

## A negative phase shift of winter AO/NAO due to the recent Arctic sea ice reduction in late autumn

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Attribution of the long-term changes in the wintertime Arctic Oscillation (AO)/North Atlantic Oscillation (NAO) to the recent Arctic sea ice reduction is studied. Observations using ERA interim reanalysis and Merged Hadley/OI-SST show that small (large) sea ice area in summer to autumn leads the negative (positive) phase of AO in early winter and NAO in late winter. Relationship with winter AO/NAO is the strongest with the sea ice variability in November rather than September. To separate influences of sea ice variability and sea surface temperature (SST) anomalies, sensitivity experiments are performed with atmospheric general circulation model (AGCM for Earth Simulator, AFES4.1), in which observed changes (anomalies of 2005-2009 from 1979-1983) of the sea ice and SST are prescribed. The Arctic ice reduction generates the negative AO/NAO pattern that brings cold winter in mid-latitude continental regions. Both SST anomalies in the tropics and mid-/high-latitudes mask the continental cooling. Model-based analysis reveals that stationary Rossby wave response to the ice reduction in Barents Sea induces anomalous meridional circulation corresponding to the negative AO. The ice reduction increases (decreases) a frequency of the large negative (positive) AO occurrence about a twice (half). The anomalous meridional circulation warms the Arctic and cools the mid-latitudes. This provides additional Arctic heating about 25% of heat release due to the ice reduction. As a response to ice reduction, transient eddy activity over northern Eurasia is reduced and the change in the eddy damps the stationary responses.

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