Prolonged Effect of the Stratospheric Pathway in Linking Barents-Kara Sea Sea Ice Variability to the Midlatitude Circulation in a Simplified Model

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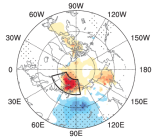
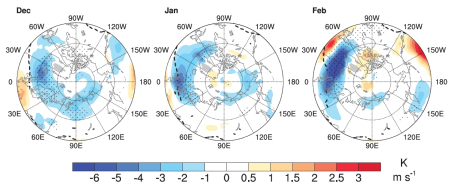
Motivations

- Observations indicate that the early winter Barents-Kara Sea (BKS) sea ice variability could affect the later winter midlatitude circulation response (e.g., Wu and Zhang, 2010; Koenigk et al., 2016; Yang et al., 2016; also see below). However, the underlying dynamical mechanism is not yet fully understood.

(a) Regression of Nov-Dec SAT to BKSIC_Nov



(b) Regression of 700hPa Uwnd to BKSIC_Nov

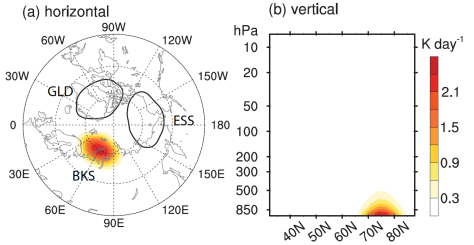


- Therefore, the major question to be addressed is: What is responsible for the prolonged midlatitude circulation response to BKS sea ice?

Idealized Model Experiments

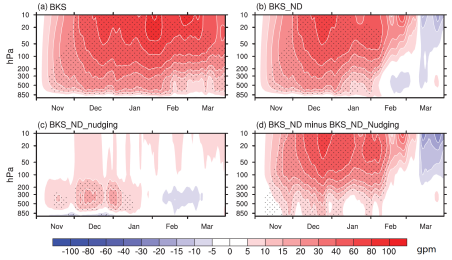
- Our hypothesis: stratospheric pathway and the long time scale of the stratosphere
- Model: GFDL dry dynamical core (Held and Suarez, 1994), a simple representation of the stratospheric polar vortex (Polvani and Kushner, 2002), an idealized seasonal cycle in both the troposphere and stratosphere (Kushner and Polvani 2006), and a realistic topography (Smith et al., 2010)
- Perturbation Experiments:

1. BKS: an imposed near-surface heating is added in the BKS region (see below), maximized during Nov. and Dec.
2. BKS_ND: similar to BKS run except that the heating is only applied during Nov. and Dec.
3. BKS_ND_Nudging: similar to BKS_ND run except that a nudging method is applied in the stratosphere to shut down the stratospheric pathway and thus explicitly isolate the tropospheric pathway

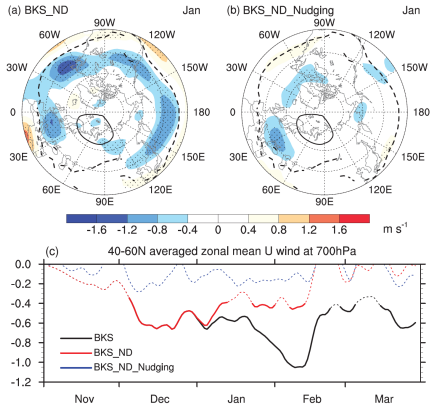


Prolonged Effect Due to Stratospheric Pathway

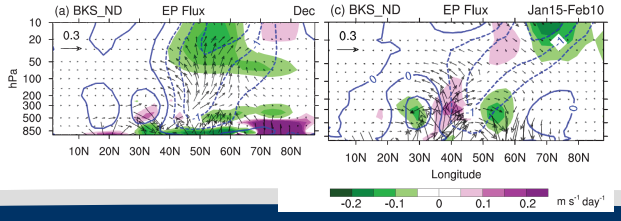
- Even though the surface heating is switched off after Jan. 1st, the circulation response still persists until early Feb., mainly due to the stratospheric pathway.



- More specifically, in Jan, about 70% of the midlatitude jet deceleration is attributed to Nov-Dec forcing, and during the first two weeks of Feb, about 40% of the response is due to Nov-Dec forcing.

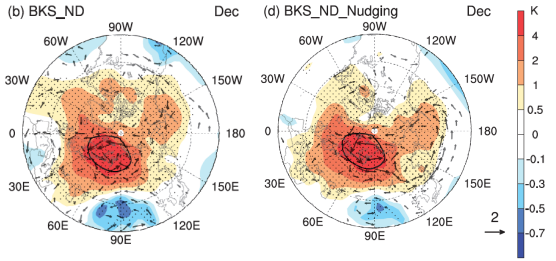


- The dynamical mechanism involves 1) linear constructive interference and anomalous upward propagation of planetary-scale waves, which weakens the stratospheric polar vortex, and 2) downward migration from the stratosphere to the troposphere and an equatorward shift of the midlatitude jet.



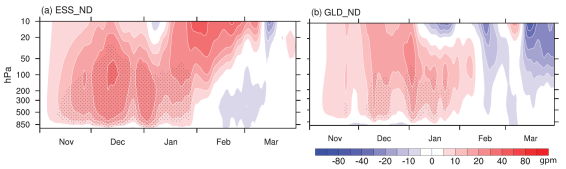
Induced Cold Winter over Central Asia

- A cold temperature anomaly occurs over central Asia and is largely amplified by the stratospheric pathway.



Sensitivity to Geographical Location of the Forcing

- Sensitivity to geographical location of the forcing is examined by shifting the surface heating to East Siberian Sea (ESS) and Greenland (GLD), and much weaker circulation response is found. Therefore, it suggests from the idealized model experiments that the BKS region is the most effective in influencing the midlatitude circulation than other regions over the Arctic.



Conclusions

1. The idealized model is able to reproduce the persistent winter circulation response during Jan-Feb with an imposed near-surface heating during Nov-Dec.
2. With an explicit separation of the tropospheric and stratospheric pathway, the prolonged midlatitude circulation response is largely due to the stratospheric pathway.
3. An induced cold anomaly is simulated over central Asia and the stratospheric pathway also acts to amplify and extend the cold events in the region.
4. Midlatitude circulation response is sensitive to the geographical location of the forcing. The BKS region is found the most effective in influencing the midlatitude circulation response than other regions over the Arctic.

References

- Wu and Smith (2016) Response of Northern Hemisphere Midlatitude Circulation to Arctic Amplification in a Simple Atmospheric General Circulation Model. J. Climate, 29, 2041-2058.
- Zhang, Wu and Smith (2017) Prolonged Effect of the Stratospheric Pathway in Linking Barents-Kara Sea Sea Ice Variability to the Midlatitude Circulation in a Simplified Model. Clim. Dyn., under revision.