北極海氷域減少に伴う環状モードの変調と成層圏過程の役割

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A Role of the Stratopsheric Processes on the Annular Mode Modulated by the Recent Arctic Sea Ice Reduction

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We reported impacts of the recent Arctic sea ice reduction on the Northern Hemisphere climate in The 4th Symposium on Polar Science [*Nakamura et al.,* 2014]. Sensitivity experiments using AGCM for the Earth Simulator (AFES) with T79 horizontal resolution and 56 vertical levels up to about the 60 km model top showed that negative phase of Arctic Oscillation (AO)/North Atlantic Oscillation (NAO) tends to occur as the atmospheric responses to the Arctic sea ice reduction. Results also showed that the signals of the negative annular mode deepen in the mid- to late winter when the stratospheric polar vortex anomalously weakens in association with the Arctic sea ice reduction. The stratospheric signals connected with the tropospheric annular mode signals, suggesting roles of the troposphere-stratosphere coupling processes on the ice-induced atmospheric variations. We thus investigate the role of the stratosphere by the sensitivity experiments using same model with same ice condition but the stratospheric variations were artificially suppressed.

Based on the *Nakamura et al.* [2014], 60 years integration of *CNTL* run were performed with SST and sea ice thickness averaged for 1979-1983 (Early period). *N.ICE* run is same with *CNTL* except for sea ice averaged for 2005-2009 (Late period). Because only change in sea ice condition is responsible to the difference between *CNTL* and *N.ICE*, we define the atmospheric responses to the recent sea ice reduction as 60 years average of *N.ICE* minus *CNTL*. Figure 1 shows simulated wintertime seasonal evolution of geopotential height anomalies at 50 and 500 hPa from October-November-December (OND) to January-February-March (JFM). In the stratosphere, while only positive anomalies are evident in Far East Russia in OND and NDJ, large positive anomalies and surrounding negative anomalies are found in the Arctic and the mid-latitudes, respectively, in DJF and JFM. This indicates the weakening of the polar vortex in mid- to late winter. In the troposphere, negative AO like anomalies are continuously found and becomes strong from the late autumn to late winter. Furthermore, the dipole pattern in the north Atlantic resembling the negative NAO is more apparent in DJF and JFM than in OND and NDJ. Figure 2 shows daily anomalies (*N.ICE* minus *CNTL*) of zonal mean zonal wind. Significant deceleration of the polar night jet and corresponding stratospheric warming anomaly are found in the end of January. The signals propagate downward and penetrate into the troposphere in the February. These simulated anomalies are consistent with typical feature of the downward propagation of the stratospheric signature induced by the planetary wave modulation [*Baldwin and Dunkerton,* 1999, 2001].

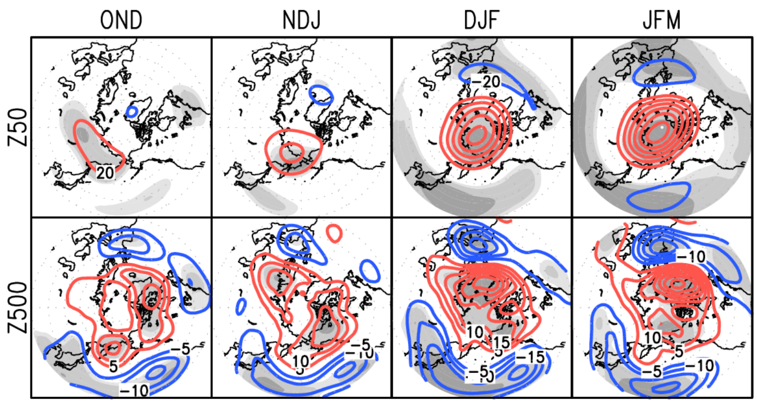

Figure 1. Geopotential height anomalies at (upper row) 50 and (lower row) 500 hPa of *N.ICE* compared with *CNTL* in OND, NDJ, DJF, and JFM, respectively. Contours indicate anomalies with unit [m]. Light, moderate, and heavy shading indicate 90, 95, 99% statistical significance, respectively.

In addition to this set, we performed 20 years

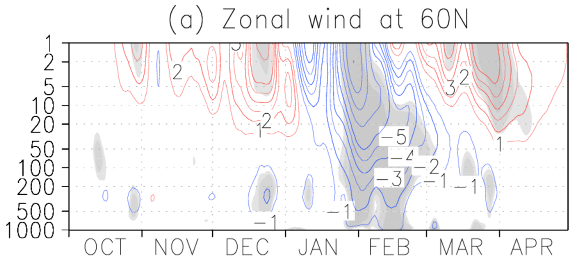

Figure 2. Winter seasonal evolution of anomalies of *N.ICE* compared with *CNTL* for zonal mean zonal wind at 60°N [m s^{-1}]. Contours and shading intervals are as in Figure 1.

integration of three sets of experiments with artificially suppressed stratosphere. The additional runs use same boundary condition with *CNTL* and *N.ICE*, but the zonal mean zonal wind above 10 (*CNTL10* and *N.ICE10*), 31.623 (*CNTL30* and *N.ICE30*), and 100 (*CNTL100* and *N.ICE100*) hPa were relaxed toward the climatological daily evolution of the *CNTL* run with minimum time scale of 1 day as shown in Figure 3.

Figure 4 shows vertical profiles of standard deviation of zonal mean zonal wind at 60N in January for *CNTL, CNTL10, CNTL30,* and *CNTL100* runs. While in the middle to upper stratosphere (above 50 hPa) interannual variations of the stratosphere-suppressed runs largely decrease compared with *CNTL*, in the upper troposphere/lower stratosphere (200–100 hPa) only the variation of *CNTL100* largely decreases compared with the other three runs. Furthermore, even in the troposphere, the variations of the stratosphere-suppressed runs slightly decrease compared with *CNTL*. This indicates that the stratospheric variations can affect the tropospheric circulation. It is thus not unrealistic to consider a possible link between sea ice reduction and negative phase shift of the NAO in late winter via the stratospheric path. To investigate the stratospheric influences on the tropospheric responses to the ice reduction in more detail, the sample size of the stratosphere-suppressed runs should be increased as even with *CNTL* and *N.ICE* runs.

References

Baldwin, M. P. and T. J. Dunkerton (1999), Downward propagation of the Arctic Oscillation from the stratosphere to the troposphere, *J. Geophys. Res., 104(D24),* 30937–30946, doi:10.1029/1999JD900445.

Baldwin, M. P. and T. J. Dunkerton (2001), Stratospheric harbingers of anomalous weather regimes, *Science, 294,* 581–584, doi:10.1126/science.1063315.

Nakamura. T., K. Yamazaki, K. Iwamoto, M. Honda, J. Ukita, Y. Miyoshi, Y. Ogawa (2014), A negative phase shift of the winter AO/NAO due to the recent Arctic sea ice reduction in late autumn, in preparation (soon submit to *Journal of Geophysical Research*).

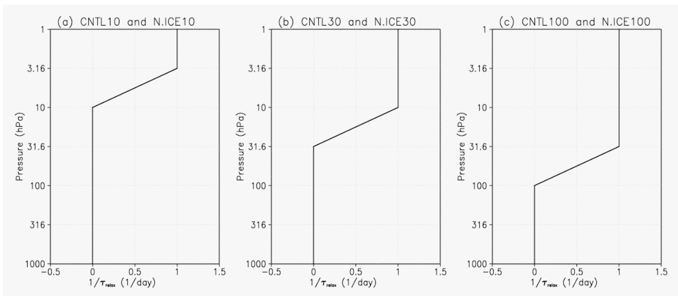

Figure 3. Vertical profiles of relaxation time for (a) *CNTL10* and *N.ICE10*, (b) *CNTL30* and *N.ICE30*, and (c) *CNTL100* and *N.ICE100.*

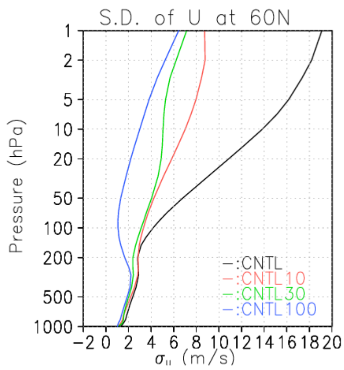

Figure 4. Vertical profiles of standard deviation of zonal mean zonal wind at 60N. Indication of line colors is denoted at bottom-right corner of the figure.