential information for the management and conservation of avian species and their habitats. the objective of this study is to identify temporal changes in bird diet compositions over nearly a century. This will be accomplished through the measurement of stable isotopes (specifically δ13C and δ15N) in feathers collected at different ages, spanning almost 100 years.

## 2) Methods

Feathers of bird specimens with different collection time from Tianjin Nature Museum will be used in this study. Meanwhile, feathers of the same birds will be also collected as the sample of the present time. The samples will cover different ecological groups. Meanwhile, the information on ecological status at the specimen collection sites will be recorded and analyzed. All the collected feathers will be rinsed and dried. Subsequently, Nitrogen-15 and Carbon-13 will undergo further analysis via Isotope Ratio Mass Spectrometry (IRMS) at ISEE.

## 3) Results

The sample measurement results are listed in Table 1. It should be noted that all the measurement has not been finished yet and the sample measurement is still ongoing.

**Table 1 Sample measurement results.**

| Sample Name | Weight (mg) | Carbon Content (mg) | Percentage (%) | $\delta^{13}C_{PDB}$ (%) | Nitrogen Content (mg) | Percentage (%) | $\delta^{15}N_{AIR(N1)}$ | $\delta^{15}N_{AIR(N2)}$ | $\delta^{15}N_{AIR}$ (%) |
|---|---|---|---|---|---|---|---|---|---|
| L3_P | 1.284 | 0.63 | 49.45 | -19.14 | 0.17 | 13.45 | 8.99 | 9.09 | 9.04 |
| L4_B | 0.542 | 0.31 | 56.48 | -23.27 | 0.07 | 12.76 | 8.94 | 9.04 | 8.99 |
| L4_P | 1.017 | 0.51 | 50.60 | -26.16 | 0.13 | 13.14 | 7.72 | 7.82 | 7.77 |
| L7_P | 1.42 | 0.69 | 48.35 | -20.72 | 0.21 | 15.09 | 8.53 | 8.63 | 8.58 |
| L10_P | 1.348 | 0.73 | 54.40 | -23.36 | 0.17 | 12.50 | 4.88 | 4.98 | 4.93 |
| L12_P | 1.012 | 0.58 | 57.38 | -28.93 | 0.11 | 11.22 | 12.38 | 12.48 | 12.43 |
| L15_P | 0.936 | 0.48 | 50.79 | -22.93 | 0.13 | 13.77 | 4.17 | 4.27 | 4.22 |
| L14_P | 1.072 | 0.52 | 48.06 | -24.36 | 0.15 | 14.17 | 7.02 | 7.12 | 7.07 |
| L16_P | 0.782 | 0.37 | 47.72 | -22.92 | 0.11 | 14.57 | 6.36 | 6.46 | 6.41 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| L17_P | 1.608 | 0.78 | 48.26 | -18.17 | 0.25 | 15.76 | 7.51 | 7.61 | 7.56 |
| L18_P | 1.637 | 0.79 | 48.09 | -27.22 | 0.25 | 15.06 | 8.49 | 8.59 | 8.54 |
| L19_P | 1.343 | 0.64 | 47.29 | -26.91 | 0.19 | 14.00 | 12.17 | 12.28 | 12.23 |
| L3_B | 1.175 | 0.54 | 45.86 | -17.70 | 0.17 | 14.11 | 11.15 | 11.25 | 11.20 |
| L7_B | 1.003 | 0.49 | 48.91 | -21.99 | 0.14 | 13.52 | 8.97 | 9.07 | 9.02 |
| L10_B | 1.011 | 0.50 | 49.02 | -21.60 | 0.15 | 14.67 | 5.26 | 5.36 | 5.31 |
| L12_B | 1.486 | 0.71 | 47.99 | -30.20 | 0.23 | 15.41 | 12.53 | 12.63 | 12.58 |
| L13_B | 1.482 | 0.71 | 48.22 | -18.04 | 0.22 | 15.06 | 8.25 | 8.35 | 8.30 |
| L14_B | 1.043 | 0.51 | 48.91 | -21.84 | 0.16 | 15.16 | 7.94 | 8.04 | 7.99 |
| L15_B | 1.104 | 0.53 | 48.08 | -22.46 | 0.16 | 14.35 | 4.40 | 4.50 | 4.45 |
| L16_B | 0.827 | 0.40 | 48.97 | -24.32 | 0.11 | 13.16 | 5.31 | 5.41 | 5.36 |
| L17_B | 1.096 | 0.54 | 49.60 | -19.57 | 0.14 | 13.15 | 8.87 | 8.97 | 8.92 |
| L20_B | 1.179 | 0.56 | 47.58 | -16.22 | 0.17 | 14.63 | 4.79 | 4.89 | 4.84 |
| L21_B | 1.009 | 0.47 | 46.34 | -22.77 | 0.15 | 14.56 | 7.07 | 7.18 | 7.13 |
| L21_P | 1.135 | 0.53 | 46.97 | -24.56 | 0.17 | 14.93 | 8.48 | 8.58 | 8.53 |
| L1_B | 1.066 | 0.51 | 47.60 | -25.57 | 0.15 | 14.37 | 7.94 | 8.04 | 7.99 |
| L2_B | 1.245 | 0.57 | 45.39 | -22.75 | 0.18 | 14.13 | 6.10 | 6.20 | 6.15 |
| L5_B | 0.951 | 0.44 | 45.80 | -14.67 | 0.13 | 13.96 | 13.44 | 13.54 | 13.49 |
| L8_B | 0.979 | 0.46 | 46.94 | -21.22 | 0.13 | 13.60 | 7.39 | 7.49 | 7.44 |
| L9_B | 1.238 | 0.48 | 38.50 | -19.85 | 0.14 | 11.29 | 7.20 | 7.30 | 7.25 |
| L11_B | 0.938 | 0.37 | 39.88 | -23.62 | 0.11 | 11.28 | 21.07 | 21.17 | 21.12 |

**4) Periods of stay in ISEE**

I visited ISEE twice and each time I stayed about one week.

**5) Publications**

Because the measurement is still ongoing, there is no paper published yet. Hopefully, we may publish one co-authored paper in 2025.

(Form02-2)

# Comparative studies on Earth's and Mercury's dynamic magnetospheres

Prof. Jih-Hong Shue (National Central University, Taiwan)

The main goal of our visit (including my students Mr. Pai-Sheng Wang and Ms. Wun-Jyun Lin) to Institute for Space-Earth Environmental Research (ISEE) of Nagoya University is to perform an international joint project on planet Mercury and to consolidate an international relationship with some researchers from ISEE and Nagoya City University. We collaborated with the researchers on the dynamics of planet Mercury's magnetosphere as compared to Earth's. We intended to work together on some topics during the visiting period and publish papers on either Mercury or Earth in the future. With the travel budgets supported from ISEE and our own, the visit was finally realized in the two periods: One was the period of April 1-15, 2024 and the other was October 31 - December 2, 2024.

During the first visit, I interacted with Profs. Masafumi Hirahara, Akimasa Ieda, and Tomoaki Hori on some research topics, including plasma and magnetic fields just outside the subsolar magnetopauses and the structure of the current sheet of the magnetotail around substorm onsets for both Mercury and Earth. I also presented a seminar [Pre1], entitled "A comparative study on the compressibility of Earth and Mercury's dayside magnetospheres," reporting their differences in the compression ratio and the location of the subsolar magetopause. During the seminar, I fully interacted with the ISEE researchers attended, receiving valuable comments from them. Meanwhile, I took some time to discuss Prof. Masahito Nosé of Nagoya City University about which IMF condition is for the quietest direct-driven geomagnetic activity. We submitted a paper to Earth, Planets, and Space near the end of this project [Pub1].

Under an arrangement by Prof. Hirahara, I went to Institute of Space and Astronautical Science (ISAS) of the Japan Aerospace Exploration Agency (JAXA) for one day on April 10, 2024, visiting Profs. Yoshifumi Saito, Iku Shinohara, Hiroshi Hasegawa, and Go Murakami. I presented a seminar about a comparative study on Mercury and Earth's magnetospheres there [Pre2]. Under my interaction with them, they understood more about my new results and I knew more about the BepiColomo mission. For examples, due to the planned orbits of BepiColomo, the region near the subsolar magnetopause will not be traversed. Therefore, I need to modify my research ideas of using data from BepiColombo.

During the second visit, two of my students, Mr. Pai-Sheng Wang and Ms. Wun-Jyun Lin, came to ISEE with me. We worked closely with Profs. Masafumi Hirahara, Tomoaki Hori, Akimasa Ieda, Masahito Nose, and Yoshizumi Miyoshi. We made some progress in the research, including establishing the magnetic profile of the magnetosheath, developing a technique in fitting both single and bifurcated current sheets of the magnenetotail, understanding more about the FTE and ULF near the magnetopause of Mercury, and studying the properties of magnetospheric chorus subelements.

In addition to visiting ISEE, we made two business trips: One was to the Institute of Advanced Energy (IAE) on the Uji campus of Kyoto University on November 6, 2024, and the other was to ISAS on November 13-14, 2024. During our visit to IAE, we met with Profs. Shigeru Inagaki, Yasuhiro Nariyuki, Yuto Katoh, and Yikai Hsieh. We drew an analogy between magnetospheric chorus waves and currents generated in a fusion device in a repetitive manner. I presented a talk there [Pre3]. After the meeting on Bursty Phenomena in Space and Experimental Plasmas was ended, Prof. Inagaki took us a tour to see his Heliotron-J fusion device. During our visit to ISAS, we intensively discussed with Profs. Iku Shinohara, Yoshifumi Saito, Hiroshi Hasegawa, and Go Murakami on our research progress on Mercury's magnetosheath profiles and Earth's current sheets of the magnetotail. The questions and comments they gave us help improve the quality of the results in the future. They also updated our knowledge on the BepiColombo mission in the aspects of future flybys and a delay of inserting Mercury's orbit.

In summary, the outcome received from our two visits is considered substantial. We have made some progress in the research on Mercury and Earth. Both sides understood better to each other through the interactions. Although the results derived from the research are not published yet [Pub2, Pub3], both sides are willing to keep in touch afterward. We will discuss any research progress, problems, or difficulties via email, or plan another scholar exchange for further collaboration. For examples, Prof. Masafumi Hirahara helped us (me and Dr. Shu-Hua Lai) to apply for the memberships of the MPPE team for the BepiColombo mission in February of 2025. We will be delighted to work on data obtained from BepiColombo when available. Moreover, Prof. Hiroshi Hasagawa has planned to visit National Central University in April 9-23, 2025. We will work together on magnetic reconnection related topics on Mercury and Earth.

**Publications:**

[Pub1] Shue, J.-H., and M. Nosé, Which interplanetary magnetic field condition is for the quietest direct-driven geomagnetic activity?, Submitted to Earth, Planets, and Space, 2025.

[Pub2] Chiu, I-H., J.-H. Shue, H. Hasegawa, J. Zhong, and M. Hirahara, A survey of the anomalous reconnection layer on Mercury, Submitted to EGU General Assembly, April 27 – May 2, 2025.

[Pub3] Lin, W.-J., J.-H. Shue, X. Tao, Y. Miyoshi, Y. Omura, H.-W. Shen, and Y.-K. Hsieh, Invariant distributions of magnetospheric chorus subelements, To be submitted to Geophysical Research Letters, 2025.

**Presentations:**

[Pre1] Shue, J.-H., A comparative study on the compressibility of Earth and Mercury's dayside magnetospheres, ISEE Seminar, Nagoya University, 2024/03/27.

[Pre2] Shue, J.-H., A comparative study on the compressibility of Earth and Mercury's dayside magnetospheres, JAXA/ISAS Seminar, 2024/04/10.

[Pre3] Shue, J.-H., Bursty phenomena in space: Magnetospheric chorus waves, IAE Workshop, Kyoto University, 2024/11/06.

(Form02-2)

# Effects of Ionospheric Scintillation on the Precision of GNSS Precise Point Positioning (PPP) Technique at Low-latitude region

Prayitno Abadi (Research Center for Climate and Atmosphere, BRIN)

I stayed at the Institute for Space-Earth Environmental Research (ISEE) at Nagoya University from October to November 2024. I studied the performance of GNSS positioning techniques affected by ionospheric scintillation in low-latitude regions. In this study, the occurrence of ionospheric scintillation is represented by an increase in the Total Electron Content (TEC) change index (ROTI), observed from a Global Navigation Satellite System (GNSS) receiver in Indonesia. In low-latitude areas like Indonesia, scintillation events and ROTI enhancements are primarily associated with the nocturnal Equatorial Plasma Bubble (EPB) phenomenon, which refers to a localized depletion of plasma density in the F region of the ionosphere. Both scintillation and ROTI enhancements reflect the ionospheric irregularities (plasma density fluctuations) within the EPB. During my stay at ISEE, I investigated the performance of two precise positioning techniques, namely the Real-Time Kinematic (RTK) and precise point positioning (PPP) techniques, during EPB presence. After I return to my country, Indonesia, I continue to conduct the experiments of ionospheric effects on PPP technique since my focus on this topic, and this report to present the results of investigating the effects of EPB on the PPP technique

I used the Canadian Spatial Reference System PPP (CSRS-PPP) to compute precisely positioning the P14P GNSS station (a priori position: Longitude: 119.836°, Latitude: -0.905°) in Indonesia, both during EPB occurrences and non-occurrences. I collected the Receiver Independent Exchange Format (RINEX) data from the P14P station between March and April 2023 (54 days). CSRS-PPP is a free online PPP service that allows us to submit RINEX files from specific GNSS stations to obtain positioning outputs in cm levels. PPP requires ambiguity resolution (AR), which can significantly enhance accuracy and reduce initialization time by identifying and correcting integer biases in carrier-phase measurements. Therefore, the performance of PPP can be assessed by the percentage of fixed ambiguities, which indicates how much the CSRS-PPP achieves AR in calculating the precise position of the station. Furthermore, the ROTI enhancement is used to determine the presence of EPB. We calculated the root mean square (RMS) of ROTI values from 10 to 24 UT to represent the strength and duration of ROTI enhancement on each observation night.

Figure 1 presents the results of PPP performance during EPB occurrence (ROTI enhancement). Fig. 1(a) provides an example of ROTI enhancement during nighttime on March 10, 2023, indicating the presence of EPB that night. On the other hand, Fig. 1(b) displays the output of CSRS-PPP, showing the number of available satellites and the percentage of ambiguity resets on the night of March 10, 2023. Fig. 1(b) highlights that the CSRS-PPP performed ambiguity resets coinciding with the period of ROTI enhancement, as indicated by the ambiguity resets feature (red “×”). On that night (from 10 to 24 UT), the percentage of fixed ambiguities (PPP-AR) achieved was 87.58%. Fig. 1(c) importantly illustrates our experiment on PPP performance during EPB occurrences. The EPB occurrences were quantified by the RMS ROTI enhancement at night, while the performance of PPP was quantified by the percentage of AR achieved. Fig. 1(c) indicates that the percentage of AR tends to decrease as the RMS ROTI increases. Here, we conclude that the ionospheric irregularities present during EPB can influence the performance of the PPP technique in low-latitude regions. Stronger ionospheric irregularities associated with EPB can degrade PPP performance by reducing the fixed ambiguity resolution.

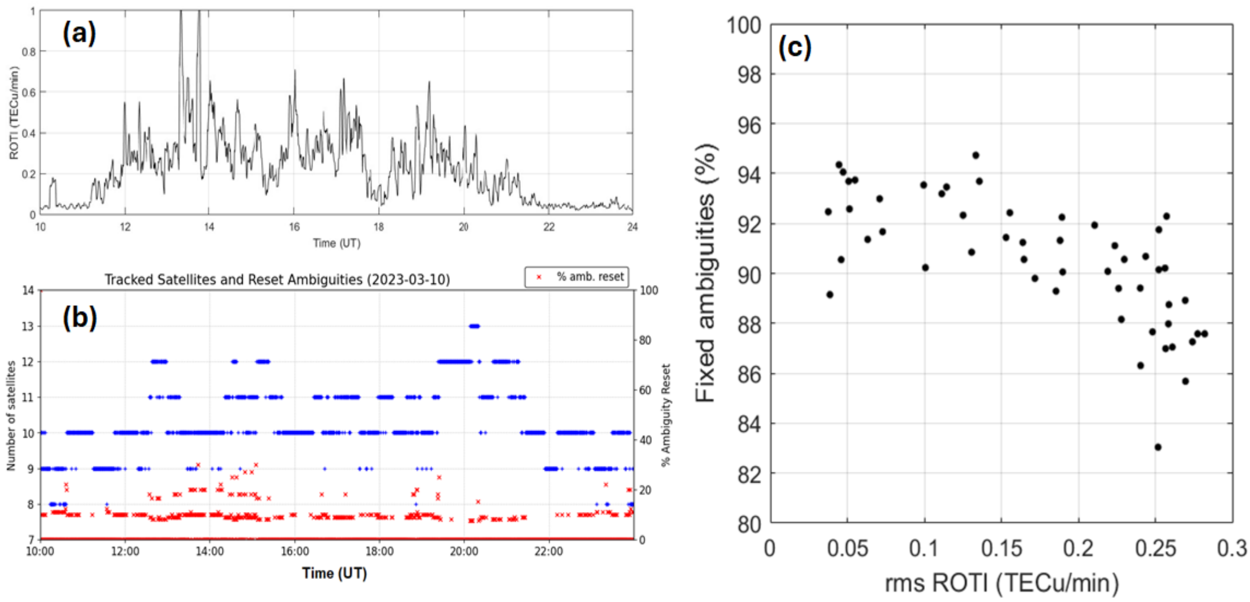



Figure 1. (a) ROTI enhancement obtained from P14P station on 10 March 2023. (b) The output from CSRS-PPP showing the number of satellites (blue dots) and ambiguity resets (red crosses). (c) The performance of PPP (percentage of fixed ambiguities) as a function of RMS ROTI enhancement from the experiment in this study.

List publications:

I have not published any material from this report in a peer-reviewed international journal, but I plan to do so in the future. I plan to focus on the performances of the PPP technique under the EPB presence in low-latitude regions.

(Form02-2)

## Vortical plasma and magnetic structures in the solar atmosphere and beyond

Dr Gary Verth, The University of Sheffield,
School of Mathematical and Physical Sciences
Hicks Building, Hounsfield Road
Sheffield, S3 7RH

Within this project we investigated the dynamical physical properties of the vortical coherent plasma motions in the solar atmospheric plasmas. It includes the identification of the vortical motions, energy transfer within vortical structures, wave excitation and propagation, interaction and life cycles of K and M vortex tubes (Silva et al, 2021). For the analysis we utilised the data obtained from magneto-hydrostatic simulations (with presence of the rotational flow, PLUTO code (Mignone et al. 2007, 2012, 2018)), the magnetoconvection numerical data obtained with use of MURaM (Vogler et al., 2005), RAMENS (Iijima & Yokoyama, 2017) and R2D2 (Hotta et al., 2019; Hotta and Iijima, 2020) codes and observational data. In magneto-hydrostatic simulations we investigate the contribution from MHD waves to the Poynting flux in a 3D realistic solar atmosphere, modelling a solar vortex tube in the presence of different plasma rotational flow configurations. These simulations feature a closed magnetic loop system where a rotational flow is imposed at one foot-point in addition to photospheric perturbations acting as a wave driver mimicking those of p-modes. It was found that variety of MHD waves exist within the vortex tube, including sausage, kink and torsional Alfven waves, owing to the photospheric wave driver and the nature of the rotational flow itself. Comparison of simulations with and without the rotational plasma flow, shows that the Poynting flux increases in the presence of the rotational flow as the waves transport increased magnetic energy. It was also demonstrated that a vortex tube considerably increases the effectiveness of magnetic wave energy flux transport into the corona. For the analysis of the magnetoconvection data and recovering plasma flow velocities and therefore vortical motions we trained DeepVel neural network on the R2D2 radiative MHD simulation depicting the emergence and decay of a magnetic flux tube. DeepVel achieved strong correlations with flows from an unseen MURaM simulation. We have shown that DeepVel is able to capture the detailed topology well, e.g., the structure of vortical and diverging structures across all scales present in the flows. DeepVel performed slightly less well in the umbra, this is likely explained by magnetic field suppression and reduced contrast. We demonstrate for the first time that the DeepVel-recovered velocities accurately (in comparison to the FLCT and coherent structure tracking) reflected the flow's transport barriers. These findings highlight the precision and reliability of the DeepVel and its ability to emulate plasma flows surrounding and within active regions.

Dr Suzana Silva visited ISEE between 14-20$^{th}$ of March 2025. During her visit she presented our work on vortex detection with use of PCA techniques and Gamma method, discussed an analysis of vortical motions within active regions as well as analysis of data previously provided to the Plasma Dynamics Group (Iijima et al., ApJL, 2023). In the framework of this project Prof Viktor Fedun visited ISEE between 23-31$^{st}$ of March 2025. He updated ISEE colleagues with the project results, discussed plans for future collaboration and required data transfer for future work. In particular, there is a new data available from simulations (RAMENS) that build upon the framework of the paper published in Iijima et al., ApJL, 2023, with the aim of exploring the connection between surface dynamics and processes in the solar wind. The primary objective of the proposed analysis is to study the plasma flow vortical behaviour (within horizontal slices) and energy transfer varying initial conditions. While the box size remains consistent across all simulations, each one incorporates different boundary conditions, specifically varying the strength of the small-scale dynamos. A key focus of our future work will be to analyse the distribution of coherent structures across 16 simulations (h=0-20 solar radius). Given that these simulations are initialised with different small-scale dynamo configurations, we aim to investigate how these variations impact the formation and evolution of plasma coherent flow structures and wave propagation. It is also important to highlight that the collaboration within this joint research supported establishing of the Solar Physics International Network for Swirls (an international initiative devoted to study all kind of vortices in the Sun and their role in the solar plasma dynamics and successful ISSI application: "Opening new avenues in identifying coherent structures and transport barriers in the magnetised solar plasma", ISSI Team led by S. Silva & V. Fedun, Dr Haruhisa Iijima is a member of the Team. Currently we are working on preparation of two papers: "Solar Vortex Communities and their Interactions" (with use of RAMENS data) and "Identification and Tracking of the Coherent Flow Structures within Active Regions" (based on the analysis of R2D2 data).

**Publications**

Recovering Coherent Flow Structures in Active Regions using Machine Learning, Lennard, M., Silva, S., Tremblay, B., Ramos, A. A., Verth, G., Ballai, I., Iijima, H., Hotta, H., Rempel, M., Park, S-H., Fedun, V., MNRAS, 2025 (Accepted)

Skirvin, S., Fedun, V., Verth, G., Ballai, I., 3D MHD wave propagation and energy transport in a simulated solar vortex, ApJ, 2025 (Submitted)

Skirvin, S., Fedun, V., Goossens, M., Silva, S.S.A., Verth, G., Poynting flux of MHD modes in magnetic solar vortex tubes, ApJ, 975,176, 2024

Silva, S. S. A., Verth, G., Ballai, I., Rempel, E., Shelyag, S., Schiavo, L. A. C. A., Gomes. T. F. P., Fedun, V., Solar Vortex Tubes III: Vorticity and Energy Transport, ApJ, 975, 118, 2024

Schiavo, L. A. C. A., Gordovskyy, M., Browning, P., Silva, S. S. A., Verth, G., Ballai, I., Shelyag, S., Ruzheinikov, S., McLaughlin, J., Fedun, V., Modeling the effects of a lightbridge on properties of MHD waves in solar pores, ApJ, 975, 45, 2024

Jafarzadeh, S., Schiavo, L.A.C., Fedun, V., Solanki, S.K., Stangalini, M., Calchetti, D., Verth, G., Jess, D.B., Grant, S.D.T., Ballai, I., Gafeira, R., Keys, P.H., Fleck, B., Morton, R.J., Browning, P.K., Silva, S.A., Appourchaux, T., Gandorfer, A., Gizon, L., Hirzberger, J., Kahil, F., Orozco Suarez, D., Schou, J., Strecker, H., del Toro Iniesta, J.C., Valori, G., Volkmer, R., Woch, J., Sausage, kink, and fluting MHD wave modes identified in solar magnetic pores by Solar Orbiter/PHI, Astronomy & Astrophysics, 2024

Berretti, M., Stangalini, M., Verth, G., Jafarzadeh, S., Jess, D., Berrilli, F., Grant, S. D. T., Duckenfield, T. and Fedun, V. Unexpected frequency of horizontal oscillations of magnetic structures in the solar photosphere, Astronomy & Astrophysics Letters, 687, L21, 2024

(Form02-2)

# Estimation of quasi 2-day wave Momentum flux in the high latitude middle atmosphere

Dr. Grandhi Kishore Kumar (Centre for Earth, Ocean and Atmospheric Sciences, University of Hyderabad)

**Summary and purpose:**

The mesosphere and lower thermosphere (MLT) region act as a critical transition zone for wave dynamics and dissipative processes. Energetically, the MLT is primarily influenced by waves propagating from the lower atmosphere, ranging from short-period gravity waves to long-period planetary waves. The quasi-2-day wave (QTDW) is a global-scale planetary wave with variable periodicity. This study focuses on understanding QTDW characteristics, along with its seasonal and interannual variability over polar latitudes. These waves play a key role in coupling the MLT with the upper atmosphere, as their effects extend into the ionosphere. Estimating QTDW momentum flux and quantifying its forcing on the mean flow will provide insights into its impact on MLT dynamics and the broader atmospheric circulation.

**Database and Methodology**

To accomplish our objectives, we utilized extensive observations from meteor radars strategically positioned around the Arctic Circle. Table 1 provides detailed information regarding these observations, while Figure 1 illustrates the radar locations. The long-term enabled a comprehensive investigation of the quasi-2 day wave over polar latitudes.

**Table 1**: Details of the meteor radar observations

| **Station Name** | **Location** | **Time period** | **Reference** |
|---|---|---|---|
| Alta | 69.97ºN, 23.24ºE | 08/09/2015-31/12/2022 | Stober et al., 2021 |
| Tromsø | 69.97ºN, 19.2ºE | 19/11/2003-26/08/2021 | Hall et al., 2001 |
| Svalbard | 78ºN,15.99ºE | 14/03/2001-31/12/2022 | Hall et al., 2002 |

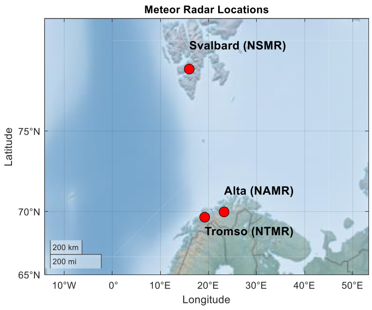



**Fig. 1**. Locations of the Meteor radar observations

In the present study, we utilized hourly mean winds in the altitude region of 80-100 km with 2 km resolution. We also used the meteor decay time ($\tau$) observations, which are related to the ambipolar diffusion coefficient (D).

$$D = \frac{\lambda^2}{16\pi^2\tau}$$

Where '$\tau$' is meteor decay time, and 'λ' is the radar wavelength

Further, the ambipolar diffusion coefficient can be related to the other atmospheric parameters as

$$D \propto \frac{KT^2}{p} \propto \frac{KT}{\rho}$$

Where 'K' is the zero-field reduced mobility of ions, 'T' is atmospheric temperature, 'p' is pressure and '$\rho$' is density (*McDaniel and Mason,* 1973).

*Tsutsumi et al.* (1996) demonstrated that $\frac{D'}{D_0} \sim 2\frac{T'}{T_0}$ under the assumption of valid Boussinesq approximation, where the factor '2' ranges anywhere between 2 and 2.2, as per *Ellis et al*. (1984). Based on this relation, we used $\frac{D'}{D_0}$ to estimate heat fluxes.

To determine the quasi-2 day wave, we used a least square fit with variable periodicities ranging from 44 to 55 hours, in conjunction with tidal components (8hr, 12hr and 24hr). We consider the selected period of QTDW, which exhibited maximum amplitude. The least-square fit equation is listed below

$$u(t) = u_0 + \sum_{k=1}^{3} u_k \cos\left(\frac{2\pi k}{T}\,(t - \emptyset_k)\right) + u_q \cos\left(\frac{2\pi}{T_q}(t - \emptyset_q)\right)$$

Where $u_0$ stands for mean wind, 't' stands for time, 'T' stands for Time period, $u_k$ stands for amplitudes of diurnal tide, semidiurnal tide, and terdiurnal tide for k=1,2,3, respectively. Similarly, $\phi_k$ stands for Phase. '$u_q$' stands for QTDW amplitude and $\phi_k$ stands for QTDW phase.

The extracted wave amplitudes and phases of zonal, meridional and ambipolar diffusion coef. are used to estimate horizontal momentum flux, zonal heat flux and meridional heat flux following *Devara and Ahmed (1986)* and using the following equations:

Horizontal Momentum Flux $\overline{u'v'} = 0.5 * u'_q v'_q cos(\emptyset_{uq} - \emptyset_{vq})$

Zonal Heat Flux $\overline{u'D'} \sim 0.5 * u'_q \frac{D'_q}{D_0} cos(\emptyset_{uq} - \emptyset_{Dq})$

Meridional Heat Flux $\overline{v'D'} \sim 0.5 * v'_q \frac{D'_q}{D_0} cos(\emptyset_{vq} - \emptyset_{Dq})$

Where $u'_q, v'_q$ *and* $\frac{D'_q}{D_0}$ represents the amplitudes of the wave in zonal, meridional and Ambipolar diffusion, respectively, of quasi-2 day wave. Similarly, $\emptyset_{uq}, \emptyset_{vq}$ *and* $\emptyset_{Dq}$ denote the corresponding phases.

To address the variations of QTDW, we extracted the QTDW amplitudes and phases using a 5-day window shifted by 1 day. By applying this technique, we could effectively capture and analyze the temporal evolution of QTDW. Further, we computed monthly means of QTDW to understand the interannual variability of QTDW.

**Results**

QTDW amplitudes exhibit clear seasonal and interannual variations, with larger amplitudes during winter and summer. Both zonal and meridional components show nearly equal QTDW amplitudes. For the first time, we have extracted momentum and heat fluxes over polar latitudes using meteor radar observations, revealing distinct seasonal variations. Our current work focuses on the interannual variability of QTDW and uncovering the underlying mechanisms driving these variations, contributing to a deeper understanding of MLT dynamics and coupling between different atmospheric layers.

**Period of Stay and Interactions**

From May 31 to July 2, 2024, I participated in the ISEE International Joint Research Program at the Institute for Space-Earth Environmental Research (ISEE). My visit was hosted by Associate Professor Satonori Nozawa from the Division of Ionospheric and Magnetospheric Research. During my stay, I closely collaborated with Prof. Masaki Tsutsumi from the National Institute of Polar Research (NIPR), Tokyo.

As part of my visit, I delivered a talk on June 27, 2024, titled *"Characteristics and Momentum Flux of the Quasi-2-Day Wave in the MLT Region,"* presenting insights from our research conducted over the low-latitude station in Tirupati, India. After returning to India, I continued my research in close communication with Dr. Nozawa. One of my PhD students has actively engaged in this work, demonstrating a strong interest and contributing significantly. Recently, we submitted an abstract to AOGS-2025, Singapore, which has been accepted for presentation.

The collaborative experience at ISEE was invaluable in advancing our understanding of atmospheric dynamics. I sincerely thank Dr. Nozawa and his colleagues at ISEE for their warm hospitality and support, which made my visit both productive and enjoyable. Their generosity, expertise, and dedication have greatly enriched our research efforts and laid the foundation for continued collaboration. I look forward to furthering our joint scientific pursuits in the future.

**References**


Devara, P. C. S., & Ahmed, M. I. (1986). Momentum flux variations at lower thermospheric levels as seen from mid-latitude meteor wind observations. *Meteorology and Atmospheric Physics*, *35*(4), 236–241. https://doi.org/10.1007/bf01041816

Ellis, H. W., Pai, R. Y., McDaniel, E. W., Mason, E. A., & Viehland, L. A. (1976). Transport properties of gaseous ions over a wide energy range. *Atomic Data and Nuclear Data Tables*, *17*(3), 177–210. https://doi.org/10.1016/0092-640x(76)90001-2

Hall, C. M., The Ramfjordmoen MF radar (69N, 1E): Application development 1990–2000, J. Atmos. Sol. Terr. Phys., 63, 171–179, 2001.

Hall, C. M., T. Aso, and M. Tsutsumi, An examination of high latitude upper mesosphere dynamic stability using the Nippon/Norway Svalbard Meteor Radar, Geophys. Res. Lett., 29(8), 1280, doi:10.1029/ 2001GL014229, 2002.

McDaniel, E. W., & Mason, E. A. (1973). *The mobility and diffusion of ions in gases*. *Wiley eBooks*. Retrieved from http://ci.nii.ac.jp/ncid/BA06958868

Nozawa, S., Hall, C.M., Tsutsumi, M., Brekke, A., Ogawa, Y., Tsuda, T.T., Oyama, S., Fujii, R., 2012. Mean winds, tides, and quasi-2 day waves above Bear Island. J. Atmos. Solar-Terr. Phys. 90-91, 26–44.

Stober, G., A. Kozlovsky, A. Liu, Z. Qiao, M. Tsutsumi, C. Hall, S. Nozawa, M. Lester, E. Belova, J. Kero, P. J. Espy, R. E. Hibbins, and N. Mitchell, Atmospheric tomography using the Nordic Meteor Radar Cluster and Chilean Observation Network De Meteor Radars: network details and 3DVAR retrieval, Atmospheric Measurement Techniques, 14, 6509–6532, 2021, https://doi.org/10.5194/amt-14-6509-2021

Tsutsumi, M., Tsuda, T., Nakamura, T., & Fukao, S. (1996). Wind velocity and temperature fluctuations due to a 2-day wave observed with radio meteor echoes. *Journal of Geophysical Research Atmospheres*, *101*(D5), 9425–9432. https://doi.org/10.1029/95jd03579

(Form 2-2)

# Warm Plasma Cloak and Cross-Calibration Project

Jing Liao (University of New Hampshire)

**Period of stay at ISEE:** From 6 Oct. 2024 to 21 Oct. 2024.

**Project Summary:**

My visit at ISEE in the Nagoya University was both a pleasant and productive trip. During the period of visiting, I presented my work on the plasma cloak including the statical study itself, and the cross-calibration work, participated weekly meeting with Prof. Miyoshi's team and students, discussed various interesting research topics with ISEE physicists.

**Purpose:**

The term "warm plasma cloak" refers to a population of bidirectional field-aligned ions, H+ and O+, bouncing along the magnetic field near the Earth. The warm energy ranges (a couple of eVs to the order of keV) and the signature bidirectional pitch angle distribution separates this population from the cold dense plasmasphere (< a few eV), and the energetic ring current (~ 1 keV to 300 keV), both of which are isotropic or "pancake" (pitch angle peaked at 90°). Earlier studies showed the population in observations. Recent work has shown that the warm plasma cloak population has a crucial impact on physical processes within the magnetosphere [Fuselier et al. 2019], influencing the solar wind / magnetosphere coupling. However, much is still unknown about this population. We are still in need of a full statistical picture of the bidirectional population with an energy range from eV to keV, as well as its dependence on the solar and geomagnetic activities. However, the source of the warm plasma cloak is still an open question.

**Data Analysis and Methodology:**

To understand the origin of the population, the generation mechanism of the bidirectional pitch angle and the reason behind the particular range of their energy, we performed a statistical study of this population throughout the inner magnetosphere using data from the Magnetospheric Multiscale (MMS), the Van Allen Probes missions, and the Exploration of energization and Radiation in Geospace (ERG). This allows us to characterize the origin of the warm plasma cloak ions, their transport pathways and drivers.

To utilize flux data measured by instrument onboard different satellite, we will perform a task of cross-calibration between ion spectrometers: MMS / HPCA, ERG / LEP-i, ERG / MEP-i, and Van Allen Probes / HOPE, using Cluster / CODIF, which has been verified with pressure balance, as a yard stick.

**Preliminary Results:**

During the investigation, we have identified a newer, yet not released, version of HOPE data. Will be using this version data in the cross-calibration work. Figure 1 shows how we compare the energy flux of LEP-i and MEP-i, and decided that there is factor between energy flux measured by LEP-i (MEP-i) and HOPE onboard Van Allen Probe B data.

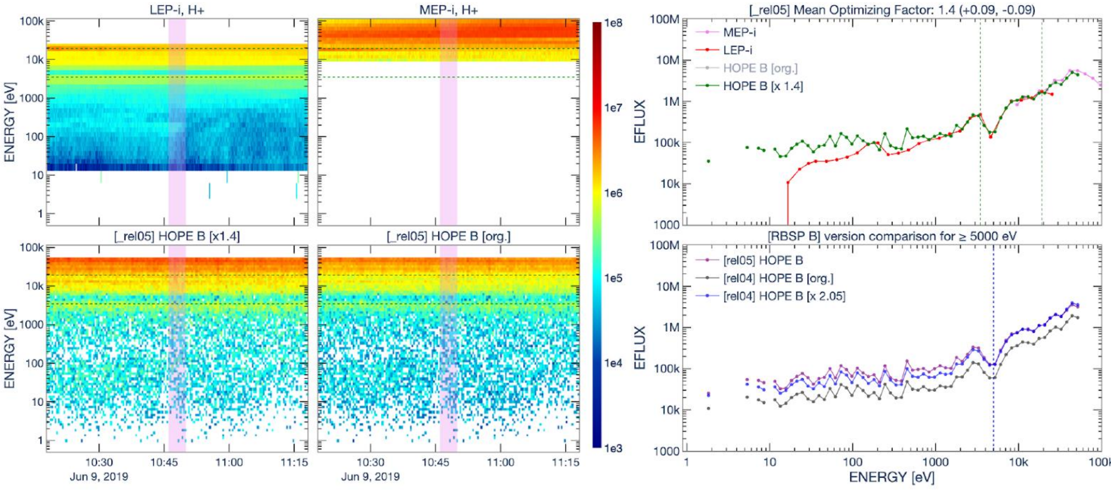



Figure 1. This conjunction event for cross-calibration around 10:45 Jun 9th, 2019. Left 4 spectra panels from top left to bottom right: energy spectra of LEPi, MEPi, HOPE B (rel05 multiplying a factor of 1.4), HOPE B (original rel05). The conjunction event (~4 minutes) marked as the highlighted regions, is the time periods that were used to produce the flux line spectra (on the right). The 2 line-plots on the right are: top panel, the energy flux vs energy for MEP-i, LEP-i, and HOPE B during the conjunction time, and bottom panel energy flux verse energy for HOPE data in different release version.

From the visual inspection of the line-plot on the top, MEP-i and LEP-i data have a smooth transaction, indicating that good agreement between the two instruments. The agreement stays true for many other events as we. To calibration these two instrument with the HOPE, we minimized the Mean Squared Difference (MSD) of time-averaged and energy-step-interpolated energy flux between HOPE and MEP-i and LEP-i, and determine that the factor 1.4 will is needed when comparing the flux data of HOPE to the MEP-i and LEP-i, showed by the agreement between the green line and the red/pink line in top line-plot.

**Publications:**

We are currently wrapping up both the early warm plasma cloak work and the cross-calibration work and preparing two manuscripts. We are aiming to submit both publications by the end of this summer.

(Form02-2)

# Solar and terrestrial effects in the 70-year long tritium and beryllium-10 records from the Dome Fuji in East Antarctica

Principal Investigator: Stepan Poluianov (University of Oulu, Finland)

Past intense solar eruptions are thought to have been recorded as positive anomalies of cosmogenic isotopes (e.g., $^{10}$Be) in paleoarchives, such as ice cores. However, the reconstruction using the cosmogenic isotope method is uncertain because the cosmogenic isotopes archived in the ice cores reflect not only changes in the production of cosmogenic isotopes in the upper atmosphere but also the atmospheric transport and deposition processes at the site. Therefore, to reconstruct the past solar eruptions, it is essential to understand the sensitivity of ice-core records to variations in the production of cosmogenic isotopes in the upper atmosphere. Here, we experimentally examine the sensitivity of cosmogenic isotopes in the ice cores to variation in past solar activities. We collected a snow-pit sample from a depth of 5.4 m Dome Fuji in December 2022. Subsequently, we measured $^{10}$Be concentrations with 3-cm intervals and obtained a $^{10}$Be profile with a high temporal resolution. Additionally, we analyzed several properties of the chemistry and determined the age of the snow pit samples from volcanic signals recorded and tritium peaks from past bomb tests. The age of the deepest sample corresponds to the early 1950s.

Theoretically, we expect the observed $^{10}$Be record to show a good agreement with the variations in $^{10}$Be production owing to solar cycles. Here, we calculated the time series of the $^{10}$Be production rate at Dome Fuji over the past 70 years using the model developed by Poluianov et al. (2016) and then compared it with the observed $^{10}$Be record (Fig. 1a-b). However, observed $^{10}$Be variations related to solar cycles were unclear, although multi-year variations in $^{10}$Be were evident. This result suggests that the variability of $^{10}$Be associated with atmospheric circulation may be as large as or even larger than the variability of $^{10}$Be production associated with the solar cycle. Reconstructing a reliable history of past solar eruptions from ice core records requires removing or reducing the influence of atmospheric circulation.

The ISEE group has been intensively studying the spatio-temporal variability of tritium ($^{3}$H) in response to changes in atmospheric circulation. They reported that water vapor transport from the coastal region is characterized by a lower tritium concentration. In contrast, tritium concentrations increase as water vapor travels from the interior. This supports that atmospheric circulation contributes significantly to the cosmogenic isotopic variability at Dome Fuji. In addition, this suggests that tritium can be used as an indicator of changes in atmospheric circulation. However, because anthropogenic tritium was injected into the upper atmosphere by bomb tests until the early 1970s, we cannot use tritium as a tracer further back than the 1980s. Thus, an additional tracer is needed to cover the entire period of our snow pit samples. Interestingly, the temporal variability of the decay-corrected tritium concentrations in the snow-pit samples at Dome Fuji corresponded well to that of isotopic content of deuterium. In addition, the temporal variability of deuterium shows a good correlation with that of $^{10}$Be. Here we calculated the $^{10}$Be anomaly from the regression line between deuterium ($^{2}$H) and $^{10}$Be and defined it as the $^{10}$Be-anomaly proxy. As can be seen in Fig. 1c, the $^{10}$Be-anomaly proxy shows a clear cycle associated with the solar cycle, although they cannot reproduce the amplitude. This is a rough attempt, but this result indicates that we can reasonably reduce the influence of changes in atmospheric circulation using deuterium.

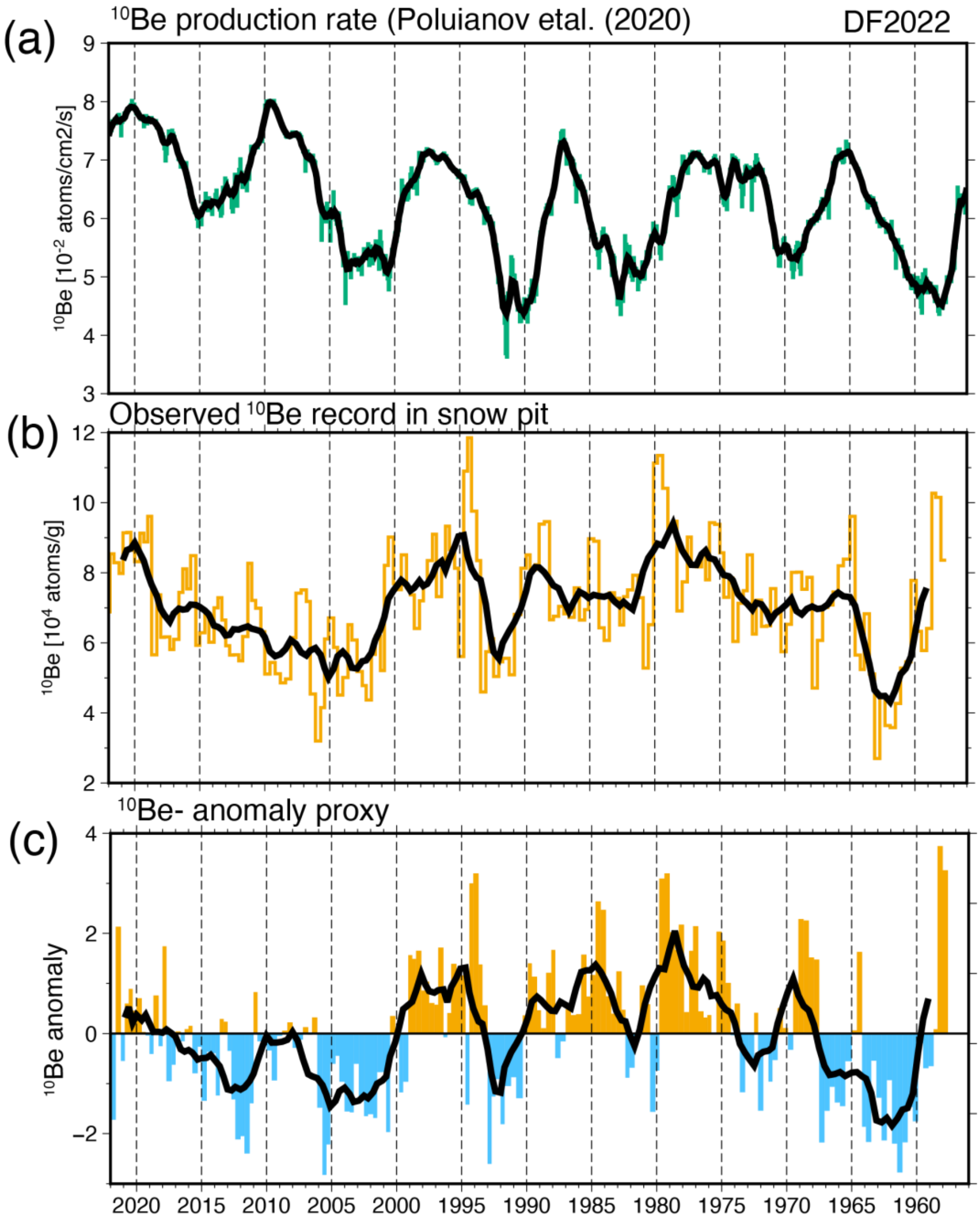



Figure 1. Time series of (a) simulated $^{10}$Be production rate (green line), (b) observed $^{10}$Be in snow pit (orange line) and (c) $^{10}$Be-anomaly proxy (blue and orange bar) at Dome Fuji from 1950s. Solid line represents the 8-year running mean.

**References**

Poluianov, S. V., G. A. Kovaltsov, A. L. Mishev, and I. G. Usoskin (2016), Production of cosmogenic isotopes $^{7}$Be, $^{10}$Be, $^{14}$C, $^{22}$Na, and $^{36}$Cl in the atmosphere: Altitudinal profiles of yield functions, *Journal of Geophysical Research: Atmospheres*, 121, 8125–8136, doi:10.1002/2016JD025034.

**List of presentations:**

N. Kurita et al., Development and evaluation of new $^{10}$Be anomaly proxy for past solar activity, the 9th space climate symposium/ISEE symposium, ISEE, Nagoya, Japan, 02/10/2024

N. Kurita et al., Warming in the Dome Fuji region of East Antarctica driven by strengthening Indian Ocean subtropical front, The 15th Symposium on Polar Science, NIPR, Tokyo, Japan, 03/12/2024

(Form02-2)

# Relationship between Gamma-Ray Flares and White Light Flares

Seiji Yashiro (The Catholic University of America)

Gamma-rays (GRs) are produced during the pion decay (Lingenfelter and Ramaty, 1967, in High-Energy Nuclear Reactions in Astrophysics, p.99), whose pions are produced by accelerated protons (> 300 MeV) colliding with hydrogen and heavier elements in the solar atmosphere. Forrest et al. (1985, Proc. 19th ICRC, 4, p. 146) found solar GRs have two components, namely the prompt and the late-phase components. Although the source of the protons producing late-phase GRs are still in question, the source of protons producing prompt GRs is believed to be due to flare's magnetic reconnection. White-light (WL) emission of the WL flares is produced by accelerated electrons which reach the photosphere. Accelerated protons are also considered as a candidate of the energy carrier. The WL enhancement is well correlated with hard X-rays, so both are emitted by high energy electrons accelerated by flare's magnetic reconnection. Common mechanisms in both phenomena are the emitting region (photosphere) and the particle acceleration site (flare's magnetic reconnection). The difference is that the accelerated energy-carrier particles are the protons for GR and the electrons for the WL flares. In general, both GR and WL flares are the energetic populations of solar flares, but ordinary flares, e.g. M1-class, rarely produce both emissions. The scientific goal of the project is to understand the origin of GR and WL flares.

The Large Area Telescope (LAT) on board Fermi satellite observes gamma-rays from the astronomical objects by scanning the entire sky every 3 hours. The GR from solar flares can be observed when the Sun is in the LAT field of view (40% of the time). Fermi/LAT identified 45 solar flares during solar cycle 24, and the First Fermi-LAT Solar Flare Catalog was released (Ajello et al. 2021, ApJS, 252, 13; https://doi.org/10.3847/1538-4365/abd32e). In order to investigate the WL emission from the 45 GR flares, continuum intensity data from the photosphere obtained by Helioseismic and Magnetic Imager (HMI) on board Solar Dynamic Observatory (SDO) were used. SDO/HMI has observed the photosphere in WL continuum with the cadence of 45 seconds. The WL emissions were examined around the flaring active region. For three behind-the-limb events, the WL emissions from the entire Sun were checked. We found that out of the 45 Fermi GR flares, 28 had clear WL emissions and 13 lacked WL emissions. The remaining 4 events had faint WL emissions. For the 28 flares who had clear WL emission, their WL intensities were examined. In order to perform the analyses described above, the PI visited the ISEE/Nagoya University during October 21-25, 2024, and the National Defense Academy of Japan on October 28 and 29.

Table 1: White-Light Emissions in the 45 Fermi Gamma-Ray Flares

| Clear WL Emission | Faint WL Emission | No WL Emission | Total |
|---|---|---|---|
| 28 | 4 | 13 | 45 |

The results obtained by this project are as follows: (1) Out of the 45 Fermi GR flares, 28 (or 71%) had WL emissions while 13 (or 29%) lacked WL emissions (Table 1). (2) All WL emissions were found at the flare ribbons during the impulsive phase of the solar flares. No WL emission was identified when the late-phase (or sustained) GRs were emitted. (3) No WL emission was identified for three behind the limb GR flares. (4) All but one flares (17/18) with the prompt GR component had the corresponding WL emission; (5) However, no clear relation was found between the prompt GR fluxes observed by Fermi/LAT and the WL intensities observed by SDO/HMI. (6) An X3.2 flare on 2013-05-14 did not have the prompt GR component but the flare had clear WL emissions. The results (1), (2), (3), and (4) suggest that the protons producing late-phase (or sustained) GRs are accelerated by different mechanisms from ones producing prompt GRs. Because the source of the proton producing prompt GRs are thought to be due to flare's magnetic reconnection, the results support the idea that late-phase GRs are due to protons accelerated by shocks driven by coronal mass ejections. The results (5) and (6) support the idea that WL emissions are due to accelerated electrons. The good correspondence between the prompt-GR and the WL flares (the result #4) is possibly due to the big flare syndrome. The conclusion is that the prompt GR, late-phase GR, and WL have different origins; flare-accelerated protons, CME-accelerated protons, and flare-accelerated electrons, respectively.

The PI visited the ISEE/Nagoya University on March 10 and 11, 2025 to discuss the obtained results and the future plan. In order to build firm and comprehensive pictures of the GR and the WL flares, the hard X-ray data should be involved because the hard X-rays are known to be due to accelerated electrons. Unfortunately the results obtained have not been presented yet, but the updated results including hard X-ray analysis will be presented in the refereed journals.

(Form02-2)

# Feasibility Study of In Situ and Remote Observations of the Heliosphere and the Sun at the L4 Point

Yukinaga Miyashita (Korea Astronomy and Space Science Institute, South Korea)

**Members**

Yukinaga Miyashita, Kyung-Suk Cho, Jongdae Sohn, Sung-Hong Park (KASI), Kwangsun Ryu (KAIST), Yoshizumi Miyoshi, Kazumasa Iwai, Hideyuki Hotta (ISEE, Nagoya University)

**Introduction: The Korea-Led L4 Mission Plan**

Solar eruptions cause huge ejection of magnetized plasma, often including high-energy particles from the solar atmosphere into the heliosphere. When they arrive at Earth, modern technologies are exposed to severe threats, such as power outage and communication disruption.

The Sun-Earth Lagrange point L4 is considered as a unique place where the solar activity and heliospheric environment can be observed in a continuous and comprehensive manner. The Korean space science community, including Korea Astronomy and Space science Institute (KASI), is preparing the development of a heliospheric observatory equipped with remote-sensing and in situ instruments at the L4 point with international collaborations. Currently we are carrying out a feasibility study for the L4 mission, which will significantly contribute toward advancing the heliophysics science, improving the capability of space weather forecasting, and extending space weather studies far beyond near-Earth space, together with comprehensive and coordinated multi-point observations of the heliosphere by other existing and planned L1 and L5 missions. The L4 spacecraft will have a large-class weight and be targeted to launch in 2035.

The L4 mission affords a clear and wide-angle view of the Sun-Earth line for the study of the Sun-Earth and Sun-Moon connections from the perspective of remote-sensing observations by a photospheric vector magnetograph, an Hα imaging spectrograph, an extreme ultraviolet imager, a white-light coronagraph, a heliospheric imager, and an X-ray spectrometer. In situ measurements of the solar radiation, solar wind, and heliospheric magnetic field by a solar wind plasma analyzer, a high-energy particle detector, a fluxgate magnetometer, a search coil magnetometer, a radiation monitor, and a radio and plasma wave detector are critical components necessary for monitoring and forecasting the radiation environment, since it relates to the issue of safe human exploration of Moon and Mars. Furthermore, a dust detector on the ram side of the spacecraft allows for an unprecedented detection of local dust and its interactions with the heliosphere.

**Purpose and Results of Joint Research with ISEE**

As described above, we are planning to propose the L4 mission for the comprehensive in situ and remote observations with the 13 instruments. To realize the mission, not only domestically developed instruments but also advanced instruments from international cooperation are essential. Hence, we have been seeking for international partners. ISEE, which covers the entire solar and heliospheric sciences, is considered as an important partner for the L4 mission.

In this fiscal year’s joint research program, we had two in-person meetings at ISEE and two online meetings to discuss and elaborate the scientific objectives and specifications of the in situ and remote instruments for the L4 mission, mainly focusing on the radio and plasma wave detector. In particular, we discussed future potential collaboration on the wave instrument with Japanese developers and strategies for securing the instrument. In addition, we discussed the scientific objectives and specifications of the radiation monitor as well as future potential collaboration on research on solar energetic particles. These discussions largely help us prepare a report of the feasibility study of the L4 mission that will serve as a mission proposal to the Korean government.

**Visits to ISEE**

(1) October 31, 2024: Y. Miyashita and K.-S. Cho

(2) March 24-25, 2025: Y. Miyashita and J.-D. Sohn

**Presentations**

- Miyashita, Y., The Korea-led L4 mission, Solar Orbiter RPW 31st Consortium Meeting, Athens, Greece and online, 2024/11/26 (oral, invited).
- 宮下幸長、The Korea-led L4 mission、2024 年度名古屋大学宇宙地球環境研究所研究集会「太陽地球惑星圏の研究領域における将来衛星計画検討会」、宇宙科学研究所/online、2025/03/21 (口頭).

(Form02-2)

# Investigation of electromagnetic waves in the Earth's magnetosphere using spacecraft and ground-based measurements

Principal Investigator: Ondrej Santolik, Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences, Prague, Czechia
Project period : Start date : 2024/4/1 End date : 2025/3/31
ISEE researcher : Prof. Yoshizumi Miyoshi

This international collaborative research project aimed at innovative joint research of whistler-mode electromagnetic waves in the plasma environment of the Earth proposed by scientists form the Institute of Atmospheric Physics of the Czech Academy of Sciences in cooperation with colleagues from the Nagoya University and Kanazawa University. We focused on the analysis of the actual data from the Japanese Arase (ERG) and European Cluster spacecraft mission complemented with data from other spacecraft missions (NASA's Van Allen Probes and Themis, Japanese Geotail and Akebono) and with ground based measurements from the Japanese PWING and Czech VLF and HF stations.

Our 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. High-energy particles are trapped in the Earth's magnetic field and form the Van Allen radiation belts. During huge magnetic storms, the radiation belts are largely deformed, and significant flux enhancements are observed in the slot region and the inner belt. The outer belt electrons fluxes decrease significantly during the main phase of storms and then recover to, or often increase over, the prestorm level during the recovery.

The program contributed to a part of the airfare of IAP researchers visiting ISEE on 10-14 March 2024 and actively participating in the Arase SWT meeting. Another part of airfare, and entire accommodation and per-diem costs were funded by IAP Prague. This brief visit was consecrated to seminars with University of Nagoya students, analysis and interpretation of PWING and 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 the recently launched ESA mission JUICE to Jupiter and the Comet Interceptor mission project.

List of publications in journals with referees


1. I. Kolmašová, O. Santolík, A. Kolínská, S. Pédeboy, R. Lán & L. Uhlíř, (2025) Rapid evolution of energetic lightning strokes in Mediterranean winter storms. npj climate and atmospheric science 8:71. https://doi.org/10.1038/s41612-025-00965-6
2. A. Masters, R. Modolo, E. Roussos, ..., O. Santolík, ..., (2025) Magnetosphere and Plasma Science with the Jupiter Icy Moons Explorer. Space Science Reviews 221:24. https://doi.org/10.1007/s11214-025-01148-8
3. Grison, B., Darrouzet, F., Maggiolo, R., Hajoš, M., Dvořák, M., Švanda, M., Jeřábková, A., Taylor, M.G.G.T., Herment, D., Masson, A., Souček, J., Santolík, O., De Keyser, J. (2025), Localization of the Cluster satellites in the geospace environment. Sci Data 12, 327. https://doi.org/10.1038/s41597-025-04639-z
4. Němec, F., Santolík, O., & Albert, J. M. (2025). VLF transmitter signals observed by the cluster spacecraft over a wide range of latitudes. Journal of Geophysical Research: Space Physics, 130, e2024JA033621. https://doi.org/10.1029/2024JA033621
5. J.-E. Wahlund, J. E. S. Bergman, L. Ahlén, W. Puccio, B. Cecconi, Y. Kasaba, I. Müller-Wodarg, H. Rothkaehl, M. Morawski, O. Santolik, J. Soucek, ..., B. Grison, J. Jansky, I. Kolmasova, R. Lan, D. Pisa, U. Taubenschuss, L. Uhlir, ... (2025) The Radio & Plasma Wave Investigation (RPWI) for the JUpiter ICy moons Explorer (JUICE). Space Sci Rev 221, 1. https://doi.org/10.1007/s11214-024-01110-0
6. Vratislav Krupar, Oksana Kruparova, Adam Szabo, Lynn B. Wilson III, Frantisek Nemec, Ondrej Santolik, Marc Pulupa, Karine Issautier, Stuart D. Bale, and Milan Maksimovic (2024). Radial Variations in Solar Type III Radio Bursts, The Astrophysical Journal Letters 967, L32, DOI 10.3847/2041-8213/ad4be7
7. Kolmašová, I., Santolík, O. & Manninen, J. (2024). Whistler echo trains triggered by energetic winter lightning. Nat Commun 15, 7166. https://doi.org/10.1038/s41467-024-51684-0
8. Kašpar, P., Marshall, T., Stolzenburg, M., Kolmašová, I., & Santolík, O. (2024). Electromagnetic model of K-changes. Journal of Geophysical Research: Atmospheres, 129, e2023JD040503. https://doi.org/10.1029/2023JD040503
9. Santolík, O., Shprits, Y., Kolmašová, I., Wang, D., Taubenschuss, U., Turčičová, M., & Hanzelka, M. (2024). Strong effects of chorus waves on radiation belts expected for future magnetic superstorms. AGU Advances, 5, e2024AV001234. https://doi.org/10.1029/2024AV001234
10. Němec, F., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2024). Magnetospheric line radiation: Temporal modulation corresponding to a bouncing wave. Geophysical Research Letters, 51, e2024GL111477. https://doi.org/10.1029/2024GL111477
11. Linzmayer, V., Němec, F., Santolík, O., and Kolmašová, I. (2024). Lightning-induced energetic electron precipitation observed in long-term DEMETER spacecraft measurements. Journal of Geophysical Research: Space Physics, 129, e2024JA032713. https://doi.org/10.1029/2024JA032713

(Form02-2)

# Project Title

Dr. Viswanathan Lakshmi Narayanan (Krea University, India)

Please write your research summary including purpose, methods, and results, periods of stay in ISEE, and list of publications in maximum two pages.

**<u>On the impact of geomagnetic disturbances in the gravity wave and tidal dynamics of the mesosphere in the auroral region</u>**

**Purpose of proposed research:**

Mesosphere responds to forcing from below and above, particularly in the high latitudes. While many sources are identified for the gravity waves (GWs) in the mesosphere, their relative importance are not known. It is not clearly known how deep the waves generated by the geomagnetic disturbances and auroral activity penetrate. Recently, using SABER/TIMED data for over 18 years, Narayanan et al., (2024, https://doi.org/10.1029/2023JA032157) found that within the mesosphere GWs forced by geomagnetic activity are identified only in the high latitudes for about half of the geomagnetically disturbed periods and they are unambiguous only above 80 km. However, since that study was using satellite measurements having poor spatio-temporal resolution, local time response and finer variations in the GW activity within a day could not be investigated. Further, it is not known if GWs are forced only in a restricted geographical extent. In addition, how the background temperature and winds change in the mesosphere during geomagnetic activity in high latitudes is not well studied. Here, we proposed to study this complicated problem using ground based measurements from Tromsø (69.6◦ N, 19.2◦ E).

Objectives: 1. To investigate GW and tidal variabilities immediately following geomagenetic disturbances in the auroral region, 2. Understanding the changes in the background mesospheric temperatures and winds and their influence on gravity wave variabilities, and 3. Cross-comparison of winds measured by sodium lidar, Fabry-Perot interferometer (FPI), medium frequency (MF) and meteor radars during the identified events.

**Methods**

We identified that the sodium lidar at Tromsø [Kawahara et al., 2017, https://doi.org/10.1364/OE.25.00A491; Nozawa et al., 2023, https://doi.org/10.1186/s40623-023-01771-1] is the most suitable instrument for the study of GWs following intense geomagnetic activity in the auroral latitudes since it is least affected by intense auroral emissions. In the case of radars, the electrodynamics may affect the electron drifts that are utilized to measure the neutral winds. Nevertheless, we proposed to use other coincident airglow and radio measurements available with sodium lidar for the work. We planned to carryout analysis in two different ways: (i) we will identify events using Tromsø magnetometer recordings and AE indices, within the interval of 2011 – 2023, and execute detailed case studies, (ii) we will make a statistical study of mesospheric GW and tidal response to geomagnetic activity using lidar and radar datasets.

**Results**

Since sodium lidar data is intermittent owing to cloudy sky and nocturnal conditions, we selected some windows of long lidar data availability. For example, Figure 1 shows background temperature and wind observations during disturbed conditions. Such comparisons have not given conclusive results regarding change in the background parameters so far. At present we are attempting case studies by identifying observations when Tromsø K indices are very high, i.e. above 7, indicating extremely disturbed geomagnetic conditions. We could identify only about three promising cases with probably a couple of more insightful ones. The analysis is underway at present.

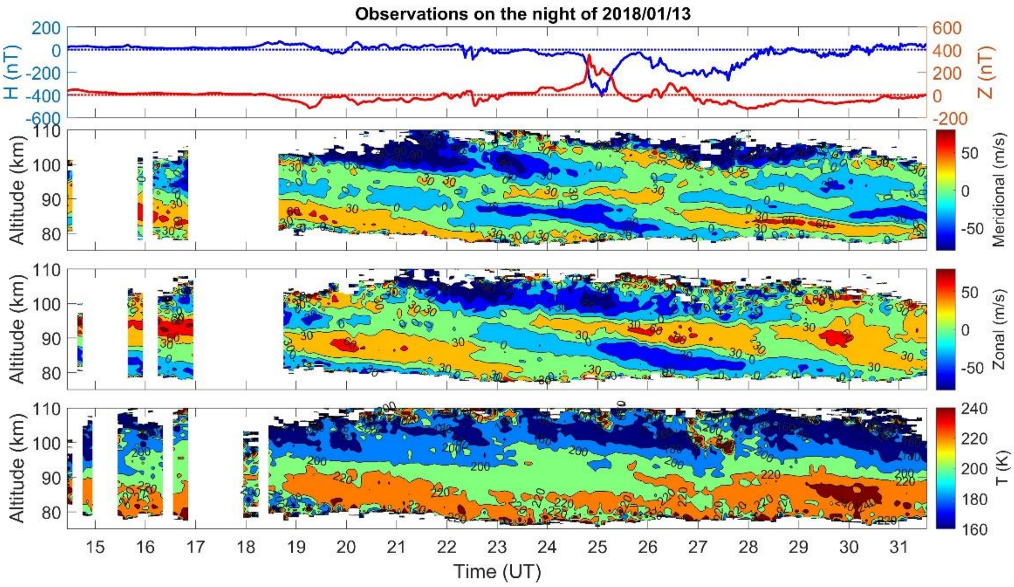



Figure 1. Observations on the night of 13 January 2018. (Top) Deviations in magnetic H and Z components from monthly mean for Tromsø magnetometer measurements, (second and third from top) Meridional and zonal winds respectively, from sodium lidar, (bottom) Temperature from sodium lidar observations.

**Periods of Stay in ISEE:**

PI visited ISEE, Nagoya University during 21 June 2024 – 13 July 2024 and 21 July 2024 – 24 July 2024

**Research Outcomes:**

***The project will continue through this summer to get conclusive results and peer reviewed publications. However, we have submitted another proposal under the Indo-Japan Cooperative Science Program call by DST, India and JSPS, Japan.*** Details of the submitted proposal for which the motivation is derived from this project, and discussions were based on preliminary work done herein are given below.

Title: Investigation of vertical and lateral coupling in the mesosphere – thermosphere – ionosphere region for forcings from space weather and stratospheric polar vortex disturbances

Indian PI: Viswanathan Lakshmi Narayanan, Japanese PI: Satonori Nozawa, Indian co-PI: Sathishkumar Sundararaman, Japanese co-PI: Yuichi Otsuka

Though there is delay due to unanticipated teaching and administration commitments of the PI, we expect to get peer reviewed publications later this year and ISEE Joint Research support will be duly acknowledged in those papers.

(Form02-2)

# Conjugate observations of magnetospheric whistler-mode waves by KAN, PWING, and ERG/ARASE

Jyrki Manninen (SGO, University of Oulu, Finland)

**Periods of stay in ISEE**

Adj. Prof. Jyrki Manninen (SGO, University of Oulu) 18 October – 18 November 2024

**Purpose of the visit**

We used ground-based data obtained by KAN and PWING stations to determine the spatiotemporal variability of measured electromagnetic waves and to better understand their propagation from the source region down to the ground. We focused particularly on not yet well-understood emission types (e.g., quasiperiodic emissions (QP), magnetospheric line radiation (MLR)). We used data from ATH, GAK, IST, KAP, and MAM for the year 2020. In addition, as of now, solely the station pair KAN-OUJ can be used for studying latitudinal propagation, meaning that this station pair data will be analyzed from October 2022 to September 2023 as well.

**Science questions we addressed**

1) *What is the spatial extent of analyzed emissions and respective source dimensions?*
   During the visit to ISEE, event listings and the identification of relevant events from receivers at ATH, GAK, IST, KAP, and MAM was started. The KAN listings were already available.
2) *What are the properties and formation mechanisms of the fine inner structure of QP/MLR emissions?*
   These events from different PWING receivers have been listed, and the preliminary research has started.
3) *What is the relative importance of wave ducting and how do the emissions reach the ground?*
   This study has been started, but it still requires some satellite data and a more elaborate analysis.

**Data**

KAN, operated by the Sodankyla Geophysical Observatory in Northern Finland, was arguably the most sensitive receiver in the world. Unfortunately, a lightning discharge hit the antenna mast on 28 May 2024 and destroyed it. However, KAN data before 28 May 2024 is available and has good quality. It is greatly complemented by data from other PWING stations operated by ISEE. Notably, in October 2022 a new PWING receiver was established in Oulujarvi (OUJ), Finland, less than 400 km southward of KAN. Furthermore, the newest PWING receiver was installed in August 2024 at Angeli (ANG), Finland, some 150 km north of KAN. All these stations are equipped with direction-finding capabilities. ERG/ARASE spacecraft data are used in conjunction with ground-based measurements to observe the respective wave phenomena at larger distances and determine respective spatial scales.

**Methodology**

Extensive lists of quasiperiodic emissions and magnetospheric line radiation were compiled and expanded to include the latest available data. Conjugate events, observed by several different ground-based stations were identified. The ERG/ARASE spacecraft data analysis is in progress.

Two different approaches are used:

i) Direct evaluation of spatial extents and durations of events through analysis of times and locations at which individual instruments observed a given emission. This greatly benefits from the fact that both QP emissions and MLR exhibit a very characteristic frequency-time structure, allowing for unique identification of whether two instruments are observing the same emission or not.

ii) High-resolution measurements are used to investigate detailed frequency-time structures of the emissions and their relation to wave propagation through the magnetosphere and bouncing between hemispheres. Lightning-generated whistlers observed in conjunction with the events, their dispersions, and corresponding propagation paths are used for comparison. This approach further incorporates detailed timing analysis, wave analysis of ERG/ARASE measurements, and ray tracing calculations. The aim is to characterize and understand the short time delays between the moments when a given wave packet arrives at different observation points. This inherently allows us to assess the importance of wave ducting for the event formation and propagation to the ground, as well as to estimate the wave source dimensions and experimentally confine possible generation mechanisms.

**Presentations & Publications**

Nemec, F., K. Drastichova, **J. Manninen**, C. Martinez-Calderon, K. Shiokawa, and M. Connors (2024). Comparison of very low frequency wave intensities measured by a low-altitude spacecraft and on the ground. Journal of Geophysical Research: Space Physics, 129, 7, e2024JA032655.

Two additional manuscripts are under preparation.

The team has made in total 9 presentations at various conferences (EGU, URSI AT-RASC, VERSIM Workshop, CHAMOS Workshop, ISEE Seminar, SGO Observatory days, etc.). These presentations are listed in Form 02-1.

(Form02-2)

# Comparing Remote Observations, In-Situ Measurements and Simulations of the Variation of the Properties of Coronal Mass Ejections Over 1°–10° in Longitude

Noé Lugaz (University of New Hampshire)

***Purpose***

The goal of the project is to investigate the variations of the properties of coronal mass ejections on intermediate scales (~10°, corresponding to about 0.17 au in arclength). This is a new area of research that has recently opened up thanks to the availability of multi-spacecraft measurements by combining ACE, or Wind at L1, STEREO-A in 2022-2024 and Solar Orbiter when it is close to the Sun-Earth line. This is critical to understand coronal mass ejections, the major drivers of intense space weather at Earth but also to advance our space weather forecasting capabilities, as differences of a few degrees are likely between Earth and future sub-L1 monitoring platforms. A key question for the stay at ISEE is to determine whether any differences measured *in situ* between different spacecraft is due to ***propagation*** effects or to ***eruption*** effects**.**

***Methods***

It was decided during the stay at ISEE to focus on a single event rather than performing a more statistical approach. This was decided to be the best way to combine various methods. It was decided after meeting with collaborators at ISEE that the 2023 April 23 CME was a good candidate. Four other events were considered but there were no good solar observations of the erupting CME for these events. In order to answer the question highlighted above, one needs to perform reconstruction of the CME and its active region near the Sun, which can then be compared with the measurements *in situ.* This is done using non-linear-force-free field (NLFFF) interpolations.

<u>List of Other CMEs Considered:</u>

- 2023/09/24 at Earth: 2023 September 21 M-class flares
- 2023/07/16 at Earth: Unclear source, potentially from the 2023 July 13-14 flares
- 2023/09/12 at Earth: unclear eruption potentially on September 9
- 2023/08/01 at Earth: July 28 filament eruption (~21 UT)

***Results***

The NLFFF interpolation of the active region that erupted and generated the 2023 April 23 CME is shown below (Figure 1, left). As can be seen from the images, the active region magnetic field was relatively diffuse and the NLFFF reconstruction may not be extremely reliable. In-situ measurements of the CME by STEREO-A and Wind are also shown below (Figure 1, right). The spacecraft were separated by 10.6°. It shows both significant similarities (the overall rotation of the magnetic field, speed profile in the magnetic cloud, etc.) as well as clear differences (the duration of the sheath, the magnetic field strength profile, etc.). Minimum variance analysis on the magnetic field profile inside the magnetic cloud indicate that it can be understood as a similar orientation but with a non-straight axis (results not shown here due to space limitations and further

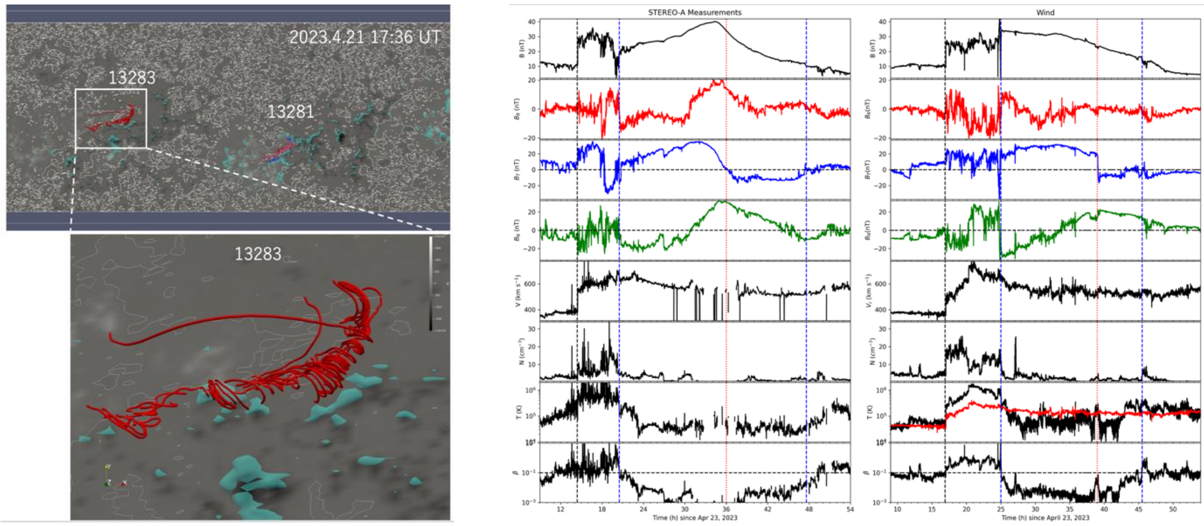



*Figure 1: Left; NLFFF extrapolation of active region 13283 that resulted in the CME that was measured at 1 au on 2023 April 23. Right: STEREO-A and Wind measurement of the CME. From top to bottom, total magnetic field, magnetic field component (radial, tangential, normal), proton velocity, density, temperature (expected following Lopez et al., 1987 in red), beta.*

analysis is in progress). Further work is needed to determine if thjs is consistent with the variation in angle along the polarity inversion line in AR13283, which would indicate that the differences measured in the magnetic cloud between STEREO-A and *Wind* are due to differences that occur right from the eruption stage of the CME. Additional follow-up work will also continue through numerical simulations to better understand the solar wind and interplanetary magnetic field between the Sun and Earth/STEREO-A at the time of the eruption to determine if there could be variations that would explain the differences in the CME measurements due to propagation effects.

***Publications/Talks***

No publication yet during the time period. N. Lugaz will continue analyzing this event and a joint publication is expected some time in 2025.

N. Lugaz did two talks and participated in a panel during his stay at ISEE:

Lugaz, N., Predictive Space Weather Research: Steps Forward, Panel during the 2025 ISEE Symposium, U. Nagoya, 7 March 2025.

Lugaz, N. et al., The Need for Sub-L1 Space Weather Research Missions: Current Knowledge Gap, 2025 ISEE Symposium, U. Nagoya, 7 March 2025.

Lugaz, N., Simultaneous Multi-Point Measurements of CMEs: Physical Insights and Consequences for Future Heliophysics and Space Weather Missions, Solar Seminar, ISEE, U. Nagoya, 10 February 2025.

(Form02-2)

# Reconstruction of physical properties of historical solar energetic particle events

Sergey Koldobskiy (University of Oulu, Finland)

The ISEE International Joint Research Program Project "Reconstruction of physical properties of historical solar energetic particle events" led by Dr. Sergey Koldobskiy aimed at:

1. Analysis of historical ground-level enhancement events that were recorded in the 1940s – 1950s by different kinds of ground-based and balloon-borne detectors. Within this project, we aim to search for contemporary sources of the data of these events, systemize the found data, and perform the physical analysis to reconstruct the fluxes of solar energetic particles (SEPs) during these events.
2. Analysis of extreme solar particle events imprinted in cosmogenic isotope archives. These events represent the most hazardous space weather phenomena that we know. Using modern modeling techniques, it is possible to estimate the expected SEP flux capable of producing the observed cosmogenic isotope records. We will work on the reconstruction of the new data (if any data will appear) as well as the estimation of extreme solar particle event (ESPE) SEP flux and duration.
3. Discussion on the possible space-weather and terrestrial effects of strong and extreme SEP events.

During the project, one visit of Dr. Koldobskiy to ISEE was planned for autumn 2024. During the visit, Dr. Koldobskiy planned to collaborate with scientists from ISEE on the abovementioned topics as well as participate in the Space Climate 9 / ISEE Joint Symposium as well as Sunspot Number Workshop that were scheduled in Japan in October 2024.

Throughout the project, we successfully collaborated on the activities listed above.
Within aim 1, we started to study and systemize data from non-standard detectors, which recorded solar particle events on ground level (GLE events) in the 1940s – 1950s. For now, we spent efforts on finding, digitizing, and verifying records from contemporary detectors for GLE #5 (23-Feb-1956), a GLE with the greatest flux and the hardest spectrum, which was also recorded by neutron monitors. For now, we found, digitised, and verified about 50 records, part of which had been completely unknown to the scientific community. We are planning to analyse these new records, follow the data publication. This will allow us to better reconstruct the spectral characteristics of solar energetic particles for GLE #5 and to bridge modern statistics to the early GLEs #1—4 that were recorded exclusively by non-standard detectors.
Within aim 2, we were discussing possible ways to proceed with the analysis of extreme solar particle events imprinted in cosmogenic isotope records. Among other opportunities, we were thinking of considering a separate representation of galactic cosmic ray (GCR) and SEP-produced Be10 signal to test if this will change the resulting reconstruction of SEP flux for ESPEs.
Within aim 3, we were thinking on the importance of consideration of disturbed geomagnetic conditions accompanied by the registration of SEP events – for both instrumental records and cosmogenic isotope data. We agreed, that further simulations are needed to answer this question quantitatively.
We also were working together on an analysis of modern GLE events, including GLE 74, which occurred on

11 May 2024.

During the project, Dr. Sergey Koldobskiy had 1 visit (17 days, 26 September to 12 October) to Japan to work on project and participate in following events organized by ISEE: Space Climate 9 / ISEE Joint Symposium (solicited talk: “Solar energetic particle events: bridging direct observations and imprints in cosmogenic isotopes”) and Sunspot Workshop (solicited talk: “Possible extension of the Sunspot Number with Proxy Data. Sunspot Number Workshop”).

Within the project, up to date, we have published one joint research paper:

Hisashi Hayakawa, Yusuke Ebihara, Alexander Mishev, Sergey Koldobskiy, Kanya Kusano1, Sabrina Bechet, Seiji Yashiro, Kazumasa Iwai1, Atsuki Shinbori, Kalevi Mursula, Fusa Miyake, Daikou Shiota, Marcos V. D. Silveira, Robert Stuart, Denny M. Oliveira, Sachiko Akiyama, Kouji Ohnishi, Vincent Ledvina, and Yoshizumi Miyoshi “The Solar and Geomagnetic Storms in 2024 May: A Flash Data Report,” Astrophys. J., vol. 979, no. 1, p. 49, Jan. 2025.

(Form02-2)

**EISCAT – Arase study of energetic electron precipitation**

Neethal Thomas (SGO, University of Oulu, Finland)

**Purpose of visit:** The visit aimed to conduct a study on Energetic Electron Precipitation (EEP) events utilizing EISCAT measurements, Arase satellite plasma data, and various ground-based measurements. During the visit, I worked with Prof. Yoshizumi Miyoshi on a case study of an EEP event observed in the EISCAT-VHF measurements during a recent geomagnetic storm on 10-11 October 2024. This event was observed during the onset of the storm in conjunction with the sudden storm commencement. Strong electron precipitation down to 60 km was observed in the EISCAT electron density data. This EEP event is studied with a focus on understanding the energy and flux of the precipitating electrons and its magnetospheric sources. As a first step, we estimated the energy-flux spectrum of this EEP event by inverting the EISCAT-VHF measurements. The study is ongoing, and the future steps to proceed with this study are discussed during the visit.

**Methods used:**

a) Firstly, the EISCAT VHF raw data is analysed to estimate the spectral parameters such as backscattered power (electron density) in the D region altitudes ranging 50-100 km. The incoherent scatter spectral parameters are obtained by performing the pulse-to-pulse fitting of the backscattered signal autocorrelation function. The fitted backscattered power (which is proportional to electron density, Ne) is then inverted to energy-flux spectrum using the forward model utilizing (i) the parameterization by Fang et. al., [2010] to calculate the ionization profile Q and (ii) then to turn the ionization profile (Q) into the electron density (Ne) using Sodankylä Ion and neutral Chemistry model. The precipitation flux spectrum is then estimated by matching the modelled Ne(h) to the EISCAT Ne(h).

b) KAIRA imaging riometer data is checked to understand the spatial distribution of the EEP event and is under further investigation.

c) We have estimated the plasmapause location for this event using the O’Brien and Moldwin [2003] model. According to the model results, the EISCAT was located outside the plasmapause during the event. This is important for identifying the possible wave sources responsible for this intense electron precipitation.

d) Pulsation magnetometer and riometer absorption data from different PWING stations are also checked to look for the EEP and the associated signatures.

e) Arase was in the morning sector and was not co-located with EISCAT during this event; hence, a direct comparison was not possible. However, Arase data will be studied to understand the possible EEP signatures in the morning side.

**Results:** The inversion of EISCAT data showed **relativistic electron precipitation with energies close to 1 Mev.** We are further investigating this event to understand its global extent using various ground-based measurements, including a global network of magnetometer and riometer measurements and satellite observations.

**Periods of stay in ISEE:** One week from 9-15 February 2025

A manuscript of this study will be prepared and submitted once the work is completed. During the visit, a seminar presentation on the EISCAT-VHF measurements in the Mesosphere Lower Thermosphere altitude was given.

**References:**

Fang, X., et al., (2010), Parameterization of monoenergetic electron impact ionization, GRL., doi:10.1029/2010GL045406

O’Brien, T. P., and M. B. Moldwin, (2003) Empirical plasmapause models from magnetic indices, GRL, doi:10.1029/2002GL016007.

(Form02-2)

# Investigating Helicity Transformation in Coronal Mass Ejections using Numerical Simulations

Nada Al-Haddad (University of New Hampshire)

The key goal of the joint research project at ISEE is to **study the helicity transformation in CMEs from SUSANOO-CME** at Nagoya. Dr. Al-Haddad arrived at ISEE on January 6th 2025, and left on March 19th 2025, totaling 2 months and 13 days.

a. Upon coming to ISEE, Dr. Al-Haddad shared more details about the techniques that were developed through a collaboration with Dr. Mitchell Berger to derive the magnetic helicity from numerical simulations. This was done through meetings with Prof. Kusano and Prof. Iwai. This technique is a unique technique to quantify the magnetic helicity of coronal mass ejections (CMEs) in interplanetary space by analyzing their 3D magnetic topology using numerical simulations. Unlike traditional methods that focus solely on twist, our approach incorporates quasi-separatrix layers (QSLs) to divide the CME volume into sub-regions and calculates self-helicity (including twist and writhe) and mutual helicity between regions.
b. During the stay at ISEE, Dr. Al-Haddad gave a seminar to introduce her research project. After that seminar, Dr. Al-Haddad and collaborators discussed various techniques to extract the SUSANOO-CME in a manner to allow for proper extraction of the magnetic helicity using the technique developed by Al-Haddad & Berger, 2025, *In revision*. Several meetings and discussions have been made in order to come up with a method that allows for such extraction, accounting for the continuous evolution of the CME and resolving the different coordinates problem. A simulation that propagates to 2 AU was selected for applying the analysis technique.
c. Over the subsequent 2.5 months, extraction of the simulation files different solar radial distances has been performed while the helicity analysis technique was adapted to perform the analysis on the simulation data.
d. By the end of her stay, a plan for drafting a manuscript of the analysis was ready. This investigation will continue until conclusion.
e. Drs. Al-Haddad and Hayakawa continued their discussions and deepened their collaboration on the history of solar and space physics, which had started at IUGG in Berlin in 2023 and continued at the European Space Weather Week in Toulouse later that year. Drs. Al-Haddad and Hayakawa served as chair and co-chair of the inter-divisional commission on History of IAGA starting in 2023.
f. The "ISEE Symposium Frontier of Space-Earth Environmental Research as Predictive Science" took place March 5th – March 7th 2025, during the this collaboration. Dr. Al-Haddad gave an oral presentation on March 7th 2025 entitled "Technique for Extracting the Total Magnetic Helicity of CMEs" highlighting the current and future collaboration with ISEE.

g. During her stay, and to further collaboration with ISEE members from different division, Dr. Al-Haddad established collaborations with Professors Fusa Miyake, Hisashi Hayakawa and Kasumasa Iwai, designing a multi-faceted project on the “Investigations of Extreme Geomagnetic Storms”, through:
    1. The development of Celestial Phenomena in Historical Records Database
    2. 14C Analysis for Case Studies
    3. Analyses and Simulations of Extreme CME Events

This project plan was submitted as a proposal for the ISEE designated professor position by Dr. Al-Haddad.

(Form02-2)

# Linking Coronal Mass Ejections Observed Near the Sun and at 1 AU

Nariaki Nitta (LMSAL)

The main purpose of this investigation is to accumulate knowledge of the relation between the properties of eruptions on and near the Sun and those of the solar wind at 1 AU disturbed by CMEs. It is critical to employ realistic numerical simulations to fill the gap of observations between 0.1 AU and 1.0 AU. Another valuable information comes from IPS observations. For the first time, we started to make detailed comparison of AWSoM simulations with CMEs at large distances (e.g., 0.4 AU –0.7 AU) from the Sun as detected in ISEE IPS observations.

As planned, we studied two contrasting events, one associated with a large eruption and intense flare, and another one that left very weak signatures in the solar corona (i.e., a stealthy CME). To our surprise, the latter event was detected in the IPS observations. The ISEE IPS data are routinely interpreted using the SUSANOO simulations as developed at the National Institute of Communication Technology. (NICT). To understand the CME propagation, the steady-state ambient solar wind has to be properly modeled. Therefore, we compared the steady state solutions of SUSANOO and AWSoM, and found good agreement for the period of the stealthy CME if we choose one magnetic map as the inner boundary conditions for AWSoM. For the CME associated with a major flare, we already had AWSoM simulations extended to 1 AU that were consistent with in situ observations such as the shock arrival time. We experimented with the initial CME parameters for SUSANOO so that it also reproduces the shock arrival time reasonably well.

Drs. Nitta and Jin visited ISEE for a week, following the Space Climate 9 Symposium.

We have not produced publications directly from this investigation, but plan at least to write a short note to report on the IPS observations of the stealthy CME that will include the discussion on why this particular CME was responsible for a very strong geomagnetic storm.

(Form02-2)

# Analysis of radial propagation of the solar wind in the inner heliosphere with multi space missions and SUSANOO propagation model

Sae Aizawa (LPP, CNRS, France)

**Introduction and Purpose of the project**

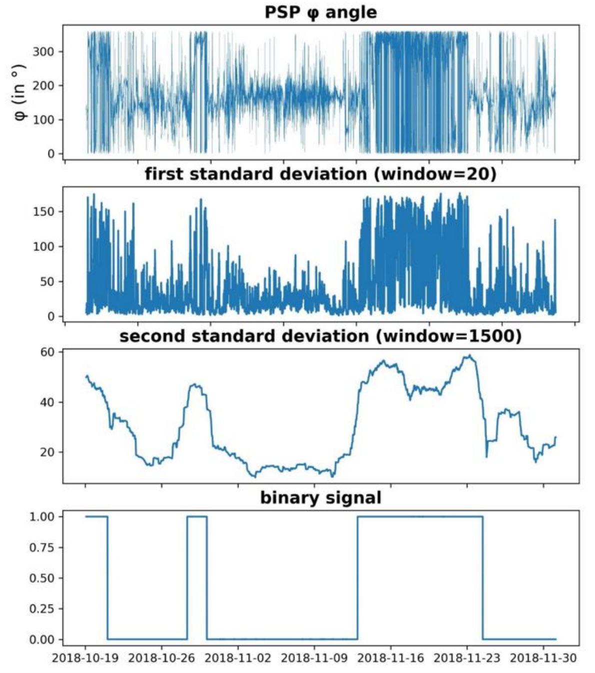
The solar wind propagates approximately radially through interplanetary space, shaping the extent of the heliosphere. As it travels outward from the Sun, it interacts with planetary bodies, creating distinct plasma environments around each one. Understanding the behavior of the solar wind and the solar activity that drives it is therefore essential.To investigate the characteristics of the solar wind at its source, numerous space missions are dedicated to solar and heliospheric physics. The combination of data from these missions enables a more comprehensive understanding of plasma processes and its propagation throughout the heliosphere. Among recent missions, BepiColombo—a joint Mercury exploration mission by ESA and JAXA currently en route to Mercury—has demonstrated its capability to detect a variety of solar events in addition to the , making it a valuable probe for studying the inner heliosphere in addition to other space missions such as Solar Orbiter and Parker Solar Probe.However, to accurately interpret multipoint measurements and interconnect data from different spacecraft, comprehensive modeling is required. In this project, we analyze solar wind propagation using a global MHD simulation called SUSANOO, incorporating magnetic field data obtained by in-situ observations from BepiColombo, PSP, Solar Orbiter, MESSENGER. We focus on assessing the timing errors of heliospheric current sheet crossings as a proxy for typical solar wind propagation behavior.

**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, MESSENGER, Parker Solar Probe, Solar Orbiter points, and compared it with the observed magnetic field. We have checked its radial component or clock/cone angles, binarized them where it reverses the sign which is a proxy to identify the heliospheric current sheet (HCS) crossings and compared the time of those reversals between the outputs from SUSANOO and in-situ observations to understand the large structure of the solar wind from the Sun in the inner heliosphere.

**Results**

We first have developed the method to identify the HCS crossings with noisy in-situ observations. Since in-situ observations can capture small variations in the data but we would like to focus on the large structure, we have smoothed out and binarize them. Figure 1 shows an example of those steps with Parker Solar Probe (PSP) observations. This method is validated by comparing already published HCS crossings shown in Szabo et al. (2019). The results have been compared with 5-min SUSANOO data, and then calculate the time shift between them. The same method is applied to Solar Orbiter data, and found that about 45% of HCS crossings detected by PSP or Solar Orbiter are missed in the SUSANOO. Average and median offsets are about 2.3 days and 1.6 days. Those values are similar to the values reported by Want et al. (2019) which has used other Solar Wind propagation model.



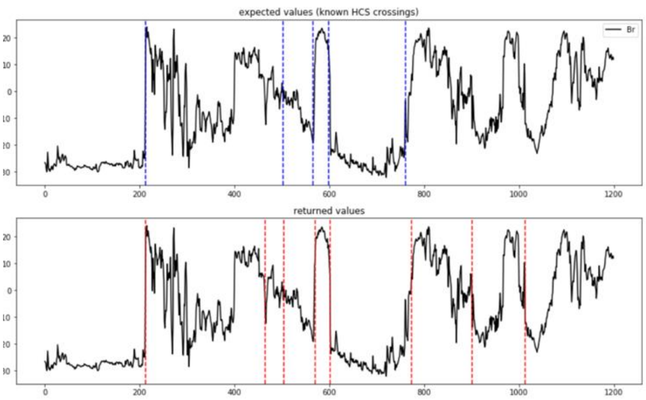




**Figure 1.** HCS identification steps with PSP data (left) and returned results (right).

Interestingly, missed HCS crossings are less frequently reported when the Earth–Sun–probe angle is small (see Figure 2). This aligns with our expectations, as SUSANOO utilizes synoptic maps based on Earth-based observations. The number of missed HCS crossings in SUSANOO increases as this angle widens, but appears to stabilize beyond 180 degrees. However, a greater number of HCS crossing observations from other satellites is still needed, as the current dataset remains statistically limited. To improve this point, we started including other data sets from MAVEN, MESSENGER, BepiColombo. Meanwhile, SUSANOO itself gets further developed in parallel. New boundary conditions will bring us better prediction of HCS crossings and our statistical results can get better.

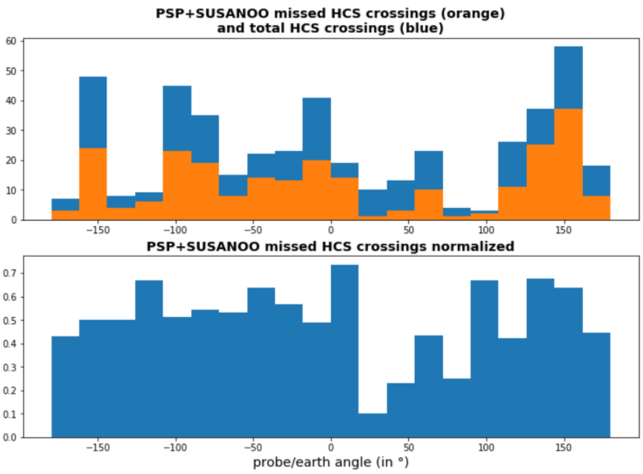



**Figure 2.** Missed HCS crossing with respect to the Earth–Sun–probe angle.

**Periods of stay in ISEE:** Mar 17th – Mar 21nd, 2025

**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.