On the atmospheric response experiment to a Blue Arctic Ocean

Tetsu Nakamura[1], Koji Yamazaki[1], Meiji Honda[2], Jinro Ukita[2], Kazuhira Hoshi[2],
Ralf Jaiser[3], Dörthe Handorf[3], and Klaus Dethloff[3]

[1]*Hokkaido University*

[2]*Niigata University*

[3]*Alfred-Wegener-Institut*

We examined atmospheric responses to a reduction in Arctic sea ice via idealized simulations using AGCM for Earth Simulator (AFES) version 4.1, which had successfully captured the negative AO-like responses to a reduction in sea ice. In the simulation, Arctic sea ice was prescribed stepwise from the present-day range to an ice-free range (Table 1 and Figure 1). In all cases, the tropospheric response exhibited a negative Arctic Oscillation (AO)-like pattern (Figure 2). Our analysis revealed that there are two processes that control the association between Arctic sea ice changes and the polarity of the winter AO, which are described below.

- The stratosphere–troposphere coupling process followed by a negative AO-like pattern is dominated by an intensified climatological planetary-scale wave structure (the stratospheric pathway). This is mainly due to the intensification of the lower stratospheric Siberian trough associated with a reduction in Arctic sea ice on the Atlantic side of the Arctic Ocean.
- The tropospheric process is controlled by the eddy heat flux due to a planetary-scale wave response in the troposphere (the tropospheric pathway). Increased meandering of the tropospheric jet stream, corresponding to the response of the stationary Rossby wave to Arctic sea ice reduction, is related to a negative AO-like pattern. The associated eddy momentum flux response is consistent with the conventional understanding of AO dynamics.

The resultant negative AO-like response is accompanied by secondary circulation in the meridional plane and increased atmospheric heat transport into the Arctic, leading to the acceleration of the Arctic amplification.

Table 1. Outline of the experimental set up. High (1979–1983) and low (2005–2009) years are the time periods for which the monthly average sea-ice thickness (SIT) was used for the boundary conditions. Observation data of sea ice concentration (SIC) from 0 to 100% was linearly converted into SIT from 0 to 50 cm. Climatological mean (1981–2010) sea surface temperature (SST) was also used. 150-year integrations of each run were performed.

Run	SIT
CNTL	*High* ice period, 1979-1983
AICE	*Low* ice period, 2005-2009
Im30	Decrease of 30 cm from *CNTL*
Im40	Decrease of 40 cm from *CNTL*
Im50	Decrease of 50 cm from *CNTL*

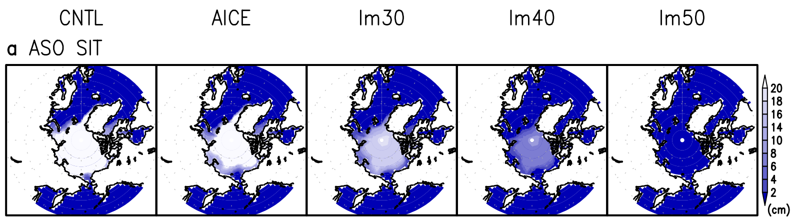

Figure 1. August-September-October averaged sea ice thickness (SIT) prescribed in the respective runs.

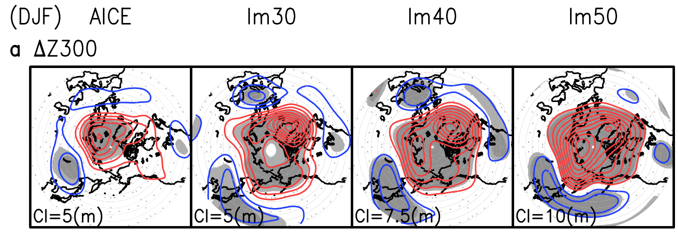

Figure 2. Differences in the 150-year average of the December-January-February averaged geopotential height at 300 hPa. Anomalies of (from left to right) AICE, Im30, Im40, and Im50 runs from the CNTL run are shown. A positive (negative) anomaly is indicated by red (blue) contours. The zero line is omitted and the contour interval is displayed at the bottom-left corner of the panel. Statistical significance greater than 95% and 99% are indicated by light and heavy gray shading, respectively.

References

Nakamura, T., K. Yamazaki, M. Honda, J. Ukita, R. Jaiser, D. Handorf, and K. Dethloff, On the atmospheric response experiment to a Blue Arctic Ocean, Geophysical Research Letters, 2016.