ISEE Symposium

Frontier of Space-Earth Environmental Research as Predictive Science

Abstract Booklet

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Status and Possibilities of Space-Earth Environmental Research as Predictive Science

Kanya Kusano

The space-earth environment is a complex nonlinear system that impacts our lives and society. Predicting its variability and dynamics is a highly advanced scientific challenge and a social requirement. In this presentation, I will provide an overview of the current status and potential of space-earth environmental research as a predictive science, focusing on space weather and space climate.

Presentation type: Keynote

Flare simulations with the MURaM radiative MHD code

M. Rempel, G. Chintzoglou, M.C.M. Cheung, Y. Fan, A. Malanushenko, L. Kleint &
MUSE and CMEx science teams

Over the past few years, the MURaM radiative MHD code was expanded for its capability to simulate the coupled solar atmosphere from the upper convection zone into the lower solar corona. The code includes the essential physics to synthesize thermal emission ranging from the visible spectrum in the photosphere to EUV and soft X-ray from transition region and corona. A more sophisticated treatment of the chromosphere has been recently implemented. After a brief review of the code's capabilities and limitations, I present a few recent examples of solar flare simulations computed with the MURaM code. Specifically, I present data inspired simulations that do capture a scenario that has been proven to be flare productive in solar observations: compact collisional polarity inversion lines (cPILs) that result from the collision of sunspots. We conduct two studies: (1) A simplified bipolar setup with colliding sunspots that allows us to study the effect of speed, distance and sunspot coherence during collision on the energy built up and resulting flares; (2) A quadrupolar setup that mimics AR 11158.

Presentation type: Invited

Supercomputing for Climate Extremes: Global Storm-Resolving Models and Advanced Satellite Observations

Masaki Satoh

We have been promoting the development of a global atmospheric model with a horizontal grid size of approximately one kilometer or less. These models, known as global storm-resolving models (GSRMs), realistically simulate extreme precipitation and winds associated with tropical and extratropical cyclones as well as mesoscale convective systems. With increasing computational resources, GSRMs are now capable of running longer simulations on decadal scales, enabling the representation of climate aspects of extreme weather events.

Cloud and precipitation processes are central to GSRMs, and their accurate modeling is crucial to the performance of these models. Advanced satellite missions, such as the Global Precipitation Measurement (GPM) and EarthCARE, provide high-resolution observational datasets on clouds and precipitation, offering valuable opportunities for the validation and refinement of GSRMs. The synergistic integration of GSRMs with advanced Earth observations enhances the credibility of climate extreme simulations.

This presentation offers an overview of progress in GSRM research and simulations conducted by our group using the supercomputers K and Fugaku. It highlights key achievements and explores future directions for further enhancing high-resolution modeling.

Presentation type: Invited

Numerical modeling of the Earth and planetary dynamos for the understanding of the interior dynamics and prediction of magnetic secular variation

Futoshi Takahashi

In general, the planetary magnetic fields are generated and maintained by dynamo action operating in their electrically conducting fluid outer core. Thus, the dynamo-generated magnetic field and its secular variation reflect many dynamical aspects of the deep interiors and thermal history of the planets, which we want to understand to predict future magnetic field behavior. For this purpose, we have taken an approach using numerical modeling of the core dynamo. In the last two decades, numerical dynamo modelling has shown great progress. At present, dynamo modeling is a very powerful tool to understand the dynamo action and dynamics in the planetary core, as well as in-situ observation of the magnetic field. In terms of prediction, 5-year scale forecast of geomagnetic secular variation contributing to IGRF is available based on dynamo modeling and data assimilation. In this talk, we summarize such efforts showing our results of geo- and planetary dynamo simulations.

Presentation type: Invited

Super-high-resolution global MHD simulations of the Earth's magnetosphere for the GEO-X and SMILE missions

Yosuke Matsumoto, Ryota Momose, Yoshizumi Miyoshi

This invited presentation will focus on the numerical modeling of the Earth's magnetosphere and its interaction with the solar wind, focusing on the solar wind charge exchange (SWCX) process. We examined high-resolution global MHD simulations of the magnetosphere and studied associated X-ray emissions through SWCX on the day side and night side of the magnetosphere. Within the simulation data, virtual satellite observations revealed intensive X-ray emissions near the dayside magnetopause. With the high-resolution data and a synthesized X-ray map, we discern the topology of the dayside reconnection region, enabling us to estimate the reconnection rate from a geometrical perspective. We further examined the nightside flow-breaking region. With the space-resolved simulation data, we propose that the X-ray emission can be a proxy for revealing how the fast reconnection jet is injected into the near-Earth magnetosphere. Implications of the present study to future missions, such as GEO-X and SMILE, will be discussed.

Presentation type: Invited

Magnetic flux emergence simulations with the radiative MHD code R2D2: Status and the way to predictions

Shin Toriumi, Hideyuki Hotta, Kanya Kusano

Active regions and sunspots, which sometimes produce massive eruptions, are formed as a consequence of magnetic flux emergence from the deep solar convection zone. To this end, we have performed a series of flux emergence simulations using the radiative magnetohydrodynamics code R2D2, which allows us to study the close interplay between deep, large-scale convection and rising magnetic flux systems in a single computational box. This presentation will summarize how large-scale turbulence perverts the magnetic flux, produces complexly shaped active regions, and supplies magnetic helicity and magnetic energy to the upper atmospheres, with an emphasis on the future flux emergence/flare predictions.

Presentation type: Oral

Multi-scale nature of magnetic reconnection by multi-hierarchy simulation

Keita Akutagawa, Shinsuke Imada, Munehito Shoda

Magnetic reconnection is a fundamental process that converts magnetic energy into plasma energy by changing the magnetic field line topology. Magnetic reconnection has multi-scale nature, that is kinetic-scale and fluid-scale interacts. It is important to consider multi-scale nature when a phenomenon is fluid-scale but a current sheet is in collisionless regime, like solar flares. Plasmoid-mediated model is one scenario of connecting different scales, however whether it is applicable or not in collisionless system is unknown. Kinetic simulation cannot treat whole system of solar flare because of the computational costs. Multi-hierarchy simulation is one possible solution to overcome this difficulty. In this scheme, almost all of the system is treated by MHD and small but important region is treated by PIC.

We developed multi-hierarchy simulation code from scratch and named it ”KAMMUY”. Our code is written in CUDA C++ & MPI for multi-GPUs acceleration. We carried out some simulations by changing the current sheet length and thickness. We found that kinetic effect was appeared around X point and fluid-like structure was appeared far from the X point(over 100 ion inertial length). We will show the above results and discuss the limits of multi-hierarchy simulation approach.

Presentation type: Oral

A Ten-year Project Tropical cyclones-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts (T-PARCII)

Kazuhisa Tsuboki

The T-PARCII (Tropical cyclone-Pacific Asian Research Campaign for Improvement of Intensity estimations/forecasts) project has been conducted for 2016-2021 as the first phase and 2021-2026 as the second phase. The objectives of T-PARCII are improvements of intensity estimations and predictions of the tropical cyclones (TCs) in the western North Pacific. By the end of 2024, T-PARCII made successfully dropsonde observations of typhoon Lan in October 2017, Trami in September 2018, Mindulle in September 2021, Nanmadol in September 2022, Barijat in October 2024, and an atmospheric river associated with typhoon Aere in July 2022. In the presentation, the activity of T-PARCII will be introduced and some results of the aircraft observations will be summarized. In particular, the supertyphoon Lan and Nanmadol will be focused on. The two-day observations of Nanmadol showed a rapid increase in wind speed more than 15 m/s within 20 h in the deep layer up to 300 hPa. This is a rapid intensification in the deep layer, which is the main objective of the second phase. An assimilation of dropsonde data observed at the center of the eye significantly improved the simulation of thermodynamic structure of the warm core and intensity forecasts.

Presentation type: Invited

The mathematical framework for forecasting complex evolutions of volcanic eruptions

Takehiro Koyaguchi,Kyle R. Anderson, Tomofumi Kozono

Volcanic eruptions are influenced by various physical processes of multiphase flow, and their dependence on geological conditions is highly non-linear. As a result, sequences of volcanic eruptions are extremely complex. The mathematical framework of data assimilation to forecast complex eruption sequences was investigated using a numerical model of the chamber-conduit system. The model applies a quasi-steady approximation and an analytical steady solution of the conduit-flow model. Through the quasi-steady approximation, the model is reduced to a 2-variables ordinary differential equation that extracts the mathematical essence causing the complex eruption sequences. Furthermore, the analytical steady solution of the conduit-flow model explicitly expresses how the simulation results depend on model parameters related to geological conditions. Forecasting an eruption sequence including the timing of its end is accomplished by solving an inversion problem to estimate the model parameters from time-varying geophysical observations during the earlier stage of the eruption (i.e., data assimilation). We have clarified how the model parameters in the highly non-linear dynamical system are constrained in the inversion problem by individual observations. The results suggest that simultaneous multiple observations of eruption column heights and ground deformation is indispensable for forecasting eruption sequences using data assimilation.

Presentation type: Invited

Integrating Fundamental Science and Space Weather Applications

T. G. Onsager

The recognition of space weather as a significant natural hazard continues to increase worldwide. Accurate and timely space weather information is now needed for a growing number of industry and government applications. This requires progress in both our fundamental understanding of the space environment and the development of timely and accurate services. An outline for improving space environment prediction over the next decade (2024-2033) was recently released by the U.S. National Academies of Sciences, Engineering, and Medicine. This presentation will summarize the recommendations made in this plan, including the integration of research and applications-oriented activities in the U.S. and internationally.

Presentation type: Invited

Toward Establishing the Global Space Weather Warning System

Mamoru Ishii

The Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and its Scientific and Technical Subcommittee (STSC) published a report to improve international coordination for space weather services on 2022, and invited the World Meteorology Organization (WMO), International Space Environment Services (ISES) and Committee on Space Research (COSPAR) to lead efforts to improvec the global coordination with other activities in consultation and collaboration with other relevant actors and international organizations. As a first step of this action, the International Space Weather Coordination Forum (ISWCF) was held in WMO headquarter, Geneve on Nov. 17, 2023 and mainly discuss (1)coordination of space based observation, (2)coordination of ground based observation and (3) User engagements. Establishing the Global Space Weather Warning System is one of the candidates of pilot projects discussed in ISWCF. It is essential to build the global framework and it has been discussed for long time. The establishment of ISWCF makes the way for realization of global warning system more clear. As a first trial, now we prepare to build a global comprehensive ionosonde group named GION (Global Ionosonde Observation/Operation Network). We will discuss data sharing and cooperative project in this framework.

Presentation type: Invited

The Role of Small-Scale Magnetic Reconnections in Triggering the X1.3 Flare in NOAA AR 13777

Eun-Kyung Lim, Donguk Song, Kanya Kusano, Vasyl Yurchyshyn, Masahito Kubo, Ryohtaro Ishikawa, Kyoung-Sun Lee

We investigate the triggering mechanism of the X1.3-class solar flare in NOAA active region (AR) 13777 by analyzing pre-flare activities using observations from SDO/HMI, AIA, ground-based GONG H α, and high-resolution imaging spectroscopy from FISS/GST. The flare occurred near the leading sunspot, where an arc-shaped filament was anchored with one footpoint inside the sunspot and the other at remote eastern site. Detailed analysis of both space-based and ground-based data reveals that small-scale flux emergence and cancellations at the remote site, approximately an hour before the flare onset, played a pivotal role in altering the filament's magnetic topology. This led to filament-filament reconnection, dynamic filament plasma motion, and eventual eruption. The magnetic topology of the filament was conductive to the double-arc instability, and kappa-scheme analysis further supported the prediction of the X-class flare. Our findings align with the established view that small-scale flux emergence and cancellation are key triggers of flares. Moreover, we emphasize that the location of such flux emergence is critical in determining whether a flare is triggered.

Presentation type: Oral

How does global warming regulates space weather impacts on the thermosphere and ionosphere

Huixin Liu, C. Tao, H. Jin

Geomagnetic storm impacts on the thermosphere/ionosphere (T/I) dominantly determine the satellite drag and communication environment, thus how the T/I respond to solar and magnetosphere forcing is at the heart of space weather applications. On the other hand, increasing CO2 in the atmosphere leads to long-term changes of the background thermosphere/ionosphere. This raises the question on how increasing CO2 would affect space weather impacts on the thermosphere/ionosphere? With the T/I cools and contracts towards the future, will a storm have the same impacts on the T/I as they do today? We examined these questions using the GAIA whole atmosphere model. The simulation results reveal a strengthening of the storm impacts on the T/I, with larger disturbance in the thermosphere density and ionosphere plasma. In addtion, an interdependency was found to exist between the efficiency of CO2 and geomagnetic activity (GA) forcing, with the former enhances at lower GA levels while the latter enhances at higher CO2 concentration. This implies that the CO2-driven changes would accelerate in periods of declining geomagnetic activity, while effects of geomagnetic storms will become larger with increasing CO2 in the future. These effects are closely related to circulation and tidal changes in the thermosphere (Liu et al. 2020). These model experiments provide a preliminary framework to understand interactions between meteorological forcing from from below and the geomagnetic forcing from above.

Presentation type: Oral

Digitizing the Continuous Magnetic Recordings from London UK for the 1859 'Carrington' Storm

Ciaran Beggan and Hisashi Hayakawa

Dedicated scientific measurements of the strength and direction of the Earth's magnetic field began at Greenwich and Kew observatories in London, United Kingdom, in the middle of the nineteenth century. Using advanced techniques for the time, collimated light was focussed onto mirrors mounted on free-swinging magnetized needles which reflected onto photographic paper, allowing continuous analog magnetograms to be recorded. By good fortune, both observatories were in full operation during the so-called Carrington storm in early September 1859 and its precursor storm in late August 1859. Based on digital images of the magnetograms and information from the observatory yearbooks and scientific papers, it is possible to scale the measurements to International System of Units (SI units) and extract quasi-minute cadence spot values. However, due to the magnitude of the storms, the periods of the greatest magnetic field variation were lost as the traces moved off-page. The digitized magnetic records to date of the 10-day period from 25 August to 5 September 1859 encompassing the Carrington storm and its lesser recognized precursor on 28 August are shown and their implications for the impact on modern technology are discussed.

Presentation type: Invited

Relationship between climate and solar activity suggested by Dome Fuji ice cores and RIKEN AGDF Project

Yuko Motizuki

Dome Fuji (Antarctica) ice cores show an apparent relationship between climate and solar irradiation. After reviewing the preceding work on a long-time scale range with a rough temporal resolution, we present our annually-resolved temperature reconstruction for the past 2,000 years using a well-established temperature proxy, delta-18O, of the ice core. We found a clear periodicity of ~10 years and ~20 years in the delta-18O time series data for the "pre-industrial" period of 1750 – 1940 CE, which overlapped the sunspot number observations by the telescope. We recently found that solar activity proxies, including 14C, 10Be, and the Dome Fuji nitrate ion concentrations, have a pink noise, which may be inherited from the solar five-minute oscillations and sunspot 11-year cycles. We will then further discuss the origin of the ~10-year and the ~20-year periodicity found in the temperature proxy through pink noise analysis and the cross-correlation with the sunspot number variations. Finally, we will mention our AGDF (Astro-Glaciology Data Factory) project to investigate a million-scale temperature history and the solar activity of the past.

Presentation type: Invited

Paleo-Space-Weather inferred from cosmogenic radionuclides in ice cores

Raimund Muscheler

High-energy galactic and solar cosmic rays leave their imprint in ice cores and tree rings through the atmospheric production and subsequent deposition of cosmogenic radionuclides. This allows us to infer past solar activity (through solar modulation of galactic cosmic rays) and solar storms (through the direct effect of high-energy solar particles on the radionuclide production rates). Combining 10Be and 36Cl records from different ice cores and 14C data from tree rings allows us to extract the production rate signal and reduce problematic effects such as time scale uncertainties, atmospheric transport and deposition effects on 10Be and 36Cl, and carbon cycle influences on 14C. Furthermore, the different atmospheric production rate sensitivities of 36Cl versus 10Be and 14C to solar energetic particles provides information on the energy distribution of the incoming solar particles. Nevertheless, so far none of the known solar storms of the instrumental period has been reliably identified in the indirect radionuclide data. In this presentation I will discuss the current status of paleo solar storm identification and characterization und ways forward for pushing the limits of solar storm detection with the rather indirect cosmogenic radionuclide data from natural archives.

Presentation type: Invited

Cosmogenic isotopes as a tool to explore solar cycle dependence of extreme space weather

Hiroko Miyahara, Fuyuki Tokanai, Toru Moriya, Mirei Takeyama, Ryuho Kataoka, Kazuaki Yamamoto, Motonari Ohyama, Kazuho Horiuchi, Hideyuki Hotta, Hongyang Xu, Limin Zhou, Hiroyuki Matsuzaki

Cosmic-ray induced isotopes, such as carbon-14 and beryllium-10 stored in natural archives, serve as indices of past solar activity and are used for the reconstruction of solar activity at various timescales. In this talk, we will present our recent progress in improving the precision of carbon-14 analysis and the detailed reconstruction of 11-year solar cycles. These advancements enable the reconstruction of 11-year solar cycles with high precision, facilitating the analysis of the solar cycle dependence of past extreme solar proton and geomagnetic storm events. High-precision analyses also make it possible to detect relatively small-scale extreme solar proton events, enhancing the number of events available to investigate their characteristics. In this talk, we also introduce our newly developed methodology for reconstructing past solar activity using carbonate deposits, known as travertine.

Presentation type: Invited

Model for the recurrence of Grand Minima based on stochastic resonance

Carlo Albert, Antonio Ferriz-Mas, Filippo Gaia, Simone Ulzega

The amplitude of the 11-year solar cycle is well-known to be subject to long-term modulation, including sustained periods of very low activity known as Grand Minima. Stable long-period cycles found in proxies of solar activity have renewed the debate about a possible influence of the planetary tidal forcing. We present a model supporting the idea that the weak tidal effect of the planets on the Sun could be amplified by stochastic resonance up to a level that it can affect the long-term magnetic activity. We use a simple dynamo model, which includes a delay caused by meridional circulation as well as a quenching of the α-effect at toroidal magnetic fields exceeding an upper threshold.

The idea of "stochastic resonance" goes back to Benzi et al. 1981 and 1982, who suggested that it may be the mechanism responsible for the amplification of the weak radiative forcing owing to the variation of Earth's orbital parameters and it might thus explain the alternance of glacial and interglacial periods in the Quaternary.

Presentation type: Oral

Some Aspects of Predictions with Noise and Delay

Toru Ohira

In many systems, the presence of ”noise” and delays in interactions or feedback often complicates their behavior, making predictions more challenging. Mathematically, such systems are analyzed using methods from probability theory and nonlinear dynamics. While this analysis is difficult, our understanding has gradually progressed. Moreover, recent studies suggest that these two ”villainous” factors, noise and delay, may actually play beneficial roles, such as in signal processing in nature. In this presentation, I aim to illustrate both the negative aspects of the challenges noise and delay pose to prediction, as well as their potential positive contributions, through specific examples.

Presentation type: Invited

Prediction Science: the fifth science integrating inductive and deductive sciences

Takemasa Miyoshi

Data assimilation (DA) brings together the model and data for better estimation, prediction, and control of large-scale, complex systems. DA plays a key role in numerical weather prediction (NWP) and has been extended to other problems such as the ocean, ecosystem, and planetary atmospheres. The model is based on theory and computation and is a process-driven, deductive approach. As for data, recent technological advances enabled Big Data beyond direct human manipulation, so that advanced statistical methods based on computation are effective, leading to rapid advances of data-driven, inductive approaches such as artificial intelligence (AI) and machine learning (ML). Although DA has evolved to be as powerful, the idea of bringing together the inductive and deductive approaches would be more general. We proposed the Prediction Science as the fifth science to develop the general theory and methods for estimation, prediction and control of large-scale, complex systems by integrating the (1) experimental science, (2) theoretical science, (3) computational science and (4) data-centric science, where (1) and (4) are data-driven and (2) and (3) are process-driven. RIKEN started a pioneering project "Prediction for Science" for 5 years in 2020 and expanded to be RIKEN Prediction Science under the TRIP (Transformative Research Innovation Platform of RIKEN platforms) in 2024. This presentation will summarize RIKEN's activities on Prediction Science.

Presentation type: Invited

Modelling of the magnetosphere-ionosphere system with reservoir computing

S. Nakano, R. Kataoka, S. Reddy, A. Nakamizo, and S. Fujita

Reservoir computing is an approach for modelling time series patterns using a dissipative system called reservoir. Our recent studies applied the reservoir computing for representing the dynamics of the magnetosphere and ionosphere, and revealed that it is useful for analyse the response of the magnetosphere-ionosphere system to the solar wind. For example, the occurrence frequency of substorm onsets is successfully modelled with the echo state network, which is one of recurrent neural networks for reservoir computing. We also employ the echo state network for developing an emulator of a global MHD model of the magnetosphere-ionosphere system, REPPU, and represent the response of the polar ionosphere to the solar wind input. The computational efficiency of the reservoir computing allows us to incorporate the various observations into the emulator. Assimilating the ground-based radar observation data into the emulator with the ensemble transform Kalman filter, we can analyse temporal variations of the ionospheric environment which was difficult to predict especially during substorms.

Presentation type: Invited

Implementation of a physics-based flare prediction model κ-scheme to operational space weather forecasting in NICT

Yumi Bamba, Daikou Shiota, Kanya Kusano

It is still difficult to alert the incidence of a large flare in advance, although we at NICT forecast the largest magnitude of solar flares for the following 24 hours. We are thus working on the development of a flare-alert system that predicts and alerts a large flare at least several hours prior to its onset. Our flare-alert system is based on a physics-based flare prediction method, which was proposed by Kusano et al. 2020 and is named ”kappa-scheme”. We adjusted parameters in the kappa-scheme for space weather operation and automated the codes of the scheme. The kappa-scheme was partially used in NICT space weather forecast from April 2024 and was fully implemented from the end of October 2024. We have already succeeded in forecasting some X-class flares by utilizing the kappa-scheme. In the presentation, we report how the kappa-scheme works well in NICT space weather forecasting and the progress of the flare-alert system development in NICT.

Presentation type: Oral

An Explainable AI by discovery science and machine learning -"Wide Learning" technology and its applications-

Tatsuya Asai

AI such as machine learning is widely used in business and data science. Deep learning, one of the most well-known machine learning methods, is highly black-box, making it difficult for humans to understand the reason of its predictions and judgments. There has been a rise in research into explainable AI (XAI), which can provide the reason for machine learning output results and support humans for their decision-making. In this talk, we will introduce "Wide Learning" technology, which is an explainable AI developed by combining discovery science and machine learning. By using Wide Learning, we can expect to discover new hypotheses based on the process of scientific discovery, going beyond the framework of prediction and classification that conventional machine learning has performed. In addition, we will also talk on several use cases of applying Wide Learning to business, social issues, and scientific researches.

Presentation type: Invited

Statistical Characteristics of Whistler Mode Chorus Waves Based On Observations from Van Allen Probes and ARASE Satellite

Dedong Wang, Alwin Roy, Yuri Y. Shprits, Ting Feng, Thea Lepage, Ingo Michaelis, Ondrej Santolik, Geoffrey Reeves, Jay Albert, Yoshizumi Miyoshi, Yoshiya Kasahara, Mariko Teramoto, Atsushi Kumamoto, Shoya Matsuda, Ayako Matsuoka, Kazuhiro Yamamoto, Iku Shinohara, Fuminori Tsuchiya

Chorus waves play an important role in the dynamic evolution of energetic electrons in the Earth's radiation belts and ring current. Due to the orbit limitation of Van Allen Probes, our previous chorus wave model developed using Van Allen Probe data is limited to low latitude. In this study, we extend the chorus wave model to higher latitudes by combining measurements from the Van Allen Probes and Arase satellite. As a first step, we intercalibrate chorus wave measurements by comparing statistical features of chorus wave observations from Van Allen Probes and Arase missions. We first investigate the measurements in the same latitude range during the two years of overlap between the Van Allen Probe data and the Arase data. We find that the statistical intensity of chorus waves from Van Allen Probes is stronger than those from Arase observations. After the intercalibration, we combine the chorus wave measurements from the two satellite missions and develop an analytical chorus wave model which covers all magnetic local time and extends to higher latitudes. This chorus wave model will be further used in radiation belt and ring current simulations.

Presentation type: Invited

Technique for Extracting the Total Magnetic Helicity of CMEs

Nada Al-Haddad & Mitchell Berger

Coronal mass ejections (CMEs) are magnetized plasma systems with highly complex magnetic topology and evolution. Methods developed to assess their magnetic configuration have primarily focused on reconstructing three-dimensional representations from one-dimensional time series measurements taken in situ using techniques based on the ”highly twisted magnetic flux rope” approximations. However, the magnetic fields of CMEs is know to have more complicated geometries. Their structure can be quantified using measures of field line topology, which have been primarily used for solar physics research. In this work, we describe techniques for quantifying the complexity of the magnetic field geometry within a CME in interplanetary space. We use a relatively simple three-dimensional simulation of a CME initiated with a highly-twisted flux rope. We find that a significant portion of the magnetic helicity near 1AU is contained in writhe and mutual helicity rather than just in twist. We discuss the implications of this finding for fitting and reconstruction techniques.

Presentation type: Oral

20th anniversary of the super-droplet method

Shin-ichiro Shima

The super-droplet method (SDM) is a Lagrangian particle-based numerical algorithm designed to model cloud microphysics and its coupling with cloud dynamics. It was 2005 when I joined Prof. Kusano's group at the Earth Simulator Center, JAMSTEC. With an eye on the future of supercomputers, we worked on creating novel numerical algorithms for multiscale-multiphysics phenomena. SDM was one of the significant outcomes of our efforts.

In Shima, Kusano, et al. (2009), we discussed the general framework of SDM and key algorithms required for its numerical implementation. Instead of applying Eulerian mixing ratios for various predefined cloud condensate and precipitation categories (cloud water, rain, cloud ice, snow, graupel, hail), SDM applies point particles, referred to as super-droplets or super-particles, to represent the enormous number of aerosol, cloud, and precipitation particles present inside the simulated domain of a cloud model. The super-particles are traced in physical space using the model-predicted flow field, and they grow or shrink as they move with the flow. The treatment of particle collision-coalescence was challenging, so we constructed an efficient Monte Carlo algorithm to address it. In SDM, the fundamental process rate equations are directly solved, allowing us to seamlessly simulate various cloud related phenomena from the aerosol scale to convective scale.

SDM offers significant advantages over Eulerian approaches typically used in cloud models, but it took a long time for the idea to gain acceptance within the atmospheric science community. Today, Lagrangian particle-based cloud models are being used widely for various applications, and SDM has become synonymous with them. In this talk, I will present an overview of recent advances and applications of the Lagrangian particle-based cloud models. Those include applications to warm-rain development studies, inclusion of habit prediction and proper representation of various ice growth mechanisms, and refinement of the numerical algorithms.

Presentation type: Invited

Simulation of auroral formation and dynamics by means of an interdisciplinary approach of fusion and space research

T.-H. Watanabe, K. Fujita, and T. Sakaki

Aurora is one of the most familiar phenomena in space, but is still filled with a variety of mysteries. To tackle the long-standing problem in auroral physics, that is, the mechanism of spontaneous formation and dynamics of auroras, we have investigated theoretical modeling and simulation of auroras by means of fusion plasma theory. Magnetized plasma dynamics in a low-frequency range is well described by the reduced magnetohydrodynamics (MHD) in a long wavelength regime, or by the gyrokinetics in a gyrorradius scale, which have been developed in studies of magnetic fusion plasma. We have developed the magnetosphere-ionosphere coupling models by means of the fusion theory, which successfully describe spontaneous formation of auroras and their nonlinear dynamics as well as the electron acceleration, and are extending them to further applications to space and astrophysical plasmas.

Presentation type: Invited

Generation of equatorial plasma bubble after the 2022 Tonga volcanic eruption

Atsuki Shinbori, Takuya Sori, Yuichi Otsuka, Michi Nishioka, Septi Perwitasari, Takuo Tsuda, Atsushi Kumamoto, Fuminori Tsuchiya, Shoya Matsuda, Yoshiya Kasahara, Ayako Matsuoka, Yoshizumi Miyoshi, Iku Shinohara

Equatorial plasma bubbles (EPBs) are a phenomenon of plasma density depletion with small-scale density irregularities observed in the equatorial and low-latitude ionosphere. The EPB, which impacts satellite-based communications, was observed in the Asia-Pacific region after the largest-on-record January 15, 2022 eruption of the Tonga volcano. We used satellite and ground-based ionospheric observations to demonstrate that an air pressure wave triggered by the Tonga volcanic eruption could cause the generation of an EPB. The most prominent observation result shows a sudden increase of electron density and height of the ionosphere several ten minutes to hours before the arrival of the air pressure wave in the lower atmosphere. After the ionospheric perturbations, plasma density depletion with one or two order of magnitude appeared in the equatorial and low-latitude ionosphere. We stress that tracking such ionospheric signals before the initial arrival of the air pressure wave helps us to predict the arrival and scale of Tsunami.

Presentation type: Oral

Astrophysical and geophysical turbulence modelling based on a multiple-scale and response-function formulation

Nobumitsu Yokoi

Interesting flows in astrophysics and geophysics are almost invariantly strongly turbulent. Since direct numerical simulations of these flows are just impossible, we have to construct a reliable turbulence model for prediction in a consistent manner. With the aid of a multiple-scale renormalised perturbation theory, where the response functions as well as the correlation functions are utilised for closure of a nonlinear system of fundamental equations, the turbulent fluxes are analytically expressed. On the basis of these analytical expressions of turbulent fluxes, we can construct self-consistent turbulence models in terms of one-point turbulent statistical quantities such as the turbulent kinetic and magnetic energies, several helicities, and their dissipation rates. Some illustrative examples in astrophysics and geophysics will be presented, which include the large-scale flow generation in rotating hydrodynamic turbulence, the non-equilibrium effects in dynamo transport, the electromotive force in strongly compressible magnetohydrodynamic turbulence, and the turbulent heat and mass fluxes in stellar convection. Further applications relevant to astrophysical and geophysical contexts will be also discussed.

Presentation type: Oral

How do plasmas generate structures?

Zensho Yoshida

We formulate topological constraints as foliation of phase space, and discuss how they work to generate structures in plasmas.

Presentation type: Invited

Opening New Horizons with the Korea-led L4 Mission: March 2025 Progress Report

Kyung-Suk Cho

The Sun-Earth Lagrange point L4 is considered as one of the unique places where the solar activity and heliospheric environment can be observed in a continuous and comprehensive manner. 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 he perspective of remote-sensing observations. In-situ measurements of the solar radiation, solar wind, and heliospheric magnetic field are critical components necessary for monitoring and forecasting the radiation environment as it relates to the issue of safe human exploration of the Moon and Mars. The purpose of this talk is to emphasize the importance of L4 observations as well as to outline a current progress of the Korea-led L4 mission with remote and in-situ payloads onboard a Korean spacecraft.

Presentation type: Oral

The Need for a Sub-L1 Space Weather Research Mission: Current Knowledge Gaps on Coronal Mass Ejections

Noe Lugaz, Bin Zhuang, Nada Al-Haddad, Christian Moestl, Emma Davies, Sahanaj Banu, Toni Galvin

Over the past decades, missions at the L1 point have been providing solar wind and interplanetary magnetic field measurements that are necessary for forecasting space weather at Earth with high accuracy and a lead time of a few tens of minutes. Improving the lead time, while maintaining a relatively high level of accuracy, can be achieved with missions sunward of L1, so-called sub-L1 monitors. However, too much is unknown to plan for sub-L1 monitors as operational missions: both the orbital requirements of such missions, and the achievable accuracy of forecasts based on their measurements have not been quantitatively defined. We review here some proposed mission concepts and explain the knowledge gaps related to coronal mass ejections (CMEs) that require a space weather research or science mission. We first show how STEREO-A measurements in 2023 can be used as a proof of concept of the use of sub-L1 monitor slightly off the Sun-Earth line to forecast the Dst index. We then highlight that separations of $\leq 10°$ are needed to ensure that CMEs measured by a sub-L1 monitor impact Earth. We also discuss how CME evolution over the last 0.05–0.2 au before impacting Earth is strongly under-constrained and needs to be better understood before using measurements of sub-L1 monitors for real-time space weather forecasting.

Presentation type: Oral

Interplanetary Influence on Thermospheric Mass Density: Insights from Deep Learning Analyses

Li Wenbo, Liu Libo, Chen Yiding, Zhou Yi-Jia, Le Huijun and Zhang Ruilong

We extracted the thermospheric mass density (TMD) features observed by CHAMP using deep learning (DL) technology, and the TMD features were mapped and modeled with the Interplanetary Environment Information (IEI), solar radiation, and geomagnetic indices. The DL model was used to simulate the TMD features during DOY 222-241 in 2014, a period that experienced complex solar-terrestrial environmental variations. We explore the TMD features under different solar-terrestrial environmental conditions and discuss the effects of various inputs by comparing the DL simulation results with satellite observations from GRACE-A and Swarm-A, as well as the simulation results from JB2008, Msis 2.1, and DTM 2013. These results show that the DL model can better capture the TMD features after adding IEI. Part of these TMD features, including the high-latitude TMD enhancement during the space hurricane event and global TMD variations under complex solar-terrestrial environmental disturbances, cannot be well described by the geomagnetic indices. The DL model indicates that the east-west component of the interplanetary magnetic field has a great impact on TMD variations, and its modulation is different from the typical energy injection process during storms. Our results emphasize the crucial influence of IEI on TMD under both geomagnetic disturbances and quiet conditions.

Presentation type: Poster

Archival reanalyses for early GLEs in the 1940s — 1950s

Hisashi Hayakawa

Intense solar eruptions occasionally accelerate charged particle to high energies. Such solar energetic particles (SEPs) can reach the Earth, depending on the relative geometry between the Sun and the Earth. Sometimes, SEPs have sufficiently high energy and flux to be detected by ground-level detectors known as ground-level enhancements (GLEs). Such GLEs have been consequently numbered since 1942 (htpps://gle.oulu.fi). Among such GLEs, GLE #5 on 23 Feb 1956 is associated with the hardest spectra and greatest flux. Some of the GLEs in the 1940s are arguably considered as intense. As such, these GLEs have been used as a benchmark reference for solar particle storms, radiation dose analyses, and as a bridge between the known GLEs and extreme solar particle events recorded in cosmogenic isotopes. However, we know little about their source data. Here, we collect, review, and analyse available contemporaneous reports for the measurements for these early GLEs based on an archival investigation of original observational records and logbooks. The new datasets significantly revise the source datasets, improve the time-series accuracy, and form basis for further discussions on their spectra.

Presentation type: Poster

Torus Instability Analysis of Flaring Active Regions with Non-neutralized Currents

Johan Muhamad, Kanya Kusano

Solar flares often accompany coronal mass ejections (CMEs), which can trigger geomagnetic disturbances on Earth. However, many flares occur without associated CMEs. The underlying mechanisms driving flare-CME associations remain uncertain. To better understand this relationship, we analyzed active regions that produced solar flares with and without CMEs during solar cycle 24. We calculated the electric current neutralization of each active region by carefully selecting relevant magnetic fluxes based on nonlinear force-free field models. Additionally, we assessed their stability against torus instability by estimating critical heights. Our findings suggest that some non-eruptive active regions, despite lacking clear signs of neutral electric currents, exhibit higher critical heights indicative of torus instability. This highlights the importance of combining both electric current neutralization and torus instability analysis to comprehensively characterize solar flare eruptivity.

Presentation type: Poster

Unveiling the Initiation Route of Coronal Mass Ejections through Their Slow Rise Phase

Chen Xing, Guillaume Aulanier, Xin Cheng, Chun Xia, Mingde Ding

Understanding the initiation of coronal mass ejections (CMEs) is the key to forecasting solar eruptions and induced disastrous space weather. Although many initiation mechanisms have been proposed, a full understanding of CME initiation, which is identified as a slow rise of CME progenitors (hot channels and filaments) in kinematics before the impulsive acceleration, remains elusive. With state-of-the-art magnetohydrodynamics simulations, we determine the complete CME initiation route in which multiple mechanisms occur in sequence yet are tightly coupled. For CMEs with a hot channel as the progenitor, the slow rise is first triggered and driven by the hyperbolic flux tube (HFT) reconnection. Subsequently, the slow rise continues as driven by the coupling of HFT reconnection and torus instability. The end of slow rise, i.e., the onset of impulsive acceleration, is induced by the fast magnetic reconnection coupled with the torus instability. For CMEs with a filament as the progenitor, their initiation route is similar to that of CMEs with a hot channel, while the filament drainage also plays an important role in triggering and driving the slow rise. These results unveil that the CME initiation is a complicated process involving multiple mechanisms, thus being hardly resolved by a single initiation mechanism.

Presentation type: Poster

quantitative analysis of the formation of magnetic flux rope in RMHD simulation

Can Wang, Takaaki Yokoyama, Feng Chen, Mingde Ding, Chen Xing, Zekun Lu

Magnetic flux ropes (MFR), qualitatively identified as a group of helical magnetic field lines winding around a common axis, is the key magnetic structure in solar eruptions. Therefore, research on the formation of MFR help to improve the understanding of solar eruptions. Theories about MFR formation can be divided into two categories: formed in convection zone and emerging into atmosphere, or formed directly in atmosphere by photospheric motions and magnetic reconnection. Based on a RMHD simulation conducted with MURaM code, we try to analyze the roles of these two mechanisms quantitatively. We calculate two main components of helicity injection rate on the photosphere: advection term related to emerging or submerging horizontal magnetic field, and shear term related to photospheric motions. Shear term is mainly located at edges of polarities, while advection term is concentrated near the PIL region. When integrating the injection rate within whole AR, we notice that shear term always dominates. However, if only focusing on MFR region, two terms make comparable contribution in early period; when close to eruption, shear term increases quickly and dominates. We also calculate the helicity injected into the flux rope through different heights and find that as height increases, contribution from advection term also increases, indicating there may be magnetic reconnection occurring above photosphere, which can generate rising horizontal magnetic field and provide additional advection term.

Presentation type: Poster

A Study on Magnetic Parameters to Determine the Formation of CME

MORIYAMA Tomoki, KUSANO Kanya, MASUDA Satoshi

Coronal Mass Ejection (CME) is a sudden ejection of plasma mass from the solar corona and is not always associated with solar flares. CMEs can cause disturbance of space weather and impact on social activity, so we try to detect the parameter that determine CME eruptivity of solar flares before their onsets. In this study, we focus on non-potential magnetic field (BNP), that is a positively contributing to magnetic free energy, and set High Free Energy Region (HiFER) to make parameters focusing on energy-stored region. We consider individual parameters and dimensionless parameters, expressing the balance between HiFER and its surrounding magnetic field. For evaluate the ability of CME discrimination of them, we introduce receiver operating characteristic skill score (ROCSS). As a result, some dimensionless parameters have better ROCSS value than others. Moreover, as for individual parameters, those derived from observed magnetic field have better ROCSS than those derived from BNP . These results suggest that the balance between CME-driving energy and CME-suppressing effect is important for CME onset, and especially the latter has lager contribution to CME eruptivity of flares. Following these results, we will consider torus instability, that is caused by the loop current and outer magnetic field.

Presentation type: Poster

Data assimilation of a whole atmosphere-ionosphere model GAIA using ionospheric observations

Hidekatsu Jin, Satoshi Andoh, Chihiro Tao, Yasunobu Miyoshi, Hiroyuki Shinagawa, Hitoshi Fujiwara

Prediction of the earth's ionosphere and thermosphere is an important topic of space weather research, since the variation in these regions have impacts on the GNSS applications and communications as well as satellite operations. For the purpose of upper atmospheric prediction, we are developing a data assimilative model using a whole atmosphere-ionosphere model called GAIA and global GNSS TEC observations as well as FORMOSAT/COSMIC radio occultation observations. We adopt a data assimilation platform, DART, developed by NCAR, which provides ensemble Kalman filter approach. The approach calculates the most probable solution considering the observation errors and model uncertainties. It is necessary for the approach being effective that the model uncertainty is well reproduced by the ensemble. For this reason, we first extracted uncertain parameters used in GAIA that lead to the uncertainty of model outputs and then evaluate the covariance between the parameters and ionospheric observations. We will introduce our data assimilation method and preliminary results.

Presentation type: Poster

Prediction of the solar wind disturbances by the MHD simulation based on the next generation interplanetary scintillation observations

Kazumasa Iwai Ken'ichi Fujiki, Hirofumi Isogai, Yushuke Kagao, Keita Morishima, Daichi Takehara, Haruto Watanabe (ISEE, Nagoya University)

Solar wind and coronal mass ejections (CMEs) are main drivers of the space weather disturbances. Three dimensional global MHD simulation is a one of the efficient tools to predict the solar wind and CME. Interplanetary scintillation (IPS) is a radio scattering phenomenon generated by the disturbances in the solar wind. ISEE, Nagoya University have observed IPS to derive the solar wind velocity and density irregularities for several decades using multiple large radio telescopes at 327 MHz. The IPS data can be used to improve the accuracy of the heliospheric MHD simulation. We have simulated several CME events that arrived at the Earth such as observed on early May 2024 and found that the IPS observation can be explained by the MHD simulation, suggesting the predictability of the space weather disturbances using the IPS based MHD simulation. Now, a new project to develop the next-generation solar wind observation system is in progress. The multidirectional simultaneous radio scintillation observation using this system enables the solar wind observation 10 times as much as the conventional radio instruments have been done. The accuracy of the space weather predictions will be significantly improved by the data assimilated MHD simulation using the IPS data derived from the next generation system.

Presentation type: Poster

High-resolution 3-D imaging of ionospheric disturbances using ultra-dense GNSS observation networks in Japan

Weizheng Fu (ISEE, Nagoya U), Yuichi Otsuka (ISEE, Nagoya U), Nicholas Ssessanga (4DSpace, Department of Physics, University of Oslo)

We developed a three-dimensional (3-D) computerized ionospheric tomography (CIT) technique aimed at imaging electron density perturbations with high spatiotemporal resolution. The CIT is facilitated by ultra-dense total electron content (TEC) measurements from two ground-based Global Navigation Satellite System (GNSS) receiver networks in Japan. The slant TECs for tomography comprise two components: the background (generated by IRI-2016 model) and TEC perturbations. Comprehensive simulations demonstrated the good fidelity of this CIT technique in reconstructing the F-region perturbations. Based on the high-resolution reconstruction results (0.25 degree in latitude and longitude, 10 km in altitude, 30 seconds in time), we successfully reconstructed the vertical structures of traveling ionospheric disturbances (TIDs) under different conditions. With this developed CIT technique, now we are provided a robust tool for identifying disturbance of different sources. The consistencies and differences between observation results and theoretical predictions help improve our understanding of ionospheric dynamics and predict the generation of ionospheric disturbances.

Presentation type: Poster

Solar flux dependence on electric conductivity in the dayside ionosphere of Earth

Aki Ieda (Nagoya U), K. Watanabe, S. Kitajima (NDAJ), M. Nishioka, H. Jin (NICT), and T. Hori (Nagoya U)

Solar radiation ionizes the Earth's neutral atmosphere to generate the ionosphere. The ionospheric E-layer is characterized by the presence of horizontal electric currents, which cause geomagnetic variations. The solar radio flux F10.7 (10.7 cm, 2.8 GHz) index has often been utilized as a proxy for the solar flux in models associated with the E-layer. However, such usage of F10.7 may be inappropriate because the E-layer is theoretically not generated by solar radio waves, but rather by Lyman β.

In this study, we compared the maximum electron density with solar fluxes, namely, the F10.7 index, Lyman β (103 nm), and Lyman α (122 nm). Although the resultant correlation coefficients were similar among the three solar flux quantities, the fitted straight lines showed qualitative differences regarding the origin. The line fitted to the Lyman β data passed near the origin, suggesting that Lyman β directly generates the Earth's ionospheric E-layer. In contrast, the line fitted to the F10.7 index deviated from the origin, implying that the offset of F10.7 index should be subtracted in models associated with the E-layer. This correction presumably improves models of ionospheric electric conductivity, and thus, horizontal electric currents, geomagnetic variations, and Joule heating.

Presentation type: Poster

A Role of Magnetic Reconnection in the Solar Eruption: As a key factor among fast, slow, and failed eruption

Satoshi Inoue, Takahiro Miyoshi, Keiji Hayashi, Ju Jing, and Haimin Wang

Magnetic reconnection has long been regarded as one of the leading energy release mechanisms of solar eruptions. However, it is not clear how the magnetic reconnection is involved in a fast or slow eruptions. In this study, we performed data-based magnetohydrodynamic (MHD) simulations to clarify this issue. We successfully produced magnetic flux ropes with slightly different twist using the data-driven MHD simulation, which determines the onset of the torus instability and produces a variety of different eruption speeds, despite using the same ambient field with the same decay index profile. The most important factor is that the growth of the torus instability is dramatically altered by the amount of tether-cutting reconnection that occurs during the pre-eruption stage. Therefore, it is not only the decay index that determines the fast and slow eruptions, but also the magnetic reconnection in the pre-eruption plays an important role.

Presentation type: Poster

Extensive Parameter Survey of Three-dimensional Solar Wind Simulations from the Solar Interior

Haruhisa Iijima, Daiko Shiota, Hideyuki Hotta

The solar wind varies significantly depending on time and location, classified in terms of speed, plasma density, temperature, Alfven wave fluctuations, variability, and composition. A representative classification divides solar wind into fast and slow winds, which interact in interplanetary space to form structures that can drive geomagnetic disturbances. Understanding the origin of this diversity is critical for predicting solar wind impacts on space environments.

This study employs a 3D radiative MHD model with minimal empirical assumptions to explore the origins of solar wind diversity. Simulations cover a horizontal domain of 70 x 70 Mm^2, from 20 Mm below the solar surface to 19 solar radii above. A parameter survey of 16 cases examines global magnetic structures and local dynamo strength, uniformly sampling a four-dimensional parameter space using Latin hypercube sampling. The resultant dataset shows diverse solar winds, with speeds ranging from below 300 km/s to above 500 km/s.

Presentation type: Poster

Continuous Observations of Interplanetary Scintillation Over 50 Years

Ken'ichi Fujiki, Kazumasa Iwai, Yasushi Maruyama, Takayuki Yamasaki

At Nagoya University, the construction of antennas for interplanetary scintillation (IPS) observation began in the late 1960s, and in 1974, a multi-station IPS observation system operating at a frequency of 70 MHz (located in Toyokawa, Fuji, and Sugadaira) started regular observations. Although the observations at that time were limited to a small number of radio sources, the advantage of multi-site observations allowed for the determination of solar wind velocity. The data obtained during that period have been integrated with the data from the University of California, San Diego (UCSD), which conducted similar multi-station IPS observations.

A new IPS project using a frequency of 327 MHz, which is better suited for inner heliosphere observations, was initiated in the 1980s. In 1984, three-station observations began at the previously established sites. By 1993, a new observation site was established in Kiso, enabling four-station observations, which provided a more robust observation system. In 2009, the Toyokawa antenna was upgraded, resulting in a 1.5-fold increase in observation data. However, the Sugadaira antenna collapsed in 2014 due to heavy snowfall, leading to the closure of that observation site. Currently, IPS observations are being conducted at three sites.

In this presentation, we introduce the IPS observation data accumulated over 50 years and report the results of comparative studies conducted with other observational data, focusing on the long-term nature of these observations.

Presentation type: Poster

How can the differential emission measure of the solar corona help to improve solar flare prediction?

Sung-Hong Park

Solar flares are thought to occur when magnetic energy stored in the solar atmosphere is suddenly released via the process of magnetic reconnection and converted into other forms including acceleration of particles (non-thermal energy) and heating of plasma (thermal energy). Magnetic reconnection during a flare takes place in a region of a current sheet that may be formed and developed due to stretching of magnetic field lines by an erupting magnetic flux rope. There have been reports on observational signatures of magnetic flux ropes prior to the onset of flares, including hot plasma structures seen in coronal lines. In this context, here I present a feasibility study on whether and how the differential emission measure (DEM) of the solar corona can help to improve solar flare prediction. DEM maps of the entire solar disk are derived applying a regularized inversion method to near-real-time (NRT) full-disk images of the solar corona in six EUV channels (centered at 94, 131, 171, 193, 211, and 335 Å) obtained by the Atmospheric Imaging Assembly (AIA) aboard the Solar Dynamics Observatory (SDO).

Presentation type: Poster

Developing an AI Predictive Model of Solar Energetic Particle Events Occurrence and Fluence via Academia-Industry Collaboration

Yuta Kato, Kanya Kusano, Naho Fujita, Kentarou Doi, Hiroyuki Kawasaki, Tomoki Moriyama, Tomoki Kubo, and Chihiro Mitsuda

The Institute for Space-Earth Environmental Research (ISEE) and Fujitsu have conducted joint research since September 2023 to develop improved space weather forecasting for the safety of human space activities. Solar Energetic Particle (SEP) events, associated with solar flares (SFs) and coronal mass ejections (CMEs), pose significant risks to human health, spacecraft, and ground-based systems. Our presentation mainly focuses on two key areas: (1) SEP event occurrence prediction using explainable AI (Fujitsu Kozuchi XAI) for multi-class classification of SEP-productive solar flares, incorporating data from Solar Cycle 24 to June 2024; and (2) prediction of SEP event flux and fluence using time series data of X-ray and proton flux with various machine learning (Fujitsu Kozuchi AutoML) and deep learning regression techniques. This presentation will summarize our current results and discuss future prospects for this project.

Presentation type: Poster

Fully automate system health management for next-generation solar wind observation system using machine learning

TAKEHARA Daichi, IWAI Kazumasa

At Nagoya University, a next-generation solar wind observation system (ngSW) has been developing. The ngSW has 1024 channels of analog input and a 2-D digital phased array system. Due to the implementation of digital multibeam systems with many analogue inputs in the ngSW, the system will be more complicated and the cost of identifying instrument failures and calibration errors will be increased. The implementation of fully automated real-time system health management (SHM) is required to ensure the stable execution of high-quality observations. However, there have been few attempts to fully automate the SHM.

The aim of this study is to develop a machine learning(ML) system that enables the automated SHM that required by next-generation radio telescopes and maximize their operational efficiency. Calibration plays a very important role for next-generation radio telescopes with phased array systems. In particular, the phase difference between each channel has a significant impact on the accuracy of beam forming. Phase differences are sensitive to dynamically changing environments, such as temperature. By using ML, flexible phase calibration can be performed in response to environmental changes. This improves not only observation efficiency but also observation accuracy.

By using 64 channels system of ngSW which has already been developed, an AI was developed and implemented to detect anomalies in the analog signal before beam forming. This AI used a logistic regression model and was cross validated five times. In this experiment, a continuous wave was input as pseudo-signal, and 12,000 spectral data with and without a 3 dB attenuator on randomly selected analog input were used. The results show that a detection accuracy if the developed AI system is 99.925%.

Presentation type: Poster

Evolution of a weak solar flare observed at 30 THz by AR30T telescope

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An open question about solar flares is how the released energy is transported from the flaring site to the lower layers of the solar atmosphere. Some studies suggest that thermal conduction could play a key role in transporting the energy and heating the lower layers. The aim of this work is to understand the energy transport from the corona to the chromosphere that produced the event occurred on February 28, 2022 at 15:23 UT. Despite its relatively low magnitude (B5.5 class flare), the AR30T Mid-IR (30 THz) telescope installed at the OAFA (Félix Aguilar Astronomical Observatory) in Argentina was capable of detecting this solar event. For the analysis, we use multi- wavelength observations, including microwaves from RSTN, H-alpha line (6562.8 Å) by GONG, UV (1700, 1600 Å) and EUV (304, 171, 94, 131 Å) recorded by SDO/AIA, soft X-rays by GOES, and hard/soft X-rays by STIX/SolO. This data set in a broad range of wavelengths allowed us to investigate the temporal evolution of the flare and its morphological characteristics. The temporal evolution of the flare in microwaves from 15:00 to 15:40 UT did not exhibit any significant enhancement and the spectrum in X-rays recorded by STIX observations do not presented energies above than 20 keV. Therefore, the data analysis suggested thermal emission as the main mechanism during the flaring time. Hence, the most likely scenario for the energy transport and heating of the lower layers that induced emission at 30 THz is mainly via thermal conduction. In principle, due to energy input via a conductive flux. The total conductive energy was computed using X-ray spectral observations recorded by STIX (4 - 20 KeV). The physical parameters needed for estimating the total conductive energy were obtained using the OSPEX/SSW package, by which considering two cases: (1) two thermal sources (2vth) and (2) one thermal source plus a thick target (vth + target), we fit the data. The fitting results yield the emission measure ($\approx$ 2.6 $\times$ 10^47 cm^-3) and temperature ($\approx$ 10 MK) for the thermal component. Thereafter, we concluded that the best-fitting is one thermal component, so we estimated the total thermal flux energy for one thermal component result in 6.38 $\times$ 10^28 erg. Moreover, based on the 30 THz observation we estimated the brightness temperature of the flare excess amounting to $\approx$ 10 K and the radiated energy at 30 THz resulting as 1.6 $\times$10^25 erg. On the other hand, the characteristics of the temporal profile observed at 30 THz, we found a good correlation with the profiles at other wavelengths.

Presentation type: Poster

Observations of solar microwave spectra by the Yokosuka Radio Polarimeter (YoRP)

Kyoko Watanabe, Ryoka Shirogauchi, Kensho Yasui (National Defense Academy of Japan), Masumi Shimojo (National Astronomical Observatory of Japan), Kazumasa Iwai, Satoshi Masuda (ISEE, Nagoya University)

Observations of total solar microwave emission have been performed in Japan at Toyokawa and Nobeyama (NoRP) for more than 70 years. In order to obtain not only continuous observations of solar microwaves, but also dynamic spectra of solar microwave emissions, which have only been observed at limited frequencies at NoRP, a new instrument has been installed at the National Defense Academy of Japan. In this paper, we introduce the Yokosuka Radio Polarimeters (YoRP) and reports on the observed solar microwave spectra and the latest data acquisition status.

Presentation type: Poster

Spectroscopic Observations of the Solar Cycle Variation of Polar Off-limb Chromosphere

Akiko Tei

It is suggested that the chromosphere in the polar coronal hole regions are taller and move faster than the chromosphere in the polar quiet-Sun regions (Tei et al.). In addition, the magnetic field structure in the solar polar regions changes over the solar activity cycle. Taken together, the nature of the chromosphere is expected to change over the solar activity cycle. To examine this, we used about 10 years of weekly polar spectral data acquired by IRIS to examine how characteristic parameters such as the brightness and line width of the Mg II hk lines have changed as a function of time and height above the solar limb. The results show that the height of the chromosphere is higher and the line width is larger during the minimum period than during the maximum period. These results may suggest that chromospheric conditions, in addition to the photosphere, are very important in modeling the solar atmosphere and solar wind.

Presentation type: Poster

The physical characteristics of solar microflares by microwave observation

Ayatoshi Taniguchi, Satoshi Masuda

Solar flares are the most energetic events occurring in the solar corona, and have a huge effect on the space weather. The magnetic energy released by flares is converted to various kinds of energy such as thermal energy, energy for particle acceleration and kinetic energy. It is not clarified how the distribution of such various energies changes depending on the size of solar flares. Clarifying this issue is important to understand flares more deeply. Accelerating electrons have been observed with microwave (gyrosynchrotron radiation) and hard X-ray (bremsstrahlung). The previous study revealed a strong correlation between microwave and hard X-ray in spite of the different radiation mechanisms (Krucker et al. 2020). In the same paper, it was shown that Nobeyama Radioheliograph (NoRH) observing microwave has higher sensitivity than hard X-ray observing instruments like RHESSI. Thus, to statistically study the characteristics of small flares, we developed a small-flare detecting algorithm using NoRH data. We investigated the correlation in peak flux between microwave and soft X-ray. As a result, we found no significant difference in the correlation from large flares to small ones.

Presentation type: Poster

Statistical study of the acceleration site in solar flares observed with Fermi by applying multiple Time-of-Flight method

Masaya Yakura, Satoshi Masuda

Solar flare is an explosion phenomenon caused by magnetic reconnection. During a solar flare, it is well known that many electrons are accelerated but the mechanism and location have not been revealed. In previous studies, Aschwanden+ estimated the height of an acceleration site by applying the Time-of-Flight (TOF) analysis to hard X-ray (HXR) data. Thus, they concluded it is located above the loop top. According to the standard flare model, the structure of the flare grows up with time evolution. However, no signature for a continuous motion of the acceleration site has been observed yet. The simplest way to estimate the time evolution of the acceleration site is by repeatedly applying TOF to each HXR data. Then, we applied TOF for HXR spikes simultaneously observed with Gamma-ray Burst Monitor (GBM) on board Fermi. First, we selected 3 solar flares observed with Fermi, SDO, RHESSI, and NoRH. As a result, one flare showed significant continuous upward motion, but the others didn't show any tendencies. Next step, we applied this method to all flares observed with trigger mode from 2008 to 2024. In this talk, we show the preliminary results of this statistical study and discuss them.

Presentation type: Poster

Data-driven MHD simulation of sigmoid formation in a puzzling NOAA active region 12665

Yeongmin Kang, KD Leka, Denis P. Cabezas, Takafumi Kaneko, Kanya Kusano

We performed a data-driven MHD simulation which focused on the formation of a sigmoid observed in NOAA active region (AR) 12665. This active region produced two M-class flares from 2017 July 8 to July 14, and the formation of a sigmoid, one pre-flare coronal structure, was observed in a high-energy band during this period. Regarding the second M-class flare (M2.4) with a CME event observed on July 14, AR 12665 displayed a mysterious behavior in the pre-flare phase, as the photospheric magnetic field featured a relatively simple polarity inversion line, but the upper coronal observation captured the complex sigmoidal structure. To reveal and understand the formation process of sigmoid, we conducted data-driven modeling (Kaneko et al. 2021) of this process, using a time series of SDO/HMI magnetogram. Through the simulation results, we reproduced the process of sigmoid formation, enabling us to understand the coronal behaviors and its causal relation with photospheric motions. Additionally, we compared the coronal magnetic field reconstructed using non-linear force-free field modeling (Inoue et al. 2014), highlighting differences in the description of the sigmoid formation reproduced in the data-driven simulation.

Presentation type: Poster

Prominence splitting and merging due to interchange instability in helical flux rope

Takafumi Kaneko

We investigated the morphological evolution of solar prominence using MHD simulations. The three-dimensional MHD equations including thermal conduction and radiative cooling were solved numerically. In our simulations, a helical flux rope was created via reconnection between a pre-existing coronal arcade field and newly emerging flux. Cool dense prominence was formed within the flux rope due to radiative condensation. Initially, the prominence appeared as a single long thread. As the interchange (flute) instability developed in the flux rope, the prominence was highly deformed, splitting into shorter rotating segments. Over time, these segments eventually merged to reform a single long thread. We conducted four simulations varying the initial shear of the pre-existing arcade and the amount of emerging flux. In two cases with a larger amount of emerging flux, the prominences became eruptive, while in the other two cases, they remained non-eruptive. Our results revealed that the typical length of the short segments depended on the initial shear of the pre-existing arcade field in both eruptive and non-eruptive cases. The deformation was more pronounced in eruptive prominences due to the larger growth rates of interchange instability.

Presentation type: Poster

Evaluation of the effect of solar flare emission on the Earth's ionosphere by the Kakioka magnetometer

Ryosuke Okubo, Kyoko Watanabe, Shinnosuke Kitajima(National Defense Academy of Japan), Satoshi Masuda, Akimasa Ieda(ISEE/Nagoya University), Hidekatsu Jin, Chihiro Tao, Michi Nishioka(National Institute of Information and Communications Technology)

Solar EUV radiation is known to affect the Earth's ionosphere. Among these, Lyman-α (Ly α; 121.6 nm) is the strongest hydrogen line and can ionize NO molecules in the ionospheric D-region. On the other hand, Lyman-β (Ly β; 102.6 nm) is about 100 times weaker in irradiance than Ly α, but can ionize O_2 molecules in the ionospheric E-region. The O_2 density in the E-region is more than 1000 times higher than that of NO, Ly β's impact on the ionosphere is potentially significant. Milligan et al. (2020) studied temporal variations of soft X-rays, Ly α, and Kakioka magnetometer data during the X1.8 class flare on 2011 Sep 7, suggested that Ly α affected ionization in the E-region. However, Ly α mainly affects the D-region, this conclusion is controversial. It is possible that the ionization of the E-region is due to Ly β and/or other EUV emissions with similar time variations as the Ly α. In this study, Ly α (GOES/EUVS-E) and Ly β (SDO/EVE) data from 40 M-class or larger flares from 2010 to 2014 are analyzed. GAIA model indicates that Ly β contributes significantly to $O_2{}^+$ production in the lower E-region. These results suggest that Ly β plays a greater role than soft X-rays in the ionization of the E-region.

Presentation type: Poster

Flaring vs. Flare-Quiet Active Regions: Insights from Coupling the Photospheric Magnetic Field with Properties of the Chromosphere, Transition-Region, and Corona.

KD Leka, K. Dissauer, G. Barnes, E.L.Wagner, S. Petty

Recent work has shown that small-scale short-lived variation in the solar corona is statistically indicative of upcoming flare activity (Leka et al. 2023), even while studies based on static images or low spatial resolution images from the Chromosphere, Transition-Region, and Coronal (CTRC) regime has not yet proven any significant insights to this question. Long-held knowledge of the photospheric magnetic field has thus far guided most efforts into identifying flare-imminent magnetic field configurations, but evidence for the role of the upper atmosphere is both expected (in terms of energy storage, possible trigger mechanisms) and elusive. To that end, we now investigate the question of distinguishing flare-imminent active regions by evaluating both magnetic characteristics from SDO/HMI (beyond the SHARP parameters, see accompanying poster) as compared to, and combined with, the characteristics of the CTRC regime as parameterized using SDO/AIA Active Region Patches (Dissauer et al 2023) covering much of the SDO mission. To gain physical insight from a large-sample analysis, we use the NWRA Classification Infrastructure (NCI), a facility based on nonparametric discriminant analysis, which enables a quantitative evaluation of which descriptions can best distinguish regions in imminent likelihood of flaring. We present a summary of results from this expanded analysis.

Presentation type: Poster

Direct observation of pulsating aurora electrons: LAMP sounding rocket experiment

T. Noda(1), Y. Miyoshi(1), K. Hosokawa(2), K. Asamura(3), T. Sakanoi(4), M. Lessard(5), A. Jaynes(6), M. Shumko(7), A. Halford(8), T. Namekawa(9), T. Mitani(3), M. Nose(10), M. McHarg(11), V. Ledvina(12) and D. Hampton(12)

Pulsating aurora is a subset of diffuse aurora that modulates its luminosity with a period ranging from a few to 10 seconds. An over-darkening phenomenon, characterized by a decrease in brightness by several tens of percent relative to the background, has often been observed immediately after the luminosity enhancement during the pulsation "ON" phase. We have studied the pulsating-aurora and over-darkening phenomena using electron data from EPLAS and optical data from AIC onboard the LAMP sounding-rocket, which was launched on March 5, 2022 at Poker Flat Research Range. EPLAS can observe electrons in the 10 eV-20 keV energy range, and AIC can observe optical emissions in the 667-680 nm and 844-848 nm wavelength ranges. An event of the over-darkening embed in the pulsating aurora was observed during the rocket flight. Near the apex of the trajectory, the optical aurora emission at the magnetic footprint decreased from 3,000 Rayleigh to 1,300 Rayleigh. Simultaneously, EPLAS identified a ~50% reduction in the downward energy flux. During the darkening event, an energy dispersion of precipitating electrons was observed. Time-of-flight (TOF) analysis estimated the source region of the precipitation attenuation to be approximately 55,000 km from the rocket, suggesting that the suppression of high-energy electron precipitation occurred near the magnetic equator. The results imply that the over-darkening in pulsating aurora luminosity modulations is likely caused by the suppression of precipitating electrons near the magnetic equator, possibly due to the wave-particle interactions.

Presentation type: Poster

Investigating past extreme solar energetic particle events in ice core records

Fusa Miyake, Kazuho Horiuchi, Kenji Kawamura, Akito Matsuzaki, Hiroyuki Matsuzaki, Ikumi Oyabu, Takeyasu Yamagata

Extreme solar eruptions have a significant impact on modern space infrastructure. Since the frequency of solar eruptions decreases as their intensity increases, long-term studies of past extreme solar eruptions are crucial. To conduct such studies, we use records of cosmogenic nuclides, such as 14C in tree rings and 10Be and 36Cl in ice cores, which serve as proxies for extreme solar energetic particle (SEP) events associated with solar eruptions. So far, several candidates for past extreme SEP events have been reported, e.g., 774 CE, 993 CE, ~660 BCE, and 7176 BCE. In this study, we performed 10Be analysis using NDF cores drilled inland in Antarctica to search for new events. In this presentation, we will report on the progress of the event search using ice cores, as well as the results of the analysis around 990 BCE.

Presentation type: Poster

Electron density in the lower ionosphere during solar flares using PHITS

Shinnosuke Kitajima, Kyoko Watanabe, Hidekatsu Jin, Chihiro Tao, Satoshi Masuda, Michi Nishioka, Kiyoka Murase

X-ray emission from solar flares enhances ionization of the lower ionosphere and rapidly varies the electron density, resulting in shortwave fadeout (SWF). The numerical models for the whole global atmosphere do not accurately calculate the electron density variations in the lower ionosphere. It is necessary to accurately estimate the electron density variation in the ionosphere during solar flare in order to estimate the magnitude of the SWF. We use the PHITS code (Sato et al., 2024), a Monte Carlo particle transport and collision simulation code, to reproduce the electron density in the lower ionosphere due to flare X-ray emission. We derive the effective recombination coefficient (α eff) from the electron density observed by EISCAT. We reproduce the electron density using the α eff. We found that the PHITS code can reproduce the electron density to less than 30% ($\pm 1\sigma$). We estimate the minimum reflection frequency (fmin) and the total fadeout of the ionospheric echo (blackout) in the ionogram using PHITS. The correlation coefficient between simulated and observed fmin is 0.88, and the True Skill Statistic (TSS) of blackouts is 0.70. We will discuss the reproduction of the electron density using PHITS in comparison with that of GAIA.

Presentation type: Poster

Solar Wind Parameter Dependence of Magnetic Storms Based on XAI

T. Nishino, and Y. Miyoshi

The eXplainable Artificial Intelligence (XAI) is a powerful method for identifying important parameters in time-series analysis. We applied XAI with RNN to forecast geomagnetic storms (Dst index)from 1996 to 2004 and from 2017 to 2024. Our analysis reveals that the most important parameter driving magnetic storms is IMF-Bz, contributing more than 80% to the minumum predicted value. Using this technique, we also investigate differences between solar wind drivers, such as Corotating Interaction Regions (CIRs) and Coronal Mass Ejections (CMEs). Furthermore, we discuss the dependence of key parameters on the storm driver sources and their phases.

Presentation type: Poster

Investigation of Omega Band Auroras: Ground and Magnetospheric Conjugate Observations

I.Naganawa, Y. Miyoshi, S. Kurita, K. Hosokawa, S. Oyama, Y. Ogawa, Y. Kasahara, S. Matsuda, T. Hori, Y. Kazama, S.-Y. Wang, C.-W. Jun, S. Kasahara, S. Yokota, K. Keika, A. Matsuoka, M. Teramoto, K. Yamamoto, I. Shinohara, Fuminori Tsuchiya, Atsushi Kumamoto, and Atsuki Shinbori

The Omega band auroras are a type of aurora that occur shortly after auroral breakup and drift eastward from midnight to the early morning hours. It characterized by a structure resembling an inverted Greek letter Omega (Ω). Within the torch structure of the Omega band aurora, multiple types of auroras are observed, including discrete aurora, diffuse aurora, and pulsating aurora, which contribute to its unique optical characteristics. However, magnetospheric mechanisms responsible for the Omega band aurora remain unclear due to the lack of simultaneous observations from satellites and ground-based instruments.To investigae the dynamics of magnetospheric plasma and waves corresponding to the internal structure of the Omega band aurora, we analyzed simultaneous ground-based optical observations and conjugate observations by the Arase satellite. Ground-based observations were conducted using two EMCCD cameras at two wavelengths (427.8 nm and 844.6 nm) in Tromsø, Norway. On March 25, 2021, the Omega band aurora was observed, with the Arase satellite's orbital footprint located within the optical field of view. This enabled the observation of the low-latitude portion of the torch structure, specifically the pulsating auroral region. This event occurred during dawn local time. During this event, the Arase satellite detected the injection of electrons with energies of several tens of keV along with strong chorus waves, which could be the origin of the diffuse and pulsating auroras observed within the Omega band aurora. In this presentation,we will report on the spatial characteristics of precipitating electrons within the Omega band aurora and their correlation with magnetospheric phenomena.

Presentation type: Poster

Average Profile of Outer Belt Flux Variations During Magnetic Storms: Arase observations and simulation

Y. Miyoshi, S.Kumar, S. Kurita, S. Saito, S. Matsuda, Y. Katoh, R. Kataoka, P. R. Shreedevi, I. Shinohara, K. Asamura, Y. Kazama, S.-W. Wang, C.-W. Jun,T. Hori, S. Kasahara, S. Yokota, K. Keika, T. Mitani, T. Takashima, N. Higashio,Y. Kasahara, F. Tsuchiya, A. Kumamoto, A. Shinbori, N. Kitamura, A.Matasuoka, K. Yamamoto, M. Teramoto

The Arase satellite has successfully observed the inner magnetosphere for more than 8 years, providing continuous data on a wide range of electron energies and various plasma waves. We conducted a superposed epoch analysis to identify the average variations of key parameters that contribute to the acceleration of relativistic electrons in the outer belt. The results are well consistent with the concept of cross-energy coupling, in which wave-particle interactions play an essential role. We also compare these findings with data-driven simulations of the evolution of the electron energy spectrum and discuss possible acceleration mechanisms.

Presentation type: Poster

Characteristics, evolution, and fate of NOAA active region 12665

Denis P. Cabezas, K.D. Leka, Yeongmin Kang, and Kanya Kusano

NOAA active region 12665 which transited in mid-July 2017, exhibited an unexpected evolution that contradicts the standard views. Despite being a low-complexity active region (AR) without a strong gradient Polarity Inversion Line (PIL), AR 12665 produced M-class flares and a fast CME. Using data from Hinode SOT/XRT, SDO AIA/HMI, and SMART/SDDI H-alpha, we examine AR 12665 in light of the appearance of bald-patch separatrix surfaces (BPs) on the photosphere, evolution of H α filaments in the chromosphere, formation of a coronal sigmoid, and the later M-class flare on July 14. We found that the appearance of BPs spatially coincides with the evolution of the H-alpha filament, but without immediate evidence of a magnetic flux rope in the corona. During this period, highly red- and blue-shifted plasma also manifest, and the vertical electric current is also enhanced. Subsequently, the horizontal field strength across the PIL decreased and re-oriented, during which we observed the disintegration of BPs and the formation of a twisted flux rope in the corona. We address the fundamental question of how much magnetic energy was accumulated from the initial activities in the photosphere to the flare time on July 14 by computing the Poynting flux and magnetic helicity. The total magnetic energy supplied from the photosphere to the corona amounted to ~ 4.2×10^33 erg, with the largest contribution coming from the photospheric shear motion. Such an accumulated magnetic energy, which eventually a fraction of it was released during the flare, may account for the energetic events produced by AR 12665.

Presentation type: Poster

Evaluating the characteristic of magnetic flux in spheromak on ICME Time of Arrival using SUSANOO-CME model

Hirofumi Isogai, Kazumasa Iwai, Daikou Shiota, Ken'ichi Fujiki

Accurately predicting the time of arrival (ToA) of interplanetary coronal mass ejections (ICMEs) at Earth is a critical challenge in space weather forecasting. Global magnetohydrodynamics (MHD) models have been widely used for over a decade to simulate ICME propagation, but these models inherently include uncertainties in predictions due to errors in the initial parameters derived from observations. Especially, although magnetic characteristics are critical for ICME propagation, comprehensive survey for them have not been conducted yet . In this study, we used the SUSANOO-CME model (Shiota & Kataoka, 2016) to perform a parameter survey focusing on initial parameters, including magnetic flux in the spheromak CME model. Ensemble simulations were conducted by varying initial parameters to calculate the ToA for each case. Results indicate that magnetic flux is more sensitive than CME initial velocity that is well investigated in previous studies . Moreover, the magnetic flux characteristic on ToA changes with other conditions such as ambient solar wind speed. Additionally, using the correlation between soft X-ray fluence of flares and the magnetic flux involved in flares, we estimated the magnetic flux included in the spheromak. Using this approach, we estimated the potential ToA errors resulting from magnetic flux uncertainties in an operational forecasting context.

Presentation type: Poster

Statistical study of prominence eruptions observed with Nobeyama Radioheliograph

Satoshi Masuda, Shoya Ueda (Nagoya University), and Seiji Yashiro (Catholic University and NASA/GSFC)

Nobeyama Radioheliograph (NoRH) has a capability to track the continuum radio emissions from an erupted prominence to the high-altitude corona without being affected by the Doppler shift that occurs in H-alpha line observations. Shimojo et al. (2013) conducted a statistical study on the change in the latitude of occurrence relative to the solar activity cycle using NoRH data up to 2013. We extended this study using all the NoRH data from 1992 to 2020 and found the similar variation after 2013. In addition, we investigated the velocity variation of prominence eruptions relative to the solar activity cycle. In this presentation, we discuss these results and interpret them.

Presentation type: Poster

Comparison of polar magnetic fields derived from MILOS and MERLIN inversions with Hinode/SOT-SP data

Masahito Kubo (NAOJ), Daikou Shiota (NICT), Yukio Katsukawa (NAOJ), Masumi Shimojo (NAOJ), David Orozco Suarez (IAC), Nariaki Nitta (LMSAL), Marc DeRosa (LMSAL), Rebecca Centeno (HAO), Haruhisa Iijima (Nagoya U.), Takuma Matsumoto (Nagoya U.), Satoshi Masuda (Nagoya U.))

Precise measurements of the polar magnetic field are essential for understanding the solar cycle, as they provide important constraints for identifying the source regions of the solar wind. The Spectropolarimeter (SP) of the Solar Optical Telescope (SOT) on board Hinode has been the instrument best suited to make such measurements. In this study, we compare the SOT-SP data for the polar regions, processed using two representative Milne-Eddington inversion codes, MILOS and MERLIN. These codes are applied to the same level-1 SOT-SP data sets at different phases of the solar cycle, and the same disambiguation algorithm is used on the maps that go through the two inversions. We find that the radial magnetic flux density provided by the MERLIN inversion tends to be approximately 7-10% larger than that obtained from the MILOS inversion. When MILOS is run with the same scattered light profile and the same magnetic filling factor that are derived with the MERLIN inversion, the radial magnetic flux density derived from the two inversions is almost the same. We attribute the difference in the radial magnetic flux density to different filling factors adopted by the two inversions, based on different assumptions of the scattered light profiles.

Presentation type: Poster

Reproduction of near surface shear layer in the solar convection zone

Hideyuki Hotta

We carried out a high-resolution numerical simulation for the solar convection zone and succeeded in reproducing the near-surface shear layer for the first time. The near-surface shear layer is an interesting layer where the small and large-scale flows and magnetic fields interact. There have been several attempts to reproduce the near-surface shear layer, but it is still difficult to reproduce it. In our unprecedentedly high-resolution simulation, the near-surface shear layer is reproduced. Interesting interactions between flow and magnetic field construct the layer.

Presentation type: Poster

Knowledge transfer from long-term solar microwave data to stellar observations

Masumi Shimojo

Stellar microwave observations are useful for studying stellar activity, but stellar studies with radio observations are not active, except for stellar flare studies based on non-thermal emissions. Although thermal microwave emission from stellar atmospheres is essential for the study of stellar long-term variations, it has not been studied because the detection of the emissions has been challenging due to the small flux for the previous radio telescopes. The state-of-the-art radio interferometers changed the situation. Some authors reported the detection of microwave emissions from thermal plasma in the chromosphere and corona of main-sequence stars. In Japan, total solar fluxes and their circular polarizations have been monitored at 1, 2, 3.75, and 9.4 GHz since the 1950s to the present. Therefore, we investigated the relationships between these long-term and multi-frequency solar data and the other solar activity indices to understand the relationships and apply the knowledge to stellar data. Based on the results, we propose to obtain the information for the stellar magnetic field distribution from the microwave flux and the information for the stellar magnetic field distribution from the microwave flux and its circular polarization degree without spatially resolving the stars. We also show the possibility of predicting the stellar UV emission flux from its microwave flux.

Presentation type: Poster

The Solar flare studies with Solar Magnetic Research Activity Telescope (SMART)

Shin'ichi Nagata, Tomoya Iju, Takako T. Ishii, and Satoru Ueno

The Solar Magnetic Activity Research Telescope (SMART) consists of four refractive telescopes with diameters of 200 mm and 250 mm. Every 12 seconds, full disk spectroscopic measurements of +/-9 angstrom around H-alpha are obtained. Two other partial disk instruments are also carrying out daily observations. One is for the high time cadence continuum and H-alpha imaging, and the other is for photospheric magnetic field measurements. The characteristic of the SMART is that all the instruments utilize the narrow band filters instead of the spectrograph. The data obtained in the daytime are processed during the night and after the visual inspection, those data are opened in a few days. Apart from this visual inspection, almost all the operations are now automated. In this paper, we report the SMART observations system and recent improvements as well as the science highlights.

Presentation type: Poster

SuperDARN - powerful tool for nowcasting / forecasting the ionospheric disturbances

Nozomu Nishitani (ISEE, Nagoya University)

The Super Dual Auroral Radar Network (SuperDARN) is a network of Hgh Frequency (HF) radars located in the high- and mid-latitude ionosphere in both hemispheres. More than 35 SuperDARN radars are operating under the international collaboration of about 10 countries. The mid-latitude SuperDARN radars started operation about 20 years ago and have been monitoring the ionospheric convection dynamics during quiet and disturbed periods, providing information crucial for nowcasting / forecasting the ionospheric disturbances. The SuperDARN Hokkaido Pair of (HOP) radars, operated by ISEE, Nagoya University, are located at the lowest geomagnetic latitude (36.9 degrees) and provide information on ionospheric disturbances, including those of recent massive geomagnetic storms. In this presentation, recent scientific achievements and future perspectives of the SuperDARN, with the main focus of the SuperDARN HOP radars, will be presented.

Presentation type: Poster

Development of an ion energy-mass spectrum analyzer for observations of suprathermal ions originating from the ionosphere

K. Terasawa, K. Asamura, A. Nagatani, Y. Miyoshi

In the inner magnetosphere, oxygen ions, nitrogen ions, and molecular ions flow out from the ionosphere along the Earth's magnetic field lines. These ions, which have energies below several eV in the ionosphere, are heated to tens of eV in the magnetosphere through several mechanisms. However, the details of this mechanism remain unclear. To investigate the mechanisms, we have developed a new suprathermal ion energy-mass spectrum analyzer for the upcoming sounding rocket experiment "LAMP-2" and the future geospace satellite mission "FACTORS". These missions require several key functions in the instrument, including a sensitivity adjustment function and a field-of-view control function The instrument primarily consists of two components: a top-hat type energy-per-charge electrostatic analyzer and a Time-Of-Flight with a linear electric field (LEF-TOF) type mass spectrum analyzer. Numerical simulations demonstrate that our instrument design enables the measurement of mass-discriminated energy spectra of N+ and O+ ions below 10 eV/q. Furthermore, a dedicated electrode system allows sensitivity adjustments over a range of 10000x and provides a field-of-view of ~ 90 degrees. In this poster, we report on the current development status and outline our future plans.

Presentation type: Poster

Variations of He++ Ions in the inner magnetosphere at Different L-Shells: Arase LEP-i Observations

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He++ ions in the inner magnetosphere mainly originate from the solar wind. He++ in the inner magnetosphere can serve as a tracer of solar wind-origin ions. However, since there have been few satellites that continuously observed He++ ions in the inner magnetosphere, the detailed variations of these ions are still not well understood. An ion analyzer LEP-i onboard the Arase satellite has high mass resolution and can discriminate different ion groups, including He++. In this study, we analyzed Time-of-Flight (TOF) data from LEP-i with 10-min time resolution to investigate the long-term variations of He++ ions in the inner magnetosphere as well as their dependence on L-shell, which covers the declining phase of Solar Cycle 24 through the rising phase of Solar Cycle 25. Analyzing the observational data LEP-i/TOF, it was found that He++ ion counts exhibit different long-term variations in the outer region (L >= 4.5) and the inner region (L < 4.5). This suggests that the origin of He++ may differ between the outer and inner regions.Furthermore, unlike previous studies using GEOS, observations by the Arase satellite's LEP-i instrument suggest that He++ counts depend on solar activity and geomagnetic activity.

Presentation type: Poster

Ion injections from the magnetotail during geomagnetic storms observed by Arase

Milla Kalliokoski, Lynn Kistler, Yoshizumi Miyoshi, Kazushi Asamura, Iku Shinohara, Ayako Matsuoka, Shoichiro Yokota, Satoshi Kasahara, Kunihiro Keika, Tomoaki Hori, Mariko Teramoto, Kazuhiro Yamamoto

During geomagnetic storms, energetic ions are injected from the Earth's magnetotail into the plasma sheet boundary layer (PSBL) and the inner magnetosphere. Owing to its off-equatorial, inclined orbit the Arase satellite is in the prime position to observe these injections in the PSBL on the nightside at apogee. Arase can also observe dispersions in pitch angle better than low-latitude satellites. There are two main ion sources into the PSBL: low-energy ($< \sim 1$ keV) ionospheric outflow and high-energy ($> \sim 5$ keV) injections. The injections are observed as energy and pitch angle dispersed features in the Arase LEP-i and MEP-i data. H+ dispersions are common, but O+ dispersions are predominantly seen during storm times. The energy dispersion can be used to estimate the location and timing of the ion injections. Our study of dispersed structures during storms suggests that there are two possible acceleration regions: the near-Earth neutral line above ~20 Earth radii, and dipolarization closer to the Earth at ~10 Earth radii and below. We also discuss the correspondence between H+ and O+ dispersions and injections, and the concurrent plasma waves and ion outflow in the PSBL.

Presentation type: Poster

Systematic Photospheric Magnetic Evolution Prior to Powerful, Eruptive Flares

Prof. Brian T. Welsch (Univ. of Wisc. - Green Bay), Dr. Yang Liu (Stanford University)

Energy released in solar flares and coronal mass ejections (CMEs) is believed to be stored in electric current systems flowing in the solar corona. Because coronal currents cannot be directly measured, their properties are often deduced from proxies, such as measures of photospheric twist derived from vorticity in the photospheric magnetic field. In a sample of 15 eruptive, X-class flares, we find systematic tendencies for some measures of twist to decrease over several hours prior to event onset, an effect which could reveal aspects of pre-eruption coronal evolution, and which could yield predictive capability. In particular, the area containing high-twist pixels decreases; changes in twist tend to occur near polarity inversion lines (PILs) of the photospheric radial magnetic field; and total unsigned vertical flux decreases within areas of significant twist change. Our results are consistent with the Pre-Flare coronal Inflation (PCI) model, which posits that the build-up of magnetic energy in the corona prior to an eruptive flare causes coronal current systems to expand, with subsequent contraction of currents (consistent with the "coronal implosion" model) occurring during the eruptive flare itself. Evidence for pre-eruptive coronal inflation might be also observed via radio or extreme-ultraviolet (EUV) coronal observations.

Presentation type: Poster

SUNRISE III balloon observations of 3D magnetic fields in the solar atmosphere

Y. Katsukawa, S. K. Solanki, A. Korpi-Lagg, P. Bernasconi, J. C. del Toro Iniesta, T. Berkefeld, A. Gandorfer, A. Feller, T. Riethmuller, M. Kubo, H. Hara, T. Shimizu,T. Oba, Y. Kawabata, SUNRISE III team

Magnetic fields in the solar atmosphere are the driving source of hot coronae, solar winds, and flares and are fundamental information as a boundary condition for the heliosphere. Magnetic field extrapolation, such as potential-field or force-free approximation, has been widely used in various studies based on measurements of the surface, i.e., photosphere. Because magnetic structures pervading photosphere-chromosphere-corona drastically change their configuration because of strong atmospheric stratification, it is demanded to directly obtain magnetic fields by an observation. To do it, we need a highly sensitive and broad wavelength spectro-polarimetric observation. One of the projects aiming for it is the SUNRISE III balloon-borne solar telescope, which is the third flight of the international stratospheric balloon project SUNRISE. It carries a 1-meter aperture telescope and provides a unique platform to perform seeing-less observations at UV-Visible-IR wavelengths. The IR instrument SCIP observes many spectral lines including chromospheric and photospheric spectrum lines with an angular resolution of 0.2" which is higher than that of the HINODE Solar Optical Telescope. SUNRISE III conducted a successful 6.5-day flight in July 2024, capturing unprecedented data on the solar atmosphere and magnetic fields for various targets.

Presentation type: Poster

A real-time prediction system of CME arrival and its magnetic field with SUSANOO-CME simulation

Daikou Shiota

The predictions of CME arrival to the Earth and the southward magnetic field brought by the CME flux ropes are one of crucial tasks for space weather forecast. We recently have developed a new prediction system of CME impact (arrival of CME and magnetic field) with MHD simulation SUSANOO-CME (Shiota & Kataoka 2016). The prediction system became available in the space weather forecast operation in August 2022. Based on the real-time observation of flares and CMEs, ensemble simulation can be conducted on the supercomputer in NICT and the results are automatically visualized within 1 hour. The system is design to be operate through a browser and is available to a forecaster who does not have a supercomputer account. In case of emergency for an extremely large flare expected the association of a powerful CME, we can conduct ensemble simulation without CME observation. In the presentation, we introduce overview of the developed system reviewing the results of several powerful CME events such as those of 2024 May storm used in the actual forecast operation, and discuss future directions.

Presentation type: Poster

Space Weather forecasting models for Space Weather events

Tommaso Torda

Solar Energetic Particles (SEPs) and geomagnetic storms are major Space Weather events which require efficient forecasting for ensuring mitigation against their harmful effects for technological systems and humans. We have implemented a machine learning model (Stumpo et al., 2024), based on the Random Forest Regressor algorithm, to forecast SEP events at the Earth by using observations of only energetic electrons. The model can provide a reliable prediction of the >10 MeV proton flux expected at the Earth with an advance of 1 hour (i.e., before an increase of the proton flux is directly measured) by taking as input: the electron flux in four differential channels between 0.25 and 10.40 MeV; their derivatives; the proton derivative in the integral channel between 7-8 and 53 MeV; these nine physical observables multiplied by the two statistical measures (mean and standard deviation). For forecasting geomagnetic storms, we have developed a method based on an Artificial Neural Network (ANN) for making a real-time regression of SYM-H index. We adapted the EDDA (Empirical Dst Data Algorithm) algorithm, developed by Pallocchia et al. (2016), using only magnetic field data, to predict the Sym-H index 1 hour ahead every 20 minutes. We have evaluated both models and have obtained a good performance in both cases. These models will be operating onboard the HEliospheric pioNeer for sOlar and interplanetary threats defeNce (HENON) mission (Provinciali et. al., 2024) to provide alerts for potential harmful Space Weather events with a 10 time improvement in the lead times with respect to current predictions.

Presentation type: Poster

Ion mass estimations with Langmuir probes onboard the Swarm satellites over one complete solar activity cycle

Matthias Förster(1), Johnathan Burchill(2), and Levan Lomidze(2) (1) GFZ Helmholtz Centre for Geosciences, Section 1.1, 14473 Potsdam, Telegrafenberg, Germany (2) Department of Physics and Astronomy, University of Calgary,Calgary, Alberta, Canada

Swarm is a European Space Agency (ESA) three-satellite constellation mission to study the Earth's magnetic field that was launched on November 22, 2013, into near-polar circular orbits at about 500 km altitude. High-precision and high-resolution measurements of the strength, direction and variations of the Earth's magnetic field are complemented by precise navigation, accelerometer and electric field instrument (EFI) measurements onboard the satellites. They provide data for modelling the geomagnetic field and its interaction with other physical aspects of the Earth system, the ionosphere and thermosphere. Two spherical Langmuir probes aboard each of the three Swarm satellites, that are part of the EFI, provide in situ measurements of plasma parameters, which contribute to the study of the ionospheric plasma dynamics. Recently, a novel data product of the Langmuir probe (LP) measurements has been developed, called SLIDEM (Swarm LP Ion Drift and Effective Mass), which yields improved estimates of the plasma density, the along-track ion drift and the effective ion mass along the orbital path. This is done by additional use of the ion current to the faceplate at Swarm's front side. It will be shown, that the measurements of the Langmuir probe alone can result in reliable effective ion mass (m_eff) and accordingly revised plasma density estimations.

Presentation type: Poster

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