# GRENE Arctic Climate Change Research Project (2011-2016)

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Under global warming due to anthropogenic increases in atmospheric carbon dioxide concentration, the surface air temperature in the Arctic is increasing with a speed that is more than double the global average, called "Arctic amplification (AA)." To grasp these changes in the Arctic, to understand the mechanism, to know the global influences, and to contribute to future climate projection, a new Arctic research project was assigned to the National Institute of Polar Research (NIPR) under the Green Network of Excellence Program (GRENE) by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT). Four **Strategic Research Targets** were presented as follows:

1) Understanding the mechanism of warming amplification in the Arctic,
2) Understanding the Arctic system for global climate and future change,
3) Evaluation of the impacts of Arctic change on weather and climate in Japan and on the marine ecosystem and fisheries,
4) Projection of sea ice distribution and Arctic sea routes,

under the Terms of Reference: to a) conduct cooperative research projects (themes) with applications, b) improve infrastructures, and c) support research community such as Japan Consortium for Arctic Environmental Research (**JCAR**) and that cooperation among different research fields and especially cooperation between observation and modeling were desired. NIPR, to conduct cooperative research on Arctic climate change as a core institution among universities and research institutes, started the GRENE Arctic Climate Change Research Project with the title, "Rapid Change of the Arctic Climate System and its Global Influences" (Project Manager: Takashi YAMANOUCHI, NIPR; Deputy Project Manager: Masao FUKASAWA, JAMSTEC), and issued Research Announcements to research community. Among 22 applications, seven **Research Themes** were selected as follows: modeling, terrestrial ecosystem, atmosphere, cryosphere, greenhouse gases, marine ecosystem, and sea ice, and then worked together and reached to the outcomes. Since the research themes answered the top-down strategic targets in a bottom-up manner, it became a unique and optimized construction as a research project.

Activities and the significant outcomes of the GRENE Arctic were overviewed and synthesized in the **review article** (Yamanouchi and Takata, 2020), and the notable key research findings were highlighted as below:

1) The role of various factors contributing to the Arctic warming amplification (AA) was quantified, and their seasonality was clarified.
2) The function and behavior of glacier microorganisms called cryoconite were demonstrated to darken and melt the snow/glacier surfaces of the Greenland Ice Sheet.
3) Both observations and model simulations provided evidence that reductions in Arctic sea ice tended to cause a negative Arctic Oscillation (AO) phase and warm Arctic and cold Eurasia (WACE) pattern, including extreme weather in winter Japan, especially through the stratospheric pathway.
4) Atmosphere – sea ice – ocean coupling was a key element to decide sea ice area, and ice divergence in the early melt season was a crucial trigger for amplifying ice retreat through ice-ocean albedo feedback.
5) Prediction of the Arctic sea ice distributions was made in three timeframes. The excellent forecast was achieved for the seasonal-scale sea ice prediction, which would contribute to selecting the Arctic sea routes.
6) Seasonal change of ocean acidification, primary production dependence on sea ice retreat, and the northward shift in the geographic distribution of the zooplankton community, benthos, fishes, and marine mammals were documented.
7) The global carbon cycle was estimated from the Arctic, and $CO_2$ sink by terrestrial biosphere was rather variable while ocean uptake was much steady but gradually enhancing, corresponding to the increase of atmospheric concentration.
8) Studies on the GHG balance were gathered, and the integrated study suggested that terrestrial ecosystems in the pan-Arctic could be $CO_2$ source due to the increase of soil respiration with warming, though a weak sink at present.

The GRENE Arctic was epoch-making as the first all-Japan comprehensive project incorporating multidisciplinary studies and collaboration between observation and modeling. Thirty-nine institutions from all over Japan participated in the project, and more than 360 Japanese scientists tackled all aspects of the Arctic climate system. Comprehensive Arctic research incorporating multidisciplinary work and collaborations between observation and modeling had been realized.

**References**

Yamanouchi, T., Takata, K., 2020. Rapid change of the Arctic climate system and its global influences – Overview of GRENE Arctic climate change research project (2011-2016). Polar Science, 25, https://doi.org/10.1016/j.polar.2020.100548