G1–P1

AEROSOL CHARACTERISTICS OVER NORWEGIAN ARCTIC: RESULTS FROM INDIAN SCIENTIFIC EXPEDITIONS

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In the context of global climate change, there is an increased need in understanding the role of atmospheric aerosols in arctic atmosphere in changing the snow Albedo, phenomenon like ‘Arctic haze’ and ‘thinning of Arctic Sea’ and perturbation to the radiation balance in the Arctic region. As a part of Indian Scientific Expedition to Arctic, extensive measurements of scattering and absorption properties of aerosols have been in progress at Ny Alesund (78.9°N, 11.9°E) in Svalbard archipelago of Norwegian Arctic since June 2011. The results from the year round measurements indicate that the mass concentration of Black Carbon (BC) aerosols showed large annual variation with values as low as ~5 ng m^{-3} to as high as ~ 300 ng m^{-3} (during winter/spring). Similarly, the scattering coefficients also showed significant annual variation with higher values (~ 30 Mm^{-1}) during the winter and spring. However, the aerosol single scattering albedo was lower (as low as 0.85) during the summer. In addition, the investigation of aerosol black carbon in the snow samples collected around Ny-Alesund during the onset of Arctic spring (2012) indicates that the mean concentration of BC in snow varied from ~ 1 to 5 ppb; while the corresponding atmospheric BC varied from ~ 25 ng m^{-3} to 50 ng m^{-3}. Since there was no significant snowfall during this period, the observed BC in snow is usually associated with dry deposition. The details of the observational program and the results will be presented.

G1–P2

Fluctuation of Polar Night Jet with Propagation of the AO from the Stratosphere to the Troposphere

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Arctic Oscillation (AO) is defined as a leading mode of Empirical Orthogonal Function (EOF) of Sea Level Pressure (SLP) (Thompson and Wallce, 1998). The AO has an annular structure with negative anomaly in the Arctic and positive anomaly surrounding mid-latitudes, when the AO index is positive. Baldwin and Dunkerton (1999) defined that the AO is represented by the leading mode of geopotential height between 1000 and 10 hPa, and examined the time series of AO signatures at tropospheric and stratospheric levels. It is shown that AO anomalies typically appear first in the stratosphere and propagate downward. Baldwin and Dunkerton (2001) showed that the tropospheric anomalies tend to persist while the anomalies in the stratospheric polar vortex persist about 60 days, insisting the possibility of using the downward propagation to improve extended range forecast. However some cases don’t propagate downward, and the AO anomalies appear only in the stratosphere or troposphere. Thompson and Wallace (2000) showed the AO has a barotropic structure, so there are still some inconsistent points. In this study, we investigate the AO time series in order to reconfirm the stratosphere troposphere connection extending the analysis period to 2011.

G1–P3

COMBINED MEASUREMENTS OF GRAVITY WAVES WITH AN AIRGLOW IMAGER AND ALOMAR LIDARS IN NORWAY

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To investigate the vertical propagation of gravity waves from the lower to the upper atmosphere, combined measurements with an airglow imager and lidars were carried out at the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR) station (69.3ºN, 16.0ºE) in Norway. Airglow imaging reveals the two-dimensional structure of gravity waves in the mesopause region, while the ALOMAR Rayleigh/Mie/Raman (RMR) lidar and sodium lidar provide the vertical structures between the stratosphere and the lower thermosphere. On 26 November 2010, the imager identified a mesoscale gravity wave structure in the sodium airglow that had a horizontal wavelength of 277 km, a wave period of 59 min, and propagated northeastward at a phase speed of 78 m s^{-1}. Simultaneous lidar measurements also showed upward wave signatures with a similar wave period in the temperature perturbations; the vertical wavelength of the upward wave seen in the temperature data is consistent with the dispersion relation for gravity waves. Based on the combined measurements with the imager and sodium lidar, momentum flux of this gravity wave was estimated to be 1.0 m^2 s^{-2} at the sodium airglow height. Ray-tracing analysis suggested that the observed gravity wave was generated by a distortion of the polar jet at the tropopause via a geostrophic adjustment process.

G1–P4

Variations of the polar lower thermosphere, mesosphere, and ionosphere due to a SSW ~ A case study of the January 2012 event~

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Effects of Sudden Stratospheric Warming (SSW) on the Thermosphere have been paid great attentions for last half decades in terms of the atmospheric vertical coupling process. We report results of a case study of the January 2012 SSW event based on observations made at Tromsø (69.6°N, 19.2°E). In Tromsø, we have been conducting comprehensive observations using European Incoherent SCATer (EISCAT) radars, MF radar, meteor radar (owned by NIPR), Fabry-Perot Interferometer (FPI), aurora imagers, photometer, and sodium LIDAR. From 0739 UT on January 13, 2012 to 2300 UT on January 23, 2012, the EISCAT UHF radar was operated with a scanning mode (so-called ip2 mode) and succeeded in obtaining good quality data (ionospheric parameters above 90 km, and neutral wind velocity between 90-120 km) over the time interval. The weather was good, and then we succeeded in obtaining neutral temperature data for nine nights (January 13, 14, 17, 18, 19, 20, 21, 22, 23) by sodium LIDAR. MF and meter radars conducted wind observations in the mesosphere. We will show results of a case study on this event, and discuss how the lower thermosphere/mesosphere/ionosphere varied during the SSW event.

G1–P5

SODIUM DENSITY VARIATION DURING AURORAL PARTICLE PRECIPITATIONS

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Sodium atom layer is generally distributed at 80-100 km. One of mysterious subjects on high-latitude sodium layers is relationship between auroral particle precipitations and sodium atom layer variations. A previous study suggested a sodium column density decrease during a geomagnetic active period due to that the particle precipitations accompanied by electron density enhancement could induce ionization of sodium atom through their ion-molecule chemistry. Another study pointed a possibility of sodium density increase. For this reason, it is suggested that precipitating particle bombardment on meteoric smoke particles can sputter sodium atoms from the smoke particles. On the other hand, ionospheric electric fields, which may become more significant near auroral precipitating regions, could induce ion motions (i.e. can generate sodium ion convergence and/or divergence), and then also could affect generation and/or loss processes of sodium atoms through their ion-molecule chemistry. Thus, for the evaluation of the causarity, it is important to distinguish the effects of auroral particle precipitations and ionospheric electric fields. Using a sodium lidar (which was installed in early 2010) and European incoherent scatter (EISCAT) radar at Tromsø, Norway (69.6ºN, 19.2ºE), we have investigated, for the first time, that the actual effect of the particle precipitation to the sodium density variations without electric filed injection. In the nighttime observation on 24 January 2012, we detected a significant decrease of sodium atom density coincied with electron density enhancements (implying strong particle precipitations) and low ion temperatures (implying no electric field injections). These results strongly suggested that auroral particle precipitations induced sodium atom density decrease.

G1–P6

CURRENT STATUS OF THE STEL OPTICAL OBSERVATIONS AT THE TROMSØ EISCAT RADAR SITE

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Solar-Terrestrial Environment Laboratory (STEL), Nagoya University has operated various kinds of optical instruments for more than 10 years at the Tromsø EISCAT (European Incoherent Scatter) radar site in Norway (69.6ºN, 19.2ºE), which is one of the state-of-art observatories for the upper atmospheric physics at high latitudes. Seven instruments are now in operation regularly from October to March: (1) a three-wavelength photometer (simultaneously measuring the emission intensity of aurora at 427.8 nm, 630.0 nm, and 557.7 nm), which is fixed to look along the magnetic field line, (2) two digital cameras for monitoring weather and aurora, (3) a proton all-sky camera (wavelength at 486.1 nm), (4) multi-wavelength all-sky camera (programmatically selecting one of the optical filters at 557.7 nm, 630.0 nm, near-infrared OH band, 589.3 nm, 572.5 nm, and 732.0 nm), (5) a Fabry-Perot interferometer (programmatically selecting one of the optical filters at 557.7 nm, 630.0 nm, and 732.0 nm), (6) a sodium LIDAR. All of them (except for the sodium LIDAR) are automatically operated. These instruments have joined many campaign observations with the EISCAT radars, rockets, satellites, and other ground-based instruments by adjusting the observation mode. The quick looks are available to see on the web at:

www.stelab.nagoya-u.ac.jp/~eiscat/data/EISCAT.html

This paper reports the current operation status and some new results of these optical instruments until the end of 2012.

G1–P7

GRAVITY WAVE ANALYSIS USING METEOR WIND RADARS IN ARCTIC NORWAY

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Horizontal propagation characteristics of atmospheric gravity waves in the northern high latitude mesopause region (around 80-100km) are studied based on long-term wind and temperature fluctuation observations made with operational meteor radars at Arctic Norway sites, Adventdalen, Spitzbergen (78N,16E) and Ramfjordmoen, Norway (70N,19E) [e.g., Hall et al., 2006].

The targets of the radars are ionized meteor trails produced at 70-110 km altitude by meteor bodies, which impinge onto Earth's atmosphere, collide with atmospheric molecules and ionize them along their paths. After its formation, the meteor trail follows the motion of the ambient neutral atmosphere, that is, winds. The trail also expands rapidly due to molecular diffusion, which is a function of atmospheric temperature and density. Wind velocity and diffusion coefficient are estimated from Doppler frequency shift and echo power decay in observed radar meteor echoes, respectively. Atmospheric temperature fluctuation due to gravity waves can be further estimated from the diffusion coefficient [Tsutsumi, et al., 1994;1996]. One of the major advantages of the present meteor radar systems is its very high echo rate (6000-20000 echoes a day) despite the relatively small transmitting power (7.5kW peak). Horizontal winds and temperature fluctuations can be continuously measured with time and height resolutions better than 1 hour and 2km.

The horizontal propagation directions, estimated using the theoretical relation between wind and temperature fluctuations, are mostly opposite to those of back ground mean winds below around 90 km, showing a good agreement with a well known scenario that gravity waves generated in the lower atmosphere carry wave energy and momentum flux high into the mesosphere and then release them so that they decelerate and reverse the prevailing winds in the region. This sort of radar study has been only possible with very powerful large aperture radars so far, which are mostly on a campaign basis. By fully utilizing the present continuous long term observation data set we will present results of gravity wave analyses in more details focusing on its relation with background winds.

Hall, C. M., et al., J. Geophys. Res., 111, 2005JD00674, 2006
Tsutsumi, M. et al., Radio Sci., 29, 599-610, 1994.
Tsutsumi, M. et al., J. Geophys. Res., 101, 9425-9432, April, 1996.

G1–P8

EISCAT-JAPAN COLLABORATIVE STUDIES DRIVED BY EISCAT/EISCAT_3D RADARS

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The EISCAT(European Incoherent SCATter) Scientific Association is an international research organization, which operates incoherent scatter radars at 931MHz, 224MHz and 500MHz in northern Scandinavia and Svalbard for studies of physical and environmental processes in the middle/upper atmosphere and near-Earth space. Since 1996 , National Institute of Polar Research, in collaboration with STEL of Nagoya University has promoted the EISCAT project for the user community in Japan to use the EISCAT facility for their scientific subjects.

EISCAT-3D is the major upgrade of the existing EISCAT radars in the northern Scandinavia. With a multi-static phased array system composed of one central active (transmit-receive) site and several receive-only sites, the EISCAT -3D system is expected to provide us 10 times higher temporal and spatial resolution and capabilities than the present radars.

In this presentation, we will overview our scientific activity and achievements with the EISCAT facility, and emphasize the science targets which we expect to be clarified by EISCAT_3D in near future.

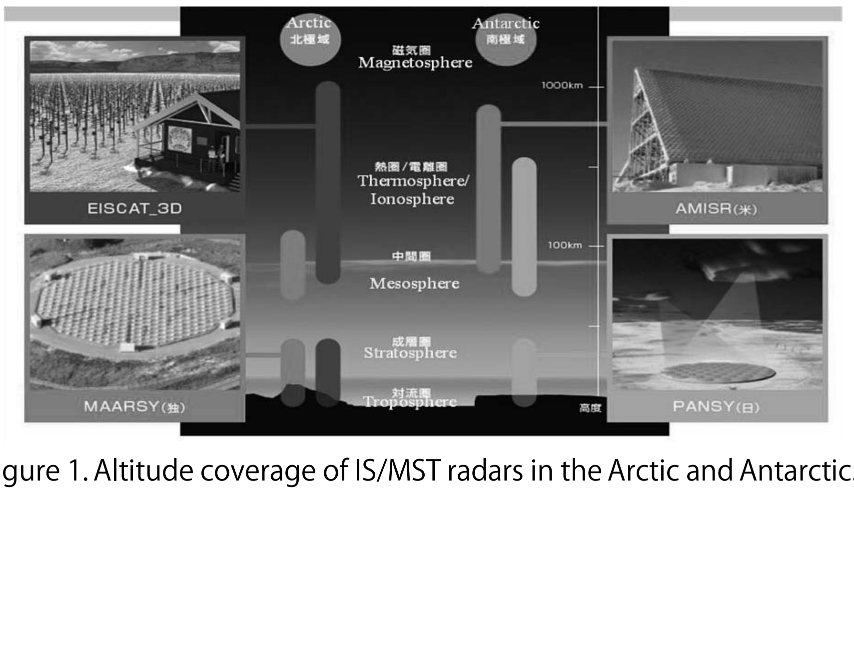

Figure 1. Altitude coverage of IS/MST radars in the Arctic and Antarctic.

G1–P9

THE POLARIZATION OF HIGHER HARMONIC AURORAL RADIO EMISSIONS

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This is a report on the first polarization measurements of auroral radio emissions near 4 times the electron cyclotron frequency (f_{ce}) in the Earth's polar ionosphere. Recently Sato et al. [2012]* discovered auroral roar emissions near ionospheric 4f_{ce}, which were detected with a passive receiver installed in Svalbard, Norway (Invariant LAT 75.1N). The initial observations, performed for about a year, showed that 4f_{ce} roar emissions were detected from 5.27 to 5.70 MHz during moderate geomagnetic disturbances in 22 days between May and September 2011 only from noon to evening, while no event occurred during the 2010-2011 winter season. Examination of 2011-2012 polarization measurement data in Iceland (Invariant LAT 65.3N) reveals four events of 4 f_{ce} roar emissions. 4f_{ce} roar in two events was observed to be left elliptically polarized with respect to the local magnetic field during daylight hours. This polarization is consistent with the idea supported by the observation in Svalbard; the origin of 4f_{ce} roar is mode conversion to the L-O mode of upper hybrid waves favorably generated under the condition of f_{UH} ~ 4f_{ce}. The other two events showed that 4f_{ce} roar was right elliptically polarized during darkness hours. This polarization indicates that nonlinear coupling of two upper hybrid waves may also works in the bottomside auroral ionosphere to generate R-X mode 4f_{ce} roar.

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* Sato, Y., T. Ono, N. Sato, and Y. Ogawa (2012), First observations of 4 f_{ce} auroral roar emissions, Geophys. Res. Lett. , 39, L07101, doi:10.1029/2012 GL 051205.

G1–P10

CURRENT STATUS OF UPPER ATMOSPHERE PHYSICS OBSERVATION IN ICELAND IN 2012

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Syowa Station (SYO) in Antarctica and Iceland in the northern hemisphere are located at auroral latitudes, and in the geomagnetic conjugate relationship, where both are connected with each other with a same magnetic field line. Conjugate observations of auroral phenomena in Iceland have been carried out since 1984 as a collaborative project between National Institute of Polar Research (NIPR), Japan and University of Iceland. At present, there are two observatories in Iceland; Husafell (HUS) and Tjornes (TJR). Conjugate point of Syowa, which was initially located between HUS and TJR in 1984, is now located just north-eastward of TJR. Various ground-based instruments are operated now. We will show the current status of the upper atmosphere physics observations in Iceland as of 2012.

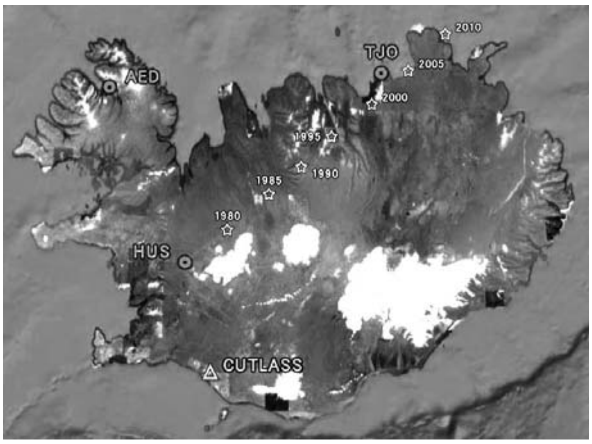

Fig.1. Map of Iceland. Indicated are locations of observatories in Iceland (HUS, TJO, AED), and geomagnetic traced footprint of Syowa Station (star symbols) from 1980 to 2010.

G1–P11

Impact of NICAM-LETKF on the Arctic

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In the university of Tsukuba, the Local Ensemble Transform Kalman Filter (LETKF) is applied to the Nonhydrostatic Icosahedral Atmospheric Model (NICAM) to develop the NICAM-LETKF system. The NICAM is designed to perform cloud-resolving simulations by directly calculating deep convection and mesosclase circulation, such as the tropical storm, arctic cyclone and so on. Moreover, the NICAM is able to avoid the pole problem by adopting icosahedral grid structure. The LETKF is one of the ensemble based Kalman filter. It has highly parallel performance because it is implemented in each grid. It is expected that the NCIAM-LETKF system describes much clear the atmospheric phenomena by assimilating observations with the NICAM-LETKF system.

In this study, the data assimilation experiments with the NICAM-LETKF system are implemented under the perfect model scenario to investigate the feasibility and stability of the NICAM-LETKF system in the Arctic. The horizontal resolution is 224 km and the number of vertical layers is 40. The ensemble size is fixed to 40.

According to the results, the NICAM-LETKF system works appropriately and stably under the perfect model scenario. We confirm that the NICAM-LETKF system converges stably, and the analysis errors are smaller than the observation errors. Moreover, in the areas where there is a disturbance, we find that not only the analysis error but also the ensemble spread are large as expected.

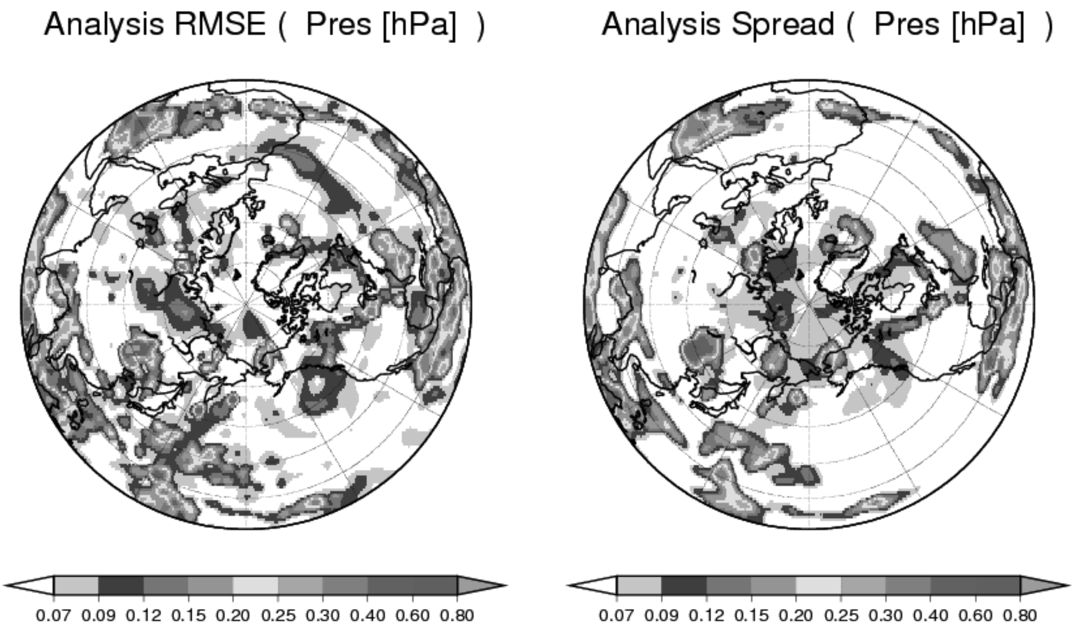

Fig. 1. Spatial distributions of the analysis RMSE (right panel) and ensemble spread (left panel) of 13th layer from the bottom at 00 Z 1 Sep. 2011.

G1–P12

DECADAL VARIABILITY AND A RECENT AMPLIFICATION OF THE SUMMER BEAUFORT HIGH: IMPLICATIONS FOR SEA-ICE, UPWELLING AND POLYNYAS IN THE WESTERN ARCTIC OCEAN

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The Beaufort High (BH), an anti-cyclone over the Beaufort Sea, is an important feature of the summer atmospheric circulation over the Arctic Ocean. For example, years characterized by low Arctic sea ice extent are typically associated with the presence of a stronger BH; with the opposite occurring during years with high sea ice extent. Here we show that there exists variability on the decadal time scale in the intensity and location of the summer BH. We also show that there has been a trend towards a stronger summer BH that began in the late 1990s. This trend is shown to be associated with a tendency towards a reduction in summer cyclogenesis over the Beaufort Sea. We argue that that these trends are the result of a warming of the Arctic troposphere and the concomitant reduction in baroclincity in the region. We furthermore show that this amplification in the BH results in enhanced easterly flow across the Beaufort and Chukchi Seas that results in a number of impacts including: the reduction of sea-ice in the region; the formation of polynyas in the vicinity of Wrangel Island and the Siberian coast of the Chukchi Sea; and an increase in frequency of reversal of the Chukchi Sea shelfbreak jet. The later leads to more frequent upwelling of nutrient rich water that may impact primary productivity in the region.

G1–P13

RECENT LINKAGE BETWEEN SPRING SNOW COVER AND SUMMER ARCTIC SEA ICE EXTENT

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Recent studies have suggested that variations of northern Eurasian spring snow cover can result in changes in the summertime northern atmospheric circulation via land–atmosphere interactions (Matsumura et al., 2010; Matsumura and Yamazaki, 2012). In particular, earlier-snowmelt reduces surface albedo, which leads to a rapider surface warming in spring. A strong snow–hydrological effect was also observed in eastern Siberia, where reduced soil moisture persists into the following summer and then contributes to an increased surface warming. In conjunction with the multidecadal decreases in Eurasian spring snow cover extent, Arctic sea ice cover has also rapidly declined over the recent two decades. We found that the land snow melting leads sea ice melting. This phase differences would result in an increased temperature contrast across the Arctic coastline, which may impact overlying atmospheric circulation.

Reference

Matsumura, S., K. Yamazaki, and T. Tokioka (2010), Summertime land-atmosphere interactions in response to anomalous springtime snow cover in northern Eurasia, J. Geophys. Res., 115, D20107, doi:10.1029/2009JD012342.

Matsumura, S. and K. Yamazaki (2012), Eurasian subarctic summer climate in response to anomalous snow cover, J. Climate. 25, 1305-1317.

G1–P14

CHANGES IN THE LENA RIVER DISCHARGE AND NET PRECIPITATION OVER THE BASIN DURING 2005-2008

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The Lena River has the second largest discharge among all rivers into the Arctic Ocean, which accounts for about 7% of total freshwater inflow. The Lena River discharge plays a role as a large freshwater source into the Arctic Ocean. While previous studies have been made on interannual variation of the river discharge (R) from the Lena River and associated precipitation, net precipitation (precipitation minus evapotranspiration, P-E), moisture transport and so on, several drastic changes in terrestrial water cycles are observed around Yakutsk in the past decade, especially during 2005-2008. This study examined the changes in the Lena River discharge and associated net precipitation and moisture transport during 2005-2008. In this analysis, we calculated vertically integrated moisture flux on the basis of atmospheric reanalyses and then estimated net precipitation from the moisture flux and precipitable water by means of the atmospheric water budget method without using P and E datasets.

To examine interannual variations of the R and P-E, it needs to take into account a time lag between those two, because the Lena River has a large area of the basin and precipitation during winter accumulates as snow. Comparison of the R to P-E indicated that summer (winter) P-E quantitatively corresponds to autumn (spring) R. They are positively correlated in each of the seasonal combinations. This indicates that the interannual variation of the Lena River R is controlled by the change in P-E over the basin in each season. The summer P-E and autumn R were high during 2005 2008, and also the winter P-E and spring R were high during 2007-2008. A decomposition analysis of moisture flux into stationary and transient components (Oshima and Yamazaki (2006, GRL), Tachibana et al. (2008, JGR)) showed some results about moisture transport as follows. In summer, the total moisture flux convergence over the Lena River basin is positively correlated with stationary component during the first half of the past three decades, however, the correlation becomes moderate during the second half. In the second half, the total and transient components of moisture flux convergences show weak positive correlation. These contributions of stationary and transient component were different in 2008 during 2005-2008. The stationary component dominates the total moisture flux convergence in 2008, on the other hand the transient component dominates in the other years.

G1–P15

ANNUAL CLOUD VARIATION OBSERVED AT NY-ÅLESUND FROM 2005 TO 2008

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It is of great importance to invesitgate cloud variation since cloud is one of the critical contributors to the Arctic radiation energy budget. Arctic clouds generally make the atmosphere warmer as the cloud coverage and altitude are wider and lower, respectively. The observation has been carried out with ground-based All-Sky Camera (ASC) and Micro Pulse LIDAR (MPL) to investigate the cloud coverage and cloud bottom height at Ny-Ålesund, Svalbard, Norway for about a decade. In this study, annual variation of the cloud coverage (or fraction) and base height data were analyzed from 2005 to 2008. As a result of statistical analyses on a monthly-average basis, the mean cloud fraction was 7.7 out of 10.0 during this period. The seasonal variation was also obtained such that they had a minimum value (5.9) in March and a maximum one (8.6) in August, even though the observation was carried out from March to October due to the limitation of the sunshine duration. The results were then compared to the MPL measurements and Eye observation, both of which could be available all through the year. The comparison showed a reasonable consistency of the mean values with 7.2 (MPL) and 6.7 (Eye), and of the same seasonal variation, i.e., the minimum in March and the maximum in August. The MPL also provided the cloud base height (CBH) statistics, which showed that there dominated lower level clouds with CBH up to 1 km all through the year during the period.

G1–P16

THE STRUCTURE OF THE ARCTIC CYCLONE IN SUMMER ANALYZED BY THE JRA-25/JCDAS REANALYSIS DATA

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In recent years, the Arctic has undergone a dramatically change in warming and sea ice melting. The arctic cyclone is one of the facters to these problems. Although the arctic cyclone was studied statistically in the area of the generation or the variability of the number, few studies have examined in the dynamical structure.

In this study, we investigated the three-dimensional structure of the arctic cyclone for some cases, using reanalysis data of JRA-25/JCDAS. As a result, the arctic cyclone is different from the mid-latitude cyclone in many features. The arctic cyclone moves randomly in direction over the Arctic Ocean and surface pressure drops rapidly to the mature stage. The arctic cyclone detected at the sea level pressure is connected with polar vortex. Importantly, the arctic cyclone has the cold core in the troposphere and warm core at around 250 hPa. Also, the downdraft exists at around 250 hPa. Hence, the warm core accompanied by the downdraft at 250 hPa and connecting with the polar vortex is the important mechanism of maintenance and development of the artic cyclone.

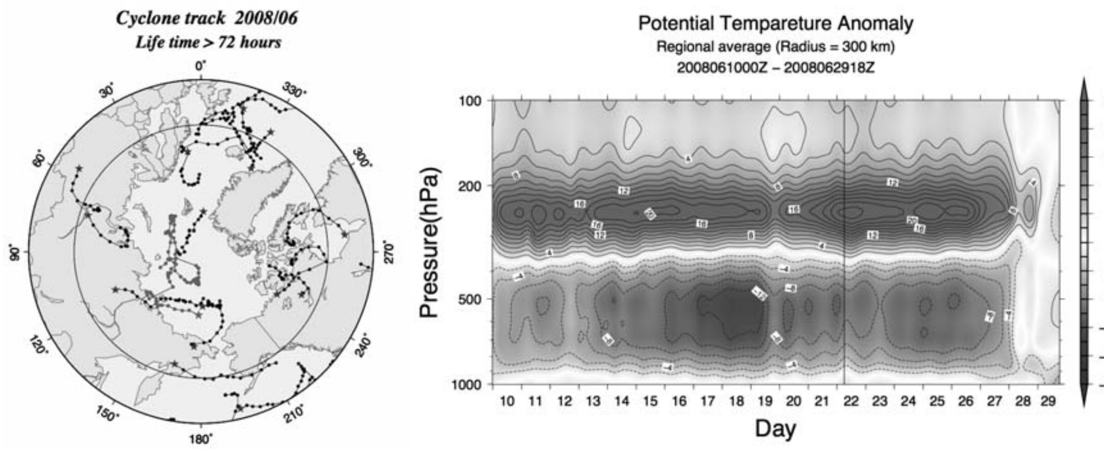

Figure: Tracks of the arctic cyclone in August 2006 (left). The red line is the analyzed cyclone. Vertical-time section of the potential temperature anomaly averaged within 300 km radius from the center of the arctic cyclone (right) for June 2008.

G1–P17

MICROPHYISICAL PROPERTIES OF BOUNDARY LAYER MIXED-PHASE CLOUD OBSERVED IN NY-ALESUND, SVALBARD (OBSERVED CLOUD MICRO-PHYSICS AND CALCULATED OPTICAL PROPERTIES)

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The cloud-radiation interaction plays an important role in global climate system and has been investigated by many researchers. However, the understanding of mixed-phase boundary layer cloud in Arctic has remained one of the unknown factors. During the period of May to June, 2011, in situ measurement of mixed phase boundary layer clouds were carried out at Zeppelin Station of Norwegian Polar Institute (NPI) in Ny-Alesund (78.9N, 11.9E), Svalbard.

The instruments consist of Cloud, Aerosol and Precipitation Spectrometer (CAPS), PVM-100（Gerber Particulate Volume Monitor） and Cloud Particle Microscope imager (CPM). CAPS is composed of Cloud and Aerosol Spectrometer (CAS）and Cloud Imaging Probe (CIP). CAPS-CAS and CAPS-CIP have same measurement capabilities of Forward Scattering Spectrometer Probe (FSSP) models 100 and 300 and tow dimensional optical imaging probe (2D-OAP), respectively. PVM-100 measures liquid water content and effective radius of water droplet clouds. CPM consists of CCD camera and microscope and takes an image of cloud particles. These instruments were installed on the roof of Zeppelin Station of NPI, which is near the top of Mt. Zeppelin and is at the altitude of 474 m.

The clouds associated with outbreak of westerly cold air mass from the sea were observed on June 9, 2011. The atmospheric temperature during the measurement was from -3 to -5 C. The large part of cloud particles that were measured by CAPS-CIP consisted of column type. We show the cloud microphysical properties; cloud particle size spectrum, liquid water content, ice water content and calculated optical properties.

G1–P18

Diagnostic Analysis of the Decadal Variability of the Arctic Oscillation using the AOI Equation

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In this study, we investigated the dynamical origin of the Arctic Oscillation Index (AOI) using the AOI equation to which is derived from 3-D spectral primitive equations. The purpose of this study is to divide the factor of AOI into the portions depending on the linear term of internal dynamics, the portion depending on an interaction with unsteady turbulence (the nonlinear term), and the portion depending on external forcing (the force term) using an AOI equation. Using this equation we investigate the origin of the decadal variability of the AOI.

According to the result the AOI has a resonant relation for the linear term and a damping relation for the nonlinear and force terms. This means that the linear term has positive feedback to AOI and the nonlinear and force terms have negative feedback to AOI. Moreover, it shows that the most of AOI of decadal variability is caused by the linear term. This means that the decadal variability of the atmosphere in the Northern Hemisphere is not induced by the external forcing but is excited by the internal change of the atmosphere. On the other hand, it becomes clear that the great portion of change of AOI is brought by the nonlinear term for the short time scale less than about a month.

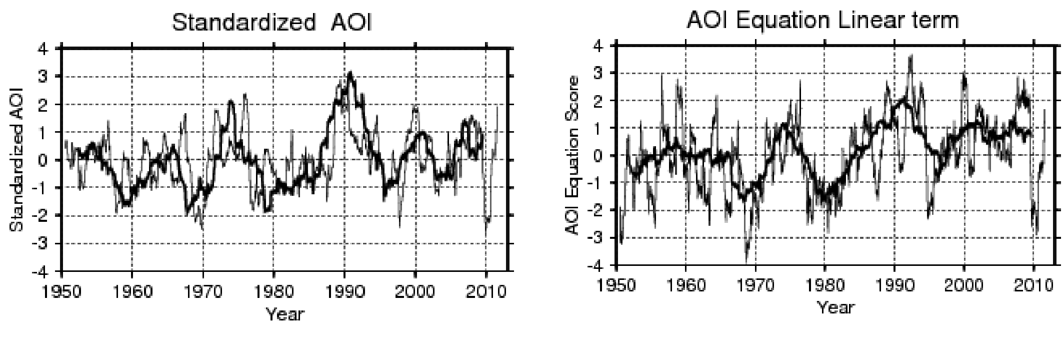

Figure: Time series of AOI (right) and AOI Equation Linear term (left). Thin line is 1 year running mean. Bold line is 5year running mean.