Cooperation on Arctic Research between Japan and Russia

Research Theme

Human Resource

Infrastructure

Network

日露北極研究ワークショップ

Joint Group of Japan and Russia on Arctic Research

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Preface

This is the report on the results of the discussions conducted by Japanese and Russian institutes and researchers on Arctic research following the recommendations made by the 11th Japan-Russia Joint Committee on Science and Technology Cooperation in September 2013. The discussions were mainly conducted at two workshops (WSs) held in July and October of 2014 in Tokyo, Japan.

The Arctic region has been facing drastic changes in recent years. These changes are affecting the region's environment and life in society, and moreover pose a threat to affect regions outside the Arctic region as well as the global environment. Clarification of these changes is an urgent issue, and it needs to be carried out by international and domestic efforts as well as through bilateral cooperation. The discussion on cooperative research between Russia, which dominates the largest area in the Arctic region among the Arctic countries, and Japan, which is a non-Arctic country but has long history of Arctic research, will surely make a substantial contribution to the overall understanding of these phenomena.

We hope that the discussion made here will be implemented in some manner in the near future. Furthermore, continuous discussions in WSs are needed to narrow the existing gaps between the themes, and define other potential and productive research themes that could not be discussed in 2014.

The organizers would like to thank Dr. Vladimir Pavlenko and Professor Tetsuo Ohata who on took the roles of WS coordinators and finishing the report for each side, and the International Science and Technology Center (ISTC), which financially supported the realization of the WSs and the development of this report.

The organizers would also like to thank Mr. Hiroyasu Kumagai, Ms. Yukie Uwaso of NIPR and Mr. Takeshi Matsunaga of ISTC for great support at the WSs which was the basis of the report, and editing of the report at the last stage.

March 10, 2015

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Summary

The first official discussions on cooperative research between Japan and Russia on Arctic research, which was recommended at the Japan-Russia Joint Committee on Science and Technology Cooperation at the government level, were made at the level of institutes and academies during 2014. Continuous negotiations between the government level and institute level led to a productive discussion on cooperative research between the two countries and mutually agreed themes were determined.

The following 12 research themes were approved as future joint research themes.

(1) THEME 1: Climate impacts of black carbon aerosols in the Arctic (Spitsbergen, Baranov Cape, Tiksi)
(2) THEME 2: Preliminary joint study in the frame of the Polar Prediction Project
(3) THEME 3: Reliability and risk estimation for sea-ice navigation along the Northern Sea Route
(4) THEME 4: Comparative study on carbon and water in the permafrost ecosystem of Siberia
(5) THEME 5: Glacier research in the Russian Arctic and sub-Arctic
(6) THEME 6. Contemporary changes of water, heat, and dissolved and suspended organic/inorganic matter fluxes from Siberian rivers into the Arctic Ocean
(7) THEME 7: Variability of snow cover including blowing snow and snowmelt processes of the permafrost area under Arctic environment change
(8) THEME 8: Development of space remote sensing technologies to monitor seasonal variations in temperature and moisture in the active topsoil of the Arctic tundra
(9) THEME 9: Permafrost changes in Siberia in the past and future based on projections of climate warming
(10) THEME 10: Ecosystems and biodiversity
(11) THEME 11: Effects of global climate change on commercial fishing and indigenous coastal cultures in Siberia and the North Pacific
(12) THEME 12: Arctic and global climate change: feedbacks and forecasting dynamics

Some of the themes are well-focused research themes, and some are themes with broad perspectives; some are small-group and some are large-group; some are new and some are research related to ongoing projects. In the case of implementation, these conditions will need to be considered.

It was acknowledged that human resource development is an important issue for both countries, and the cooperation on research networks and research stations is important for efficient and sustainable observation in the Russian Arctic. Moreover, the actual style of cooperation needs to be discussed further and developed, and data and legal regulation issues need to be discussed continuously.

It was agreed that successive WSs need to be held in 2015, preferably in Russia, to substantiate and follow up the discussions made at the WSs in 2014, and to broaden the potential for cooperation.

§1. Introduction

1.1 Objectives of the report

This report has been developed in order to present the process and conclusions made by the Japanese and Russian government and scientists in order to fulfill the recommendations on discussion on cooperation on Arctic Research made at the 11th Meeting of the Japan-Russia Joint Committee on Science and Technology Cooperation held in Tokyo, Japan on September 11, 2013.

This report on the results of the discussion is scheduled to be presented at the 12th Meeting of the Joint Committee, to be held in 2015.

1.2 Past history of Japanese and Russian cooperation on Arctic research

Cooperative research on the Arctic in Russia can be said to have been initiated in the 1970s. The Permafrost Conference organized by the IPA held in Yakutsk in 1973 was an important conference, since several Japanese scientists attended that meeting and also directly visited the permafrost landscape to understand the extraordinary phenomena there. This was a chance for the Japanese community to become acquainted with the vast permafrost region in Siberia.

The Hokkaido University Group started their research activities in Eastern Siberia with the institute in Yakutsk in the early 1970s. They engaged in sporadic research observation after that, and did research work at Tiksi and other sites, under the topic of permafrost degradation due to forest fires (wildfires) in the 1990s.

The National Institute for Environmental Science (NIES) initiated GHG studies with the Central Aerological Observatory for the Siberia Region starting in 1991, and has cooperated with other institutes since then. They used an old tower to monitor GHGs near Yakutsk, and carried out aircraft measurement of GHGs in Western Siberia, and this is still continuing.

The National Institute of Polar Research (NIPR) implemented snow cover observations for a limited period in the latter half of the 1990s in Eastern Siberia in cooperation with the Melnikov Permafrost Institute (MPI).

The greatest interaction on Arctic research between Japan and Russia started in 1997, when the WCRP-GAME Project started and selected the Lena River Basin as the target region. Experts from the leading Russian scientific centers representing mainly the Russian Academy of Sciences (RAS) and Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) have taken part in this program. They included the Institute of Geography (IG) (leading organization), the Melnikov Permafrost Institute (MPI, SB, RAS; Yakutsk), the Institute of Biological Problems of Cryolithozone, SB of RAS (Yakutsk), the Institute of Physical and Technical Problems for the North, SB of RAS (Yakutsk), SB of RAS, the Polar Geocosmophysics Observatory (Tiksi) of RAS, and the State Hydrological Institute (SHI, Saint-Petersburg), the Central Aerologic Observatory (CAO, Moscow region), RIHMI-WDC (Obninsk) of Roshydromet, and the Institute of Agrophysics, Russian Academy of Agriculture Sciences (Saint Petersburg), and so on.

As a symbolic event, the IBPC and Japanese universities (Hokkaido University, Nagoya University, etc.) constructed a 32-m high observation tower for meteorological and surface observation at Spasskaya Pad. Another Arctic observation site was constructed at Tiksi at the same time, and land surface processes were studied. This study was later enhanced by the participation of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and also other countries such as a group form the Netherlands.

As glaciological and meteorological observations on glaciers, helicopter photo and infrared camera surveys of the entire glaciers of the Suntar-Khayata Mountains were organized by Institute of Geography, RAS in cooperation with Japanese universities in the first half of the 2000s.

The cooperation between Japan and Russia mainly occurred in the region of Eastern Siberia on the topics of permafrost, the water cycle, GHGs, and land surface processes, on an institute basis, and this is still continuing under the present project. Cooperation on the other research subjects and other regions was carried out on a smaller scale.

1.3 Present status of Arctic research in both countries

(1) Russia

First Russian expeditions and discoveries in the Arctic are dated by 15th century, while the Russian scientific research as such in the Arctic started in the middle of 18th century (P. Chichagov's expedition). At the present stage, it is developing in the following directions: solar activities and solar – Earth interactions, atmosphere and ionosphere physical processes and their impacts on climate; radio astronomy, electromagnetics in the Arctic; acoustics, oceanology of the Arctic Ocean, glaciology, interaction between land/ocean and atmosphere; onshore and offshore geology and geophysics, glaciations and permafrost; biology and bio-chemistry, continental hydrology within the Arctic Ocean watershed; terrestrial and aquatic ecosystems in changing climates and environments; CO_2 and CH_4 stocks and cycles; paleontology, and the behavior of radioactive and stable pollutants in various Arctic landscapes and seas, economic and social development in Subarctic regions, Arctic ethnography, anthropology and archaeology.

Research has been particularly active in recent years due to the increased attention of the state to economic development and research in the Arctic. Major research programs are implemented by the institutes of Roshydromet and the RAS. In general a synergic effect of the Russian scientific research in the Arctic is provided by cooperative realization and thematic overlapping of activities carried by RAS and Roshydromet.

The institutes of Roshydromet have carried out scientific and applied development and natural experiments. These activities are directed to: complex development of basic scientific knowledge about the processes occurring in the Arctic environment (ice cover, oceans, island water, river estuaries, atmosphere, upper atmosphere, ionosphere) and interaction between these media; creation of new technical means and technologies for contact and remote-sensing measurement of parameters of the media under study; collection, concentration, analysis, and distribution of data on the state and variability of media including those under anthropogenic influence, long range transport, and climate changes; hydro-meteorological, hydro-physical, and ecological provision (including operative provision) of economic and defense activities of Russia in polar regions including work on Arctic shelves; planning, coordination, and provision of complex scientific research in the Arctic using research vessels, aircraft, polar stations etc.; training of highly skilled scientific staff to perform complex investigations in the Arctic in the field of oceanography, physics of ice, oceans and inland water, meteorology, ocean/air interaction, geophysics, sea ice studies, glaciology, polar geography, hydrochemistry, hydrology of river mouths and water resources, ecology, interaction of ship hulls and other engineering constructions with ice, and polar medicine.

Investigations in Arctic regions are being carried out within the framework of existing and newly organized programs of the Russian Academy of Sciences (RAS) and programs of the Central and Regional Branches of RAS.

The Presidium of the RAS has been implementing a large-scale program on basic research for the development of the Russian Arctic since 2014. One of the three parts of this program concerns environmental, socio-economic, and political problems. Within its framework new methods are being developed for the study of snow cover, Arctic sea ice, permafrost, gas hydrate, and methane emissions and models of their evolution in time and space are being created; new global and local factors modifying environmental systems and biological resources of the Arctic are investigated; the scientific basis for improving the quality of life of the population of the Arctic territories is being developed; and geopolitical, environmental, social, and humanitarian problems of the Arctic regions are being examined.

International and bilateral programs and projects also have important role. Russian specialists participate in these programs and projects, which are implemented with the support of international and national funding from a number of countries (Japan, Germany, and so on).

Among the largest international projects in which Russian experts are actively involved and participating, highlights are the Siberian sub-project executed in 1996–2004 within the large regional program GAME (GEWEX Asian Monsoon Experiment, http://www.hyarc.nagoya-u.ac.jp/game/), the Northern Eurasian Earth Science Partnerships Initiative (NEESPI), http://neespi.org (since 2005), and the International Polar Year, 2007–2009 (http://www.ipy.org/, www.ipyrus.aari.ru).

More detail conditions about the present RAS follows. Extractable resources in the Arctic, their known and expected reserves contain a general part of the Russian Federation mineral ore materials base. This is the area where over 90% of nickel and cobalt, 60% of copper, over 96% of platinum metals are produced and about 80% of gas and 60% of oil are extracted. Herewith expected reserves of mentioned materials make over 70-90% of that in Russia. Arctic regions of Russian take a first place in the world for selected materials, like nickel, diamonds, platinum metals, oil and gas. Arctic seabed is undoubtedly may be considered as strategic reserve for enforcement of the mineral-ore security of Russia.

Continental part of the Russian Arctic zone, as most broad and industrially developed among other subarctic states, is the significant test site for global fundamental and applied research in various areas of knowledge, for transfer of knowledge into a new technologies of the regional resources development.

Fig. 1.3-1 Main structures of the Arctic research in Russia.

Arctic research always has been taking an important place in activities of research institutes of various departments due to their role in the economic development of the country. Currently these studies involve institutes of the Russian Academy of Sciences, Russian Hydro-meteorological Service, ministries of Natural Resources, Education and Science, Federal Agency for Fisheries.

9 research clusters of the Russian Academy of Sciences and its regional branches, and connected with the Arctic research in various disciplines, are located in appropriated regions of Federation.

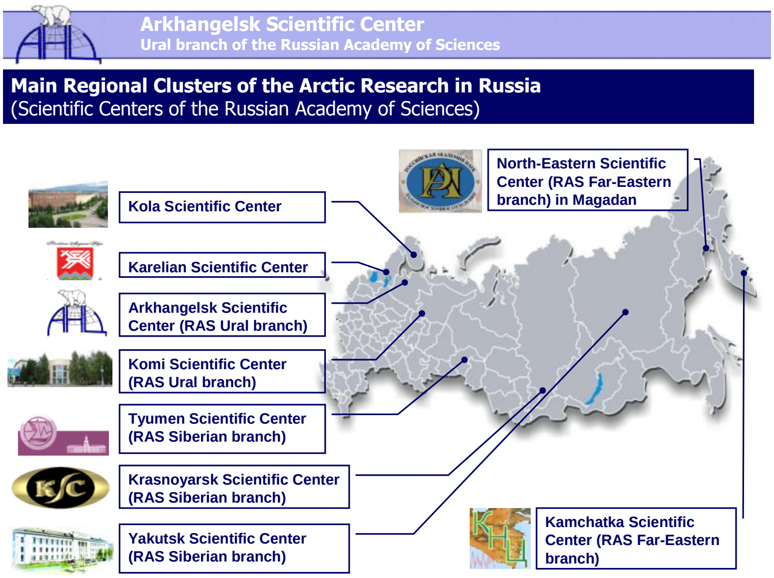

Fig. 1.3-2 Main Regional Clusters of the Arctic Research in Russia (Scientific Centers of the Russian Academy of Sciences).

Potential of the RAS Regional Scientific Clusters in the Arctic Research:

- 43 research institutes
- 21 stand-alone centers and departments of fundamental and applied research
- Laboratories and test sites
- Doctorate courses in over 40 specializations
- Scientific journals and publication facilities
- Scientific archives and museums
- United information systems and e-libraries
- Social infrastructure
- Advanced networks of international cooperation

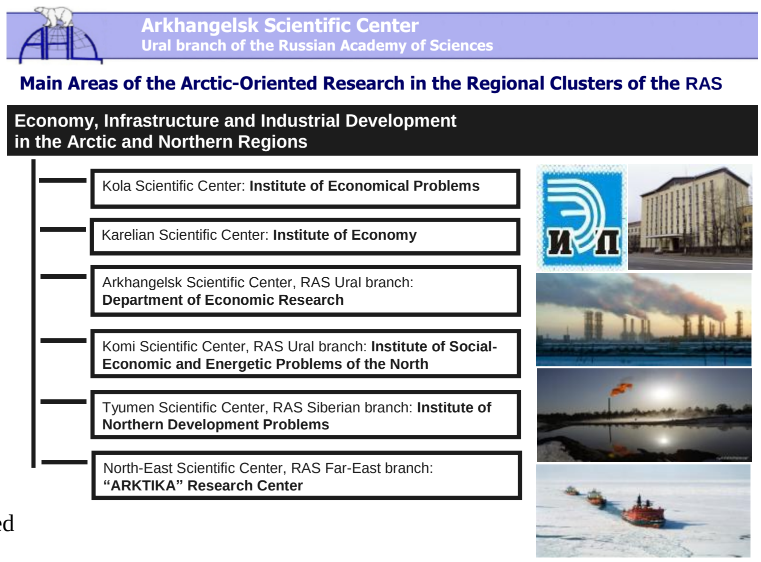

Fig. 1.3-3 Main areas of the Arctic-oriented research in the regional clusters of the RAS.

Among them 6 are primary oriented to the Arctic research in the areas of industrial and infrastructural development, environmental protection and social-cultural development. They are located in Murmansk, Arkhangelsk, Tyumen and Magadan regions, republics of Komi and Karelia.

Financing of the Arctic research, along with federal budget, has been provided within programs of Russian Scientific Foundation, Russian Foundation for Basic Research, Russian Foundation for Humanities, and by National corporations and big extracting companies and regions.

Fig. 1.3-4 Sourcing of the Arctic research in the regional clusters of the Russian Academy of Sciences.

(2) Japan

Japan has long history of Arctic research dating back to the IGY period (1957–59) in various parts of the Arctic region. However, this consisted of ad-hoc and small-group research. It has been enhanced since the 1990s when NIPR established an Arctic Environment Research Center and a research station was built in Svalbard. JAMSTEC initiated its Arctic sailings in 1997 and several large projects such as GAME were started in 1996. Long-term observations under institute-level agreements were initiated. In the 2000s, research projects of various scales were initiated, but they were not interconnected. From the middle of the 2000s, Japanese scientists and institutes started to exchange information among research areas and groups, and started to interact to build interdisciplinary research topics.

Based on such activities, Japan started the new GRENE Arctic Project in 2011 to enhance Arctic research in addition to what was being done by the institutes and various research activities of university groups. The research presently being done in relation to Russia mainly covers the area of on-site research in the Siberian region of Russia through cooperation with institutes such as the MPI and IBPC of RAS. Japan started a consortium called JCAR (Japan Consortium for Arctic Environmental Research), which is composed of individual scientists, to enhance research activities on various aspects of Arctic science. At the government level, there is the Strategic Committee on Arctic Research, but there are plans to reform it in the coming year.

In addition to the large movements of Arctic research under the GRENE Arctic Project, the cruises made by R/V “Mirai” and other foreign vessels of JAMSTEC, various research studies at Svalbard where NIPR has a station, and other institutional and group research such as that done in Greenland, and also wider research areas such as the upper atmosphere and paleoclimate studies are being done.

At present, the post-GRENE Arctic Project is being discussed in Japan, and one of the directions is to strengthen international cooperation on Arctic research. We hope that the discussions made and reported here on Russia-Japan cooperation will be realized somehow in the post-GRENE Arctic Project.

1.4 The role and structure of the report

The present discussions, which are based on the discussions at the government level, mark a new direction in the history of cooperative research between Japan and Russia on Arctic research. From these discussions, it is hoped that both countries will widen their cooperation subjects to a new and larger scale, as well as sustainable and higher-level research on subjects that have a past history.

This report will be structured in the following way. The process of negotiations between Russia and Japan from 2013 to 2014 for the discussions and the outline of the two WSs will be described (Section 2), the scientific themes proposed and agreed by both countries will be introduced (Section 3), the proposals and discussions on other important matter such as infrastructure will be described (Section 4), and finally important matters and future prospects will be cited (Section 5). The steering group for the development of the report consisted of three persons from Russian side (Pavlenko, Priamikov and Georgiadi) and two persons from Japanese side (Ohata and Enomoto).

§2. Activities Related to the Discussions on Cooperation

2.1 The building phase of mutual relations (October 2013 to April 2014)

The following actions were taken at the initial negotiations between the Japanese and Russian sides until the direct visits and talks by institute members.

Through the Embassy in Moscow, the Japanese side made contact with AARI, Roshydromet, RAS Presidium, and also the Russian Science Foundation to discuss the recommendation made by the Joint Committee. During the discussions, the present conditions and past activities of Arctic research on the Japan side in relation to Russia, the present conditions of Russian institutes and funding agencies, and the thoughts of each side about the topics of cooperative research were exchanged. All participants on the Russian side expressed the necessity for and welcomed discussions about this new step of cooperation on Arctic research. The Russian side expressed that not only the Roshydromet institutes specialized in Arctic research, but also the RAS institutes, which also do research work in the Arctic, should be incorporated in the discussions. The preliminary responsible persons for the discussions on cooperative research were appointed by each side in January.

Negotiations on the persons, date, place, and content of discussions at the time of the visit of Japanese delegates (MEXT and NIPR) to Russia continued up to March and were determined.

2.2 Visit of Japanese members to Russian organizations (April 2014)

The first direct contacts between Japanese and Russian institutes to discuss the new cooperation were realized from April 14–15, 2014, just after ASSW2014 in Helsinki, Finland. Two staff members from NIPR and one person from MEXT visited AARI and the RAS Presidium, as well as one institute of RAS in Moscow (the Institute of Geography). In St. Petersburg, at AARI, they were greeted by the Director and related AARI scientists, and introduced their activities related to Arctic research, as well as their thoughts about the planned WS. Both found out that there are many areas for cooperation in future activities.

In Moscow, the Japanese delegates visited the RAS Presidium and met the past Vice President and several other related personnel. They discussed the proposal on research themes made and sent beforehand to the Russian side by the Japanese side, and comments and discussions on them were carried out. It was interesting that there were some differences in thinking about the basic science concerning Arctic warming between the two sides, but they agreed to go forward, and the Russian side agreed to make proposals in the coming 1 to 2 months, and discuss them along with the Japanese proposals, at the planned preparatory WS in June. The Russian side promised to determine the delegates for the June WS. Due to practical matters, the WS was finally scheduled for early July. The Russian members attending the WS and the main contact persons for Russia changed slightly from the original proposed members in February, based on discussions made during the visit in April.

2.3 Preparatory WS (July 2014)

This WS was held at NIPR from July 3–4, 2014. This WS was designated as a preparatory WS for the October WS. Six persons attended from the Russian side and 14persons attended from the Japanese side. The main objective of the meeting was preparation for the main WS in October. The main discussion was the selection and treatment of the scientific proposals made by both side beforehand, which were to be discussed at the main WS. 19proposals were made by the Russian side and 11 proposals were made by the Japanese side. Some were discussed and became subjects for merging with other themes, and some were downgraded based on the discussions. Finally, the proposed themes were classified into three categories: (1) appropriate themes for which scientists exist on both sides; (2) appropriate theme for which scientists exist only on one side; and (3) additional themes to be proposed soon and to be included in the October WS. The meeting concluded that close information exchange would be made in the coming months, and the themes to be discussed by scientists and the participants to attend the WS in October would be decided by the beginning of September.

Detailed information about (2) proposed by the Russian side arrived in Japan and was distributed to the JCAR Network in August in order to search for Japanese counterparts. Provisional themes to be brought up at the October WS were determined and participant selection began in mid-September. Finally, 13 themes were determined for inclusion in the October WS.

Figure 2.3-1. Photograph of participants at the July WS, held on July 3–4, 2014 at NIPR.

2.4 Main WS (October 2014)

The October WS was held at Arcadia Ichigaya in Tokyo from October 28 to 30, 2014. Thirteen Russian scientists and more than 50 Japanese scientists and related persons attended the meeting (See Figure 2.4-1). The first day was an introduction day for the Russian participants, and the second day was an open meeting for JCAR members and other people. The meeting consisted of brief information on Japanese and Russian Arctic research, presentation and discussion of 13 themes, discussion on infrastructure, and other related matters. The third day was a day for further discussions such as infrastructure and the results of discussions made on research themes between the corresponding scientists. It was the first time in the history of both countries to have a meeting on discussions of future cooperation and possibilities with such a wide range of topics. In the end, the recommendation was that another WS should be held to follow up this meeting in 2015 in Russia, because some discussions had not been deep enough, and there might be other themes that could be investigated together. Moreover, the Japanese scientists wanted to know more about Russian scientists by visiting Russia.

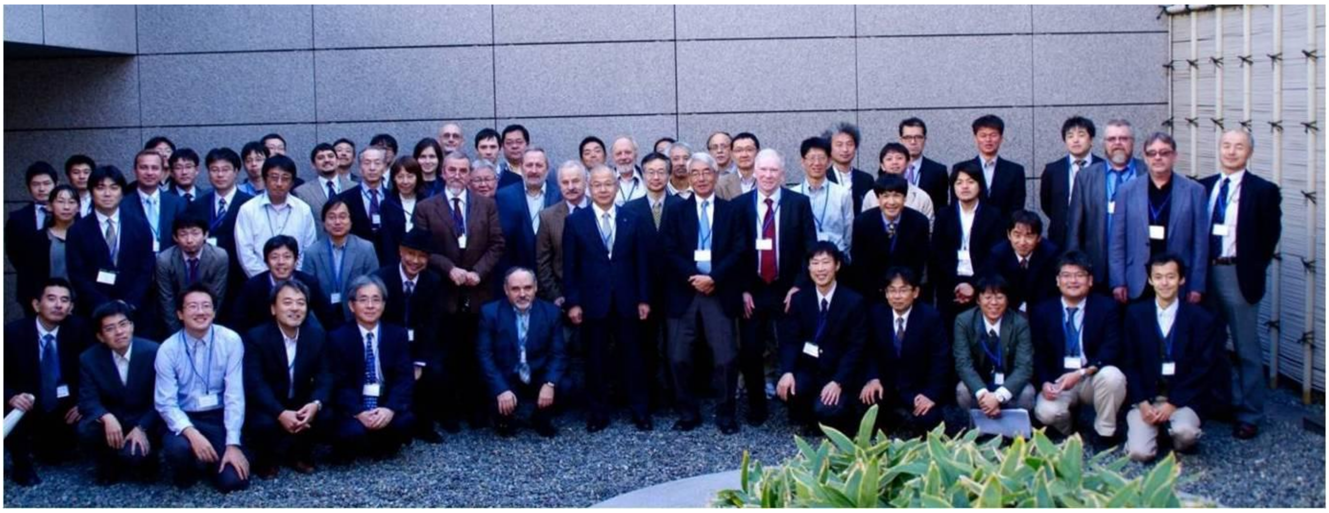

Figure 2.4-1. Participants in the October WS, held on October 28–30, 2014 at Arcadia Ichigaya.

2.5 Several discussions during the WSs

(1) Geographical extent of the Arctic

The geographical extent of Arctic research is always a matter of discussion when visioning research on the Arctic. This differs among countries, and also within the research bodies of each country, as well as according to the research subject. The geographical extent of Arctic research in the present discussion is considered as follows. The Arctic is generally considered to be the region of the Arctic Ocean and terrestrial area north of the Arctic Circle, but it is necessary to consider an area down to around 60°N or so for certain topics. This is needed in order to include the processes related to matters of global importance, and for Arctic change that is strongly dependent on Arctic warming, which is the most essential and strongest background for the present Arctic research. Two examples of such research subjects are (1) topics related to the hydrological cycle (i.e., topics such as change in the Arctic flow of large river basins into the Arctic Ocean) and (2) globally important phenomena (i.e., the changes in GHG emissions under the changing permafrost landscape), for which it is strategically necessary to consider drainage basins and tundra-taiga transect areas, which need to include southern regions.

(2) Note on terminology and concepts

During the discussions between the Russian and Japanese sides, there were several matters that are interesting to note here to illustrate the necessity for deeper discussions between the two sides. One example concerns the research facilities in Russia. The research infrastructure is equipped with research instruments called bases, stations, or laboratories, or identified in some other manner. The Japanese side had rather vague impressions about this, but the Russian side had more precise definitions. This was not a point of severe discussion, but it seemed to be a difference in customs on both sides.

Another example was the expression used to describe the Arctic warming that is occurring at present. The Japanese side expressed it as “change,” but the Russian side had a strong argument that it is not a “change,” but part of a cyclic fluctuation of climate, and is “variation.” This showed a slight difference in the general understanding of the present phenomena occurring in the Arctic.

It can be said that Japan and Russia have slightly different cultures regarding environmental science and Arctic research, and also use different wording and in some aspects have different understandings and concepts about phenomena. When, as was done on this occasion, two such communities need to hold discussions together using English, which is a foreign language for both sides, the problem becomes much greater. The discussions sometimes needed to go as far as identifying definitions, but this was unavoidable in order to go forward, and very worthwhile in narrowing the gaps between the two communities, which is something that is necessary for doing productive cooperative research.

§3. Proposed Research Themes

The following research themes were discussed at the October WS, and approved as potential collaborative themes.

3.1 THEME 1: Climate impacts of black carbon and aerosols in the Arctic (Spitsbergen, Baranov Cape, Tiksi)

(1) **Proposers** (Main Proposers:＊)

<Japanese side>

＊*Makoto Koike* (Department of Science, University of Tokyo, Japan)

Yutaka Kondo (Department of Science, University of Tokyo, Japan)

<Russian side>

＊*Alexander Makshtas* (Arctic and Antarctic Research Institute, St. Petersburg, Russia)

Vladimir Radionov (Arctic and Antarctic Research Institute,St. Petersburg, Russia)

Olga Popovicheva (Institute of Nuclear Physics, Moscow State University, Moscow, Russia)

(2) Introduction and Background of the Problem

Black carbon (BC) is the atmospheric particulate species that is most efficient at absorbing visible light. As a result, it exerts a warming effect that contrasts with the cooling effect of purely scattering aerosol components. Pure BC particles rarely occur in the atmosphere, however. Soon after emission, BC becomes mixed with other aerosol chemical components such as sulfates and organics. BC-containing aerosols can have either a warming effect or a cooling effect on climate depending on the albedo of the underlying surface relative to the albedo of the BC haze itself. The albedo of the haze depends on what other chemical species are present, their relative amounts, and whether they primarily scatter or absorb light. As a result, when determining the climate impact of BC and the effectiveness of a given mitigation strategy, species co-emitted with BC (e.g., OC and SO_2) must be taken into account.

BC-containing aerosols in the Arctic can perturb the radiation balance in a number of ways. Direct aerosol forcing occurs through absorption or scattering of solar (shortwave) radiation by aerosols. An absorbing aerosol, such as one containing BC, over a highly reflective surface will result in warming at altitudes above and within the haze layer (Shaw, 1995). The added atmospheric heating will subsequently increase the downward longwave radiation to the surface, warming the surface and accelerating the initiation of snow/sea ice melting. With the highly reflective surfaces typical of the Arctic springtime, even a moderately absorbing aerosol can lead to a heating of the surface-atmosphere-aerosol column.

Radiative forcing by BC can also result from aerosol-cloud interactions (Yun et al., 2013). The aerosol first indirect effect in the shortwave occurs when pollution particles lead to an increase in cloud droplet number concentration, a decrease in the size of the droplets, a corresponding increase in shortwave cloud albedo, and cooling at the surface (Twomey, 1977). Measurements made at Barrow, Alaska over a four-year period indicate that pollution transported to the Arctic produces high cloud drop number concentrations and small cloud droplet effective radii in low-level cloud microstructures (Garrett et al., 2004).

Measurements and global modeling studies indicate that carbonaceous aerosols have a significantly larger impact on cloud albedo than sulfate aerosols (Lohmann et al., 2000). Aerosol-cloud interactions can also lead to significant longwave forcing and warming at the surface. When the cloud droplet number concentration of thin Arctic liquid-phase clouds is increased through interaction with anthropogenic aerosols, the clouds become more efficient at trapping and re-emitting longwave radiation (Garrett et al, 2006).

BC-containing aerosol has an additional forcing mechanism when it is deposited to snow and ice surfaces (Clarke and Noone, 1985; Bogorodsky et al., 2014). Such deposition enhances absorption of solar radiation at the surface, which can warm and induce snow and ice melting. The BC snow/ice forcing mechanism is in addition to the stronger snow-albedo feedback process. Snow-albedo feedback is driven by the melting of snow and loss of sea ice exposing darker surfaces and enhancing absorption of radiation and surface warming. Surface temperature responses are strongly linked to surface radiative forcings in the Arctic because the stable atmosphere of the region prevents rapid heat exchange with the upper troposphere (Hansen and Nazarenko, 2004).

In light of the many atmospheric processes altering the properties and lifetime of BC, the potential for transport of BC to the Arctic and deposition to reflective surfaces, and the multiple forcing mechanisms, it is necessary to consider the entire source-climate response spectrum in order to establish the impact of changing emissions and the effectiveness of mitigation action.

(3) Goal

To quantify how changes in black carbon (BC) emissions affect atmospheric concentrations of BC and surface albedo in the Arctic.

(4) Possible scientific directions for collaboration

- Elaboration of approaches and advanced methods for BC physical and optical measurements.
- Quantification of aerosol emission sources of pollution by diesel, shipping, and biomass burning (agricultural and wildfires).
- Estimation for imputing the local and long-transport aerosol impacts on the Arctic marine environment.
- Study of cloud formation processes due to aerosols in the Arctic.
- Characterization of BC in snow cover during deposition events to quantify the role of BC in snow/ice transformation.
- Development of light instruments for studying vertical distribution BC with unmanned aircraft.

(5) Proposed methodology

- Measure BC and other aerosols in the Arctic region on the basis of on-going international monitoring methods in the global network.
- Measure BC in sampled precipitation (rain and snow) and snow on the ground.
- Make model calculations to identify source regions and transport processes of BC and evaluate its impact on snow/ice albedo.

(6) First steps in collaboration

1) We plan to organize atmospheric BC measurement using the COSMOS instrument, developed by the University of Tokyo (UT), in the Russian Arctic. The University of Tokyo (UT) will provide the COSMOS instrument and AARI will operate the COSMOS instrument on their own responsibility in the Ice Base Cape Baranova scientific station. For this purpose, Russian scientists will visit UT in Tokyo, Japan for training on operation and data analysis (this will likely take two weeks to one month). This is a critical step for accurate measurement in Russia. AARI will send data to UT in a timely manner. If satellite Internet is installed, it will be possible for UT to monitor the data on a computer used for COSMOS, using TeamViewer or other software. AARI will send the instrument back to UT if instrument trouble occurs, because, due to the limitations of human resources in UT, their scientists cannot visit the observation site.
2) A new mobile portable aethalometer will be developed by MSU/CAO for long-term atmospheric monitoring in the Ice Base Cape Baranova station. It will be inter-calibrated with the COSMOS instrument and linked to build a local network for mobile monitoring measurement campaigns.
3) We also plan to collect and analyze precipitation (rain/snow) water and samples from filters installed by the Institute of Nuclear Physics (INP) and AARI in the Hydrometeorological Observatory Tiksi and Ice Base Cape Baranova.
4) We plan to execute short field campaigns for measurements of BC vertical distributions with Unmanned Arial Vehicles (UAVs) equipped with jointly developed lightweight instruments, developed in Russia.

As a result, we expect to obtain important new information about BC and other aerosol pollution in the Russian Arctic, its origin, and its influence on the Arctic environment in less-investigated regions. UT, AARI, and INP will share data and write scientific papers together with appropriate co-authorship.

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3.2 THEME 2: Preliminary joint study in the frame of the Polar Prediction Project

(1) Proposers

<Japanese side>

Jun Inoue (National Institute of Polar Research, Tokyo, Japan)

<Russian side>

Alexander Makshtas (Arctic and Antarctic Research Institute, St. Petersburg, Russia)

(2) Introduction and Background of the Problem

Radiosonde data over the Arctic Ocean are very limited due to the difficulty of operational observations. To date, only a few Arctic expeditions have provided data (e.g., Inoue et al., 2011). The number of radiosondes launched over the Arctic Ocean has been very limited; however, the impact of Arctic radiosonde observations on weather forecasts and reanalyses data has not been fully investigated. Using the special radiosonde data observed by the Japanese research vessel "Mirai" and the data assimilation system developed by the Earth Simulator Center at JAMSTEC, Inoue et al. (2013) demonstrated that high-temporal radiosonde observations over a portion of the ice-free Arctic Ocean can help reduce uncertainty, not just at the local observation site and time, but throughout the northern half of the Northern Hemisphere for weeks afterwards.

An improved weather forecasting capacity over the ice-free Arctic Ocean is vital for safe ship navigation in the Northern Sea Route and Northwest Passage, because storms can generate strong winds, high waves, icing on the ship surface, and sea-ice advection. A precise prediction depends on not only a sophisticated model itself, but also in situ observations. Expansion of the Arctic observation network would also help improve weather forecasting over the mid-latitudes. Therefore, the impact of a special sounding array on local and remote atmospheric circulations will be investigated by expanding the observation network with international collaboration. Japan has led the Arctic Research Collaboration for Radiosonde Observing System Experiment (ARCROSE) since the autumn of 2013. This project consists of intensified Arctic sounding network and data assimilation. The aim of this project is to understand the uncertainty of Arctic atmospheric circulation, and to propose a future observation network.

(3) Definition of Research Questions and Goals

This scientific direction is a timely fit with the Polar Prediction Project (PPP), which has been formally established by the WMO's World Weather Research Programme (WWRP). One of the key elements of the Polar Prediction Project is the Year of Polar Prediction (YOPP), which will consider both the Arctic and Antarctic, and is scheduled to take place from mid-2017 to mid-2019. The intention is to have an extended period of coordinated intensive observational and modeling activities in order to improve polar prediction capabilities on a wide range of time scales. YOPP is expected to foster relationships with partners, provide common focused objectives, and be held over a bit more than a one-year period in association with a field campaign providing additional observations. It should coincide with, support, and draw on other related planned activities for polar regions.

During the YOPP Preparation Phase (until mid-2017) plans will be further developed through international workshops, there will be engagement with stakeholders and arrangement of funding, coordination of observations and models, and preparatory research. The YOPP from mid-2017 to mid-2019 encompasses four major elements: an intensive observing period, a complementary intensive modeling and forecasting period, a period of enhanced monitoring of forecast use in decision making including verification, and a special educational effort. The YOPP Consolidation Phase from mid-2019 to 2022 will provide a legacy of data and publications, as well as implementation of YOPP findings to achieve significant improvement in environmental prediction capabilities not only for the polar regions, but also beyond these regions, because of linkages with lower latitudes.

(4) Approaches and Methods

In the framework of preparation for the Year of Polar Prediction there has been a proposal to organize radiosoundings more often (four times per day) at the Hydrometeorological Observatory Tiksi and at Ice Base Cape Baranov on the Bolshevik Island (in recent times both polar observatories have been executing one sounding per day). The cooperation could be organized (among other options) under the Program of Scientific and Technical Cooperation between the Russian Federation and Japan for 2013–2016. The ARCROSE project might be a good opportunity for mutual collaboration.

The Russian side presented information about the radiosounding systems installed at Tiksi and Bolshevik Island, which could be used during YOPP. Based on the discussion, the following things to be prepared for soundings at Cape Baranova during YOPP under Japan-Russia collaboration have been elaborated: (1) equipment for data transmission for GTS; (2) extra Vaisala (RS92) sensors (two extra launches per day × 365 days); and (3) high-quality balloons (e.g., TOTEX balloons: four balloons per day × 365 days). The total estimated cost is approximately 350,000 USD.

Preliminary estimations for Tiksi, executed by the Yakutian Branch of Roshydromet, would be done during the year before the beginning of the joint study. After meeting and taken into account the absence of any plans for field studies of free atmosphere by NIPR in 2015, this joint study would be focused on the YOPP/MOSAiC year (2018–2019).

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3.3 THEME 3: Reliability and risk estimation for sea-ice navigation along the Northern Sea Route

(1) **Proposers** (Main proposer：＊)

<Japanese side>
＊*Hajime Yamaguchi* (University of Tokyo)
Noriaki Kimura (NIPR/University of Tokyo)
Kazutaka Tateyama (Kitami Institute of Technology)
<Russian side>
＊*Sergei Frolov* (AARI)
Tatiana Alexeeva (AARI)

(2) Introduction and Background of the Problem

The Northern Sea Route (NSR) has been opened due to sea ice retreat in the summer Arctic Ocean. We need to focus on hydrometeorological conditions and ecological safety in the NSR area caused by increased shipping transportation. Sea ice is the main obstacle for navigation in the Arctic. Risk estimation of ice navigation with the help of simulation modeling of vessel movement will lead to obtaining the objective performance of the maritime transport system and to the development of effective recommendations for risk minimization.

Concerning these problems, research on the use of the NSR in Japan has been carried out since the International Northern Sea Route Programme (INSROP) in 1999. Additional research on temporal and spatial variations of sea ice by using numerical models, satellite remote-sensing data, and field observation has become active in recent decades.

In Russia, a model for risk estimation of ship navigation through the ice cover had been developed at the AARI in the 1980s. The empirical model has been the main instrument to select an optimal route of navigation up to the present time. Information on the ice cover, and correspondingly the calculations, are robust, i.e., oriented on an estimation of average parameters of difficulty of navigation. This method makes it possible to provide navigational recommendations, obtain comparative analyses of various routes of navigation, study temporal variability of conditions of navigation, etc.

(3) Definition of Research Questions and Goals

We propose the following framework of collaborative work between Russia and Japan.

1) Analysis of sea ice and hydrometeorological conditions.
2) Advanced sea ice prediction and forecasting with requirements from shipping operations taken into consideration.
3) On-site observations to improve satellite remote sensing and model predictions.
4) Risk analysis and databases during ice-ship impact and ship icing.
5) Cost/benefit analysis.
6) Developing an empirical-statistical model of quantitative estimation of navigational difficulty for operating and projected vessel types, developed in the AARI.
7) Developing objective criteria and methods of estimation of integrated risks of icebreaker exploitation and ice class vessel navigation through the ice cover.

8) Drawing up recommendations for independent objective estimations of navigation reliability.

(4) Justification of why collaboration between Japan and Russia is necessary

Under the GRENE Arctic Project, a Japanese group is proceeding with studies of sea ice and NSR: high-resolution numerical modeling of sea ice, medium-range ice forecasting by a statistical method, satellite monitoring of sea-ice thickness, optimum routing of ships in the ice area, ship-ocean interaction, and economical evaluation.

AARI has a wealth of data and expertise on hydrometeorological and ice conditions in Arctic seas, including work on ice navigation and hazard assessments through model simulation, which will be evaluated to minimize risks for operators and coastal communities.

The Japanese group's experience in satellite remote sensing, numerical modeling, and economical evaluation will be useful for Russian activities. Knowledge and data from the Russian side are necessary for the Japanese group to develop these studies. This collaboration will certainly bring a wide range of benefits for both sides.

(5) Approaches and Methods

First, we will analyze sea ice and hydrometeorological conditions using field observation and remote-sensing data. The Japanese side anticipates opportunities to participate in on-site observations using Russian icebreakers (e.g., the Akademik Fyodorov) and drifting ice/ground stations (e.g., NP or Tiksi) from 2015. The Japanese side hopes to use their remote sensing tools such as ship-borne/airborne electromagnetic induction ice thickness profilers, 3D laser scanner, passive microwave radiometers, and so on to measure snow depth, ice thickness, roughness, surface salinity, and temperature. Based on these analyses, Japanese collaborators will develop several algorithms for deriving information on snow depth, ice thickness, and surface melting from satellite microwave data (SSM/I, SSMIS, AMSR-E, AMSR2) and improve the method for medium-range ice forecasting using the field observation data from the Russian side of the Arctic.

In the framework of Japanese-Russian collaboration, there is a plan to adapt the model to estimate risks of navigation along the NSR. Distribution of characteristics and determined difficulties of navigation on the perspective routes of navigation will be analyzed. The present changes in the ice cover and limited amount of operating information will be taken into account. To test a model and to show its application to planning navigation in the Arctic, a model will be used to estimate risks of navigation of the most likely types of ships along the NSR over the years with easy, average, and difficult ice conditions.

A model experiment to estimate the difficulties of ship navigation in various ice conditions, and to calculate the probability of damage to ships in the definite area of navigation, will be carried out. We plan to create an instrument that will enable quantitative estimation of the difficulties of modern ship navigation.

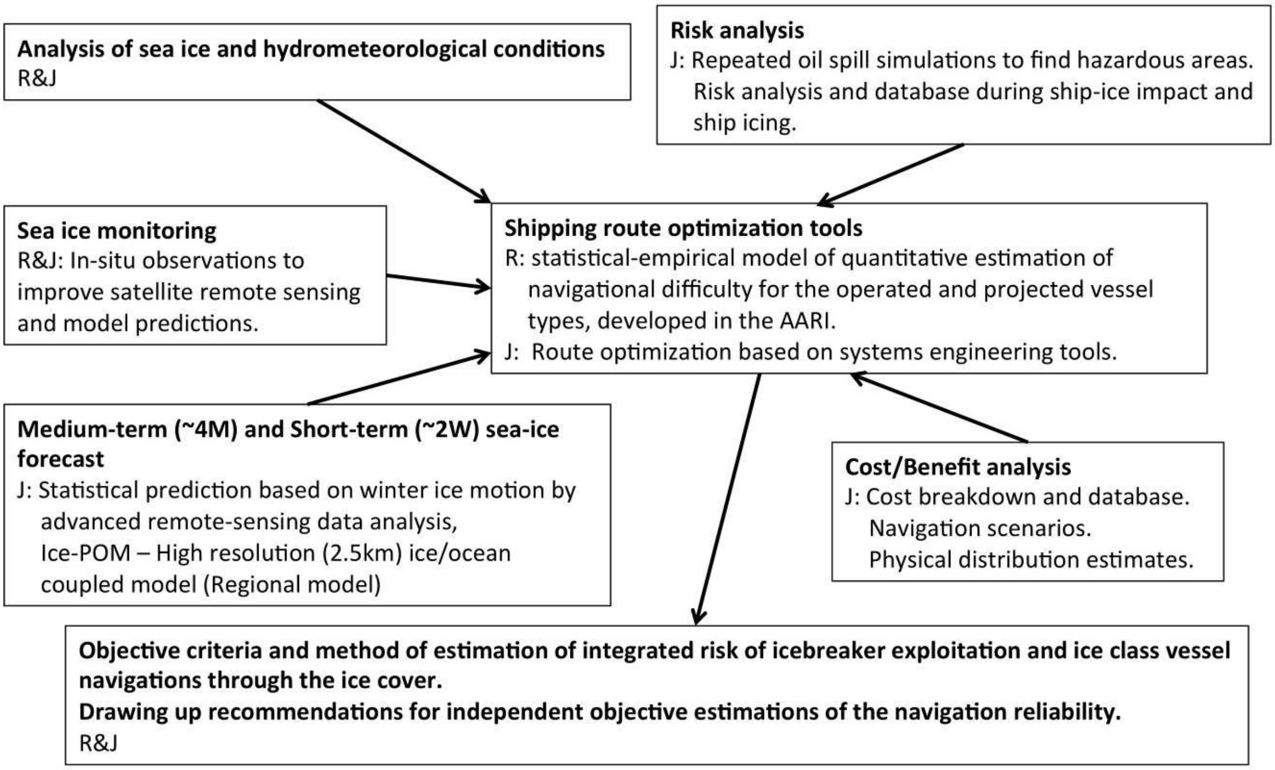

Figure 3.3-1. Scheme of the study and responsibility of each sides.

3.4 THEME 4: Comparative study on carbon and water in the permafrost ecosystem of Siberia

(1) **Proposers** (Main proposer: ＊)

<Japanese side>

＊*Atsuko Sugimoto* (Hokkaido University)

Yoshihiro Iijima (Japan Agency for Marine-Earth Science and Technology)

Toshinobu Machida (National Institute for Environmental Research)

Yojiro Matsuura (Forestry and Forest Product Research Institute)

Takeshi Ohta (Nagoya University)

Rikie Suzuki (Japan Agency for Marine-Earth Science and Technology)

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Alexander Fedorov (Melnikov Permafrost Institute)

Sergey Goryachkin (Institute for Geography)

Boris Belan Zuev (Institute of Atmospheric Optics)

Anatoly Prokushkin (Sukachev Institute of Forest)

(2) Introduction and Background of the Problem

The Russian Arctic occupies one-quarter of the total terrestrial region of the Arctic. Material cycles in this large area seem to greatly affect the global climate system through various feedback processes. The Arctic and sub-Arctic region in Siberia play an important role in the Arctic system due to the existence of permafrost, which also creates uncertainties for future projections including greenhouse gas (GHG) emissions. The permafrost condition undergoes significant spatial changes from west to east, which results in changes in the response of larches and also in the carbon and water cycles. The geology and soil type in each region also affect these factors. Terrestrial ecosystems in Siberia vary not only from south to north, but also from west to east.

(3) Definition of Research Questions and Goals

As described above, permafrost characterizes the ecosystem in Siberia. Permafrost degradation has a great influence on the ecosystem, and results in changes in the water and carbon cycles, and GHG emissions. Irreversible change such as alas formation may occur if the permafrost in the area is rich in ice, as shown in the figure below. How the ecosystem changes depends on the characteristics of the permafrost and the geological setting. Changes in surface condition severely affect vegetation and GHG emissions. Therefore, due to the spatial variability of the ecosystems, current status, responses to environmental changes, and

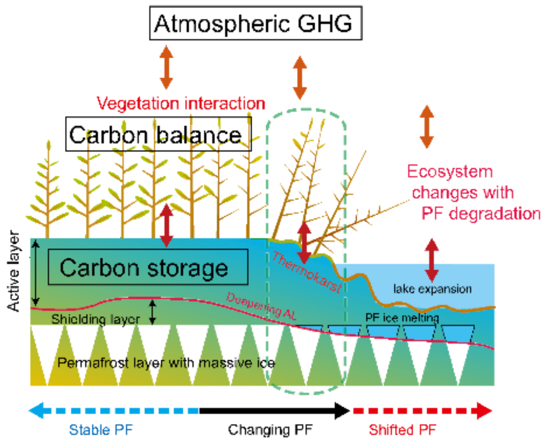

Figure 3.4-1. Schematic figure of changes in surface condition and carbon cycle with permafrost dedradation.

resulting feedback are expected to be different among regions. We therefore set the research questions as follows.

Q1: What are the differences in the status of climate, soil, vegetation, and carbon budget among Siberian regions?

Q2: How does the feedback mechanism in each region differ?

Clarifying these research questions will contribute to a better understanding of the Arctic system.

(4) Justification of why collaboration between Japan and Russia is necessary

Japanese and Russian scientists have been cooperating on observational research in Siberia for more than 20 years. Spasskaya Pad is a super-site in eastern Siberia, where fully equipped hydro-meteorological observation was initiated in 1998 under cooperation between Russian and Japanese scientists in the GEWEX-GAME/Siberia project. Spasskaya Pad is also placed as an important site to acquire ground truth values for satellite remote sensing. Observations in central Siberia and western Siberia have also been started by Russian and Japanese joint projects. There are already many findings on the processes of material cycles in each region, while comparative studies or trans-regional studies have not yet been fully attempted. Based on this long history as well as the experience and achievement in each region, it is possible to take on trans-regional and comparative studies, as proposed here. Cooperation between Russian scientists and Japanese scientists who are well acquainted with the processes at the site is essential for the proposed research here.

(5) Approaches and Methods

(a) Regional studies

To clarify and predict future changes in water and carbon cycles in terrestrial ecosystems, and GHG exchange and emission, observations will be conducted as follows.

- Comprehensive hydro-meteorological and biogeochemical and ecological observations at super-sites for tundra (Tiksi), the tundra-taiga boundary (Chokurdakh), and taiga (Yakutsk and Ust-Maya), including tower flux observations, soil respiration and CH_4 emissions, and ecological investigations on biomass and carbon storage.
- Reconstruction of forest stand structure and carbon sequestration trajectory through stand development.
- Observations on atmospheric greenhouse gases by aircraft and ground towers in Siberia.
- The flow of greenhouse gases and ^{14}C of litter, peat, and soils at various sites with different kinds of climate and land use in European Russia, and other regions.

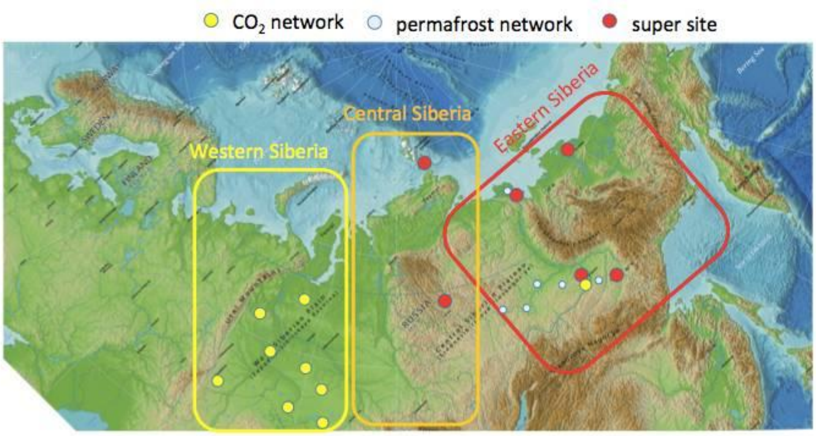

Figure 3.4-2. Map of observation area. Observation sites will be set in western, central and eastern Siberia.

(b) Trans-regional, continental-scale, and comparative studies

On the basis of the results at each site, investigations will be expanded to trans-regional and continental scales by monitoring and sampling as follows.

- Permafrost monitoring across the region to ascertain the current status.
- Observations on tree ring width and carbon isotope ratios to clarify the trend of growth change and its controlling factors.
- Estimation of soil carbon and biomass by observation and data mining.
- Airborne observation on GHGs for comparison between western and eastern Siberia.
- Satellite image analysis to estimate leaf area index (LAI), forest above-ground biomass (AGB), and phenology (growing season) accompanied by ground-level surveys for ground truth acquisition.

(6) Expected Outcomes or Products

Differences and similarities in the processes of water and carbon cycles and responses of permafrost ecosystems will be clarified from comparative and synthetic studies by means of comparisons among the regions. These results will be fundamental for future projections by modeling.

Regional- to continental-scale vegetation distributions (LAI, forest AGB, and growing season) will be delineated based on satellite data, which will provide us with a baseline to discuss the spatio-temporal variability of vegetation and related material cycles.

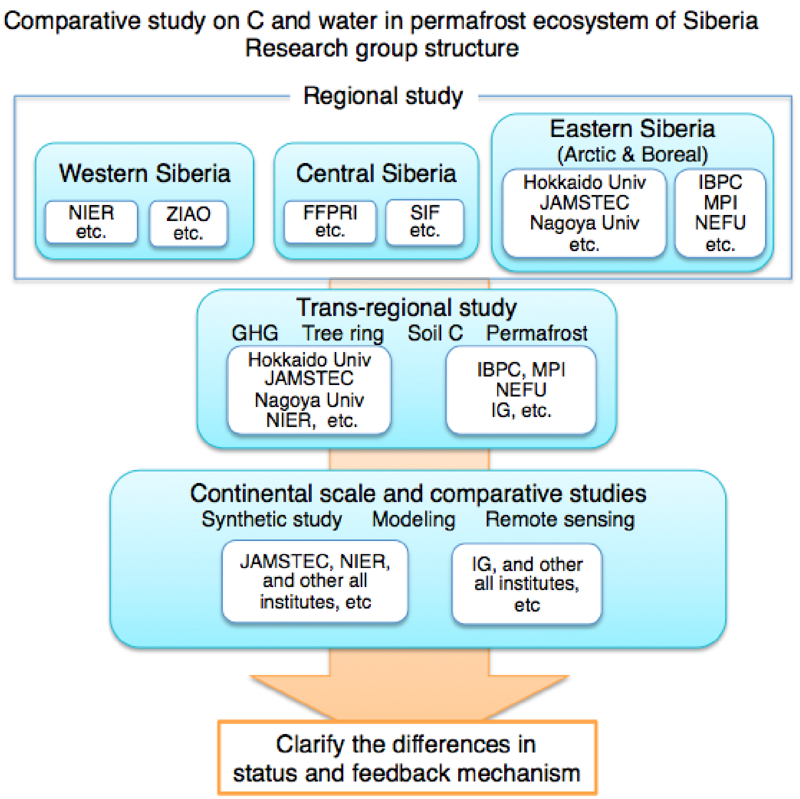

Figure 3.4-3. Research structure of comparative study on carbon and water in permafrost ecosystem of Siberia.

3.5 THEME 5: Glacier research in the Russian Arctic and sub-Arctic

(1) **Proposers** (Main proposer: ＊)

<Japanese side>

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Nozomu Takeuchi (Chiba University)

Hiroyuki Enomoto (NIPR)

Tetsuo Ohata (JAMSTEC)

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＊*Vladimir M. Kotlyakov* (Institute of Geography RAS, Moscow)

Andrey F. Glazovsky (Institute of Geography RAS, Moscow)

Maria Ananicheva (Institute of Geography RAS, Moscow)

Sergey R. Verkulich (Arctic and Antarctic Research Institute, St. Petersburg)

(2) Introduction and Background of the Problem

(a) Glaciers in the Russian Arctic and sub-Arctic

Glaciers in the Russian Arctic cover an area of 51,160 km^2, which corresponds to 7% of the total glacier area on earth (IPCC, 2013). Most of these glaciers are located on the archipelagos in the Arctic Ocean: Novaya Zemlya, Severnaya Zemlya, Franz Josef Land, and the De Long Islands (Figure 3.5-1). In addition to those in the Arctic Ocean, glaciers are distributed in the sub-Arctic, including the Northeast Siberia and Kamchatka regions.

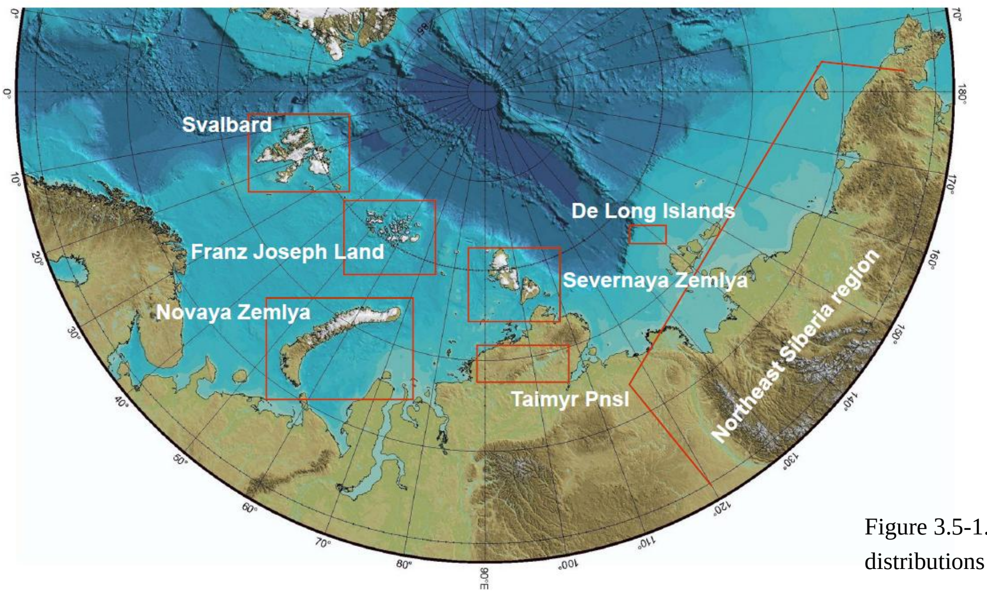

Figure 3.5-1. Map showing glacier distributions in the Russian Arctic.

(b) Glacier changes in the Russian Arctic and sub-Arctic

The glaciers in Russia are losing mass, resulting in contributions to sea level rises. Recent projections of sea level rises in the 21st century state that glacier mass loss in the Russian Arctic accounts for 13% of the total contribution of global glacier mass loss (Radic and Hock, 2014). This estimate indicates a relatively rapid glacier mass loss in this region, because glacier volume in the Russian Arctic corresponds to only 8% of the global total. Among these glaciers, those on Novaya Zemlya lost ice mass most rapidly over the last decade: 80% of the mass loss in the Russian Arctic archipelagos from 2003 to 2011 has occurred on this island (Figure 3.5-2) (Moholdt et al., 2012), which is covered by ice over an area of 22,182 km^2.

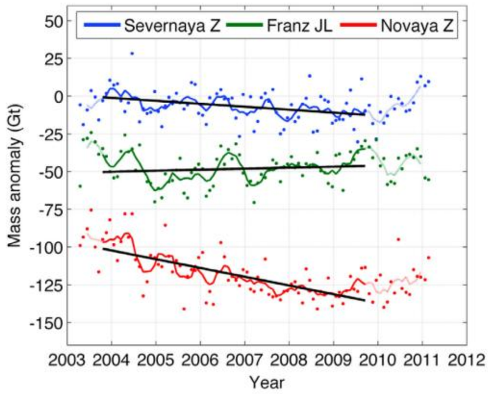

Figure 3.5-2. Recent mass loss in the three archipelagos in the Russian Arctic (Moholdt et al., 2012)

The influence of rapidly rising air temperature in the Russian Arctic is clear (e.g., Konya et al., 2014). However, the glacier changes are not spatially uniform, suggesting additional controls on the rate of ice mass loss in the Russian Arctic (Kotlyakov et al, 2010). Surface elevation changes over the glaciers on Novaya Zemlya show that ice thinning is greater near the coast, particularly near the front of marine-terminating calving glaciers (Carr et al., 2014). Thinning and retreat are more significant on the western side of the island (Barents Sea side) as compared to those on the eastern side (Kara Sea side). It has been suggested that the glaciers on the eastern side are more protected by sea ice, which covers the Kara Sea over a longer period of the year than the Barents Sea (Figure 3.5-3). Such interaction with the ocean is suspected as a control of the recent rapid retreat of calving glaciers in Greenland.

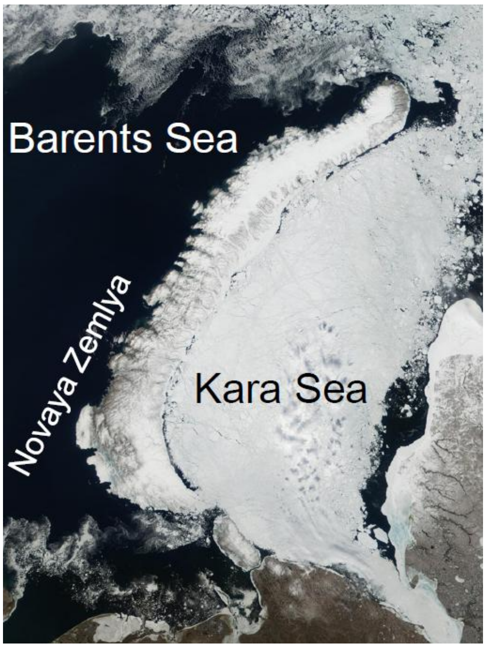

Figure 3.5-3. Satellite image of Novaya Zemlya. Note the clear contrast in the sea ice coverage over the Barents and Kara Sea. This MODIS satellite image was acquired on June 11, 2001 (NASA).

(c) Previous Japan-Russia collaboration in glaciology

Japanese and Russian researchers have been collaborating in glaciological research activities for the last several decades. Previous collaborations include glacier research in the Eastern Siberia and Kamchatka regions, and drilling and analyses of ice cores from Russian glaciers and other regions such as Antarctica. Japanese researchers in Hokkaido University, the National Institute of Polar Research, and the Kitami Institute of Technology have been deeply involved in these collaborations. In Russia, the Institute of Geography, Russian Academy of Sciences, and Arctic and Antarctic Research Institute have played a central role in the collaboration.

With the background described above, we propose future collaboration between Japanese and Russian scientists in the field of glaciological research in the Russian Arctic and sub-Arctic regions. Because of the recently accelerating warming trend in the Arctic, it is urgently necessary to quantify glacier changes and understand the mechanisms driving ice mass loss in the region. Moreover, studying paleoclimatic conditions using ice cores is increasingly important to better understand current and future climate changes. Based on the discussion at the Japan-Russia Workshop on Arctic Research held in Tokyo on October 28–30, 2014, possible research subjects, methodologies, and study sites are proposed in the following sections.

(3) Definition of Research Questions and Goals

(a) Mass loss of glaciers

Glaciers are retreating and thinning in the Russian Arctic. However, measurements of the ice mass change are relatively sparse in the region, and thus more accurate quantification of current glacier mass loss is required. Moreover, a detailed understanding of glacier mass balance processes (i.e., snow accumulation, surface melting, melt water refreezing, calving, and melting in the ocean) is required to project mass loss in the future. More reliable long-term data are needed, and therefore monitoring of mass balance and ice speed is essential to achieving these goals. To study ice-ocean interactions, collaborative research activities with an ocean research group should be considered.

(b) Microbes and impurities in snow and ice

Among the processes related to the glacier mass balance, the influences of dust, black carbon, and microbes on glacier surface albedo are poorly defined. Recent studies in Greenland revealed a substantial impact of darkening of the ice surface on the glacier mass balance (Sugiyama et al., 2014), and this change in the ice surface condition is driven by biological processes as observed in other regions (Takeuchi et al., 2001). On the snow surface, black carbon and dust play key roles in the reduction of albedo by absorbing insolation, as well as by accelerating snow grain growth. Collection of ice and snow samples from different regions is needed to better understand the spatial distributions of organic and inorganic impurities and their roles in glacier changes in the Arctic.

(c) Ice cores

New ice cores from Russian Arctic glaciers will act as an excellent tool for the reconstruction of environmental history in the Arctic. Detailed knowledge of the past is also important to project changes in the future. New data from ice cores are required to better understand the recent warming trend, changes in precipitation, sea ice conditions, and deposition of chemicals, dust and black carbon. These ice core data can be applied to estimate the past and future mass balance of glaciers as well as material transport in the Arctic.

(4) Approaches and Methods

The above-proposed subjects will be studied by means of field measurements, satellite and airborne remote sensing, snow and ice sampling and analyses, climatic data analysis, and numerical modeling. Japanese and Russian scientists will share their resources and facilities in the field and laboratory, and jointly develop novel research techniques and instruments. We list possible research activities below.

(a) Land-based measurements: GPS measurements for ice speed and surface elevation; radar echo sounding for ice thickness; subglacial and englacial measurements in hot-water-drilled boreholes; verification data for satellite remote sensing (e.g., surface elevation, ice speed, albedo).

(b) Airborne measurements: radar echo sounding for ice thickness; laser altimetry; aerial photogrammetry.

(c) Satellite remote sensing: glacier front position; surface elevation (stereo photogrammetry); ice velocity; speed; albedo; sea ice; sea surface temperature.

(d)Ocean measurements: seawater properties (e.g., temperature, salinity, turbidity, circulation); ocean depth sounding; water sampling and analysis; sea ice observation.

(e) Ice core analyses: black carbon; isotope composition; aerosols; chemical impurities; physical properties of ice.

(f) Climate data analysis: weather station data; reanalysis data.

(g) Numerical modeling: mass balance modeling; ice dynamics modeling; regional climate modeling.

(h) Glacial microbe analysis.

(5) Study sites

(a) Novaya Zemlya

To study glacier mass loss in the Russian Arctic, the scientifically most interesting region is Novaya Zemlya (Figures 3.5-1 and 3.5-3), where the most rapid mass loss is occurring at calving glaciers. This is an ideal site to study ice-ocean interactions, which is possibly a most important driver in rapid glacier changes. We should bear in mind that field activity in this region is logistically demanding. Helicopter operation for a long distance and lodging in a difficult environment should be solved in advance. We can probably start with satellite studies and look for a possibility to organize a field campaign that is well-focused on an important subject.

(b) Severnaya Zemlya

Severnaya Zemlya (Figures 3.5-1 and 3.5-4) provides locations for different types of glaciological research. For the last half-century, many measurement and sampling activities have been performed in this region (Figure 3.5-4). Large ice caps are ideal sites for long-term mass balance monitoring, as well as snow and ice sampling. Some parts of the ice caps are flowing into the ocean, and thus offer locations for studies on ice-ocean interaction. The summits of ice caps are ideal drilling sites for ice cores, and indeed, several ice cores have been drilled on some of the ice caps in the past (Fritzsche et al., 2002). These activities are more feasible on Severnaya Zemlya because of logistical support from the Baranov research station.

Figure 3.5-4. Satellite image of Severnaya Zemlya, showing the locations of previous glaciological research activities (1–5) and Baranov station (Δ). (1) Mass balance measurements on Dezhnev Ice Dome (1965–1975). (2) Mass balance and ice thickness measurements, and drilling on Vavilov Ice Dome (1974–1990). (3) Ice core drilling on Academy of Sciences Ice Cap (1986–1987, 2001–2003). (4) Snow and ice sampling. (5) Mass balance measurements on Mushketov Glacier. This MODIS satellite image was acquired on July 6, 2001 (NASA).

(c) Northeast Siberia and Kamchatka

Japan and Russia have been working together on the glaciers in northeastern Russia. Glacier measurements and ice core drilling were carried out in the Kamchatka Peninsula in the late 1990s (Shiraiwa et al., 2001). Field campaigns have been organized on the glaciers in the Suntar-Khayata region (Takahashi et al., 2011), and this research activity was continued by the recent Japanese GRENE Arctic Project. Glaciers in these regions are relatively less studied, and thus suffer from a lack of on-site data. Because old glaciological data exist for many sites in these areas, collecting new data provides an opportunity to study glacier changes over the last several decades. The project, proposed by a group of glaciologists from IG RAS, Moscow, will also include assessment of mountain glaciers in Northeast Siberia in the changing climate from the recent past to the present time and up to the near future. This will be done using glaciological and climate data, field measurements, satellite imagery, and projections by climate change models. The study of mountain glaciers had been conducted earlier in those regions shown in Figures 3.5-5 and 3.5-6.

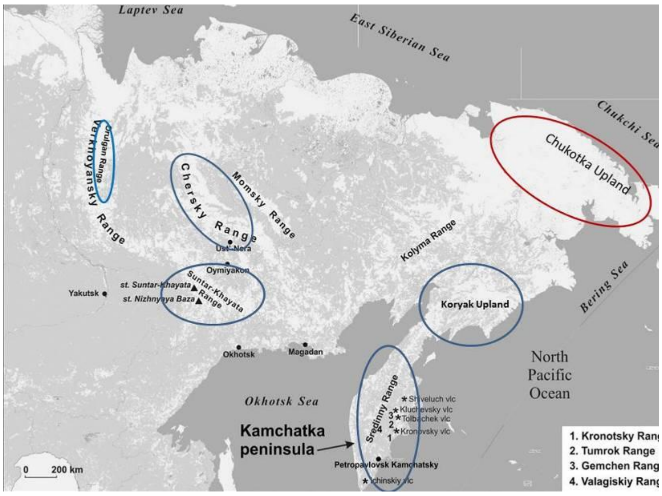

Figure 3.5-5. Study regions where estimation of the state of mountain glaciers was conducted (blue ovals) and is proposed for new work in the future cooperation (red oval).

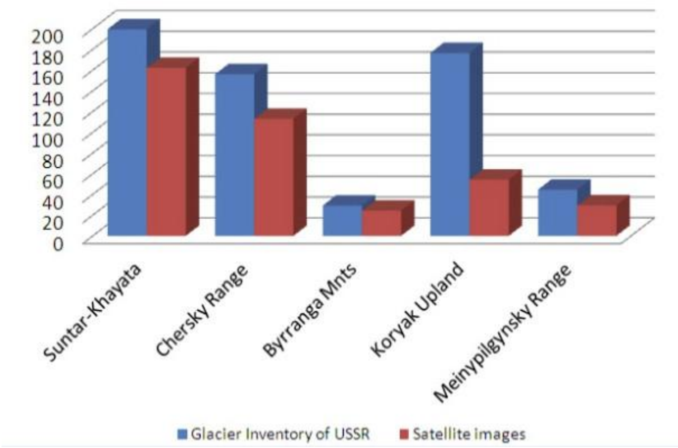

Figure 3.5-6. Total reduction of glacier areas in km^2 in all glacier regions until the present: Suntar-Khayata Range, since 1945, Chersky Range, since 1970, Byrranga Mountains, since 1967, Meinypylginsky Range, since revision in the 1980s (Ananicheva, 2014).

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3.6 THEME 6. Contemporary changes of water, heat, and dissolved and suspended organic/inorganic matter fluxes from Siberian rivers into the Arctic Ocean

(HyARCrio: Hydrology of pan-ARCtic rivers and its impact on the ocean)

(1) Proposers

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Irina Fedorova (Arctic and Antarctic Research Institute, St. Petersburg, Russia)

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(2) Introduction and Background of the Problem

There has been noticeable warming during the last few decades in the vast Siberian region (area about 10 million km^2). It has been accompanied by a rise in air temperature, and to lesser degree by increased precipitation. These changes are characterized by considerable spatial heterogeneity and significant changes in the hydrological regime, fluxes of heat, and dissolved/suspended matter. River runoff changes have a significant impact on the surrounding seas, affecting the circulation of seawater masses, the formation and dynamics of multi-year sea ice, and the balance of biogeochemical substances. The phase of long-term climate cooling, which began in 1940s, continued until the 1970–1980s. After that, the phase of climate warming has continued to the present. It could be that the phase of global warming will stop temporally, and it could change due to a decadal mature phase in the near future, which would lead to corresponding hydrological changes. Anthropogenic factors could also have a significant impact on the considered hydrological characteristics. They must be characterized by considerable spatial heterogeneity and their scale and impacts could have changed markedly in recent decades.

Various aspects of long-term changes in different characteristics such as runoff, fluxes of heat, and suspended sediment and dissolved matter of major rivers in the region have been studied (Alekseevsky, 2007; Georgiadi and Kashutina, 2011, 2014; Georgiadi et al., 2011; Gordeev, 2012; Georgiadi and Zolotokrylin, 2007; Holmes et al., 2012; Lammers et al, 2007; Nikanorov et al., 2007; Shiklomanov et al., 2007; Stuefer et al., Georgiadi and Fukushima, 2007; Shiklomanov, 2008; Yang et al., 2002). However, the degree of their synchronicities in time and space has not been sufficiently developed, and climatic-anthropogenic contributions to the long-term dynamics of their changes have not been revealed.

This study is a first attempt to provide an integral assessment of the long-term spatio-temporal dynamics of the main characteristics of river runoff, fluxes of heat, and suspended sediment and dissolved matter of major rivers of the Eurasian sector of the Arctic Ocean watershed. New knowledge will be obtained about: (1) the long-term phase of change for characteristics of annual and seasonal runoff, heat, and suspended sediment and dissolved matter in the lower reaches of the large rivers as well as the main tributaries; (2) the degree of inter-basin and intra-basin simultaneity of changes; (3) contingency of hydrological changes with climate change (including macro-scale atmospheric circulation and anthropogenic influences); (4) the climatic and anthropogenic contribution to the long-term changes; and (5) the possible impact of these changes on surrounding seas.

(3) Definition of Research Questions and Goals

Overall goal

The overall goal is to investigate contemporary changes of river runoff, fluxes of heat, and dissolved/suspended organic/inorganic matter of the three largest Siberian rivers due to climatic and anthropogenic impacts, based on the use of long-term data sets of state network stations and by conducting special field work.

Objectives (research issues)

There are four research issues in this study. They are as follows.

1) Water temperature and dissolved organic/inorganic matter, which affect sea ice extent and the primary production of the Arctic Ocean, will be monitored in the Arctic rivers (Lena, Yenisei, and Ob) at main junctions of tributaries as well as river mouths.
2) Spatial and temporal changes in river discharge, heat, and material fluxes due to climate/anthropogenic impacts will be investigated.
3) Differences of hydro-geochemical processes between delta-river (Lena delta) and estuary-river (Ob and Yenisei) interaction under climate change will be investigated.
4) Re-distribution and reaction of the terrigenous matter in river-ocean mixing zones of the surrounding sea (i.e., Kara, Laptev, and East Siberia) will be observed.

Research details are given as follows.

1) Investigation of features of long-term changes regarding annual and seasonal characteristics in river waters during periods of observation caused by climatic changes and anthropogenic impact.

For this purpose, long-term changes of characteristics downstream of the major rivers, along them from the upper to lower reaches, and also downstream of their main tributaries will be analyzed, taking into account the main anthropogenic factors.

2) Items

(a) Spatio-temporal synchronicity of changes in characteristics within the large river basins and between them.

(b) Correlation of contemporary changes for runoff of large rivers and climatic changes (air temperature, precipitation, and large-scale atmospheric circulation).

(c) Anthropogenic impact on long-term changes.

3) Profiling of water temperature, and dissolved and suspended matter in the Arctic rivers

Water temperature and suspended/dissolved organic/inorganic matter, which affect sea ice extent and the primary production of the Arctic Ocean, will be monitored in the Arctic rivers (including river mouths) such as Lena, Yenisei, and Ob.

4) Creation of GIS of large river basins including hydrometeorological, hydrochemical long-term data sets

5) Investigations in river-ocean mixing zones for a quantitative understanding of process differences between delta-ocean (Lena delta) and estuary-ocean (Ob and Yenisei) interaction under climate change

Research vessels, fishing boats, or zodiacs will be used for observations in coastal areas (it will be necessary to seek opportunities). Also, historical observations of biogeochemical parameters in coastal regions (in the Hydrochemical Atlas of the Arctic Ocean) will be investigated and compared with changes in river water.

6) Area of investigation

Large river basins of Siberia (Ob', Yenisei, Lena), their major tributaries, and their estuaries and delta will be the area of investigation (see Figure 3.6-1).

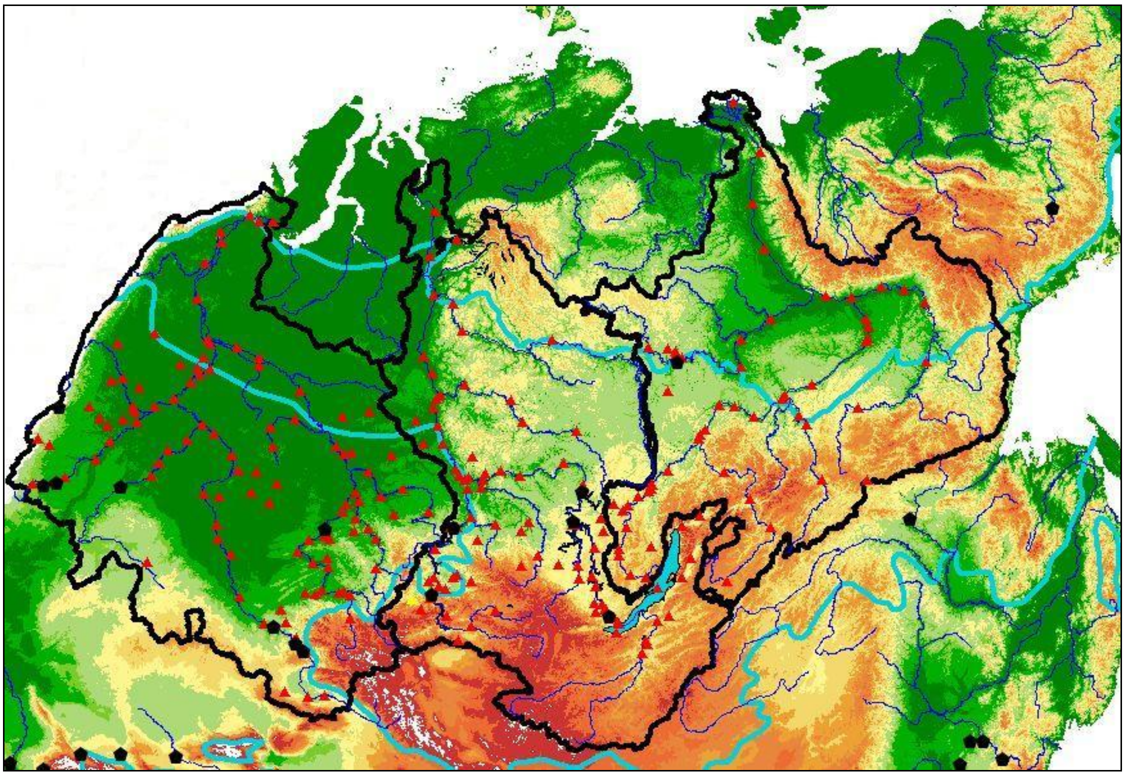

Figure 3.6-1. Map showing the area of investigation.

7) Considered characteristics

- Mean annual and seasonal water discharges (river runoff).
- Water temperature and heat flux.
- Mean annual and seasonal fluxes of dissolved organic/inorganic matter.
- Mean annual and seasonal fluxes of suspended matter.
- Ice cover characteristics for river channels and estuaries and deltas.

8) Initial data

No.	Data
1	Long-term data of standard hydrological, meteorological and hydrochemical observations Hydrometric data 1) Monthly and daily water discharges 2) Water temperature 3) Ice cover characteristics 4) Suspended matter Hydrochemical data 1) Physical-chemical data 2) Major ions (cations and anions) 3) Organic matters and nutrients 4) Metal trace elements
2	Data of other projects (PARTNERS, ArcticGRO etc.)
3	Data collected in the UNEP GEMS/Water Program etc.

(4) Justification of why collaboration between Japan and Russia is necessary

Cooperation among scientists from different specialties and countries is particularly necessary for such complex investigations. Cooperation by experts from Russia and Japan will allow us to obtain significant results as modern technologies for determination of a number of investigated characteristics. This first concerns water quality indicators, and will allow us to obtain more reliable results.

(5) Approaches and Methods

The studies will be based on interconnected geographical, hydrological, and statistical techniques, forming an original approach that allows us to identify regularities of long-term changes in the considered characteristics. Relationships, degrees of synchronicity in time and space, and the contribution of climatic and anthropogenic factors in the long-term dynamics will be analyzed. The project participants have contributed to the development of a number of methods and have significant experience in applying the methods mentioned above in river basins of the Siberian sector of the Arctic Ocean watershed (Alekseevsky, 2007; Georgiadi et al., 2008a, 2008b; Georgiadi et al. 2011; Georgiadi and Kashutina, 2011, 2014).

Methods

We will apply the following methodologies.

(a) Long-term data set analysis

- Geographical regionalization using GIS (Geographical Information System) to explore: (1) intra-year and long-term changes of characteristics; and (2) the types of human impacts on the hydrological regime.
- Methods for naturalization of river runoff based on river indicators of climate conditions and methods of hydrograph transformation.
- Methods for analysis of long-term and short-term changes of characteristics (curves of cumulative sums of

normalized annual values of characteristics; Fourier and wavelet analysis).

- Statistical approaches to detect characteristics of regressions for two periods with different types of climate and anthropogenic influences.
- Methods of hierarchical classification.

(b) Use of a three-dimensional hydrodynamic model

The POM (Princeton Ocean Model) will be used to detect seasonal hydrological processes including ice processes. Using this model, long-term changes in the seasonal processes of interaction between the river and sea in the Ob and Yenisei estuaries will be performed. Boundary conditions using data from state network stations to calculate the characteristics of hydrological processes in these estuaries will be applied.

(c) Conducting field measurements and laboratory analysis of water samples

DOC, DIC, DON, DIN (together with C and N isotopes), water isotopes, and major cations and anions will be monitored. The sampling sites will be major junctions of tributaries as well as main streams.

Outline of Project Working Packages

Project working packages (WPs) are shown in Figure 3.6-2.

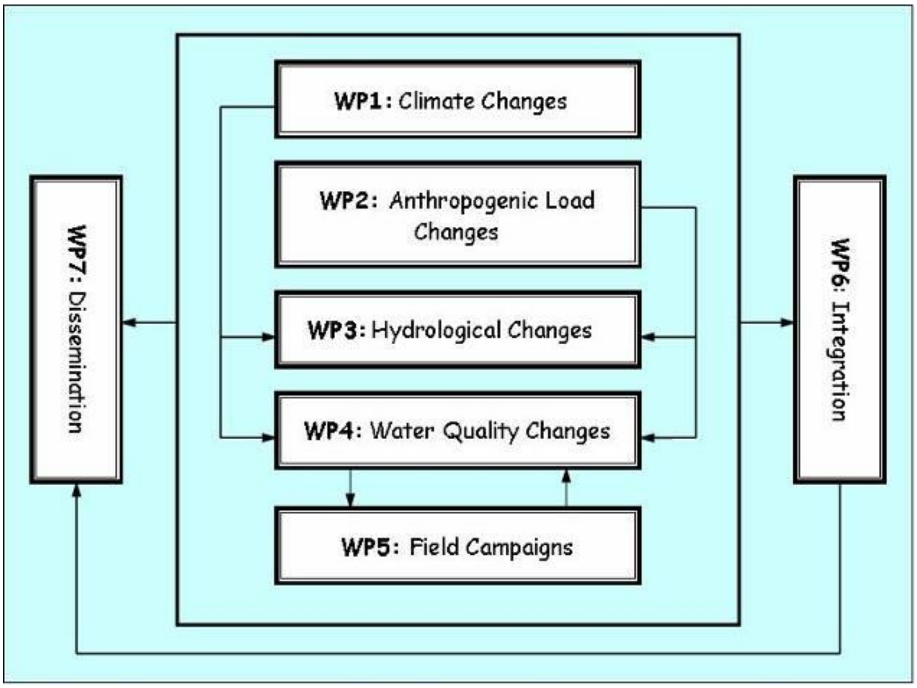

Figure 3.6-2. Working package of the Project.

(5) Expected Outcomes or Products

Knowledge regarding temporal and spatial regularities of long-term changes for the complex of characteristics within this huge region (including estuaries) caused by changes of climate and anthropogenic influence will be improved. A hydrologically oriented GIS of large Siberian river basins will be presented. The investigation results will be disseminated through a special website and joint publications.

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3.7 THEME 7: Variability of snow cover including blowing snow and snowmelt processes of the permafrost area under Arctic environment change

(1) Proposers (Main proposer:＊)

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Trofim Maximov (IBPC, RAS)

Vladimir Makarov (MPI, RAS)

(2) Introduction and Background of the Problem

The temperature in the Arctic is expected to increase during this century. Snow cover conditions in this region are sensitive to changes in climate. In these circumstances, the snow cover has significant spatial and temporal heterogeneity. The snow cover is significant in determining the stability of permafrost and ground and soil thermal conditions. The heat-resisting properties of snow cover, which are characterized by its thermal resistance, depend both upon its thickness and density and upon the stratigraphy of snow mass (Osokin et al., 2013). To date, the thermal resistance of the snow cover as a complex parameter that determines thermal insulation properties of the snow cover has not been studied. The thermal resistance of the snow cover depends on the heat conductivity of snow. Currently, there are many formulas for calculating the thermal conductivity of snow. However they do not account for the structure of snow and thermal conditions (Osokin et al., 2012).

Therefore, an important research element is the mathematical modeling of heat and mass transfer in the snowpack to assess the variability of the thermal conductivity of snow (Kotlyakov et al., 2004). Currently, there are few empirical dependencies of the thermal conductivity of snow on the temperature in a small range of variation of the density of the snow (Osokin and Sosnovsky, 2014).

An important area of research on the interaction of the snow cover and permafrost is the analysis of spatial and temporal variability of snow cover heat-resistance in case-study areas in the Russian and foreign Arctic on the basis of experimental and field research, and archive data analysis. Analysis of the variability of the thermal resistance of the snow cover will provide an opportunity to evaluate the stability of permafrost in different regions under climate change (Osokin et al., 2005; Osokin et al., 2013). The assessment of the influence of snow cover heat-resistance variability upon permafrost thermal conditions will be based on mathematical modeling and numerical experiments (Osokin et al., 2000; Sosnovsky, 2006).

(3) Definition of Research Questions and Goals

For the study and assessment of thermophysical properties of snow cover having different densities and structures, we will continue the experimental study regarding the bases in the Moscow region and Svalbard (Norway). In the course of this work, we will study the stratigraphy of snow and its thermal regime, and perform experimental studies on the thermal conductivity of varying structures of snow. The purpose of these studies is to evaluate the thermal conductivity of snow of varying structures and densities, and especially depth hoar. Its presence can significantly increase the thermal resistance of the snow and worsen freezing conditions and cooling of permafrost. In areas with the presence of discontinuous permafrost, this would enhance its degradation.

In these experimental bases, soil temperature is being measured at the depth of the active layer, including those under the snow and different thicknesses of moss. These measurements are the basis for the mathematical modeling of freezing-thawing, and evaluate its thermal stability under different conditions.

Thus, another goal of the research is to assess the thermal properties of different structures of snow cover and the impact of snow cover on the thermal regime of the soil, as well as the stability of permafrost in different geographic and climatic conditions.

An important factor affecting the thermal resistance of the snow cover is its stratigraphy. Our research has shown that neglecting the stratigraphy can result in more than 50% underestimation of the thermal insulation properties of the snow cover, which strongly affects the evaluation of the thermal state of the soil. The dynamics of the thermal resistance of the snow cover, and its spatial and temporal variability, make it possible to determine areas with different permafrost stability under climate change. Processing and analysis of archival materials regarding the spatial and temporal dynamics of the height and density of snow cover make it possible to construct distribution maps of the thermal resistance of snow cover (Figure 3.7-1). In the calculations of thermal resistance and thermal conductivity of snow λ [W/(m·K)], we use a simplified formula of Pavlov (2008): $\lambda = k\rho$, where $k = 10^{-3}$, ρ = snow density [kg/m^3].

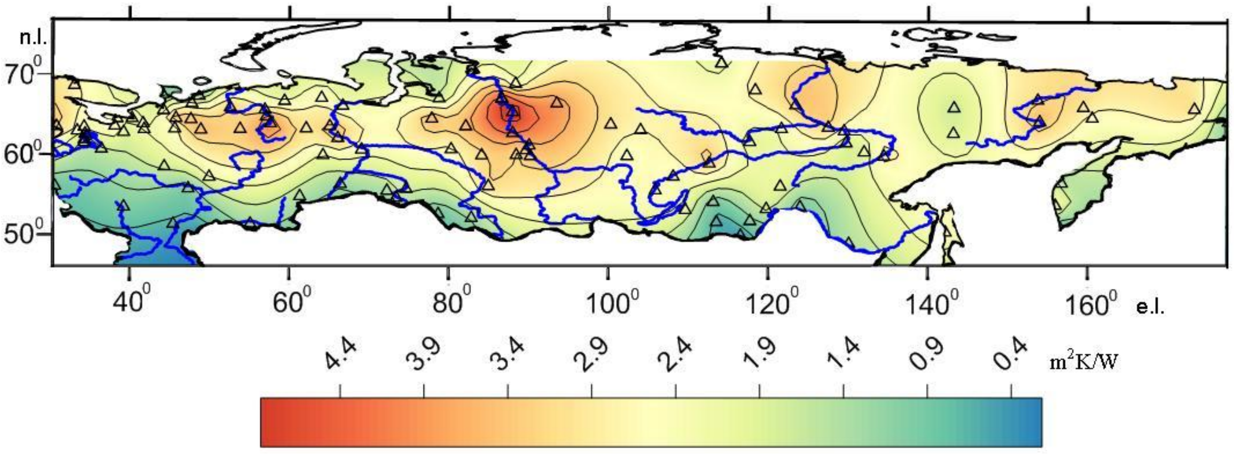

Figure 3.7-1. The thermal resistance of the snow cover in March for the period 2001–2010.

Another factor affecting the thermal regime of the permafrost is the growth dynamics of snow depth and temporal variability of the thermal resistance of the snow cover. Rapid growth of snow depth at the beginning of the cold period will worsen conditions of freezing and cooling of permafrost. Numerical experiments show that the difference in the rate of freezing of the soil at different growth rates of snow cover can exceed 50%. To evaluate such conditions requires an analysis of archival material on the dynamics of change in the height and density of the snow cover. The difference in the thermal state of the permafrost will be even more significant at a different thermal resistance of the snow cover (Figure 3.7-2).

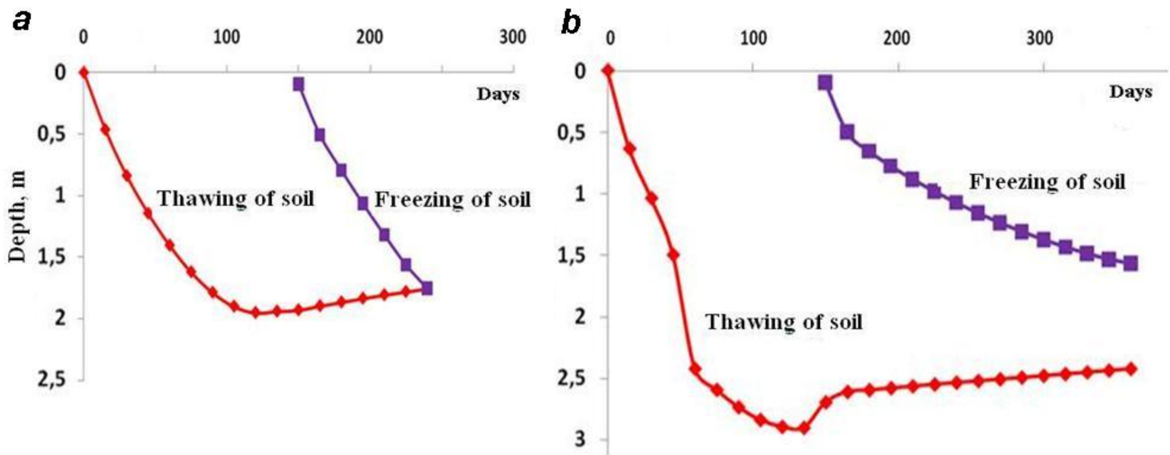

Figure 3.7-2. The freezing and thawing of the soil for a snow cover thickness of 1 m;
(a) density of snow ρ_s = 400 [kg/m^3]; (b) ρ_s = 100 - 200 [kg/m^3]

The research aims are as follows.

1) To study and evaluate the physical and chemical properties of the snow cover in the typical landscape of the Arctic.
2) To analyze the spatial and temporal variability of the physical and chemical characteristics of the snow cover in the Russian Arctic on the basis of experimental and field studies, and the analysis of archival data.
3) To evaluate the influence of snow cover variability in terms of the thermal resistance regarding the permafrost thermal conditions on the basis of mathematical modeling and numerical experiments.
4) To estimate snow cover variability due to blowing snow and snowmelt processes in the Arctic, which experiences rapid warming, on the basis of a land surface model and re-analysis data.

(4) Justification of why collaboration between Japan and Russia is necessary

Measurement of temperature and heat flow in snow with different structures and stratigraphy requires the use of modern technical means. Russia has different structures of permafrost and snow cover, which will make it possible to study the interaction of permafrost and snow cover with a wide range of parameters. Observation areas with vast, flat snow cover, as well as climate conditions such as tundra and taiga related to rich snow types, are limited in Japan. Collaboration between Japan and Russia will produce a network of skilled researchers who have gained experience in the Arctic.

(5) Approaches and Methods

The research methods are as follows.

1) Field studies of physical and chemical parameters of the snow cover in the Arctic regions.
2) Experimental studies regarding the Permafrost Institute SB RAS Tuymaada research site, including changes in temperature, moisture flux, stratigraphy, and chemical composition of the snow during the cold season of the

year.

3) Mathematical modeling of heat and mass transfer in the snowpack.
4) Analysis of the transformation of the physical and chemical parameters of snow cover during the environmental changes in the Arctic during the monitoring period (since 1998).
5) Analysis of aerial and space information.
6) Data analysis using a land surface model and re-analysis data.

(6) Expected Outcomes or Products

These include the spatial and temporal variability of the physical and chemical characteristics of the snow cover in the Russian Arctic, as well as evaluation of the influence of snow cover variability in terms of thermal resistance regarding permafrost thermal conditions.

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3.8 THEME 8: Development of space remote sensing technologies to monitor seasonal variations in temperature and moisture in the active topsoil of the Arctic tundra

(1) Proposers (Main proposer：＊)

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(2) Introduction and Background of the Problem

The temperature and moisture profiles in the active layer of the permafrost zone are crucial indicators of energy exchange between the soil and the atmosphere as well as of the processes of permafrost degradation that result in the additional release of carbon dioxide and methane. At the same time, the weather station networks in the northern latitudes are too sparse to provide sufficient data on temperature and moisture profiles of the active layer of permafrost. Currently, the World Meteorological Organization (WMO) provides some data on the temperature and moisture in the permafrost active layer (http://www.wmo-sat.info/oscar/). Space remote sensing is a highly sought-after information technology for monitoring seasonal variations of temperature and moisture in the active topsoil of Arctic tundra. However, according to the studies in (Hachem S,et al.,2012), (Jones LA, et al.,2007), and (Muzalevskiy KV,et al.,2013), these data do not meet the WMO standards. In particular, studies carried out for the North Slope of Alaska have shown that the data attained for soil temperature and moisture with the use of the space-borne radiometers MODIS (Hachem S,et al.,2012), AMSR-E(Jones LA, et al.,2007), and SMOS (Muzalevskiy KV,et al.,2013) have errors reaching 10–12°C and 0.3 cm^3/cm^3.

At the same time, the error in temperature and moisture retrieval from space remote sensing data using the radiometer on board the SMOS have been recently reduced down to 3°C and 0.06 cm^3/cm^3, and even temperature profiles in the active permafrost layer have been derived with error of about 3°C to 5°C (Muzalevskiy KV, et al.,2013), (Mironov VL,et al.,2013). This result has been obtained by the Russian team due to using physically based models of emission and scattering from the permafrost active layer. At the same time, the Japanese team has demonstrated the feasibility of improving existing scattering models when applied to radar space remote sensing of the permafrost active layer and subglacial environments (Watanabe M, et al.,2012),(Fujita S, et al.,2012). This advance has been achieved by using the data from the ALOS/PALSAR space-borne radar in conjunction with the elaborated on-site observations, making it possible to improve the physical basis of radar remote sensing. As a result of recent activities of both the Russian and Japanese teams, an opportunity has appeared to promote space remote sensing technologies, with the WMO standards for data on temperature and moisture in the active permafrost layer having been reached.

(3) Definition of Research Questions and Goals

In the framework of our joint project, we will focus on the development of physically based models for emission and scattering from the permafrost active layer as the major research question. The goal of the project will be to develop remote sensing retrieval algorithms that provide WTO-eligible data on temperature and moisture in the permafrost layer on the basis of observations from space, using the radiometers GCOM-W1/AMSR2 and SMOS/MIRAS, and the radars ALOS-1,2 /PALSAR, SMAP, and Sentinel-1.

(4) Justification of why collaboration between Japan and Russia is necessary

The Japanese team has long-standing experience of research in remote sensing of the Earth's surface with the use of the domestically produced space sensors ALOS-1,2 /PALSAR and GCOM-W1/AMSR2, having free access to all the data provided by these instruments. They also have comprehensive experience in fieldwork, and have conducted in-situ measurements at a number of Arctic sites, such as North Slope, Alaska, and Ny-Ålesund, Norway.

At the same time, the Russian team has expertise in developing physically based models for thermal radiation and wave scattering from the Earth's surface. In particular, a data processing algorithm providing Level 2 data on soil moisture regarding the temperate latitudes, with the use of radio brightness data measured by SMOS, has been developed in cooperation with the Russian team. Recently, the Russian team has extended its experience in developing adequate models for thermal radiation from the Earth's surface, having suggested retrieval algorithms to derive temperature and moisture in the active permafrost layer over some Arctic tundra sites in Alaska and the Yamal Peninsula, using the SMOS data. In addition, the Russian team has access to the infrastructure situated on the Yamal Peninsula and on Samoylov Island, with the facilities required to conduct long-term fieldwork being available together with the regular weather station data. The advantages of both teams complement each other, making it possible to achieve the goals of this project through cooperative research.

(5) Approaches and Methods

In this project, a multi-pronged approach is assumed. First, the data potentially provided by the radiometers GCOM-W1/AMSR2 and SMOS/MIRAS, and the radars ALOS-1,2/PALSAR, SMAP, and Sentinel-1, will be attained and systematized in time series form regarding the test sites in North Slope, Alaska, the Yamal Peninsula, Samoylov Island, and Ny-Ålesund (the final choice for a test site will be made later on). Second, in-situ measurements of brightness temperature and backscatter coefficient will be measured by the Japanese team with the use of a radiometer (6 GHz, 18 GHz, 36 GHz) and scatterometer (4–6 GHz). At the same time, the temperature and moisture profiles, as well as profiles for dielectric constants, in the active permafrost layer will be registered in-situ with the use of weather stations and a complex dielectric constant device (50 MHz to 6 GHz). Along with this, the soil surface roughness parameters will be measured with a needle profiler. Third, a number of soil samples from the active permafrost layer at the test sites will be collected, and laboratory dielectric measurements will be conducted by the Russian team with the use of a network analyzer (50 MHz to 16 GHz) to develop temperature-dependent dielectric models for the collected soil samples (Mironov VL,et al.,2010). Fourth, on the basis of in-situ and laboratory soil measurements, physically based models of emission and scattering from the permafrost active layer will be developed by both the Japanese and Russian teams. Fifth, the moisture and temperature profiles in the permafrost active layer will be derived using the developed models of emission and scattering and the data from both space-borne and in-situ radiometers and radars. Finally, the moisture and temperature profiles pertaining to the remote sensing measurements, from space as well as on the ground, will be compared with those obtained by contact sensors placed in the soil. As a result, the root mean square error for the temperature and moisture profiles obtained with the use of the developed remote sensing algorithms can be estimated. Ultimately, this approach will ensure a search for optimal retrieval algorithms in terms of minimal error by modifying the developed models of emission and scattering.

(6) Expected Outcomes or Products

(a) On the basis of radiometric data from the SMOS and GCOM-W1 instruments, Level 2 products for some territories of Arctic tundra will be developed; regarding the temperature and moisture profile in the active permafrost layer, this will be done down to a depth of 20 cm. The error in retrieving these values from remote sensing data is expected not to exceed 3–5°C and 0.04 cm^3/cm^3.

(b) On the basis of radar data from the ALOS-2 instrument, Level 2 products for some territories of Arctic tundra will be developed; regarding the temperature and moisture profile in the active permafrost layer, this will be done down to a depth of 5 cm. The error in retrieving these values from remote sensing data is expected not to exceed 5°C and 0.04 cm^3/cm^3.

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3.9 THEME 9: Permafrost changes in Siberia in the past and future based on projections of climate warming

(1) Proposers (Main proposer:＊)

<Japanese side>

＊*Mamoru Ishikawa* (Hokkaido University)

Tetsuo Sueyoshi (NIPR)

Yoshihiro Iijima (JAMSTEC)

Kazuyuki Saito (JAMSTEC)

<Russian side>

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A.V. Eliseev (IAP, RAS)

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S.N. Denisov (IAP, RAS)

D.S. Drozdov (Institute of the Earth Cryosphere, RAS)

G.V. Malkova (Institute of the Earth Cryosphere, RAS)

M.N. Zheleznyak (Melnikov Permafrost Institute, RAS)

A.N. Fedorov (Melnikov Permafrost Institute, RAS)

A.A. Velichko (Institute of Geography, RAS)

V.E. Tumskoy (Lomonosov Moscow State University)

(2) Definition of Research Questions and Goals

Past changes: Study of permafrost development in northeast Eurasia from paleoreconstructions. Here we propose investigating glacial-interglacial variations of permafrost distribution between the Last Glacial Maximum and the Holocene by means of a transient climate simulation with the state-of-art climate model CCSM3 (Liu et al., 2009). The model simulation is run with realistic changes in boundary conditions and forcing, with the model results generally capturing major features of deglacial climate evolution.

Recent changes: Global, regional, and local dynamics of permafrost under contemporary climate changes.

Future changes: Assessment of changes in the permafrost characteristics in the Northern Hemisphere under different scenarios of anthropogenic and natural forcings. An analysis of the permafrost reaction to climate changes in terms of the dependence on the rate and direction of the external forcing. Synthesis of the results for the permafrost dynamics in northeast Eurasia.

(3) Approaches and Methods

The simulation starts at 22,000 years before present (22 ka) and finishes in 1990 CE. The model is forced with transient orbital parameters and greenhouse gas concentrations. Transient boundary conditions include the ICE-5G ice sheets: extent and topography, and changing paleogeography as sea level rises from its LGM low stand to modern levels. There is also a prescribing transient scenario of freshwater forcing to the oceans from the retreating ice sheets. The soil variables are calculated using the detailed scheme for computation of the thermal and hydrological state of soil developed at IAP RAS. The scheme employs a deep soil column with 250 computational layers including layers reserved for snowpack calculation. The upper two soil layers in the regions covered by tundra and taiga are prescribed to contain organics, which is interpreted as a mixture of litter fall and low-level vegetation.

Future projections of the permafrost extent and thaw depth will be made by using the global climate model developed at IAP RAS. The scenarios of external forcings employed in these simulations will correspond to the SMIP5 (Coupled Models Intercomparison Project, Phase 5) protocol. This suite of scenarios covers a wide range of possible anthropogenic influence on the climate system, from the mitigation scenario to the scenario with very high anthropogenic emissions of greenhouse gases and aerosols, and with aggressive land use. The simulations will start in 1700 and will be continued until the year 2300.

To assess the dependence of the permafrost reaction on the rate and direction of external forcings, the CMIP5 scenario will be extended further up to the year 4000 by illustrative paths, in which anthropogenic forcing returns to the preindustrial level. This will be supported also by the IAP RAS global climate model simulations with an idealized forcing to interpret the respective simulations obtained under the extended CMIP5 scenarios.

(4) Expected Outcomes or Products

Compiling present and future permafrost maps in northeastern Eurasia and regions. The obtained results will be highly relevant for the interpretation of past variations of permafrost extension derived from paleoreconstructions, as well as for a better understanding of anticipated future changes. The estimates of possible permafrost changes in the Northern Hemisphere under anthropogenic scenarios will be obtained. An assessment of the dependence of the permafrost reaction on the rate and direction of external forcings will make it possible to estimate how the permafrost recovers if the anthropogenic forcings on climate are diminished. The latter simulations will also be compared with the paleoreconstructions for the last several glacial cycles.

3.10 THEME 10: Ecosystems and biodiversity

(1) Proposers (Main proposers:＊, ST: Sub-Theme)

<Japanese side>

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Shirow Tatsuzawa (Hokkaido University) (ST: 1.3)

Hazuki Arakida (RIKEN) (ST: 1)

Satoshi Ohdachi (Hokkaido University) (ST: 2)

<Russian side>

＊*Arkadiy Tishkov* (Institute of Geography, RAS) (ST: 1)

Innokentiy Okhlopkov (Institute for Biological Problems of Cryolithozone, SD, RAS) (ST: 1, 3)

Nikita Solomonov (Institute for Biological Problems of Cryolithozone, SD, RAS) (ST: 1, 3)

Isaev Arkady (Institute for Biological Problems of Cryolithozone, SD, RAS) (ST: 1, 3)

Tatiana Vlasova (Institute of Geography, RAS) (ST: 1)

Irina Pokrovskaya (Institute of Geography, RAS) (ST: 1)

Alexei Abramov (Zoological Institute, RAS) (ST: 2)

Pavel Kosintsev (Institute of Plant and Animal Ecology, RAS) (ST: 2)

Andrey Puzachenko (Institute of Geography, RAS) (ST: 2)

(2) General introduction to the study

(a) Content of the study

The purpose of this cooperative study is to identify the biogeographical implications of rapid climate changes and anthropogenic influences that lead to synergetic, cumulative, and cascading effects for biota and ecosystems in the Russian Arctic and sub-Arctic regions. In addition, we would like to study the biogeographical history of mammals in northern Eurasia, compared with temporal environmental changes. By clarifying the current and past status of biodiversity, biological resources, and landscapes, we will be able to forecast their changes in the near future.

For these purposes, studies on phylogeography, zoogeography, and ecology will be performed as follows.

1) Molecular and morphological variation and diversification on modern populations of mammals, especially carnivores, insectivores, and rodents, which are distributed in northern Eurasia.
2) Development of methodology for ancient DNA analysis from old museum specimens, archaeological mammalian bones, and fossils in permafrost.
3) Application of the developed ancient DNA analytical techniques to the investigation of biogeographic history, and temporal and spatial changes of mammalian populations, compared with the modern and ancient changes in environments of northern Eurasia.
4) Reconstruction of the paleo ranges of some specific species, which can be indicators of climate changes during the Late Pleistocene and the Holocene of northern Eurasia.
5) Dynamics of mammalian species diversity from the Pleistocene to the Holocene in northern Eurasia.

6) Detection of behavioral changes (especially on habitat use and migration behavior) of ecological key species (e.g., wild reindeer, bear species, wolves, geese, sandpipers, etc.) and domestic species in arctic ecosystems under a global warming environment by satellite auto-location techniques and ground observation.
7) Habitat evaluation of the above migratory species by analysis of remote sensing data, i.e., the Normalized Difference Vegetation Index (NDVI).
8) Detection of the features of new fauna under global warming by using stable isotope ratio analysis from the standpoints of the food web and resilience of ecosystems.
9) Clarification of the cause of ecological changes (in migration behavior, habitat use, population dynamics, etc.) and prediction of their multi-temporal changes by combining of results of the above three studies (6) to (8) with the GIS technique.
10) Proposals for social adaptation for local indigenous people in wildlife conservation and resource animal use by means of a socio-economical analysis of the above results with system dynamics models.

Figure 3.10-1. Wild reindeer in Siberia

(b) Introduction

In the Russian Arctic and sub-Arctic regions, the present status and causes of changes in biodiversity have not been fully investigated, although these changes have already directly and indirectly influenced ecosystems and people’s lives. To understand and take effective counter-measures to these changes, we need short- and long-term perspectives. In this collaborative study, we will study the short-term dynamics of biodiversity and biogeography by ecological methods, and the long-term dynamics by morphological and molecular phylogenetic methods. We will then propose some social options for the conservation and wise use of biota in this region by combining the results of these studies.

In ecological studies for the short-term perspective, we will take notice of changes in migration behaviors and habitat environments of some key species from the Arctic and sub-Arctic fauna. Changes in migration/habitat use will be detected, and the relationships between their behavioral and climatic/environmental changes will be analyzed.

In addition to the above perspective, we will perform stable isotope ratio analysis of new emerging fauna in the Arctic as a middle scale perspective, because this technique should clarify the features of the local food web system and we can assume its resilience.

For the long-term perspectives, studies on biogeographical variation and biodiversity, especially in mammals of northern Eurasia, have never been fully conducted, because this region comprises a huge area including the Arctic region and Siberia. However, a high level of biodiversity is found in this area, and thus it is very important to further understand the mechanisms of biodiversity formation and the evolutionary history of each organism that is widely distributed in this region. The changes in the climate and environment of northern Eurasia both in the short and long terms have affected the evolutionary and ecological processes of organisms. Thus, a comparison between the results of phylogeographical and environmental investigations (zoogeography and paleogeography) is an appropriate method to understand the natural history of the region. Morphological, genetic, and biogeographical approaches will be applied in this project, and the obtained knowledge can contribute to clarification of the relationships between the evolutionary history and the environmental changes in northern Eurasia.

(c) WS and Progress

At the WS, the Japanese group (Drs. Ryuichi Masuda, Satoshi Ohdachi, and Shirow Tatsuzawa) met Dr. Arkadiy Tishkov (main proposer of Russian side), and we deeply discussed the future collaborative project. Based on our discussion, we clarified the purpose of our collaboration, key species, study areas, approaches, and methods. We then determined the three major projects shownbelow. In addition, some members had another meeting about detailed planning of our collaboration in Moscow and Yakutsk.

(d) Sub-Themes

The details will be cited according to the following three sub-themes.

- Sub-Theme 1 :
  Biogeographic implications of modern natural and human impacts on the biota, biological resources, and landscape of the Russian Arctic. (This group will be divided into some sub-groups by region, i.e., western and eastern parts of Russia.)
- Sub-Theme 2:
  Biogeographic variation and biodiversity of mammals in northern Eurasia.
- Sub-Theme 3:
  Wildlife and indigenous peoples in the North: their transformations in ecology and life history in the Russian arctic and sub-arctic ecosystems.

(3) Introduction and background of the problems

We have already experienced rapid influences of global warming on local ecosystems and local societies. To make scientific and practical policies for a sustainable relationship between humans and nature, we need sufficient knowledge of the history and present status, and appropriate predictions of natural dynamics. However, these have not been fully researched.

For Sub-Theme 1 and Sub-Theme 3, we will study changes of migration behaviors and habitat environments of some selected species of Arctic and sub-Arctic fauna. The short-term changes of migration and habitat use will be detected, and the relationships between their behavioral and climatic/environmental changes will be analyzed. We will then perform stable isotope ratio analysis of new emerging fauna in the Arctic as a middle scale perspective to clarify the features of the local food web system, and we can assume its resilience.

In addition, the long-term changes will be investigated by morphological and molecular phylogenetic methods in Sub-Theme 2. We have already studied genetic and morphological regional differences on some mammals including carnivores, insectivores, and rodents in northern Eurasia, and found that even mammalian species with similar ranges often have different phylogeographic features, reflecting the different biogeographic events. This is related to dynamic environmental changes of habitats from past to present. However, we have investigated only a small part of the whole animal fauna in this region. Therefore, the phylogeographical study of more species of mammals in their whole range, in collaboration with zoogeographic and paleogeographic studies, can contribute to our further understanding of biodiversity and evolutionary history in northern Eurasia.

(4) Research questions and goals

The purposes of Sub-Theme 1 and Sub-Theme 3 are divided into four as follows.

1) To reveal the contemporary changes in biodiversity, distribution, and population dynamics of Arctic and sub-Arctic animals.
2) To investigate changes in migration processes for some species including geese, sandpipers, wild reindeer, etc.
3) To establish the process of irreversible changes in the distribution of some plants and animals, using the statistical data for bio-resources of game species and remote sensing data (e.g., to identify spatial alteration of the productivity of natural pastures for reindeer).
4) To undertake a synthesis of data for natural and anthropogenic factors on changes in biogeographic boundaries, zonal borders, the increased number of some boreal species in the North ("green" tundra, which is especially clearly viewed on the NDVI), and ecosystem services, including the transformation of the "nursing landscape" for indigenous peoples of the North.
5) To make suggestions for sustaining original fauna and ecosystems and for sustainable development for local societies in the Russian Arctic.

The purpose of Sub-Theme 2 is to identify the biogeographic implications for mammals in the wide range of northern Eurasia, especially Siberia, compared with the knowledge of environmental and zoogeographic changes.

For this purpose, the following tasks will be performed.

1) Analysis of molecular and morphological phylogeography of modern populations of mammals, especially carnivores, insectivores, and rodents. Specimens to be examined are museum collections and newly collected specimens from the field.
2) Development of a methodology for ancient DNA analysis from old museum specimens, archaeological mammalian bones, and permafrost fossils.
3) Application of the developed ancient DNA technology to examine temporal and spatial changes in mammalian populations, compared with modern and past changes of environments in northern Eurasia.
4) Application of reconstructions of the selected species ranges during the Late Pleistocene and the Holocene in the north of Eurasia to compare with the results of phylogeographic analysis.
5) Development of a methodology for biodiversity analysis based on paleontological data.

(5) Justification of why collaboration between Japan and Russia is necessary

The Russian group has extensive field-based information about changing ecosystems and related issues (i.e., hunting and economics), and some Russian and Japanese members have already collaborated on these issues using new techniques such as habitat analysis and isotope ratio analysis. Thus, our further collaborations should be fruitful not only for the natural sciences, but also for policies and local societies.

The Russian group has also already studied the morphological evolution and zoogeography of mammals in Eurasia, and thus far has accumulated data on mammals from comprehensive areas of their habitats. The Russian group has a huge collection of modern and fossil mammals collected from a wide range of Eurasia including the Arctic and sub-Arctic regions. In addition, the Russian group has access to one of the largest databases on fossil North Eurasian mammals (PALEOFAUNA). Meanwhile, the Japanese group has been studying molecular phylogenetics and population genetics of mammals and birds that are distributed in northern Japan and Eurasia, and has discussed migration history from the continent to the Japanese islands. The Japanese group also has conducted modern DNA analysis as well as ancient DNA analysis on mammals including a mammoth from the Siberian permafrost, and brown bear and deer bones from archaeological sites. They clarified the bottleneck event of these animals and the relationships between the animals and human cultures. Therefore, when combining these research backgrounds and achievements between the Japanese and Russian groups, it will be possible to achieve remarkable advances and development in the study of the evolution and biodiversity of mammals throughout northern Eurasia, and it will be a breakthrough for our further understanding of the relationships between animal migration history and environmental changes from the past to present in these regions.

(6) Approaches and methods

In Sub Theme 1:

- Development of new algorithms for interdisciplinary approaches, which will allow us to trace the entire chain of changes in the biota and landscape. The GIS-technology and statistical data on the status of landscapes, the number of commercial fish fauna, and the status of rare species and forests at the northern limit of distribution can be applied to analysis.
- In analysis on migrations of waterfowl, the “labeling” method will be used to track their movement during the seasonal migrations.
- In the phytogeographic study, the status of vegetation at different levels of transformation will be recognized.
- The analysis of climate data will be conducted using a global database of climate information and forecasts.
- Satellite telemetry auto-location system to detect real-time and long-term movement and habitat use of some ecological key species.
- Habitat evaluation using remote sensing data such as NDVI.
- Stable isotope ratio analysis to clarify the feature of local food web systems and their resilience.

Fig. 3.10-2 Capturing a wild reindeer for ecological study

- Socio-economic analysis with a system dynamics model.
- Main research fields: Olenek district, Kytalyk-Chokurdagh, Lena River delta, Koryma region, etc.

In Sub Theme 2:

- Morphological analysis of modern and fossil animals from museum collections and collections newly obtained from fieldwork.
- Molecular phylogenetic analyses and population genetic analyses using nuclear DNA and mitochondrial DNA of modern species and populations.
- Ancient DNA analyses of museum samples, including old skins, fossils, and subfossil bones of past and extinct populations and species.
- Study of the range dynamics of selected species as indicators of climate and other environmental changes during the Pleistocene-Holocene transition in north of Eurasia.
- Mammalian diversity analyses for the Late Pleistocene and the Holocene using a GIS-based technique.

In Sub Theme 3:

- Satellite telemetry auto-location system for domestic animals.
- Habitat evaluation model by using remote sensing data such as the HSI model.
- Socio-economic analysis with a system dynamics model.
- Main research fields: Olenek district, Kytalyk-Chokurdagh, Lena River delta, Koryma region etc.

(7) Expected outcomes or products

- The establishment process of the biodiversity of the Russian Arctic will become apparent with the molecular genetic and phylogenetic analyses of museum materials. It will be possible to define conservation policy by the results of these analyses.
- Remote sensing and simulation technologies will clarify the qualitative and quantitative changes of animal behavior (habitat use) and habitat environment under global warming in present and the near future. These results will be essential to prevent the deterioration of ecosystem services and mitigate regional biodiversity.
- Stable isotope ratio analysis of flora and fauna will reveal changes in the interspecific relationships (especially prey-predator interactions). The results will be able to contribute to predicting the vulnerability and resilience of regional ecosystems and to establishing conservation and restoration policies for Arctic biodiversity.
- Publications of scientific articles in international journals and books written in English.
- Symposia on ecosystems, biodiversity, and biogeography relating to the environmental changes in northern Eurasia, to be held in Japan and Russia.
- New biodiversity monitoring and evaluation systems.
- Proposals for ecological, economic, and social adaptation tactics for the Arctic ecosystem and indigenous people.

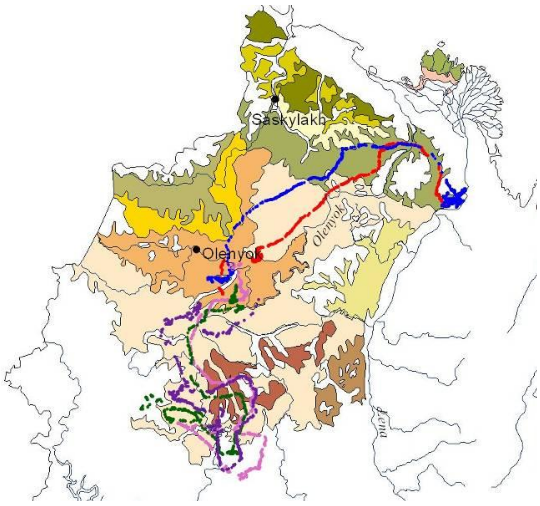

Figure 3.10-3. Migration routes of wild reindeer (coloured dots) and distribution ranges of “reindeer moss” (coloured areas) in the preparatory study, as determined by satellite tracking system.

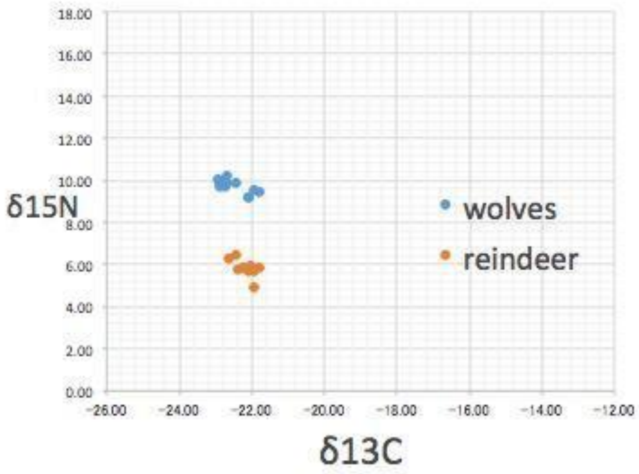

Figure 3.10-4. An example of a stable isotope ratio analysis, which shows “simplification” of prey-predator interaction in a new wolf habitat in the Russian Arctic.

(8) Other

Human Resources

- Proposers from Japan and Russia.
- Graduate students in Master’s and PhD courses in the proposers’ laboratories at Hokkaido University.
- Young researchers in the proposers’ institutes of the Russian Academy of Sciences.

Observation and research bases

- Hokkaido University (Faculty of Science; Institute of Low Temperature Science [Graduate School of Environmental Science], Graduate School of Letters), Sapporo.
- Zoological Institute, RAS, St. Petersburg.
- Institute of Geography, RAS, Moscow.
- Institute of Plant and Animal Ecology, RAS, Ekaterinburg.
- Institute for Biological Problems of Cryolithozone, SD, RAS, Yakutsk.

Data

- Morphological measurement data to be published in scientific journal articles.
- DNA sequence data to be deposited in DNA sequence databases and published in scientific journals.

- Genotypic data to be presented in journal articles.
- Zoogeographical data to be published in scientific journal articles and stored in the PALEOFAUNA database (state registry certificate # 2011620493, June 29, 2011).
- Ecological data to be published in scientific journal articles.

(9) Summary

In this collaborative study, we would like to identify the biogeographical implications of rapid climate changes and anthropogenic influences that lead to synergetic, cumulative, and cascading effects for biota and ecosystems in the Russian Arctic and sub-Arctic regions. In addition, we will study the biogeographical history of mammals in northern Eurasia, compared with temporal environmental changes. By clarifying the current status of biodiversity, biological resources, and landscapes, we will be able to forecast their temporal changes in near future.

3.11 THEME 11: Effects of global climate change on commercial fishing and indigenous coastal cultures in Siberia and the North Pacific

(1) Proposers (Main proposer: ＊)

<Japanese side>

＊*Hiroki Takakura* (Tohoku University, Japan)

<Russian side>

＊*Sardana Boyakova* (Institute of Humanities and Indigenous Studies of the North, SB RAS)

Vanda Ignatyeva (Institute of Humanities and Indigenous Studies of the North, SB RAS)

(2) Introduction and Background of the Problem

According to the Intergovernmental Panel on Climate Change (Assessment Report No. 5, 2013), global warming causes a rise in temperatures of the Arctic Sea, which may accelerate the development of Arctic and sub-Arctic fishing resources. Today, while commercial fishing is prohibited in many related sea areas except for purposes of indigenous subsistence, some of these regions are already connected to global markets, and as a result, Arctic and sub-Arctic fishing in Russia and its relationship with the Japanese market would also change.

(3) Definition of Research Questions and Goals

The purpose of this project is to explore the possibility of sustainable indigenous fishing in the northern region as an important stakeholder of Arctic human society. The primary target is salmon, because this species is specially favored among the northern indigenous peoples as an economically valued resource and a religiously sacred being. The salmon is also a highly valued resource in the international market. Taking account of climate and societal changes, the goal of this research is to investigate how the change in the environment of the Arctic region would affect the existing regional dynamics of the Russian Far East with East Asian markets, in relation to using fishing resources.

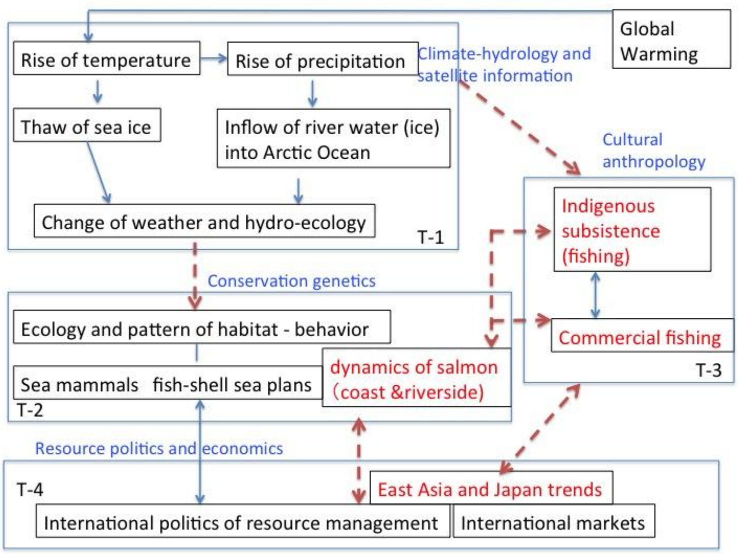

Figure 3.11-1. Project concept and interdisciplinary framework.

Integrating interdisciplinary knowledge from climate hydrology, conservation genetics, socio-cultural anthropology and resource management, and economics, we would attempt to identify the effects of the changing habitat of salmon caused by climate change, and responses of indigenous fishing related to commercial fishing. We also plan to explore trends in demand for salmon in East Asian markets, including Japan. Finally, integrating all the knowledge gained from these studies, we will attempt to identify strategies for building a sustainable management structure for fishing resources in the Arctic and Subarctic areas.

(4) Justification of why collaboration between Japan and Russia is necessary

The salmon is an ecologically, economically, and culturally important maritime resource between Japan and Russia. Climate change would have some effect on the habitat and migration of various types of salmon populations in the North Pacific and Arctic Oceans. The salmon is embedded in Japanese cuisine and food culture, which demands a vast volume of consumption. The Russian Far East has played a role as one of the major suppliers to the Japanese market. This relationship is historically and economically close.

The salmon is also a cultural symbol of some indigenous societies of the Russian North. They have developed their own sustainable ways of skill, knowledge, and religion to deal with maritime resources. Coastal villages in Northern Japan have also transmitted their unique fishing of salmon and related cultural customs. Comparative studies of local salmon cultures both in the Russian North and Japanese North will provide new perspectives on human adaptation in the North.

An interdisciplinary approach to salmon and climate change is a matter of social and economic concern for both nations. The collaboration of Japan and Russia will effectively strengthen the feasibility of scientific implementation, and encourage people in Japan and Russia as regional stakeholders to understand changes in the environment and the impact on human society in the Arctic and North Pacific.

(5) Approaches and Methods

(a) Research Area

The research area is in the Russian Far East. We have identified three different target regions for field research, in Sakhalin-Amur, Kamchatka, and the Lena River. Comparing differences in latitude and water type (river and sea) that may be affected by climate change, the responses of indigenous and commercial fishing will be explored in relation to international market trends and the politics of resource management.

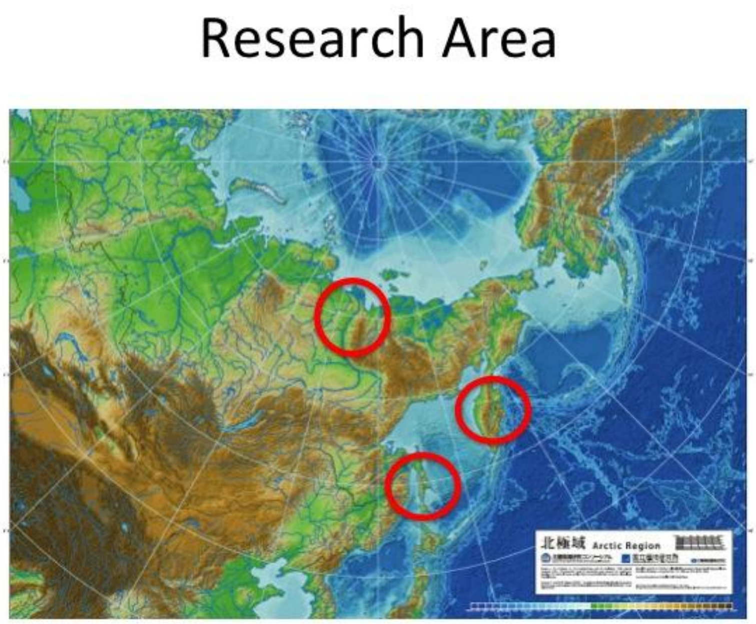

Figure 3.11-2.Research area.

(b) Key to Integration

The key to integration in this project is the method of combining the results of conservation genetic analysis with anthropological field research. Conservation genetics will examine the genetic diversity of salmon and describe the phylogeography of target regions. It will evaluate changes of habitat both in the recent past and the future. Anthropologists have conducted ethnographic fieldwork, both in indigenous and commercial fishing sites, which will be shared by conservation geneticists. They will describe the techniques, knowledge, and social organizations related to fishing and evaluate the resilience of these communities and organizations.

Climate hydrology offers knowledge related to climate and ecological conditions related to the habitat of the salmon and its behavior. Resource politics and economics also offer knowledge related to politics and economics related to human organization and behavior.

(c) Research Organization

In order to implement this interdisciplinary project, our research organization would be divided into three groups: a climate-genetics group, an anthropology group, and a resource politics and economics group. The Japanese side covers all these disciplines. However, the Russian side is not sufficiently represented in these disciplines, or in geography. We need Russian scientists in Kamchatka and Sakhalin as counterparts of conservation genetics and anthropology.

(6) Expected Outcomes or Products

The research results will contribute to evaluating the development of indigenous and commercial fishing in Siberia and the North Pacific, in relation to East Asian market trends. These fishing resources are one of the critical mediums connecting the Arctic with globalized markets. In particular, the relations of Siberia and the North Pacific with East Asian countries are important and need to be fully exploited; unfortunately, they are presently veiled and not under special study.

The conclusions of this study would show how climate change and globalization could change the Arctic and sub-Arctic regions from the perspective of the Russian Far East and East Asia. They would also contribute to international Arctic science by including the unique viewpoint gained through Japanese and Russian collaboration.

3.12 THEME 12: Arctic and global climate change: feedbacks and forecasting dynamics

(1) Proposers

<Japanese side>

M. Uchida (NIPR)

<Russian side>

S.I. Bartsev (IBP SB RAS)

(2) Introduction and Background of the Scientific Problem

The final goal of the research is to predict the response of regional Arctic ecosystems to observed and expected climate change on the basis of revealed mechanisms formalized by mathematical models of different hierarchical levels. However, nonlinearity of ecosystems and climate systems and a number of feedbacks make doubtful a simple extrapolation of observed time series to the future. In addition, experimental assessment of the sensitivity of the ecosystem compartments to global changes in the environment is insufficient for long-term prediction, since global changes themselves can be subject to the total response of local ecosystems.

Therefore, predicting long-term changes in regional ecosystems is possible only by analyzing the global system, since feedbacks influencing global dynamics manifest themselves at the global level. Mathematical models capable of organizing and matching data with different origins (i.e., field observation, remote sensing, experimental testing of tundra ecosystem fragments) are thus necessary. Only after matching the data will it be possible to make an adequate prediction for a regional ecosystem and the biosphere-climate system.

The ultimate criterion of data matching correctness is compliance with the matter conservation law, which must be performed in material cycles and first of all in the carbon cycle. This data matching is not a trivial objective. For example, a small-scale model of global carbon cycle accounting data on the dynamics of global net primary production, soil respiration, temperature, atmospheric CO_2, terrestrial and marine carbon sinks, and burning of fossil fuels was balanced only after assuming additional flux of carbon into the system (Degermendzhi et al., 2013). This means that matching the data is the key step in understanding regional Arctic ecosystems (and any others) and their contribution to global changes. In the context of the problem, simple mathematical models closely connected with the maximum set of ecological and climatologic data are the obligatory tools for this kind of investigation.

(3) Definition of Research Questions and Goals

The question is how to provide a correct self- and data-consistent description of Arctic (regional) ecosystems involved in the biosphere-climate system. The answer to this question can be obtained in the course of investigations concentrating on the following topics or goals.

I. Studying the biological response of tundra ecosystems to variations of external conditions.

a) Coordinated (synchronized) data gathering from observations in the field and experiments, and acute experiments (green part, roots, organic matter, micro flora) (expected collaborators: A. Sugimoto, Hokkaido University; T. Maximov, IBPC RAS; A. Degermendzhi, IBP SB RAS).

b) Mathematical modeling of typical tundra ecosystems (data organization and matching) (expected collaborators:

M. Uchida, NIPR; A. Degermendzhi, IBP SB RAS).

II. Matching tundra models with global data for evaluating interactions and feedbacks (expected collaborators: M. Uchida, NIPR; A. Degermendzhi, IBP SB RAS).

III. Developing permafrost soil descriptions.

a) Mathematical modeling of seasonal transitions of soil states (expected collaborators: A. Degermendzhi, IBP SB RAS; M. Uchida, NIPR; M. Ishikawa, Hokkaido University; P. Bogorodski, AARI).

b) Coupling physical models of soil transition with biological components (expected collaborators: M. Uchida, NIPR; A. Degermendzhi, IBP SB RAS).

IV. Remote sensing evaluation of NPP of tundra ecosystems (upland, lowland, lakes) (expected collaborators: R. Suzuki, JAMSTEC; A. Degermendzhi, IBP SB RAS; V. Mironov, KIP SB RAS).

V. Cross-validation of data of different natures, in the scope of mathematical models accounting for natural laws, biochemical data, etc. (expected collaborators: A. Degermendzhi, IBP SB RAS; M. Uchida, NIPR).

All these topics will contribute to accomplishing the final goal of the research: predicting the response of regional Arctic ecosystems to observed and expected climate change.

(4) Justification of why collaboration between Japan and Russia is necessary

Each of the expected collaborators has their own achievements and opportunities in specific areas. Some of these opportunities are complementary to each other, and some concern the same things, but differently. In any case, the association is expected to have a synergistic effect that will justify the joint efforts.

(5) Approaches and Methods

1) Statistical analyses of global and regional time series of climate and ecological data, which make it possible to detect principal regularities in the systems. For example, a climate shifts hypothesis has recently been suggested on the basis of statistical analyses of global temperature time series (Belolipetskii et al., 2015). If it is true, then it has to be accounted for in any prediction of the Arctic future.

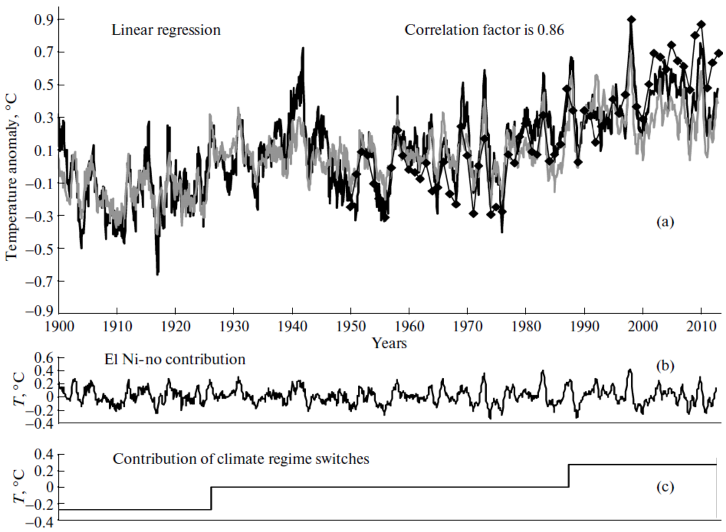

Figure 3.12-1. Reconstruction of the SST time series for the tropical zone (30° S to 30° N). (a) The black line is the SST; the gray line is a linear regression based on El Nico and the index of the climate regime, adjusted for 1900–2012; the rhombic line describes average annual temperatures on land based on CRUTEM4 for the tropical zone. (b) Contribution of El Nico to changes in SST in the tropical zone. (c) Contribution of climate regime switches to changes in SST in the tropical zone.

2) Analyzing regional and global feedbacks by small-scale process mathematical models, based on the principle of the worst-case scenario. Understanding that, for practical purposes, it is important to know the worst-case scenario, this can essentially reduce the complexity of biosphere-climate system (BCS) models, and makes it completely transparent. This approach makes it possible to build small-scale models for organizing and matching diverse data on Arctic ecosystems and BCS. In addition these models can play the role of conceptual models.

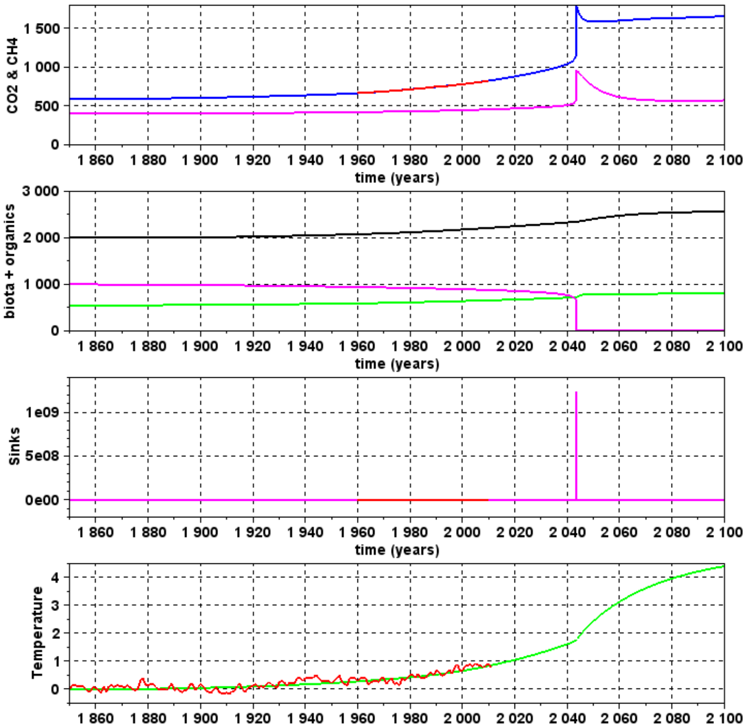

Figure 3.12-2. The results of modeling the effect of self-heating tundra soil. Red lines represent the experimental data that were used for BCS-model fitting. The purple line in the upper graph indicates the concentration of methane increased 100-fold. In the second picture from the top, the green curve describes the dynamics of biomass: black indicates change in soil organic matter except the permafrost soil; and purple indicates the dynamics of tundra soil organic matter. On the sinks chart, the blue line describes the flow into the ocean, green the flow into terrestrial ecosystems, and purple is the total flux.

3) Experimental modeling of ecosystem fragments under controlled conditions. In principle, this makes it possible to investigate the response of an ecosystem to conditions that are expected but which did not take place yet.

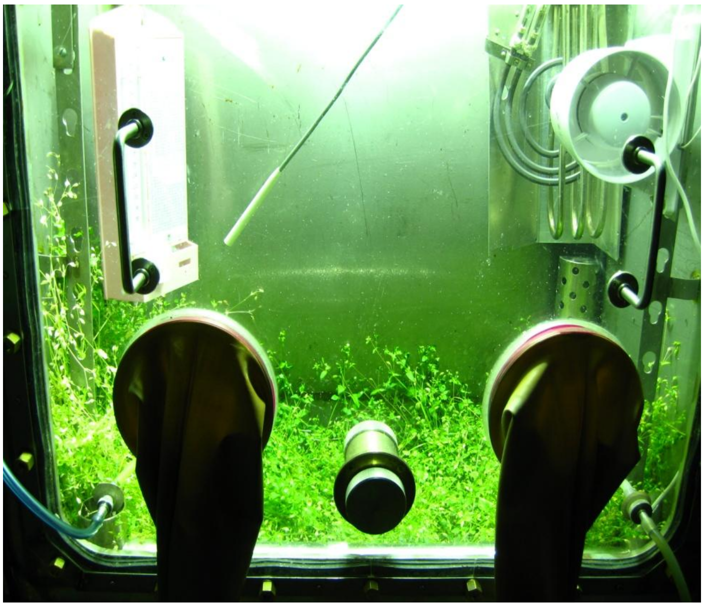

Figure 3.12-3. BIOMS facility for studying temperature impact on an ecosystem.

4) Modeling of specific properties of permafrost vertical structure at seasonal changes. This seems to be obligatory for a correct description of seasonal changes in the soil micro flora activity and their contribution into carbon cycle.

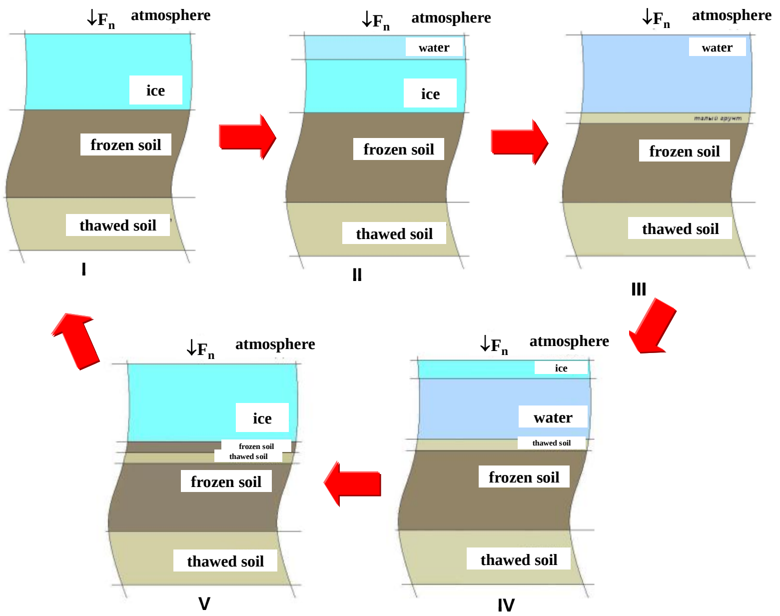

Figure 3.12-4. Permafrost vertical structure at seasonal changes.

5) Adaptation of remote sensing estimations of NPP to local terrestrial biota. This approach is of great importance, since discrepancies between the field measurements and remote sensing can essentially disturb assessment of carbon fluxes.

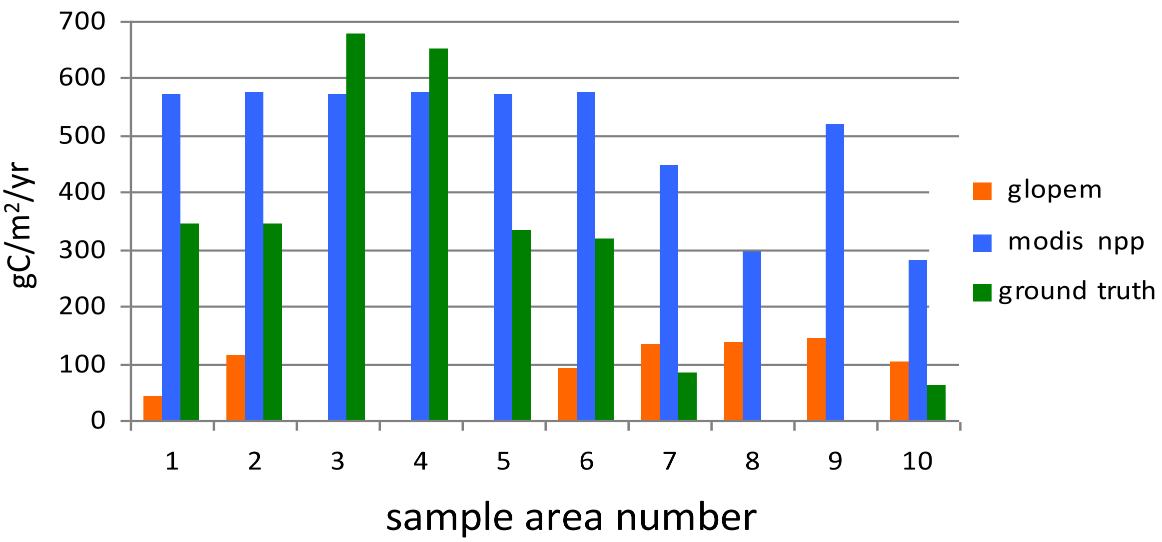

Figure 3.12-5. Comparison of NPP values based on satellite data (GLO-PEM and MODIS NPP models) and ground-based measurements in different areas: 1–6, Dark taiga belt; 7–9, Mountain taiga belt; 10, Subalpine belt.

(5) Expected Outcomes or Products

Organization, matching, and cross-referencing data of different type by means of small-scale mathematical models as the base for prediction of the response of Arctic ecosystems to different variants of anthropogenic and natural impacts.

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§4. Research Infrastructure

This discussion was carried out at the two WSs for the following reasons.

(1) There are common actions that need to be pursued between Japan and Russia for good relations in the cooperative work for a long time, and to fulfill the objectives of the research themes cited in Section 3.

(2) To maintain the efficiency of the research, especially the research which includes in-situ observations.

(3) There are several matters that need to be considered when doing fieldwork in Russian territory.

4. 1 Human resource development 1

＊Proposal by *Atsuko Sugimoto* (Hokkaido University) and *Trofim C. Maximov* (IBPC/NEFU)

(1) Content of proposal

Field observations, as well as data and/or laboratory analyses, are essential activities for Arctic research. To conduct field observations and to understand the processes, a wide range of scientific viewpoints and fieldwork experience are necessary to solve the problems that happen very often in fieldwork in remote areas under severe conditions such as the Arctic and sub-Arctic regions.

Russian research institutes and universities provide various field courses including international courses using their field facilities, while Japanese universities and institutes have well-equipped laboratories. On the basis of these advantages, human resource development can be enhanced under cooperation between the Japanese and Russian sides. The internationalization of young scientists is an important direction for both sides. Therefore, cooperation and exchange between Japan and Russia should also contribute to this.

As described regarding the research base in eastern Siberia, Hokkaido University has been contributing to the establishment of the BEST center at NEFU. The BEST center is managed by scientists from NEFU and also research institutes, and conducts education as well as research. Field stations such as the Spasskaya Pad experimental forest station of IBPC are also important and useful for on-site research training. This is very important, especially for students who are just beginning their research. The BEST center also plays an important role not only in on-site research training, but also in the recruitment of young people for the next generation.

On-site research training is one of the effective methods for training young scientists in both countries. Graduate students and young scientists can develop their research skills during fieldwork and laboratory work experience. Infrastructure for on-site research training and also a joint program framework to involve students and young scientists including universities in both countries are necessary for human resource development. The involvement of universities, which generally have various research fields, makes it possible to broaden the fields of research including humanity and society. This is also a currently important scientific direction.

(2) Discussions and conclusions

The Russian side commented that scientific research and education in the Federal Universities is different, although reform is currently underway in Russia. Therefore, the topic raised here is an important matter for the promotion of Arctic science, but it is not a topic that can be discussed and conclusions reached in the present meeting, since the Russian side in the present discussions is composed of the research institutes of Roshydromet and the Russian Academy of Science. However, it was stated that AARI has a system of education for young scientists under cooperation with foreign countries, and this is working well. Also, it was stated that foreign students can carry out studies in RAS Institutes. These kinds of activities can be considered for human resource development, but not those presented by Professor Sugimoto in the present framework.

The conclusion of this proposal will be that this proposed topic is not a matter for direct discussions in this WS, but may be a discussion topic in another meeting with other organizations in Russia. The way forward would be to alternate the character of the meetings between Japan and Russia (WSs such as this one) by including other ministries in Russia, or to make a proposal that can fit the objectives of the presently participating Russian institutes. In any case, cooperation on human resource development is important and essential, and needs to be further discussed between Russia and Japan.

4.2 Human resource development 2

＊Proposal by *V. Pavlenko* (Archangel Scientific Center, Presidium of RAS, Arkhangelsk)

(1) Content of proposal

Russian side additionally commented that all scientific centers of RAS related to the Arctic research provide post-graduate and PhD studies and professional training of early career scientists specialized in wide scope of disciplines. Annual research plans of all RAS scientific centers related to the Arctic research obligatorily include expeditions and field activities with the use of own equipment facilities.

Research institutes under the RAS, federal ministries and agencies related to disposal of the Russian Federation' Arctic Zone carry a various activities on extension of infrastructural opportunities of research of the Arctic resources, conditions of natural complexes, peculiarities of the climate change and their impacts on the life activities within the region borders.

There is network of scientific facilities, including mobile laboratories, located in the Arctic Zone of the Russian Federation, mostly in the coastal areas. Marine research expeditions by specially equipped vessels have been regularly carried out. Frequently, mostly in the autumn-winter period, icebreakers or vessels of enhanced ice class are being used.

The network of research facilities in the Arctic Zone of the Russian Federation is considered as test site for the field research in various areas, field trainings for young researchers which are, as a rule, post-graduates or trainees of institutes related to the RAS of federal ministries and agencies. Students from universities and other higher educational institutions are also have an access to this infrastructure for the filed training after signing of appropriate agreements.

All RAS scientific centers located in the Arctic Zone have their remote research facilities. Equipment of these facilities supposes an initial processing of research data and provisional accommodation of the limited-numerous expedition teams.

However the growth of the Russian Federation Arctic Zone social-economic development demands the further development of research, establishment of a new integrated research facilities, first of all in the regions of intensive industrial and oil&gaz resources development. For instance, in the Nenets Autonomous district on the Pechora sea coast for purposes of environmental explorations in the areas of intensive oil extraction, and on Gydanskiy peninsula characterized by absolute absence of anthropogenic and technical impacts.

(2) Discussions and Conclusions

Japanese side showed interest to this proposal. They also felt the necessity to broaden their area of activity, not only the Eastern region of Russia, but also the western to central region, in order to understand the whole Russian Arctic. However, due to the lack of knowledge of this region and lack of people who presently have interest in these regions, deeper discussions could not be made on this matter in this WS. Continued discussions need to be made in the future including those who have possibility or have will to do activities in these regions.

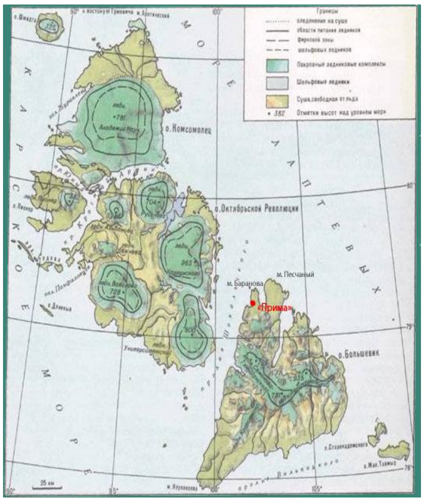
4. 3 Research stations: The scientific stationary base Ice Base Cape Baranova

＊Proposal by *V.T. Sokolov* (Head of High Latitude Expedition, AARI) and *A.P. Makshtas* (Leading Scientist, AARI)

(1) Content of Proposal

The key places for comprehensive studies in the Arctic, which are needed as a source of quality meteorological and oceanographic information, are the research stations located on the Arctic archipelagos. One such station was organized in 1986 at Cape Baranova (Archipelago Severnaya Zemlya) as a research field stationary base of AARI. The station was closed in 1991. In summer 2013, after complex repair and restoration works, it was reopened as the scientific stationary base Ice Base Cape Baranova.

The stationary base is located at a sufficiently high (30 m) shore of the Shokalsky Strait separating the Bolshevik and October Revolution Islands, near Cape Baranova. Its coordinates are 79°16'N, 101°45'E. The Shokalsky Strait is 40 km wide and 350 meters deep. The area adjacent to the location of the stationary base is characterized by a wide range of drifting and fast sea ice, small lakes and rivers, high (up to 800 m) dome-shaped glaciers, and numerous grounding icebergs (Figure 1).



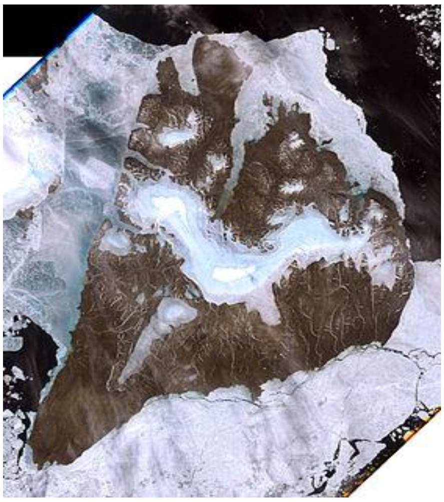


Figure 1. The map of Archipelago Severnaya Zemlya and view of the Bolshevik Island from space.

The main investigations started in April 2014 are as follows.

- Standard and special weather, solar radiation, and upper-air observations, including observations of atmospheric gas composition and black carbon.
- Studies of dynamic-thermodynamic processes and evolution of the physical-mechanical and morphometric characteristics of sea and lake ice cover.
- Investigations of thermohaline circulation and hydrochemical structure of the water masses and currents in the Shokalsky Strait.
- Studies of the components of the carbonate system in the upper mixed layer of the sea and in the atmospheric surface layer.
- Execution of hydrological and hydro-biological studies.
- Glaciological investigations conducted on the Mushketov glacier.
- A study of the history of the formation and current state of the landscape in the vicinity of the stationary base.

  The stationary base equipment includes tracks, snowmobiles, buildings, and electricity (220V).

Other sites for joint studies could be as follows:

- Hydrometeorological Observatory Tiksi (all information available at site www.iasoa.org); and
- Scientific Center at Spitsbergen in Barentsburg (information at site www.aari.ru).

In addition to the directions of joint observations following Theme 1, there could be studies of permafrost, soil and vegetation, glaciology, radiation measurements, zoology, and projects with unmanned planes.

(2) Discussions and conclusions

There were questions about a North Pole station by ship in relation to this by a Japanese colleague. The answer was that a station on ice is being considered, but due to the condition of the ice, this was not started, although it may be organized in future. It was also mentioned that it is very expensive. Another question was about CO_2 observation in the inner area.

The Japanese side showed interest in this station, since the use of this station had already been presented in four of the scientific themes (Sections 3.1, 3.2, 3.4, and 3.6), which means that scientific results can be derived by the use of this station. The Japanese and Russian sides should discuss this in more detail, and find a way to cooperate in doing scientific work at Cape Baranova and in its surroundings.

4. 4 Research network

＊Proposed by *Y. Iijima* (JAMSTEC)

(1) Content of proposal

This is written in the theme proposal in Section 3.4. The concept is shown in Figure 3.4-2 with distribution of potential network.

(2) Discussion and Conclusion

The proposal stresses the networking of stations for the advance of science. All Japanese and Russian scientists agreed that this is very important. Comments about an international network (INTERACT, page 21) were brought up, but practical conclusions could not be derived.

This matter needs to be discussed further in relation to the science objectives of the network. One direction of discussion may be how we can effectively use observations and data sets from East Siberian stations through networking of these stations, and how both countries can cooperate on such issues.

4.5 Data archive

＊Proposed by *H. Yabuki* (NIPR/JAMSTEC)

(1) Content of Proposal

Various observation sites with various kinds of observations have been installed in Arctic and sub-Arctic Russia. These observational data sets have resulted in useful information for Arctic researchers. Operational observational data (i.e., meteorological and hydrological data) are now available in Russia. The situation of the availability of experimental observational data is not clear. The Arctic Data archive System (ADS) has now been constructed in Japan for the mutual use and distribution of Arctic research data.

However, the biggest question of Japanese side concerned why there was not much information from Russian research institutes about observations such as when, where, and what kind of observations are made, and data availability. This is not a question for this report.

In order to solve these problems, the creation of observation metadata (inventory) by the Russian side has been proposed. The Japanese side proposed the construction of an interoperable data center to share data and observation metadata (inventory).

The concrete proposal from the Japan researcher side is outlined below.

1) Metadata and data sharing/exchange between the Russian data archive and the data archive system (ADS) in Japan.
2) Russian and Japanese researchers' use of the Arctic Data archive System (ADS).
3) The Japanese ADS system software will be supplied to the Russian institutes. Russian and Japanese research data system will develop ADS–GRID for each institute.
4) Creation of a database of satellite images on the Russian Arctic from Japanese and Russian sources.

Benefits of the use ADS in Japan are outlined below.

1) The ADS system has already been completed, and new development is needed for better cost performance.
2) ADS not only has a data search function, but also the visualization of data is better.

The development of a data archive system for mutual use and the distribution of observational data is proposed, in order to clarify environmental and climate change in the Russian Arctic. This data archive system will benefit society by making Arctic data more available, and improve the efficiency of science through reduced costs and reduced time required to produce high quality research results.

(2) Discussion and Conclusion

There were no objections to the promotion of a data archive from either side, but the possibility of achieving it was questioned by the Russian side. Requests for metadata information were made by the Japanese side, which would make it easy to access the data, although the data itself is not automatically available.

Among the cases proposed, Case 3 seemed to be realistic: put simply, it would be to implant the data archive system in the Russian institutes for data management, for organizing and opening up the data. The interest of the Russian institutes needs to be promoted, and future continuation of discussions will be necessary. As ADS is still developing, the performance of ADS may be a key factor in developing Russia-Japan cooperation on data sharing.

4.6 Regulations in Russia

＊Proposed by *Y. Matsuura* (FFPRI)

(1) Content of Proposal

Scientific field study in Russian territories is strongly restricted by federal regulations. Common digital devices, such as small box-type data loggers, portable CO_2 analyzers, temperature loggers, and so on, are not allowed to be brought into the territory. It is necessary to declare all devices six month before entering. Not only foreign scientists, but also Russian scientists do not entirely know what we have to declare. We conduct field surveys to collect specimens and samples to analyze. However, no soil, water, air, or plant samples are allowed to be taken out of Russia. Moreover, the degree of regulation and items of regulation are sometimes different from region to region. The rules for what is allowed in a given region often have no utility. Our cooperative scientific activities suffer a great deal and are seriously hindered.

(2) Discussions

This matter is an old issue, but difficult to solve, because it is based on Russian law. This problem seems to involve the regionality of Russia. The Russian participants said that every institute differs in treating this problem, with some having an effective method and some being strict. The only present way to solve this problem is to talk it over and ask for efforts including studies of changing rules, involving each institute with which Japanese groups are doing work, and to solve or at least decrease the problem. AARI mentioned that they pursue a number of special methods and do not have or solve large problems. Also, it was mentioned that developing the program into a high-level program between Japan and Russia may solve these issue to a certain degree.

Dr. Pavlenko, the WS Chair for the Russian side, commented as follows. Russian legal regulations regarding international research activities are based on the assumption of significance of the region from ecological, cultural, economic and security considerations. Nevertheless Russian legislation does not have prohibitive character towards international scientific research in the Arctic upon condition of adherence of priority of the federal norms over regional ones. Terms and conditions specified by Russian legislation take a premise that appropriate activities should be planned 1–1,5 (2) years beforehand. Which, in its turn, stimulates concerned parties to perform an extended planning and to develop elaborated and comprehensive cooperation in a long-term perspective. In addition to, while research activities in the Arctic fall under overlapping terms of the Russian and international statutes of civil, ecological, maritime and branch law, this requires Russian institutes involved into international research projects in the Arctic to provide a professional juridical support to such activities.

§5. Concluding Remarks

The selection and discussion of scientific themes and issues related to infrastructure and so on were quite fruitful for the Russian and Japanese sides to understand each other regarding present conditions, the direction of studies, and the problems that still exist in doing cooperative research.

In the concluding section, the whole process of discussion will be summarized and future issues will be cited.

5.1 Summary of the process of discussion on cooperative research

In the beginning, MEXT and the Japanese Embassy in Moscow made a great deal of effort in making contact with scientific organizations in Russia to start talks on cooperative research. Gradually, the main Russian and Japanese institutes were selected and determined, and the form of discussion such as the style of the WSs became clear. The visit of MEXT and NIPR to Russia in April really moved this work forward, since face-to-face discussions are crucial for the development of new relations. Both sides started to understand the views of the other country.

The next step was to select the topics of discussion. The process of selection of Russian institutes and their proposal themes seem to have been different in Russia and Japan. AARI selected their main missions as themes for cooperative study. RAS selected their themes from 100 ongoing Arctic projects. Finally, at the June stage, Russia proposed 19 themes. The Japanese side based their selection on the research topics included as ongoing and new themes in the list of joint research in the document of the 11th Meeting of the Japan-Russia Joint Committee on Science and Technology Cooperation, and a few other emerging themes related to the Russian Arctic. They were all listed in the July meeting, and their adequacy as joint themes and the consolidation of themes were discussed at the July WS. During the summer, Japanese scientists searched through JCAR for themes proposed by Russia without Japanese counterparts, and several themes became joint proposals through that study. Finally, 13 themes were settled in September, and were presented at the October WS, and it was possible to include 12 themes in the present report.

The titles of the proposals that were proposed but could not be built up as joint themes at this time are listed below. They are cited here for reference, so that the Japanese and Russian sides can consider joint work in the future.

(1) Research Collaboration in Spitsbergen
(2) Research collaboration in MATCH (Baranova St.)
(3) NABOS
(4) The establishment of prevalence patterns and biogeochemical behavior of hydrocarbon gases and radioactive elements in the sediments of the Arctic basin
(5) Development of new methods for the study and modeling of the distribution and dynamics of the situation of submarine permafrost and methane emissions from the Eastern Arctic seas
(6) Ecological-biochemical characteristics of stability of hydrobionts of the Arctic zone of Russia in the conditions of climate change
(7) Ecological bases of preservation of natural reproduction and biodiversity of anadromous fish in the Arctic zone of the Russian Federation
(8) The influence of temperature oscillations and acidification on seawater bio resources and the productivity of the ecosystems of the Arctic seas

(9) Understanding the ecology and population genetic structure of salmonid species in Russia

We consider that the process of selection went generally well. At the beginning the Russian and Japanese sides had slightly different views on the approach of selecting mutually agreed themes, but their understanding about the other side advanced and gaps narrowed, and this resulted in productive discussions and an agreed list of themes at the October WS.

5.2 Future issues

The work of contact between Russia and Japan, and discussion and reporting, started in November 2013 and finished in February 2014: it took one-and-a-half years of work. Themes were proposed and only joint themes were selected, and these are written in Section 3. In addition to the scientific themes, cooperation on infrastructure was discussed, and the understanding of both sides was advanced on each matter.

Both sides agreed on the necessity of another workshop in 2015. The reason for its necessity is as follows.

(1) Some themes need to be deepened more in order to be implemented.
(2) There are potential and promising themes that can be tackled by Russian and Japanese scientists. Since this was the first time for such discussions, not all the concerned scientists made proposals and attended the meeting.
(3) Infrastructure issues need to be discussed more, and there is a need to start the ones that can be done. This is not only important for Russia and Japan, but for the international community, since Russian territory dominates a large part of the Arctic Ocean and land.
(4) In history, good and productive bilateral relations have been built on continuous discussions and better understandings between scientists.
(5) Some important discussions made at the two WSs need to include other organizations in Russia and also Japan for best implementation.

5.3 Main conclusions

The main conclusions that have been acknowledged by both the Russian and Japanese sides at the WSs and further discussions can be stated as follows.

(1) The first official discussions on cooperative research between Japan and Russia on Arctic research recommended by the respective governments were carried out at the institute and academy level during 2014. Continuous negotiations between the government level and institute level led to productive discussions on cooperative research between the two countries and mutually agreed themes were determined, and it advanced the potential of cooperative research.
(2) Twelve research themes (listed from Section 3.1 to 3.12) were developed and approved as future joint research themes. They are as follows.
   ・THEME 1: Climate impacts of black carbon and aerosols in the Arctic (Spitsbergen, Baranov Cape, Tiksi)
   ・THEME 2: Preliminary joint study in the frame of the Polar Prediction Project

- THEME 3: Reliability and risk estimation for sea-ice navigation along the Northern Sea Route
- THEME 4: Comparative study on carbon and water in the permafrost ecosystem of Siberia
- THEME 5: Glacier research in the Russian Arctic and sub-Arctic
- THEME 6: Contemporary changes of water, heat, and dissolved and suspended organic/inorganic matter fluxes from Siberian rivers into the Arctic Ocean
- THEME 7: Variability of snow cover including blowing snow and snowmelt processes of the permafrost area under Arctic environment change
- THEME 8: Development of space remote sensing technologies to monitor seasonal variations in temperature and moisture in the active topsoil of the Arctic tundra
- THEME 9: Permafrost changes in Siberia in the past and future based on projections of climate warming
- THEME 10: Ecosystems and biodiversity
- THEME 11: Effects of global climate change on commercial fishing and indigenous coastal cultures in Siberia and the North Pacific
- THEME 12: Arctic and global climate change: feedbacks and forecasting dynamics

(3) Some of the themes are well-focused research themes, and some are themes with broad perspectives; some are small-group and some are large-group; some are new and some are research related to ongoing projects. In the case of implementation, these conditions will need to be considered.

(4) Human resource development is an important issue for both countries, and the cooperation on research networks and research stations is important for efficient and sustainable observation in the Russian Arctic. Moreover, the actual style of cooperation needs to be discussed further and developed.

(5) Data and legal regulation issues need to be discussed continuously.

(6) Successive WSs need to be held in 2015 to substantiate the discussions made at the WSs in 2014 and to broaden the potential for cooperation. The WSs in 2015 need to be held in Russia. Since the governments of the Japanese and Russian sides are considering certain immediate funding for Arctic research, certain actions for implementation of the proposed themes need to be considered.

Appendix

Appendix 1. Agenda of WS in July, 2014.

Preparatory Workshop for " Japan-Russia Workshop:
Toward future Japan-Russia cooperation in Arctic observation and research"

Agenda

Venue: Room C201, NIPR
Chairs: Ohata, T. and Pavlenko, V.

July 3　10:00～17：30

10:00　1. Opening speech (5 minutes each)
Kiyoura, T. (MEXT)
Khanchuk, A. (RAS)
Shiraishi, K. (NIPR)

10:15　2. Introduction of members and practical information

10:30　3. Present condition of Arctic Research in Russia and Japan
(including past cooperation between two countries) (15minutes each)
Khanchuk, A. (RAS)
Enomoto, H. (NIPR)
Priamikov, S. (AARI)
Kikuchi, T. (JAMSTEC)

11:30　4. Summary of the discussions made until this WS and expected outcome of the WS
Ohata, T. (NIPR）

11:45　5. Discussion on Cooperative Research Areas and Themes
(3 minutes talk on each proposed theme by respective person)

12:00　Lunch

13:00　Special Seminar for NIPR
Priamikov, S. (AARI)
Khanchuk, A. (RAS)

14:00　Group Photo ＆ Short Visit to the Polar Science Museum

14:30 5. Discussion on Cooperative Research Areas and Themes
(3 minutes talk on each proposed theme by respective person)

16:00 Break

16:15 6. Other common issues related to Cooperation
Any matters other than research themes will be discussed. Such matters as research infrastructure and others.

17:00 7. First day wrap-up and second day's schedule

17:30 Close of 1st day

19:00 WS Dinner

July 4 9:00～12：00

09:00 8. Today's discussion

09:10 9. Outline of the WS in October, 2014(Including Agenda 1st Draft)
(Comments on the October WS including dates are welcome)

09:55 10. Report to be developed from this meeting and the October WS

10:40 Break

10:55 11. Schedule of Preparation for October WS

11:40 12. Others

12:00 Close of WS
Lunch

Appendix 2. Participant List of WS in July, 2014.

RUSSIA	
AARI:	
Sergei Priamikov	Head of the Department of International Science Cooperation
RAS:	
Alexander Khanchuk	Academician of RAS, Professor, Member of the Presidium of RAS
Vasily Bogoyavlensky	Corresponding member of RAS, Professor, Deputy Director (Artic & World Ocean) of Oil & Gas Research Institute, Head of “Shelf” Laboratory
Vladimir Pavlenko	Professor, Chairman of the Presidium of the Archangel Scientific Center, Vice-President of the International Arctic Science Committee (IASC)
Alexander Georgiadi	Leading Scientist, Institute of Geography
Vladimir Sukhov	Expert, Foreign Relation Department
JAPAN	
MEXT:	
Takashi Kiyoura	Director, Ocean and Earth Division, Research and Development Bureau
NIPR:	
Kazuyuki Shiraishi	Director-General
Hiroyuki Enomoto	Director, Arctic Environment Research Center
Koichi Abe	Deputy Director, Arctic Environment Research Center
Tetsuo Ohata	Professor, Arctic Environment Research Center, Japanese representative of IASC Council
Yuji Kodama	Executive Director, Japan Consortium for Arctic Environmental Research
Tetsuo Sueyoshi	Research Administrator
JAMSTEC:	
Takashi Kikuchi	Group Leader, Arctic Ocean and Climate System Research Group
Tetsuro Isono	Deputy Manager, Planning Department
Hokkaido University:	
Atsuko Sugimoto	Professor, Faculty of Environmental Earth Science, Chair of Japanese IASC Subcommittee, Science Council of Japan
Embassy of Japan in Russia:	
Yutaka Hara	First Secretary, Economic Section
JST	
Yuko Tsuda	Fellow, Center for Research and Development Strategy
ISTC:	
Takeshi Matsunaga	Senior Project Manager

Appendix 3. Agenda of WS in October 2014.

Japan-Russia Arctic Research Workshop

Toward Future Japan-Russia Cooperation in Arctic Observation and Research

Date	**October 28 ~ 30, 2014**
Venue	**Arcadia Ichigaya Shigaku Kaikan**
	4-2-25, Kudan-kita, Chiyoda-ku, Tokyo
	Phone: +81-3-3202-9921
	http://www.arcadia-jp.org/top.htm
Organizer	Russian Academy of Sciences (RAS)
	Arctic and Antarctic Research Institute (AARI)
	National Institute of Polar Research (NIPR)
	International Science and Technology Center (ISTC)
Support	Japan Consortium for Arctic Environmental Research (JCAR)
Chairs of the WS	*V. Pavlenko (RAS), T. Ohata (NIPR)*

Program

◆

October 28

Pre-Meeting

14：00〜16：30 Room: Kibune 貴船 (6F)

Briefing of the WS and practical matters to the Russian participants,

by the WS Steering members and Secretariats.

◆

October 29

（Open Day、Plenary）

Room: Kotohira 琴平 (7F)

9:30~10:30

① Opening speech — *T. Kiyoura (MEXT), V. Pavlenko (RAS), K. Shiraishi (NIPR)*

② Russian Arctic studies — *V. Pavlenko (RAS)*

③ Japanese Arctic studies — *H. Enomoto (NIPR)*

④ Objective and outcome of the WS. — *V. Pavlenko (RAS), T. Ohata (NIPR)*

10:30~10:45 Break／Photo

10:45~12:00 Room: Kotohira 琴平 (7F) R-J: Mutually agreed, R:Russian side, J:Japanese side

The number under the theme number is the total talk +discussion time.

⑤ Research Area 1:Intensified warming and atmospheric processes

1-1 (25)	Climate impacts of black carbon aerosols in the Arctic (Spitsbergen, Baranov Cape, Tiksi) **(R-J)**	*A. Makshtas (AARI)* *M. Koike (Univ. of Tokyo)*
1-2 (25)	Preliminary joint study in the frame of Polar Prediction Project **(R-J)**	*A. Makshtas (AARI)* *J. Inoue (NIPR)*

⑥ Research Area 2: Decrease of Sea Ice and Arctic Ocean

2-1 (25)	Reliability and risk estimation for sea-ice navigation along the Northern Sea Route **(R-J)**	*S. Frolov (AARI)* *T. Alekseeva (AARI)* *N.Kimura* *(NIPR/Univ. of Tokyo)*

12:00~13:00 Lunch

13:00~13:35 Room: Kotohira 琴平 (7F)

⑦ Research Area 3: Material Cycle and GHG

3-1 (35)	Carbon and water cycles in Arctic and sub-Arctic terrestrial ecosystems - Terrestrial environmental change in Eastern Siberia **(R-J)**	*T. Maximov (IBPC, RAS)* *A. Sugimoto* *(Hokkaido Univ.)*
	- Greenhouse gas study in Siberia **(R-J)**	*T.Machida (NIES)*
	- Carbon cycle and forest in the Northeast Siberia **(R-J)**	*Y.Matsuura (FFPRI)*
	- Estimation of changes in carbon cycle in ecosystems of the Arctic zone of the Russian Federation as a result of climate change and nature use in radiocarbon data and measurements of greenhouse gases.The establishment of prevalence patterns and biogeochemical behaviour of hydrocarbon gases and radioactive elements in the sediments of the Arctic basin **(R)**	*No Participation*

13: 35~14:50 Room: Kotohira 琴平 (7F)

⑧ Research Area 4: Glacier, permafrost and hydrology

4-1 (25)	Glacier dynamics in a changing climate in Arctic and sub-Arctic **(R-J)**	*S.Verkulich (AARI)* *S. Sugiyama* *(Hokkaido Univ.)*
4-2 (25)	Contemporary changes of water discharge, temperature, heat flux and dissolved organic / inorganic matters from Northern Eurasian rivers into Arctic Ocean **(R-J)**	*A. Georgiadi (IG, RAS)* *T. Hiyama (Nagoya Univ.)*
4-3 (25)	Variability of snow cover including blowing snow and snowmelt processes of permafrost area under the Arctic environment change **(R-J)**	*A. Sosnofsky (IG, RAS)* *K. Sugiura(Univ. of Toyama)*

14: 50~15:05 Break

15:05~15:40 Room: Kotohira 琴平 (7F)

⑨ Research Area 4: Glacier, permafrost and hydrology

4-4 (20)	Development of scientific bases of space monitoring of humidity and temperature in active layer in the Arctic tundra **(R**）	*K. Muzalevskiy (KIP, RAS)*
	Development of microwave remote sensing observation technology for permafrost research in the Arctic（**J)**	*H. Enomoto (NIPR)*
4-5 (15)	Permafrost changes in Siberia in the past and in future based on projecting climate warming **(R)**	*No participation*
	Observational evidences, innovative expression and eco-hydrological influences of permafrost degradation over the northeastern Eurasia **(J)**	*M. Ishikawa (Hokkaido Univ.)*

15:40~17:00 Room: Kotohira 琴平 (7F)

⑩ Research Area 5: Ecosystem and bio-diversity

5-1 (15)	Ecological bases of preservation of natural reproduction and biodiversity of anadromous fish in the Arctic zone of Russian Federation **(R)**	*No participation*
	Understanding ecology and population genetic structure of salmonid species in Russia **(J)**	*H. Araki (Hokkaido Univ.)*
5-2 (35)	Biogeographic implications of modern natural (climate) and anthropogenic (economic development) impacts on biota, biological resources and landscapes of the Russian Arctic **(R)**	*A. Tishkov (IG, RAS)*
	Biogeographical variation and biodiversity of mammals in northern Eurasia **(J)**	*R. Masuda (Hokkaido Univ.)*
	Wildlife and indigenous peoples in the North: their transformations in ecology and life history in the Russian arctic and sub-arctic ecosystems **(J)**	*S. Tatsuzawa (Hokkaido Univ.)*
5-3 (5)	Effects of global climate change on commercial fishing and indigenous coastal cultures in Siberia and the North Pacific **(J)**	*H. Takakura (Tohoku Univ.)*
5-4 (25)	Mechanisms of global climate change and the dynamics of tundra ecosystems of Eastern Siberia: satellite and ground based **(R)**	*S. Bartsev (IBP, RAS)*
	Change in biodiversity and material cycle in tundra ecosystem in response to environmental change **(J)**	*M. Uchida (NIPR)*

17:00:~17:30 Room: Kotohira 琴平 (7F),

⑪ Research Infrastructure

#: This will be presented on October 29, others October 30.

Human Resource	*V. Pavlenko (RAS)#,* *A. Sugimoto (Hokkaido Univ.)*
Base and Laboratory	*A. Makshtas (AARI)# V. Pavlenko (RAS)#,* *A. Sugimoto (Hokkaido Univ.), H. Enomoto (NIPR)*
Data	*H.Yabuki (NIPR)*

18:00~20:00 Reception Room: Daisetsu-nishi 大雪西 (5F)

◆

October 30

(Plenary and Split sessions)

9:00~ 9:10　Introduction　Room: Aso-nishi　阿蘇西 (6F)

9:10~10:40　Split sessions for theme discussion　(Including Break)

Room: Kibune 貴船 (6F)

Room: Yoshino 吉野 (7F)

Room: Choukai　鳥海 (7F)

Room: Aso-nishi　阿蘇西(6F)

Room: Aso-nishi　阿蘇西(6F)

10:40~12:00　Room: Aso-nishi　阿蘇西 (6F)

⑫ Research Infrastructure (Continue)

12:00~13:30　Lunch

13:30~15:30　Room: Aso-nishi　阿蘇西 (6F)

⑬ Report from each themes (result of split session and other matters)

⑭ Report on research infrastructure

⑮ Content of the WS Report

⑯ Schedule of writing the Report

⑰ Others (Future activities)

16:00　Adjourn

Appendix 4. Participants List of WS in October 2014.

Legend:☆＝Steering member, ○＝Secı

Russia

Anatolii Aleksanin	Automation and Control Processes, Siberian Branch of RAS, Vladivostok
Tatiana Alekseeva	Scientific Researcher, Arctic and Antarctic Research Institute, St. Petersburg
Sergey Bartsev	Head of Theoretical Biophysics Laboratory, Institute of Biophysics, RAS, Krasnoyarsk
Andrey Dolgikh	Second Secretary, Science and Technology, Embassy of the Russian Federation in Japan, Tokyo
Sergei Frolov	Leader of Ice Navigation Laboratory, Arctic and Antarctic Research Institute, St. Petersburg
☆Aleksandr Georgiadi	Leading Scientist, Lab of Hydrology, Institute of Geography, RAS, Moscow
Aleksandr Makshtas	Leading Scientist, Arctic and Antarctic Research Institute, St. Petersburg
Trofim Maximov	Head of Biogeochemical Cycles of Permafrost Ecosystems Lab., Institute for Biological Problems of Cryolithozone, RAS, Yakutsk
Konstantin Muzalevskiy	Research Fellow, Kirensky Institute of Physics, Siberian Branch of RAS, Krasnoyarsk
☆Vladimir Pavlenko	Professor, Chairman of the Presidium of the Archangel Scientific Center, Presidium of RAS, Arkhangelsk
☆Sergei Priamikov	Head of International Science Co-operation Department, Arctic and Antarctic Research Institute, St. Petersburg
Aleksandr Sosnovskii	Leading Scientist, Institute of Geography, RAS, Moscow
○Vladimir Sukhov (did not attend)	Expert, Foreign Relation Department, Presidium of RAS, Moscow
Arkadiy Tishkov	Professor, Deputy Director, Institute of Geography, RAS, Moscow
Sergei Verkulich	Head of Polar Geography Department, Arctic and Antarctic Research Institute, St. Petersburg

JAPAN

Yoshito Ando	Specialist, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology, Tokyo
Hitoshi Araki	Professor, Research Faculty of Agriculture, Hokkaido University, Sapporo
☆Hiroyuki Enomoto	Vice Director-General / Director of Arctic Environment Research Center, National Institute of Polar Research, Tokyo
Koichiro Harada	Associate Professor, School of Food, Agricultural and Environmental Sciences, Miyagi University, Sendai
Tetsuya Hiyama	Professor, Hydrospheric Atmospheric Research Center, Nagoya University, Nagoya
Morio Ichihara	Administrative Staff, Planning Division, Planning Department, Japan Agency for Marine-Earth Science and Technology, Yokohama
Yoshihiro Iijima	Senior Scientist, Research and Development Center for Global Change, Japan Agency for Marine-Earth Science and Technology, Yokosuka
Motoyoshi Ikeda	Professor Emeritus, Hokkaido University, Sapporo
Jun Inoue	Associate Professor, National Institute of Polar Research, Tokyo / Visiting Scientist, Japan Agency for Marine-Earth Science and Technology, Yokohama
Mamoru Ishikawa	Associate Professor, Faculty of Environmental Earth Science, Hokkaido University, Sapporo
Tetsuro Isono	Deputy Director, Planning Division, Planning Department, Japan Agency for Marine-Earth Science and Technology, Yokosuka
Hisaya Kakiuchi	Senior Researcher, Department of International Affairs, Japan Science and Technology Agency, Tokyo
Masaki Kanao	Associate Professor, National Institute of Polar Research, Tokyo
Noriaki Kimura	Project Researcher, National Institute of Polar Research, Tokyo / Visiting Researcher, The University of Tokyo, Kashiwa
Takashi Kiyoura	Director, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology, Tokyo
Hideki Kobayashi	Senior Scientist, Department of Environmental Geochemical Cycle Research, Japan Agency for Marine-Earth Science and Technology, Yokohama
〇Yuji Kodama	Project Associate Professor / Executive Director for Japan Consortium for Arctic Environmental Research National Institute of Polar Research, Tokyo
Makoto Koike	Associate Professor, Graduate School of Science, The University of Tokyo, Tokyo
Yuuki Komata	Research Administrator, Task Force for Research Strategy, Creative Research Institution, Hokkaido University, Sapporo

Keiko Konya	Research Scientist, Department of Environmental Geochemical Cycle Research, Japan Agency for Marine-Earth Science and Technology, Yokosuka
Satoru Kuwata	Director for Polar Research Programs, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology, Tokyo
Toshinobu Machida	Head of Office for Atmospheric and Oceanic Monitoring, Center for Global Environmental Research, National Institute for Environmental Studies, Tsukuba
Ryuichi Masuda	Professor, Faculty of Science, Hokkaido University, Sapporo
○Takeshi Matsunaga	Senior Project Manager, International Science & Technology Center, Astana
Yojiro Matsuura	Chief of Office, International Forest Informatics Laboratory, Bureau of International Partnership, Forestry and Forest Products Research Institute, Tsukuba
Yosuke Nishida	Trainee, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology, Tokyo
Shigeto Nishino	Senior Research Scientist, Research and Development Center for Global Change, Japan Agency for Marine-Earth Science and Technology, Yokosuka
☆Tetsuo Ohata	Project Professor, National Institute of Polar Research, Tokyo
Satoshi Ohdachi	Assistant Professor, Institute of Low Temperature Science, Hokkaido University, Sapporo
Takeshi Ohta	Professor, Graduate School of Bioagricultural Sciences, Nagoya University, Nagoya
Yuka Oishi	Graduate Student, Graduate School of Humanities, Tokyo Metropolitan University, Tokyo
Hotaek Park	Senior Scientist, Department of Environmental Geochemical Cycle Research, Japan Agency for Marine-Earth Science and Technology, Yokosuka
Hideki Sasaki	Deputy Director, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology, Tokyo
Kazuyuki Shiraishi	Director-General, National Institute of Polar Research, Tokyo
○Tetsuo Sueyoshi	Research Administrator, National Institute of Polar Research, Tokyo / Visiting Scientist, Japan Agency for Marine-Earth Science and Technology, Yokohama
Atsuko Sugimoto	Professor, Faculty of Environmental Earth Science, Hokkaido University, Sapporo
Konosuke Sugiura	Associate Professor, Center for Far Eastern Studies, University of Toyama, Toyama
Shin Sugiyama	Associate Professor, Institute of Low Temperature Science, Hokkaido University, Sapporo

Rikie Suzuki	Director, Department of Environmental Geochemical Cycle Research, Japan Agency for Marine-Earth Science and Technology, Yokohama
Nozomu Takeuchi	Professor, Faculty of Science, Chiba University, Chiba
Shingo Tanaka	Research Administrator, Task Force for Research Strategy, Creative Research Institution, Hokkaido University, Sapporo
Kazutaka Tateyama	Associate Professor, School of Engineering, Kitami Institute of Technology, Kitami
Shirow Tatsuzawa	Assistant Professor, Graduate School of Letters, Hokkaido University, Sapporo
Masaki Uchida	Associate Professor, National Institute of Polar Research, Tokyo
Koichi Watanabe	Deputy Director, Arctic Environment Research Center, National Institute of Polar Research, Tokyo
Manabu Watanabe	Senior Scientist, Japan Aerospace Exploration Agency, Tsukuba
Yasumasa Watanabe	Professor, Center for Engineering Education Development, Faculty of Engineering, Hokkaido University, Sapporo
Hironori Yabuki	Senior Scientist, Japan Agency for Marine-Earth Science and Technology, Yokosuka / Project Associate Professor, National Institute of Polar Research, Tokyo
Akiko Yamada	Administrative Staff, International Affairs Division, Business Promotion Department, Japan Agency for Marine-Earth Science and Technology, Yokohama
Hajime Yamaguchi	Professor, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa
Michiyo Yamamoto-Kawai	Associate Professor, Research Center for Advanced Science and Technology, Tokyo University of Marine Science and Technology, Tokyo
Takashi Yamanouchi	Professor, National Institute of Polar Research, Tokyo
Yong Zhang	Project Researcher, Arctic Environment Research Center, National Institute of Polar Research, Tokyo

.

Appendix 5. Acronym list of organization and others

<Organization>

AARI: Arctic and Antarctic Research Institute, Roshydromet. (St. Petersburg, Russia)

AERC: Arctic Environment Research Center, NIPR. (Tachikawa, Japan)

ARHSC: Arkhangelsk Scientific Centre, UB, RAS. (Arkhangelsk, Russia)

CAO: Central Aerological Observatory. (Moscow, Russia)

FEB: Far-east Branch, RAS. (Vladivostok, Russia)

FFPRI: Forestry and Forest Products Research Institute, Ministry of Agriculture, Forestry and Fisheries. (Tsukuba, Japan)

GEOKHI: Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS. (St. Petersburg, Russia)

HU: Hokkaido University. (Sapporo, Japan)

IAP: Institute of Atmospheric Physics, RAS. (Moscow, Russia)

IASC: International Arctic Science Committee.(Potsdam, Germany)

IB: Institute of Biology, Karelian Research Centre, RAS. (Petrozavodsk, Russia)

IBP: Institute of Biophysics, SB, RAS. (Krasnoyarsk, Russia)

IBPC: Institute for Biological Problems of Cryolithozone. (Yakutsk, Russia)

IG: Institute of Geography, RAS. (Moscow, Russia)

INP: Budker Institute of Nuclear Physics, RAS. (Novosibirsk, Russia)

IPA: International Permafrost Association. (Potsdam, Germany)

IPOI: V.I.II'ichev Pacific Oceanological Institute, FEB, RAS. (Vladivostok, Russia)

ISTC: International Science and Technology Center. (Moscow, Russia)

JAMSTEC: Japan Agency for Marine-Earth Science and Technology.(Yokosuka, Japan)

JAXA: Japan Aerospace Exploration Agency. (Tsukuba, Japan)

JCAR: Japan Consortium for Arctic Environmental Research. (Tachikawa, Japan)

JST: Japan Science and Technology Agency. (Tokyo, Japan)

KIT: KITAMI Institute of Technology. (Kitami, Japan)

KIP: Kirensky Institute of Physics, SB, RAS. (Krasnoyarsk, Russia)

MEXT: Ministry of Education, Culture, Sports, Science and Technology. (Tokyo, Japan)

MPI: Melnikov Permafrost Institute, SB, RAS. (Yakutsk, Russia)

NEFU: Northeast Federal University. (Yakutsk, Russia)

NIES: National Institute for Environmental Studies, Ministry of Environment.(Tuskuba, Japan)

NIPR: National Institute of Polar Research. (Tachikawa, Japan)

NU: Nagoya University. (Nagoya, Japan)

RAS: Russian Academy of Sciences (Moscow, Russia)

RIKEN: Institute of Physical and Chemical Research. (Wako, Japan)

Roshydromet: Russian Federal Service for Hydrometeorology and Environmental Monitoring. (Moscow, Russia)

SB: Siberian Branch, RAS. (Nobosibirsk, Russia)

SHI: State Hydrological Institute, Roshydromet. (St. Petersburg, Russia)

SIEE: Sevetsov Institute of Ecology and Evolution, RAS. (Moscow, Russia)
SIF: Sukachev Institute of Forest, SB, RAS. (Krasnoyarsk, Russia)
TU: Tohoku University. (Sendai, Japan)
UB: Ural Branch, RAS.
UT: University of Tokyo. (Tokyo, Japan)
UT: University of Toyama. (Toyama, Japan)
TUMST: Tokyo University of Marine Science and Technology. (Tokyo, Japan)
WIM: V. E. Zuev Institute of Atmospheric Optics, SB, RAS. (Tomsk, Russia)
WMO: World Meteorological Organization. (Geneva, Switzerland)
ZIN: Zoological Institute, RAS. (St. Petersburg, Russia)

<Others>
BC: Black carbon.
GAME: GEWEX Asian Monsoon Experiment.
GRENE: Green Network of Excellence.
GHG: Greenhouse Gas.
MATCH: Determination of Stratospheric Polar Ozone Losses
NABOS: Nansen and Amundsen Basins Observational System.
NDVI: Normalized Vegetation Index.
WCRP: World Climate Research Program.
YOPP: Year of Polar Prediction.

Cooperation on Arctic Research between Japan and Russia

(AERC Report 2015-1)

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