A report from JCAR to inform the ICARP IV Process

Topic Area 1: The Role of the Arctic in the Global System

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Japan Consortium for Arctic Environmental Research (JCAR) published "Long-term Plan for Arctic Environmental Research (JCAR, 2024)" with its Executive Summary (JCAR, 2024) that includes research priorities from the viewpoints of Japanese Arctic research communities. Here, from the Executive Summary (JCAR, 2024), we have extracted, edited, and added elements that the Japanese research community could contribute significantly to the implementation of priority studies for the next decade related to "Topic Area 1: The Role of the Arctic in the Global System" of ICARP IV. We note that some comments from JCAR members were reflected in the document.

- Global energy budget with some emphasis on the impact of terrestrial changes

While the Arctic covers only a small portion of the Earth's surface, it constitutes an important element of the global environmental system that is highly interactive with the regions outside the Arctic. Changes in surface albedo associated with snow, ice, and vegetation cover disturb the Earth's energy budget. To understand and accurately predict such changes, it is necessary to establish a continuous and improved polar observation system whose target includes terrestrial ecosystems and permafrost. The in-situ observations are vital for the effective use of satellite remote sensing data which enables us to capture the Arctic-wide changes of the Earth's surface.

Changing fluxes (emissions and sinks) of CO_2 and CH_4 at the surface need to be evaluated in both observational and modeling studies, making use of isotopic ratios of these compounds. Emissions of CO_2 and CH_4 from organic matter in the permafrost can also disturb the global energy budget. As the processes in the natural ecosystem and permafrost occur on various temporal and spatial scales, it is necessary to elucidate the mechanism using land surface and ecosystem models that are appropriate for the target of interest. Clouds and aerosols are other important players in determining the Earth's energy budget, but our knowledge is severely limited. To fill in the knowledge gaps, laboratory experiments and observations to understand the microphysical processes of mixed-phase clouds are particularly recommended. Studies on behaviors and radiation effects of clouds formed under various conditions need to be conducted in terms of atmosphere-ocean and cloud-aerosol interactions. Contributions of aerosols of anthropogenic and natural origin that act as cloud condensation nuclei (CCN) and ice nucleating particles (INP) also need to be studied. The role of wildfires over the Northern Hemisphere on CO_2 emission and the effect on clouds over the Arctic region would be emerging scientific issues.

- Sea level change

The impact of sea level rise is global, and it brings large consequences to human society even though some of its origins are in the Arctic. Glaciers have been contributing to the ongoing sea level rise, and the contributions of ice sheets are increasingly important. To quantify and understand the mechanism of the mass loss of the Greenland ice sheet and glaciers in the Arctic, long-standing field observations, satellite remote sensing, and numerical modeling are essential. One important element that needs to be achieved is the quantification of organic and inorganic impurities in snow and ice, and the evaluation of their impact on surface albedo and melting across Arctic glaciers. Ice sheets interact not only with the atmosphere and ocean but also with the solid Earth. Thus, another important element is the satellite-based analysis of regional crustal deformation, the development of an absolute gravimeter network, and the development of high-resolution numerical models to reconstruct these observables. Ice sheets are known to have long memories and to exhibit nonlinear dynamical behaviors associated with the so-called "tipping point". To obtain a comprehensive understanding of the long-term behaviors of the Greenland ice sheet, paleoclimatic studies based on both reconstruction and numerical modeling of ice sheets, which are not necessarily limited to Greenland, would be very useful.

- Atmospheric linkage between the Arctic and mid-latitude

The Arctic is not an isolated system. It exchanges energy, moisture, and materials with mid-latitudes. There is an intense debate over how much of the observed winter cooling in the recent decades at the mid-latitude continent is attributable to the loss of sea ice in the Barents and Kara seas. Although the debate is far from settled, it points out the potentially very important influence of Arctic climate change on regions outside the Arctic. Such remote influence may be framed as the classical atmospheric "teleconnection", but the involvement of the Arctic in the teleconnection theory is poorly established. In that, the coupling between the troposphere and the stratosphere may also be important. Link between extreme events and global-scale teleconnections requires a special attention. The interaction between the Arctic and mid-latitude may also be understood in terms of modes of atmosphere-ocean variability. Sustaining mechanism for modes of natural climate variability and their modulation under global warming has a high priority of research. To predict extreme events skillfully, the strategy of sustaining the Arctic observing network and developing the modeling framework should be discussed. It is worth stressing that it is important not only to strengthen the international Arctic research collaboration framework but also to strengthen the international research collaboration with the mid-latitude or global research activity.

- Sea ice

Sea ice is a unique property of the polar regions (apart from some exceptional seas), but its change is at the heart of various global environmental changes as seen in the above discussions. The change in sea ice is not only driven by the local energy balance at the top of the atmosphere but also influenced by atmospheric and oceanic heat transport to the Arctic. Extreme events may also be important as the transport mechanism and the link between weather events and climate change requires special attention. Sea ice prevents exchanges in energy, momentum, and materials between the atmosphere and the ocean. As to the momentum exchange, the interaction between sea ice and ocean surface waves needs to be elaborated. The initialization of climate models to the current conditions plays a critical role in the relatively near-term future projection. Therefore, the establishment of an appropriate assimilation technique is important. For the long-term future projection, the poor reproducibility of the current sea ice condition by climate models yields severe limitations to our prediction skills. In either time scale, a reliable dataset of sea ice thickness is essential. In addition, process understanding of sea ice changes and its incorporation into the climate model representation is a high priority of research. The fate of sea ice has a profound impact on the global environment which is a part of Arctic warming amplification processes, and the integrative understanding of the mechanism for Arctic amplification from a process-oriented viewpoint (e.g., laboratory experiment, in-situ observations, and numerical modeling) to a macroscopic viewpoint (e.g., remote sensing, paleoclimate, numerical modeling, and data assimilation) needs to be established.

Submitted together with:
JCAR (2024): Executive Summary of Long-term Plan for Arctic Environmental Research.

References:

Japan Consortium for Arctic Environmental Research (2024). Executive Summary of Long-term Plan for Arctic Environmental Research. https://www.jcar.org/e/longterm/

Japan Consortium for Arctic Environmental Research (2024). Long-term Plan for Arctic Environmental Research. In press. [in Japanese]