Modulation of Stratospheric Sudden Warming characteristics by sea-ice reduction in the Barents-Kara Sea

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There has been much discussion on climatological impacts of the Arctic sea ice reduction through stratosphere-troposphere coupling, in particular those from Barents-Kara sea ice anomalies. Both observational and modeling studies indicate that this stratospheric pathway became more apparent after 2000. This was concurrent with a period of frequent stratospheric sudden warming (SSW) occurrence. Here we postulate that the Arctic sea-ice reduction modulates temporal and spatial characteristics of the atmospheric conditions leading to and during SSWs. To test this we compare respective tropospheric conditions between the light and heavy Barents-Kara sea ice years based on the Japanese 55-year reanalysis data for the period of 1979-2015.

First, we identify SSW events based on the daily Northern Annular Mode index, the leading principal component time series of geopotential height at 10 hPa northward 20˚N, for the winter (December-February) period. Using early-winter (December) Barents-Kara sea-ice criterions, those SSW events are classified into 14 low sea ice and 23 high sea ice SSW events. For the low sea ice case, the tropospheric precursor (-10 days to the starting date of SSW) is characterized by a wave pattern over Eurasia (anticyclonic anomalies over the central Eurasia and cyclonic anomalies over the eastern Eurasia), which resembles a spatial pattern of the stationary Rossby wave response to the sea ice reduction in the Barents-Kara Sea. This anomalous wave pattern is in phase with the climatological wavenumber-2 structure. At the lower stratospheric level, wavenumber-2 contribution to the vertical Eliassen-Palm (E-P) flux component is larger than the wavenumber-1 contribution. After the SSW, the negative phase of the Arctic Oscillation and Eurasian cooling appear at the surface level due to downward propagation of the signals.

In contrast, SSWs in the high sea ice years are marked with more dominant contribution from the wavenumber-1 component to the vertical E-P flux, which is related to the enhanced climatological trough over the Pacific and the ridge over Europe at the upper tropospheric level. Downward propagation of the stratospheric signals to the troposphere and the negative phase of the surface AO pattern are much less pronounced. Based on the above analysis, we conclude that the Barents-Kara sea ice reduction modulates SSWs in such a way that upward planetary wave propagation with the wavenumber-2 structure is enhanced by the stationary Rossby wave response of the sea ice reduction.

Keywords: SSW, Arctic sea ice loss, stratosphere-troposphere coupling

