The 13th Symposium on Polar Science

15 – 18 November 2022

National Institute of Polar Research
Research Organization of Information and Systems

Session IW

Whole atmosphere

Program and Abstracts

Conveners
Yoshihiro Tomikawa, Mitsumu K. Ejiri, and Takanori Nishiyama (NIPR)

【IW】Whole atmosphere

Scopes

Earth's lower, middle, and upper atmosphere interact with one another through various kinds of vertical coupling processes induced by waves, physical and chemical processes, and energy input from the sun and magnetosphere. It compelled us to deal with the earth's atmosphere comprehensively, so that a new concept of "whole atmosphere" was recently introduced to the atmospheric research community. In the Antarctic, the first MST (Mesosphere-Stratosphere-Troposphere)/IS (Incoherent Scatter) radar has been operated since 2011 as a part of the JARE (Japanese Antarctic Research Expedition) phase VIII and IX prioritized projects. These projects aim at detecting climate change signals in each layer of the Antarctic atmosphere and exploring vertical coupling processes between these layers through the coordinated observations including the MST/IS radar in the Antarctic. These backgrounds stimulated us to propose this "whole atmosphere" session. Viewpoints of both aeronomy and meteorology, and related interdisciplinary studies, are essential to understanding a wide altitude region from the troposphere to the thermosphere. This session provides an opportunity to present and discuss observational, theoretical, and modeling studies focusing on a variety of phenomena in each layer or across multiple layers of the earth's atmosphere.

Conveners : **Yoshihiro Tomikawa, Mitsumu Ejiri, and Takanori Nishiyama (NIPR)**

Real-time Oral presentations (10:00 – 12:00, 13:15 – 14:30)

Date: Fri. 18 November

Note: [I] represents an invited talk.

Chair: Yoshihiro Tomikawa (NIPR)			
	10:00 - 10:05	Opening remarks	
IWo1	**10:05 - 10:20**	Seasonarity of turbulent energy dissipation rates over Syowa Station, Antarctic	*Masashi Kohma (The University of Tokyo), Kaoru Sato (The University of Tokyo)
IWo2	**10:20 - 10:35**	A statistical study of inertia gravity waves over Syowa Station: comparison between the pansy radar and the ERA5 reanalysis	*Lihito Yoshida (SOKENDAI), Yoshihiro Tomikawa (NIPR,SOKENDAI), Mitsumu K. Ejiri (NIPR,SOKENDAI), Masashi Kohma (The University of Tokyo), Kaoru Sato (The University of Tokyo)
IWo3	**10:35 - 10:50**	First Campaign Results of LODEWAVE (LOng-Duration balloon Experiment of gravity WAVE over Antarctica)	*Yoshihiro Tomikawa (NIPR & SOKENDAI), Kaoru Sato (U. Tokyo), Yoshitaka Saito (JAXA/ISAS), Isao Murata (Tohoku U.), Naohiko Hirasawa (NIPR & SOKENDAI), Masashi Kohma (U. Tokyo), Kyoichi Nakashino (Tokai U.), Daisuke Akita (Tokyo Inst. Tech.), Takuma Matsuo (Meiji U.), Masatomo Fujiwara (Hokkaido U.), Takana Kaho (Shonan Inst. Tech.), Lihito Yoshida (SOKENDAI)
	10:50 - 11:00	Break	
IWo4	**11:00 - 11:15**	Development of a novel Meteorological observation system using the air traffic control protocol for commercial aircrafts	*Taishi Hashimoto (NIPR), Shuichi Mori (JAMSTEC)
IWo5	**11:15 - 11:45**	[I] Polar Atmosphere Lidar Observation System at Zhongshan Station, Antarctica	*Wentao Huang (PRIC), Rui Wang (PRIC), Xiangcai Chen (PRIC), Chao Ban (IAP, CAS), Fuchao Liu (Wuhan Univ.), Zhangjun Wang (Institute of Oceanographic Instrumentation, SDAS), Weilin Pan (IAP, CAS), Huigen Yang (PRIC), Hongqiao Hu (PRIC)

IWo6	**11:45 - 12:00**	Development of a resonance scattering lidar for simultaneous measurement of meteoric metal atom and ion in the mesosphere and thermosphere	*Mitsumu K. Ejiri (NIPR & SOKENDAI), Masayuki Katsuragawa (UEC), Ayaka Hashimoto (UEC), Sota Kobayashi (UEC), Takuo T. Tsuda (UEC), Takuji Nakamura (NIPR & SOKENDAI)
Lunch			
Chair: Mitsumu K. Ejiri (NIPR)			
IWo7	**13:15 - 13:45**	[I] Observations of the Polar Cap Mesopause Region from Eureka, Nu, Canada	*William Ward (University of New Brunswick)
IWo8	**13:45 - 14:00**	Variation of OH airglow with various time scales revealed by long-term ground observation at Syowa Station	*Satoshi Ishii (Meiji Univ.), Hidehiko Suzuki (Meiji Univ.), Yoshimasa Tanaka (ROIS-DS), Masaki Tsutsumi (NIPR), Makoto Taguchi (Rikkyo Univ.), Mitsumu K. Ejiri (NIPR), Takanori Nishiyama (NIPR), Akira Kadokura (ROIS-DS)
IWo9	**14:00 - 14:15**	Aurora and airglow observations with the imaging system onboard Antarctic research vessel "Shirase"	*Saki Yamashina (Kyoto Univ.), Akinori Saitou (Kyoto Univ.), Takeshi Sakanoi (Tohoku Univ.), Yuta Hozumi (NICT), Takuo Tsuda (UEC), Takeshi Aoki (UEC), Takahiro Naoi (NICT), Masato Nagahara (NICT), Mitsumu Ejiri (NIPR), Takanori Nishiyama (NIPR)
	14:15 - 14:25	2-minute poster appeal (4 short talks of IWp1 – IWp4)	
	14:25 - 14:30	Break	
	14:30 - 16:00	Poster session core time	

Real-time Poster presentations (14:30 – 16:00)

Date: Fri. 18 November

IWp1	Variations in polar mesospheric clouds observed by the Advanced Himawari Imager onboard the Japanese geostationary-Earth-orbit meteorological satellite Himawari-8	*Takuo Tsuda (UEC), Yasunobu Miyoshi (Kyushu Univ.), Yuta Hozumi (NICT), Yoshiaki Ando (UEC), Keisuke Hosokawa (UEC), Hidehiko Suzuki (Meiji Univ.), Ken Murata (NICT), Takuji Nakamura (NIPR), Jia Yue (NASA), Kim Nielsen (UVU)
IWp2	Disturbances in the Mesosphere and the Ionosphere Elucidated by Airglow Imaging Observation from the International Space Station	*Akinori Saito (Kyoto University), Yuta Hozumi (NICT), Takeshi Sakanoi (Tohoku University), Septi Perwitasari (NICT), IMAP Working group
IWp3	M-transform Analysis of Gravity Waves and TIDs: Application of Horizontal Phase Velocity Spectra to Various Airglow Imaging Data	*Takuji Nakamura (NIPR & SOKENDAI), Masaru Kogure (Department of Earth and Planetary Science, Kyushu Univ.), Septi Perwitasari (NICT), Mitsumu K. Ejiri (NIPR & SOKENDAI), Yoshihiro Tomikawa (NIPR & SOKENDAI), Masaki Tsutsumi (NIPR & SOKENDAI), Kazuo Shiokawa (ISEE, Nagoya University)
IWp4	A plan of new spectroscopic and imaging observation of short-wavelength infrared aurora and airglow (1.05-1.35 μm) at Longyearbyen (78.1°N, 16.0°E) coordinated with EISCAT Svalbard radar	*Takanori Nishiyama (NIPR & SOKENDAI), Masato Kagitani (Planetary Plasma and Atmosphere Research Center, Tohoku Univ.), Senri Furutachi (Department of Computer and Network Engineering, Cluster II, UEC), Takuo T. Tsuda (Department of Computer and Network Engineering, Cluster II, UEC), Yuki Iwasa (Research Institute for Physical Measurement, AIST), Yasunobu Ogawa (NIPR & SOKENDAI), Fuminori Tsuchiya (Planetary Plasma and Atmosphere Research Center, Tohoku Univ.), Fred Sigernes (Kjell Henriksen Observatory, The University Centre of Svalbard)

Seasonarity of turbulent energy dissipation rates over Syowa Station, Antarctic

Masashi Kohma[1], and Kaoru Sato[1],
[1]*Department of Earth and Planetary Science, The University of Tokyo*

The turbulent energy dissipation rate (ε) is one of the fundamental physical quantities for atmospheric turbulence. We have investigated the seasonality of ε and the characteristics of ε in the stratospheric polar vortex margins using ε estimated by a VHF radar at Syowa Station, Antarctica (PANSY radar; Sato et al., 2014). In this study, we focus on the seasonality of ε in the upper troposphere and lower stratosphere using five years of observation data, and discuss the factors that cause the ε seasonality.

As also shown in Kohma et al. (2019), ε increases from winter to spring in the lower stratosphere. We have shown in previous analyses that this is likely due to a seasonal change in polar vortex and gravity wave activity. It is interesting to note that the seasonal variation of ε just above the tropopause (z=9~11 km) has a maximum value in February. The frequency histogram of ε in this altitude region shows that the right tail of the histogram of ε is extended in February compared to other months. In other words, strong turbulence events frequently occur in February, resulting in an increase in the monthly mean value of ε. We will discuss the background winds and gradient Richardson number during the strong turbulence events.

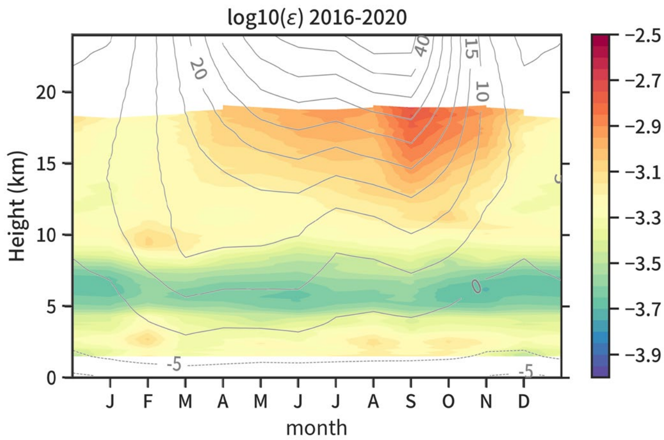

Fig. 1: Monthly mean ε (color) and zonal wind (contours) over Syowa Station as a function of height.

A statistical study of inertia gravity waves over Syowa Station: comparison between the pansy radar and the ERA5 reanalysis

Lihito Yoshida[1], Yoshihiro Tomikawa[1,2], Mitsumu K. Ejiri[1,2],
Masashi Kohma[3], and Kaoru Sato[3]
[1]*The Graduate University for Advanced Studies, SOKENDAI*
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Gravity waves (GWs) are atmospheric waves whose restoring force is buoyancy. They are originated mainly from mountains, jet-front systems, and convection, and can modify a global wind structure through momentum transport and deposit. They do not only decelerate the upper part of the mesospheric jets, but also affect the horizontal winds in the lower stratosphere and contribute to driving the global meridional circulation. However, GW observations are not enough to verify their behaviour especially in the Antarctic, due to the harsh environment there. In addition, GWs have a wide range of horizontal wavelength (i.e., from several km to several thousand km) and period (i.e., from Brunt-Väisälä period (approximately 5 minutes) to inertial period (over 12 hours)), which makes it difficult to reproduce GWs in the entire frequency range even in the state-of-the-art atmospheric models in spite of the recent increase of the model resolution. In order to implement the effect of subgrid-scale phenomena into the models, which are not explicitly represented, GW parameterizations are introduced. In general, nonorographic GW parameterization assumes nearly constant wave sources and instantaneous upward propagation, but in reality, the wave sources are not constant and GWs propagate horizontally as well (Sato et al., 2009; Geller et al., 2013; Plougonven et al., 2020). Thus, it is required to constrain the GW effect in the models based on observations which cover the whole frequency range of GWs and estimate the GW momentum transport in the Antarctic.

Intermittency, a measure of how transient or intermittent a GW event is, has recently received much attention. Even if the total amount of momentum flux is the same, continuous, small amplitude events deposit momentum to higher altitudes, while sporadic and large amplitude events deposit momentum to lower altitudes. As a result, the structure and strength of the driven meridional circulation depend on the GW intermittency (Hertzog et al., 2008). In Antarctica, intermittency has been studied using super pressure balloons (Hertzog et al., 2012) and the Program of the Antarctic Syowa MST/IS radar (PANSY radar) at Syowa Station (Minamihara et al., 2020), suggesting differences in the characteristics of intermittency due to different wave generation mechanisms and wave filtering.

Our purpose of this study is to investigate the characteristics of sporadic and large amplitude GW events that can have a large impact on the overall momentum transport, and also to investigate how well the reanalysis data reproduces the GW events in the Antarctic. We used the PANSY radar for the observation data and the ERA5 reanalysis for the reanalysis data. The PANSY radar, which was installed at Syowa Station (69°S,40°E) in 2011, observes vertical profiles of three-dimensional winds in the troposphere and lower stratosphere with high accuracy and fine temporal and vertical resolution (Sato et al., 2014). It is the only instrument in the Antarctic that enables us to capture GWs in the almost entire frequency range. The ERA5 reanalysis is the latest meteorological reanalysis dataset provided by the European Centre for Medium-Range Weather Forecasts. The ERA5 data is distributed at 137 vertical levels from the surface to 0.01 hPa with a horizontal spacing of 0.25 degree every 1 hour.

We use three dimensional winds of the PANSY radar and the ERA5 reanalysis during the period of October 2015 to September 2016, in which the PANSY radar was continuously operated (Minamihara et al.,2018). The inertia-GWs are extracted by applying a bandpass filter with a cutoff period of 4-24 h and a cutoff vertical wavelength of 0.8-8 km. As a result, we found many similar wave-like structures between the PANSY radar and the ERA5 reanalysis. In order to examine the propagation characteristics of inertia-GWs, we use a hodograph analysis. It utilizes the feature that the hodograph (i.e., vertical change of the horizontal wind vector drawn in the zonal and meridional wind space) becomes an ellipse, in which the amplitude, intrinsic period, vertical wavelength, phase velocity, and group velocity of GWs can be estimated. Although the hodograph analysis generally has an ambiguity of horizontal propagation direction by 180°, we exclude it by covariance of major axis amplitude $u_{\parallel}$ and vertical wind w and vertical wave number m (Minamihara et al.,2018). Since the GWs are assumed to be quasi-monochromatic in the hodograph analysis, three dimensional winds are separated into components with upward and downward phase velocities by a two-dimensional Fourier transform. This procedure makes it possible to extract quasi-monochromatic GW events that were previously impossible to extract.

The results of the hodograph analysis show that the intrinsic period and the direction of the horizontal wavenumber vector of GWs are in good agreement between PANSY and ERA5. On the other hand, vertical and horizontal wavelengths were found to be overestimated by ERA5. We also plan to discuss altitude variations in the reproducibility of momentum fluxes.

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First Campaign Results of LODEWAVE
(LOng-Duration balloon Experiment of gravity WAVE over Antarctica)

Yoshihiro Tomikawa[1,2,3], Kaoru Sato[4], Yoshitaka Saito[5], Isao Murata[6], Naohiko Hirasawa[1,2,3], Masashi Kohma[4], Kyoichi Nakashino[7], Daisuke Akita[8], Takuma Matuso[9], Masatomo Fujiwara[10], Takana Kaho[11], and Lihito Yoshida[2]

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In order to clarify the roles of atmospheric gravity waves in the Antarctic region in driving the general circulation, we planned a super pressure balloon (SPB) observation of atmospheric gravity waves over Antarctica, which is called LODEWAVE (LOng-Duration balloon Experiment of gravity WAVE over Antarctica). The first campaign observation was carried out at Syowa Station in Antarctica from January to February 2022 (during JARE63 summer period). In this presentation, we report on the purpose of this project, outline of the observation at Syowa Station, the results of data analysis, and its future plan.

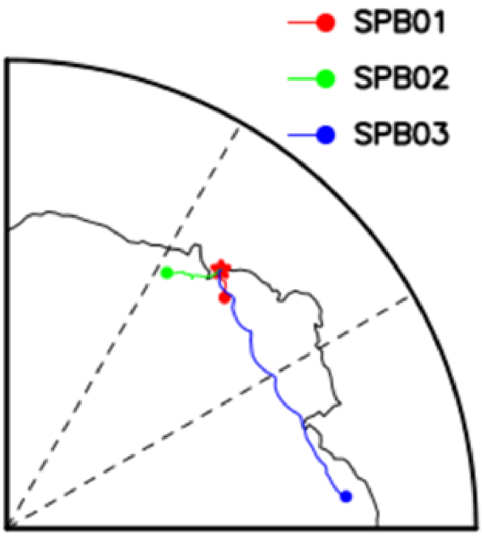


Figure 1. Trajectories of 3 SPBs. A red star denotes Syowa Station (69S, 40E).

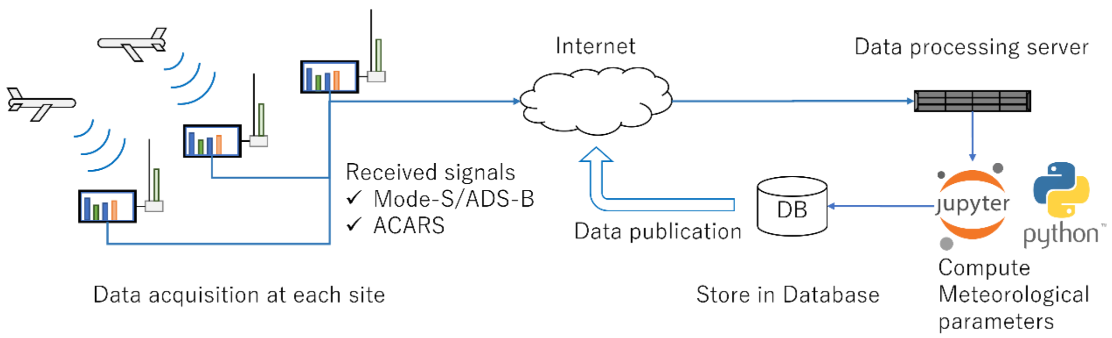
Development of a novel Meteorological observation system using the air traffic control protocol for commercial aircrafts

*Taishi Hashimoto (NIPR), Shuichi Mori (JAMSTEC)

Abstract

We introduce a novel meteorological observation technique using air traffic control protocol for commercial aircraft. The method is based on airborne digital radio communication protocols for air traffic control named Secondary Surveillance Radar (SSR) Mode S and Automatic Dependent Surveillance – Broadcast (ADS-B). They are relatively new protocols that started in 2007 and are now widely used in many commercial flights. The communication via SSR Mode S and ADS-B includes parameters about the position, direction, speed, and attitude of aircraft, which are computed from measurements of their surrounding atmosphere. Hence, they can be regarded as in-situ measurements of the atmosphere like those obtained by Radiosondes, and we can reconstruct atmospheric parameters such as wind speed/direction and temperature by receiving these signals at ground stations.

To implement the meteorological observation system using SSR Mode S and ADS-B, we developed small and cheap Raspberry Pi-based receivers and a data processing server connected via the internet. The whole system is called "atc2met," and the schematic diagram is shown in the figure below. This atc2met system aims to be a complementary data source for the existing AMDAR (Aircraft Meteorological Data Relay) system by WMO. We currently have two sites at Yokosuka (JAMSTEC) and Shigaraki (MU observatory) in Japan. Several airports in Indonesia are planned to be equipped with the atc2met system in the future.



This presentation shows the development status of the whole system, followed by preliminary results of the measured vertical profiles of winds and temperatures.

Polar Atmosphere Lidar Observation System at Zhongshan Station, Antarctica

Wentao Huang[1], Rui Wang[1], Xiangcai Chen[1], Chao Ban[2], Fuchao Liu[3], Zhangjun Wang[4], Weilin Pan[2], Huigen Yang[1] and Hongqiao Hu[1]

[1]*Polar Research Institute of China, Shanghai, China*

[2]*Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China*

[3]*Wuhan University, Wuhan, China*

[4]*Institute of Oceanographic Instrumentation, Shandong Academy of Sciences, China*

The polar regions are key parts of the global general circulation of Earth's atmosphere with unique phenomenon and processes, as well as main entrances for the energy and particles of solar wind entering geospace. Chinese Zhongshan Station (69°22'24"S, 76°22'40"E) in Antarctica is near the shore of the continent and at the unique polar cusp latitude. Besides the distinctive local properties, its atmosphere should also experience a wide variety of coupling processes with the ionosphere since it crosses the aurora zone twice a day. Considering as an ideal place for polar atmopshere observation and research, the Polar Research Institute of China developed and deployed a Polar Atmosphere Lidar Observation System (PALOS) at Zhongshan Station, which is a synthetic lidar observation system covering all layers of neutral atmosphere and the first of its kind in Antarctic.

In PALOS, a Sodium (Na) resonance fluorescence Doppler lidar is established in 2019 to observe the Mesosphere and lower Thermosphere, which is capable of measuring the horizontal winds, temperature and Na number density around 75-110 km for both day and night. A pure rotation Raman lidar, a Rayleigh/Mie scattering lidar module and a coherent Doppler wind lidar are installed in 2020, which realize the high-precision measurement of troposphere-stratosphere-mesosphere temperature and boundary layer wind. The Raman lidar can observe diurnal temperature around ~0.5-15 km (night) and ~0.5-3 km (day), while the integrated Rayleigh/Mie module measures the temperature and atmosphere density around 40-70 km at night. The boundary layer atmospheric wind field from 30 to 800 meters is monitored by the Doppler wind lidar.

The deployment and the operation of PALOS are mostly supported by Chinese National Antarctic Research Expedition (CHINARE), and thousands of hours of observation data have already been accumulated, which can be used to study the basic characteristics of the polar atmosphere, the thermal/dynamic processes in middle and upper atmosphere, etc. When PALOS makes coordinated observation (Figure 1), silmutaneously observed temprature profiles covering most part of the neutral atmosphere can be provided as shown in Figure 2. We have observed very active sporadic and thermospheric Na layers, which are associated with the activites of sporadic E layers (Es) and aurora. Continouse horizontal winds and temperature data covering mutiple days in the mesopause region also reveals strong atmospheric wave activities above Zhongshan Station. More researches are in progress based on these valuable data set.

Figure 1. PALOS makes coordinated observation during polar night.

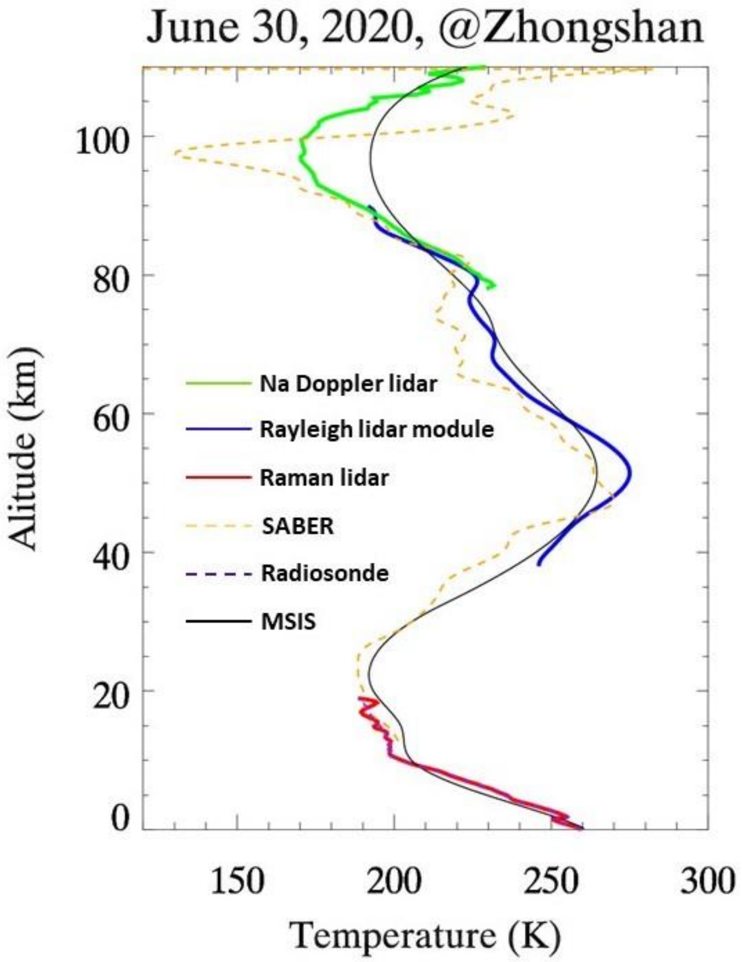


Figure 2. Silmutaneously observed temprature profiles on June 30th, 2020.

References

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Chen, X., Huang, W., Ban, C., Kosch, M. J., Murphy, D. J., Hu, Z., et al., Dynamic properties of a sporadic sodium layer revealed by observations over Zhongshan, Antarctica: A case study. Journal of Geophysical Research: Space Physics, 126, e2021JA029787, 2021.

Development of a resonance scattering lidar for simultaneous measurement of meteoric metal atom and ion in the mesosphere and thermosphere

Mitsumu K. Ejiri[1,2], Masayuki Katsuragawa[3], Ayaka Hashimoto[3], Sota Kobayashi[3], Takuo T. Tsuda[3], Takuji Nakamura[1,2]
[1]Natianl Institute of Polar Research, [2]SOKENDAI, [3]The University of Electro-Communications

In a transition region between neutral atmosphere and geospace plasma (80 - 500 km), the vertical mass transport process has still to be revealed because simultaneous measurement of neutral atmosphere and plasma is quite difficult. There are layers of metal atoms and ions in the mesosphere and lower-thermosphere region produced by meteoric ablation. The meteoric ablation occurs mainly around 80-120 km, so metal layers are usually observed below 120 km. However, there have been many recent reports confirming the presence of metal atoms at altitudes higher than that by resonant scattering lidar observations. A simulation study conducted by Chu and Yu (2017) to investigate a possible source of thermospheric iron layers observed at McMurdo Station in Antarctica suggested that metal atoms may be incorporated into vertical transport in geospace with ionization and neutralization, moving over a wide altitude range. Simultaneous observation of the vertical density profiles of metal atoms and ions and tracking their temporal changes could provide observational evidence of large-scale vertical mass transport in the transition region. Calcium is the only metal that can be observed in both atom (Ca) and ion (Ca^+) by ground-based resonant scattering lidar observations. To measure temporal variation in vertical density distributions of Ca and Ca^+, as a dynamical tracer in this region, we started to develop a resonance scattering lidar system, which has an injection-locked Ti:Sapphire laser; a multi-frequency, nanosecond pulse, and a broad frequency tenability. In this presentation, we will introduce the new lidar system and show some preliminary results of test observations.

References

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Observations of the Polar Cap Mesopause Region from Eureka, Nu, Canada

William E. Ward[1], Samuel K. Kristoffersen[2], Dustin Fraser[1] and Dustin Gamblin[1], Chris Meek[3] and Alan Manson[3]

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The Polar Environment Atmospheric Research Laboratory was established in 2005 at Eureka, Nunavut, Canada on Ellesmere Island (80N 85W) and is collocated with the pre-existing Eureka weather station. Instrumentation was installed over the following two years to provide observations of the polar atmosphere from the ground to the lower thermosphere. Instruments providing observations of the polar mesopause region include an all-sky imager (PASI, irradiance images), a meteor radar (MR, wind), a Spectral Airglow Temperature Imager (SATI, temperature and irradiance) and a field-widened Michelson interferometer (E-Region Wind Interferometer (ERWIN) - wind and irradiance). Analysis of the past 12 years of observations are providing insights in the character of the dynamics of this region of the atmosphere.

In this paper, results from three of these instruments (PASI, MR, and ERWIN) are presented. First, the character of the variability of the airglow and winds is described. Horizontal wind amplitude spectra peak in the 6 – 12 hour period region but this peak is not seen in the vertical and airglow brightness spectra. There is significant intermittency in the horizontal wind. Wind comparisons between the MR and ERWIN horizontal winds are in reasonable agreement though the meteor wind variations are generally a little larger. Annual and solar cycle variability of airglow examined. Some solar cycle dependence appears present. Analysis of individual gravity wave events are discussed. The vertical wind variations and airglow irradiance are generally found to be in quadrature although there are exceptions. These results point to the complexity of this region of the atmosphere.

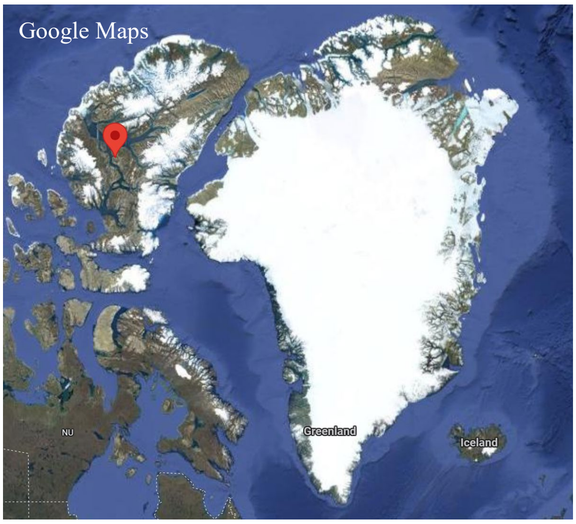

Figure 1. Location of PEARL at Eureka, Nu, Canada.

Figure 2: The Ridge Lab of PEARL in October
(Photo Credit: WEW)

Variation of OH airglow with various time scales revealed by long-term ground observation at Syowa Station

Satoshi Ishii[1], Hidehiko Suzuki[1], Yoshimasa Tanaka[2, 3, 5], Masaki Tsutsumi[2, 3], Makoto Taguchi[4], Masaki Tsutsumi[2, 3], Mitsumu K. Ejiri[2, 3], Takanori Nishiyama[2, 3], Akira Kadokura[2, 3, 5]

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OH (8-4) airglow spectral observations conducted at Syowa Station, Antarctic, during the winter season from February 2008 until October 2019. We derived the rotational line intensity of OH airglow (OH airglow intensity) and the rotational temperature for 12 years dataset. We detected distinct intensity variations with various time scales; (1) a decadal scale that may be caused by the solar cycle, (2) seasonal intensity variations with a maximum around April and a minimum around the winter solstice, (3) relatively long-timescale events that lasted for several days and (4) relatively short-time scales of several tens of minutes to several hours.

The intensity of OH airglow is thought to be a fluctuation due to changes in atmospheric composition in the upper polar mesosphere associated with the energetic particle precipitation (EPP) and the vertical transport of air masses with rich [O] from altitudes higher than the OH airglow layer. We compared the peak altitude of the airglow layer, temperature distribution, and timing of the vertical transport enhancement with satellite data from TIMED/SABER, AURA/MLS. The results showed that the (1) ~ (3) variations can be generally understood by the supply of oxygen atoms associated with vertical transport to the OH layer. Regarding the variations (4), we focused on the relationship with auroral particles, which had been reported only once by Suzuki et al. (2010). We extracted EPP events from the cosmic noise absorption (CNA) data from the riometer observations at Syowa Station. Superposed epoch analysis of OH airglow intensity for three hours before and after the events suggested the OH airglow intensity decayed for about tens of minutes after the EPP events. We used a simple 1-D model for numerical experiments to understand the mechanism of the temporary decrease in OH airglow intensity associated with EPP.

In this presentation, we will present OH airglow intensity variations detected at Syowa Station with various time scales, as well as the results of satellite data analysis and initial results of 1-D numerical experiments. We discuss the specific dynamics occurring in the upper polar mesosphere region.

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Aurora and airglow observations with the imaging system onboard Antarctic research vessel "Shirase"

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Optical observations of the ionosphere have been widely conducted by ground-based imagers [Shiokawa et al., 1999] and satellites [Immel et al., 2004]. There are, however, some observational gaps due to limited observation areas. As for ground-based observations, there are large observational gaps especially in the southern hemisphere, which has a large proportion of the ocean. To fill these gaps, we developed vessel-borne imaging system and conducted observations of the ionosphere and mesosphere from the ocean. The system was installed on the Antarctic research vessel "Shirase" and multi-wavelength observations were conducted during three voyages: The 61th Japanese Antarctic Research Expedition (JARE61) (from November 2019 to March 2020), JARE62 (from November 2020 to February 2021), and JARE63 (from November 2021 to March 2022). Figure 1 shows Shirase's routes of the three voyages. It makes a round trip between Japan and Syowa Station once a year, and so it is possible to conduct observations widely from the high latitude zone to the equatorial anomaly zone on its routes. 630.0 nm emission was observed in JARE61, 630.0 nm and 670.0 nm emissions were observed in JARE62, and 630.0 nm and 760.0 nm emissions in JARE63. Both 670.0 nm and 760.0 nm emissions correspond to N_2 molecular aurora and OH airglow in the E-region of the ionosphere and the mesosphere. The vessel-borne imaging system is affected by the movement and vibration of the vessel, and so it is necessary to compensate them, unlike ground-based imagers. The imagers were mounted on a 3-axis attitude-stabilized gimbal and designed to cancel out the vessel's vibration during the exposure time. The yaw-angle direction drift over a long time, however, changes the imagers' line-of-sight directions. Therefore, a method to solve this problem specific to vessel-borne imagers and to correct the orientation of the images was established. The aurora was successfully observed during JARE61 and 63, the atomic oxygen airglow in 630.0 nm associated with equatorial ionization anomaly in JARE61 and 62, and the OH airglow during JARE63. The accuracy of the imaging system and image correction method was evaluate using the these observed phenomena. It was found that the accuracy of them was equivalent to that of the ground-based imagers. The vessel-borne imaging system for the ionosphere and mesosphere has been completed, and it is anticipated that the observation area will be further expanded by vessel-borne imaging systems in the future.

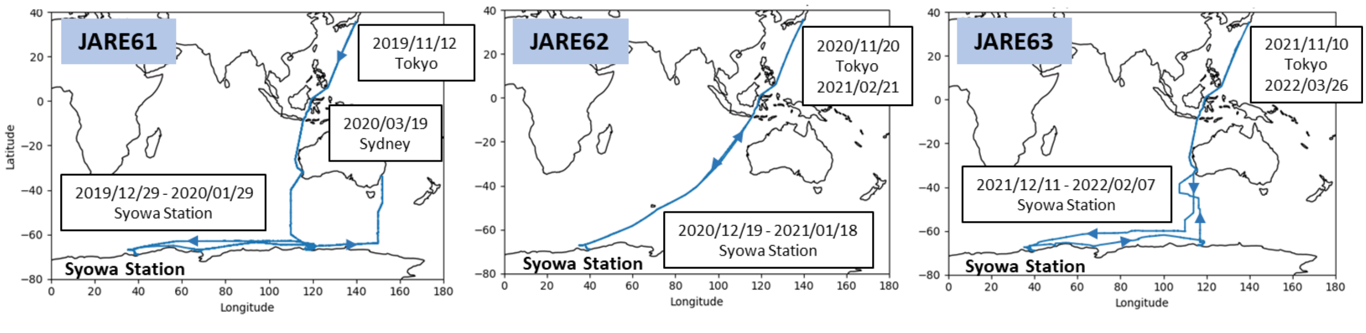

Figure 1. The routes of Shirase in JARE61-63.

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Variations in polar mesospheric clouds observed by the Advanced Himawari Imager onboard the Japanese geostationary-Earth-orbit meteorological satellite Himawari-8

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To advance polar mesospheric cloud (PMC) observations by Advanced Himawari Imager (AHI) onboard the Japanese geostationary-Earth-orbit (GEO) meteorological satellite Himawari-8, we have developed a PMC detection method for application to the Himawari-8/AHI full-disk images. The PMC detection method consists of two steps: the detection of stronger PMC signals in the first step and the detection of weaker PMC signals in the second step. By using this two-step detection, we eliminate false detections as much as possible and enhance detection sensitivity. As a result, the PMC detection sensitivity by Himawari-8/AHI is well comparable to that by Cloud Imaging and Particle Size (CIPS) onboard Aeronomy of Ice in the Mesosphere (AIM). By analyzing the detected PMC data, various PMC variations such as quasi-5-day waves and mid-latitude extensions can be revealed. Among them, we focus on interhemispheric coupling, specifically a relationship between PMC occurrence rates in the summer hemisphere and sudden stratospheric warmings in the winter hemisphere.

Disturbances in the Mesosphere and the Ionosphere Elucidated by Airglow Imaging Observation from the International Space Station

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Imaging observations of the airglow in the Mesosphere and the Ionosphere enable to capture two-dimensional structures of the disturbances in the Earth's upper atmosphere. Large number of ground-based all-sky imagers have been widely used, and a few space-borne imagers have been deployed in these decades. Space-borne imagers have an advantage to capture the airglow structures globally even over clouds that prevent optical measurement from ground. Visible-light and infrared spectrum imager (VISI) of Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping (ISS-IMAP) mission was an airglow/aurora imager installed on the Exposed Facility of Japanese Experiment Module of the International Space Station. It carried out the mesospheric and ionospheric observations between 2012 and 2015 below about 55 degrees of the geographic latitude. It mainly observed the airglow from the molecular oxygen in 762nm wavelength and from the atomic oxygen in 630nm wavelength [Sakanoi et al., 2011]. The typical altitude of the 762nm emission layer is 95km altitude in the Mesosphere, and that of the 630nm emission layer is 250km altitude in the Ionosphere. ISS-IMAP/VISI revealed the occurrence of the concentric wave structures generated by atmospheric gravity waves in the Mesosphere [Akiya et al., 2014; Perwitasari et al., 2015; Perwitasari et al., 2016]. The high occurrence rate of the structures at midlatitudes was firstly revealed by these observations. The global distribution of the mesospheric bores that are generated by the temperature inversion layer on the top of the Mesosphere is also firstly elucidated by the VISI observation [Hozumi et al., 2018; Hozumi et al. 2019]. These structures in the Mesosphere are results of the vertical atmospheric coupling from the Troposphere to the Thermosphere. The ionospheric structures, plasma bubbles, on the bottom side of the F-region Ionosphere were investigated by Nakata et al. [2018]. The disturbances in the Mesosphere and the Ionosphere, and the coupling process to generate the disturbances will be discussed in the presentation.

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M-transform Analysis of Gravity Waves and TIDs: Application of Horizontal Phase Velocity Spectra to Various Airglow Imaging Data

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The 2-D (two dimensional) horizontal phase velocity spectrum using 3-D Discrete Fourier Transform (DFT) has been introduced by Matsuda et al. (2014). They analyzed the gravity waves observed in the airglow image data obtained at Syowa station (69S, 40E) collected for one winter season. Horizontal phase velocity spectra between four stations in ANGWIN (Antarctic Gravity Wave Instrument Network), Halley (76S, 27W), McMurdo (78S, 167E), Davis (69S,78E) and Syowa have been compared on the gravity wave energy and propagation direction (Matsuda et al., 2017). The software to calculate the horizontal phase velocity spectrum for common use has been developed and delivered by NIPR as a function written for IDL (Perwitasari et al., 2018). This phase velocity analysis, M-transform, has been applied to various airglow images at various locations. M-transform has further been used to analyze GPS/TEC map, and SuparDARN HF radar data.

In this presentation, the M-transform analyses of the different imagers and instruments are reviewed, and we discuss how the M-transform could be widely applied to different dataset with different observational setup and parameters.

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A plan of new spectroscopic and imaging observation of short-wavelength infrared aurora and airglow (1.05-1.35 μm) at Longyearbyen (78.1°N, 16.0°E) coordinated with EISCAT Svalbard radar

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A new ground-based optical observation of aurora and airglow in short-wavelength infrared (SWIR) is being planned in Longyearbyen (78.1°N, 16.0°E) coordinated with EISCAT Svalbard Radar (ESR). Two state-of-the-art instruments, a SWIR imaging spectrograph and a monochromatic imager, have been developed to focus on study on dayside magnetosphere-ionosphere-atmosphere coupling processes in the high polar regions.

The 2-D imaging spectrograph, NIRAS-2, has a fast optical system and high spectral resolutions to challenge twilight/daytime aurora measurements from the ground. It is designed for SWIR wavelength from 1.05 to 1.35 microns in which sky background intensity is weaker than in visible. It covers strong auroral emissions in N_2^+ Meinel band (0-0) and N_2 1st Positive bands (1-2, and 0-1). Its field-of-view (FOV) and angular resolution are 55 degrees and 0.11 degrees per pixel, respectively. If a 30-microns slit is used, spectral bandpass around 1.1 microns are 0.53 nm and 0.21 nm with two different gratings (950 lpmm and 1500 lpmm). In a test observation, we successfully measured airglow emissions of OH (5,2), (6,3), (7,4), and (8,5) bands in 1.07-1.33 microns, and O_2 IR band at 1.27 μm. With the 1500-lpmm grating and a 60-m slit, each line in OH (5,2) band was spectrally resolved well. It should be noted that peak intensity of N_2^+ (0,0) band is about 10 times greater than that of OH (5,2) P_1(3) line, and therefore we concluded that the spectrograph can detect aurora activities with sufficient time resolutions shorter than 30 seconds and allows us to investigate spatial and temporal variations associated with magnetosphere-ionosphere coupling and particle precipitations. For upper mesosphere, OH (8,5) band was measured with good quality, and rotational temperature can be estimated with 10-min resolutions and errors less than 3 K.

In addition to the NIRAS-2, we have been developing the brand-new SWIR camera, NIRAC, focusing on aurora emissions in N_2^+ (0-0) band. The camera consists of a few commercial SWIR lenses for security/defense purposes, plano-convex lenses, a custom optical filter (center: 1112.76 nm, FWHM: 13.8 nm) and an InGaAs FPA (640 × 512 pixels). Total optical system is fast (*F*1.5) and we examined that the point spread function is less than 5 pixels in full width at half maximum even near the end of the FPA. The FOV is 92 × 73 degrees and slightly wider than that of the spectrograph. In a test observation, we successfully identified horizontal structures of OH (5,2) band airglow layers with 30-seconds exposures.

Sensitivity of both the instruments was calibrated by light sources consists of two integrated spheres with different diameters (76-inch and 6-inch) in the following two steps. At first, using spatially uniform light with known spectrum emitted from a port (diameter less than 20 mm) of the small integrate sphere, we calibrated absolute sensitivity only in the centers of the FOVs. Next, light from the large integrate sphere, which can illuminate the whole FOVs, was used to calibration for non-uniform sensitivity within the FOVs caused by each optical system.

The instruments are going to be installed at The Kjell Henriksen Observatory/The University Centre in Svalbard (KHO/UNIS) in November 2022. Taking geographical advantage of the observatory, 24-hours continuous observations can be expected near the winter solstice. Observational study in conjunction with active/passive radio remote sensing, such as ESR and VLF/LF radio wave receivers, are also planned to precisely estimate energy flux of precipitating particles associated with aurora and sub-sequent changes in electron density and neutral/ion temperatures. We are going to address the following scientific goals: dayside reconnections and wave-particle interactions monitored by auroral emissions, ion upflow observed as enhancements of resonant scattering of N_2^+ ions, energetic particle precipitation impacts on OH chemistry in the upper mesosphere, atmospheric waves variability, and its connection to ionospheric disturbances in E-F regions. We will also discuss the observational strategies and future collaborations