Revision of Master Plan Proposal ‘Frontier of Polar Science’ - Study on Global Environmental Change through Development of the Antarctic and Arctic Observations -

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Our proposal for the Master Plan 2017 of large scale research projects by Science Council of Japan is to install a platform in the polar region in order to contribute to the understanding the global environmental change by providing invaluable information from the Antarctic and the Arctic region. This proposal was discussed by a joint IASC and SCAR working group in Science Council of Japan, and submitted by National Institute of Polar Research. This paper presents the background, the outline of the proposal and the revision for Master Plan 2020.

The global environmental change attains great interest by the governments and general public, as well as scientists on the earth and planets. The Arctic and the Antarctic regions significantly affect global environment and also provide invaluable information on its variation. In the Arctic region, for example, temperature increase due to the global warming is the largest on the globe. The climate change is most significantly emerging which causes change of ecology, human economic activity and life. On the other hand, very little is known on the response of the huge Antarctic ice sheet to the global warming, and hence a possible change in Antarctica on a global scale and its prediction are of greatest interest. Variations in the polar regions are not independent but teleconnected through ocean and atmospheric circulations, and therefore it is necessary to consider them to be one unified system. Moreover, the Arctic and Antarctic regions are the best observation and/or investigation field for space/planetary sciences, atmospheric/hydrospheric sciences, and solid earth sciences, indicating that the polar regions are important windows for earth and planetary sciences.

Keywords: polar science, Antarctic, Arctic

Abrupt changes and interactions of polar oceans and ice sheets as a research subject in Master Plan 2020

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Ice sheets and polar oceans are fundamental components of unique environments in the Antarctic and Arctic regions. The Antarctic ice sheet, which stores ~90% of entire ice on the globe, is interacting with the surrounding Southern Ocean characterized by Antarctic Circumpolar Current and Coastal Current. In the Arctic, the Greenland ice sheet is situated at a corner of the Arctic Ocean, discharging freshwater and sediments into the ocean from numbers of outlet glaciers. Both in the Antarctic and the Arctic, changes in the ocean are affecting mass balance of the ice sheets, and in turn physical and chemical conditions of the ocean are influenced by freshwater discharge from the ice sheets. Further, the changes in the oceans and ice sheets affect not only on polar systems, but also give imact on global environments, such as sea level rise and thermohaline circulations. Thanks to recent advance in remote sensing and numerical modelling techniques, as well as increasing amount of field data collected in the field, overview of the ocean and ice sheet systems is progressively understood. However, changes at the deeper regions in the ocean and the interior of the ice sheets are difficult to observe, and processes occurring at the ice-ocean interface are complex. Thus, further effort is needed to better understand recent changes in the polar oceans and ice sheets, mechanisms connecting the ocean to the mass change of the ice sheets, consequences of ice sheet changes to the polar oceans, and how these interactions between the ocean and the ice sheets drive global environmental changes. With this background, we present recent progress in the understanding of the polar oceans and ice sheets, and propose techniques, instruments, facilities and observational platforms, which are needed to tackle the problems for the next 5-10 years. For example, construction of a new icebreaker for operation both in the Arctic and Antarctica should help a breakthrough in the field of polar science. Development and utilization of AUV (autonomous underwater vehicle) and ROV (remotely operated vehicle) would be strong tools for understanding of the key processes of glacier-ocean interaction. The objectivce of the presentation is to stimulate discussion among the polar, ocean and ice sheet researchers to develop a research plan for Master Plan 2020 to be called by Science Council of Japan.

Keywords: Antarctica, Arctic, ice sheet, ocean

Interpretation of both-polar environmental variability through the investigation of sea ice variability

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Sea ice area has been continuously monitored by satellite observations since 1970’s. Long-term record of sea ice area to date reveals prominent difference between sea ice areas in the Arctic Ocean and the Southern Ocean. Drastic sea ice reduction has been observed, especially after 1990’s in the Arctic Ocean, while sea ice area has gradually increased in the Southern Ocean. Although sea ice variability is considered to be the response to recent climate change, no detailed mechanisms controlling these different results is explained. To understand sea ice variability, which is one of the key mechanisms for global climate variability, the integrated/multidisciplinary investigation is quite indispensable for both polar oceans, where shows different sea ice dynamics.

Sea ice variability is affected by the variability of atmosphere, ice sheet and ocean. Also sea ice variability modulates the variability of atmosphere, ice sheet, ocean and ecosystems. The atmosphere-ice-ocean system with their complicated interaction is still unclear, even the research for each process has been carried out. Resolving the mechanisms of this complicated system could contribute to forecasts of climate variability/weather/ice-navigation and conservation of ecosystem. However, few research groups cannot do this kind of effort. Hence, interdisciplinary and comprehensive research activity is needed.

Until now, the investigations in both polar oceans using available satellite observations, numerical simulation, and ice-strengthened vessel have been conducted in Japan. However, observations of the atmosphere above sea ice, the ocean underneath sea ice and ice sheet close to sea ice are big challenges for us due to the existence of sea ice. To overcome this situation, installation of Japanese own icebreaker, which can conduct direct measurements in sea ice area, is most effective solution.

Currently, Japanese research activities are usually conducted on the other country’s icebreaker because Japan does not have our own icebreaker. However, the utilization of academic icebreaker will enable us to conduct interdisciplinary observational research covering the atmospheric science, glaciology, oceanography, and submarine geology. Furthermore, interdisciplinary observational research with icebreaker in both polar oceans will contribute to the interpretation of earth environmental variability through the investigation of sea ice variability. Installation of icebreaker, which is needed for breakthrough in polar science and the study of climate change, will open the door which leads to a new stage of global climatic and environmental science.

Keywords: both polar oceans, sea ice variability, atmosphere-ice-ocean system, research icebreaker

Sea ice changes evidenced in the both polar regions

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Sea ice in the Arctic has recorded decreasing trend of area and thickness, and significant decreas was happen in 2012. Sea ice area in 2016 was 2nd lowest record. After seasonal minimun. ice recovering speed was low and lowest ice covered area has recorded until now.
On the other hand, sea ice area in the Southern Ocean recorded maximum in Autumn of 2014, however, next year, in July 2015, the ice covered area quited the expand even the middle of freezing season. namely, the sea ice area became the minimum year of the record. As the reduced areal condition has been continued since then, the total sea ice coverage, the sum of Arctic and Southern Ocean showed drastic drop in 2016.
Discussions on climate change and prediction such as IPCC, the future decline of Arctic sea ice is a well defined concern, large varaibility of sea ice around Antactica and uncertainty of future prediction are concern. This presentation introduces recent large variation of sea ice in polar regions aiming to provide available information for discussions on big project.

Keywords: Arctic, Antarctic, Sea ice, Climatic change, Polar observation

Japanese contribution to the Year of Polar Prediction (YOPP)

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To evaluate the impact of additional observation on the predictability of weather and sea-ice patterns at high latitude and beyond, Japan has contributed to establishing an experimental Arctic observing network as part of an international collaboration. It was shown that the incorporation of additional Arctic observations improves the initial analysis and enhances the skill of weather and sea-ice forecasts. Based on these achievements, Japan will extend this activity during the Year of Polar Prediction (YOPP), from mid-2017 to mid-2019, under the Japanese flagship projects, called ArCS (Arctic Challenge for Sustainability) and JARE (Japanese Antarctic Research Expedition). Using a data assimilation technique and observation data obtained from ships, land stations and drifting buoys under international collaborations, the impact of additional polar observations on predicting extreme evens in local (e.g. along Northern Sea Route) and remote regions (e.g. extreme weather events at mid-latitudes) will be assessed, contributing to optimizing a sustainable polar observing network on a cost-benefit basis.

Keywords: Arctic & Antarctic, numerical predictions for weather and sea ice, observations & modelings

Towards drilling of deep ice core exceeding 1 Ma for reconstructing past climate

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In the next phases of Antarctic glaciological research, National Institute of Polar Research together with Dome Fuji Ice Core Consortium (ICC) plans to perform various activities related to the third deep ice-core drilling in the vicinity of Dome Fuji, in order to obtain the “oldest ice” with age much older than 800 kyr. This is also a contribution to International Partnership in Ice Core Sciences (IPICS), which defines the oldest ice project as most challenging. During the next six years (JARE Phase IX), we (i) investigate glaciological conditions (ice sheet surface conditions, englacial conditions and subglacial conditions) of the candidate site area; (ii) determine the exact location of the drilling site, and (iii) start pilot hole drilling, casing and shallow/middle range deep drilling. The drilling will then continue to reach the bedrock and obtain the old ice core.

Keywords: Antarctic ice core, Climate change, Glacial-interglacial cycles

Mass loss of outlet glaciers and ice caps in the Qaanaaq region, northwestern Greenland

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The Greenland ice sheet and peripheral ice caps are rapidly losing mass. Recently, ice mass loss is increasing particularly in northwestern Greenland (e.g. Enderlin and others, 2014). It is urgently important to understand the ongoing changes in this region, but observational data are sparse in northern Greenland. To quantify current ice mass loss in northwestern Greenland and better understand processes driving the mass loss, we studied outlet glaciers and ice caps in the Qaanaaq region as a part of GRENE Arctic Climate Change Research Project. Field and satellite observations were performed to quantify ice surface elevation change of outlet glaciers and ice caps (Saito et al., 2016; Tsutaki et al., 2016). Frontal position and ice speed of outlet glaciers were mapped by satellite data. We also studied processes occurring near the front of outlet glaciers to investigate interaction of the glaciers and the ocean (Ohashi et al., 2016). Our field activities include mass balance monitoring on Qaanaaq Ice Cap since 2012 (Sugiyama et al., 2014), integrated field observations near the calving front of Bowdoin Glacier since 2013 (Sugiyama et al., 2015; Podolskiy et al., 2016), and ocean measurements in front of the glaciers. In this contribution, we present the overview of the results obtained in the GRENE project, and introduce a new project established under the framework of ArCS (Arctic Challenge for Sustainability Project). Our presentation aims to stimulate community discussion on research plan in Greenlnad for Master Plan 2020 called by Science Council of Japan.

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Keywords: Greenland, ice sheet, ice cap, calving glacier

Establishment of a new integrated geodetic observation system in Syowa Station for mm Global Geodetic Reference Frame (GGRF)

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Syowa Station has three independent techniques for space geodetic observation, namely, Very Long Baseline Interferometry (VLBI), Global Navigation Satellite System (GNSS), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS). Observations by the three techniques have been continued for more than 15 years. Hence Syowa Station is one of the most critical geodetic sites in southern hemisphere for maintaining the current International Terrestrial Reference Frame (ITRF).
In addition to these space geodetic observations, continuous gravity observation with superconducting gravimeters have been carried out for more than 20 years as well as repetitive absolute gravity measurements. This means that Syowa Station is a promising site to realize and maintain the GGRF with mm accuracy which is an integrated geodetic reference frame incorporating the ITRF, the International Celestial Reference Frame, the International Height Reference Frame and the Global Absolute Gravity Reference System.
To accomplish mm accuracy of the position coordinates of Syowa Station, we plan the following actions; (1) Replacement of the current VLBI system to the next generation VLBI system, (2) New installation of a next generation Satellite Laser Ranging (SLR) system, (3) Implementation of co-location survey between the space geodetic observation sites and the absolute gravity measurement site with an accuracy of 1 mm, and (4) Realization of gigabit data communication between Syowa Station and Japan.
Establishment of the new space geodetic site can provide co-located position coordinates of 1 mm accuracy combined with the absolute gravity value. The coordinates and gravity value will contribute to realization and maintenance of the mm GGRF. At the same time, the provided temporal variations of the coordinates and the gravity value allow us to investigate solid Earth deformation induced by Glacial Isostatic Adjustment (GIA), plate motion and current change in cryosphere, ocean and atmosphere.

Keywords: GGRF, space geodetic observation, GIA

A perspective for observations on ecosystem response in the Arctic

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Arctic and sub-Arctic ecosystems are exposed to a larger magnitude of warming in comparison with the global average, as a result of warming-induced environmental changes. Understanding the sensitivity of tree growth to climate in these ecosystems is an important factor in the accuracy of future projections of the terrestrial carbon cycle, and also of global climate. However, it is not certain how these ecosystems respond to these changes.
We have conducted research on tree growth response to climate change over the Arctic and sub-Arctic ecosystems using ring width indices (RWI) from a tree-ring width dataset accessed through the International Tree-Ring Data Bank (ITRDB) and found that the responses differed among regions, depending on the characteristics of each region. Tree radial growth decreased with recent rapid warming in southern boreal forests located on continental dry climate region such as inner Alaska and Canada, southern part of Europe, southern part of Lena river basin of eastern Siberia and Mongolia. Conversely, radial growth increased in the Arctic ecosystems. It is clear that spatial heterogeneity in Arctic and sub-Arctic ecosystems response to climate change existed.
However, we still have following questions with regard to advancing our understanding of these ecosystems response; (i) to which extent does the clear spatial heterogeneity in those ecosystems response deduced from RWI data set correspond to that from other kinds of data set?; (ii) what is controlling factor for the spatial heterogeneity in those ecosystems response?; (iii) how can we expect future carbon cycling in the Arctic and sub-Arctic ecosystems?
To answer these questions, we plan to conduct observation-based multilateral study in which we investigate relationship among tree-ring parameters, i.e., ring width (RWI) and stable carbon isotope ratio, remotely sensed spectral vegetation indices, i.e., normalized difference vegetation index (NDVI) and CO_2 flux observations. The comparisons are conducted for linking those data sets each other and for obtaining better estimate of vegetation activity response to climate change over Arctic and sub-Arctic ecosystems. For example, our comparative analysis between RWI and NDVI (Tei et al., in preparation) showed disagreement in their trends over extensive areas; the accelerated RWI trend over some regions did not correlate with greening and, inversely, with browning where tree experienced a slower growth. Comparison of such proxies with direct CO_2 flux observational data set is also useful to know what NDVI and RWI represent at the ecosystem level, how to optimally integrate them each other, and what related challenges need to overcome. Such efforts are expected to improve our understanding of forest carbon cycling in the Arctic and sub-Arctic ecosystems and place current developments into a long-term perspective. It could also help to evaluate the performance of earth system models regarding the simulated magnitude and dynamics of forest carbon uptake, and inform these models about growth responses to climatic drivers.

Keywords: Arctic and sub-Arctic ecosystems, carbon cycle, tree ring, CO2 flux, remote sensing

Characteristics of total ozone measured in the western Antarctica

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To figure out the temporal variation and spatial distribution of Antarctic ozone loss, we investigate the characteristics of long-term (at least longer than 15 years) total ozone columns measured by Dobson or Brewer spectrophotometer at five ground stations in the western Antarctica: King Sejong, Marambio, Belgrano, Halley, and Belgrano stations. All measured total ozone columns, well evaluated through an inter-comparison with OMI total ozone measurements, recently show the recovery pattern, particularly in September. They are generally analogous but often different during the austral springtime when the stratospheric ozone loss strongly occurs. As shown in the comparison of potential vorticity among stations, regional differences of total ozone are attributed to the spatial scale of polar vortex. Additional analyses of other meteorological factors also indicate the large spatiotemporal variations of atmospheric pattern over the western Antarctica. This probably implies that the total ozone variation in this region has higher sensitivity to the large-scale circulation and even climate change compared to the eastern Antarctica. We also find the well-known positive correlation between total ozone and lower stratospheric air temperature all the year round, particularly at 50-100 hPa heights during austral spring. But this positive correlation is not apparent in the upper stratosphere (higher than 10 hPa). Correlation with tropical sea surface temperature is not clear, but the signal looks meaningful and somewhat asymmetry between austral spring and summer. Further analysis will be required for better understanding of this feature.

Keywords: Antarctica, Ozone, Brewer, Dobson

Integrated multidisciplinary study on change in the Southern Ocean and the Antarctic ice sheet

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The Antarctic ice sheet holds 90% of ice, which is equivalent to about 70 m height of sea level. On the other hand, the Southern Ocean produces densest seawater, called the Antarctic bottom water, which drives ocean circulation. The Antarctic ice sheet and the Southern Ocean are the most significant components that control global climate and sea level changes. However, the Antarctic ice sheet and the Southern Ocean are the mostly unknown components in the Earth system due to the difficulties of the observation in these areas, especially in the East Antarctica.
The primary processes and the mechanism of the interactions among the atmosphere, ice sheet, solid earth and ocean should be made clear in the context of the global environmental changes driven by the Antarctic ice sheet and the Southern throughout the various kinds of the interactions. The integrated multidisciplinary study is required with the different fields of the observation data from geological to present time scale together with modeling studies. Furthermore, the developments of the observation instruments are important element to obtain the field observation data in the unexplored under and edge of sea ice. The project of the integrated multidisciplinary study focused on changes in the Southern Ocean and the Antarctic ice sheet are introduced, and the prospects of this program are discussed.

Keywords: Southern Ocean, Antarctic ice sheet, ocean circulation, sea level

Long-term field experiment for detection and study of climatological change in East Antarctica

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This presentation will make a review on the Antarctic climatic change during the last decades and discuss important observation to understand the mechanism of the present situation of Antarctica and the future trajectory.

The observation indicates robust warming of West Antarctica since the middle of the last century as one of the most rapid warming area among the world. In East Antarctica, on the other hand, we have not detected clear temporal tendency in the surface air temperature. The mechanism of the suppression of surface warming of East Antarctica has not been understood yet.

Mass balance of the Antarctic ice-sheet also is one the most important issue because it is the largest source to push the sea level upward. While West Antarctica continues to loss the mass, Droning Maud Land, the western part of East Antarctica, recently, got much accumulation, resulting in increasing the mass of the area. The accumulation may be caused by activity of synoptic-scale disturbances. But the mechanism is still studied and we do not know the future trajectory of the mass balance of Antarctica.

To understand the air temperature change and the surface mass balance in East Antarctica, we need to enhance the observations on the ice-sheet and to keep them for more than ten years, favorably. Thus, we are planning a long-turm field experiment for detection and study of climatological change in East Antarctica.

Keywords: atmosphere, antarctic, arctic

A new perspective on atmospheric and geospace sciences in the Arctic with EISCAT_3D

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The European Incoherent Scatter(EISCAT) radar system in northern Feno-Scandinavia and Svalbard have been playing a pivotal role in advancing cutting edge sciences in various area including atmospheric, ionospheric and geospace studies, space weather and global change. Affiliated in the EISCAT Scientific Association in 1996, the EISCAT user community in Japan has jointly contributed to understanding of the magnetosphere-ionosphere-thermosphere coupling processes using the coordinated ground-based and rocket/satellite simultaneous observations with EISCAT radars.
EISCAT_3D is the major upgrade of the existing EISCAT mainlamd radars, with a multi-static phased array system composed of one central active (transmit-receive) site and 4 receive-only sites to provide us 50-100 times higher temporal resolution than the present system. The core site will transmit radio waves at 233MHz with 10MW power, and all five receiving sites will have sensitive receivers to detect the returned signal using phased-array antenna with 10,000 cross-Yagi elements.
The new radar is expected to overcome current observational difficulties and then open new scientific world that have been never realized. One of the great characteristics is continuous measurements of the space environment-atmosphere coupling in the auroral oval and at the southern edge of the polar vortex. High time resolution data with 3D volume-metric will be obtained by EISCAT_3D. Scientific topics addressed in the Science Case documents (i.e.. McCrea, et al., 2015) are as follows:

1. Atmospheric physics and global change
-a. Vertival coupling between the atmospheric layers
-b. Turbulence and waves in the mesosphere and lower thermosphere
2. Space and plasma physics
-a. Multiple scale interactions in ionosphere-magnetosphere plasmas
-b. Plasma turbulence and active experiments
3. Inflow and outflow of matters in the Earth’ s atmosphere
4. Space debris, near-earth objects and space weather
5. Radio astronomy

In this paper, we will overview scientific subjects to be challenged by the new EISCAT_3D radar facility in the Arctic, as well as the possible inter-hemispheric coupling studies with the PANSY radar in the Antarctic.

Keywords: incoherent scatter radar, bipolar, vertical coupling

