Synthesis and Legacy of GRENE Arctic Climate Change Research Project

*Takashi Yamanouchi[1,2], Kumiko Takata[1,3,4]

1.National Institute of Polar Research, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.National Institutes for Environmental Studies, 4.JAMSTEC

Green Network of Excellence Program (GRENE) Arctic Climate Change Research Project “Rapid Change of the Arctic Climate System and its Global Influences” had been conducted from Fy 2011 to 2015, and was the first Japanese interdisciplinary and model-observation collaborating project, advanced by many participants under a system that encompasses nearly all of Japan. Four Strategic Research Targets were presented:

1. Understanding the mechanism of warming amplification in the Arctic,
2. Understanding the Arctic climate system for global climate and future change,
3. Evaluation of the impacts of Arctic change on weather and climate in Japan, marine ecosystems and fisheries,
4. Projection of sea ice distribution and Arctic sea routes.

In order to analyze these targets, seven bottom up Research themes were selected:

1. Modeling Theme,
2. Terrestrial Theme,
3. Atmosphere Theme,
4. Cryosphere Theme,
5. Greenhouse Gas Theme,
6. Marine Ecosystem Theme,
7. Sea Ice and Arctic Sea Routes Theme.

It was such a unique structure that bottom up research themes answer the top down strategic research targets.

In the project, field observations were conducted at pan-Arctic sites such as Svalbard, Russian Siberia, Northern Canada, Greenland and Arctic Ocean. A high precision Cloud Profiling Radar (95 GHz) was established at Ny-Ålesund, Svalbard and intensive atmospheric observation campaigns had been held. In the Arctic Ocean, research cruises by RV “Mirai” and other ice breakers were conducted and mooring buoys were deployed. Observational data were collected in the Arctic Data archive System (ADS) and opened to the public with interfaces for the analysis. Modeling studies were carried out using various types of the models from the principal physical models to the general circulation models.

Through these observation, analysis and modeling studies, plenty of outcomes have been produced, typically as:

Identification and quantitative evaluation of the feedback processes with the seasonal cycle that cause Arctic warming amplification,

Mid-latitude link of the Arctic warming and sea ice reduction through the troposphere-stratosphere interaction including the effect to extreme weather in Japan such as cold winter and heavy snow,

Projection of sea ice distribution and possibilities of Arctic sea routes,

Changes in terrestrial ecosystems and strengthening of atmospheric CO_2 sink,

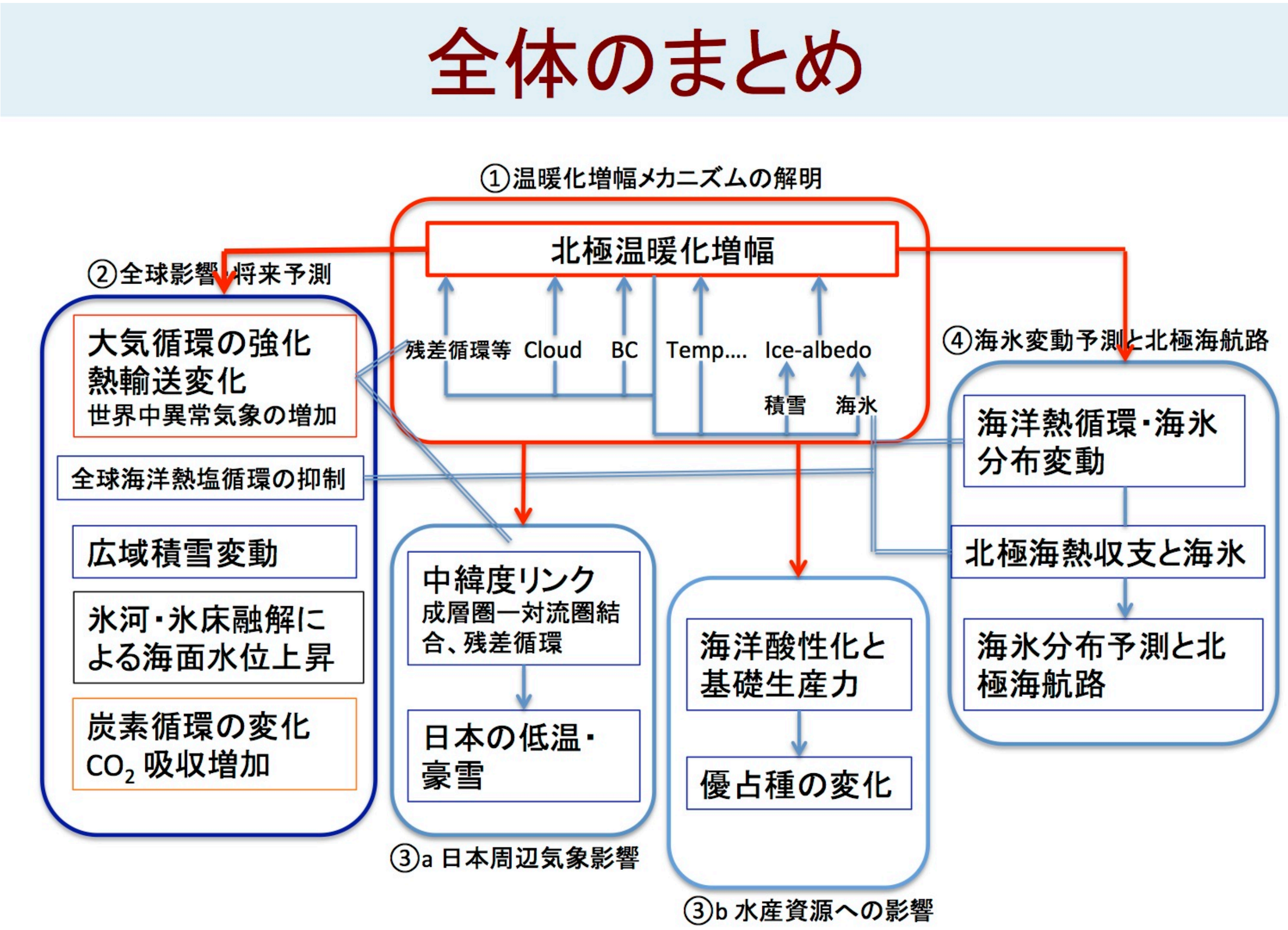
Impacts of marine environment change including ocean acidification to the marine ecosystems and change in superior species,

Contributions of glacier and ice sheet collapse to the sea level rise.

However, still many issues remain unsettled such as cloud behaviors according to the warming, advancing polar prediction capabilities, improvement of understanding water cycles and methane

emission from permafrost and offshore region, and extensive future research activities are waited. It is greatly welcomed to further research programs using Cloud Profiling Radar as a basic infrastructure and interdisciplinary study circumstances cultivated during the project as a legacy of GRENE. Already ArCS (Arctic Challenge for Sustainability) has been started and study aimed at joining YOPP (Year of Polar Prediction; WMO/PPP) is planned, it is expected to proceed with much more new research studies on Arctic climate change.

Keywords: Arctic, sea ice, warming amplification, mid-latitude link, Arctic sea routes



Mid-winter transport of subsurface warm water in western Arctic Ocean

*Eiji Watanabe[1], Jonaotaro Onodera[1], Motoyo Itoh[1], Shigeto Nishino[1], Takashi Kikuchi[1]

1.Japan Agency for Marine-Earth Science and Technology

Ocean heat transport is a possible important factor for recent sea ice decline, especially in the western Arctic Ocean. It has been indicated that vertical hydrographic profiles in the Canada Basin were characterized by three temperature maxima. The near-surface temperature maximum was the shallowest one arising from summer solar heat absorption and subsequent autumn Ekman downwelling. The subsurface temperature maximum reflected intrusion of Pacific summer water. The deepest maximum was located in the Atlantic layer. Substantial parts of upper ocean heat would eventually affect sea ice freezing/melting. However, spatial and temporal variabilities of these warm layers still remain uncertainties. Recently, year-long moorings in Chukchi Abyssal Plain detected mid-winter subsurface warming, plausibly caused by lateral advection of shelf-origin water. In this study, a pan-Arctic sea ice-ocean modeling was performed to address overwinter transport of subsurface warm water. The horizontal grid size was approximately 5 km to resolve mesoscale eddies and narrow jets. The interannual experiment from 2001 to 2014 demonstrated that Barrow Canyon throughflow and westward shelf-break jet established primary pathways of subsurface heat transport toward Chukchi Borderland. Shelf-break heat was partly lost by event-like wind mixing but remained under highly stratified surface layer until mid-winter.

Keywords: Arctic Ocean, Subsurface temperature maximum, Shelf-break jet

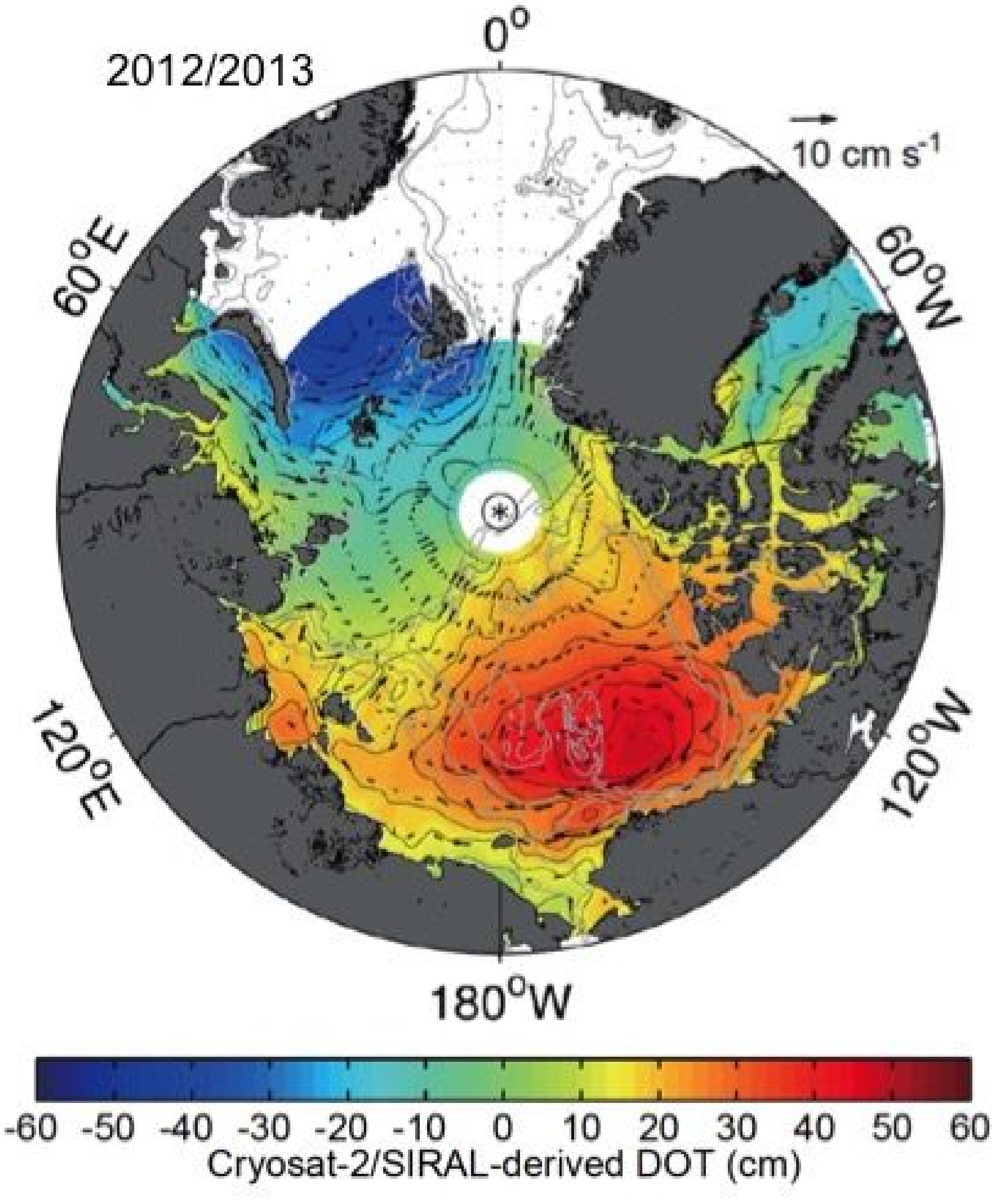
Wintertime variability of the Beaufort Gyre in the Arctic Ocean derived from CryoSat-2/SIRAL measurements

*Kohei Mizobata[1], Eiji Watanabe[2], Noriaki Kimura[3]

1.Tokyo University of Marine Science and Technology, 2.Japan Agency for Marine-Earth Science and Technology, 3.National Institute of Polar Research

The monthly dynamic ocean topography (DOT) of the Arctic Ocean was successfully estimated .by using the sea surface height measured by the SAR / Interferometric Radar Altimeter (SIRAL) on board CryoSat-2 (CS-2). The CS-2 monthly DOT showed the interannual and monthly variability of the Beaufort Gyre (BG) during winter between 2010/2011 and 2014/2015. Estimated BG in the Pacific Sector of the Arctic Ocean indicates that the northward flow at the western edge of the BG was primarily estimated over the Chukchi Borderland (CBL). However, in the winter of 2012/2013, the BG extended across the CBL (see figure). Our analyses revealed a significantly variable BG in response to changes in the sea surface stress field. Our analysis suggests that 1) sea ice motion, driven by wind fields, acts as a driving force for the BG when sea ice motion was intensified during winter and 2) sea ice motion can also act as an inhibiting force for the BG when sea ice motion is weakened during winter. In addition, the relationship between the DOT, steric height and ocean bottom pressure implied that the DOT during winter responded to varying wind stresses through baroclinic and also barotropic adjustments. According to a tracer experiment based on our monthly CS-2 DOT and derived geostrophic velocity field, we inferred that in the winter of 2012/2013, the Pacific-origin water carried into the BG through the Barrow Canyon was transported to the northern shelf and shelf break of the Chukchi Sea rather than the CBL, which is where the Pacific-origin water had been transported in the other years of the observation period.

Keywords: Beaufort Gyre, CryoSat-2/SIRAL, Dynamic ocean topography



2012/2013
0°
10 cm s-1
60°E
60°W
120°E
120°W
180°W
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
Cryosat-2/SIRAL-derived DOT (cm)

Medium-range prediction of the Arctic sea ice

*Noriaki Kimura[1,2], Hajime Yamaguchi[2]

1.National Institute of Polar Research, 2.Graduate School of Frontier Sciences, The University of Tokyo

INTRODUCTION

The summer Arctic sea-ice extent has decreased in this several decades. This reduction has accelerated maritime transport using the Arctic sea route. Sea ice prediction is essential to realize safe and sustainable use of the route. Especially, medium-term forecast looking several months ahead is necessary to determine whether or not the shipping route through the Arctic will be navigable.

The Arctic Ocean is nearly fully covered by sea ice until April or May, after which time interannual differences in ice area become noticeable. One possible cause of the interannual difference of ice retreat is ice thickness in spring before the start of melting. However, observations of ice thickness are insufficient in their spatial and temporal coverage, observation period or their accuracy to resolve the interannual difference of the thickness. Recently, Krishfield et al. (2014) shows the way to derive the daily sea ice thickness from the satellite microwave data.

To estimate the spatial distribution of spring ice thickness, we focus on the winter ice motion and redistribution. Our prediction is basing on the relationship between the ice thickness in spring and ice area in the following summer. We predict the summer ice area based on this relation.

DATA

We prepare a daily ice-velocity product on a 60 km resolution grid for 2003-2015, calculated from data of the satellite microwave sensors Advanced Microwave Scanning Radiometer-Earth Observing System (AMSR-E) and AMSR2. The procedure for detecting ice motion is based on the maximum cross correlation method (Kimura et al., 2013). Ice thickness is calculated from AMSR-E and AMSR2 images using the algorithm by Krishfield et al. (2014). This study also uses satellite derived daily ice concentration on a 10 km resolution grid, distributed by Arctic Data archive System (https://ads.nipr.ac.jp/index.html).

METHOD OF ICE PREDICTION

To investigate the dynamic redistribution of sea ice during winter, movement of particles spread over the ice area is calculated. About 20000 particles having initial ice thickness are arranged at an interval of 30 km over the ice area on December 1 of each year. Daily displacement of the particles is calculated from the satellite derived ice velocity on one-day time steps up to April 30.

Provisional ice thickness on April 30 is estimated by 1) particle density only, 2) particle density multiplied by the initial ice thickness, 3) particle density multiplied by the initial ice thickness only in the thick-ice (>1.5m) area. We found the highest correlation between the spring ice thickness and summer ice cover in the case of 3. We can predict the summer ice area based on the relationship between the provisional ice thickness and summer ice area. Based on the analysis, first report of the summer ice prediction showing the ice concentration map for July 1 to September 11 is released in May on our website.

The medium-term forecast looking several months ahead should be useful for safe and efficient use of the Arctic sea route. As a next step, we are trying to predict the ice thickness distribution.

ACKNOWLEDGEMENTS
We wish to thank the Arctic Data archive System for the gridded AMSR-E and AMSR2 data. This study was supported by the Green Network of Excellence Program Arctic Climate Change Research Project.

REFERENCES

Kimura N., Nishimura A., Tanaka Y. and Yamaguchi H. (2013) Influence of winter sea ice motion on summer ice cover in the Arctic, Polar Research, 20193.
Krishfield, R. A., Proshutinsky, A., Tateyama, K., Williams, W. J., Carmack, E. C., McLaughlin, F. A., and Timmermans, M. L. (2014) Deterioration of perennial sea ice in the Beaufort Gyre from 2003 to 2012 and its impact on the oceanic freshwater cycle, J. Geophys. Res., 119, 1271-1305.

Keywords: Arctic, Sea ice, Satellite remote-sensing

Impact of radiosonde data over the Arctic ice on forecasting winter extreme weather over mid latitude

*Kazutoshi Sato[1], Jun Inoue[1,2,3], Akira Yamazaki[2], Joo-hong Kim[4], Marion Maturilli[5], Klaus Dethloff[5], Stephen R Hudson[6]

1.National Institute of Polar Research, 2.Japan Agency for Marine-Earth Science and Technology, 3.SOKENDAI (Graduate University for Advanced Studies), 4.Korea Polar Research Institute, 5.Alfred Wegener Institute, 6.Norwegian Polar Institute

In February 2015, the Arctic air outbreak caused extreme cold events and heavy snowfall over the mid latitude, in particular over the North America. During the winter, special radiosonde observations were made on the Norwegian RV Lance around the north of Svalbard under the N-ICE2015 project. We investigated the impact of the radiosonde data on forecasting of a cold extreme event over the eastern North America using the AFES-LETKF experimental ensemble reanalysis version2 (ALERA2) data set. ALERA2 was used as the reference reanalysis (CTL) while the observing-system experiment (OSE) assimilated the same observational data set, except for the radiosonde data obtained by the RV Lance. Using these two reanalysis data as initial values, ensemble forecasting experiments were conducted. Comparing these ensemble forecasts, there were large differences in the position and depth of a predicted polar vortex. The CTL forecast well predicted the southward intrusion of the polar vortex which pushed a cold air over the eastern North America from the Canadian Archipelago. In the OSE forecast, in contrast, the trough associated with southward intrusion of the polar vortex was weak, which prevented a cold outbreak from Arctic. This result suggested that the radiosonde observations over the central Arctic would improve the skill of weather forecasts during winter.

Keywords: Arctic, polar vortex, ensemble forecast

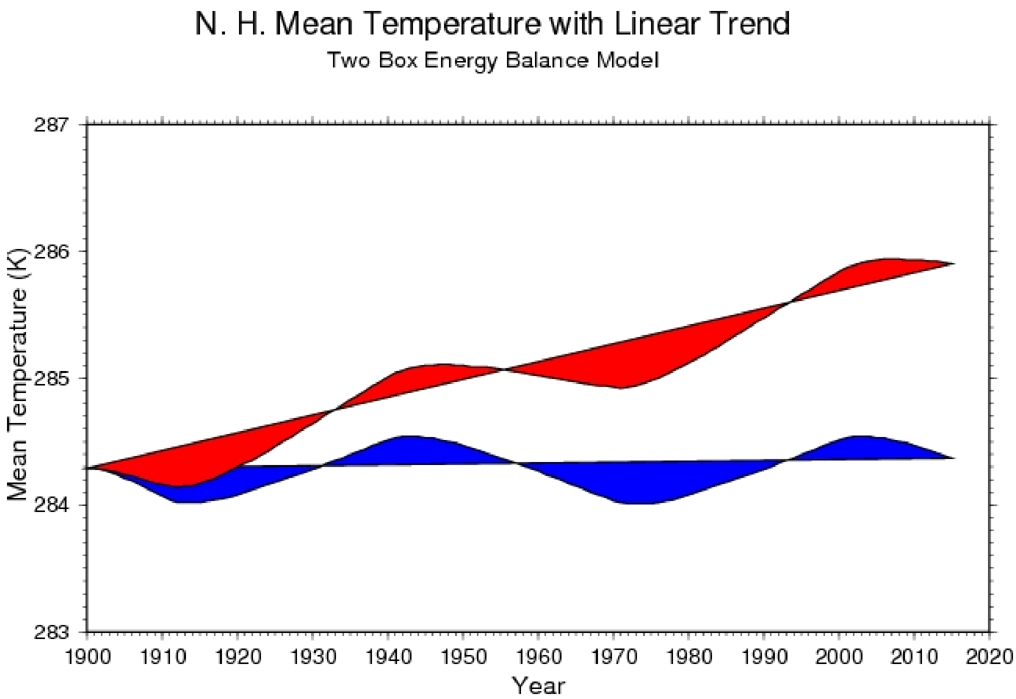
Relationship between the Arctic Oscillation and Surface Air Temperature in Multi-Decadal Time-Scale

*Hiroshi Tanaka[1]

1.Center for Computational Sciences, University of Tsukuba

In this study, a simple energy balance model (EBM) was integrated in time, considering a hypothetical long-term variability in ice-albedo feedback mimicking the observed multi-decadal temperature variability. A natural variability was superimposed on a linear warming trend due to the increasing radiative forcing of CO2. The result demonstrates that the superposition of the natural variability and the background linear trend can offset with each other to show the warming hiatus for some period. It is also stressed that the rapid warming during 1970 to 2000 can be explained by the superposition of the natural variability and the background linear trend at least within the simple model.
The key process of the fluctuating planetary albedo in multi-decadal time scale is investigated using the JRA-55 reanalysis data. It is found that the planetary albedo increased for 1958 to 1970, decreased for 1970 to 2000, and increased for 2000 to 2012, as expected by the simple EBM experiments. The multi-decadal variability in the planetary albedo is compared with the time series of the AO mode and Barents Sea mode of surface air temperature. It is shown that the recent AO negative pattern showing warm Arctic and cold mid-latitudes is in good agreement with planetary albedo change indicating negative anomaly in high latitudes and positive anomaly in mid-latitudes. Moreover, the Barents Sea mode with the warm Barents Sea and cold mid-latitudes shows long-term variability similar to planetary albedo change. Although further studies are needed, the natural variabilities of both the AO mode and Barents Sea mode indicate some possible link to the planetary albedo as suggested by the simple EBM to cause the warming hiatus in recent years.

Keywords: Arctic Oscillation, Arctic Amplification, Energy Balance Model, Planetary Albedo, Multi-decadal Variability


N. H. Mean Temperature with Linear Trend
Two Box Energy Balance Model
Mean Temperature (K)
287
286
285
284
283
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

Cooperation between the arts and science ----Integration of disintegration----

*Henry Stewart[1]

1.Former professor of the Open University of Japan

Integration of research in the arts (humanities) and science is the focus of attention, both in academia and the media. However, little attention has been given to the fundamental differences in methodology and research posture between the two. This difference can, and often does hinder productive cooperation, as well as becoming the grounds of distrust in research results. Based upon personal experience as an Arctic anthropologist, I discuss instances of success and failure in cooperative research. As a contribution to further cooperation, I conduct natural scientists on a journey into the mysteries and pitfalls of anthropological field research.

Observation of Atmospheric Environment over The Arctic and West Siberia using ROSHYDROMET Airplane

*Ryoichi Imasu[1], Toshinobu Machida[2], Shuji Aoki[3], Takashi Yamanouchi[4], Tsuneo Matsunaga[2], Hidekazu Matsueda[5], Yugo Kanaya[6], Yutaka Matsumi[7], Taro Shinoda[7], Hiroshi Tanimoto[2], Daisuke Goto[2], Isamu Morino[2], Yousuke Sawa[5], Kazuhiro Tsuboi[5], Yosuke Niwa[5], Naoki Kaneyasu[8], Shohei Murayama[8], Tetsuo Sueyoshi[4], Masayuki Takigawa[6], Fumikazu Taketani[6], Yousuke Sato[9], Wataru Takeuchi[10], Hitoshi Irie[11], YASUKO KASAI[12], Mikhail Strunin[13], Boris Fomin[13]

1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.National Institute for Environmental Studies, 3.Graduate School of Science, Tohoku University, 4.National Institute of Polar Research, 5.Meteorological Research Institute, Japan Meteorological Agency, 6.Japan Agency for Marine-Earth Science and Technology, 7.Institute for Space-Earth Environmental Research, 8.National Institute of Advanced Industrial Science and Technology, 9.RIKEN, 10.Institute of Industrial Science, The University of Tokyo, 11.Center of Environmental Remote Sensing, Chiba University, 12.National Institute of Information and Communications Technology, 13.Central Aerological Observatory, ROSHYDROMET

The Arctic, including West Siberia, is the most sensitive region in the world to the global warming. Continuous and synthetic monitoring of the atmospheric environment has been desired in this region. For this and related purposes, airplanes are extremely useful for environmental observation. Recently, the Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET) has deployed a new airplane, the Yakovlev-42D (photo), a so-called "Airplane-Laboratory", and has entrusted the Central Aerological Observatory (CAO) with its operation. This is the only airplane that can fly over the Arctic and Siberia in Russian domain for scientific studies. On the other hands, Japanese organizations have on-going and future satellite missions, e.g., GOSAT and GCOM-C1. It is expected that the synergetic use of the satellite data and the "Airplane-Laboratory" can contribute to comprehensive monitoring of the Arctic environment. To promote the synergetic operation of the satellites and the airplane, AORI/UT and CAO entered an agreement for scientific cooperation on November 7, 2014, and within the framework, we co-organized a kick-off meeting on 23–24 November 2015 in Moscow and started discussion on its flight schedule and usage of the observational data. The cabin of the "Airplane-Laboratory" is divided into six sectors, i.e. 1)Meteorology, 2)Gas and aerosol (including a lidar), 3)Radiation (including an imager), 4)Radioactivity, 5)Cloud microphysics, and 6)Radar, and each sector is equipped with various types of instruments to measure the gaseous and particulate matters in the troposphere. Many gaseous species, CO_2, CH_4, O_3, NO, NOx, NOy, can be measured not only by exclusive sensors for each but also Cavity Ring-Down Spectroscopy (CRDS) operated onboard. Size distribution of aerosols of which size ranging 0.06-3.0μm can be measured by particle counters, and cloud condensation nuclei (CCN) and black carbon (BC) are also measured simultaneously. As for cloud microphysics, size distribution of cloud particles can be measured by various types of probes as well as detection of cloud crystal habits. The radiometers measure up- and down-welling radiation in the spectral range from ultra violet (UV) to thermal infrared (TIR). Up-looking lidar and down-looking imager whose spectral band covers UV through near infrared (NIR) are also equipped. Russian side expects Japanese community to contribute to calibrate CRDS and Single Particle Soot Photometer (SP2) instruments for more precise measurements of gaseous species and BC. Total flight time was 200 hours in 2014, and 500 hours are scheduled to be allotted in 2015-2033 (totally 20 years). We are negotiating over how much amount of flight time will be allotted to the joint observations with Japanese side in future.

Keywords: The Arctic, Airplane, Atmospheric Environment, ROSHYDROMET, West Siberia

Tropical Forcing of the Early Twentieth Century Warming over the Arctic

*Hiroki Tokinaga[1,2], Shang-Ping Xie[3], Hitoshi Mukougawa[1]

1.Disaster Prevention Research Institute, Kyoto University, 2.The Hakubi Center for Advanced Research, Kyoto University, 3.Scripps Institution of Oceanography, University of California San Diego

Land air temperature over the Arctic had warmed by about 1.5C during the early twentieth century (20C). We examine a remote forcing of tropical oceans on the early 20C warming over the Arctic, analyzing new sea surface temperature (SST) products and comparing SST-forced atmospheric general circulation model (AGCM) simulations. The new SST products feature a significant warming in the equatorial Pacific during the early 20C while conventional ones exhibit a broad warming over the tropics and subtropics. Only AGCM simulation forced with the new SST product successfully reproduces the observed Arctic warming and atmospheric teleconnection patterns triggered by the equatorial Pacific warming. They effectively transport heat from the subtropics to the higher latitude, contributing to the Arctic warming during the early 20C.

Keywords: Arctic warming, Interdecadal Pacific Oscillation

On the mechanism of vegetation feedback to the Arctic warming amplification

*Masakazu Yoshimori[1,2], Ryouta O'ishi[3,4], Ayako Abe-Ouchi[3]

1.Faculty of Environmental Earth Science, Hokkaido University, 2.Arctic Research Center, Hokkaido University, 3.Atmosphere and Ocean Research Institute, The University of Tokyo, 4.National Institute of Polar Research

It is well known that the Arctic climate is sensitive to the external radiative forcing and its response is generally larger than the rest of the world. Observations show that the Arctic is indeed warming at about twice the speed of the global average, and climate model simulations also projects that the Arctic warming amplification continues to the future. Various physical processes have been listed as important contributors to the amplification, but the feedback effect of vegetation distribution change in response to the climate change is not always taken into account. Here, we extend the study of O’ishi and Abe-Ouchi (2009) in which the vegetation change is internally predicted in a coupled climate-dynamic vegetation model. In the current study, a calibration for the model’s systematic bias against present-day observations is added. This is important as the present-day vegetation distribution impacts on how the vegetation changes under the perturbed climate, and that the vegetation responds to the temperature itself and not to the temperature anomaly. Detailed energy transport and energy balance analysis are conducted for the doubled and quadrupled CO_2 equilibrium experiments.
In the experiment of atmospheric CO_2 increase, much of the current tundra area is replaced by the boreal forest, and the temperate forest expands as the boreal forest migrates to the north. Arctic land surface warms the most in spring due to albedo increase through vegetation-type changes and earlier snow melting. The effect of vegetation feedback is, however, not confined to the land warming. The large warming occurs in the Arctic Ocean in winter. Part of the excessive energy over land is cancelled by the increased evaporative cooling and part of it is transported to the Arctic Ocean in spring. This transport is accomplished by the mean meridional circulation (polar cell) in the atmosphere. This increased heat transport induces sea ice albedo feedback in summer and large heat release from the ocean in winter, causing the Arctic warming amplification.

Keywords: Arctic warming amplification, vegetation feedback, climate model, dynamic vegetation model

Comparison of CO_2 fluxes estimated by top-down and bottom-up methods -- a case study at Yakutsk, Siberia --

*Kumiko TAKATA[1,2,3], Prabir Patra[3], Dmitry Belikov[2,1], Ayumi Kotani[4], Junko Mori[3,1], GTMIP Group, Kazuhito Ichii[3], Tazu Saeki[3], Yosuke Niwa[5], Kazuyuki Saito[3], Takeshi Ohta[4], Shamil Maksyutov[2], Toshinobu Machida[2], Alexander Ganshin[6,7], Ruslan Zhuravlev[6,7], Atsuko Sugimoto[8], Shuji Aoki[9]

1.Arctic Environment Research Center, National Institute of Polar Research, 2.CGER, National Institute for Environmental Studies, 3.Japan Agency for Marine-Earth Science and Technology, 4.Nagoya Univ., 5.Meteoroligical Research Institute, JMA, 6.Tomsk State University, 7.Central Aerological Observatory, 8.Hokkaido University, 9.Tohoku University

Carbon balance of the forested ecosystem is widely recognized as an important component in climate change research, but remains uncertain at the same time. Attempts have been made, recently, to understand the origin of the uncertainty by comparing estimates of carbon budgets with bottom-up and top-down methods. In the Green Network of Excellence (GRENE) Arctic Climate Change Research Project (hereafter as, GRENE Arctic project), terrestrial and atmospheric observations are conducted in the Arctic regions, where observational data were not available otherwise, e.g., in Siberia. At the same time, CO_2 fluxes are estimated using process-based terrestrial ecosystem,models and atmospheric CO_2 inversion models as a part of the GRENE Arctic project.
In the terrestrial sub-program, observation on energy-water-carbon balances are conducted in the Circum-Arctic, and the fluxes are estimated by a suite of terrestrial ecosystem models at four super-sites in the GRENE-TEA model intercomparison project (GTMIP) (Miyazaki et al., 2015). In the greenhouse gas sub-program, atmospheric CO2 concentration is measured at high accuracy using aircrafts and at surface stations and top-down/inverse modeling is performed for estimating regional CO_2 fluxes. We have compared the CO_2 fluxes estimated from tower observation at Yakutsk, Siberia with the CO2 flux estimates by the land-surface models for Yakutsk and CO_2 surface fluxes estimated by inverse models around the Yakutsk region (area ~500 x 500 km^2). The Net Ecosystem Production (NEP) or Net Biome Production (NBP) are considered for this analysis at monthly time intervals over the period of 1980 - 2012 (from 2004 - 2011 for flux observation).
We find that the seasonal cycle of CO_2 flux consists of a large drawdown in June-August from the atmosphere, and weaker emissions or absorptions in other months. This result agrees well among the models and observation. As for the long-term changes, the model variation is smaller in summer (June-August) than for the annual values. That is because respiration takes a dominant part of CO_2 flux in winter, that would have large uncertainty both for the observation and the model estimation. Thus the large uncertainty in CO_2-flux estimates in winter would affect the large fluctuation for the annual values. The year-to-year variations in summer by some models agree, at least in part, with the observation, but the reasons for the agreement/disagreement should carefully be investigated. At first, the difference in the horizontal scale represented by each method should be considered. Besides, different treatments of forest fire are identified as one of the possible causes for model-to-model differences. The extreme climate, such as very humid or hot-and-dry summer, resulted in year-to-year changes in NEP/NBP with the tower observation, but some models do not agree to those changes. Making thorough examination of each case is required to identify the causal process of the disagreements and to reduce the uncertainty in CO_2 balance.

References

Miyazaki, S., K. Saito et al., GRENE-TEA model intercomparison project (GTMIP): overview and experimental protocol for Stage 1, Geosci. Model. Dev., 8, 1-16, doi:10.5194/gmd-8-1-2015

Keywords: CO2 balance, boreal forest region, topdown and bottomup hethod, tower observation

Weather Conditions During Large-Scale Widespread Forest Fires in Alaska

*Hiroshi Hayasaka[1], Hiroshi L Tanaka[2], Peter A Bieniek[3]

1.NPO Hokkaido Institute of Hydro-climate, 2.University of Tsukuba, 3.University of Alaska Fairbanks

Global maps of wildfires show large-scale widespread fire zones throughout the world. One major fire zone is in the boreal forests of Alaska. The boreal forest in Alaska encompasses about 0.47×10^6 km^2 (i.e. 32% of the total Alaskan land area) and has experienced large-scale widespread fires more frequently in recent years, most notably in 2004, 2005, 2009, and 2015. The total burnt area by wildfires in 2004 was largest on record. The burnt area by wildland fires was approximately 26,700km^2 in 2004 (the largest burnt area on record) and 20,900km^2 in 2015 (the second-largest burnt area). The total burnt area in just these two fire years comprised approximately 10.5% of the entire Alaskan boreal forest.
In this study, we analyzed the daily fire weather conditions during recent severe fire-periods. Synoptic-scale weather conditions were analyzed using upper (500hPa) and near surface level (1000hPa) atmospheric reanalysis data. Synoptic-scale weather maps based on the atmospheric reanalysis data were used to document the severe fire weather conditions leading to extensive wildfire activity under both high- and low-pressure conditions. For high-pressure conditions, wind direction change from south-westerly to north-easterly associate with high-pressure system movement from south to north was discussed using weather events related to Rossby waves breaking (RWB). We discussed relationship among weather events related to RWB and fire activities.
The results are summarized as follows:
1. Fire weather conditions of the high-pressure type occurred under unique weather phenomena related to RWB. RWB occurred in easterly wind flow with large Jet stream meandering (JSM) occurring near Alaska. The high-pressure system at the lower level (1000hPa) moved toward the north under a ridge and blocking high over Alaska at the upper air level (500hPa). During the movement of the high-pressure system from south to north, two severe fire weather conditions the first hotspot peak (1) and second (largest) hotspot peak (2) appeared.
2. Two distinctive hotspot peaks, the first peak (1) and second peak (2) during each fire-period, occurred under two different synoptic-scale fire weather conditions. Fire weather conditions during first hotspot peak (1) consisted of a ridge in the Gulf of Alaska at the lower- and upper-levels. The ridge in the Gulf of Alaska supplied south-westerly wind into inland Interior Alaska. The weather conditions during the second hotspot peak (2) were dominated by the Beaufort Sea High (BSH) after high-pressure system passed over Alaska related to RWB phenomena.
3. The BSH occurred in conjunction with a blocking high aloft and supplied easterly wind into Interior Alaska. The BSH located at northern coast of Alaska resulted in relatively stronger easterly wind than the south-westerly wind during the first hotspot peaks (1) due to large pressure difference between the BSH and Interior Alaska. This is likely a key reason that the second hotspot peak (2) is larger than the first during the top four fire-periods.
4. A low-pressure fire weather type also occurs with south-westerly wind in Interior Alaska that results in a single large hotspot peak. This wind condition occurs due to the large pressure difference between a low-pressure system in the Arctic Ocean and a high-pressure system in the Bering Sea.
5. The onset of the high- and low-pressure fire weather types in Alaska may both be predictable. This study suggests that : (a) onset of large Jet stream meandering in the west of Alaska may indicate the high-pressure fire weather type, (b) onset of low-pressure system development

(cyclogenesis) in the Arctic Ocean and a high-pressure system in the Bering Sea may precede the low-pressure fire weather type.

Keywords: Beaufort Sea High, Jet stream meandering, Rossby waves breaking, Widespread fires, MODIS hotspot

InSAR detection of thermokarst after a tundra wildfire, using ALOS-PALSAR

*Go Iwahana[1], Masao Uchida[2], Tsutomu Yamanokuchi[3], Larry Hinzman[1]

1.International Arctic Research Center, University of Alaska, 2.National Institute for Environmental Studies, 3.Remote Sensing Technology Center of Japan

Through the subsidence of ice-rich permafrost upon thaw (thermokarst), the consequences of permafrost degradation for surface ecology, landscape evolution, and hydrological processes have been of great scientific interest and social concern. Part of a tundra patch affected by wildfire in northern Alaska (27.5 km2) was investigated here, using remote sensing and in-situ survey to understand permafrost thaw dynamics after surface disturbances. L-band InSAR with spatial resolution of less than ten meters detected ground subsidence triggered by the tundra fire. We introduced a calibration procedure comparing burned and unburned areas for InSAR subsidence signals to remove the noise from seasonal surface movement. In the first year after the fire, an average surface subsidence rate of 6.2 cm/year (vertical) was measured. Subsidence in the burned area continued over the following two years with decreased rates. These results suggest that this InSAR-measured ground subsidence is caused by the thaw of ice-rich permafrost (thermokarst), a feature supported by surface change observations from high-resolution optical images and in-situ ground level surveys. InSAR analysis clearly showed spatial variation in thermokarst subsidence at fine scale, enabling us to investigate dynamics of thermokarst processes and quantify permafrost degradation, and leading to accurate estimates of ground ice loss upon permafrost thaw.

Scanning Electron Microscopy (SEM) analysis of Black Carbon in Arctic snow

*Naoko Nagatsuka[1], Ramona Valentina Mateiu[2], Kumiko Goto-Azuma[1,3], Yoshimi Ogawa-Tsukagawa[1], Konosuke Sugiura[4], Hiroyuki Enomoto[1,3], Teruo Aoki[5]

1.National Institute of Polar Research, 2.Technical University of Denmark, 3.SOKENDAI (The Graduate University for Advanced Studies), 4.University of Toyama, 5.Meteorological Research Institute

Snow and ice on glaciers in Arctic contain various atmospheric depositions, such as soot (black carbon) and mineral dusts. These light-absorbing impurities can reduce surface albedo and affect melting of glaciers. Thus, it is important to understand optical characteristics of the impurities on Arctic glaciers. In this study, we analyzed structure and surface chemistry of black carbon collected from snow in several Arctic regions (Siberia, Alaska, Greenland, and Sapporo) with Scanning Electron Microscope (SEM, QUANTA FEG 450) and Energy Dispersive X-ray Spectrometer (EDS). Microscopic observation revealed that snow samples from Alaska, Greenland and Sapporo contained black carbon particles with chain-like structures and compact aggregate structures as shown in Scarnato *et al.* (2013). However, the proportion of these black carbon structures were different among the samples. For example, snow from Greenland contained higher abundance of chain particles, while that from Alaska contained higher compact particles coated by membrane like material.

Keywords: Black Carbon, SEM, Arctic Snow

Concentrations and depositions of black carbon and insoluble particles in Alaskan snows

*Yoshimi Ogawa-Tsukagawa[1], Kumiko Goto-Azuma[1], Yutaka Kondo[1], Konosuke Sugiura[2], Sho Ohata[3], Tatsuhiro Mori[3], Moteki Nobuhiro[3], Makoto Koike[3], Motohiro Hirabayashi[1], Remi Dallmayr[1], Hiroyuki Enomoto[1]

1.National Institute of Polar Research, 2.Center for Far Eastern Studies, University of Toyama, 3.Graduate School of Science, The University of Tokyo

Snow cover in the Arctic is affected by global warming and has strong effects on albedo feedback. Light-absorbing particles such as black carbon (BC) and mineral dust could decrease snow albedo and accelerate snow melt, thus exerts influence on climate. In order to evaluate their impacts on snow albedo, it is important to know accurate concentration and deposition flux of light absorbing particles. Under the GRENE Arctic Climate Change Research Project, we collected seasonal snow cover samples from Alaska. During 2012-2015, we collected snow samples from 22 sites across Alaska in late February or early March. BC particles were measured using a single particle soot photometer (SP2), which is based on the laser-induced incandescence technique. Insoluble particles were measured using a Coulter Counter. From the spatial variations of BC concentrations, our sampling sites can be divided into five regions, i.e. Barrow (71.32°N), Prudhoe Bay (70.19°N), north region (66.56-68.62°N), middle region (63.57-65.9°N) and south region (61.82-63.27°N). The middle region shows the highest BC concentrations. These five regions also show different BC mass size distributions. BC mass size distributions in south region is similar to that in typical ambient air, whereas snow in middle region displays high percentage of large BC particles (>645nm). Mass concentrations of insoluble particles show spatial trend similar to that of BC concentrations. BC and insoluble particle depositions in snow were calculated with snow water equivalent (SWE) and concentrations. Averaged SWE in south region is the highest of three regions, but winter BC depositions is the highest in middle region, as is BC mass concentrations. Winter depositions of insoluble particles show no significant spatial trends.

Keywords: black carbon , Alaska

The sources of nitrogen and its effect on microbes on glacial snow and ice in the northwest Greenland

*Nozomu Takeuchi[1], Nobuhito Ohte[2], Naoko Nagatsuka[3], Jun Uetake[3], Sota Tanaka[1], Yukihiko Onuma[1]

1.Chiba University, 2.Kyoto University, 3.National Institute of Polar Research

The quantity and distribution of insoluble impurities are one of the most significant factors to determine surface albedo and have been reported to affect substantial melting of glacier ice and snow. Supraglacial impurities usually consist of inorganic and organic material accreted on the ice surface by wet precipitation or aeolian deposition. Microbes and organic matter are also dominant biotic constituents of supraglacial impurities. Microbes include cold-tolerant snow and ice algae, cyanobacteria, and heterotrophic bacteria, and they can grow and proliferate on the melting snow or ice surfaces. These microbes and their derivative organic matter often aggregate with mineral particles and form spherical granules called cryoconite. Cryoconite and some pigmented algae usually display a higher light absorbency (i.e. dark colored) compared with pure snow and ice, thus they can efficiently reduce surface albedo of snow and ice. Nitrogen is one of the important nutrients supporting growth of such microbes, however, information on their sources and dynamics on the glacial systems is still limited. We report soluble nitrogen concentrations and the nitrate stable isotopes (18O and 15N) in snow, ice, and meltwater collected in the north-west Greenland Ice Sheet. Nitrate was contained in both of snow and glacial ice. O and N isotopes of the nitrate showed that nitrate in snow is mostly supplied from atmosphere derived from natural origin, while that in glacial ice is from anthropogenic origins. Nitrogen isotope in organic faction in the impurities coincided to that of snthoropogenic nitrogen, suggesting that that microbes on the glacier used mainly anthropogenic nitrogen.

Keywords: Greenland, microbe, nitrogen

Seasonal variations in frontal positions and flow speeds of marine terminating outlet glaciers in northwestern Greenland

*Daiki Sakakibara[1,2], Shin Sugiyama[2]

1.Graduate School of Environmental Science, Hokkaido University, 2.Institute of Low Temperature Science, Hokkaido University

Greenland ice sheet is losing mass due to increase in surface melting and ice discharge from marine terminating outlet glaciers. The mass loss from the Greenland ice sheet accounts for a substantial part of global sea level rise over the last several decades. To accurately include the contribution of marine terminating outlet glaciers in the future projection of global sea level rise, better understanding of mechanisms controlling the glacier dynamics is required. Thus, it is important to study changes of marine terminating outlet glaciers in connection with atmospheric and the ocean conditions. For this purpose, we analysed Landsat images to measure frontal positions and flow speeds of marine terminating outlet glaciers along the coast of the Prudhoe Land, northwestern Greenland between 1987 and 2015. Relationships among frontal position, flow speed, sea ice condition in front of glacier terminus, and air temperature were investigated with special focus on seasonal variations.
All of studied 19 glaciers retreated from the 1980s to 2014. Among those, Heilprin, Tracy, Farquhar, Melville, Bowdoin, and Diebitsch Glaciers retreated by more than 1 km. Most of the studied glaciers began retreat around 2000, as demonstrated by the increase in the mean retreat rate from −1 m a^{-1} in 1980s–1999 to 66 m a^{-1} in 2000–2014. A possible driver of the rapid retreat since 2000 is atmospheric warming because the rapid retreat followed the onset of summer temperature increase in northwestern Greenland. Within 5 km from the studied fronts, ice speed ranged between 14 and 1814 m a^{-1}. Many of the studied glaciers accelerated in the early 2000s. Magnitude of the acceleration was correlated with the retreat rate as demonstrated by rapid retreat and flow acceleration at Heilprin, Tracy, Farquhar, Bowdoin and Diebitsch Glaciers. The acceleration was greater near the front, suggesting the change in the flow regime enhanced stretching of ice along the glacier and induced dynamic thinning. These results indicate that ice thinning due to flow acceleration was the driver of the rapid frontal retreat of the sutdied glaciers.
In general, studied glaciers advanced from spring to early summer, which was followed by retreat in late summer. Then, the front stayed at the retreated positions throughout the following fall. Magnitude of the seasonal front variations ranged in 50–400 m. The timing of the seasonal retreat agreed with the disappearance of sea ice in front of the glacier terminus. Many of the glaciers indicated speedup from spring to mid-summer and deceleration in late summer. Magnitude of the seasonal variations in ice speed was between 80 and 440 m a^{-1}. Because the speed changes were correlated with air temperature in summer season, the seasonal speedups were probably due to enhanced basal sliding driven by meltwater input to the bed.

Keywords: Glacier, Greenland

