The 13th Symposium on Polar Science

15 – 18 November 2022

National Institute of Polar Research
Research Organization of Information and Systems

Session OS

Space and upper atmospheric sciences

Program and Abstracts

Conveners
Ryuho Kataoka, and Mitsumu Ejiri (NIPR)

【OS】Space and upper atmospheric sciences

Scopes

This session covers the solar-terrestrial science related to topics in the polar upper atmosphere, ionosphere and magnetosphere.

Conveners : **Ryuho Kataoka, and Mizuki Fukizawa (NIPR)**

Real-time Oral presentations (09:00 – 12:00, 13:30 – 15:45)

Date: Wed. 16 November

Note: [I] represents an invited talk.

Chair: Mizuki Fukizawa (NIPR)			
OSo1	**9:00 - 9:30**	[I] Formation of Beading Auroral Arcs at Substorm Onset: Outstanding Issues and Observational Constraints on Modeling Their Formation	*Shinichi Ohtani and Tetsuo Motoba (Johns Hopkins University Applied Physics Laboratory)
OSo2	**9:30 - 10:00**	[I] Sensitivity of middle-atmospheric chemistry to energetic particle precipitation	*Antti Kero (University of Oulu)
OSo3	**10:00 - 10:15**	Evaluation of atmospheric ionization by solar X-rays, solar protons, and radiation belt electrons in September 2017 space weather event	*Kiyoka Murase (SOKENDAI), Ryuho Kataoka (NIPR), Takanori Nishiyama (NIPR), Kaoru Sato (University of Tokyo), Masaki Tsutsumi (NIPR), Yoshimasa Tanaka (NIPR), Yasunobu Ogawa (NIPR), Tatsuhiko Sato (JAEA)
OSo4	**10:15 - 10:30**	Thermospheric energy budget during extreme solar storms: Preliminary Results	*Tikemani Bag (NIPR), Yasunobu Ogawa (NIPR)
	10:30 - 10:45	Break	
OSo5	**10:45 - 11:00**	Reconstruction of precipitating electrons and three-dimensional structure of a pulsating auroral patch from monochromatic auroral images	*Mizuki Fukizawa (NIPR), Takeshi Sakanoi (Tohoku University), Yoshimasa Tanaka (NIPR), Yasunobu Ogawa (NIPR), Keisuke Hosokawa, (UEC), Björn Gustavsson (UiT), Kirsti Kauristie (FMI), Alexander Kozlovsky (SGO), Tero Raita (SGO), Urban Brändström (IRF), Tima Sergienko (IRF)
OSo6	**11:00 - 11:15**	Simulation study of darkening of the pulsating aurora by large amplitude chorus waves	*Kazuteru Takahashi (Nagoya University), Shinji Saito (NICT), Yoshizumi Miyoshi (Nagoya University), Kazushi Asamura (ISAS), Keisuke Hosokawa (UEC)
OSo7	**11:15 - 11:30**	Unified theory of the arc auroras: formation mechanism of the arc auroras conforming general principles of convection and FAC generation	*Takashi Tanaka (Kyushu University)
OSo8	**11:30 - 11:45**	Plasma transport across the magnetopause of the magnetotail in the magnetic field topology of the null-separator structure	*Shigeru Fujita (ROIS), Takashi Tanaka (Kyushu University)

OSo9	**11:45 - 12:00**	Toward a reanalysis of the magnetosphere-ionosphere system with a global magneto-hydrodynamic model	*Shin'ya Nakano (Center for Data Assimilation Research and Applications, Joint Support Center for Data Science Research), Shigeru Fujita (Center for Data Assimilation Research and Applications, Joint Support Center for Data Science Research), Akira Kadokura (Polar Environment Data Science Center, Joint Support Center for Data Science Research), Yoshimasa Tanaka (Polar Environment Data Science Center, Joint Support Center for Data Science Research), Ryuho Kataoka (NIPR), Aoi Nakamizo (NICT), Keisuke Hosokawa (UEC), Satoko Saita (National Institute of Technology, Kitakyushu College)
Lunch			
Chair: Ryuho Kataoka (NIPR)			
OSo10	**13:00 - 13:15**	Antarctic large area network observation of auroral phenomena using unmanned system: Event studies of multi-point simultaneous observations	*Akira Kadokura (Research Organization of Information and Systems), Yasunobu Ogawa (NIPR), Yoshimasa Tanaka (ROIS-DS/NIPR), Hisao Yamagishi (NIPR), Masaki Okada (NIPR), Ryuho Kataoka (NIPR), Yuichi Otsuka (Nagoya University), Henri Robert (International Polar Foundation), Gopi K. Seemala (Indian Institute of Geomagnetism)
OSo11	**13:15 - 13:30**	Big data publishing of high-speed auroral imagers	*Ryuho Kataoka (NIPR), Satoshi Kurita (Kyoto University), Keisuke Hosokawa (UEC), Herbert Akihito Uchida (NIPR), Yasunobu Ogawa (NIPR), Mizuki Fukizawa (NIPR), Kiyoka Murase (NIPR), Yoshimasa Tanaka (NIPR)
OSo12	**13:30 - 13:45**	Development of new multi-wavelength all-sky imagers for observation of polar cap aurora	*Hiroyasu Kondo (Tohoku University), Takeshi Sakanoi (Tohoku University), Masato Kagitani (Tohoku University), Ryuho Kataoka (NIPR), Yoshimasa Tanaka (NIPR), Yasunobu Ogawa (NIPR), Takanori Nishiyama (NIPR), Kiyoka Murase (NIPR), Keisuke Hosokawa (UEC), Yoshizumi Miyoshi (Nagoya University), Yusuke Ebihara (Kyoto University), Saki Yamashina (Kyoto University), Yuta Hozumi (NICT)
	13:45 - 14:00	Break	
OSo13	**14:00 - 14:15**	The AMIDER database: a cross-disciplinary platform for the polar science	*Masayoshi Kozai (ROIS-DS), Yoshimasa Tanaka (ROIS-DS), Shuji Abe (Kyushu University), Yasuyuki Minamiyama (NII), Atsuki Shinbori (Nagoya University)
OSo14	**14:15 - 14:30**	Anisotropic cosmic ray decrease in September 12, 2017 observed with Global Muon Detector Network	*Yuki Hayashi (Shinshu University), Chihiro Kato (Shinshu University), Ryuho Kataoka (NIPR), Masayoshi Kozai (ROIS-DS), Akira Kadokura (Joint Support-Center for Data Science Reasearch Organization of Information and Systems), Syoko Miyake (National Institute of Technology, Ibaraki College), Kiyoka Murase (SOKENDAI), Kazuoki Munakata (Sinshu University)
OSo15	**14:30 - 14:45**	Large amplitude bidirectional anisotropy of cosmic-ray intensity observed in November, 2021	*Kazuoki Munakata (Shinshu University)
	14:45 - 15:00	Break	

OSo16	**15:00 - 15:15**	Atmospheric Electric Field variation at Syowa Station Associated with Auroral Activity	*Yasuhiro Minamoto (Mount Fuji Research Station), Akira Kadokura (Joint Support-Center for Data Science Research, Research Organization of Information and Systems), Masashi Kamogawa (University of Shizuoka), Yoshimasa Tanaka (ROIS-DS), Mitsuteru Sato (Hokkaido University)
OSo12	**15:15 - 15:45**	[I] Effects of Electric fields on Magnetosphere-Ionosphere system during space weather events: Recent developments	*Diptiranjan Rout (GFZ German Research Centre for Geosciences, Potsdam, Germany)
Chair: Ryuho Kataoka and Mizuki Fukizawa (NIPR)			
	16:00 - 16:15	3-minute poster appeal (1-6 short talks of OSp1 – OSp6)	
	16:15 - 17:30	Poster session core time	

Real-time Poster presentations (16:00 – 17:30)

Date: Wed. 16 November

OSp1	EISCAT_3D and Japan's Activities	*Yasunobu Ogawa (NIPR, & SOKENDAI), Hiroshi Miyaoka (NIPR), Satonori Nozawa(Nagoya University), Taishi Hashinmoto (NIPR & SOKENDAI), Shin-ichiro Oyama(Nagoya University), Koji Nishimura(Kyoto University), Takuo Tsuda (UEC), Hitoshi Fujiwara (Seikei University), Masaki Tsutsumi (NIPR, & SOKENDAI), Yoshimasa Tanaka (NIPR, & SOKENDAI), Takanori Nishiyama (NIPR, & SOKENDAI), Mizuki Fukizawa (NIPR), Takuji Nakamura (NIPR, & SOKENDAI), Ryoichi Fujii (ROIS), Heinselman Craig (EISCAT Scientific Association)
OSp2	Estimation of precipitating electron energy characteristics of the Omega band aurora by two-wavelength optical measurements	*Yudai Morii (Nagoya University), Yoshizumi Miyoshi (Nagoya University), Satoshi Kurita (Kyoto University), Keisuke Hosokawa (UEC), Shin-ichiro Oyama (Nagoya University), Yasunobu Ogawa (NIPR), Shinji Saito (National Institute of Information and Communications Technology), Kazushi Asamura (ISAS)
OSp3	Relationship between energy of pulsating auroral electrons and duct propagation of chorus wave: simultaneous observations with EISCAT radar, ground-based all-sky imagers, and Arase satellite	*Yuri Ito (UEC), Keisuke Hosokawa (UEC), Yasunobu Ogawa (NIPR), Yoshizumi Miyoshi (Nagoya University), Mizuki Fukizawa (NIPR), Kiyoka Murase (NIPR), Shin-ichiro Oyama (Nagoya University), Satoko Nakamura (Nagoya University), Yoshiya Kasahara (Kanazawa University), Shoya Matsuda (Kanazawa University), Satoshi Kasahara (University of Tokyo), Yoichi Kazama (Academia Sinica), Tomoaki Hori (Nagoya University), Shoichiro Yokota (Osaka University), Kunihiro Keika (University of Tokyo), Shiang-Yu Wang (Academia Sinica), Sunny Tam (NCKU), Iku Shinohara (ISAS)

OSp4	SENSU SuperDARN radars essential improvement for future monitoring observation	*Akira Sessai Yukimatu (NIPR/SOKENDAI), Nozomu Nishitani (Nagoya University), Tomo Hori (Nagoya University), Keisuke Hosokawa (UEC), Masakazu Watanabe (Kyushu University), Hideaki Kawano (Kyushu University), Yusuke Ebihara (Kyoto University), Ryuho Kataoka (NIPR/SOKENDAI), Yoshimasa Tanaka (NIPR/ROIS-DS/SOKENDAI), Natsuo Sato (NIPR), Yuka Kadowaki (ROIS-DS/PEDSC)
OSp5	Reinterpreting “polar cap bifurcation” reproduced by magnetohydrodynamic simulations	*Masakazu Watanabe (Kyushu University), Dongsheng Cai (University of Tsukuba), Peikun Xiong (University of Tsukuba), Shigeru Fujita (ROIS), Takashi Tanaka (Kyushu University)
OSp6	Precipitation of high-energy electrons into the mesosphere associated with pulsating aurorae: Arase and EISCAT conjugate observations	*Yuya Obayashi (Nagoya University), Yoshizumi Miyoshi (Nagoya University), Kazuteru Takahashi (Nagoya University), Shinji Saito (National Institute of Information and Communications Technology), Satoko Nakamura (Nagoya University), Keisuke Hosokawa (UEC), Yasunobu Ogawa (NIPR), Shinichiro Oyama (Nagoya University), Kazushi Asamura (ISAS), Satoshi Kurita (Kyoto University), Yoshiya Kasahara (Kanazawa University), Shoya Matsuda (Kanazawa University), Fuminori Tsuchiya (Tohoku University), Atsushi Kumamoto (Tohoku University), Ayako Matsuoka (Kyoto University), Iku Shinohara (ISAS)

Formation of Beading Auroral Arcs at Substorm Onset: Outstanding Issues and Observational Constraints on Modeling Their Formation

Shinichi Ohtani & Tetsuo Motoba
Johns Hopkins University Applied Physics Laboratory

The onset of auroral substorms, that is, the initial brightening of an onset arc, often takes place along with the formation of longitudinally periodic auroral structures. They are called "auroral beads" or "beading auroral arcs" especially if bright auroral rays are isolated. Their formation is often discussed in the context of substorm initiation. One popular idea is that auroral beads are an auroral manifestation of an instability in the plasma sheet that has a periodic structure in the dawn-dusk direction. Ballooning-type instabilities are such candidate processes. Another possibility is the ionospheric feedback instability, which is driven by the spatial gradient of ionospheric conductance in the presence of convection electric field. The feedback instability is often discussed for explaining the formation of auroral arcs, but it also creates a longitudinal periodic structure along auroral arcs if the wave vector has a component perpendicular to the conductance gradient. At present it is still controversial whether the formation of auroral beads is magnetospheric or ionospheric, and the answer to this question could impact our overall understanding of the substorm initiation process.

In this study we examine ground ASI observations of auroral beads, and address five aspects of their development and propagation, which have been widely overlooked but are potentially critical for understanding their formation process. The results are summarized as follows: (1) the expansion and propagation of auroral beads do not depend on whether they form in the east or west of a preceding equatorward flow; (2) Auroral beads propagate either eastward or westward when the westward auroral electrojet intensifies without any preceding approach of an equatorward flow in neighboring sectors; (3) A nearby arc does not seem to be affected even if auroral beads form only a few tenths of degree apart in latitude; (4) two wavy arcs occasionally form next to each other and propagate in different directions; (5) the evolution of beading arcs is not always conjugate in two hemispheres. Results 1 and 2 suggest that meso- or large-scale ionospheric convection as inferred from ground magnetic disturbances does not regulate the development and propagation of auroral beads. Results 3 and 4 imply that the development of auroral beads can be attributed to a small-scale process, possibly a convection flow, at a latitudinal scale of a few tenths of degree or less. Such a small-scale process may not be conjugate in two hemispheres, which potentially explains Result 5. These results do not necessarily mean that the cause of auroral beads is ionospheric, but strongly suggest that the magnetosphere-ionosphere coupling plays an important role in their development.

Sensitivity of middle-atmospheric chemistry to energetic particle precipitation

Antti Kero[1]
[1]*Sodankylä Geophysical Observatory/University of Oulu, Finland*

There is plenty of evidence that the energetic particle precipitation (EPP) can significantly modulate the middle-atmospheric ozone related chemistry, and possibly alter the global atmospheric circulation, via ionic production of minor species such as odd hydrogen HOx (H, OH and HO2) and odd nitrogen NOx (N, NO and NO2).

In this presentation, the response of the HOx and NOx chemistry to the EPP forcing is studied by using the Sodankylä Ion and neutral Model (SIC) in terms of ionisation rate and duration. In particular, a lower limit for the particle forcing to have a noticeable chemical impact at different altitudes is estimated. As this limit also directly links to the electron density caused by the ionisation, this survey enables a direct comparison to the EISCAT and EISCAT_3D datasets, i.e., are the electron densities (observed during some events) high enough to expect any chemical changes?

Evaluation of atmospheric ionization by solar X-rays, solar protons, and radiation belt electrons in September 2017 space weather event

Kiyoka Murase[1,2], Ryuho Kataoka[1,2], Takanori Nishiyama[1,2], Kaoru Sato[3], Masaki Tsutsumi[1,2], Yoshimasa Tanaka[1,2], Yasunobu Ogawa[1,2], Tatsuhiko Sato[4]

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[2]*NIPR*

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On September 11, 2017, when the solar proton flux peaked at the geostationary orbit, the PANSY radar at Syowa Station observed mesospheric echoes at 42 km, the lowest altitude ever observed. The estimated ionization rate by PHITS (Particle and Heavy Ion Transport code System) air-shower simulation with the proton flux obtained by the GOES satellite peaked at ~40 km, suggesting that the echo power is enhanced by the increase in electron density due to proton precipitation. The intensity of cosmic noise absorption (CNA) from the resultant ionization rate was ~2.8 dB, which consistently explains the maximum intensity of observed CNA level of ~3.0 dB. Further, we used the X-ray flux observed by the GOES satellite as the input data for PHITS to estimate the electron density enhancements as observed by the EISCAT radar at Tromso, Norway due to the two X-class flare events at ~9 and ~12 UT on September 6. Obtained density profiles and the time sequence are roughly consistent with the observed EISCAT data, within the error of a factor of two. In this presentation, other events will also be presented to test whether ionization in the D region is dominated by X-rays during solar flares. At ~1345 UT on September 6, a transient low-altitude PANSY echo at <50 km and CNA spike (~2.0 dB) were accompanied by Pc1 geomagnetic pulsations, which can be a dayside relativistic electron precipitation event associated with EMIC waves. The ionization rate due to the energetic electrons is also evaluated by PHITS with the inputs from NOAA MEPED electron data, and the observed CNA level of ~2.0 dB can be reproduced by the contribution of sub-MeV electrons. We conclude that the September 2017 space weather event with the cutting-edge space-borne and ground-based observations provides a rare opportunity to cross-validate the use of PHITS simulation with different types of inputs (X-rays, protons, and electrons) to evaluate the atmospheric ionization.

Thermospheric energy budget during extreme solar storms: Preliminary Results

Tikemani Bag[1,*] and Y. Ogawa[1]

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Abstract:

The geomagnetic storm is the manifestation of the solar wind-magnetosphere interaction. It deposits enormous amount of energy into Earth's magnetosphere-ionosphere-thermosphere (MIT) system subsequently creating global perturbations in the density, temperature as well as in the chemical and dynamical processes. The NO-5.3 µm radiative emissions as observed by the SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) instrument onboard the NASA's TIMED (Thermosphere Ionosphere Mesosphere Energetics Dynamics) satellite and the NCAR TIEGCM (Thermosphere-Ionosphere-Electrodynamics General Circulation Model) simulation are utilized to investigate the response of the thermospheric energy budget during extreme solar storms observed in the space era. We empirically calculate the Thermospheric Climate Index (TCI) using geomagnetic parameters and explore the possible correlation and cross-correlation between the radiative cooling flux, TCI and energy propagation within the MIT system. In addition, the fractional contribution of magnetospheric energy input into the thermospheric energy is investigated during these extreme storm events.

Reconstruction of precipitating electrons and three-dimensional structure of a pulsating auroral patch from monochromatic auroral images

Mizuki Fukizawa[1], Takeshi Sakanoi[2], Yoshimasa Tanaka[1, 3, 4], Yasunobu Ogawa[1, 3, 4], Keisuke Hosokawa[5], Björn Gustavsson[6], Kirsti Kauristie[7], Alexander Kozlovsky[8], Tero Raita[8], Urban Brändström[9], Tima Sergienko[9]
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[8]Sodankylä Geophysical Observatory, University of Oulu, Oulu, Finland
[9]IRF-Swedish Institute of Space Physics, Kiruna, Sweden

This study is published as Fukizawa et al. (2022). Aurora Computed Tomography (ACT) is an inversion analysis method to reconstruct the three-dimensional (3-D) structure of auroral luminosity using multipoint monochromatic auroral images. The ACT method has been applied to discrete auroras. On the other hand, the reconstruction of pulsating aurora (PsA) patches has not been reported since it is difficult to apply ACT to PsA patches due to low signal-to-noise ratio (SNR) of PsA images. In this study, we reconstructed the 3-D volume emission rate (VER) by improving the ACT method and using high-sensitive cameras. The two-dimensional horizontal distribution of precipitating electrons in PsA patches was also reconstructed. The reconstruction accuracy was evaluated using a model aurora and the EISCAT radar.
The characteristic energy of the reconstructed precipitating electron flux ranges from 6 keV to 23 keV and the peak altitude of the reconstructed VER ranges from 90 to 104 km. These results are consistent with previous studies. We found that the horizontal distribution of precipitating electron's characteristic energy was neither uniform nor stable in the PsA patch during the pulsation. The observed spatial temporal variations of PsAs are important to understand the background magnetic field and plasma conditions in the magnetospheric source region.
To quantitively evaluated the reconstruction results from the observed auroral images, we compared them with those from pseudo auroral images. We confirmed that the center part of the PsA patch was correctly reconstructed. In addition, we converted the VER to the electron density to compare with the electron density observed by the EISCAT radar. Considering the time derivative term in the electron continuity equation, the electron density was reconstructed with sufficient accuracy even when the PsA intensity decreased from ~1 kR to ~0.1 kR. If the time derivative term is not considered, the electron density rapidly decreases as the PsA intensity decreases. This result suggests that the time derivative term should be considered when we derive the electron density associated with PsAs from the continuity equation.

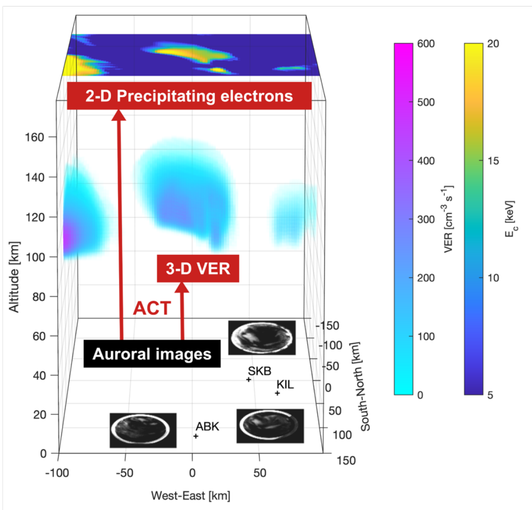

Figure 1. The 2-D characteristic energy (*Ec*) of precipitating electron flux and 3-D volume emission rate (VER) reconstructed from monochromatic auroral images from Abisko (ABK), Kilpisjärvi (KIL), and Skibotn (SKB).

References

Fukizawa, M., Sakanoi, T., Tanaka, Y., Ogawa, Y., Hosokawa, K., Gustavsson, B., Kauristie, K., Kozlovsky, A., Raita, T., Brandstrom, U. and Sergienko, T.: Reconstruction of Precipitating Electrons and Three-Dimensional Structure of a Pulsating Auroral Patch from Monochromatic Auroral Images Obtained from Multiple Observation Points, Ann. Geophys., 40, 475–484, doi:10.5194/angeo-40-475-2022, 2022.

Simulation study of darkening of the pulsating aurora by large amplitude chorus waves

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Kazushi Asamura (3), Keisuke Hosokawa (4)
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(2) National Institute of Information and Communications Technology,
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The Pulsating aurora is a type of diffuse aurora, and pulsation periods are several seconds - several tens of seconds. The amplitudes of the optical emissions should be proportional to the downward energy flux inside the loss cone, so it is natural to consider that that optical emission increases when the wave amplitudes increase if we consider the quasi-linear process. Recent observations indicated that the non-linear wave-particle interactions are essential to cause the pulsating aurora, and it is expected that the relationship between the optical emissions and wave amplitude is not always simple as expected from the quasi-linear theory. For example, the phase-trapping effect may suppress the precipitation flux if the wave amplitudes increase. In order to investigate how the precipitation flux changes with the amplitudes of chorus waves, we conduct a test-particle simulation about chorus wave-particle interactions using GEMSIS-RBW (Saito+, 2012). Besides non-linear wave-particle interaction processes, stochastic differential equations that is equivalent to the Fokker-Planck equation are included to realize stable background precipitations as like the quasi-linear process. Using the simulated precipitating electron flux from the test-particle simulation, we calculate the optical emissions at different wavelength at the ionospheric altitudes. From the simulations, we found that both the intermittent precipitations by chorus wave particle interactions and steady precipitations by quasi-linear process are suppressed when chorus amplitude increases, which are not expected from the quasi-linear process.

Unified theory of the arc auroras: formation mechanism of the arc auroras conforming general principles of convection and FAC generation

T. Tanaka[1]
[1]*Kyushu University*

The arc aurora can be considered as the visualization of the field-aligned current (FAC). In various cases, the numerically reproduced FAC morphologically matches well with that of the observed arc aurora. Such example can be seen in the sun-aligned arc, the fan arc, and the theta aurora under the northward interplanetary magnetic field (IMF), and the substorm, the quiet arc, and the initial brightening under the southward IMF. The FAC reproduced by the global simulation is based on the general principle of the magnetohydrodynamic (MHD). In such general principle, the FAC is transmission of net charge, net charge is divE, and E is equivalent to motion. After all, the FAC is transmission of convection motion. In order to transmit the FAC to the dissipative ionosphere based on the MHD, formations of the dynamo and shear that leads from the magnetosphere to the ionosphere are essential. The dynamo and shear are reproduced so as to properly match with each convection structure. The comparison under various magnetospheric topologies between the global simulation and the arc aurora observation indicates that the arc aurora and the FAC occurs inevitably controlled by convection structure. Such a principle of the FAC and convection holds even for the onset FAC.

References

Tanaka, T., Y. Ebihara, M. Watanabe, S. Fujita, N. Nishitani, and R. Kataoka (2022). Unified theory of the arc auroras: formation mechanism of the arc auroras conforming general principles of convection and FAC generation, Journal of Geophysical Research: Space Physics, 127, 2022JA030403.

Plasma transport across the magnetopause of the magnetotail in the magnetic field topology of the null-separator structure

Shigeru Fujita[1,2]
[1] *Joint Support-Center for Data Science Research, ROIS*
[2] *The Institute of Statistical Mathematics, ROIS*

The null-separator structure (Watanabe et al., 2010) gives a fundamental structure of the magnetic field in the solar wind-magnetosphere system. When the plasma effect is ignored, the null-separator structure is characterized by the boundary surface of the four magnetic field regimes, say, the interplanetary magnetic field (IMF), the open magnetic field lines with the foot points in the northern ionosphere, the open ones from the southern ionosphere, and the closed magnetic field lines. Figure 1(a) shows the boundary surfaces (Σ_A and Σ_B) for the northward IMF condition. The magnetic field lines merge at the null points, A and B. The four magnetic field regimes share the separator lines that connect the two null points. It is characteristic that Σ_A and Σ_B form a tube extending into the solar wind region. We now develop a tool that automatically draws the boundary surfaces from the numerical outputs of the global MHD simulation as shown in Fig. 1 (b) and (c). Figures 1(b) and (c) show the IMF-open field boundary part of Σ_A seen from the Sun and 18hMLT, respectively. It is noted that a long slot extending along the magnetotail appears. This structure is a remnant of the tube in Fig. 1(a). Plasmas can be transported across the magnetopause through this slot.

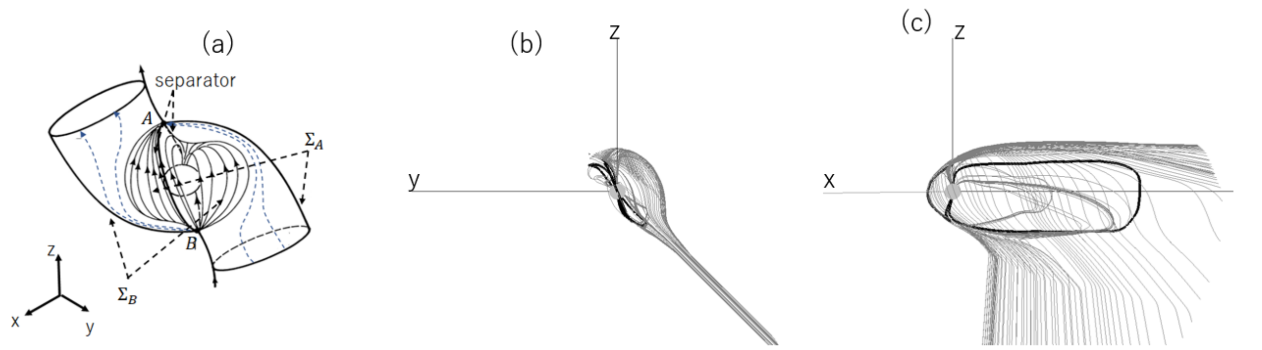

Figure 1. (a) null-separator structure of the vacuum field. Σ_A and Σ_B are the bounray surfaces of the magnetic field regimes. (b) and (c) IMF-open field boundary part of Σ_A seen from the Sun and 18hMLT, respectively.

Let us consider the role of the slot in the magnetotail. Figure 2 shows the plasma pressure, convection flow vectors, and the IMF-open field part of Σ_A at x~-32Re. As the slot is a pathway between the magnetotail and the solar wind, the plasmas enter the tail from the solar wind as shown in Figure 2. In addition, there appears plasma pressure plume in the slot region. A similar plasma structure is found by Ebihara and Tanaka (2016). They explained this structure by the interchange instability and the ionospheric feedback. In addition to the mechanism, the plasma entry from the solar wind through the slot plays an important role in forming the plasma plume. Furthermore, we notice the plasma flow shear appears in the slot region. That is to say, the shea motion indicates the FAC. This FAC may

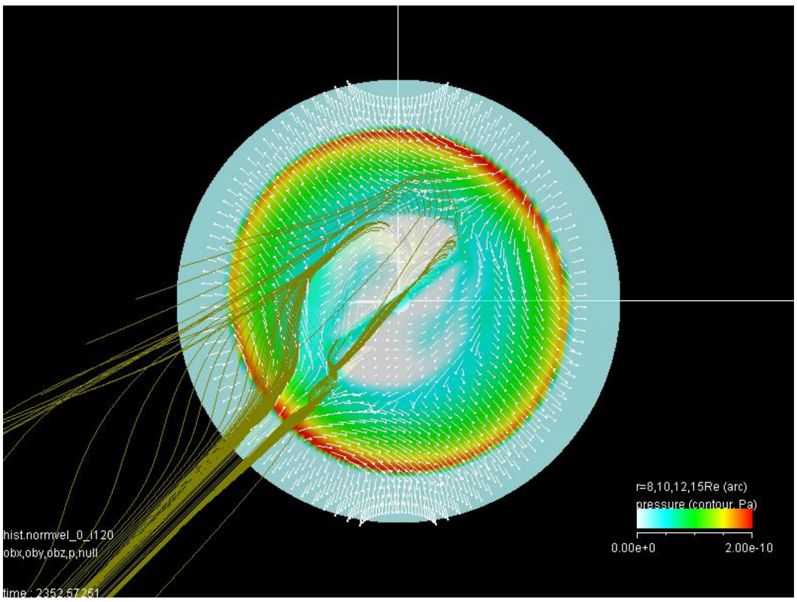

Figure 2. plasma pressure (shading), convection (white arrows), and IMF-open field boundary part of Σ_A (yellow curves) at x~-32Re

be associated with the sun-aligned arc [Tanaka et al., 2017].

References

Ebihara, Y., and T. Tanaka (2016), Substorm simulation: Quiet and N-S arcs preceding auroral breakup, *J. Geophys. Res. Space Physics*, 121, 1201-1218, doi:10.1002/2015JA021831.
Tanaka, T., T. Obara, M. Watanabe, S. Fujita Y. Ebihara, and R. Kataoka (2017), Formation of the Sun-aligned arc region and the void (polar slot) under the null-separator structure, *Journal of Geophysical Research: Space Physics*, 122, doi:10.1002/2016JA023584.
Watanabe, M., K. Kabin, G. J. Sofko, R. Rankin, T. I. Gombosi, and A. J. Ridley (2010), Dipole tilt effects on the magnetosphere-ionosphere convection system during interplanetary magnetic field BY-dominated periods: MHD modeling, *J. Geophys. Res.*, 115, A07218, doi:10.1029/2009JA014910

Toward a reanalysis of the magnetosphere-ionosphere system with a global magneto-hydrodynamic model

Shin'ya Nakano*[1,2,3], Shigeru Fujita[1,2], Akira Kadokura[4,5,3], Yoshimasa Tanaka[4,5,3], Ryuho Kataoka[5,3], Aoi Nakamizo[6], Keisuke Hosokawa[7], and Satoko Saita[8]

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One fundamental difficulty in studying the magnetosphre and ionosphere is the shortage of observations. Since the available observations are limited, it is a hard task to obtain a global picture of the system. Meanwhile, recent global magneto-hydrodynamic (MHD) models enable to successfully simulate various observed phenomena in the magnetosphere and the ionosphere. The temporal evolution of the system in a real event can well be reproduced with a time series of solar-wind variables as an input. Moreover, data assimilation into a model is potentially useful for improving accuracy of the model output.

We are conducting a research project which aims to realistically reproduce the magnetosphere-ionosphere system using a global MHD model for the comparison with real observations. This project is supported by Research Organization of Information and Systems (ROIS) under Challenge Exploratory Research Projects for the Future. First, the global MHD model has been improved to consider the deviation of the Earth's magnetic axis from the rotation axis to facilitate the comparison with the observations. Second, the values of some parameters have been optimized by data assimilation. We are planning to provide the data assimilation products as an open reanalysis data set to the community under the framework of IUGONET supported by Polar Environment Data Science Center, Joint Support Center for Data Science Research, ROIS in the future.

In the presentation, we will demonstrate a result of data assimilation for improving the parameter values of the MHD model. The future prospects of the project will also be discussed.

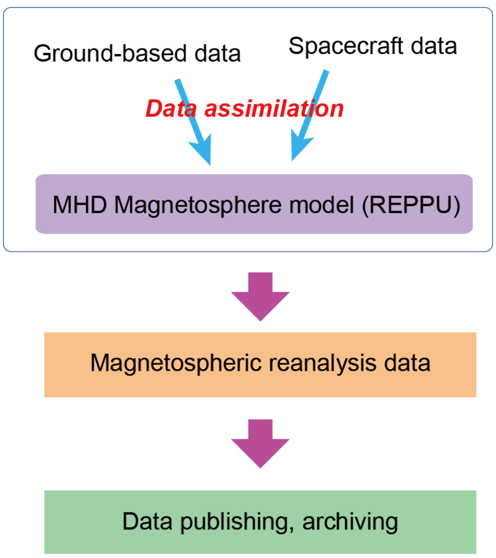

Figure 1. Overview of our research project

Antarctic large area network observation of auroral phenomena using unmanned system: Event studies of multi-point simultaneous observations

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Space and upper atmospheric sciences group in the National Institute of Polar Research (NIPR) is now constructing an observation network for auroral phenomena along the coast of the Dronning Maud Land in the Antarctica including Japanese Syowa Station (SYO), and has developed a Unmanned Auroral Observation system (UAO), which is equipped with a 3-axis fluxgate magnetometer, all-sky auroral imager, GNSS/TEC receiver, and a data communication system using the Inmarsat satellite data link with a low power consumption. The first UAO (UAO-1) had been installed at Amundsen Bay area (AMB), which is located about 500 km eastward from Syowa Station, in February, 2017 in the summer operation of the 58th Japanese Antarctic Research Expedition (JARE-58). The second UAO (UAO-2) had been installed at Belgium Princess Elisabeth Antarctica Station (PEA) in January, 2020. Electric power of the UAO-1 is supplied by a hybrid natural energy electric generation system which consists of three sets of 192W wind generators and 8 sets of 62W solar panels, while that of the UAO-2 is supplied from the AC power source of the PEA Station which is generated by a power generation system of the station using nine big wind generators and solar panels. For the UAO, observed magnetometer data (1 sec resolution), GNSS BINEX data (30 sec resolution), daily Keogram and sample image data of the auroral imager, and House Keeping data (temperatures and power voltages) (1 min resolution) are transmitted at every 1 hour via the satellite link system to a server in Japan by FTP, and auroral image data of 1 sec resolution are stored in a memory card of the video encoder in the system. Sample interval and pixel resolution of the transmitted auroral image data are 1 hour (5 minutes) and 640x480 (160x120) for the UAO-1 (UAO-2), respectively. UAO-2 has the other USB memory in the system which can store auroral still image of 1 sec resolution with 640x480 pixel resolution and GNSS BINEX data of 1 sec resolution. PEA Station is maintained during summer season, and becomes an unmanned station during winter season, while the electric power to all the instruments at the station is supplied continuously all through the season. In January, 2020, we had also installed an auroral imager system at Indian Maitri Station (MAI), which consists of four sets of all-sky imager using Watec cameras: 1) Panchromatic (color) ; 2) Panchromatic (black&white); 3) filtered at 560nm (FWHM:10nm); 4) filtered at 632nm (FWHM:10nm), respectively. Maitri is a year-round station. The auroral imager system is run autonomously. We ask expedition members at Maitri to send daily summary files via E-mail to us. We could obtain the simultaneous observation data at those four staions, MAI, PEA, SYO and AMB, on several nights in 2020. In our presentation, we will show some results of the event studies on those nights.

Big data publishing of high-speed auroral imagers

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The original data size of ground-based high-speed auroral imagers (HAI) at Syowa Station (2017-2022) and the conjugate Tjornes Station (2017-2019) became more than petabyte. We are solving an issue how to publish the big data for accelerating the open science. HAI data consists of 256 by 256 pixels, the depth is 1 byte, sampling rate of 100 Hz (hundred monochromatic all-sky images are obtained in 1 s). Approximate data size for a single day can therefore be >100 GB. We are making 0.1 s resolution CDF data for each min, with mapping tables for geographical transformation. The data size is reasonable for analysis, 45 MB for every 1 min CDF file. We are preparing to publish the CDF dataset via IUGONET framework, and to get the DOI for reference. In this presentation we will briefly demonstrate how to read and analyze the CDF data, including the geographical mapping, for pulsating auroras.

Development of new multi-wavelength all-sky imagers for observation of polar cap aurora

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We are developing a camera system to observe the polar cap aurora as a part of the phase X Priority Research program of the NIPR. The period of phase-X (FY2022-2027) involves the solar maximum, and we expect to obtain sufficient data at high-latitude Antarctic region. The main purpose of this program is to understand how the Earth's environment is an open system to space. There have been few observations in the polar cap region because of limited observational places, and only a limited number of large space weather events such as solar proton events (SEP) have been reported. The polar cap region is particularly important since the direct interaction between the solar wind and atmosphere happened in by precipitating electrons and ions in a wide energy range from hundreds eV (typical solar wind) to MeV (SEP). SEP causes the ionization in the middle atmosphere and induce chemical processes including O3, HOx, and NOx, and may change temperature structure.

To estimate the energy of precipitating particles, it is essential to observe auroras at multiple wavelengths. Our auroral camera systems will be installed in automated stations over Antarctic polar region during the phase X, and there are a variety of development items such as isolated long-term monitoring system, power-saving multi-wavelength cameras, power, insulation box, etc.

To check the functions of our camera system, this year we plan to install four all-sky monochromatic imagers in the Syowa station as a part of the JARE 64, and also install two camera system at Longyearbyen, Svalbard. The wavelengths of the Syowa station system are N2+ 391.4 nm, O 557.7 nm, O 630.0 nm, N2 670.0 nm. The exposure time for the cameras of 391.4 nm and 630.0 nm is 18 sec with a cadence of 20 sec, and that for the cameras of 557.7 nm, 670.0 nm is sampled with up to ~10 Hz. The wavelengths of the Longyearbyen system are N2+ 391.4 nm and O 630.0 nm, and the exposure is 18 sec with a cadence of 20 sec.

The camera system consists of CMOS sensor (ZWO ASI183MM Pro), fisheye lens (Fujinon FE185C086HA, f=2.7 mm, F/1.8) and bandpass optical filter made of Andover. The filter is equipped between the lens and sensor to minimize the whole optical system. The cameras are controlled by small PCs (ESC LIVA-Q2 and LIVA-Z2, OS: Linux Ubuntu). Each PC is designed to control one camera, and all of the cameras are operated at simultaneous PC timings. The imaging schedule is based on a software whose start and end times are automatically generated every day. The imaging program uses a ZWO's library as a module, and automatic operation is performed based on the imaging schedule. The data are stored on a NAS (Synology) with a mode of RAID-1 (mirroring) via network. The LIVA PCs, NAS and router are powered by an internet switch (Watchboot). Watchboot is capable of ping monitoring via the internet, and when there is no response from the PC and so on, power turns off and on to recover. To check the camera system remotely, we make thumbnail images for the quick-look plot. The system will also be rebooted automatically when problem happens in the camera system. If the PC freezes, the ping monitoring will detect the problem and temporarily cut off the power supply, allowing the system to reboot.

Currently, all of the development was done, and we are ready to ship them. The Syowa system will depart Japan in this November and install at the Syowa station by the members of JARE64. Automatic four-wavelength auroral all-sky imaging will start in the next winter season, and these data will be brought back to Japan by JARE65. For the Longyearbyen cameras, we will install them at the observatory (KHO) in this November, and we expect to transfer most data via internet and bring the data back in next spring or summer. In addition, next year we plan to install similar camera system at the South Pole, and develop isolated inland system with a power-saving camera electronics, power, insulation box for unmanned observatories which is the key of phase X program.

The AMIDER database: a cross-disciplinary platform for the polar science

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The Polar Environment Data Science Center (PEDSC) of the Joint Support-Center for Data Science Research (DS), Research Organization of Information and Systems (ROIS), aims to promote the publication and use of scientific data obtained from research activities of the polar science community. One of the key pillars of PEDSC is the development of a cross-disciplinary database, AMIDER. The AMIDER project aims to establish a new database for demonstrating and proposing a new model toward a next-generation data-science platform.

In the AMIDER project, we are promoting a zero-base review of the database system and can implement a new design or approach with minimized interference to the existing system. We developed a uniform and user-friendly interface based on popular services such as an e-commerce site. It will invite non-specialized users such as educators, students, and researchers interested in connecting to broad scientific fields. The database provides a function to propose relationships between datasets in diverse scientific fields. A walk-around experience between datasets induced by this function will support researchers in discovering an unexpected idea for cross-disciplinary research. We are also planning to collaborate with NII RDC (Research Data Cloud) as one of the future extensions of the AMIDER system.

The platform for upper atmospheric science, IUGONET, is one of the successful projects promoting cross-disciplinary data science. AMIDER project started with core members of the IUGONET. Its basic programs, data standardization (metadata schema and raw-data format), and know-how have been provided. The datasets provided by IUGONET form one of the main contents of AMIDER.

The AMIDER database is scheduled to start a test operation this fiscal year. Further optimization will be made based on the results of the test operation, and we will prepare for the public release in 2023. In this presentation, we report on the concept and design of the AMIDER database.

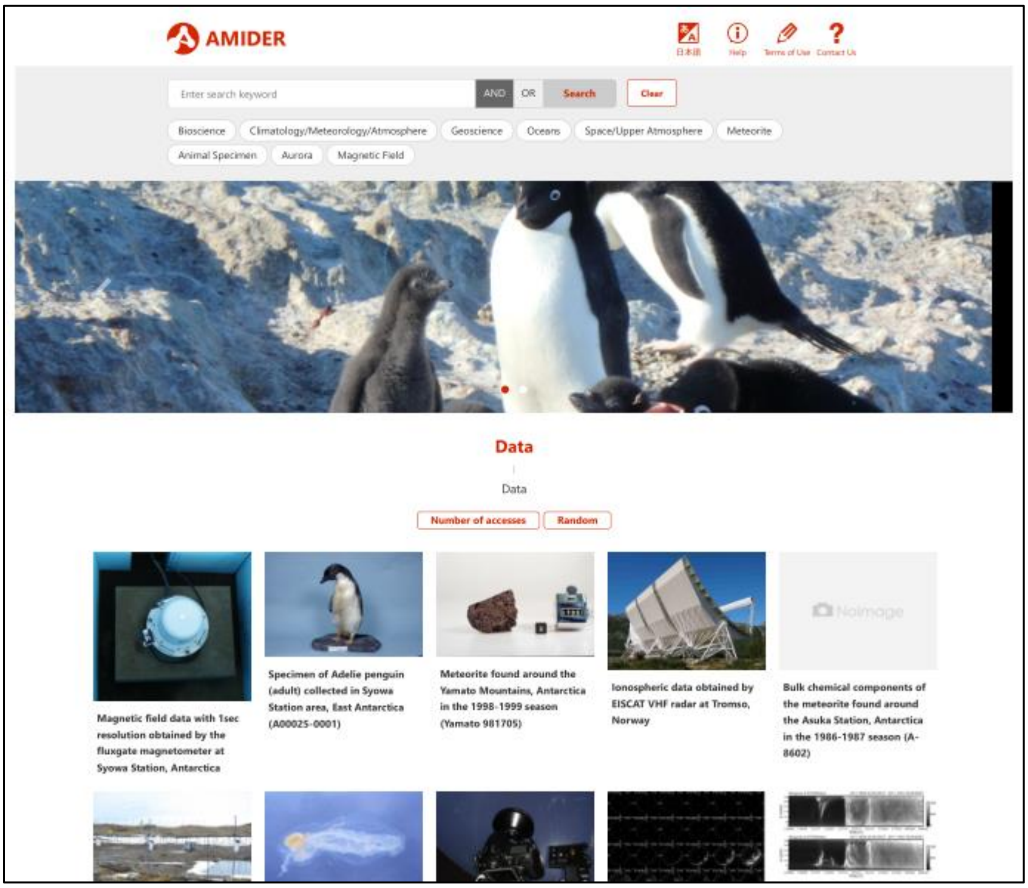

Figure 1. Screen shot of the AMIDER web site.

Anisotropic cosmic ray decrease in September 12, 2017 observed with Global Muon Detector Network

Y. Hayashi[1], C. Kato[1], R. Kataoka[2,3], M. Kozai[4], A. Kadokura[2,3,4], S. Miyake[5], K. Murase[3], and K. Munakata[1]

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We analyze the galactic cosmic-ray (GCR) observed with ground-based muon detectors. The GCR intensity transiently changes related to solar activities, such as the interplanetary coronal mass ejections (ICMEs). The arrival of ICMEs causes spatio-temporal variations of GCR intensity. Therefore, the analysis of fluctuating GCR provides us with information about the near-Earth GCR environment and the ICME arrivals. The variations of GCR intensity consist of two different components, density and anisotropy. Only a single detector cannot separate the density and anisotropy, while a global network enables us to do it. In other words, we are observing GCR flux using the Earth as a large single detector. This network is called the Global Muon Detector Network (GMDN), which consists of four multidirectional ground-based muon detectors in Japan, Australia, Kuwait, and Brazil. The previous studies using the data of GMDN include the papers by Munakata et al. (2022), Kihara et al. (2021), and Rockenbach et al. (2014). Figure 1 shows the asymptotic viewing directions of GMDN. In addition, we installed a pair of an NM64 neutron monitor and a muon detector at the Syowa Station, Antarctic, and started simultaneous measurements with both detectors in 2018. The Syowa neutron monitor and muon detector measure GCR with different energies coming from similar asymptotic directions. Combining these data, both GMDN data and Syowa data, we investigate the energy dependence of time variations of GCR intensity. Data from Syowa will play a key role to connect neutron monitors and muon detectors. In September 2017, one of the largest solar flares occurred and the associated ICMEs arrived at the Earth. We analyze the data of GMDN and separated the density and anisotropy. As a result, we identified a decrease of GCR density and the increase of anisotropy >2 days after the ICME passage, which is different from standard Forbush decrease events. We observed both the first- and second-order anisotropies corresponding to the uni- and bi-directional GCR flows, respectively. In this talk we report the progress of further analysis of this particular GCR decrease event.

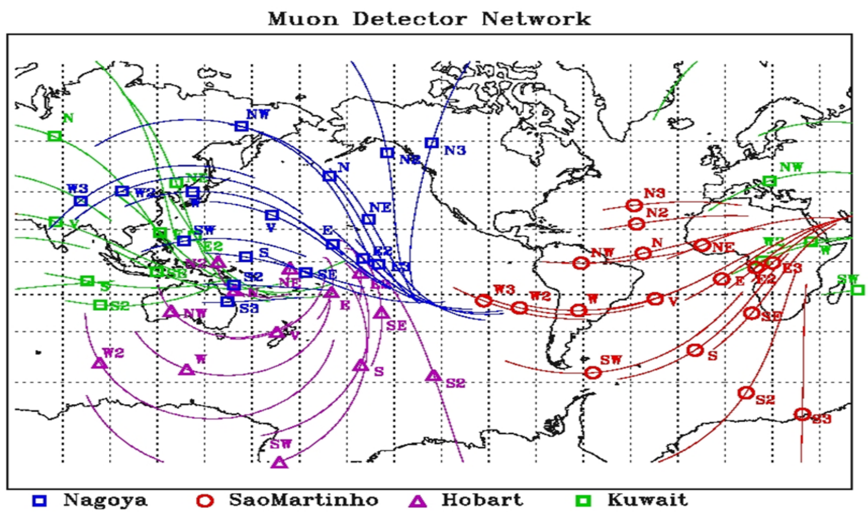

Figure 1. Asymptonic viewing directions of GMDN.

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Large amplitude bidirectional anisotropy of cosmic-ray intensity observed in November, 2021

K. Munakata[1], M. Kozai[2], C. Kato[1], Y. Hayashi[1], R. Kataoka[3], A. Kadokura[2,3,4] and the GMDN collaboration

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We analyze the cosmic-ray variations during a significant Forbush decrease observed with world-wide networks of ground-based muon detectors and neutron monitors including detectors at Syowa Station in November 3-5, 2021. Utilizing the difference between primary cosmic-ray rigidities monitored by neutron monitors and muon detectors, we deduce the rigidity spectra of the cosmic-ray density (or omnidirectional intensity) and the first- and second-order anisotropies separately, for each hour of data. A clear two-step decrease is seen in the cosmic-ray density with the first ~2 % decrease after the interplanetary shock arrival followed by the second ~5 % decrease inside the magnetic flux rope (MFR) at 15 GV. Most strikingly, a large bidirectional streaming along the magnetic field is observed in the MFR with a peak amplitude of ~5 % at 15 GV which is comparable to the total density decrease inside the MFR. The bidirectional streaming could be explained by adiabatic deceleration and/or focusing in the expanding MFR, which have stronger effects for pitch angles near 90 degree, or by selective entry of GCRs along a leg of the MFR. The peak anisotropy and density depression in the flux rope both decrease with increasing rigidity. The spectra vary dynamically indicating that the temporal variations of density and anisotropy appear different in neutron monitor and muon detector data. We demonstrate the significance of simultaneous observations with a neutron monitor and a muon detector at the same location.

References

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Atmospheric Electric Field variation at Syowa Station Associated with Auroral Activity

Yasuhiro Minamoto[1], Akira Kadokura[2, 3, 4], Masashi Kamogawa[5], Yoshimasa Tanaka[2, 3, 4], and Mitsuteru Sato[6]

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The variation of atmospheric electric field (AEF) associated with auroral activity was examined using the data observed at Syowa Station during 2015 to 2017. We derived the reference values of AEF from the fair-weather AEF data at Syowa under the inactive auroral conditions, and compared the difference between observed and reference values of the AEF with Cosmic noise absorption (CNA), geomagnetic field, and Auroral Electrojet Index (AE-index). The results showed that the AE-index which is an indicator of the global current had a higher correlation with AEF variations than CNA and geomagnetic field, which represent local variations near the stations.

When the AE-index was increased, the AEF also increased in the dawn MLT sector, while it decreased in the dusk-to-midnight sector. Furthermore, the diurnal variation of AEF values when the AE-index exceeded 600 nT had a maximum in the morning and a minimum in the afternoon. This was quite different from the usual diurnal variation of AEF (Carnegie curve).

The relationship between the AEF values, AE-index and MLT suggested that the variation of the AEF was caused by the ionospheric potential variations (positive in the dawn MLT sector and negative in the dusk-to-midnight sector) occured with the substorms.

Effects of Electric fields on Magnetosphere-Ionosphere system during space weather events: Recent developments

Diptiranjan Rout,
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It is well known that various types of electric field perturbations affect the global Magnetosphere-Ionosphere-Thermosphere system during geomagnetically disturbed conditions. These include Prompt penetration of the interplanetary electric field, Disturbance dynamo generated electric field, substorm-induced electric field, and solar wind pressure-induced electric field. In this talk, the generation of these electric fields and their impacts on global ionospheric plasma distributions will be discussed based on recent observations. These results will help us to understand a few critical aspects of the effects of space weather events on magnetosphere-ionosphere coupling processes.

EISCAT_3D and Japan's Activities

Yasunobu Ogawa[1,2], Hiroshi Miyaoka[1], Satonori Nozawa[3], Taishi Hashimoto[1,2], Shin-ichiro Oyama[3], Koji Nishimura[4], Takuo Tsuda[5], Hitoshi Fujiwara[6], Masaki Tsutsumi[1,2], Yoshimasa Tanaka[1,2], Takanori Nishiyama[1,2], Mizuki Fukizawa[1], Takuji Nakamura[1,2], Ryoichi Fujii[7], Craig Heinselman[8]

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The European Incoherent Scatter (EISCAT) Scientific Association started construction of the first stage of the EISCAT_3D radar in 2017 under international collaboration. The EISCAT_3D radar is expected to be operational in 2023. At the first stage, a core site with a transmission power of about 4~5 MW and two receive-only remote sites will be operated. The ground preparation for the three sites is completed by 2022, and each radar unit is installed at the sites in 2022 and 2023. The EISCAT_3D radar is expected to be utilized for a variety of science cases, including study on energy and mass transport from the solar wind and magnetosphere to the ionosphere and atmosphere. The results and real-time data distribution will contribute to space climate research and space weather forecasting.

The National Institute of Polar Research (NIPR) had been contributing to the EISCAT_3D construction by supplying radar transmitter power amplifiers (SSPAs) in collaboration with the EISCAT scientific association and ISEE Nagoya University. The high energy-efficient SSPAs have been used for engineering verification tests at the EISCAT Tromsø and Kiruna sites since 2016. In February 2020, NIPR has concluded an MoU with EISCAT to supply in-kind Subarray Transmitter Units which are selected for the first stage by the EISCAT Headquarters through the international tendering process. After these contributions to the EISCAT_3D construction, NIPR establishes the Advanced Radar Research Promotion Center in April 2022 to promote joint usage and collaborative research of the EISCAT_3D radar.

In this paper we present the latest status of the EISCAT_3D implementation and discuss the prospects for Japan's EISCAT_3D activities.

Estimation of precipitating electron energy characteristics of the Omega band aurora by two-wavelength optical measurements

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The Omega band aurora is an auroral phenomenon that often occurs from the late expansion phase to the recovery phase of substorm. The Omega band aurora tends to drift eastward, from midnight to dawn. The Omega band aurora has a latitudinal structure with discrete auroras appearing on the polar side and pulsating auroras on the equator side. Previous studies regarding the Omega band aurora indicate that the west side is clearly divided into two parts by pulsating aurora and diffuse aurora [Oguti et al., 1981]. Since it has been considered that the Omega band aurora is related to a fast plasma flow and its shear motion in the magnetosphere [Rostoker and Samson 1984], clarification of the spatial-temporal variations in the precipitating electron energy and downward energy flux inside the Omega band is important for understanding magnetospheric processes that generate the Omega band aurora. In this study, the Omega band aurora was simultaneously observed at two wavelengths, 427.8 nm and 844.6 nm, using two EMCCD cameras installed in Tromsø, Norway (69.6°N in geographic coordinate, 66.7°N in geomagnetic coordinate). The characteristic energy of precipitating electrons and downward energy flux were estimated from the intensity ratio between the two wavelengths. Two Omega band aurora events, which were observed at 01:30-2:30 UT (around 04:00-05:00 MLT) on March 2, 2017 and at 01:00-3:00 UT (around 03:30-05:30 MLT) on February 24, 2018, showed a coincidence of pulsating and diffuse auroras as reported by the previous studies. The downward energy flux in the west side of the Omega band aurora is higher than that in the east side. In the north-south direction, discrete aurora, diffuse aurora, and pulsating aurora are present from the polar side of the Omega band. We also examine spatial distributions of the characteristic energy and downward energy flux . There was no significant difference of the characteristic energy between the diffuse and discrete auroral areas, but we found that the pulsating auroral area has a slightly larger characteristic energy than the other areas by approximately 30%. We found that the discrete auroral region in the westside of the Omega band has the largest downward energy flux while the pulsating auroral region has a larger downward energy flux than the diffuse auroral region. We discuss possible processes that cause such characteristics of the Omega band auroras.

Relationship between energy of pulsating auroral electrons and duct propagation of chorus wave: simultaneous observations with EISCAT radar, ground-based all-sky imagers, and Arase satellite

Yuri Ito[1], Keisuke Hosokawa[1], Yasunobu Ogawa[2], Yoshizumi Miyoshi[3], Mizuki Fukizawa[2], Kiyoka Murase[2], Shin-ichiro Oyama[3], Satoko Nakamura[3], Yoshiya Kasahara[4], Shoya Matsuda[4], Satoshi Kasahara[5], Yoichi Kazama[6], Tomoaki Hori[3], Shoichiro Yokota[7], Kunihiro Keika[5], Shiang-Yu Wang[6], Sunny W. Y. Tam[8] and Iku Shinohara[9]

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Auroras are classified into two broad categories: discrete auroras, which have a distinct arc-like shape, and diffuse auroras, which have an indistinct patchy shape. Most of the diffuse auroras are known to show a quasi-periodic luminosity modulation called pulsating auroras (PsA). Magnetospheric electrons causing PsA are generally scattered through wave-particle interactions with chorus waves and precipitate into the ionosphere, being referred to as “PsA electrons”. Recent studies demonstrated that sub-relativistic electrons originating from the radiation belt precipitate into the ionosphere during intervals of PsA. It was also pointed out that the energy of PsA electrons tends to be higher when the shape of the optical structure is patchy. These facts suggest that the loss process of such highly energetic electrons in the magnetosphere can be visualized by observing the shape/distribution of PsA and the energy of PsA electrons. In order to test and further validate this visualization method, it is crucial to understand what factors control the morphology of PsA and the energy of PsA electrons, although past studies have not sufficiently examined PsA and electron precipitation in this regard.

In this study, the Arase satellite, ground-based all-sky imagers, and the European Incoherent SCATter (EISCAT) UHF radar were used in combination to carry out simultaneous magnetically conjugate observations of PsA. We investigated the relationship between the morphology of PsA and the energy of PsA electrons by using the data set. First, the energy spectra of PsA electrons were estimated from the ionization profile obtained by EISCAT with an inversion technique, a modified version of CARD originally developed by Brekke et al. (1989). The estimated spectra were compared with those of energetic electrons observed by LEP-e and MEP-e onboard Arase. As a result, it was confirmed that when the footprint of the satellite was close to the sensing area of EISCAT, the energy spectra of precipitating PsA electrons and their temporal variation were in good agreement with those of magnetospheric electrons within the loss cone at the satellite location. In addition, the energy of PsA electrons tended to change in accordance with the transition of the morphology of PsA. Specifically, when the boundary of the patch structure is distinct, the energy of the corresponding PsA electron exceeded 10 keV. Based on these observational results, we hypothesize that both the morphology of PsA and the change in the energy of PsA electrons are controlled by the existence of "ducts," which are tube-like regions where the electron density is lower or higher than the surrounding area. Those duct structures guide chorus waves along the magnetic field to propagate to higher latitudes (Figure 1). In order to test this hypothesis, now we are analyzing PWE data obtained by Arase to infer the spatial structure of electron density in the source region of PsA. In this presentation, we introduce the observational results and discuss the factors controlling the morphology of PsA and the energy of PsA electrons by showing the electron density estimates in the magnetospheric source region.

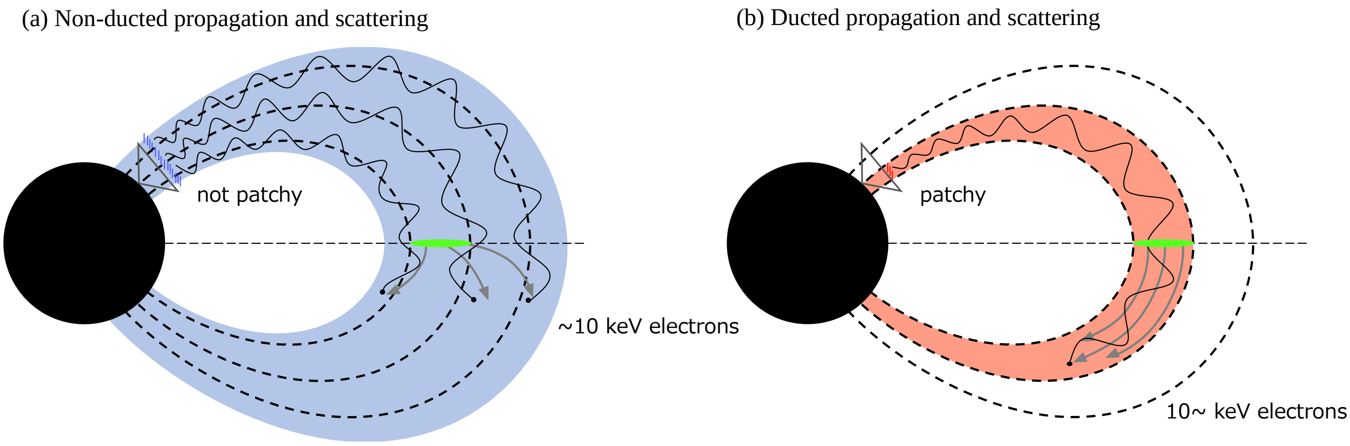

Figure 1. Schematic diagram showing the relationship between pulsating aurora, ducts, and chorus wave propagation. (a): In the case of non-ducted propagation and scattering, resonance energy is low and PsA structure is not patchy. (b): In the case of ducted propagation and scattering, resonance energy is high and PsA structure is patchy.

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SENSU SuperDARN radars essential improvement for future monitoring observation

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SuperDARN (Super Dual Auroral Radar Network) is an international high-frequency coherent radar network established in 1995 to observe the ionosphere and upper atmosphere on a global scale to obtain real-time global plasma convection and electric field potential maps, which had never been done before, to contribute primarily to space weather research. It can also address many aspects of scientific questions on the global upper atmosphere, the influence of geospace on the lower atmosphere and possible global climate change, plasma physics, and practical applied physics, including space weather nowcast/forecast. NIPR has joined the SuperDARN project since its establishment in 1995 and has been running 2 SENSU (Syowa South & East HF Radars of NIPR for SuperDARN) radars in Antarctic Syowa station (69.00 S, 39.58 E) in the polar auroral zone. Both radars have substantially contributed to the international project and scientific research, e.g., studies on auroral phenomena and storms/substorms, geomagnetic pulsations, precise neutral wind around the mesopause region using meteor echoes, studies on the polar mesospheric summer echoes (PMSEs), magnetosphere-ionosphere-neutral atmosphere vertical coupling, studies on the influence of low solar activity or grand minimum on geospace space weather.

Long-term plan-making of new Phase X 6-year JARE project (JARE 64-69, observation period: 2023.2-2029.1) starting effectively next year was discussed and finalised last two to three years especially on Prioritized Research Projects (PRP) and long-term monitoring observation. We will maintain and even accelerate Syowa SENSU SuperDARN project as an essential long-term scientific monitoring observation from this phase X JARE project for long-term stable contribution to a wider coverage of research and applications, which can also contribute to the PRP on space weather and space climate research proposed by Kataoka et al. (see Special session on this symposium.)

We will show scientific strategy of SENSU/SuperDARN research, including the PRP on space weather/climate, and focus on discussing unresolved issues and ways forward, and essential improvement for future longer-term monitoring observation that should be achieved during JARE phase X.

Reinterpreting “polar cap bifurcation” reproduced by magnetohydrodynamic simulations

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Polar cap bifurcation is a polar region phenomenon in which an island of open magnetic flux appears in the closed field line region equatorward of the polar cap boundary. It occurs preferably for periods of northward interplanetary magnetic field (IMF) and may be related to so-called sun-aligned arcs detected by optical measurements on the ground and from space. In this configuration, there exist two polar caps that are topologically non-contiguous with each other Although this phenomenon is difficult to identify by observations, magnetohydrodynamic (MHD) simulations can reproduce this peculiar configuration occasionally. Figure below shows one example of such a bifurcated polar cap. Previously, we proposed that this configuration occurs as a consequence of “crossover reconnection” in the magnetotail that locally breaks down the basic 2-null, 2-separator structure of the magnetosphere. If crossover reconnection is responsible for the polar cap bifurcation, new nulls are expected to appear in the magnetotail. Contrary to this expectation, no nulls have been found in our analysis so far. Thus, we need to reconsider this problem seriously. We have performed several global MHD simulations under different solar wind and IMF conditions, and found that polar cap bifurcation occurs almost certainly in response to an abrupt change in solar wind or IMF conditions, with a timelag of about one hour. Recently, a new tool has been developed at the University of Tsukuba employing a level set method algorithm. This new tool can trace a separatrix emanating from a magnetic null point, with enough accuracy to reach another magnetic null located remotely. We discuss possible reconnection processes causing the polar cap bifurcation, on the basis of detailed magnetic field topology analysis.

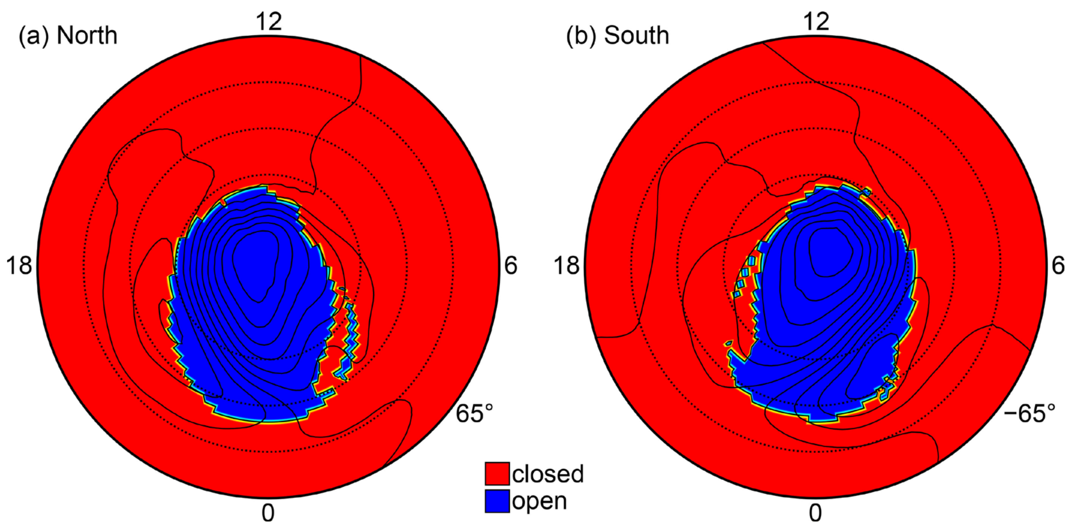

Figure. An example of bifurcated polar caps (a) in the Northern Hemisphere and (b) in the Southern Hemisphere reproduced by global MHD simulations.

Precipitation of high-energy electrons into the mesosphere associated with pulsating aurorae: Arase and EISCAT conjugate observations

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Wave-particle interactions with LBC near the equator cause electron precipitations with energies of about 1-100 keV, and pulsating aurora (PsA) is caused by intermittent precipitations. On the other hand, recent studies have shown that sub-relativistic/relativistic electrons with energies of several hundred of keV to several MeV are scattered by chorus waves, propagating to high latitudes along the field line and precipitate into the mesosphere at an altitude of 60-80 km simultaneously with PsA (Miyoshi et al., 2015, 2020, 2021). In this study, we investigate the high-energy electron precipitations during PsA events that occurred at Tromsø, Norway, from 02:00 to 06:00 UT on March 12, 2022, using data from the Arase satellite and EISCAT radars. Using the plasma wave data observed by Arase, we derived the pitch angle diffusion coefficient of electrons through interactions with whistler mode waves. The result indicates that the observed LBC causes the pitch angle scattering of electrons with 10-15 keV near the magnetic equator. The EISCAT observation showed electron density enhancement at 68 km altitudes and higher, which suggests that energetic electrons of 200-400 keV were precipitated (Turunen et al., 2009). The analysis of the pitch angle diffusion coefficients shows that such high-energy electrons can be scattered by LBC around 30 magnetic latitudes. Considering these analysis, we suggest that the pitch angle scattering by LBC along the field line causes wide energy electron precipitations from a few keV to more than 100 keV during PsA.