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Takashi Yamanouchi and Vladimir Pavlov (eds)

Report from the Japan-Norway Joint Workshop:

Arctic climate and environmental change in global warming – collaboration on observations and analyses

Tromsø, Norway, 11–12 March 2010

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Research Council of Norway (RCN) and Japan Science and Technology Agency (JST)

Norsk Polarinstitutt er Norges sentrale statsinstitusjon for kartlegging, miljøovervåking og forvaltningsrettet forskning i Arktis og Antarktis. Instituttet er faglig og strategisk rådgiver i miljøvernsaker i disse områdene og har forvaltningsmyndighet i norsk del av Antarktis.

The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in the Norwegian polar regions. The institute also advises Norwegian authorities on matters concerning polar environmental management.

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Back row from left: Jack Kohler, Corinna Schrum, Mats Granskog, Naohiko Hirasawa, Tetsuo Ohata, Tuomo Saloranta, Johan Ström, Kim Holmén, Sebastian Gerland.

Middle row from left: Elisabeth Cooper, Chris Hall, Kenichi Matsouka, Tamotsu Hoshino, Takehiko Aso, Shinpei Yoshitake, Naoya Wada, Lennart Nilsen, Yvan Orsolini, Masahiro Yamamura, Arild Sundfjord.

Front row from left: Hiroshi Kanda, Takashi Yamanouchi, Meiji Honda, Satoru Kojima, Masataka Shiobara, Hironori Yabuki, Vladimir Pavlov, Atsushi Arakawa.

Not present when the picture was taken: Nalân Koç, Inger Greve Alsos, Luca Nizzetto, Laura de Steur, Gunnar Noer.

Table of contents

Workshop program

11 March 2010 (Day 1)

09:00-09:10 Welcome remarks:

Kim Holmén, Research Director of Norwegian Polar Institute

Atsushi Arakawa, Director, Japan Science and Technology Agency, Paris Office

09:10-09:50 Overall matters (Ny-Ålesund Observatory; SIOS, Flagship program) *(Kim Holmén, Hiroshi Kanda)*

Session 1. Atmospheric Science

Chair: **Johan Ström** and **Takashi Yamanouchi**

09:50-10:10 Atmospheric science observations at the Ny-Ålesund international research site *(**Takashi Yamanouchi**)*

10:10-10:30 An observational study on cloud-aerosol interaction in Ny-Ålesund *(**Masataka Shiobara**)*

10:30-10:50 Coffee break

10:50-11:10 On aerosols and clouds in the Arctic (***Johan Ström***)

11:10-11:30 Activity of UAV-used atmospheric observation for Antarctica *(**Naohiko Hirasawa**)*

11:30-11:50 Numerical modeling of the coupling between the cryosphere and the atmospheric circulation *(**Yvan Orsolini**)*

11:50-12:10 Influence of low Arctic sea-ice minima on anomalously cold Eurasian winters *(**Meiji Honda**)*

12:10-13:10 Lunch

13:10-13:30 Coupling processes between atmospheric layers: using collaborative observations to further our understanding *(**Chris Hall**)*

13:30-13:50 On the polar upper atmosphere environmental study by long-term Japan-Norway collaborative observations *(**Takehiko Aso**)*

Session 2. Environmental Change in the polar areas (ocean, sea ice, glaciers)

Chair: **Jack Kohler** and **Tetsuo Ohata** (after coffee break)

13:55-14:15 Monitoring of sea ice off Svalbard and in the Fram Strait (***Sebastian Gerland***)

14:15-14:35 Impacts of changing Arctic sea ice cover on solar energy transfer to the ocean – some key feedback processes (***Mats Granskog***)

14:35-14:55 Outline of Arctic region research in JAMSTEC (***Tetsuo Ohata***)

14:55-15:15 Ongoing Arctic research at the Geophysical Institute, University of Bergen *(**Corinna Schrum**)*

15:15-15:35 Coffee break

15:35-15:55 Oceanographic researches of the Polar Front zone in the Barents Sea (***Vladimir Pavlov***)

15:55-16:15 Shrinking Svalbard glaciers (***Jack Kohler***)

16:15-16:35 The present condition of cryosphere data management of Japan (***Hironori Yabuki***)

16:35-16:55 Freshwater fluxes through the Fram Strait (***Laura de Steur***)

16:55-17:15 Atmospheric observations by radiosonde in the Arctic Sea (***Meiji Honda***)

17:15-17:35 Ongoing research on evolution and range shift of Arctic flora (***Inger Alsos***)

12 March 2010 (Day 2)

09:00-09:20 A short presentation of the Norwegian Meteorological Institute in Tromsø in the context of polar weather forecasting and research (***Gunnar Noer***).

Session 3. Biological interest in the High Arctic

Chair: Hiroshi Kanda

09:20-09:40 Ecology of *Dryas octopetala sensu lato*, a relict plant in mountains of Northeast Asia: Comparison between mid-latitude alpine and Arctic tundra populations (***Naoya Wada***)

09:40-10:00 Plant ecology research on Svalbard (***Elisabeth Cooper*** *and* ***Lennart Nilsen****)*

10:00 -10:20 Project introduction. Carbon sequestration in an Arctic terrestrial ecosystem following rapid glacier retreat: Long-term change and future projection (***Shinpei Yoshitake***)

10:20-10:40 Classification and habitat characterization of vegetation in Ny-Ålesund, Svalbard (***Satoru Kojima***)

10:40-11:00 Coffee break

11:00-11:20 Simulating climate change induced alterations in bioaccumulation of organic contaminants in an Arctic marine food web (***Tuomo Saloranta***)

11:20-11:40 Snow molds in the Arctic and their occurrence under climate change in Svalbard and Hokkaido, northern Japan (***Tamotsu Hoshino***)

11: 40-12:00 Climate, biogeochemical cycles and the environmental exposure to persistent pollutants ***(Luca Nizzetto)***

12:00-12:20 Ecosystem responses to climate change on a High Arctic glacier foreland (***Hiroshi Kanda***)

12:20-13:20 Lunch

13:20-14:30 Workshop discussions

Break out two groups:

1) Physical, atmospheric, oceanic and ice researches

2) Biological and ecological researches

14:30-14:45 Coffee break

Talk about future direction, future collaboration.

Summary of groups discussion. Future plans and areas of cooperation.

14:45-15:00 Group 1 (2 leaders: Takashi Yamanouchi and Johan Ström)

15:00-15:15 Group 2 (2 leaders: Hiroshi Kanda and Tuomo Saloranta)

15:15-16:00 Round table discussion. Summary of workshop.

List of participants

List of Japanese participants

1. Arakawa, Atsushi (Director, Japan Science and Technology Agency, Paris Office)
2. Aso, Takehiko (Professor, The Graduate University for Advanced Studies, Sokendai), aso_takehiko@soken.ac.jp
3. Hirasawa, Naohiko (National Institute of Polar Research), hira.n@nipr.ac.jp
4. Honda, Meiji (Niigata University), meiji@env.sc.niigata-u.ac.jp
5. Hoshino, Tamotsu (SANSOKEN), tamotsu.hoshino@aist.go.jp
6. Ohata, Tetsuo (Japan Agency for Marine-Earth Science and Technology), ohata@jamstec.go.jp
7. Kanda, Hiroshi (Head of Arctic Environmental Research Center, National Institute of Polar Research), kanda@nipr.ac.jp
8. Kojima, Satoru (Northern Ecological Research Laboratory), komasat@chime.ocn.ne.jp
9. Shiobara, Masataka (National Institute of Polar Research), shio@nipr.ac.jp
10. Wada, Naoya (Toyama University), wada@sci.u-toyama.ac.jp
11. Yabuki, Hironori (Japan Agency for Marine-Earth Science and Technology), yabuki@jamstec.go.jp
12. Yamamura, Masahiro (Japan Science and Technology Agency), yamamura@ist.go.jp
13. Yamanouchi, Takashi (National Institute of Polar Research), yamanou@nipr.ac.jp
14. Yoshitake, Shinpei (Waseda University), syoshitake@kurenai.waseda.jp

List of Norwegian participants

1. Alsos, Inger Greve (University of Tromsø), inger.g.alsos@uit.no
2. Cooper, Elisabeth (University of Tromsø), elisabeth.cooper@uit.no
3. de Steur, Laura (Norwegian Polar Institute), desteur@npolar.no

4. Gerland, Sebastian (Norwegian Polar Institute), sebastian.gerland@npolar.no

5. Granskog, Mats (Norwegian Polar Institute), mats.granskog @npolar.no

6. Hall, Chris (University of Tromsø), chris.hall@uit.no

7. Holmén, Kim (Research Director of Norwegian Polar Institute), kim.holmen@npolar.no

8. Koç, Nalân (Head of Centre for Ice, Climate and Ecosystems (ICE), Norwegian Polar Institute), nalan.koc@npolar.no

9. Kohler, Jack (Norwegian Polar Institute), jack.kohler@npolar.no

10. Matsouka, Kenichi (Norwegian Polar Institute), kenichi.matsouka@npolar.no

11. Nilsen, Lennart (University of Tromsø), lennart.nilsen@uit.no

12. Nizzetto, Luca (Norwegian Institute for Water Research), luca.nizzetto@niva.no

13. Noer, Gunnar (Norwegian Meteorological Institute), gunnar.noer@met.no

14. Orsolini, Yvan (Norwegian Institute for Air Research), yor@nilu.no

15. Pavlov, Vladimir (Norwegian Polar Institute), vladimir.pavlov@npolar.no

16. Saloranta, Tuomo (Norwegian Institute for Water Research), tuomo.saloranta@niva.no

17. Schrum, Corinna (Geophysical Institute, University of Bergen), corinna.schrum@gfi.uib.n

18. Ström, Johan (Norwegian Polar Institute), johan.strom@npolar.no

19. Sundfjord, Arild (Norwegian Polar Institute), arild.sundfjord@npolar.no

Forewords (Kim Holmén and Atsushi Arakawa)

Norway and Japan seek to inspire towards new goals in polar research

Kim Holmén, Research Director of the Norwegian Polar Institute

The Japanese-Norwegian meeting held on March 11–12, 2010 in Tromsø was another fine occasion to meet and deepen the scientific exchange and friendship. Through mutual exchange of ideas and results we can inspire and enhance our collective efforts.

Norway and Japan have long history on research collaboration in the "High North", with active Japanese presence in Svalbard over many years. Japan and Norway were leading countries in the International Polar Year (IPY), one of the largest international research projects ever. Both countries also have political interests in the "High North".

The meeting in March 2010 was timely, indeed giving opportunities to share results and ideas from IPY and looking ahead building on these experiences and accruing knowledge. There is presently a lot of discussion about building a "legacy of IPY" and it is a responsibility for the scientists to suggest fruitful initiatives for that endeavor. Clearly the most productive approach is through scientist-scientist meetings that then can continue into common project formulations. The present meeting was indeed successful in this regard with friendly but lively debate and sprouting ideas for new projects.

Polar regions have long been an area for scientific collaboration between Norway and Japan. In Dronning Maud Land the Norwegian Troll station and Japanese Syowa station are neighbors with Antarctic standards. The stations are, nevertheless, 1400 kilometers apart and the scientists seldom interact due to practical reasons. Both countries maintain bipolar research programs and in the Arctic the proximity of the stations in Ny-Ålesund and direct collaboration using other facilities in Svalbard lead to frequent meetings between our scientists. These Arctic exchanges are not only useful for the science in the north but also through friendship and collaboration a stimulus for enhancing our cooperation in Antarctica.

Two nations with long tradition and friendship but with different scientific and technical structures can potentially be able to release great results through utilizing complementarities in ability and approach. The meeting showed that there are many ideas where high technology and environmental research could make great headway by utilizing Svalbard and the Arctic both as a test bed for new techniques that later can proliferate into Antarctic but simultaneously being an important study area in its own right. We see great opportunity in pursuing such goals within the framework of the coming

SIOS project in Svalbard. The meeting strengthens Norway and Japan to continue being leading nations in polar research with strong environmental profiles.

We look forward to the next meeting where we shall reap the fruits of this scientific friendship and feel joy from the new knowledge we are able to coax forth with hard but pleasurable work together.

Atsushi Arakawa, Director, Japan Science and Technology Agency (JST), Paris Office

It is a great honor for us to deliver this opening remark for Japan-Norway “Polar Research” workshop co-sponsored by the Research Council of Norway and Japan Science and Technology Agency (JST).

First of all, we would like to express our sincere appreciation to Dr. Takashi Yamanouchi, Vice Director of the National Institute of Polar Research of Japan, and Professor Vladimir Pavlov of the Norwegian Polar Institute, for all the hard work they have contributed as organizers to this workshop. We are also grateful to all the researchers participating, our co-hosts the Research Council of Norway and to all those who have devoted their energy to host this workshop.

On 12 November 2009, Japan-Norway Joint Commission on Cooperation in Science and Technology was held in Oslo. During that commission, both governments had agreed to hold this joint workshop. Since that, this workshop was finally achieved by the valuable efforts of everyone involved.

All of us know that both countries, Norway and Japan, are playing a significant role in this research area. And in the city of Tromsø, there are so many distinguished research institutes for polar research, such as the University of Tromsø and the Norwegian Polar Institute.

I am sure that this memorable first joint workshop was held timely by the right players in the very suitable place.

JST has been holding this kind of joint workshop with many countries in order to promote international research cooperation. This is the first time for us to hold the workshop within the research area of “Polar Research”. We are pleased to have this opportunity to support this workshop and see the most advanced research in this field.

We are very delightful to say that this workshop was completed successfully thanks to the contribution made by everyone involved.

We sincerely hope this workshop become a mutually beneficial event and a launching pad for the both countries and the cooperation between Japan and Norway will continue to flourish and expand in the future.

Workshop summary: content, discussions and conclusions

Japan and Norway together with other nations share a common interest in understanding processes in the Arctic. The changing climate in the Polar Regions is of concern to many. Clearly studies related to the anthropogenic climate forcing components are of high priority. A better estimate on the magnitude of their radiative forcing is paramount in order to reduce the uncertainties in the climate predictions. However, it is not enough to get the average global warming correct; there is also a pressing need to understand the response of different Earth systems, how they interact and possible feedback mechanisms. Changes in sea ice or permafrost may exert feed backs to the climate systems, but it also has implications for ecosystems. Moreover, in the field of upper atmosphere physics, especially, bi-polar study for “comparative polar science” is important to fully understand physical processes underlying in auroral and plasma/atmospheric dynamics. Both Norway and Japan have long histories for these studies and also Arctic Norway provides scientific research platform in the mainland and further north in Svalbard.

The fact that Japan and Norway are so far apart can actually be seen as an advantage. The Arctic is too large for any single nation to make observations everywhere. Located at either side of the Arctic Ocean gates joint efforts enables Polar scale studies of scientific issues we know about today and those we will know about in the future. Presentations at the workshop confirmed the range of scientific activities conducted by the two countries, not only on a geographical scale, but also on the range of disciplines. In this report, abstracts from participants with presentations are collected that corroborate this.

It was suggested at the workshop to formulate a style of collaboration matrix that was grouped in three major environments and classified as either ongoing, or new more or less mature projects. The three environment groups were Physical/Chemical, Biological/Terrestrial and other environments, which include but were not limited to, upper atmospheric physics (UAP). The matrix of collaboration and cooperation is presented in the Appendix. This matrix shows that the number of ideas and suggestions for cooperation spawned during the workshop are as many or if not more than the number of participants at the workshop (c.f. Participant List).

During the workshop the human potential was stressed. The Japan-Norway Joint Workshop as such was praised by the participants as a fruitful opportunity to foster bilateral cooperation between Japan and Norway. However, increased exchange of scientists staying for some time in respective countries was brought up as an important way of setting the stage for scientific discussions, but also cultural exchange. This exchange and personal interaction between scientists is rewarding and inspiring for both young as senior scientist alike.

Session 1. Atmospheric science

Atmospheric science observations at the Ny-Ålesund international research site

Takashi Yamanouchi

National Institute of Polar Research, Japan

The National Institute of Polar Research (NIPR) started observations of atmospheric parameters in Ny-Ålesund (78°55'N, 11°56'E), Svalbard using Rabben Observatory close to the air strip in 1991, based on the bi-polar standpoint with the Antarctic observation at Syowa Station (69°00'S, 39°35'E). Since then, several parameters have continued to be measured at the site, such as greenhouse gases, ozone, aerosols, clouds and precipitations with the support by Norwegian Polar Institute (NPI). Founded on these ground-based observations, airborne observations were planned to obtain vertical distribution of aerosols, radiation and so on, together with balloon borne observations. International cooperative campaigns have been conducted as ASTAR (Arctic Study of Tropospheric Aerosol and Radiation) 2000, 2004, (2007) and AAMP (Arctic Airborne Measurement Program) 2002, following AAMP 98 carried out in 1998. Longyearbyen airport (78°N, 15°E) was used as a base of flight operations. In order to see air-sea exchange (source and sink) of CO_2, shipborne observations of pCO_2 were conducted during 1992 and 2001 in the Greenland Sea and the Barents Sea on board r/v Lance and others. Also, radiation and cloud climatology at Ny-Ålesund was discussed using long term record of radiation measurement by the Norwegian Polar Institute. Related to the International Polar Year (IPY) 2007–2008, several activities have been made by Japanese scientists in IPY projects. Atmospheric science activities in Svalbard by NIPR are reviewed and future directions will be presented.

An observational study on cloud-aerosol interaction in Ny-Ålesund

Masataka Shiobara

National Institute of Polar Research, Japan

Aerosols and clouds have a potential to change climate by their radiative effects on the energy balance in the global climate system. The radiative effect of clouds is determined by their optical and microphysical properties which may be interactive with aerosols such as cloud condensation nuclei and/or ice nuclei. Therefore, knowledge of optical/microphysical properties of aerosols and clouds is essential for estimating their forcing in the climate system, and also we need to understand the cloud-aerosol interaction process to determine these properties in the actual field.

The National Institute of Polar Research (NIPR) promotes atmospheric research in both polar regions. In the Arctic, NIPR has been continuing ground-based remote-sensing measurements for aerosol and clouds using a sky-radiometer, a micro-pulse lidar and an all-sky camera at Ny-Ålesund, Svalbard. In addition to the usual operations, we are planning an intensive observation campaign for clouds in May this year. This campaign aims at low-level clouds to investigate cloud optical/microphysical properties and cloud-aerosol interaction processes mainly from cloud radiation measurements at Rabben, active remote-sensing at Koldewey and in-situ microphysics measurements at Zeppelin. The in-situ instrumentation will include a conventional cloud microphysics probe and a newly developed cloud particle microscopic imager. The satellite-based cloud retrievals will be compared with such ground-based measurements.

Here we would propose a research collaboration using the Zeppelin Facility for the cloud-aerosol interaction study. Aerosol measurements to be continuously performed at Zeppelin are indispensable for the planned study. A good collaboration would be expected between Norway and Japan for this opportunity.

On aerosols and clouds in the Arctic

Johan Ström

Norwegian Polar Institute, Tromsø, Norway

Clouds are and the interactions with aerosols are the most uncertain identified climate forcers of Earth's climate system as assessed by the IPCC expert group. In their very well known figure 2.4 "Global-average radiative forcing (RF)", greenhouse gases force the climate to a warmer system whereas clouds and aerosols tend to force the climate towards a colder system. On a regional scale and in the Arctic in particular, this is no necessarily true. The special surface conditions with ice and snow together with the very different lighting conditions in summer and winter, aerosols and particularly clouds may tend to actually warm the Arctic climate.

Typically, in-situ observations of clouds and the relation to aerosols are conducted from aircraft platforms. Although these give very detailed data, these are rather expensive to conduct and provide generally only a snap-shot of the condition in time. To circumvent the problem, one may use remote sensing such as LIDAR or satellites, but the in-situ perspective is lost. In some places around the world the topography is such that hilltop observations provide a natural laboratory where a set of more complex instruments and observations can be conducted for longer time periods. A famous such site is Great dun Fell outside Manchester, and more relevant to the Arctic is the Pallas research station in northern Finland.

Within the Arctic there is only one such potential site, and that is the Zeppelin station in Ny-Ålesund, Svalbard. Here, all the components listed in the IPCC figure 2.4 is monitored except for the clouds and interactions with aerosols. As this task is typically too big for one institute it is very well suited for collaborative work. Given the mutual interests of Japan and Norway, manifested in previous work in this area, this task is an excellent opportunity to create added value through collaboration.

Activity of UAV-used atmospheric observation for Antarctica

Naohiko Hirasawa

National Institute of Polar Research, Japan

We have been challenging UAV (Unmanned Aerial Vehicle) for its Antarctic use and managed to succeed a test flight at Syowa station in the last Antarctic summer season. My presentation will introduce the last summer UAV operation at Syowa, indicate our scientific and logistic purposes by UAV, and summarize the performance of our UAV at present, based upon the domestic flights.

Most of the potential users in Antarctic activity have few experiences in UAV operation and also will do UAV operation not so many times in their activity in future. Actually, the participants in the UAV project are from the fields of geomagnetism, meteorology, biology, aeronautical engineering, and logistic section. Thus, the important concepts of our UAV project are small number of persons to operate, easy to use and maintenance, and low expense. Those conditions are generally required for the Antarctic operation.

Our main frame of UAVs, which was named AntPlane-4, achieved a continuous flight of 1000 km with about 9 hours and a maximum flight altitude of 5700 m. In the long-distance flight, AntPlane-4 kept the constant height. The maximum altitude was reached in a meteorological campaign observation. The AntPlane-4 was loaded with a temperature and humidity sensor, and an aerosol particle counter, about 1.5 kg totally in weight. The presentation will demonstrate the observed meteorological results as well as the flight conditions.

Through the experiences of the domestic and the Antarctic activity, we think that further development of the techniques employed in take a off and landing are required. We aim to install the UAV system to Syowa station as a standard platform for scientific and logistic use. More Antarctic flight is necessary for it.

Numerical modeling of the coupling between the cryosphere and the atmospheric circulation

Yvan Orsolini

Norwegian Institute for Air Research, (NILU), Kjeller, Norway.

Bjerknes Centre for Climate Research, University of Bergen, Norway

Surface conditions at high northern latitudes, such as the extent of the snow cover or sea ice, act as a boundary forcing which influence not only local meteorological conditions, but can in some cases affect the propagation of planetary waves in the upper troposphere and the stratosphere. The impact of such boundary conditions on predictability from the seasonal to decadal time-scale and on the forcing atmospheric teleconnections is the focus of renewed attention. We highlight recent results on the modeling of such interactions using atmospheric or coupled atmosphere-ocean general circulation models or meteorological analyses.

Eurasian snow cover. Recent results using ensemble multi-decadal simulations with the Meteo-France climate model, where the prognostic snow cover has been nudged with satellite observations in order to be more realistic, have demonstrated that an anomalous autumn snow cover extent over Eastern Eurasia is linked with circulation anomalies over the northern Pacific. These anomalies over the Aleutian sector also impact the North Atlantic in late winter through the Aleutian-Icelandic Low Seesaw, and also manifest at stratospheric levels.

Arctic sea ice. The atmospheric impact of the 2007 minimum in summer sea ice extent has been investigated with the coupled ensemble prediction model of the ECMWF. Anomalous warming at low levels is diagnosed over the Arctic in autumn, that later spreads over parts of northern Eurasia. Of particular interest is the impact upon the Arctic summer storm tracks, which are poorly represented in climate models.

Importance of the North Pacific region. Atmospheric disturbances in the North Pacific region appear to play a key role in the coupling of the troposphere with the stratosphere. We demonstrate using meteorological analyses that the West Pacific pattern act as a precursor to a cold stratosphere and a strong polar night jet, through the interaction of North Pacific blockings with the background planetary wave trough over the Far East.

Influence of low Arctic sea-ice minima on anomalously cold Eurasian winters

Meiji Honda

Niigata University, Japan

Influence of low Arctic sea-ice minima in early autumn on the wintertime climate over Eurasia is investigated. Observational evidence shows that significant cold anomalies over the Far East in early winter and zonally elongated cold anomalies from Europe to Far East in late winter are associated with the decrease of the Arctic sea-ice cover in the preceding summer-to-autumn seasons. Results from numerical experiments using an atmospheric general circulation model support these notions. The remote response in early winter is regarded as a stationary Rossby wave generated thermally through an anomalous turbulent heat fluxes as a result of anomalous ice-cover over the Barents-Kara Seas in late autumn, which tends to induce an amplification of the Siberian high causing colder conditions over the Far East. The late-winter cold anomalies over Eurasia are also reproduced in our experiment, which is associated with the negative phase of the North Atlantic Oscillation.

Coupling processes between atmospheric layers: using collaborative observations to further our understanding

Chris Hall

University of Tromsø, Norway

We explore some of the possible interactions between the various layers in the atmosphere to illustrate how processes at different altitudes cannot be treated in isolation when predicting climate change. Next we review the upper atmosphere observations made by instruments operated by University of Tromsø in collaboration with Japanese institutes and thereafter see in which ways they can be used for climate study.

On the polar upper atmosphere environmental study by long-term Japan-Norway collaborative observations

Takehiko Aso

The Graduate University for Advanced Studies, Sokendai, Japan

Long-term collaboration between Japan and Norway has been in progress on ground-based observations of the Arctic polar upper atmosphere environment. One of the most important multilateral projects includes the EISCAT radar to probe the ionosphere in the auroral zone. A monitoring of electron density over two solar cycles since early 1980’s delineates ionization and

plasma transport in polar cap region. Change of ion up-flow flux and occurrence frequency is also shown which might be related to ion outflow. This up-flow is also studied in conjunction with our ASG-aurora spectrograph-observation in Svalbard which started in 2000 and up-flow event due to low-energy electron precipitation is suggested on its O^+ ion emission at 730nm. Also 3D view of polar ionosphere and aurora was executed by imagers ground-based and onboard Japanese REIMEI satellite and EISCAT. Regarding the reconstruction of aurora 3D luminous structure, we have been jointly working on ACT-aurora computed tomography- by Swedish ALIS imaging network in which its Norwegian site at Skibotn is a key station close to EISCAT. Recently more generalized ACT has been undertaken to infer energy spectra of precipitating particles at the top of the atmosphere by integrating optical aurora images and enhanced ionization detected by EISCAT and imaging riometer of cosmic noise absorption. At lower heights, ion motion measured by EISCAT approximates to neutral wind which smaller meteor radar can measure in terms of advection of ionized meteor trails. We have been running two meteor radars NSMR in Svalbard and NTMR in Tromsø where N stands for Nippon-Norway collaboration. These radars help us collaboratively study global atmospheric tide down to local gravity wave signatures in the mesosphere to lower thermosphere. Atmospheric tide is excited mostly by solar insolation absorption in the lower atmosphere and propagates upward. Its climatology might suggest various coupling of global atmospheric region. It is strongly emphasized here that closer collaboration between Arctic Norway and Japan can definitely contribute to comprehensive understanding of the polar upper atmosphere in view of its change associated with inherent linkage of our sun-earth environment.

A short presentation of the Norwegian Meteorological Institute in Tromsø in the context of polar weather forecasting and research

Gunnar Noer

Norwegian Meteorological Institute, Tromsø, Norway

The Norwegian Meteorological Institute in Tromsø is the main Norwegian provider of weather forecasts for the North Atlantic north of 65 degrees N to the Arctic ice edge. With respect to Arctic weather, special attention is given to the forecasting and monitoring of polar lows. The institute in Tromsø has national responsibility for ice charting. This is done on the Arctic ice cap, but with special focus on the areas around Spitsbergen.

Session 2. Environmental change in the polar areas (ocean, sea ice, glaciers)

Monitoring of sea ice off Svalbard and in the Fram Strait

Sebastian Gerland

Norwegian Polar Institute, Tromsø, Norway

The Norwegian Polar Institute runs sea ice monitoring off Svalbard and in the Fram Strait. Off Svalbard, measurements on seasonal ice are done in Kongsfjorden, Storfjorden and Hopen. The longest time series of sea ice thickness that is measured at Svalbard is from Hopen and spans more than 40 years. Since 1966, a negative trend of ice thickness development was observed. In the Fram Strait, thickness measurements are made on multiyear and firstyear sea ice during cruises each September and with upward looking sonars from moorings. In addition to ice thickness, also ice extent, snow properties and other related parameters are measured and studied. The monitoring is closely linked to climate process studies. In the presentation an overview on the methods used will be given, and examples of results will be shown.

Impacts of changing Arctic sea ice cover on solar energy transfer to the ocean – some key feedback processes

Mats Granskog

Norwegian Polar Institute, Tromsø, Norway

Changes in the Arctic sea ice cover will result in considerable alterations to the transfer of solar energy through the atmosphere-ice-ocean interface. Until now the perennial ice pack can be thought of as a solid lid on the ocean, but now drastic changes have occurred in the extent, thickness and seasonality of the ice cover. A short overview of the key processes that might have to be taken into account, besides the well known ice-albedo feedback, are other processes related to exposure to sunlight, such as primary production and photo-oxidation.

How these processes will respond to changes in the ice cover is not well known. Here I will shortly discuss the key processes and ongoing work on radiative transfer in ice covered waters at the Polar Institute.

Outline of Arctic region research in JAMSTEC

Tetsuo Ohata

Japan Agency for Marine-Earth Science and Technology, Japan

The following observational and analytical research is done in JAMSTEC.

(1) In-situ observation and satellite product studies

1. Arctic Ocean climate system studies

To elucidate on-going changes of the Arctic Ocean and to understand the role of the Arctic Ocean to global warming, JAMSTEC has been conducting multi-disciplinary studies in the Arctic Ocean with national/international collaborations.

R/V Mirai, of JAMSTEC, has been obtaining unique oceanographic and meteorological data since 1998. Results have shown evidences of the Arctic Ocean warming/freshening and these responses, e.g., ocean acidification and changes of bio-geochemical conditions in the Pacific Arctic Ocean.

Ice-drifting buoy observations by JAMSTEC, e.g., Polar Ocean Profiling System (POPS), are contributing the IABP. The buoy data, for instance, had shown changes of sea ice motion, oceanographic conditions and atmospheric circulation pattern, which are related to recent sea ice reduction in the Arctic Ocean.

2. Cryosphere and hydrological cycle research

(1) Surface processes and hydrological characteristics of Arctic draining river drainage: These researches are made with observations at research sites in Tiksi, Yakutsk and Northern Mongolia since 1997. Model simulation and other data sets (hydrometeorological station data, satellite data) are use to extend the research to the basin scale (Lena River basin). Recent abrupt changes in precipitation and soil temperature affecting the hydrology were found, and cause of long-term increase of Arctic draining rivers are investigated.

(2) Snow and ice changes in Arctic/Asian regions: In order to clarify the snow/ice conditions and change in these regions, observation at mountain research site (Altai Mts.) and traverse measurements are made. Strong decrease of ice in glaciers and unique regional characteristics of the snow cover distribution have been found.

3. Satellite data application to the regional vegetation/snow/ice characteristics

Satellite data are used by JAMSTEC scientists, in order to clarify the sea ice conditions, glacier/snow distribution and vegetation conditions. Such new sensors as ALOS are used to develop biomass algorithm, and develop three-dimensional glacier inventory.

(2) Analysis of reanalysis/future projection result and others for climate change

Atmosphere-cryosphere interaction analysis for Arctic regions

JAMSTEC scientists are interested in the influence of the recent surface changes (ocean and land) to the atmospheric circulations, and these are done using reanalysis data and models. Recent results show that open-water conditions in Barents Sea affect the winter climate condition in Eastern Asia and other regions.

(3) Development/verification/simulation of climate/earth models, hydrological and land models

1. Greenhouse Gas modeling studies under Arctic conditions

As part of global assessment of GHG (Greenhouse Gas), the characteristics of these gases are investigated, in order to develop/refine land surface model (VISIT) for GHG. This will enable us to understand the role of the Arctic region in global change.

2. Application, verification and development of GCMs for climate and ice sheet (Greenland) studies

Behavior of Greenland Ice Sheet is important for the sea ice level change and global climate change. This is studied with use of GCM, and their existence and variation are being discussed for recent time scale and palaeo time scale.

3. Hydrological models

Hydrological models are developed, in order to evaluate the regional hydrological characteristics of the circum-polar drainage.

(4) Joint activities at the International Arctic Research Center (IARC)

JAMSTEC has been implementing Collaborative Research with IARC, Alaska University since 1997. This collaboration are strengthening the data acquisition and extending the subject of Arctic Region Research more widely. A part of above listed research subjects are done under this Collaborative Research.

Ongoing Arctic research at the Geophysical Institute, University of Bergen

Corinna Schrum

Geophysical Institute, University of Bergen, Norway

The Geophysical Institute has a strong profile in Arctic research. Research activities comprise high latitude ocean physics and biogeochemistry studies. Methods to be used, comprise both, experimental work (field and lab-experiments) as well as modeling (regional and global scales). Experimental work comprise basin scale research such as understanding of water mass formation and circulation as well as small scale turbulent exchange processes under ice and in the entire water column. Moreover research is performed on air-sea-ice exchange processes and on the sea ice medium itself.

Ongoing research activities are accomplished in the frame of larger IPY-projects and EU projects as well as in the form of bi-lateral cooperations.

Here it is aimed to provide an overview about planned and ongoing research activities and recent achievements.

Oceanographic researches of the Polar Front zone in the Barents Sea

Vladimir Pavlov

Norwegian Polar Institute, Tromsø, Norway

The Barents Sea, with its considerable mineral and biological resources, is a shelf-water region with a wide spectrum of human activity. All aspects of human activity in the Barents Sea region require information about the spatial and temporal variability of oceanographic parameters. The Barents Sea is also an area through which heat and salt are exchanged between the Atlantic and Polar Oceans, in many respects determining climatic change in the Arctic regions. One of the main oceanographic features of the Barents Sea is the Polar Front – the area where warm and salty Atlantic waters meet cold and relatively fresh Arctic waters. The physical environment of the Polar Front underpins both the climatic and ecological systems of the Barents Sea. Over the last three years, the Norwegian Polar Institute has been involved in oceanographic investigations of the Polar Front as part of the IPY project NESSAR (Norwegian Component of the Ecosystem Studies of SubArctic and Arctic Regions). Our researches have been focused on providing first order answers to two questions: 1) What physical processes are responsible for maintaining the Polar Front? 2) What is the seasonal and long-term variability of the Polar Front structure?

To map the front and address these questions, one cruise was undertaken in each of 2007, 2008 and 2009. Hydrographic measurements were made using shipboard CTDs, ADCP and LADCP instruments. We applied also methodology to use multi-hours CTD-ADCP stations that has not been used in frontal studies in these regions before. This activity in a combination with analysis of a historical data provided a detailed description of the general physical structure of the front in the Barents Sea, including its location, bottom topography, cross-frontal circulation and hydrographic properties. Dynamic processes of potential biological importance were investigated, such as surface convergence at the Polar Front, upwelling at or near the Front zone, and baroclinic and barotropic instabilities along the Front and their role in mixing at the Front. We also investigated the effect of sea ice on the Front. We showed that melting of ice in the ice edge zone leads to formation of strong gradients that introduce baroclinic disturbances to the 3-D water dynamics. In the frontal zones at the ice edge the influence of the vertical water dynamics on the spatial structure of the water masses can be comparable to, or even greater than, the influence of the horizontal circulation. Analysis of inter-annual variability of hydrography has shown a clear positive trend in water temperature over almost the whole Barents Sea area in the last three decades. The maximum values of the trend are found in zones of Atlantic waters and near the Polar Front.

Shrinking Svalbard glaciers

Jack Kohler
Norwegian Polar Institute, Tromsø, Norway

Glaciers on Svalbard have been losing mass since the 1920s, as indicated by maps, photographs, and front position measurements. Mass balance measurements and various geodetic and satellite measurements made since the 1960s have been used to estimate the total mass balance for the entire archipelago, with values ranging from 5-20 $km^3 a^{-1}$. Recent geodetic measurements indicate that a number of glaciers in western Svalbard ranging in size from 5–1000 km2 have been losing mass at an accelerating rate since the 1930s.

The present condition of cryosphere data management of Japan

Hironori Yabuki
Japan Agency for Marine-Earth Science and Technology, Japan

The Asia Eurasia cryosphere is an important element of an earth climate system, glacier, frozen ground and snow elements such as large fluctuations in recent years has been focused. IPCC AR-4 Report also describes a number of following and is especially great concern about the social impact. Now in the world cryosphere data are promoted the development by the data center of the United

States such as NSIDC (National Snow and Ice Data Center) and NCDC (National Climate Data Center). The actual condition is that cryosphere data does not have an international organization about the data of WMO etc., and present condition grasp and change research do not often become since the international and systematic data archive is very weak. For a better understanding of cold regions of Asia, Eurasia, closing the unit without speaking countries about global cooling, it is important to share data over a large area. Asia and Eurasia, especially in cold regions there are several countries, in order to understand the wide variations in the cryosphere are data management needs of international organizations. The IGOS-Cryosphere and IPY and also has been pointed out the need for it. GEOSS data archiving functions to help improve. As for the cryosphere data in Japan, some of research institutions, universities open independently. The integrative data center in the cryosphere data does not exist in Japan. Construction and public distribution of the s cryosphere data set by an operational organization is progressing. Public distribution of the experimental observational cryosphere data by the university and a research institution is behind. The operational organization is public distribution on real time as important for use to disaster prevention of snow and ice data. These organizations do not public distribution the past data is almost the case.

In order to understand the actual condition of global warming, it is indispensable to collect and integrated the cryosphere data which exists in the world.

Freshwater fluxes through the Fram Strait

Laura de Steur

Norwegian Polar Institute, Tromsø, Norway

Variations of freshwater fluxes from the Arctic into the Subpolar and Atlantic Ocean are important for the oceans density contrasts which drive the northern limb of the Meridional Overturning Circulation in the global ocean. The Norwegian Polar Institute has maintained an oceanographic mooring array at ~79°N in the Fram Strait, the deepest strait where waters exit the Arctic, since 1997 up to present. This mooring array is set up to monitor the polar freshwater flux and total volume transports carried by the East Greenland Current from the Arctic Ocean into the subpolar seas. In this talk the monitoring program is presented and some recent results obtained from the moored instruments are discussed. We arrive at the conclusion that the freshwater flux from the Arctic Ocean has remained constant up to 2008 despite the fact that the Arctic has undergone many significant changes on a short time scale.

Session 3: Biological interest in the High Arctic

Ongoing research on evolution and range shift of Arctic flora

Inger Greve Alsos

University of Tromsø, Norway

From Norway, there are several research institutions studying evolution and range shift in Arctic plant species. The largest research group is at the National Centre for Biosystematics at the University of Oslo. The focus on taxonomy and evolutions of selected species groups, polyploidisation, phylogeography of Arctic and boreal species, and have lead the work with the Pan Arctic Flora checklist. In cooperation with other institutes (UNIS, University of Tromsø, University Joseph Fourier), they look at historical and expected range shift due to climate change, and as well as the genetic implications of range shifts. Range shift is expected to reduce the range of some species below a critical treshold, and conservation programs include monitoring climate sensitive species as well as ex situ conservation of seeds in Svalbard Global Seed Vault. Another focus area is the reproduction of Arctic species (mainly UNIS and University of Tromsø). Several studies on germinable seeds in seeds banks have been conducted the last years, and currently the germinability of 118 species are studied. For selected species, recruitment in field and populations dynamics are studied.

Ecology of *Dryas octopetala sensu lato*, a relict plant in mountains of Northeast Asia: Comparison between mid-latitude alpine and Arctic tundra populations

Naoya Wada

Toyama University, Japan

To understand the adaptation of a plant found in different environments, I focused on the circumArctic plant *Dryas octopetala sensu lato*, which is widely distributed from mid-latitude mountains to the high Arctic tundra. A comparison was made of environmental conditions, leaf and floral traits, and genetic diversity between populations from the mid-latitude Mt. Tateyama in central Japan and the high Arctic Ny-Ålesund in Svalbard, in order to examine ecological and genetic variations in this species. Accumulated temperature during the summer in Tateyama was 3.1 times as high as that in Ny-Ålesund, while global radiation was almost the same at both sites. LMA (leaf mass per area) was lower, and leaf N concentration higher in *Dryas* populations of Tateyama and in other mid-latitude alpines than in plants of Ny-Ålesund and the sub-Arctic tundra. Based on the relationship between flower weight and resource allocation to female function within a hermaphrodite flower, gender variation in this species appeared to be lower in the population from

Tateyama than in that from Ny-Ålesund. Moreover, genetic diversity within a population was lower in Tateyama than in Ny-Ålesund. Finally, the results are discussed in relation to the response of plants to climate change and global warming, and several traits are highlighted in order to predict the population dynamics of *D. octopetala* in the mid-latitude mountains of Northeast Asia.

Plant ecology research on Svalbard

Elisabeth Cooper and Lennart Nilsen

University of Tromsø, Norway

We present the plant ecological work being carried out on Svalbard by the Department of Arctic and Marine Biology, Tromsø University. This includes manipulative field experiments on climate change and grazing, the use of remote digital cameras for scaling up from plot to landscape level and spatial modeling of bioclimate and plant habitat distribution.

Carbon sequestration in an Arctic terrestrial ecosystem following rapid glacier retreat: Long-term change and future projection

Shinpei Yoshitake

Waseda University, Japan

In the High Arctic, glacial retreat provides new habitat for plant colonization and hence organic carbon accumulation. In addition, the Arctic terrestrial ecosystem is thought to be extremely susceptible to climate change. However, because of the diverse responses of ecosystem components to the change, an overall response of the ecosystem carbon cycle to climate change is still hard to predict. This project aims to clarify 1) how the succession proceed after the glacial retreat, 2) how each ecological component contribute to the ecosystem carbon cycle, and 3) how the ecosystem carbon cycle will respond to climate change. This project has been conducted focusing on a glacier foreland at the front of Austre Brøggerbreen in Ny-Ålesund, northwestern Spitsbergen, Svalbard, Norway. In 1994, four permanent plots were set up along a primary successional series of the deglaciated area. From 1994 to date, a number of studies on plant physiology, microbial ecology, remote sensing, and carbon flows and pools have been conducted. The major results of the project are as follows: We found clear successional changes in vegetation (e.g. species, biomass, and coverage), microbial characteristics (e.g. biomass, composition, and activity), soil organic carbon content, and soil respiration rate. We examined the photosynthetic characteristics and estimated net primary production of major vegetation types (vascular plants, moss, lichen, and soil biological crust). Net ecosystem production of mixed community was also measured. To predict the response of ecosystem carbon cycle to climate change, a compartment model that incorporated major carbon pools and flows was constructed. It suggested that the ecosystem of the later stages of primary succession was a net sink of carbon and temperature increase would have negative effects on the ecosystem carbon stock in this area. In future perspective, we consider satellite remote sensing as a very powerful tool to examine an extensive and heterogeneous area of the glacier foreland. It will also enable us to reconstruct the past changes in glacial retreat, vegetation, and function and structure of ecosystem.

Classification and habitat characterization of vegetation in Ny-Ålesund, Svalbard

Satoru Kojima

Northern Ecological Research Laboratory, Japan

1) Vegetation classification study: Vegetation of the Ny-Ålesund area was classified based on the phytosociological procedure. Throughout the area, a total of 59 sample plots were established. In the plots, all the vascular plants were recorded for their coverage and soil samples were collected. The samples were analyzed for physical and chemical properties such as moisture content, bulk density, electric conductivity, pH, cation exchange capacity, exchangeable cations (Na^+, K^+, Ca^{++}, Mg^{++}), organic carbon and total nitrogen. Based on the plot data, vegetation synthesis tables were constructed and seven vegetation types were distinguished. They were: 1. *Draba nivalis* type, 2. *Dryas octopetala* type, 3. Mature mesic moss type, 4. *Cassiope tetragona* type, 5. Immature mesic moss type, 6. Immature wet moss type, and 7. *Luzula confusa* type. These types were correlated with soil characteristics. It seemed that they had been differentiated primarily on the basis of soil moisture conditions and secondarily soil base status.

2) Vegetation succession study: In 1997, a permanent plot VSOP (Vegetation Succession Observation Plot) was established to monitor vegetation succession in the deserted coal mine site nearby Ny-Ålesund town site. The plot was of 1 m x 1 m square size, which was further divided into 100 sub-plots of 10 cm x 10 cm square. At each sub-plot, vegetation structure was scrupulously observed and all the vascular plants occurring were recorded for their coverage in 1 cm^2 unit. The VSOP plot was revisited in 1999, 2002 and 2007. All the sub-plots were then checked if any vegetation change taking place in the respective years. For the past 10 years (1997–2007), not much change was recognized in the number of species and species composition. However, vegetation considerably changed both in abundance of the component species and total dominance value. In the plot, a total of nine vascular species were recognized. Of them, *Salix polaris, Polygonum viviparum* and *Saxifraga oppositifolia* were the dominating components showing relatively high abundance. Total dominance

value has also steadily increased for the past ten years indicating the vegetation succession still progress there.

Simulating climate change induced alterations in bioaccumulation of organic contaminants in an Arctic marine food web

Katrine Borgå, Tuomo M. Saloranta and Anders Ruus

Norwegian Institute for Water Research (NIVA), Oslo, Norway

Climate change is expected to alter environmental distribution of contaminants and their bioaccumulation due to changes in transport, partitioning, carbon pathways and bioaccumulation process rates. Magnitude and direction of these changes and resulting overall bioaccumulation in food webs is currently not known. The present study investigates and quantifies the effect of climate change in terms of increased temperature and primary production (i.e. concentrations of particulate organic carbon, C_{POC}), on bioaccumulation of organic contaminants in biota at various trophic levels. The present study covers only parts of the contaminant behaviour that is influenced by climate change, and it was assumed that there were no changes in food web structure and in total air and water concentrations of organic contaminants. Therefore, other climate change induced effects on net bioaccumulation, such as altered contaminant transport and food web structure, should be addressed in future studies. To determine the effect of climate change, a bioaccumulation model was used on the pelagic marine food web of the Arctic where climate change is expected to occur fastest and to the largest magnitude. The effect of climate change on model parameters and processes, and on net bioaccumulation were quantified for three modelling substances (γ-HCH, PCB-52, PCB-153) for two possible climate scenarios. In conclusion, increased temperature and C_{POC} reduced the overall bioaccumulation of organic contaminants in the Arctic marine food web, with the largest change being for PCB-52 and PCB-153. Reduced bioavailability, due to increased C_{POC}, was the most influential parameter for the less water soluble compounds. Increase in temperature resulted in an overall reduction in net bioaccumulation.

Snow molds in the Arctic and their occurrence under climate change in Svalbard and Hokkaido, northern Japan

Tamotsu Hoshino, Motoaki Tojo, Naoyuki Matsumoto and Anne Marte Tronsmo

SANSOKEN, Japan

Snow molds are psychrophilic or psychrotrophic fungal pathogens of forage crops, winter cereals and conifer seedlings. These fungi can grow and attack dormant plants at low temperatures under snow cover. “Snow molds” or “snow mold fungi” is a generic name including diverse fungi belonging to

various taxa (oomycetes, ascomycetes, and basidiomycetes). The snow molds ascomycete, *Sclerotinia borealis* and basidiomycete, *Typhula ishikariensis* are widely distributed not only in the cool temperate zone and frigid zone but also in Arctic regions such as Alaska and the Yukon, Greenland, Finnmark, Iceland (*S. borealis* not found), Lapland, and Svalbard. These investigations suggest that *S. borealis* and *T. ishikariensis* are highly adapted to the Arctic environment. Cold tolerance is one of the important factors related to their geographic distribution, because snow molds develop mycelia under snow cover. Basidiomycetous snow molds produce extracellular antifreeze proteins. Their physiological significance is to keep the extracellular environment unfrozen. *S. borealis* shows normal mycelial growth under frozen conditions, which is faster than that on unfrozen media at optimal growth temperature. This fungus does not produce extracellular antifreeze proteins, but osmotic stress tolerance enables the fungus to grow at subzero temperatures. Different taxa of snow molds have different strategies to adapt under snow cover. *S. borealis* is distributed in area with severe winters where soil freezes deep in the ground before snowfall. *S. borealis* and *T. ishikariensis* was found in Barentsburg, Svalbard in 1999 and 2000. *S. borealis* was also collected from Longyearbyen and Ny-Ålesund in 2007. Recent, climate change is probably suitable for the magnification of this fungal distribution in Svalbard. In lower latitude snowy region, Hokkaido, the recent tendency towards global warming has certainly changed snow mold microflora. *S. borealis* is no longer a problem due to the early onset of snow cover and warm winter. *T. ishikariensis* replaced *S. borealis*.

Climate, biogeochemical cycles and the environmental exposure to persistent pollutants

Luca Nizzetto

Norwegian Institute for Water Research (NIVA), Oslo, Norway

Climate change is expected to modify meteorological conditions causing alteration in ecosystem characteristics, functions and geographic distributions. A deep knowledge of the mechanisms linking climate/biogeochemical cycles and pollutant environment partitioning is needed to assess future exposure scenarios to toxic chemicals, including the exposure of the Arctic environment and biota. Among the global environmentally relevant persistent pollutants (PPs) figure, in particular: mercury (Hg) and a range of persistent organic pollutants (POPs). These chemicals are characterized by the ability of moving long distance from source points, bioaccumulate and cause toxic effect in organisms (including humans). Distribution and fate of PPs is controlled by climatic conditions and biogeochemical cycles. In particular temperature controlled partitioning of PPs between air or water and the organic carbon rich environmental matrix plays a key role, as well as the trophic interactions between organisms (which effect the bio-magnification). The dynamics of the coupling between pollutant fate, biogeochemical cycles and climate in general is poorly parameterized. Some studies are becoming available for example on the assessment of the possible climate change effects on the Arctic food web exposure to PPs. Additionally experimental evidences are arising on the potential role of changing climatic conditions and the increased exposure of fresh water biota to PPs in fresh water catchments. Glacier also can store significant burdens of PPs emitted in the past, and ice melting could remobilize these pollutants. An assessment of the inter-compartment exchange flux between air or water and the organic substrate through experimental observation and modelling across different climatic/ecological conditions and scenarios is therefore essential to predict future exposure to PPs.

Ecosystem responses to climate change on a High Arctic glacier foreland

Hiroshi Kanda

National Institute of Polar Research, Japan

In recent decades, glaciers throughout much of the Northern Hemisphere have lost mass. On Greenland, a 17% expansion of the melt region has been observed over a period of 10 years (1992–2002) (Comiso and Parkinson, 2004). Such glacial retreat provides new habitat for plant colonization and hence organic carbon accumulation. Therefore, to predict future ecosystem response to climate change in the High Arctic glacier foreland, it is also important to consider future glacial retreat as well as present. In this report, I introduce the project "Ecosystem Responses to Climate Change on a High Arctic Glacier Foreland". This project aims 1) to estimate changes of glacial retreat and vegetation distribution for the past 30 years using remote sensing data and 2) to construct a compartment model to evaluate structure and function of various vegetation types. At the same time, I will investigate the relationship between carbon cycle and ecosystem development. Finally, we will predict changes in the distribution and function of the ecosystem on future glacier foreland. A comparison between ecological features in Ny-Ålesund, with maritime climate, and in Ellesmere, Canadian Arctic (Oobloyah valley, 80˚51'N, 82˚50'W) with continental climate is significant for evaluating responses to climate change in the near future.

Appendix

List of on-going and possible collaborations

Category*	Physical/Chemical environment	Biological/Terrestrial environment	Others (including UAP)
(1)	**Observations of greenhouse gases at Ny-Ålesund** (*T. Yamanouchi, NIPR/ K. Holmén, NPI)*	**UV radiation effects on biota** (*Sapporo/ M. Granskog, NPI)*	
(1)	**Atmospheric teleconnections between the Europe-Atlantic sector and the Pacific sector, and troposphere-stratosphere coupling in the North Pacific** *(H. Nakamura, U Tokyo/ M. Honda, JAMSTEC/ Y. Orsolini, NILU)* The Far East / North Pacific region appears as a key sector to better understand the	**VSOP (Vegetation Succession Observation Plot) project** *(S. Kojima)* A permanent plot was established to observe and monitor vegetation succession taking place in the abandoned coal mine site at the outskirt of Ny-Ålesund town site. The plot was originally set up in 1997, and regularly visited in 1999,	**Study of polar MLT dynamics by meteor radar network** *(Tsutsumi, Tomikawa, Aso, NIPR, Nozawa, STEL, / Hall,UiT)* **Temporal and spatial auroral dynamics by optical cameras and EISCAT radar** *(Miyaoka, NIPR, Nozawa, STEL/Brekke, UiT)*

	troposphere-stratosphere coupling, as it is the seat of the climatological maximum wave flux into the stratosphere. Climate variations over this region, e.g. in North Pacific blockings or Okhostk Sea ice cover, have a strong potential to influence the Arctic polar stratosphere. Some of this North Pacific variability falls under the influence of the North Atlantic. Atmospheric teleconnections between the two sectors, such as the Aleutian-Icelandic Low Seesaw in winter, but also planetary wave trains and weather systems propagating from the Atlantic across Eurasia and the Arctic in summer, need to be further elucidated using climate models and observations.	2002, and 2007. Any vegetation change at each year was scrupulously described.	**High latitude ionospheric plasma dynamics by optical instruments and EISCAT radar** *(Miyaoka, Ogawa, NIPR, Taguchi, UEC/ Sigernes, UNIS)*
(1)	**Climate impacts of declining Arctic summer sea-ice extent** *(M. Honda, JAMSTEC- U. Niigata/ Y. Orsolini, NILU)*	**Shoot growth (elongation) of alpine dwarf pine** *(Toyama/ Wada, University of Toyama)*	

	The summertime Arctic sea-ice extent shows both a marked decreasing trend (~8% per decade) and a large inter-annual variability influenced by forcing oceanic factors and by Arctic circulation patterns. The feedback of this reduced summer sea-ice cover on the atmospheric circulation and weather systems in the summer but also in the following autumn and winter is poorly known. To this end, experiments with idealised sea-ice cover and realistic forecast simulations for the recent years are carried out, using either atmospheric or coupled ocean-atmosphere general circulation models, and results are compared with meteorological analyses.		
(2)	**Aerosol-cloud interactions in the Arctic environment** (*M. Shiobara, NIPR/ J. Strom, NPI, O. Hermansen, NILU)*	**Establishment of a long-term monitoring and analyzing system for detecting plant community and plant species responses to**	**Airglow imaging@ALOMAR will start in 2010** (*Nakamura, NIPR /ARR*)

		climatic related changes. Development of predictive models. (*Kojima, UBC, Kanda, NIPR, Wada, CFES/ Nilsen, UIT, Cooper, UIT)*	**Plasma-neutral interaction by FPI and ESR** (*Ogawa, NIPR, Taguchi, Rikkyo Univ./ Sigernes, UNIS*) **JAXA rockets collaborative observations under discussion:** **S-520 rocket: Pulsating aurora campaign @ARR in 2012** (*Kojima, RISH/ Moen, UiO)* **SS-520 rocket: Ion outflow campaign @NA in 2014-16** (*Saito, JAXA, Ogawa, NIPR/Moen, UiO)*
(2)	**Mesosphere-Stratosphere-Troposphere coupling processes, using radar and satellite observations**	**During our discussions, it was recommended to establish: i) permanent plots to monitor**	

	(*T. Aso, Sokendai/ C. Hall, U Tromsø/Y. Orsolini, NILU)* The downward-propagating influence of stratospheric variability onto the troposphere below, for example during stratospheric sudden warming, has received considerable attention in recent years. It has now been realized that precursory signals can appear first in the mesosphere, and that the stratopause can reform at mesospheric altitudes in the aftermath of major stratospheric warmings. Radars at high latitudes (e.g. Svalbard, or Northern Norway) nicely complement satellite observations by providing detailed highly-resolved wind or temperature observations to study wave processes and dynamical coupling between the mesosphere and stratosphere, and between the stratosphere and the troposphere.	**long-term ecosystem changes in the Arctic, and ii) experimental plots to observe behaviors of ecosystems and component organisms by manipulating environmental factors such as temperature, light conditions, soil characteristics, etc.** Such operations should be conducted in co-operations of scientists of Japan and Norway. It was also recommended that scientists of the two countries should work together as much as possible by committing themselves to the projects of counterpart countries. In this respect, it was suggested that we should include counterpart scientists in the research team when applying for any research fund.	

(2)		**Effects of global warming (Open Top Chamber) on growth and reproduction of Arctic shrubs** (*Wada, UT/Uchida, NIPR/ Kanda, NIPR)*	
(3)	**Radiation fluxes vs large scale dynamics** *(T. Yamanouchi, NIPR/ C. Pedersen, NPI)*	**Hopefully comprehensive ecological research area should be established in some places in the Arctic, where all kinds of biological/ecological research can be intensively conducted in collaborations of scientists of the two countries.** It will be something like a LTER (Long Term Ecological Research) site which is established in many areas in the world. Such site may be called ALTER (Arctic Long Term Ecological Research). Perhaps, Ny-Ålesund and Longyearbyen can be promising candidates for such research area.	**Airborne transport of spoors. Cross discipline investigations using aerosol observations to characterize particle microphysics and DNA for identification.** *(T. Hoshino, AIST/ J. Ström, NPI)*
(3)	**Ice coring in Svalbard** (*E. Isaksson, NPI / Goto-Azuma)*	**Long-term monitoring on vegetation in glacier foreland** *(Uchida, NIPR/Wada, UT/Nakatsubo,*	**EISCAT_3D project collaboration** (*Miyaoka, NIPR, Nozawa, STEL /Brekke, UiT, EISCAT*

		Hiroshma Univ./Kanda, NIPR)	*scientific association)*

*Category:

(1) Already on-going project and need to be maintained and strengthened (need additional fund)

(2) Possible project which is recommended to be implemented after further discussion, and may be realized soon (need additional fund).

(3) Project which is raised but need further discussion.   Its scientific objectives, personnel, methodology need to be discussed further.

021 KORTRAPPORT/BRIEF REPORT SERIES

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