Reports of the ECS
Early Career Scientists

Canada in December
Kohei Matsuno / National Institute of Polar Research
(workplace:Hokkaido University)

I had an opportunity to participate in the Arctic cruise of the CCGS Amundsen, a Canadian coast guard icebreaker, in September 2014, during which time I met Professor Louis Fortier, a leading authority on Arctic marine ecology research. Since I had committed to attending the international Arctic Change Conference in Ottawa in December, I decided since I would be visiting Canada anyway to apply for a fellowship as a young researcher and study with Professor Fortier at Université Laval.

I was selected for the fellowship without incident and headed to Ottawa at the beginning of December. Ottawa was cold, naturally enough, and the river in front of the conference venue was frozen over. But at night, everything was decorated beautifully with illuminations and the lights reflecting off the white snow created a magical ambience. The conference was a great experience, as I was given advice at an oral presentation and took in several lectures.

After the conference, I spent about two weeks at Université Laval in Quebec City. The university was on winter vacation, so the campus was quiet and there were only two or three students in the lab. It may have been because it was just before the holidays, but I was impressed by how energetically Professor Fortier and everyone else pursued their research. I discussed what research I might do with the lab colleagues I had become acquainted with on the Amundsen, and I ended up analyzing zooplankton samples collected during the 2014 Amundsen cruise. At first, I was a bit lost because the microscopes, Petri dishes, and other equipment I was given were different from the equipment I normally use, but I was able to obtain data without any problems. The data obtained on this visit still require much more analysis, but I will compare these data with data from samples I collected, which hopefully will lead to some fruitful results.

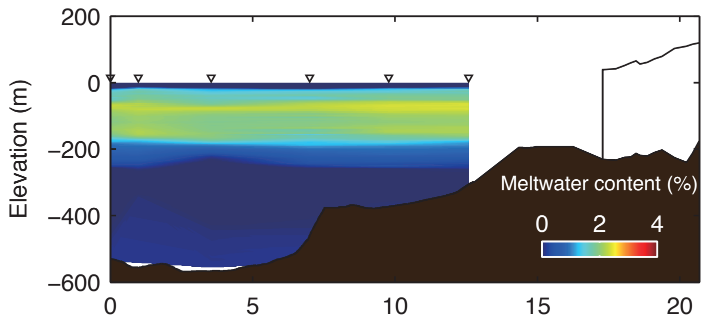

Equipment used to analyze zooplankton samples.(photo:Matsuno)

Interrelationship between Calving Glaciers and Oceans and Lakes
Masahiro Minowa / Hokkaido University

I stayed at the Glaciers Group in the Geophysical Institute at the University of Alaska Fairbanks for three months last year, from December to February, during the darkest and coldest (40 degrees below freezing) time of the year. The Glaciers Group consists of many different people, from young researchers to well-known glacier researchers, and I listened in to lively debates every day. It was an extremely stimulating experience for me because I was able to speak directly with the actual authors of the research papers I always refer to.

Presently, the world's calving glaciers (a glacier whose terminus is immersed in an ocean or lake) are retreating more rapidly than ordinary glaciers. One cause that has been put forward is accelerated glacier melting due to warming oceans and lakes. I work at Hokkaido University's Glacier and Ice Sheet Research Group and have made on-site measurements at oceans and lakes in Greenland and Patagonia. The purpose of this visit was to further the analysis of the data from these measurements at the University of Alaska, which is leading the research into calving glaciers. Analyses of ocean water characteristics measured in fjords have clarified the ratio of glacier meltwater in the ocean's water (see the figure below). My next goal is to find out what sort of impact ice melted in water has on calving glacier deformations.

I want to thank Professor Martin Truffer, who hosted my valuable and productive stay, and everyone at the Glaciers Group who welcomed me.



Cross-section of Bowdoin Glacier in the northwestern Greenland, showing the ratio of glacier meltwater in the ocean's water.

My Sojourn in Canada
Kazuhira Hoshi / Niigata University

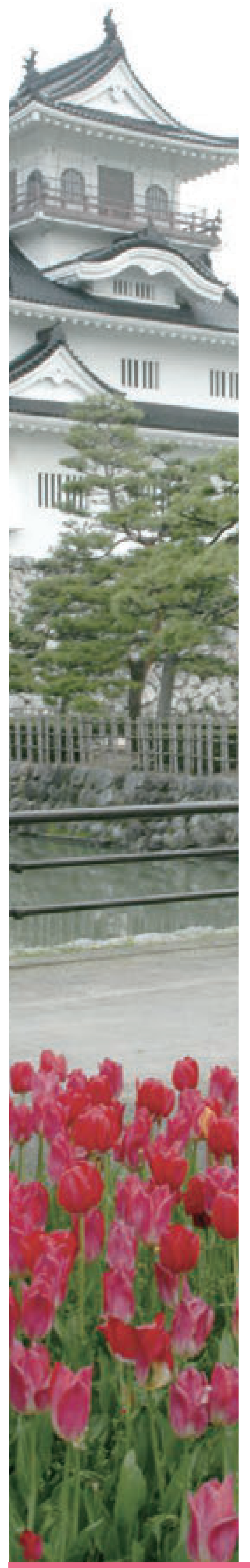
After receiving a fellowship grant, I stayed for three months at the University of Manitoba in Canada. During my stay, I attended two international conferences and made a poster presentation that included research results obtained during my visit. I was also able to speak with many researchers and obtain valuable advice.


The bear that was the inspiration for Winnie-the-Pooh (Assiniboine Park, Winnipeg / photo:Hoshi)

My research focuses on the relationship, and its processes, between Arctic sea ice area fluctuations and the North American and Eurasian climates from a meteorological perspective. The research group I stayed with was researching the Arctic climate from the perspective of meteorology but also from the perspectives of oceanography, chemistry, and biology. The group held frequent seminars with researchers invited from other institutes, and I was able to come in contact with Arctic research from many fields of great interest to me.

The site of my research happens to be near Canada' s province of Manitoba. It has been suggested that fluctuations in sea ice areas in recent years have made winters colder, but even typical winters are very cold, with daily low temperatures of -30 degrees Celsius. During my midwinter stay from November to January, I was able to feel with my own skin the Canadian climate that I had only previously known about through statistics in data analyses.

Canada' s residential areas are inhabited by wild squirrels, and in one park I was able to see a wild reindeer. Frozen rivers become skating rinks in the middle of winter. During my stay, I had many valuable experiences unique to Canada.



ASSW 2015 Toyama


ISAR-4 photo Session

The ASSW (Arctic Science Summit Week) 2015 was successfully held at the Toyama International Conference Center in Toyama, Japan with a total of 708 participants from 26 countries and region from April 23 to 30, 2015, under the auspices of IASC (International Arctic Science Committee) and co-organized by the Science Council of Japan. The ASSW is the largest annual Arctic Science Meeting in the world, and this was the first time it was held in Japan.The next ASSW will be held in March 2016 at Fairbanks, Alaska.


IASC Council

●ASSW Business Meeting April 23-25

During the first 4 days, committee meetings of IASC and other Arctic organizations were held to discuss ongoing and new research projects, as well as the role of Arctic science in society, science priorities for the coming decade and new strategies to promote international cooperation.

●ISAR-4 and ICARPⅢ Symposium April 27-30

During the final 4 days, joint sessions of ICARPIII (Third International Conference on Arctic Research Planning) and ISAR-4 (Fourth International Symposium on Arctic Research) were held. The Honorary Chairperson of the ASSW2015, Her Imperial Highness Princess Takamado attended the plenary session on the first day, and spoke of her hopes for Arctic research. Also, a message from Prime Minister Shinzo Abe was presented. During the 27 scientific sessions, there were many presentations and much discussion about Arctic natural science as well as human and social science. A session designated to the GRENE-Arctic Project had 11 oral and 24 poster presentations. At the end, the ASSW2015 Conference Statement, outlining the future direction of Arctic research, was announced.


Session


Poster Session


Banquet

●Public Lecture and Excursions April 26

A public lecture entitled "Arctic came to Toyama!" was held and nearly 500 citizens attended including people from the near-by prefectures. IASC President Susan Barr, geophysicist Syun-Ichi Akasofu and photographer Naoki Ishikawa delivered talks, followed by the panel discussion with the specialists on snow and ice of Arctic and Toyama.

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Arctic
News Letter 6

Prediction of sea ice distribution and Arctic sea routes
Koji Shimada / Associate Professor, Tokyo University of Marine Science and Technology

Prior to probing the possibilities of using Arctic sea routes, what we must think about is learning the actual sea ice variations and distributions.

The seasonal cycle of the Arctic sea ice melt in summer and ice formation in winter has continued from time immemorial. As long as the volumes of sea ice melt and growth are the same, variations in annual mean sea ice volume do not occur. When we investigate the recent reductions in sea ice, we should focus on how sea ice formation has changed as well as the changes in sea ice melt. Since the sea ice that floats in the Arctic Ocean is formed by the freezing of seawater, how much ice is formed is controlled by cooling from the atmosphere side and how warm the seawater is.

Arctic sea routes run near the coastal regions of the Arctic Ocean. However, the reduction in sea ice coverage over the entire Arctic Ocean and the presence or absence of sea ice along Arctic sea routes are not always correlated. The reason for this is the process of sea ice *rafting*, which is the process of increase in sea ice thickness not by thermodynamics but by mechanics. This rafting occurs as sea ice drifts toward coastlines and piles up where it is obstructed by land. One difficulty with projecting Arctic sea routes is forecasting, even locally, whether a given place will be obstructed by ice or navigable. Forecasts are difficult because even if the summer heat is sufficient to melt a single ice layer, where two or more layers pile up, the sea ice may survive throughout the summer. Satellite microwave observational data give us only surface information on sea ice, and we cannot judge from these data alone how much sea ice has piled up. Accordingly, we examined sea ice growth due to piling-up along trajectories of sea ice motion to identify areas where severe thick sea ice conditions are established. There were clear spatial correlations between total piling-up of sea ice and sea ice concentration in summer. This relationship is useful in forecasting timings of sea ice disappearances along the Arctic sea routes near the coast.

Canadian Coast Guard Ship Louis S. St-Laurent (photo: Kazutaka Tateyama)

The Mechanisms of Sea Ice Reduction

Koji Shimada / Associate Professor,
Tokyo University of Marine Science and Technology

The sea ice reduction pattern in the Arctic Ocean has not been spatially uniform. In the Atlantic side of the Arctic Ocean, reductions are large around the major pathways of warm Atlantic water. In the Pacific side of the Arctic Ocean, reductions have been most notable in the Western Canada Basin north of the Bering Strait where Pacific Summer Water is delivered into the deep Arctic Basin. The Pacific Summer Water spreads below the surface mixed layer, from 20 to 100 m, and is carried to the Canada Basin by ocean circulations driven by wind and sea ice motion. When ocean circulations are strengthened, more oceanic heat will be transported, which in turn makes it more difficult for the ocean to freeze and reduces the formation of sea ice. On the other hand, when ocean circulations weaken, it results in a decrease of oceanic heat, and thus the sea ice is expected to increase. This project' s field observations began in 2012, and in September of that year, the smallest sea ice area since the start of satellite measurements was recorded. Since 2013, the sea ice area has stayed above 2012 levels. If the hypothesis that variations of oceanic heat induce variations of sea ice is right, the sea ice motions that drive ocean circulations should be weakened. In the Pacific side of the Arctic Ocean, the variations of sea ice are explained by this hypothesis (Figures 1 and 2).

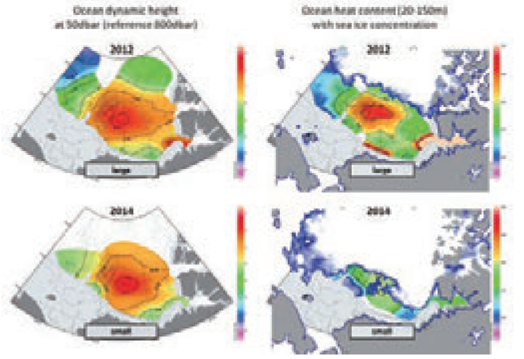


Figure 1: (Left) Clockwise ocean circulations in 2012 and 2014. Similar to a weather map, currents follow the contour lines, and the closer the contour lines are together, the larger the current.
(Right) Ocean heat content and September sea ice distribution in 2012 and 2014.

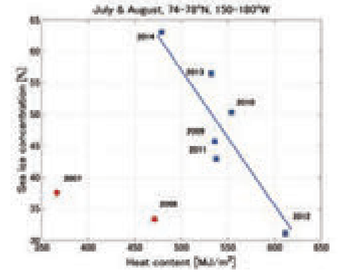


Figure 2: Relationship between the ocean heat content (at 20 to 150 meters) in 74-78oN, 150-160oW and the July-August sea ice concentration (%) in 74-78oN, 150-180oW. Since 2009, the first year in which first-year ice formed the previous winter accounted for a majority of the sea ice in the Pacific sector of the Arctic Ocean, the summer sea ice concentration has been determined by ocean heat content. In 2007 and 2008, substantial heat release occurred due to strong vertical mixing, so the sea ice concentration was much smaller than the relation after 2009.

We have also clarified through this project a time lag between variations in winds/sea ice motions, ocean circulations, and sea ice concentration; that is, changes in these three components do not occur simultaneously. Ocean circulations, which involve the currents of enormous volumes of water, take a long time to spin up. Therefore, it is important to identify the spin-up time of ocean circulations by sea ice motions and winds, and to clarify the advective time of warm Pacific Summer Water from south to north in the oceanic gyre. We have evaluated that the spin-up time scale is about three years and the advective time is about one year. These estimates suggest that sea ice variations have a time lag of about four years relative to variations of sea ice motions or winds.

The largest movements of sea ice in recent years occurred in 2008. Three years later, in 2011, ocean circulations reached their peak strength. The following year, 2012, warm water reached the inner Arctic Ocean, leading to the smallest-ever sea ice area. Sea ice movements in 2009 and beyond have not exceeded 2008 levels. Therefore, in 2013 — i.e., 2009 + three years + one year — warming of the sea abated and the sea ice recovered, which is entirely consistent with our model.

Returning to our "predicting sea ice conditions" theme, if we know the past sea ice motions, we can know the state of the present ocean. Hence we can use the "sluggish" nature of the ocean for forecasting.

Let' s now turn our attention to how the Arctic sea ice

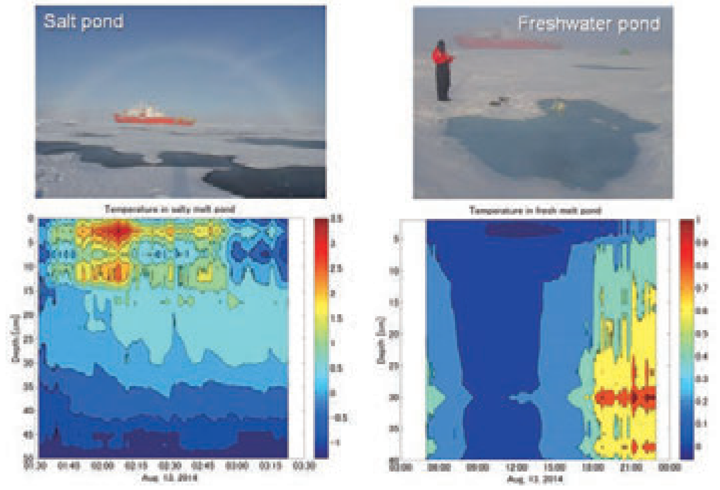


Figure 3: Differences between melt ponds filled with salt water and melt ponds containing almost-fresh water. The bottom section gives the water temperatures in the pools.

melting process has evolved. In June, the location on the Earth' s surface that receives the most solar radiation per day is not the equator but the Arctic Ocean. The maximum solar radiation can be as much as about 400 watts per square meter. Imagine one small electric heater placed in every square meter in the entire Arctic Ocean and you can easily visualize this phenomenon. This massive amount of heat is what starts to melt sea ice even in the Arctic. It is also important to remember that sea ice surface topography is not flat, but rather irregular and uneven. First, the snow accumulated on the sea ice melts, forming melt ponds on the sea ice. Because the surface changes from white to a dark color with the formation of the melt ponds, more and more solar radiation is absorbed, thus accelerating the sea ice melting process.

In the past, the melt ponds deepened, melting sea ice at their bottoms, but in recent years, the ponds spread out laterally instead, and so sea ice melt occurs at the edges of melt ponds. Fresh water without salt reaches its maximum density at a temperature of about 4 degrees Celsius. The temperature of water in melt ponds is less than 4 degrees Celsius, because it is contained by the surrounding ice. Warmer water sinks to the bottom of the ponds where it causes the ice to melt, meaning the overall area of the sea ice doesn' t change much (Figure 3, right). This was the state of the Arctic Ocean when it was covered by old, thick ice.

Recently, however, the majority of the Arctic Ocean cover has been replaced by first-year ice, which is formed during the most recent winter. When sea ice is formed from seawater, a mechanism called brine rejection expels salt from the sea ice, creating channels of expelled salt between frozen sea ice. First-year ice is ice that still has these channels. Consequently, when the ice is warmed up in the summer, seawater can easily leak into melt ponds through these channels.

On the other hand, multi-year ice, formerly the major type of Arctic ice, is ice that has survived at least one summer. Water that melts on the surface over the summer fills in the channels in the sea ice and then refreezes in the winter, resulting in ice without channels. One easy way to visualize this is to think of first-year ice as being like a sponge, whereas multi-year ice is more like a sheet of glass.

Because seawater can gradually penetrate the sponge-like first-year ice, the melt ponds that form on them have significant salt stratification. Heated water at the top of the ponds has a lower salinity and does not achieve a higher density even when heated, and so it stays near the surface (Figure 3, left). Since the water near the top of the ponds becomes the warmest, which is the opposite of the situation we just looked at, the sea ice around the edges of pools tends to melt. This sea ice melting pattern causes the surface area of melt ponds to expand, and the expanding area leads to more absorption of sunlight, which accelerates melting. As the melt ponds with a dark color enlarge in size, the strength of the ice floe weakens markedly, to the point where it will crumble and vanish with even a slight disturbance, caused, for example, by the arrival of a low-pressure system. This process is thought to be one factor behind the rapid reduction in sea ice in recent years.

Toward Achieving Accurate Decadal Projection of Sea Ice Distribution Into The Future (long-term predictions)

Takao Kawasaki / Project Researcher,
National Institute of Polar Reseach (workplace:The University of Tokyo)

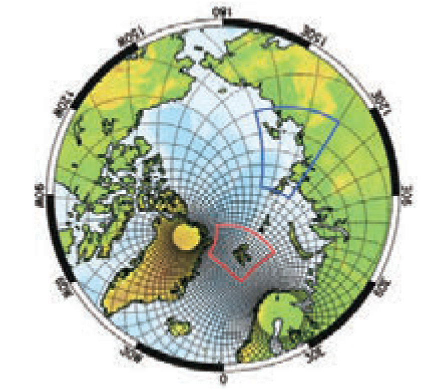
Realizing accurate decadal projection of sea ice distribution in the Arctic Ocean requires the predictive numerical models that correctly reproduce the Arctic Ocean climate. In addition to the atmosphere, which is undergoing large fluctuations typical of global warming, the ocean, which contains massive amounts of heat, has also been pegged as a component of climate system that influences sea ice distribution. Seawater coming from the Atlantic Ocean is the largest contributor of heat in the Arctic Ocean (which I will refer to as *Atlantic Water*). Observations in recent years have indicated Atlantic Water present in the Arctic Ocean is getting warmer, and understanding the influence this heat has on sea ice is essential to sea-ice projection in the future Arctic Ocean. Our sub-research project — Coordinated observational and modeling studies on the basic structure and variability of the Arctic sea ice-ocean system — uses computer simulations to calculate ocean currents and sea ice distribution in order to assess the impact of Atlantic Water on sea ice.

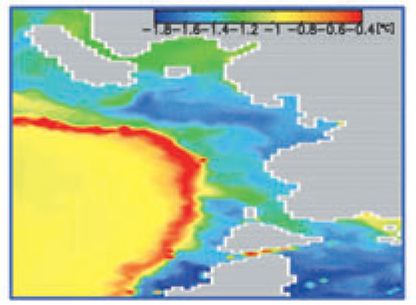
The Laptev Sea remains covered with sea ice, and impassable to ship traffic, the longest of any place along the Northeast Passage and, thus, it is the key to determine how long Arctic sea routes will be open in the future. For this reason, I will focus on our simulation results in the Laptev Sea.

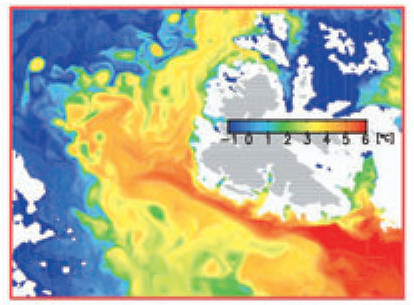
The top right figure indicates the water temperature distribution at the bottom around the Laptev Sea. The simulation reproduces high-temperature Atlantic Water in regions far from the coast, and it also closely reflects how Atlantic Water has gotten warmer in recent years. This is due to our detailed representation of the Fram Strait, which is the entrance for high-temperature water from the Atlantic Ocean to the Arctic Ocean shown in the bottom right figure. Observations have shown high-temperature Atlantic Water reaches regions near coast where Arctic sea routes lie, but our simulation cannot reproduce the arrival of any significant amount of the high-temperature water seen in the observations (top right figure). One reason that has been suggested is our inability to reproduce — despite having a state-of-the-art simulations — the transport of high-temperature water from the open ocean to region near coast, which is the result of following three phenomena.

(1) Oceanic eddies
(2) Localized, short-term wind fluctuations
(3) Vertical mixing and currents produced by ocean tides

Resolving these problems one by one is critical to improving the accuracy of projection of future Arctic sea ice distribution. More accurate simulations are expected to be achievable by using higher resolution models and the addition of ocean tides.







Left figure: The black lines show the mathematical model grid pattern (in units of 20 x 20 blocks) that was used in the ocean simulations. In our simulations, we set up a relatively fine grid pattern around the Fram Strait to reproduce the flow of the Atlantic water into the Arctic Ocean.

Top right figure: Water temperature distribution at the bottom around the Laptev Sea (the area enclosed by the bold blue line in the left figure). High-temperature Atlantic Water can be seen well offshore, but the simulation does not sufficiently reproduce the transport of high-temperature water near coast.

Bottom right figure: Water temperature distribution in the Fram Strait (the area enclosed by the bold red line in the left figure) at 200 meter depth. Because we used a high-resolution simulation around the Fram Strait, we obtained a good representation of the flow of the Atlantic water into the Arctic Ocean.

Arctic Sea Ice Predictions and Exploring Optimal Sea Routes (medium-term predictions)

Noriaki Kimura / Project Researcher,
National Institute of Polar Reseach (workplace:The University of Tokyo)

Figure 1: The first report that was released on the Web at end of May last year. The predictions were improved in the second report in June and the third report in July.

Our sub-research project — Sea ice prediction and construction of an ice navigation support system for the Arctic sea routes — spans a wide range of fields in earth science, engineering, and social science, and it involves sea ice monitoring, sea ice predictions, loading impacts on ships navigating frozen seas, ship icing, methods of determining optimal routes in frozen seas, and assessing the economics of navigating these sea routes. All of these are necessary in order to utilize the Arctic Ocean as a sea transport route.

We are engaged in both medium-term and short-term sea ice predictions. The goal of medium-term predictions is to predict by May the sea ice conditions for the coming summer season (July to September). Since sea ice extent are significantly affected by meteorological conditions (winds, atmospheric temperatures, cloud cover, etc.), meteorological predictions are a necessary part of sea ice predictions. Unfortunately, it is almost impossible to predict in spring what the weather conditions will be in summer. Therefore, we turned our attention to the thickness of sea ice in the spring. Our thinking was that ice is more likely to remain throughout the summer in areas where the sea ice is thick and melt more quickly in areas where the sea ice is thin. The problem, unfortunately, is insufficient data on sea ice thicknesses. Satellites monitor the daily sea-ice extent, but it is not easy to ascertain sea ice thicknesses from satellite data. Naturally, this sub-research project is now studying the method to derive the ice thicknesses from satellite data.

To make projections, however, we examined sea ice movements over winter and leading into spring as an alternative to sea ice thicknesses. During this period, in areas of the ocean where sea ice congregates, sea ice floes will pile up and become thicker, whereas in areas where sea ice is scattered, a large percentage of ice is thinner new ice that formed on open water.

Last year' s predictions (Figure 1) based on this thinking were very accurate in estimating the date when sea routes would open and the minimum sea ice area on the Russian side of the Arctic. On the other hand, much more sea ice remained on the Canadian side than was forecasted and, as a result, the minimum sea ice area for the entire Arctic Ocean was not as small as predicted (Figure 2). The discrepancy is thought to be caused by a failure to account for the thick multi-year ice in and around the Canadian Arctic Archipelago. Further analysis showed that this drawback could be overcome by including December sea ice thicknesses estimated from satellite data in the predictions. The aim this year is to obtain more accurate medium-term predictions using this improved methodology and to also predict sea ice thicknesses. We plan to release our forecasts on the National Institute of Polar Research' s Arctic Data Archive System.

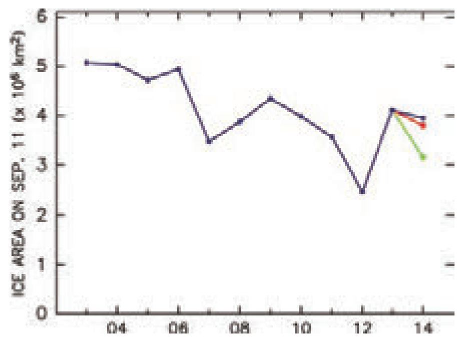


Figure 2: The minimum sea ice area in the Arctic Ocean from 2003 to 2014 (blue line) and predicted values from last year's first report (green line) and second report (red line). The first report predicted a much smaller area than the actual area.

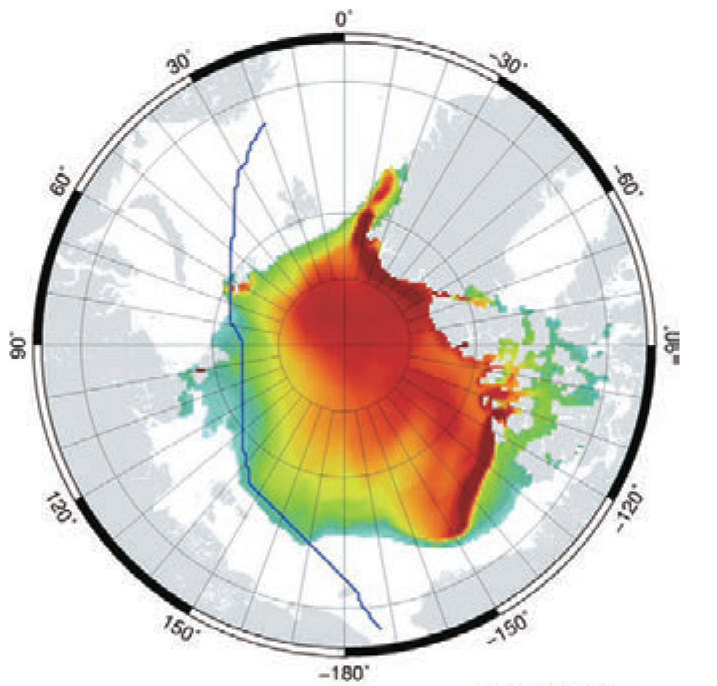


Figure 3: Model calculations of sea ice thicknesses on October 24, 2011 and an example of the optimal sea route selected based on the calculations (blue line). The route was selected assuming a ship with ice-breaking capability that can pass through regions of thin sea ice.

We are also working on short-term sea ice predictions that look about a week ahead using numerical models. By using a detailed model with a resolution of 2.5 kilometers, we can recreate eddies and other disturbances created when sea ice melts and reproduce sea ice distributions with calculated ice edge errors on the order of 10 to 20 kilometers.

We are also making progress in research that looks for the optimal routes for ships to navigate the Arctic Ocean, based on predicted sea ice distributions and monitoring data on present sea ice conditions. The optimal routes vary depending on the ability of the ship. In addition, the precision (uncertainty) of predicted sea ice conditions varies depending on the conditions. We are currently developing a method of calculating safety and time requirements, and exploring sea route that accounts for these limitations (Figure 3).