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Modulation of Stratospheric Sudden Warming properties associated with 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 becomes 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 would modulate SSWs and examined temporal and spatial characteristics of the tropospheric conditions during SSWs. In particular we compared 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 an early-winter (December) Barents-Kara sea-ice criterion, 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 prior to the starting date) is characterized by the wave pattern over the 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, the wavenumber-2 component contributes more to the vertical wave activity flux than the wavenumber-1 component does. After the SSW, the negative phase of the Arctic Oscillation and Eurasian cooling appear at the surface level due to significant downward propagation of the signals in the stratosphere.

In contrast, SSWs in the high sea ice years are marked with more dominant contribution from the wavenumber-1 component to the vertical wave activity 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 of the wavenumber-2 component strengthens associated with the stationary Rossby wave response.