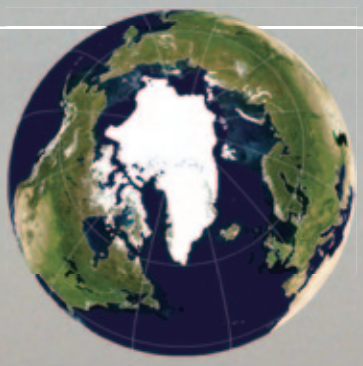


Ministry of Education, Culture, Sports, Science & Technology—Japan (MEXT)
"Green Network of Excellence" (GRENE) Program

Arctic Climate Change Research Project
Rapid Change of the Arctic Climate System and its Global Influences
2011-2016

To the Arctic.....

where you can see the future of the Earth

Core Institute
National Institute of Polar Research (NIPR)

Associated Institute
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

We are committed to Arctic climate research through the

Why is the Arctic now?

The changes occurring in the Arctic are both substantial and rapid, and different parts of the Arctic climate system are involved. The sea ice cover is retreating at an alarming rate. The ocean and surface temperatures are rising. The current temperature rise in the Arctic is about twice as much as the global average. Concurrent with these changes the Greenland ice sheet is thinning, and permafrost is thawing, which inevitably bring other changes in the Arctic hydrological cycle and ecosystems

It has long been argued that the Arctic is the precursor of our changing planet. But beyond the presence of ice-albedo feedback, which seems to accelerate both warming of the ocean and melting of sea ice, there are so many open questions regarding underlying mechanisms of the Arctic change. The roles of solar activities, ozone depletion, aerosols, clouds, methane and land processes and other factors involved in the Arctic change await better explanation and clarification.

Over 300 scientists from 35 organizations are participating in the Project

Recognizing this great scientific challenge we start a new Japanese initiative "Arctic Climate Change Research Project" within the framework of the GRENE (Green Network of Excellence) Program funded by the Ministry of Education, Culture, Sports, Science and Technology—Japan (MEXT) .

(Photo: Masataka Shiobara, NIPR)

GRENE Arctic Climate Change Research Project.

The Project is funded for 5 years starting in FY2011 and jointly managed by the National Institute of Polar Research (NIPR) and JAMSTEC. Four strategic research targets are set: ① Understanding the mechanism of warming amplification in the Arctic, ② Understanding the Arctic system for global climate and future change, ③Evaluation of the impacts of Arctic change on weather and climate in Japan, marine ecosystems and fisheries, and ④Projection of sea ice distribution and Arctic sea routes. Now over 300 scientists from 35 organizations are participating in the Project, tackling all aspects of the Arctic climate system; the atmosphere, ocean, cryosphere, land and ecosystems from a multi-disciplinary approach.

The Project also fosters close collaboration between model and observational studies. Their results complement to each other. Model results help to interpret observations while observations are used to constrain models and validate model outputs. Data archiving efforts in the Project further enhance this close relationship between model and observational studies. Last but not least, the Project seeks and promotes international collaboration with other institutes in various nations, which is essential for Arctic research, while the Japan Consortium for Arctic Environmental Research (JCAR) is founded to bolster Arctic research activities within Japan.

Strategic Research Target①

Understanding the mechanism of warming amplification in the Arctic

Principal Investigator
Toru Nozawa National Institute for Environmental Studies

Clarifying physical mechanism of the Arctic warming amplification

According to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), the global average surface temperature has increased by about 0.74 °C in the past 100 years (1906 to 2005). Average Arctic temperatures increased at almost twice the global average warming rate in this period. Arctic region is one of the places where the impact of climate change is the most significant in the world. The mechanism of warming amplification in the Arctic is, however, still not well understood.

When the surface temperature increases in the Arctic region, snow-covered areas, glaciers, ice sheets, and sea-ice extent retreat and therefore the surface albedo decreases, leading to further increases in the surface temperature. This ice-albedo feedback is one of the major contributors to the Arctic warming amplification. However, the ice-albedo feedback alone cannot explain the observed rapid warming in the Arctic; feedback in the atmosphere (water vapor, clouds, lapse rate, etc.), changes in permafrost and vegetation, carbon-cycle feedback, changes in atmospheric and oceanic heat transport, etc. also bring on the Arctic climate change.

In the GRENE Arctic Climate Change Research Project, we aim at elucidating the mechanism of the Arctic warming amplification by integrated analyses of the observations and numerical simulations.

Collaboration between modelling and observational studies

The following four research projects are collaboratively conducted to achieve strategic research target ① Understanding the mechanism of warming amplification in the Arctic.

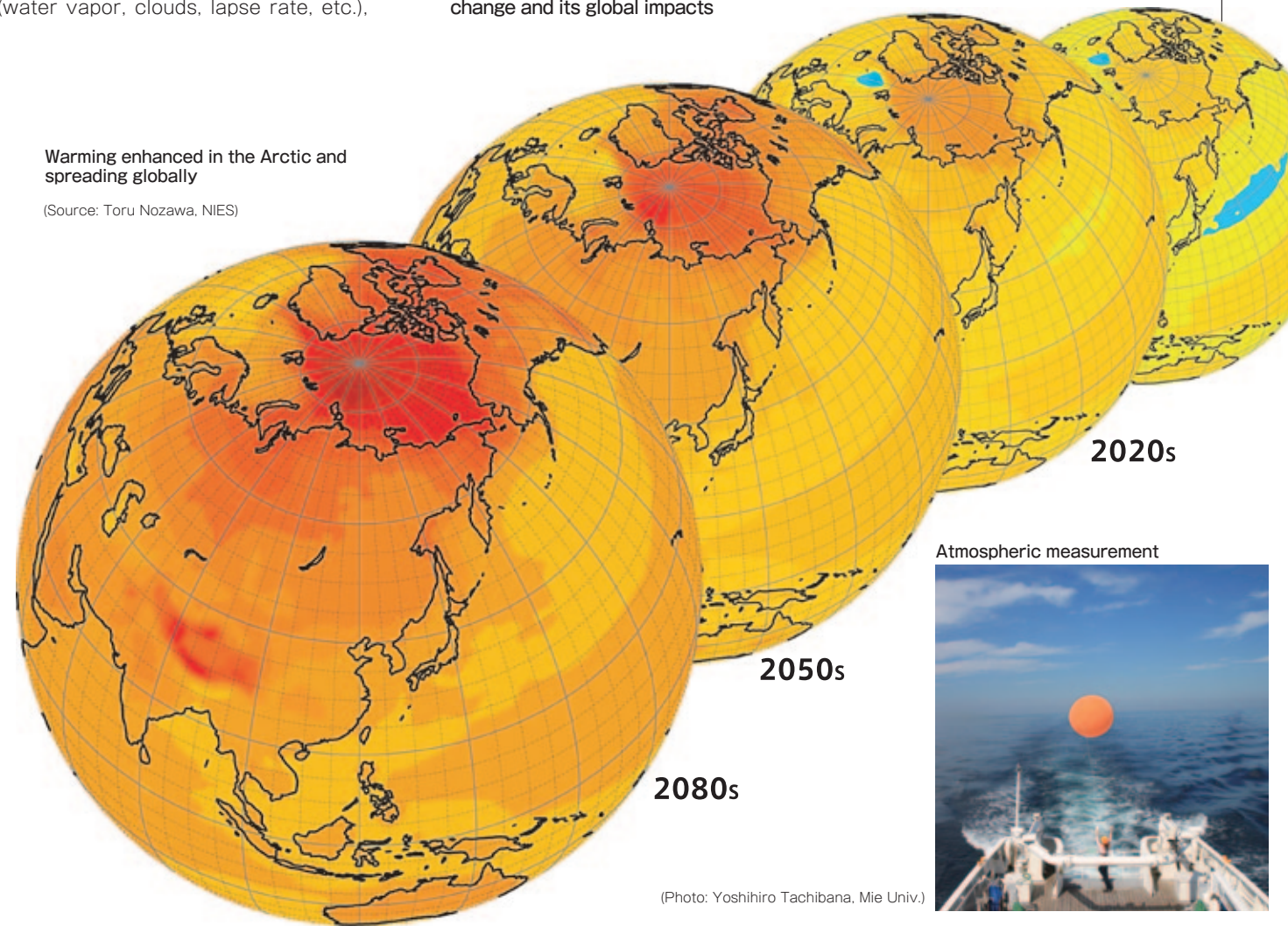
(1) Improvement of coupled general circulation models based on validations of Arctic climate reproducibility and on mechanism analyses of Arctic climate change and variability
(2) Change in the terrestrial ecosystems of the pan-Arctic and effects on climate
(3) Atmospheric studies on Arctic change and its global impacts
(4) The role of Arctic cryosphere in global change

Observational research projects (2), (3) and (4) are aiming at cooperatively launching a pan-Arctic observation network including station-based and satellite-based observations. In addition to the previous observations in Siberia, Alaska, Canada, etc., comprehensive and wide-area observations will enable us to monitor and understand the overall Arctic climate changes.

Collaboration between modelling and observational studies is very important in the GRENE Arctic Climate Change Research Project. Observational data is necessary to validate and constrain the model results, and the numerical models are useful to interpret observations. We will promote close and tight communications between modelling and observational studies and implement their joint researches to achieve the strategic research target①.

Expected results

By conducting integrated research using modelling and observations, we will quantify relative contributions of various feedback mechanisms and their interaction in the recent rapid warming in the Arctic. This would make a substantial contribution to an improvement of the coupled general circulation models, helping us to reproduce the Arctic climate changes in the past with a high degree of accuracy and reducing uncertainties in the future predictions of the Arctic warming.



Warming enhanced in the Arctic and spreading globally

(Source: Toru Nozawa, NIES)

Atmospheric measurement

(Photo: Yoshihiro Tachibana, Mie Univ.)

Strategic Research Target②

Understanding the Arctic system for global climate and future change

Principal Investigator
Atsuko Sugimoto Hokkaido University

Arctic climate change is spreading globally

The Arctic environment is rapidly changing, and the changes are spreading throughout the entire world like ripples, carried by atmospheric and oceanic circulation. A better understanding of the current change in the Arctic environment and its effect on global climate change is required for a more accurate prediction of global climate change and of our future.

In order to achieve strategic research target ②, Understanding the Arctic system for global climate and future change, we are working on the following five research projects.

(1) Improvement of coupled general circulation models based on validations of Arctic climate reproducibility and on mechanism analyses of Arctic climate change and variability
(2) Change in the terrestrial ecosystems of the pan-Arctic and effects on climate
(3) Atmospheric studies on Arctic change and its global impacts
(4) The role of Arctic cryosphere in global change
(5) Studies on greenhouse gas cycles in the Arctic and their responses to climate change

The Arctic influences global warming

Project (5), which addresses greenhouse gases has been added to research projects (1) to (4)), which are common to strategic research target ①. The increase in concentrations of greenhouse gases, such as carbon dioxide and methane, is accelerating warming. In this 100-year period, the average global air temperature has risen by about 0.74℃, and it is highly possible that the increase in greenhouse gases from manmade sources is a factor.

How will this warming progress in the future? The role of the Arctic region is crucial when we consider this aspect. As a result of the rapid warming of the Arctic, the area of sea ice and snow cover has been decreasing. The warming of the Arctic is believed to be progressing as a result of changes in the land surface and the circulation of energy, water, and other materials. Moreover, the rise in air temperature is beyond a doubt thawing the permafrost. As the permafrost thaws gradually, the methane and organic matter trapped within its ice are released. The decomposition of this organic matter is thought to increase the amount of greenhouse gases released into the atmosphere. Changes in soil temperature and soil moisture alter the rate of plant growth and the species of plants. Changing the state of the land surface alters the behavior of energy, water, and material cycles, and may in turn trigger further changes. The extensive wetlands of the Arctic region naturally release methane (a potent greenhouse gas) into the atmosphere; however the rise in soil temperature and the changes in the vegetation will increase the amount of methane released, which may accelerate global warming.

The necessity of a global climate model

Global climate models are currently used to predict climatic changes over the entire world. Unfortunately, these models do not sufficiently take into account changes in snow cover, permafrost and vegetation, and so they can not produce forecasts with a high degree of accuracy. We simply do not sufficiently understand how the snow cover, permafrost, vegetation and greenhouse gases are changing as a result of the warming of the Arctic region. The first step is to understand these changes by making observations, and to develop models that take into account the changes taking place on land.

In Greenland, located in the Arctic region, the ice sheets are rapidly decreasing. The melting of the ice sheets causes sea levels to rise. The area off the coast of Greenland is a starting point for general circulation of the ocean because the seawater there cools, becomes heavier and sinks deep below. The fresh water running off from the melting ice sheets into the ocean lowers the density of the surrounding seawater and could therefore weaken the general circulation of the ocean. This would trigger tremendous climate change on a global scale. Nevertheless, current global climate models do not sufficiently take into account the changes in ice sheets and glaciers. We will get an insight into these changes through our observations, and will develop models for sea level change.

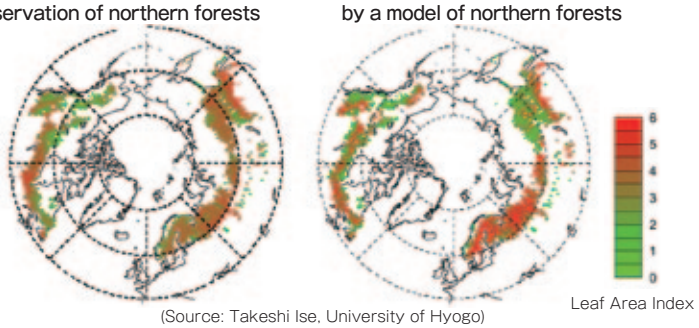
Expected results

Development of models for changes in the land system and models for changes in sea level is expected to enable scientists to quantify the changes to various factors, such as snow cover, frozen soil, vegetation, greenhouse gases, ice sheets, glaciers and sea levels, which are strongly affected by Arctic climate change. By incorporating these elements into global climate models, our research on the Arctic system will contribute to enhance predictions, not only for the Arctic, but also for the global climate in the future.

1990s

Leaf area index estimated by satellite observation of northern forests

Leaf area index calculated by a model of northern forests



Leaf Area Index

(Source: Takeshi Ise, University of Hyogo)

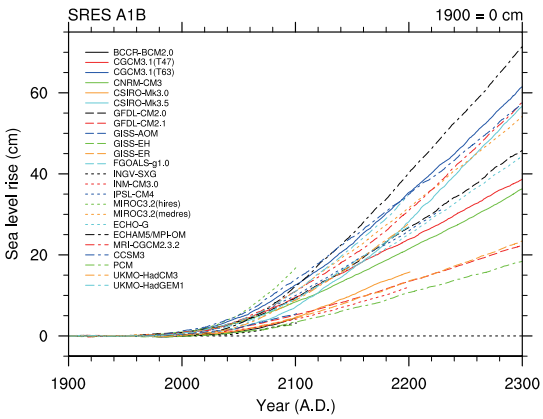
Observation of vegetation (Chorkurdakh, Russia)

(Photo: Atsuko Sugimoto, Hokkaido Univ.)

Ice sheet survey

(Photo: Hideaki Motoyama, NIPR)

Multi-model predictions of the sea-level rise due to the warming



(YOSHIMORI and ABE-OUCHI (2012). Sources of Spread in Multimodel Projections of the Greenland Ice Sheet Surface Mass Balance, J. Climate, 25, 1157-1175. DOI: 10.1175/2011JCLI4011.1)

Strategic Research Target③

Evaluation of the impacts of Arctic change on weather and climate in Japan, marine ecosystems and fisheries

③a Evaluation of the impacts of Arctic change on weather and climate in Japan

Principal Investigator
Jinro Ukita Niigata University

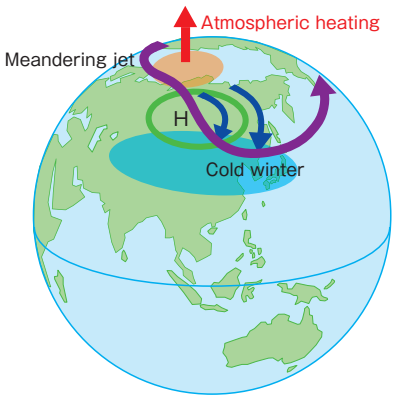
Arctic teleconnection

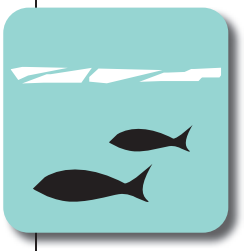
No part of the Earth's climate system is independent from the rest. The weather and climate in Japan are not exceptions. Scorching summers and severe winters in Japan are sometimes attributed to influences from remote places. Our weather and climate are linked to El Niño and La Niña conditions, which are coupled oceanic and atmospheric phenomena centered over the tropical Pacific. In recent years we are beginning to understand that the Arctic also exerts influences by changing atmospheric circulation. This is referred to as "atmospheric teleconnection". In facing the rapid Arctic changes such as sea ice reduction, warming in the Arctic Ocean and the surrounding continents, and other accompanying changes in the hydrology and biosphere, our primary task here is to better understand physical and chemical mechanisms of this Arctic teleconnection, which results from an interplay of many different processes in clouds, aerosols, radiation and circulation. Our previous studies hint that a meandering of the westerly jet stream and other circulation anomalies such as strong Siberia and Okhotsk high pressure systems are relevant to the Arctic teleconnection. Here we seek detailed explanations about the underlying processes involved and evaluate their impacts on the weather and climate in Japan.

Expected results

By gaining a better understanding of the underlying processes of teleconnection from the Arctic, we provide both qualitative and quantitative assessment on the impacts of the Arctic change on the weather and climate in Japan.

Arctic influences over Japan





③b Evaluation of the impacts of Arctic change on marine ecosystems and fisheries

Principal Investigator
Takashi Kikuchi Japan Agency for Marine-Earth Science and Technology

Is the decrease in sea ice favourable or unfavourable for the Arctic marine ecosystem and fisheries?

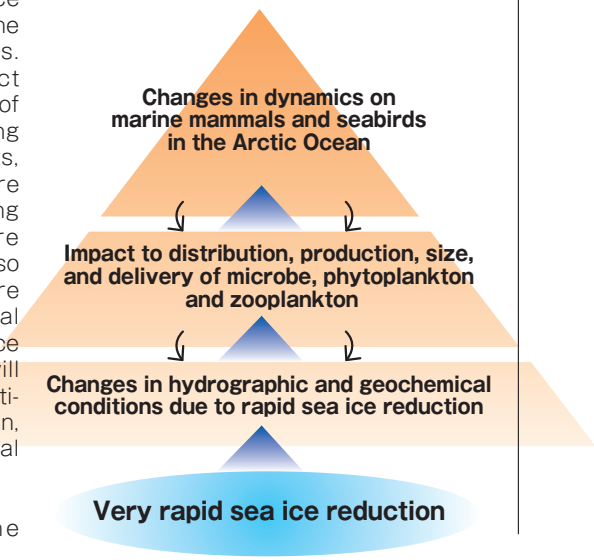
The decrease in the sea ice causes a change in the characteristics of the seawater in the Arctic Ocean, such as temperature, salinity, and nutrients as well as ocean currents. It also affects the lives of marine microbes, planktons, fishes, and other mammals. Marine fisheries resources such as cod, salmon and crab are no exception. This raises the questions: Is the decrease in sea ice favourable or unfavourable for Arctic marine ecosystems and fisheries? How does sea ice variability, i.e., ice melting/formation, ice motion, seasonal cycle, and recent inter-annually rapid decrease, affect the Arctic Ocean environments from physical, chemical and biological points of view? To achieve strategic research target ③ b: Evaluation of the impacts of Arctic change on marine ecosystem and fisheries, we initiate the following research project.

(6) Ecosystem studies on the Arctic Ocean declining sea ice

The purpose of this project is to clarify and predict the influences of sea ice reduction in the Arctic Ocean on marine ecosystem and fisheries resources. For this purposes, we will conduct field observations in the Pacific side of the Arctic Ocean, satellite monitoring on sea ice and marine environments, and numerical simulations to acquire a detailed understanding of on-going environmental changes and future conditions. Not only biological but also physical and chemical processes are involved in the Arctic environmental changes caused by the recent sea ice reduction. Therefore, this project will pay particular attention to linking multi-disciplinary studies on the Arctic Ocean, i.e., physical, chemical, and biological oceanography.

Expected outcomes

Field measurement during the project and analyses using historical and observational data can reveal on-going changes in the Arctic Ocean environment. Important multi-disciplinary processes which cause such environmental changes are also clarified. Development of marine ecosystem models for the Arctic Ocean can bring to light detailed information on on-going environmental changes and may help in predicting future changes in fisheries resources and population sizes.



Strategic Research Target④

Projection of sea ice distribution and Arctic sea routes

Principal Investigator
Koji Shimada Tokyo University of Marine Science and Technology

Linking the Pacific and Atlantic by the shortest route

Environmental changes in the Arctic Ocean have already stretched beyond the frame of a scientific problem, and are attracting social attention. The reduction of the sea ice area is expected to make the Arctic sea routes useable, which will be the shortest link between the Pacific and Atlantic Oceans. Under these circumstances, understanding of the dynamics of Arctic sea ice is absolutely essential for the safe use of the Arctic Ocean.

The following research projects are being carried out to achieve strategic research target ④ Projection of sea ice distribution and Arctic sea routes.

a. Changes in the Arctic Ocean and mechanisms of catastrophic reduction of Arctic sea ice

The reduction of Arctic sea ice has accelerated beyond the prediction of any climate model; the mechanism of the reduction is, however, still unclear. The mechanisms of the Arctic sea ice reduction must be elucidated urgently in order to build an Arctic sea ice forecasting system. In sub-project (a), we will clarify the mechanisms of the Arctic sea ice reduction based on in-situ observations and satellite data from Japan Aerospace Exploration Agency. Through a series of joint observations with overseas Arctic research observational agencies, the GRENE Arctic Climate Change Research Project is using foreign icebreakers that are essential for in-situ observations in the Arctic Ocean. These in-situ observations include hydrographic observations and also utilize moored observation systems that can measure sea ice movement and thickness, the water temperature, salinity, and the direction/speed of ocean current under the sea ice.

b. Sea ice prediction and construction of an ice navigation support system for the Arctic sea routes

An area of navigable water appears only during summer time when the Arctic sea ice shrinks. By early spring when shipping schedules are planned, people need to know when the Arctic Ocean will be ice-free. Since the sea ice distribution is changing constantly, scientists are building a system to predict sea ice on a daily to monthly time scale.

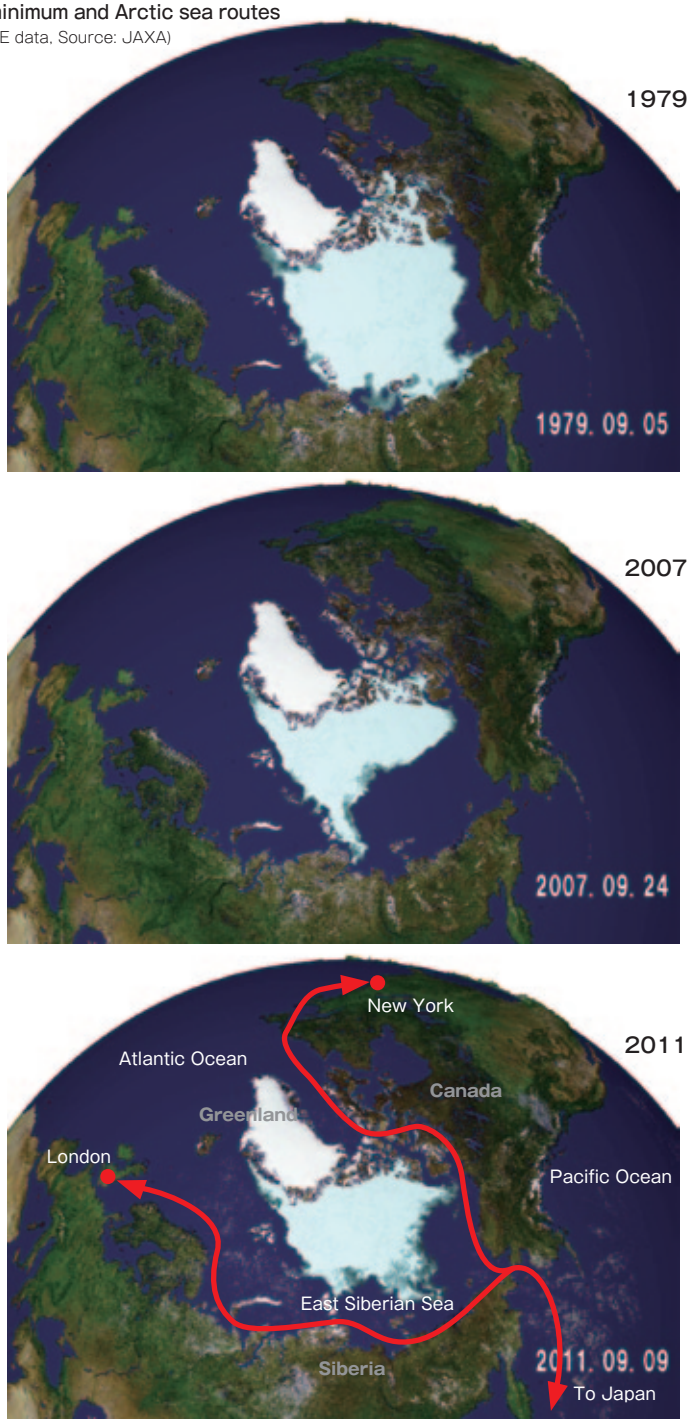
c. Coordinated observational and modeling studies on the basic structure and variability of the Arctic sea ice-ocean system

A numerical model of the Arctic Ocean is required for highly accurate sea ice forecasts. To this end, scientists are developing a model that can reproduce the complex oceanic structure involving the Pacific Ocean, Atlantic Ocean and various rivers, and simulate the development of sea ice and oceanic structures. Scientists will use this model to build a system to predict Arctic sea ice distribution over a scale that will range for a season to several decades.

Expected results

Clarifying the mechanism for the rapid reduction of sea ice and building a model for the oceanic structure of the Arctic Ocean will contribute to the building of a forecasting system for Arctic sea ice. This will enable people to determine the feasibility of the Arctic sea routes.

Distribution of sea ice on the day when its total area of coverage is at a minimum and Arctic sea routes
(AMSR-E data, Source: JAXA)



Research Projects(1)

Improvement of coupled general circulation models based on validations of Arctic climate reproducibility and on mechanism analyses of Arctic climate change and variability

Principal Investigator Toru Nozawa National Institute for Environmental Studies

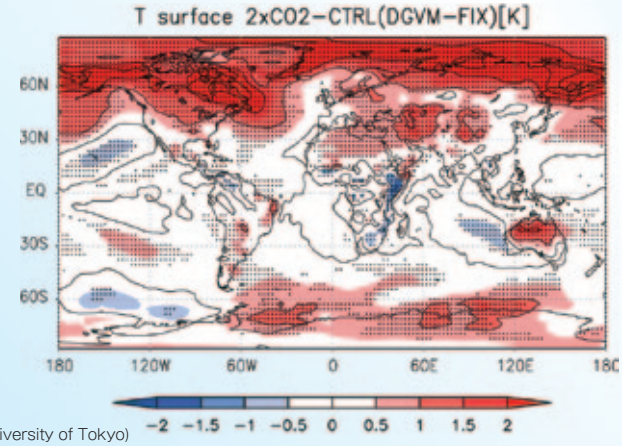
By conducting the following three sub-themes, we are aiming at improving the reliability of future Arctic climate change projected by the coupled general circulation models.

The first sub-theme is the validation of the models' ability to reproduce the Arctic climate. By comparing the simulation results from coupled general circulation models with various observation data stored in the Arctic Data Archive of the GRENE Arctic Climate Change Research Project, we will make assessments on the reproducibility of mean climate states, natural variability, and long-term climate changes in the Arctic. We will also investigate the cause of biases in the coupled general circulation models to help reduce them.

The second sub-theme is to understand the mechanisms of Arctic climate variability and change, and to identify their causes. Based on analyses of changes in the atmospheric radiation, snow cover, permafrost, vegetation, sea ice, ice sheet, etc., from many different perspectives, we will acquire a better understanding of the Arctic warming amplification mechanism. Our analyses will involve a wide range of methods, including climate feedback analysis as well as multivariate statistical analysis.

The third sub-theme is the development and improvement of component models in the coupled general circulation models. Utilizing the new findings and enhanced understanding acquired from the previous sub-themes, we will develop new, or improve existing, component models for snow cover, permafrost, sea ice, ice sheets, water isotopes, etc. which are important processes in the Arctic climate. Eventually, this will help make the coupled general circulation models more sophisticated and elaborated.

We will also closely collaborate with observational studies by, for example, constructing a new observational data set to validate the simulation results of coupled general circulation models. Through this kind of collaboration between modelling and observational studies, we are aiming to contribute to the achievement of strategic research targets ① Understanding the mechanism of warming amplification in the Arctic, and ②Understanding the Arctic system for global climate and future change.



▶ Example of climate feedback analysis. Changes in vegetation enhance the warming in the Arctic by around 20% through changes in snow cover and sea ice.

(Source: Ryouta O'ishi, The University of Tokyo)

Research Project(2)

Change in the terrestrial ecosystems of the pan-Arctic and effects on climate

Principal Investigator Atsuko Sugimoto Hokkaido University

The Arctic terrestrial system consists of elements such as snow cover, permafrost, soil/vegetation, and water. We believe that the melting of permafrost, change in the albedo through the changes in snow cover and vegetation, and changes in the amount of greenhouse gas emissions have an enormous effect on not only the Arctic climate but also global warming. We aim to clarify the role and function of the Arctic terrestrial system in the climate system, and assess the influence of changes in the Arctic on a global scale.

To achieve this goal, we need to understand the state of the Arctic terrestrial system under a rapidly changing environment. We will make field observations on frozen soil, vegetation, production of ecosystems, carbon storage, snow cover and albedo, and methane emission, etc.

To understand the terrestrial ecosystem throughout the circum-polar Arctic region, we will continue our observations at existing field observation sites, where individual researchers have set up their own systems for long-term observations. We will also set up new sites to combine observations using a mobile system to monitor spatial variation and multiple site observations with simple soil temperature probes. Satellite data will also be used for special evaluations, and tree-ring width and isotope data will be taken to investigate environmental changes over a century-long time span. Based on this observational data, we will carry out interdisciplinary studies involving both observation-based and model-based researchers, and then develop terrestrial system models that can reproduce realistic changes in the thawing of frozen soil, vegetation, and greenhouse gas emissions.

By carrying out these research projects, we will contribute to the achievement of strategic research targets ① Understanding the mechanism of warming amplification in the Arctic, and ② Understanding the Arctic system for global climate and future change.

▶ Boring of permafrost

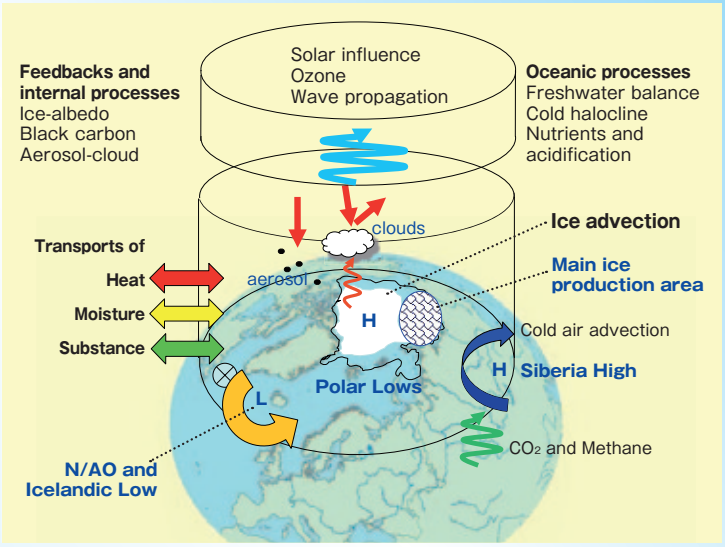
(Photo: Atsuko Sugimoto, Hokkaido Univ.)

Research Projects(3)

Atmospheric studies on Arctic change and its global impacts

Principal Investigator
Jinro Ukita Niigata University

A set of three questions must be addressed when we study underlying causes and mechanisms for the Arctic change. First we ask the question of how the Arctic climate system is influenced by the rest of the global climate system. It is under the influence of the CO_2 increase. The amounts of heat and moisture transported to the Arctic region may be increasing due to global warming. Yet, we do not know the details. The second question looks into processes more internal to the Arctic. Without doubt the ice-albedo feedback process is critical. The smaller the coverage of sea ice the larger the amount of heat entering the upper ocean, thus accelerating the speed of sea ice reduction. Beyond, we have very limited knowledge on how things operate within the Arctic climate system. For example it is not a simple question as to how



◀ Key processes and elements of the Arctic climate system

the rapid reduction in sea ice is linked to thawing of permafrost and forest fires in Siberia, thereby modifying carbon cycle. Finally we ask how the Arctic change exerts influences on weather and climate outside the Arctic, especially those in Japan, through atmospheric teleconnection.

This research project, "Atmospheric studies on Arctic change and its global impacts", addresses the above three questions - outside influences, internal processes and teleconnection, relevant to the Arctic change. Our overall goal is to gain a better understanding of key physical and chemical processes relevant to the rapid changes in the Arctic climate system and their global impacts.

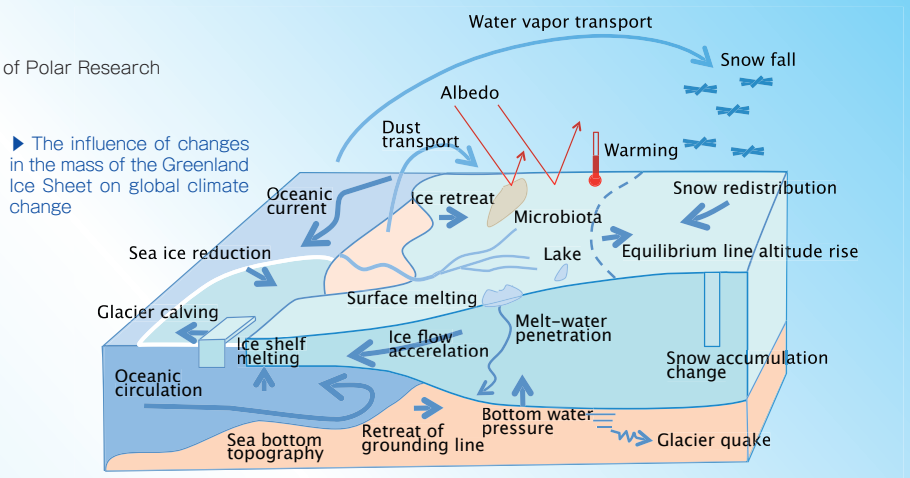
Research Projects(4)

The role of Arctic cryosphere in global change

Principal Investigator
Hiroyuki Enomoto National Institute of Polar Research

Rapid changes in snow, glaciers and ice sheet in the Arctic are occurring as a result of warming. We are aiming to get a better understanding of these changes and their changing processes, and then the role of snow and ice in the Arctic climate system to the atmosphere, hydrosphere and terrestrial systems.

Our research focuses on two targets. One is the effects of land snow and ice cover in the Pan-Arctic region to the Arctic climate. Around about half of the world's glaciers and ice caps are located in the Arctic region, and these are sensitive to warming. From data gathered in the field and from satellites, we can understand a) the spatial and temporal distribution of snow cover, and b) glacier fluctuations. We will investigate how snow accumulations respond to changes in air temperature and snowfall, and the assess ice-albedo feedback we will try to clarify the



▶ The influence of changes in the mass of the Greenland Ice Sheet on global climate change

process of changes in snow and ice cover. From a chemical analysis of snow samples, we will obtain the information of air temperature, snowfall events, and the spatial distribution of transported environmental substances. This information is helping to make climate change predictions more accurate.

Our second target of research concerns the effects of the mass change of the Greenland Ice Sheet on global climate change. The Greenland ice sheet holds about 10% of the world's ice, which is equivalent to about seven meters of sea level rise. This ice sheet is rapidly shrinking, and at an increasing rate. About half the reduction in the ice sheet is due to melting, and the other half to the discharge of ice and our goal is to quantify this reduction. We will expand observational network in Greenland, for understanding of the changes in the mass of the ice sheet and the processes responsible for them. We will use a model to incorporates our findings, to make predictions and clarify the effects of reduction in the ice sheet on climate change. The reduction in the ice sheet will lead to rising sea levels and will also influence ocean circulation. We will use modelestimation of changing sea levels to predict the effects ocean circulation.

Through this research, we will contribute to the achievement of strategic research targets ① Understanding the mechanism of warming amplification in the Arctic, and ② Understanding the Arctic system for global climate and future change.

Research Project(5)

Studies on greenhouse gas cycles in the Arctic and their responses to climate change

Principal Investigator **Shuji Aoki** Tohoku University

To elucidate temporal and spatial variations of the concentrations of carbon dioxide, methane, nitrous oxide and other greenhouse gases as well as their isotopes and oxygen concentration in the atmosphere in the higher latitudes of the Northern Hemisphere, we make comprehensive observations by using land stations and aircraft. Although it is believed that the Arctic Ocean also plays an important role in the variations of greenhouse gases and their related constituents, the role of the Arctic Ocean is not well known. Therefore, we are making oceanographic observations using the research vessel *Mirai*.

These observational data are analyzed, using almost all of the high-resolution atmospheric chemistry transport models developed in Japan, to quantify the distributions and variations of sources and sinks of the greenhouse gases in the Arctic region. We are trying to combine the high-resolution atmospheric chemistry transport models with a terrestrial ecosystem model and an oceanic dissolved carbon transport model. By conducting simulations to see how these combined models are able to reproduce observed annual changes in concentrations and isotopes, we will gain a clearer understanding of the circulation process of the greenhouse gases in the Arctic, and how the circulation of the greenhouse gases responds to climate change.

By analyzing ice cores and firn air sampled from Greenland and other locations, we can reconstruct the changes in the concentrations and isotopes of the greenhouse gases from the past to the present. By analyzing these data, we can learn about the changes in sources and sinks of the greenhouse gases in the past, as well as how each type of source has responded to climate change. This work will contribute to our understanding of the various processes involved in changes to greenhouses gases in the Arctic.

Through this research, we are contributing to the achievement of strategic research target ② Understanding the Arctic system for global climate and future change.

(Photo: NIPR)

▶ Ny-Ålesund Station in the Svalbard Archipelago, where we are making observations of greenhouse gases

Research Project(6)

Ecosystem studies on the Arctic Ocean declining sea ice

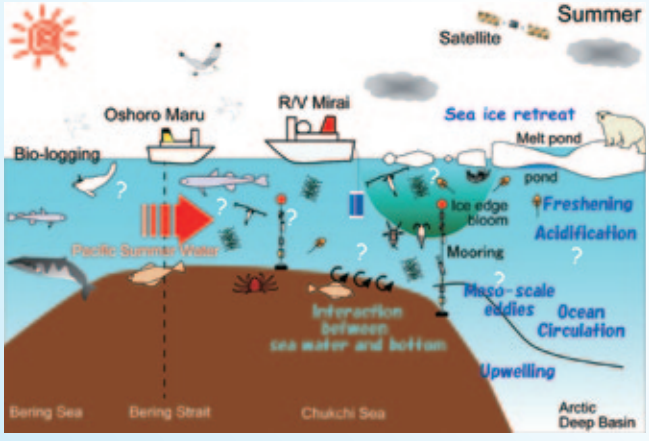
Principal Investigator **Takashi Kikuchi** Japan Agency for Marine-Earth Science and Technology

(Photo: JAMSTEC)

The recent drastic decrease in Arctic sea ice may cause various changes in the Arctic climate and ecosystems. For example, improvement of the light environment due to the sea ice reduction may induce a favourable condition for the Arctic marine ecosystem, i.e., it may cause an increase in phytoplankton in the ice-free area. However, there is observational evidence which indicates that the increase in sea ice melt-water could inhibit the phytoplankton growth, because the nutrient supply from lower layer is suppressed by enhanced stratification due to the melt-water. The benthic organisms of the Arctic Ocean are also threatened by changes in marine environments. Currently, they feed on the ice-edge bloom of phytoplankton that sinks to the seafloor (Pelagic-Benthic type). However, warming of the Arctic Ocean may increase the population of zooplanktons and fishes, which will feed on phytoplankton at the ice-edge (Pelagic-Pelagic type). What type of marine ecosystem will the sea ice reduction bring about? The reduction of sea ice influences not only species that are inherent to the Arctic but also those from the Pacific Ocean. These changes further influence the lives of marine mammals and polar bears. Many questions are being asked on the changes in the Arctic marine ecosystem resulting from the sea ice reduction. For better understanding of these changes in Arctic climate and ecosystems, we will conduct multi-disciplinary studies examining not only biological but also physical and chemical aspects of the drastically changing Arctic environments.

The research project, "Ecosystem studies on the Arctic Ocean declining sea ice (ECOARCS)" was initiated. In this project, we will focus on the Chukchi Sea on the Pacific side of the Arctic Ocean, where various environmental changes have already accompanied the sea ice reduction. Hydrographic surveys by *R/V Mirai* (JAMSTEC), *TS Oshoro Maru* (Hokkaido University), and various ice-breakers under international collaboration will be carried out. Year-round mooring observations are useful for obtaining hydrographic, chemical and biological data even in winter time (under the sea ice). To clarify the feeding behaviour of higher trophic levels, we will also use the techniques of bio-logging and monitor large areas of the Arctic Ocean via satellite throughout the year. Furthermore, we are developing marine ecosystem models for the Arctic Ocean that can diagnose in detail the on-going changes in the Arctic marine ecosystem and may predict its future.

By combining these products, we will contribute to the achievement of strategic research target ③b Evaluation of the effects of Arctic change on marine ecosystems and fisheries.



▶Schematic view of the marine ecosystem on the Pacific side of the Arctic Ocean and the observational plan of ECOARCS project (for summer).

Research Project(7)

Projection of sea ice distribution and Arctic sea routes

Sub-Research Project

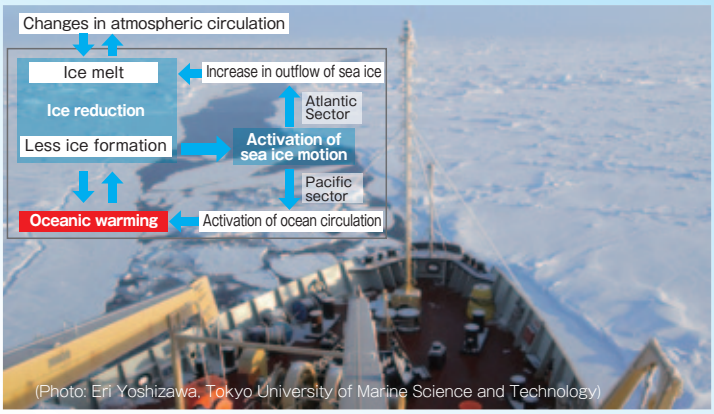
Changes in the Arctic Ocean and mechanisms of catastrophic reduction of Arctic sea ice

Principal Investigator

Koji Shimada

Tokyo University of Marine Science and Technology

Recently, the reduction rate of Arctic sea ice in summer is greater than the rate of increase in global mean surface temperature. This indicates that there is a positive feedback mechanism in the Arctic climate system, accelerating the reduction in the sea ice. Our goal is to get a better understanding of this mechanism. Therefore, we have set up a systematic ocean observation system on the Pacific side of the Arctic Ocean, where a disproportionately large degree of reduction in sea ice has been observed. We plan to use several icebreakers to measure water temperature and salinity, take water samples, and deploy moored instruments. In addition, we are also utilizing satellite data, to get a better understanding of the dynamics of heat and salinity in the atmosphere- ice-ocean systems and their impact on sea ice reduction. Based on these measurements, we plan to clarify the dynamics of a) ocean circulation, b) the amount of heat stored in the ocean, and c) the reservoir of fresh water in conjunction with changes in sea ice, and thereby contribute to the achievement of strategic research target ④ Projection of sea ice distribution and Arctic sea routes.



(Photo: Eri Yoshizawa, Tokyo University of Marine Science and Technology)

▶ Poisitive feedback driving on-going reduction of Arctic sea ice without rebound

Sub-Research Project

Sea ice prediction and construction of an ice navigation support system for the Arctic sea routes

Principal Investigator

Hajime Yamaguchi

The University of Tokyo

We are conducting research in four themes to create a forecasting system and decision-making standards needed for the use of the Arctic sea routes.

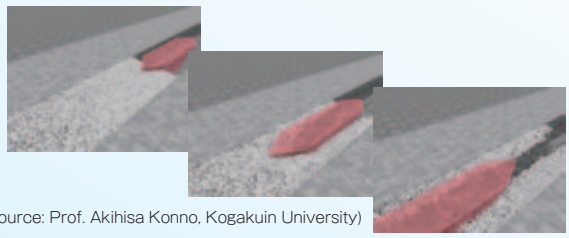
1. Forecasting the distribution of sea ice: We are establishing methods to make short-term forecasts (up to 10 days in advance) to assist the navigation of vessels in the Arctic Ocean, and medium-term forecasts (looking several months ahead) to help determine whether or not the sea lanes will be navigable, and if so, then for how long. The short-term forecasts use a high-resolution ice/ocean coupled numerical model that has been developed and used for the Sea of Okhotsk. The medium-term forecasts use a statistical model based on the analysis of satellite data to determine trends in the sea ice over a longer period.

2. Monitoring the ice conditions around shipping lanes: We are establishing methods to monitor the ice, in particular ice thickness, using satellite-based remote sensing. Based on the ice condition data that is obtained, we will develop navigation techniques that can be used to select suitable routes, for use in ice-covered waters.

3. Understanding the effects on vessels navigating through icy waters: We are assessing the impact force and safety aspects when ice blocks strike the hull of a vessel. We are also developing techniques to predict and reduce icing on ships that can lead to accidents.

4. Assessment of economic viability: We will propose shipping scenarios that take technology and economy into consideration.

By gathering together these results, we are developing a "navigation support system" so that we can decide whether or not shipping routes through the Arctic Ocean can be used, and also to use these routes more efficiently. This research is contributing to the achievement of strategic research target④Projection of sea ice distribution and Arctic sea routes.



(Source: Prof. Akihisa Konno, Kogakuin University)

◀ Assessment of the ice load on the ship hull. This model can involve around 100,000 virtual ice pieces and can analyze the mutual interaction between these pieces and a ship hull, as well as the ice load.

Sub-Research Project

Coordinated observational and modeling studies on the basic structure and variability of the Arctic sea ice-ocean system

Principal Investigator

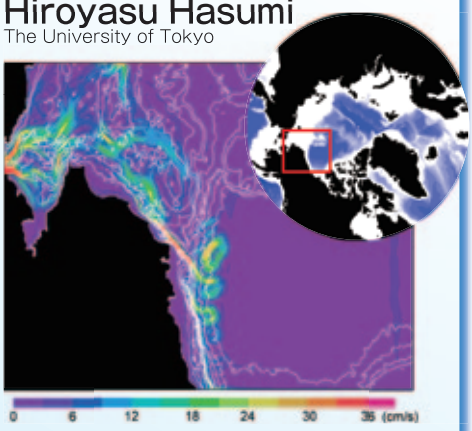
Hiroyasu Hasumi

The University of Tokyo

By clarifying the mechanism responsible for the formation of and changes to the structure of the Arctic Ocean, we will build a numerical model that can reproduce this mechanism properly. Through this model, we will gain an understanding of the role of the sea ice-ocean system in the Arctic Ocean amid global climate change.

The oceanic structure of the Arctic Ocean is incredibly complex. The development of any numerical model that is to replicate the state of this body of water has to be very closely linked to actual observations. We are able to gather information about the thickness of the sea ice and the pattern of the ice drift, the process of formation and sinking of denser water through both remote sensing via satellites and from sensing systems moored at sea. In a stepwise fashion we are building high-resolution models, ranging from those that cover various regions within the Arctic Ocean up to models that cover the entire body of water. While working to clarify the mechanism responsible for the formation of the structure of the Arctic Ocean, we are developing oceanic models that can reproduce the observed conditions to a high degree. The results that we obtain from these models will play a role in the formation of a medium- to long-term sea ice distribution forecasting system that is needed in the use of Arctic Ocean shipping routes.

Through this research, we are contributing to the achievement of strategic research target ④ Projection of sea ice distribution and Arctic sea routes.



▲ Display of sea surface current speeds in the region near the Bering Strait in the Arctic Ocean simulated by a high-resolution model (the region within the red rectangle in the world map on the upper right-hand side). The white lines indicate the contours of the ocean depths.

(Source: Eiji Watanabe, JAMSTEC)

Key Supports for Research

The GRENE Arctic Climate Change Research Project uses the following resources in its research.

Oceanographic Research Vessel *Mirai*

The *Mirai*, which is owned and operated by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), is one of the largest oceanographic research vessels in the world. She is ice resistant, and can carry out observations in the Arctic Ocean in the summer when the ice has retreated. In FY2012, the *Mirai* is scheduled to make a voyage to the Arctic.

(Photo: JAMSTEC)

Icebreakers

From FY2012 to 2015, the project plans to use the icebreakers of other countries to conduct joint observations with foreign Arctic research organizations. The project will install three kinds of moored observational systems for ice covered oceans, and provide support for setting up these systems using icebreakers.

Cloud Radar

To accurately understand the role of clouds that have an enormous influence on climate, researchers need to be informed on the clouds' 3-dimensional structure such as the proportion of water and ice within the clouds, and the size and density of cloud droplets. They also need to clearly understand the vertical movement within clouds relating to winds and the movement of cloud droplets. The project has developed a mobile Doppler 95-GHz millimetre-wavelength cloud radar, and is expected to install this system at Ny-Ålesund Observation Station on Spitsbergen Island in the Svalbard Archipelago by FY2013.

Arctic Data Archive

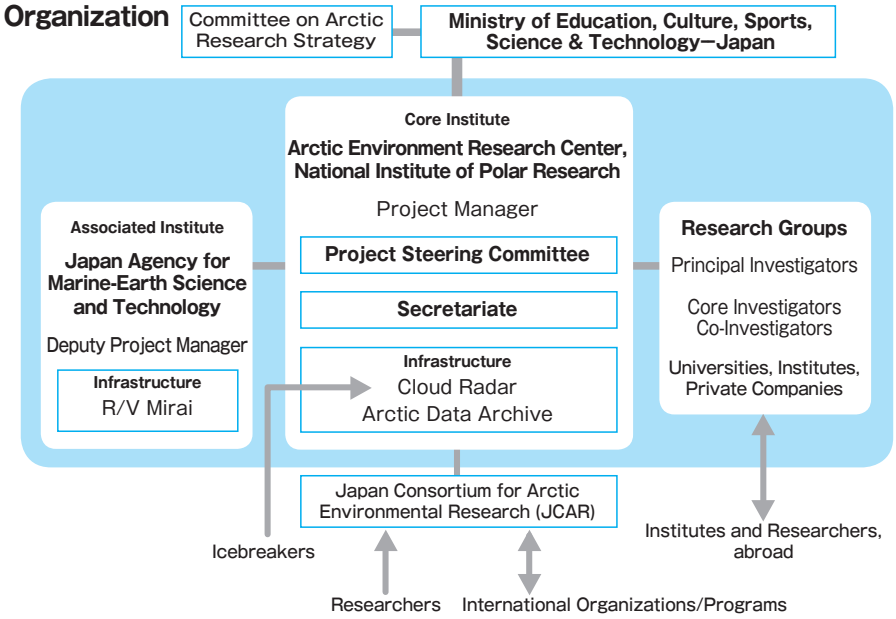
An Arctic Data Archive has been set up to promote the shared use of observational data and other resources for mutual benefit. The archive was established during FY2011 and is designed to enable sufficient data storage and use. The data set in the archive is expected to gradually expand over time and be utilized by scientific communities.

Ny-Ålesund Observation Station

The Ny-Ålesund Observation Station of the National Institute of Polar Research (NIPR) at Ny-Ålesund on Spitsbergen Island in the Arctic Ocean is used to take measurements and make observations.

(Photo: NIPR)

Organization



Arctic Climate Change Research Project Steering Committee Member

The steering committee consists of specialists in Arctic environment and climate change. It evaluates the activities of the GRENE Arctic Climate Change Research Project as well as the progress and results of individual research initiatives, and also provides advice.

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Earth Observation Research Center, Space Applications Mission Directorate, Japan Aerospace Exploration Agency
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Motoyoshi Ikeda
Hokkaido University
Professor Emeritus

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Tetsuzo Yasunari
Hydrospheric Atmospheric Research Center, Nagoya University
Professor

Takashi Yamanouchi
National Institute of Polar Research
Professor, Vice Director,

Tomoaki Wada
Tokyo University of Science
Professor

(As of October 14, 2011)

"Green Network of Excellence" (GRENE) Program is…

In June 2010, the Japanese Cabinet decided upon a new strategy for growth: the "Strategy for becoming an environment and energy power through green innovation." In response to this strategy, the Council for Science and Technology Policy brought out their report "The Science and Technology Basic Plan" in December 2010 in which they also positioned "green innovation" to be one of the main pillars supporting responses to the issues of energy and climate change.

Following on, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) initiated the Green Network of Excellence (GRENE) in FY2011. Through a strategic collaboration between universities and research institutions, GRENE aims to promote both the highest level of research in the world and the training and development of human resources. In addition to its work in the Arctic Climate Change Research Project, GRENE is also involved in research in the areas of environmental informatics, botanical science, and advanced environmental materials.

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NSIDC/NASA)