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2023　02）ISEE / CICR International Joint Research Program List

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(Form02-2)

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

Principal Investigator: Matthew A. Lazzara (University of Wisconsin-Madison, USA)

Abstract:

Antarctic climate change has been studied using temperature data at staffed stations. The stations, however, are mainly located on the Antarctic Peninsula and in the coastal regions. Climate change is largely unknown in the Antarctic plateau, particularly in the western sector of the East Antarctic Plateau in areas such as the interior of Dronning Maud Land (DML). To fill the data gap, this study presents a new dataset of monthly mean near-surface climate data using historical observations from three automatic weather stations (AWSs). This dataset allows us to study temperature variability and change over a data-sparse region where climate change has been largely unexplored.

Motivation:

The interior DML in East Antarctica is one of the most data-sparse regions of Antarctica for studying climate change. To fill in the gaps, multiple AWSs have been installed along the route to Dome Fuji since the 1990s, and observations have continued at three stations (Mizuho, Relay Station and Dome Fuji) to the present day. Several concerns need to be addressed, however, before the AWS observations can be used for the wider study of climate change. One concern is that the use of passive-ventilated radiation shields for the temperature sensors at the AWSs may have caused a warm bias in the temperature measurements due to insufficient ventilation in the summer, when solar radiation is high and winds are low. A second concern is the change in the sensor height due to snow accumulation. Due to the strong surface temperature inversions in the remote interior, gradual decreases in the sensor height lead to a cold bias. A third concern is the possible occurrence of systematic errors in the records stemming from changes in the instrumentation at the stations. All of these factors make it difficult to detect the true signals of climate change. In this study we quantify the errors associated with these factors to create a corrected dataset that is available for the study of climate variability and change in the DML interior. The primary goal of our study is to recompute the monthly mean climate data from all of the available AWS observations in the DML interior.

Results:

Figure 1 shows the time series of corrected temperatures from the AWS observations at Mizuho, Relay Station, and Dome Fuji over the past 30 years. The remoteness and harsh climatic conditions in the interior of Antarctica prevented frequent maintenance visits. As we were unable to correct for instrumental failures and power failures, the observations could not be captured as a continuous record. The percentage of missing data was 21% at Relay Station, and 28% at Dome Fuji due to the even harsher environment. The rate of missing data at Mizuho, where no UW-AWS temperature data were available until January 2014, was about 49%, or about double the rate at the other two stations. Missing observations can be estimated using temperatures from various global reanalysis data, which do not use any AWS observations in their data assimilation system. ERA5 is one of the candidates, as the monthly 2-m temperature data from ERA5 do not respond to the systematic biases that affect the original AWS observations and appear to be independent of the respective datasets analyzed. The reconstructed continuous records allow us to study temperature variability and change over the western sector of the East Antarctic Plateau, where climate change has so far been unexplored.

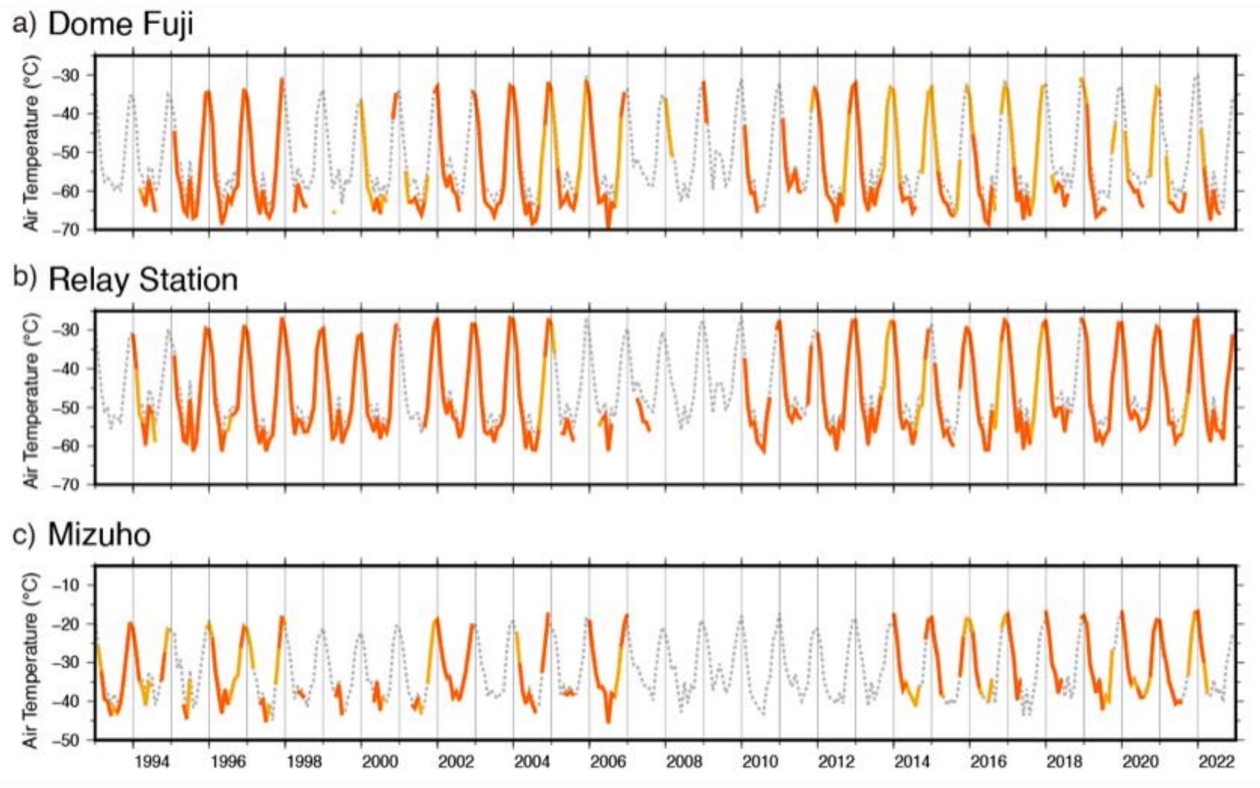


Figure 1. Monthly mean temperature time series from the corrected AWS observations (red line) and monthly mean 2-m temperature from ERA5 (dashed gray) at a) Dome Fuji, b) Relay Station, and c) Mizuho. The orange line is the corrected AWS observations, with a cut-off percentage of 70% for the computation of the monthly mean.

List of publication:

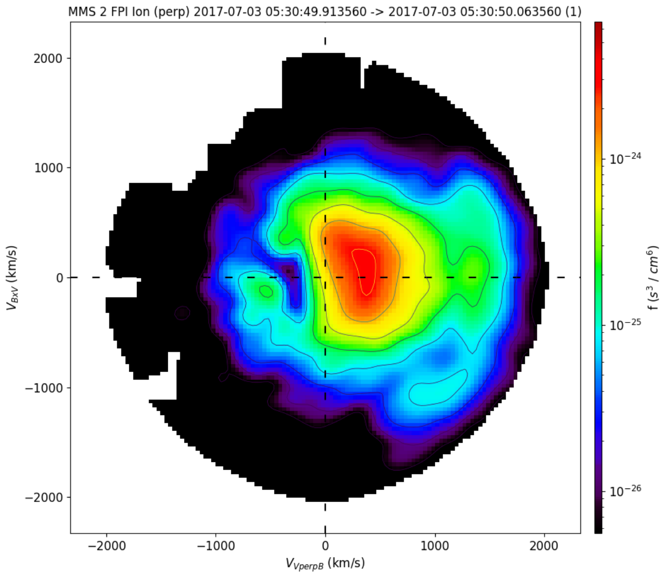
Kurita, N., T. Kameda, H. Motoyama, N. Hirasawa, D. Mikolajczyk, L. M. Keller, L. J. Welhouse, G. Weidner, M. A. Lazzara, Near-surface air temperature records over the past thirty years in the interior of Dronning Maud Land, East Antarctica, J. Atmos. Ocean Technol., 41, doi:10.1175/JTECH-D-23-0092.1, 2024

(Form02-2)

Ion physics and energy budget in reconnection region

Wai-Leong Teh (Universiti Kebangsaan Malaysia)

This research project aimed to search for multiple crescent-shaped ion velocity distribution functions (VDFs) in the magnetotail reconnection region observed by Magnetospheric Multiscale Mission (MMS). Such ion features have not been reported yet in the reconnection region. The multiple crescent-shaped ion VDFs have been successfully identified in a reconnection event in the Earth's magnetotail (see figure). This ion dynamics was observed in the ion diffusion region.



The results have not been published or presented at the conference. We do not have a physical meeting at ISEE due to the limited budget. Our regular meetings were in the Zoom platform, one time in two months.

(Form02-2)

Understanding the impact of solar proton events on middle atmospheric dynamics

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

Summary and purpose:

The mesosphere and lower thermosphere (MLT) region serve as a crucial transition zone for wave dynamics and dissipative processes. Energetically, the MLT region is primarily influenced by waves originated in the lower atmosphere. Moreover, it is frequently subject to upper atmospheric forcing, predominantly driven by energetic particle precipitation. Despite its transient nature, the impact on the MLT region is significant due to its pivotal role as a transition zone between the lower and upper atmosphere.

In this study, our focus is directed towards understanding the effects of solar proton events on the MLT region. These events manifest in variations in meteor counts and horizontal winds, highlighting the intricate relationship between solar activity and MLT dynamics. By delving into these phenomena, we aim to elucidate the complexities of MLT variations under different forcing mechanisms, thereby contributing to a deeper understanding of atmospheric dynamics.

Database and Methodology

To accomplish our objectives, we leveraged extensive observations from meteor radars strategically positioned around the Arctic Circle. Detailed information regarding these observations is outlined in Table 1. The long-term nature of our dataset allowed us to comprehensively investigate the impact of solar proton events on the MLT region.

Station Name	**Location**	**Time period**	**Reference**
Alta	69.97ºN, 23.24ºE	08/09/2015-31/12/2022	Stober et al., 2021
Bear Island	74.5ºN, 19ºE	07/10/2007-21/04/2013	Nozawa et al., 2012
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

Given the abundance of solar proton events (SPEs) spanning from 2001 to 2022, we implemented a threshold condition to focus our analysis on events deemed significant in their impact on the MLT region. Specifically, we set a criterion requiring solar proton events to exhibit an Integral Flux of ≥10 MeV exceeding 1000 pfu. Through this filtering process, we identified approximately 21 events warranting further examination. This approach ensures that we concentrate our efforts on events with substantial potential to influence MLT dynamics, thereby maximizing the relevance and impact of our study. The meteor radar observations presented an additional avenue for analysis, particularly by examining meteor counts.

To address the dynamical variations in MLT winds and tides, we employed a least square fitting approach. This method involved fitting mean wind, diurnal, semidiurnal, and terdiurnal components using a 5-day window shifted by 1 day. By applying this technique, we were able to effectively capture and analyze the temporal evolution of MLT wind and tide dynamics, providing valuable insights into their complex behavior and variability during SPE.

Results

Meteor echo intensity is intricately linked to background ionization levels, with heightened ionization during SPEs leading to decreased meteor counts. Additionally, our analysis revealed elevated noise levels during these events. Further analysis on a diurnal scale pinpointed the exact timing of the meteor count drop. Moreover, horizontal winds exhibited variations during SPEs, albeit with dynamic and case-specific impacts. These variations appear closely tied to localized circulations, potentially influenced by excessive Joule heating from strong electric fields and enhanced ionization. Efforts are underway to consolidate these findings based on long-term observations. Furthermore, enhanced semidiurnal tidal amplitudes were observed during SPEs, highlighting the complex interplay between solar activity, ionization levels, and atmospheric phenomena. These findings provide valuable insights into the effects of SPEs on MLT dynamics.

Currently, our work is focused on unravelling the underlying mechanisms driving these observed variations, thus contributing to a deeper understanding of the complex dynamics within the MLT region during solar proton events.

Period of Stay and Interactions

From 2nd June 2023 to 11th July 2023, I participated in the ISEE International Joint Research Program at the Institute for Space-Earth Environmental Research (ISEE). Associate Professor Satonori Nozawa from the Division of Ionospheric and Magnetospheric Research at ISEE hosted my visit. Throughout my stay, I collaborated closely with Prof. Masaki Tsutsumi from the National Institute of Polar Research (NIPR), Tokyo. In addition to regular engagement with my team members, Dr. Satonori Nozawa and Prof. Masaki Tsutsumi, I also engaged in scientific discussions with Prof. Mizuno and Dr. Nakajima, all of whom contributed valuable insights to our research efforts.

Dr. Satonori Nozawa provided an insightful overview of the working principles of the EISCAT radar and its associated observation datasets. Furthermore, I had an opportunity to attend an informal seminar conducted by Mr. Koyama, a PhD scholar working under Dr. Satonori Nozawa, on semidiurnal tide dynamics in the polar lower thermosphere.

As part of my visit, I delivered a talk titled “Mesosphere Lower Thermosphere Region: The Gateway between Atmosphere and Space” on 29th June 2023, sharing insights and findings from our research endeavors. I continued my research after returning to India and was also in constant touch with Dr. Satonori Nozowa. One of my PhD students is actively engaged and demonstrated a keen interest in this topic and actively contributing to our research efforts. Recently, some of our results were presented at the National Space Science Symposium-2024 held in Goa, India. The collaborative experience at ISEE was invaluable in furthering our understanding of atmospheric and space science dynamics.

I want to express my sincere gratitude to Dr. Satonori Nozawa and his colleagues at the ISEE for their warm welcome and hospitality during my stay in Nagoya. Their generosity and support made my visit both enjoyable and productive. I am grateful for the opportunity to collaborate with such talented individuals and the knowledge and insights they shared during our discussions. Their expertise and dedication have undoubtedly enriched our research endeavors and laid the foundation for fruitful collaborations now and in the future. Thank you once again to Dr. Satonori Nozawa and the entire team at ISEE for opening the door to valuable opportunities and their hospitality throughout my stay. I look forward to continued collaboration and mutual growth in our scientific pursuits.

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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.

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

(Form02-2)

Development of a calibration scheme for the next-generation digital phased array system

Shin'ichiro Asayama (SKA Observatory)

The low frequency component of the Square Kilometre Array (SKA1-LOW) will be an aperture phased array in Western Australia. It will be composed of 512 stations, each of them consisting of 256 log-periodic dual polarized antennas, and will operate in 50 MHz - 350 MHz.

ISEE, Nagoya University have operated ground-based radio telescopes at 327 MHz for more than 30 years. Dr. Kazumasa Iwai at ISEE developed a next generation digital phased array IPS observation system at the same frequency band. The signal processor of the digital phased array can prosses 8 inputs and form 4 beams simultaneously. The quality of the beams produced by the new digital beamformer is crucial for its performance, and proper calibration steps are essential to avoid calibration artefacts. The various factors affecting the quality and stability of the beams, such as electronic stability, calibration errors and the element beam patterns of the individual antennas should therefore be studied.

The aim of this international joint research program was to explore a calibration scheme for the next-generation digital phased array system of ISEE.

The PI visited ISEE in 6th to 9th September 2023 and had several discussions with Prof. Iwai and his student. The PI introduced the calibration method used in the SKA-Low telescope. A detail of the calibration method and data reduction procedures were explained to the student. The system configuration and observation plan for the commissioning of the prototype system were discussed. The PI also visited ISEE in 11th to 13th March 2024. During the stay at ISEE, the PI joined the commissioning activities of the digital phased array prototype. Collaborators from the Osaka Metropolitan University (OMU) and Fukui University of Technology (FUT) were also participated. It was confirmed that the prototype system worked as expected. After the experiments, the PI and the students discussed openly data the status of the research activities. Further discussions on the construction strategy of the phased array instrument were also made.

This collaboration was presented on 4th March 2024 at the Japan Radio Astronomy Forum Symposium 2024. Another related research for a Phased Array Feed (PAF) was reported on 15th December 2023 by FUT prof. Yusuke Miyamoto at the Japan VLBI Consortium Symposium 2023.

(Form02-2)

Geochronology and geochemistry of apatite grains in granitic rocks as a new method for discrimination of tectonic setting

HajiHossein AZIZI (University of Kurdistan, Iran)

First of all, I would like to express my deep gratitude to the ISEE members during my stay at the ISEE for two months in the summer of 2023.

During my stay at ISEE, we did the following:

1-1. We separated apatite and zircon grains from more than 50 samples of different granitoid rocks in Iran Plateau.

1-2. As for the 50 samples for the host granitoid, we measured chemical compositions by ICP-MS and Sr-Nd isotope ratios by Thermal Ionization Mass Spectrometer (TIMS).

1-3. We chemically decomposed about 20 samples of apatite grains to measure trace elements including rare earth elements (REEs) by ICP-MS and Sr isotope ratios by TIMS.

1-4. We prepared 30 polished thin sections of the apatite samples to measure REE of the apatite grains by LA (laser ablation)-ICP-MS.

1-5. We did zircon U-Pb dating by LA-ICP-MS for the samples.

2-1. We did the chemical separation of ^{10}Be for twenty samples of young volcanic rocks recently measured at the University of Tokyo.

2-2. We did mineralogical analysis using XRD for sediment samples in NW Iran.

3. We discussed with our team in this project about our results in these two years.

4. I went on a one-day field trip with members of the ISEE Chronological Research to see the Shinshiro Tonalite and the Median Tectonic Line in the Japanese Islands.

During my stay, we continued our previous collaboration to write and complete our previous papers and to start writing some new ones. Two of our papers have been published in high-quality journals (First quarter), *Lithos* and *Journal of Petrology*, which focus mainly on the whole rock chemistry and isotope ratios. Now we are continuing our work on zircon and apatite chemistry, and we are looking to publish this year for some papers.

The abstracts of our papers, which are supported by ISEE 2022−2023, are listed below.

(1) Azizi, H., Daneshvar, N., Rafat, G., Asahara, Y., Horie, K., Takehara, M., Kon, Y., Minami, M. and Anma, R., 2024. O–Hf isotope ratios of Alvand S-type granite, western Iran, reveal crustal melting in an extensional regime. *Lithos* **464**, 107437.

Abstract: There are a few intrusive bodies in the central Sanandaj-Sirjan Zone (C-SaSZ), which is parallel to the Zagros suture zone, in western Iran. The Alvand batholith in the Hamedan area is one of these bodies and consists of rock types with large variation, in particular, two-mica garnet-bearing granite with an S-type signature. Zircon U-Pb dating gives

crystallization ages of 170–163 Ma for the S-type granite. The $^{176}Hf/^{177}Hf$ ratios in the zircon grains vary from 0.282001 to 0.282780 (rim), with low $^{176}Lu/^{177}Hf$ ratios (0.002 to 0.018). The $\varepsilon Hf_{(t)}$ values (rim) are clustered into two main groups: a negative $\varepsilon Hf_{(t)}$ group (−6.9 to 0.0, *n* = 39), with some highly negative $\varepsilon Hf_{(t)}$ values (−25.8 to −21.9, *n* = 3), and slightly positive $\varepsilon Hf_{(t)}$ values (+0.3 to +2.9, *n* = 14) of inherited grains. The ^{18}O values for the zircon grains are positive and range from +10.4‰ to +11.8‰. The high $\delta^{18}O$ (positive) and mostly negative $\varepsilon Hf_{(t)}$ values are more consistent with continental crustal sources for these rocks, and the Hf model ages (T_{DM2}) show a wide range from 2.7 to 0.8 Ga, suggesting the heterogeneity of the crustal components. The long incubation time (2089 to 544 Ma) indicates a long history of crustal residence and crustal reworking. The incubation age of the zircon grains, >300 Ma, confirms the recycling of crustal material by partial melting. The simultaneous occurrence of S-type granites with mafic bodies, such as gabbro and diorite members with tholeiitic signatures, suggests that the injection of mafic magma increased the geothermal gradient from the bottom and sides along the major faults, which was the trajectory for the injection of hot mafic melts to shallow depths. These processes abnormally increased the geothermal gradients locally, and the partial melting of crustal and supracrustal materials produced S-type granites and migmatization among the hot blade-shaped mafic bodies. Therefore, the partial melting of crustal material in an extensional tectonic regime and/or in a thin continental crust occurred in a continental rift and/or in the Neo-Tethys passive margin. The present work concludes that the passive margin can be suggested as the tectonic setting for the generation of S-type granites, without the collisional regime that has been widely considered for the sources of this type of granite in the world.

(2) Azizi, H., Daneshvar, N., Asahara, Y., Minami, M., and Anma, R. 2023. The generation of Eocene mafic dike swarms during the exhumation of a core complex, Biarjmand area, NE Iran. *Journal of Petrology* **64**, egad039.

Abstract: Several swarms of parallel E–W dikes cuts late Neoproterozoic- to early Paleozoic (540 Ma) basement in the Biarjmand area, NE Iran. The microgabbroic to doleritic dike are several hundred meters long and 0.5 to 3 meters wide. U–Pb dating of their zircon grains yields a crystallization age of 46.0 ± 7.1 Ma for the dike swarms. The dikes have SiO_2 contents of 46.0–49.3 wt%, and Fe_2O_3 contents of 9.80–14.8 wt% with variable MgO (4.92–9.16 wt%), TiO_2 (1.47–2.65 wt%), and K_2O contents (0.33–1.13 wt%). The dikes have low contents of high field strength elements (HFSEs), and have some similarities to transitional mid-ocean ridge basalts (T-MORB) based on their chemical composition. Positive $\varepsilon_{Nd}(t)$ values of +5.2 to +6.0 for the dike samples imply that the basaltic magma was generated from depleted lithospheric mantle. After the closure of the Sabzevar ocean and obduction of the large mantle peridotite body over the continental crust in the late Cretaceous-Paleocene, the gravitational instability in the central Iran/Eurasia plate collision zone triggered exhumation of old basement coeval with injection of the mafic magma. During exhumation, mylonitic deformation with brittle-ductile structures affected the basement metagranite and the host rocks. The metagranite and dike swarms cut the Cretaceous Sabzevar ophiolite, and the disparting of ophiolite members probably occurred during basement exhumation in the Cenozoic. The similar ages of the mafic dike swarms and other Eocene magmatic rocks of the Urumiah (Urmia) Dokhtar magmatic arc (UDMA), western Iran, is consistent with a rapid extensional regime over the Sabzevar suture zone on an earlier collision zone in NE Iran. This process provided a suitable setting for the exhumation of the old basement, the emplacement of the parallel dike swarm, and the development of shallow basins in this area.

(Form02-2)

Advancing Predictability of Coronal Mass Ejection Occurrence by Combining Photospheric Observations and Coronal Modeling

Principal Investigator
Johan Muhamad (National Research and Innovation Agency)

Purpose

In this research proposal, we propose to investigate several parameters on flare eruptive and non-eruptive (confined) ARs. Our main focus is to investigate the electric current and magnetic energy distributions on the ARs, because we believe that these parameters should be related with the reconnected flux and the magnetic topology of the ARs. This research is intended to complement the previous works done by Toriumi et al. (2017) and Lin et al. (2020, 2021) on the study of flare eruptivity by expanding the investigation more on the magnetic topology of ARs in addition to the measurement of some quantities derived from the photospheric magnetogram.

Methods

We started the investigation with 51 events in the flare event list by Toriumi et al. (2017) that has also been extensively studied by Lin et al. (2020, 2021). In our study, further investigation is conducted on several parameters that have not been covered by the previous studies, such as calculating electric current neutralization, analyzing the decay indexes above the ARs, and estimating magnetic energy and current density distributions. To correctly analyze the electric current distribution, we use 3-D coronal magnetic field extrapolations in the ISEE NLFFF databases that can provide 3 components of vector magnetic field in the photosphere. By doing this, we differentiate our study with other studies that only calculate vertical current densities and proxies of magnetic energies from the magnetogram data that have shortcomings in the vertical direction of spatial distribution. Comparisons between our results and the previous studies are conducted by examining quantities of various parameters and also comparing various maps of the different parameters to find the essential characteristics of the eruptive flare events.

Results

Re-investigation of the flare eruptivity events listed in the previous works resulted that several events are misclassified. These misclassified events were often unexplainable because they did not fit to established models used to classify eruptive and non-eruptive flare events. This discovery is important to bring a more accurate understanding about the mechanism that governs flare eruptivity. We found that using the corrected classification, we were able to achieve a more refined discrimination between eruptive and non-eruptive flares. We used the new arranged list to assess several parameters extracted from the photospheric magnetogram and the NLFFF data in relation to flare eruptivity.

The main parameter that we attempted to evaluate is the neutrality of electric current in the selected active regions. To estimate this parameter, we used SHARP photospheric magnetogram data (Bx, By, and Bz) and calculated vertical current densities in every pixel of the data. Some conditional filters were applied regarding the quality of the confidence level of the data at each pixel by using the conf_disambig parameters in the SHARP database. Then, the electric current neutrality of each magnetic polarity is calculated by finding the ratio between the direct electric current and the return current. After calculating the electric current neutralization for all the ARs in the data set, we compared the characteristics of these values between the non-eruptive and eruptive flares. Comparisons of the electric current neutralization between the eruptive and non-eruptive flares are shown in Figure 1.

In general, most of the eruptive ARs deviated from the current neutralization state, i.e., the ratio between the direct current and the return current was far from unity. These characteristics are consistent with the initial assumption that the non-eruptive ARs tend to be neutral. However, some events are inconsistent with this hypothesis. Our detailed investigation of these events shows that many of these ARs were very large in size, but the flaring regions were only limited to certain regions. As a result, the calculated current neutralization ratio is sometimes irrelevant to the eruptivity behavior of the AR because the interested region is significantly smaller than the whole region. This problem should be treated by selecting relevant magnetic fluxes that are related to the flaring sites. In order to do this, we evaluated the connectivity of the magnetic field lines from the NLFFF data and separated the relevant fluxes for a more accurate calculation. This work is still ongoing and the updated results will be published as soon as the work has been completed. We also try to develop a new parameter that can better describe and discriminate flare eruptivity based on this electric current neutralization and some undecided spatial parameters to consider the area of the relevant regions.

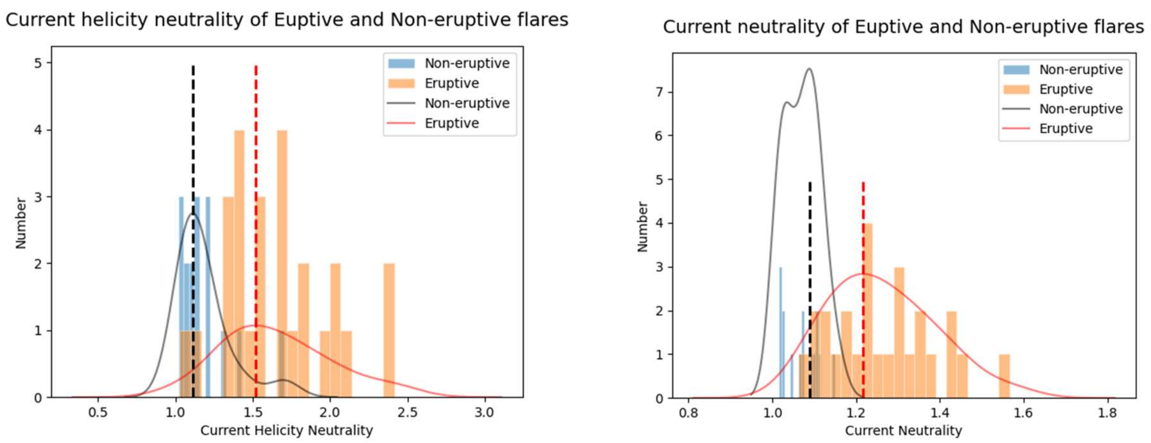

Figure 1. Calculated electric current and current helicity ratios of eruptive and non-eruptive flares.

Publication

The work is still in progress, and the results will be published as soon as the work has been completed.

Impact of Indian Ocean dipole on South Indian Ocean surface circulation and productivity- Remote sensing perspective

Benny N Peter
Kerala University of Fisheries and Ocean Studies, India

Purpose

The Indian Ocean Dipole (IOD) is the major climate mode occurring in the Indian Ocean region. It is significantly influencing the oceanic and atmospheric circulation and associated monsoon system. The oceanic ecosystems are strongly controlled by a wide range of Physical processes including temperature changes, horizontal and vertical transports and upwelling and mixing of deep water. All these physical processes are controlled by ocean dynamics. In addition to inter-annual variation, significant changes in ocean circulation are found on time scales from decades to centuries and on spatially from regional to basin scale. Such changes will result in modification of both the mean state and spatial and temporal variability of marine environment and ecosystems. Hence, the present study is carried out to understand the effect of IOD events on South Indian Ocean (SIO) circulation and biological productivity.

Method

The present study employed remote sensing observations from different platforms to derive the mean velocity field. The surface drifter data used in this study comes from the Global Drifter Program. The satellite altimetry data used were Maps of Sea Level Anomaly produced by the Collect Localization Satellites, France. Maps had been produced with a resolution of 1/3 ° latitude and 1/3 ° longitude and weekly since September 1992. The weekly mean ocean surface wind fields derived from the scatterometers on board ERS-1/2, QuikSCAT and ASCAT, generated by CERSAT, France (http://cersat.ifremer.fr/) were used to estimate the wind-driven Ekman velocity. The merged Chlorophyll Concentration obtained from GlobColor was used to study productivity.
The components of geostrophic velocity anomaly had been computed from altimeter sea level anomaly data using the conventional geostrophic relation. The time series maps of instantaneous geostrophic velocity field had been prepared by combining the time series MSLA with the estimated mean velocity field. The spatial and temporal variability of the zonal velocity component was determined employing EOF analysis. The monthly current field was superimposed over the Chlorophyll maps to find the influence of mesoscale dynamic features on Chlorophyll distribution and hence the productivity. Monthly winds and photosynthetically available radiation (PAR) were also compared with Chlorophyll distribution.

Results

Merging satellite altimetry and satellite tracked surface drifter observations the present study brings out the mean and seasonal variability of South Indian Ocean circulation. The mean field depicts the major currents of south Indian Ocean. The westward flowing South Equatorial Current (SEC) is prominent, and it spans between 8 °S and 20°S. The South Equatorial Counter Current is well developed in the western side. The mean velocity field displays strong western boundary currents in the South Indian Ocean. The SEC attains its maximum speed and branches towards the west and south as it reaches the Madagascar Coast. The SEC branches as southward flow along the Mozambique Channel and northward as East African Coastal Current when it impinges into the east coast of Africa. The Leeuwin Current (eastern boundary current) is not obvious in the mean field. Mesoscale variability is dominant along the Mozambique Channel and south off Java. The seasonal changes of Indonesian Throughflow, South Java Current and the SEC are playing significant roles in the mesoscale variability of the south Indian Ocean.

Significant changes are observed on the surface circulation of tropical south Indian Ocean during Dipole events. In positive Dipole period, the Indonesian Throughflow (ITF) is strong, and it takes a north-westward turn towards the equator. The equatorial Jet is absent and zonal westward flow prevails during the monsoon transition period. Strong circulation occurs in the eastern part compared to the west. During negative Dipole, the circulation is weak in the eastern side, whereas strong currents are observed in the west. Energetic mesoscale eddies present in the Mozambique Channel. The ITF is weak and is directed towards the SEC and SECC towards east is obvious near the equator.

Significant changes are observed in Chlorophyll distribution also between positive and negative dipole events. During positive dipole, enhanced Chlorophyll was found in the eastern side whereas, high Chlorophyll was during negative dipole in the western side between equator and 10 °S. Low Chlorophyll waters were occupied in the eastern part during negative dipole period. The significant mesoscale activity associated with surface circulation of the eastern region during positive dipole period influences the Chlorophyll distribution. During negative dipole the eastern region was not showing any significant mesoscale activity and hence diminished Chlorophyll distribution. The southeasterly wind was blowing along the coast of Java and Sumatra region during positive Dipole was favorable for upwelling. But, during negative Dipole the wind is mostly perpendicular to the coast. This causes different Chlorophyll distribution during positive and negative dipole periods of eastern part.

The distribution of PAR displayed higher intensity in eastern part in the ITF region and south of Java, while western side is cloudy During positive IOD. Just the opposite condition of PAR is found in negative IOD. Hence, the insolation is also favorable for higher Chlorophyll in the eastern side. The precipitation pattern is also shown corresponding to the PAR, thus increased rainfall in the eastern side during negative Dipole in the east south of Java, while the rainfall is comparatively stronger in the west during positive Dipole.

Thus, the IOD events are significantly influencing the SIO circulation. Both temporal and spatial changes are evident. The Chlorophyll distribution is considerably controlled by the mesoscale features of SIO circulation. Besides, the PAR also modifies the Chlorophyll enhancement of the SIO.

Period of stay in ISEE: Stayed at ISEE Nagoya 16-21st December 2023

list of publications: None so far, manuscript preparation is underway

(Form02-2)

Academic Exchange of Weather Radar Research and Application Experiences between ISEE and NCDR

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

1. Purpose

For the purpose of exchanging experiences in weather radar research and applications between the Institute for Space-Earth Environmental Research (ISEE) in Japan and the National Science and Technology Center for Disaster Reduction (NCDR) in Taiwan, Associate Researcher Dr. Chih-Chien Tsai from NCDR was granted the 2023 ISEE International Joint Research Program to visit Prof. Nobuhiro Takahashi at ISEE. Additionally, Assistant Researcher Ms. Jia-Chyi Liou and Associate Technologist Mr. Hsin-Hao Liao from NCDR joined the visit to facilitate substantive technical exchanges alongside academic discussions. The visit not only fosters friendship between the two parties but also enhances understanding of advanced remote sensing technologies and disaster prevention products.

2. Methods (six topics)

Dr. Tsai, Ms. Liou, and Mr. Liao visited Prof. Takahashi during November 20–24, 2023. Japanese scholars who also participated in the discussions included Prof. Taro Shinoda from ISEE, Prof. Yuuki Wada from Osaka University, and Dr. Nao Yoshida from the Japan Aerospace Exploration Agency (JAXA). The academic exchange covered the following six main topics:

(a) Introduction to the hardware and data processing of the multi-parameter phased array weather radar (MP-PAWR).
(b) Overview of the Laboratory of Meteorology at ISEE.
(c) Visit to the MP-PAWR at Osaka University.
(d) Introduction to the JAXA Global Satellite Mapping of Precipitation (GSMaP).
(e) Data processing and preliminary demonstrations of the MP-PAWR.
(f) Dr. Tsai’s lecture: Overview of Recent Radar- and Satellite-related Achievements in NCDR.

3. Results (of the six topics)

(a) The MP-PAWR is a radar system that utilizes phased array antennas for detection. By adjusting the phase difference of the antennas, it can take advantage of simultaneous multi-angle observations and conduct rapid scanning observations. In addition to introducing the basic observational principles, hardware structure, and experiences in data calibration, Prof. Takahashi highlighted the rapid scanning strategy of the MP-PAWR for monitoring the generation and development of precipitation systems. He also shared the status of Japan's spaceborne precipitation radar mission and participation in the Atmosphere Observing System (AOS) of the National Aeronautics and Space Administration (NASA).

(b) Prof. Shinoda introduced the relevant achievements of the laboratory. Among them, the Ka-band radar has the capability to detect smaller raindrops and cloud droplets, enabling it to provide early warning for convective systems with development potential up to 15 min in advance. The analysis results indicate that compared to the variation of vertical height over time in convective systems, the variation of area over time exhibits higher sensitivity to convective systems with development potential.

(c) Under the guidance of Profs. Takahashi and Wada, the NCDR crew entered the radome of the MP-PAWR and closely observed the radar's structural components, as well as the computer hardware and software equipment established for processing large volumes of radar data. Two different scanning strategies were demonstrated on-site. Compared to traditional radar observations, both scanning modes provide more comprehensive information of precipitation systems in shorter time frames.

(d) Dr. Yoshida introduced six different products available on the JAXA GSMaP website, each varying in latency, accuracy, and calibration against rain gauge stations. Users can select rainfall products of different characteristics according to their specific purposes. The GSMaP product integrates rainfall estimates from active sensors such as the dual-frequency precipitation radar (DPR), which includes Ku- and Ka-band precipitation radars, along with passive observations from instruments like the Global Precipitation Measurement (GPM) microwave imager (GMI) and infrared imagery.

(e) The compilation of data decoding programs was completed on the NCDR workstation, and raw data files were successfully accessed. A test was conducted using a case on July 28, 2018. The test spanned from 19:54 to 19:59 JST. Preliminary distributions of various variables (Z_H, ρ_{HV}, K_{DP}, Z_{DR}) at different altitudes were plotted using GrADS. Through radar observations with high temporal resolution, the process of convection systems moving eastward and gradually developing could be clearly observed.

(f) Dr. Tsai delivered a lecture titled "Overview of Recent Radar- and Satellite-related Achievements in NCDR" to the professors and students at ISEE, as well as several individuals on line. The topics included radar data assimilation, quantitative precipitation estimation, demonstrations of wind retrieval products, historical case studies, and applications of the Formosat-7 satellites.

4. Periods of stay

Face to face meeting on Nov. 20-24, 2023					
	20 (Mon)	21 (Tue)	22 (Wed)	23 (Thu)	24 (Fri)
9:00-10:30	Welcome Self introduction Logistics	Visit to MP-PAWR site at Osaka Univ. Meet 10:15 at the Shinkansen gate	Discussion and data processing of MP-PAWR	OFF (discussion/utilization of ISEE's room is available)	Discussion and data processing of MP-PAWR
10:30-12:00	Introduction of Met. Lab (Prof. Shinoda)				
13:30-15:00	MP-PAWR lecture Overview Hardware Calibration Application Presentation by NCDR of their web system	13:30 Arrival at Osaka U. 15:30 end of meeting Return to Nagoya	GSMaP lecture (Dr. Yoshida/JAXA) On the use of GSMaP data for disaster prevention		Discussion about the report and future collaboration and next year's plan
15:00-16:30					Lecture by Dr. Tsai @410 of building II

5. Publication

Tsai, C.-C., Liou, J.-C., Liao, H.-H., Yu, Y.-C.*, Chen, Y.-C., Lin, C.-Y., Chung, K.-S. and Jou, B.J.-D. (2023) Strategy analysis of the extrapolation adjusted by model prediction (ExAMP) blending scheme for rainfall nowcasting. *Terrestrial, Atmospheric and Oceanic Sciences*, 34, 16.

(Form02-2)

Multipoint spacecraft investigations on the solar wind and solar erupted magnetic flux ropes propagating from the solar surface to the inner heliosphere

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

Purpose of Project:

This project is two different topics to be addressed: One is to investigate the multipoint spacecraft measurements at the different heliospheric radial distances and longitudes to understand the ICME structure propagating from the solar surface through the inner heliosphere. The other is to compare of the solar wind plasma and interplanetary magnetic field (IMF) properties between the MAVEN observations at Mars and the SUSANOO simulation (*Shiota and Kataoka*, 2016), because there is no continuous solar wind monitor upstream from Mars, although Mars' plasma environment is highly variable depending on the upstream solar wind conditions (see, *Brain et al.*, 2017, and references therein). It is thus important to determine the solar wind conditions at Mars among those who studying the solar wind interaction with Mars.

Methods and Results:

Since FY2022, we have investigated the ICME event erupted in October 2021, which was simultaneously observed by BepiColombo (at ~0.33 AU *en route* to Mercury), Solar Orbiter (at ~0.68 AU), near-Earth spacecraft, and STEREO-A (at ~0.96 AU). Interestingly, a smooth rotation together with the dip-like structure in the normal component of the magnetic field in the sheath of the interplanetary shock was commonly observed by all the four spacecraft, despite that they were located at different radial distances and longitudes in the inner heliosphere. We initially considered a possibility that the magnetic feature of interest is a kind of small-scale flux rope (e.g., *Ruohotie et al.*, 2022) embedded in the CME-driven sheath. We thus attempted to reproduce the flux rope geometry at each spacecraft location by a cylindrical model fitting (e.g., *Marubashi and Lepping*, 2007). However, our first attempt was not very much successful in providing reliable and consistent parameter settings among multiple spacecraft.

We next considered a possibility that this structure is corresponding to a planar magnetic structure (PMS) (e.g., *Nakagawa et al.*, 1989). PMS is a characteristic magnetic field structure in which the magnetic field is oriented approximately along a single plane. One of the specific regions where PMSs are detected is the CME-driven sheath. Based on the minimum variance analysis, we confirmed that the magnetic field observed by all spacecraft is well aligned to the plane perpendicular to the minimum variance direction, which is consistent with an interpretation that a PMS passed through the spacecraft as proposed by the previous studies (e.g., *Palmerio et al.*, 2016; *Ruan et al.*, 2023). We further examined the angle between the shock normal and the minimum variance directions at each spacecraft to discuss the distribution of the PMS relative to the global ICME structure. We then found that the PMS tends to be formed along the shock surface shown as Figure 1 below:

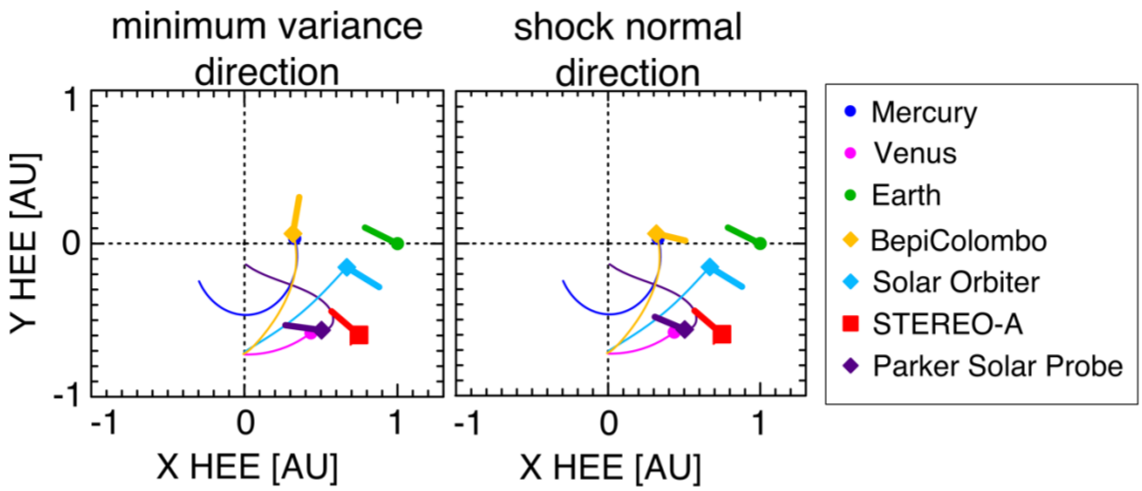

Figure 1: (Left) The minimum variance and (Right) shock normal directions projected onto the XY plane in the HEE (Heliocentric Earth Ecliptic) coordinates. Each planet and spacecraft symbols are summarized in the legend (*Bamba and Hara et al., in prep.*).

Regarding the comparison of the solar wind plasma and IMF properties between the MAVEN observations around Mars and the SUSANOO simulation, we first used the SUSANOO simulation results without the interplanetary scintillation (IPS) observations. We then examined how reasonable the SUSANOO simulation w/o IPS can predict the upstream solar wind condition at Mars' orbit (~1.52 AU). The correlation coefficients between the MAVEN observations at Mars and the SUSANOO simulation w/o IPS turn out to be ~0.14 (solar wind density), ~0.16 (solar wind velocity) and ~0.25 (IMF strength), respectively. We also found that this correlation weakly depends on the elongation between Earth and Mars. Moreover, the IMF strength predicted by SUSANOO w/o IPS tend to be sometimes extremely weaker than that observed by MAVEN at Mars, that is consistent with the pre-known issue for the SUSANOO prediction.
Next, we are planning to use the SUSANOO simulation with the IPS observations used as a simulation inner boundary. However, unfortunately, the SUSANOO w/ IPS results are not ready to share by the end of FY2023. Once these results are ready to use, we will evaluate how the SUSANOO simulation w/ IPS is improved to retrieve the actual upstream solar wind conditions at Mars observed by MAVEN.

Periods of Stay in ISEE, Nagoya University:

In FY2023, I visited at Nagoya University twice between 26 and 28, July 2023, and between 24 and 28, November 2023. When I stayed in Japan, I had several in-person meetings with colleagues to discuss the ICME event erupted in October 2021, and the comparisons of the solar wind plasma and IMF properties observed by MAVEN around Mars with the SUSANOO simulation.

Publications:

As of the end of FY2023, we are still actively struggling to finalize a manuscript on the ICME event erupted in October 2021, because our main interpretation shifted from the solar erupted magnetic flux ropes to the PMS. Our manuscript is anticipated to be submitted to either *Journal of Geophysical Research (JGR): Space Physics*, or the special issue on the *Earth, Planets and Space (EPS)* journal. The call for papers on this special issue is also delayed in FY2024.

(Form02-2)

Reconstructing Atmospheric 14C across the Inter Tropical Convergence Zone Using Vietnamese Tree Rings

Dang Xuan Phong (Institute of Geography, Vietnam Academy of Science and Technology (VAST)

This international joint project aims to develop a historical record of atmospheric radiocarbon (^{14}C) in subtropical regions by using calendrically dated tree rings in Vietnam. These new ^{14}C data will be used to constrain the spatial pattern around the equator, where the temporal variations in atmospheric ^{14}C concentrations have not been sufficiently elucidated, potentially influenced by air masses from the northern and southern hemispheres. Additionally, we will measure the stable isotope compositions of oxygen and carbon from the tree rings to investigate factors that can cause spatial and temporal variations in ^{14}C concentrations. These factors include the seasonality of tree growth and the source of rainwater, which reflects atmospheric circulation dynamics. The combined proxies aim to improve:

1. Regional and local features of past changes in atmospheric circulations.
2. Predictions of the Intertropical Convergence Zone (ITCZ) shifts in response to anthropogenic forcings.
3. ^{14}C calibration curve for the subtropical zone in the Northern Hemisphere.
4. Our results should contribute to a better understanding of paleoclimate and archaeological evidence.

In the first year of this project, we developed an efficient method for oxygen and carbon isotope analysis and radiocarbon dating of many tree ring samples. We collaborated with Mr. Nguyen Tran Quoc Trung of the Southern Institute of Ecology, Vietnam Academy of Science and Technology (VAST), to collect tree ring samples from subtropical zones in the Northern Hemisphere. In the national forest reserve on the outskirts of Dalat, Lam Dong Province, located in the mountain area of southern Vietnam (108.7E, 12.2 N), we successfully collected tree ring samples using increment borers from large trees of *Fokienia hodginsii* and *Pinus krempfii*, which may be several hundred years old (see photo 1). The tree rings of *Fokienia hodginsii* are clear, with approximately 800 rings marked in the 473 mm (longest) core. Although the tree rings of *Pinus kremp*fii are not visible to the naked eye, microscopic observations revealed variations in cell size ranging from 0.2 to 0.3 mm, which appear to be annual rings. Further verification is needed to confirm that these variations represent annual rings. However, if confirmed, the 390 mm (longest) core would contain a record of atmospheric ^{14}C and hydrological changes spanning over the past 1000 years. We are currently conducting a comparative analysis of multiple cores collected from *Fokienia hodginsii* and *Pinus krempfii* to estimate the formation ages of each tree ring.

Photo: Sampling of tree ring cores from the giant *Fokienia hodginsii* trees (Cypress family) in Lam Dong Province, Vietnam

(Form02-2)

Relationship between natural fine aerosol chemical composition investigated by application of online and offline mass spectrometry techniques

Petr Vodička (ICPF, Czech Academy of Sciences, Prague, Czech Republic)

Introduction:

Atmospheric aerosols impact Earth's climate by interacting with solar and longwave radiation. Aerosol chemical composition influences their role as cloud condensation nuclei (CCN), connecting aerosols to climate dynamics. As air pollution sources like SO_2 and NO_X decrease, organic aerosol (OA) is expected to play a more significant role. Understanding potential interactions between climate change and OA composition is crucial for further research. The main objective of this study was to characterize atmospheric OA at a Central European site in the context of its sources and transport. The aims of study was to analyze atmospheric OA at a Central European site, focusing on fine aerosol sources and their transport during summer when biogenic OA dominates. Using aerosol mass spectrometry (AMS), provided detailed insights into OA properties for better representation in atmospheric and climate models.

Project preparation, methods and measurements:

The project officially started in April 2023. For the first two months, we installed samplers to collect fine aerosols on filters for subsequent offline analysis. For this purpose, we purchased and annealed the required number of quartz fiber filters (47 mm and 150 mm diameter), weighing the smaller ones for gravimetry analyses. We also performed online calibrations of the instruments used for the measurements, in particular the AMS (measurements of OA, SO_4^{2-}, NO_3^-, NH_4^+, and Cl^-), the aethalometer (model AE-33, measurement of equivalent black carbon (eBC)) and semi-online analyzer of elemental and organic carbon (EC and OC).

Summer sampling and parallel online measurements were carried out at the National Atmospheric Observatory Košetice (NAOK, 49° 34' 24.13" N, 15° 4' 49.67" E, 534 m a.s.l.), which is officially classified as a Central European background station. Fine aerosol (PM_1) filter sampling was conducted from 23 June to 30 August 2023, with a 24-h time resolution and sampling on every second day.

Part of the aerosol samples collected for offline analysis were analyzed for water-soluble ion content using ion chromatography (Dionex ICS-5000) in a Czech laboratory during August and September 2023. These results were then combined with OC, BC and online measurements from AMS for a basic overview of the measured variables.

Visit in Japan and analyses at Nagoya University:

The Czech visit at the Nagoya University (NU) was carried out in October and November 2023. Specifically, Petr Vodička from 17 October to 2 November 2023 and Radek Lhotka from 17 October to 29 November 2023.

The main subject of the visit were the off-line analyses of samples using High Resolution Time-of-Flight AMS (HR-ToF-AMS) in Prof. Mochida's laboratory. We performed analyses of water-soluble organic matter (WSOM) and then water-insoluble organic matter (WISOM). With the exception of two samples damaged during storage, all planned analyses were carried out. The data measured at the NU were evaluated after the return of Radek Lhotka from Japan.

Data evaluation and results:

We used the measured online and offline AMS data as input to the SoFi modeling program to determine the sources/state of organic aerosol.

Modeling on the online AMS data resulted in the identification of 4 sources/states of OA. Specifically, we identified the following factors: more oxidized and less oxidized organic aerosols (MO-OOA and LO-OOA), biomass burning OA (BBOA), and hydrocarbon like OA (HOA).

Modelling based on offline analyses on WSOM identified only 2 factors, MO-OOA and LO-OOA. However, PMF

analysis of WISOM measurements provided 3 factors characterizing OA. These were differentiated by the degree of oxidation, with OOA having the largest abundance, followed by the two factors partially oxidized (C_xH_yO) and non-oxidized (C_xH_y) aerosol.
Overall, oxidized OA completely dominated, which can be assumed to be more hydrophilic and thus more easily works as condensation cores.

Future work:
Although this project on the Japanese side ends on 30 March 2024, the work on data processing will continue on the Czech side thanks to the subsequent support from the ACTRIS network infrastructure. Thanks to this, a presentation of the results at the European Aerosol Conference (EAC) is also planned. The abstract for the EAC has already been submitted and approved (Lhotka et. al., 2024).
In the following work, we will focus on analyses of two summer periods (8-16 July and 15-25 August) with elevated aerosol concentrations when heat waves occurred but the air masses were from different directions.
Since the data show good quality with interesting results, a preparation of a publication is also planned.

References:
Lhotka, Radek; Vodička, Petr; Zhou, Ruichen; Wei, Chenran E.; Pokorná, Petra; Zíková, Naděžda; Mbengue, Saliou; Schwarz, Jaroslav; Mochida, Michihiro; Ždímal, Vladimír: On the origin of summer organic aerosol at a background site in Central Europe. EAC 2024 (https://www.eac2024.fi), 25.8 - 30.8.2024, Tampere, Finland, conference abstract, submitted 6 Feb 2024.

(Form02-2)

Cross-calibration of low-energy electron measurement obtained by Mio/BepiColombo with Solar Orbiter on the 10th of August 2021 and its solar wind property

Sae Aizawa (LPP, CNRS)

Introduction and Purpose of the project

BepiColombo, ESA/JAXA joint mission to send two spacecraft to Mercury, was launched in October 2018, is en route to Mercury. Until its orbit insertion which is planned for December 2025, BepiColombo is in the cruise phase and conducts solar wind and planetary flyby observations. Because the BepiColombo flys as a single spacecraft during the cruise phase, two spacecraft is in stack configuration and one of two satelite, Mio, is located within the sun shield to protect the instruments from harsh conditions in the inner heliosphere. Such condition limits the field of view of instruments onboard Mio and does not allow us to observe the plasmas with full capabilities of the instruments but with a few windows open to space. However, electrons are more gyrotropic than ions, we can access to the information more easily than ions. Thus, those obsesrvations are good opportunities for the instrument team to cross-calibrate the data of low-energy electrons from the Mercury Electron Analyzer (MEA) with data from other space missions.

During the cruise phase of BepiColombo, there are several coordinated observations identified among several space missions (Hadid et al., 2021). In particular, the second Venus flyby of BepiColombo on the 10th of August 2021 was the greatest case among them since Solar Orbiter was just 200 Venus radius away upstream of BepiColombo just right after Solar Orbiter's Venus flyby, and both magnetic field data show they are observing the same solar wind. Taking this rare opportunity, we cross-calibrate the low-energy electron data from BepiColombo and Solar Orbiter. In addition, with intensive collaboration with the colleagues from Mio Science Center which is the part of heliospheric science center at ISEE, Nagoya University, we advance the preparation of official data product from the Mio project which will be publicaly open in coming years.

Method

From the 2nd Venus flyby of BepiColombo, several data products are available. Two MEA sensors provide us the 4 seconds time resolution omni energy spectra from a few eV to 3 keV (26 keV) for MEA1 (MEA2), onboard moments (density), and three-dimensional energy spectra for MEA1 but only every 10 min. Because of its very limited field of view, two windows are only open to space to properly observe electrons resulting in the onboard calculated density less accurate. However, Solar Orbiter has electron analyzers (EAS) is available with the collaboration with the team, thus we compare them and see the differences. In particular, we focus on the effect of the sun shield and evaluation of photoelectrons. On the other hand, such data from any space mission has to be collected and opend to public. For the case of BepiColombo, the cruise science was not planned at the beginning of the mission, thus we use this opportunity as a preparation time for data archiving, such as preparing a pipeline, contact between the instrument team and Mio science center, content of the files.

Results

Figure 1 shows an example of comparison obtained for the 2nd Venus flyby. Preliminary comparison between BepiColombo and Solar Orbiter is shown for both magnetic field data and low-energy electron data (Rojo et al., 2024). In Rojo et al. (2024), statistically speaking, we have conculeded that correction to the electron moments due to the sun shield does not necessarily give the better data, and even with two spacecraft measurements, it is always difficult to properly evaluate the effect of photoelectrons when the field of view is limited. Thus, we have also used the data from MEA2 which has wider energy range but with the same 16 energy steps to better estimate the plasma moment. Especially, different energy range with the same energy steps allows us to have better energy resolution when both are combined, which may lead in better fitting results of energy distribution and in better correction factor to be applied. In addition, in this project we try kappa distribution function rather than the Maxwellian one. Analysis is still ongoing because every single scan we need to make sure we fit them properly. After discussion with collaborators, other data than the Venus flyby will also be taken into account.

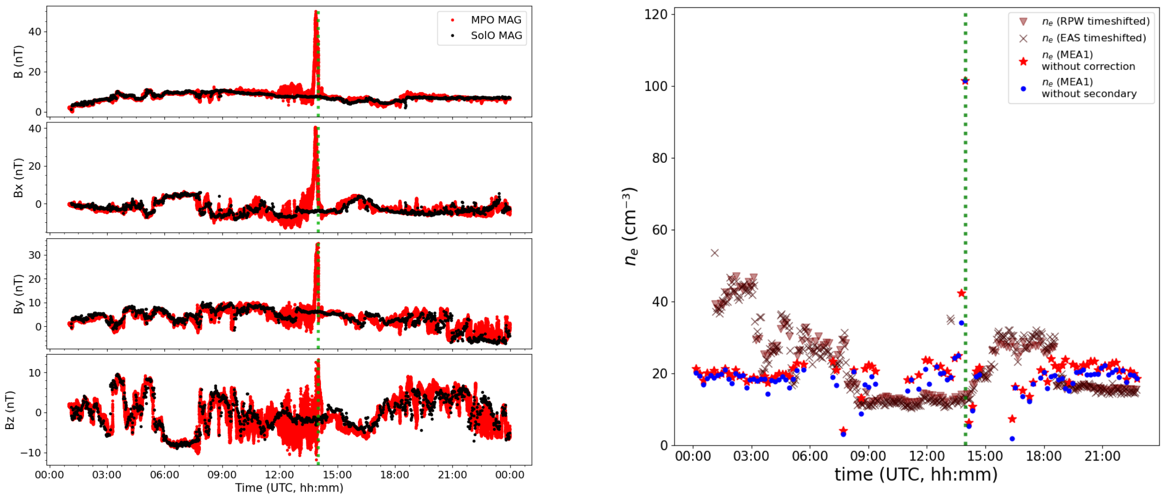

Figure 1. Comparison between BepiColombo and Solar orbiter on the 10th of August, 2021. Left panel is for magnetic field and right panel is for the electron density (Rojo et al., 2024).

In addition, preparation of the data products of MEA which will be open to public is ongoing. The instrument team has worked on the Level-2 data products, pipelines, meta-data together with the colleagues from Mio Science Center. The data will be open to public sometimes in 2025-2026 once its all settled as the project.

Periods of stay in ISEE: Jan 22 – Jan 26, 2024

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.

Rojo et al., Electron moments derived from the Mercury Electron Analyzer during the cruise phase of BepiColombo, A&A, 2024, https://doi.org/10.1051/0004-6361/202347843 (Main part of this work has been done before this project started.)

(Form02-2)

Diagnosing the Origin of Solar Energetic Particles in the Solar Corona

Nariaki Nitta (Lockheed Martin Advanced Technology Center)

Solar Energetic Particles (SEPs) observed in the heliosphere represent one of the primary space weather threats, including the health of astronauts and airline passengers and the electronics parts of satellites in various orbits. These adversary effects are caused by high particle fluxes from the so-called "gradual" (as opposed to "impulsive") SEP events, whose main acceleration agent is thought to be the shock wave driven by a fast coronal mass ejection (CME) (Reames, 1999; 2013; Desai and Giacalone, 2016). Impulsive SEP events, on the other hand, are generally attributed to magnetic reconnection that fuels solar flares and jets. The flux of energetic protons in impulsive SEP events usually do not reach the level of NOAA's radiation storms, but that of energetic electrons can be high.

Our goal is to understand the origin of energetic electrons in gradual SEP events. Are they produced in reconnection processes as in impulsive SEP events (with open field lines nearby that give them the pathway to the heliosphere)? Or are they shock-accelerated like protons? If so, as suggested in a recent study (Dresing et al., 2022) for re4lativistic electrons, do they come from the same part of the shock surface as protons, or are the shock conditions different for electrons and protons? One possibility may be that protons mostly come from the shock nose, where the shock angle is in the quasi-parallel range and protons undergo diffusive shock acceleration, and that electrons come from shock flanks, where shock drift acceleration in quasi-perpendicular geometry may be more efficient.

The methodology is to analyze remote-sensing data for eruptions that result in SEP events that have widely different behaviors of protons and electrons in terms of peak fluxes, start times and fluence spectra. We chose ~10 such events, and examined EUV, X-ray, radio and coronagraph data. Our hypothesis was that SEP events with high electron to proton (e/p) ratios may be highly correlated with strong EUV waves that may signal quasi-perpendicular shock conditions.

The PI visited ISEE in May 2023 and January 2024. Apart from giving a seminar to the ISEE solar group about topics that included this project, the PI discussed the selected events

- with Prof. Masuda (ISEE) and Dr. Watanabe (NDAJ) in relation to flare properties including hard X-ray, microwave and white-light emissions,
- with Dr. Kawate (NIFS) from the perspective of the presence of a flux rope and particle acceleration,
- with Prof. Asai (Kyoto University) in terms of observations of filament eruptions,
- with Dr. Cabezas (ISEE) concerning the characterization of the accompanying EUV waves,
- with Prof. Iwai about the possible effect of large-scale heliospheric structures on the propagation of electrons and protons.

During the May trip, the PI also attended the JpGU meeting and visited the University of Tokyo to discuss with Prof. Imada and Prof. Hoshino and their team members how to link observations with theory of acceleration of protons and electrons at shock waves with various spatial scales, emphasizing the need to model shock waves with structures.

In addition to the above scheduled sessions, the PI benefitted from discussions with scientists both in and outside ISEE (e.g., those working on Arase at ISEE and presenters at JpGU) about the magnetospheric processes relevant for electron acceleration such as whistler waves. During the January visit, the PI was encouraged to participate in a focused meeting at ISEE to discuss the BepiColombo cruise-phase science, where he developed new collaborations with the team members by making contributions to the solar origin of some of their campaign SEP events.

We are still preparing papers that investigate how the particular solar origin can be related to different behaviors of protons and electrons in SEP events. The problem is made more complex because of the issues of magnetic field connectivity between the solar source regions of SEP events and the observer, the difficulty of estimating the shock angle, and the uncertainty in modeling large-scale heliospheric structures, etc. But we plan to report a summary of our finding in a peer-reviewed journal. Good news is that the PI’s three-year proposal on a similar topic was selected by NASA, which allows him to continue the research.

(Form02-2)

Analysis of whistler-mode 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 : 2023/4/1 End date : 2024/3/31
ISEE researcher : Prof. Yoshizumi Miyoshi

This project aimed at innovative joint 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 contributes 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 pre-storm level during the recovery. The physical processes which control the dynamics of the inner magnetosphere including radiation belts and ring current have been studied for decades by different spacecraft missions. In spite of this fact, the cross-energy coupling which leads to the relativistic electron acceleration in the radiation belts, the processes that lead to depletion and loss, and dynamics of space storms is still a subject of active research.

The travel of Dr. Kolmasova and Dr. Santolik to the University of Nagoya was organized from February 24th 2024 to March 1st 2024. The ISEE International Joint Research Program funded the accommodation of the two foreign researchers on the University of Nagoya campus, on-site expenses and flight ticket of O. Santolik. Owing to insufficient funding from the program the return flight ticket of I. Kolmasova was purchased with funding from the Czech sources. 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. Jones, G.H., Snodgrass, C., Tubiana, C.,... Santolik, O.,..., et al. (2024) The Comet Interceptor Mission. Space Sci Rev 220, 9. https://doi.org/10.1007/s11214-023-01035-0
2. Němec, F., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2024). Quasiperiodic emissions: Fine structure corresponding to a bouncing wave. Geophysical Research Letters, 51, e2023GL106459. https://doi.org/10.1029/2023GL106459
3. Kletzing, C. A., Bortnik, J., Hospodarsky, G., Kurth, W. S., Santolík, O., Smitth, C.W., Christopher, I. W., Hartley, D. P., Kolmašová, I., Sen Gupta, A. (2023). The Electric and Magnetic Fields

Instrument Suite and Integrated Science (EMFISIS): Science, Data, and Usage Best Practices, Space Science Reviews, 219, 28. doi: 10.1007/s11214-023-00973-z

4. Kurth, W. S., Wilkinson, D. R., Hospodarsky, G. B., Santolík, O., Averkamp, T. F., Sulaiman, A. H., et al. (2023). Juno plasma wave observations at Europa. Geophysical Research Letters, 50, e2023GL105775. Doi:10.1029/2023GL105775
5. Fletcher, L. N., Cavalié, T., Grassi, D., (...), Santolík, O., Kolmašová, I., et al. (2023). Jupiter Science Enabled by ESA's Jupiter Icy Moons Explorer. Space Sci Rev 219, 53. https://doi.org/10.1007/s11214-023-00996-6.
6. Taubenschuss, U., Fischer, G., Píša, D., Santolík, O., Souček, J. (2023). Classification of the spectral fine structure in auroral kilometric radiation, C. K. Louis, C. M. Jackman, G. Fischer, A. H. Sulaiman, P. Zucca, Dublin Institute for Advanced Studies (Eds.), Planetary, Solar and Heliospheric Radio Emissions IX. https://doi.org/10.25546/103089.
7. Hospodarsky, G. B., Milne, A. J., Kurth, W. S., Imai, M., Kolmasová, I., Santolík, O., Connerney, J. E. P., Bolton, S. J. (2023), Jupiter Long Dispersion Lightning Whistlers that propagate through the Io torus: Juno Observations., Fischer, G., Jackman, C. M., Louis, C. K., Sulaiman, A. H., Zucca, P., Dublin Institute for Advanced Studies (Eds.), Planetary, Solar and Heliospheric Radio Emissions IX. https://doi.org/10.25546/103686
8. Sulaiman, A. H., Santolík, O., Allegrini, F., Kurth, W. S., Lysak, R. L., Elliott, S. S., Menietti, J. D., Bolton, S. J. (2023), Electron densities in Jupiter's polar regions from the identification of Ordinary-mode wave cutoffs., C. K. Louis, C. M. Jackman, G. Fischer, A. H. Sulaiman, P. Zucca, Dublin Institute for Advanced Studies (Eds.), Planetary, Solar and Heliospheric Radio Emissions IX, 2023. https://doi.org/10.25546/103098
9. Brunet, A., Dahmen, N., Katsavrias, C., Santolík, O., Bernoux, G., Pierrard, V., et al. (2023). Improving the electron radiation belt nowcast and forecast using the SafeSpace data assimilation modeling pipeline. Space Weather, 21, e2022SW003377. https://doi. org/10.1029/2022SW003377
10. Hanzelka, M., Santolík, O., Theories of Growth and Propagation of Parallel Whistler-Mode Chorus Emissions: A Review (2023), Surveys in Geophysics, https://doi.org/10.1007/s10712-023-09792-x
11. Nemec, F., Manninen, J., Santolík, O., Hospodarsky, G. B., & Kurth, W. S. (2023). Magnetospheric Line Radiation Observed Close to the Source: Properties and Propagation. Journal of Geophysical Research: Space Physics, 128, e2023JA031454. https://doi.org/10.1029/2023JA031454
12. Kolmasová, I., Santolík, O., Imai, M., Kurth, W. S., Hospodarsky, G.B., Connerney, J. E. P., Bolton S. J., Lán, R., Lightning at Jupiter pulsates with a similar rhythm as in-cloud lightning at Earth. Nat Commun 14, 2707 (2023). https://doi.org/10.1038/s41467-023-38351-6
13. Kolmasová, I., Scholten, O., Santolík, O., Hare, B. M., Zacharov, P., Lán, R., et al. (2023). A strong pulsing nature of negative intracloud dart leaders accompanied by regular trains of microsecond-scale pulses. Geophysical Research Letters, 50, e2023GL103864. https://doi.org/10.1029/2023GL103864
14. Hartley, D. P., Christopher, I. W., Kletzing, C. A., Kurth, W. S., Santolik, O., Kolmasova, I., et al. (2023). Chorus wave properties from Van Allen Probes: Quantifying the impact of the sheath corrected electric field. Geophysical Research Letters, 50, e2023GL102922. https://doi.org/10.1029/2023GL102922

(Form 2-2)

Influence of Large-scale Interplanetary Coronal Mass Ejections (ICMEs) Structures on the Propagation of Solar Energetic Particles (SEPs)

Beatriz Sanchez-Cano (University of Leicester, United Kingdom)

In the new era of planetary and heliophysics missions transiting the very inner heliosphere, such as BepiColombo, Solar Orbiter, or Parker Solar Probe, a new and unique opportunity to perform combined multi-point observations of the interplanetary medium is presented. This is of the particular interest when combined with other assets at larger distances, such as at 1 AU (i.e. Earth, STEREO-A), or even at further distances such as Mars (~1.52 AU) or even Jupiter (5.2. AU). We know that interplanetary coronal mass ejections (ICME) are known to drive strong dynamics in the solar wind and have an effect on the propagation of Solar Energetic Particle (SEP) events as they modify the magnetic connectivity of the solar wind. Recent observations from BepiColombo, STEREO-A, and Solar Orbiter of an ICME-SEP event in October 2021 by Lario et al., (2022) have shown that although these spacecraft were connected to the same region of the Sun, their connectivity at further distances (between 0.33 AU and 1 AU) was rather different as particles were trapped between a stream interaction region (SIR) and the ICME-driven shock. This configuration allowed movement of SEP particles in directions not previously expected or considered on solar wind models, such as SUSANOO.

The 2023 ISEE International Joint Research Program visit took place from January 22 until January 26 2024, together with the international workshop “Study of interplanetary coronal mass ejections propagation in the inner heliosphere combining MHD modeling, ground based observations, and in-situ multi-spacecraft data” at ISEE, in Nagoya, Japan. The discussions during this meeting as well as the workshop were a great success with 22 participants between online and in-person participants from well-known institutes across different countries: South West Reasearch Insitute/USA, Lockheed Martin Solar and Astrophysics Laboratory/USA, University of Helsinki/Finland, University of Turku/Finland, European Space Agency/Spain, Space Physics Institute/Austria, Laboratory of Plasma Physics/France, Laboratory of Astrophysics, Bordeaux/France, University of Leicester/UK, University of Tokyo/Japan, University of Nagoya

ISEE/Japan and ISAS/JAXA/Japan.

During this time, we discussed and work together on both numerical simulations and data analysis to investigate the characteristics of the solar wind propagating from the Sun and how solar transients (i.e.. ICMEs, SIRs) affect the propagation of SEPs, such as in the particular case of 12 March 2022 and 28 March-2 April 2022 events. We discussed data from several instruments onboard BepiColombo, Solar Orbiter, Parker Solar Probe, STEREO, Earth-based satellites, Hinode, Arase, and Akatsuki, as well as from the IPS (ISEE) technique, and solar wind simulations from the SUSANOO model. A paper covering this results is being prepares as a result, which will be part of the planned special issue product of the workshop.

(Form02-2)

Unique observations of ELF-VLF waves at OUJ, KAN, and other PWING locations

Jyrki Manninen (SGO, University of Oulu, Finland)

Periods of stay in ISEE

Adj. Prof. Jyrki Manninen (SGO, University of Oulu) 4 October – 2 November 2023

Assoc. Prof. Frantisek Nemec (Charles University, Prague, Czechia) 12 – 20 October 2023

Purpose of the visit

We proposed to use available ground-based data obtained by OUJ, KAN, and other PWING stations to determine the spatiotemporal variability of measured electromagnetic waves and to understand better their propagation from the source region down to the ground. We focused particularly on not yet well-understood emission types (e.g., quasiperiodic emissions, magnetospheric line radiation). Due to the current unfortunate war situation in Europe, we cannot have access to IST and MAM data after 2021. Because of this, we selected the year 2020 for detailed investigation and are using data from the PWING stations of ATH, GAK, IST, KAP, and MAM. In addition, while OUJ started operation just in October 2022, only the station pair KAN-OUJ can be used for studying latitudinal propagation, and thus this station pair data will be analyzed from October 2022 to September 2023 as well.

Science Questions planned to be solved

1) *What are the characteristic longitudinal scales of the analyzed emission types?*
   Event listings and identification of relevant events from receivers at ATH, GAK, IST, KAP, and MAM were started during the visit to ISEE. The KAN listing was available slightly earlier.
2) *What are the respective ionospheric exit points and anticipated source L-shells?*
   This work will be done after 1) is completed.
3) *What similarities and differences are observed in latitudinal observations (KAN-OUJ)?*
   Several events with similarities as well as differences have been found. Detailed analysis is in process.

Methodology

Two different approaches are used: i) Global correlation of the wave activity as observed by individual ground-based stations, and ii) Identification and detailed analysis of selected wave events of particular interest. In the first approach, correlations of the wave intensity measured by individual stations in selected frequency bands will be analyzed as a function of their spatial separation (L-shell and geomagnetic longitude differences) and relevant magnetospheric conditions (magnetic local time, geomagnetic activity characterized by Kp/AE geomagnetic indices). We will determine characteristic correlation lengths of the emissions at different frequencies and investigate how these vary as a function of geomagnetic activity (and empirical model plasmapause location).

In the second approach, significant wave events will be identified and subjected to further analysis. The event identification will strongly benefit from formerly prepared event lists, which will be further extended within this project frame. For each of the events, a detailed frequency-time structure will be investigated to confirm that the stations indeed observe the same event. Directions of the wave arrival at individual stations will then be determined, allowing us to estimate the locations of ionospheric exit points. Backward raytracing analysis, started from the respective locations will be performed to determine source locations and dimensions of the respective wave sources.

Presentations & Publications

The results obtained were presented in two contributions at the American Geophysical Union (AGU) 2023 Annual Meeting (11-15 December 2023):

C. Martinez-Calderon, J. Manninen, K. Shiokawa, M. Ozaki, D. Pisa, V. Vuolteenaho: Latitudinal propagation of VLF emissions from multi-point observations in Finland: First results from the Oulujärvi ground station

F. Nemec, K. Drastichova, J. Manninen, C. Martinez-Calderon, K. Shiokawa: Properties and characteristic scales of whistler-mode waves as observed by ground-based VLF stations and a low-altitude spacecraft

Two manuscripts are under preparation.

The influence of Indian Ocean Dipole on sea surface temperature and sea surface chlorophyll-a variations in the Andaman Sea based on satellite imageries

Anukul Buranapratheprat (Burapha University)

Purposes:

The Andaman Sea is a marginal sea, located in the northeastern part of the Indian Ocean. It is bordered by the coasts of Myanmar, Thailand, and Malaysia in the east. It is connected to the Bay of Bengal and the Indian Ocean through the straits of the Andaman and Nicobar Islands, respectively. The northeast (November to February) and the southwest monsoons (May to October) are the main environmental drivers over this region creating the variability of the marine ecosystem. The Indian Ocean Dipole (IOD) is a large-scale phenomenon developed in the Indian Ocean. This phenomenon changes in ocean and climate conditions in the Bay of Bengal, Arabian Sea and Andaman Sea. The positive phase/negative of IOD causes stronger/weaker upwelling, lower/warmer sea surface temperatures (SST) and less/high precipitation in the eastern Indian Ocean. However, the impact of IOD on marine ecosystems and SST in the Andaman Sea has rarely been investigated. This study aims to explore spatial and temporal variations of SST and surface chlorophyll-a (Chl-a) driven by monsoons and the IOD.

Methods:

Satellite-derived chl-a and SST data from the MODIS-Aqua Level 3 monthly product from 2003 to 2022 were used in the analysis. The missing data was filled in by Data INterpolating Empirical Orthogonal Functions (DINEOF) method. The Empirical Orthogonal Function (EOF) was used to analyze the patterns of Chl-a variability. The monthly mean data in each pixel was removed before applying EOF analysis. This technique leads to capturing in dominant mode of interannual time scale in both spatial pattern and corresponding temporal pattern.

Results:

The first and second mode contains 20% and 8% of total variances, respectively. The first mode shows the difference of two anomalies between northern and southern Andaman Sea with higher and lower than normal (Figure 1a). The second mode indicates lower SST near Malacca straits and northern part (Above 12^{o} N) and higher in middle of Andaman Sea (Figure 1b). These two modes show the interannual variation over the time scale (Figure 1c, 1d). The first principal component shows less correlation with IOD but a more similar pattern with El Niño-Southern Oscillation (ENSO) that create colder SST and warmer SST in the southern and northern area, respectively. Meanwhile, the second principal component shows the same peak as the IOD. Positive/negative IOD leads to lower/higher SST near Sumatran and Malacca Strait.

For surface Chl-a, the first mode contains 12% of total variances (Figure 1). This highlights Chl-a variability in the southern Andaman Sea, Malacca strait, northern Sumatra, and western Nicobar Islands with peaks during the positive IOD (2006, 2008, 2012, 2016 and 2019) and troughs in the negative IOD (2011 and 2017). Chl-a in the northwest Andaman Sea shows negative/positive anomaly during positive/negative IOD events. Surface Chl-a in this area can be separated by two responses under the same event.

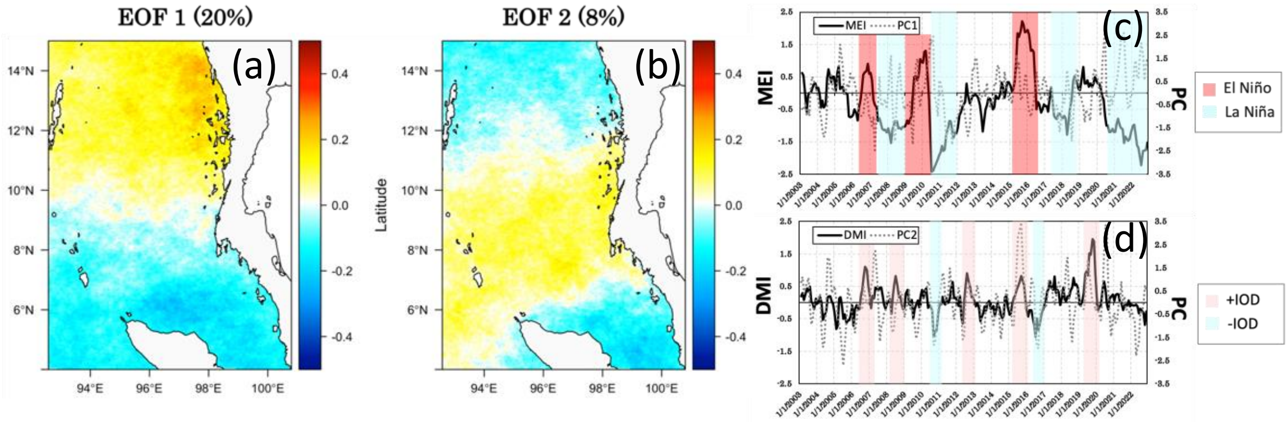

Figure 1 The first (a) and second (b) mode of EOF and principal component time series (c,d) of SST in the Andaman Sea after removing the monthly mean signal.

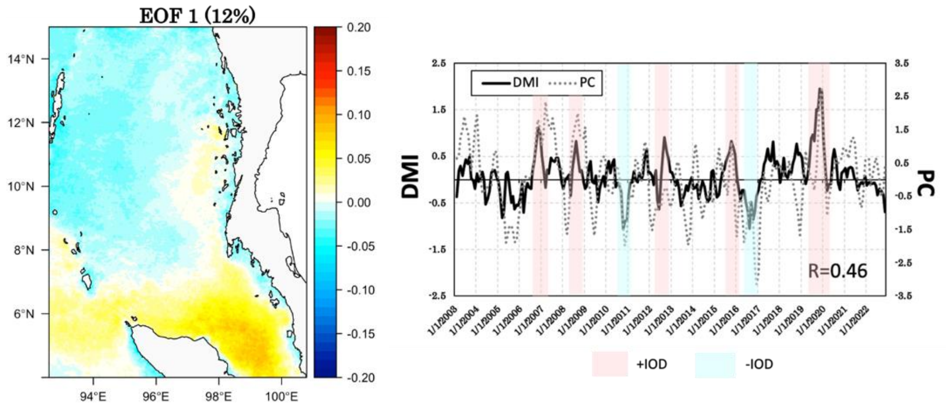

Figure 2 The first mode of EOF (left) and principal component time series (right) of surface chl-a in the Andaman Sea after removing the monthly mean signal.

In summary, the impact of the IOD is generally stronger in the southern part of the Andaman Sea. A positive/negative IOD may create stronger/weaker upwelling near the north of Sumatra and the Malacca Strait, inducing nutrients from the deep layer and supporting phytoplankton growth in the southern part of the Andaman Sea.

Periods of stay in ISEE: 16 – 26 December 2023

Presentation: Leenawarat, D., Buranapratheprat, A., Ishizaka, J., Intacharoen, P., Luang-on, J.& Tongudom, S., Spatial and Temporal Variations of Surface Chlorophyll-a in the Andaman Sea: Monsoons and Indian Ocean Dipole Influence. *In 11th AWOC / 20th KJWOC / 6th ISEE Symposium, Nagoya, Japan, 17 – 19 December 2023*.

List of publications: The paper is in preparation.