Drivers of Polar Stratospheric Circulation During Recent Low Arctic Sea Ice Years

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1. Introduction

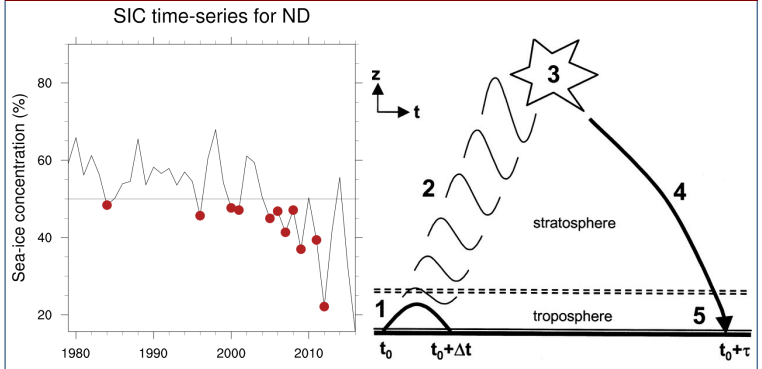

Figure 1. (Left): Time series of the observed sea ice concentration in November-December averaged over Barents-Kara Seas. (Right): Schematic illustration of the proposed recent Arctic sea ice loss effect via the stratosphere. The figure is taken from Reichler et al. (2005).

Question: What drivers explain the recent weak stratospheric polar vortex (e.g., Arctic sea ice loss, ENSO, QBO)?

2. Data and Methodology

We use ERA-40/Interim and 10-member AMIP-style historical simulations with the "higher-top" version of NCAR's climate model CAM5 (denoted L46-CAM5). L46-CAM5 has ***internally-generated*** quasi-biennial oscillation (QBO) and improved seasonal cycle of stratospheric sudden warming (SSW) frequencies than the default "low-top" version (Richter et al. 2015 and Figure 2).

The Arctic sea ice loss effect is evaluated by constructing the composite for standardized polar-cap geopotential height based on 11 years of low sea ice concentration in November-December in the Barents-Kara Seas (1984, 1996, 2000, 2001, 2005, 2006, 2007, 2008, 2009, 2011, 2012; see Figure 1).

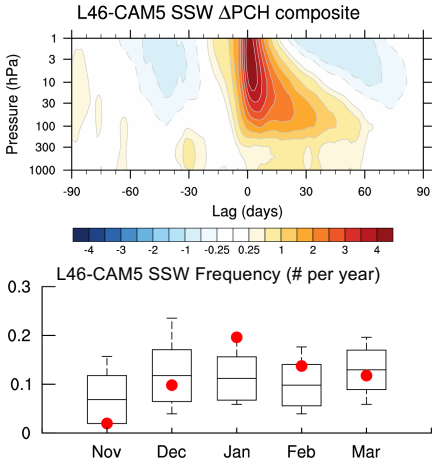

Figure 2. (Top): Composite of the standardized polar-cap geopotential height with respect to SSW for L46-CAM5. **(Bottom):** Seasonal cycle of the SSW frequency in L46L-CAM5. The red dot indicates the reanalysis results. The box-plots show the mean values (solid horizontal line), plus and minus one standard deviation (box outline), minimum and maximum values (whiskers) across all ensembles.

3. OBS Polar-cap Height Composite

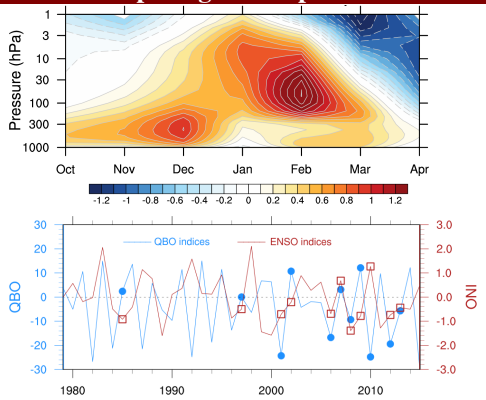

Figure 3. (Top) Composite of the standardized polar-cap geopotential height based on 11 years of low sea ice in the Barents-Kara Seas using ERA-Interim data, **(Bottom)** Observed winter QBO (blue line) and ENSO (red line) indices. The dot and square denote the QBO and Nino3.4 values for those 11 low Arctic sea ice years, respectively.

4. Model Polar-cap Height Composite

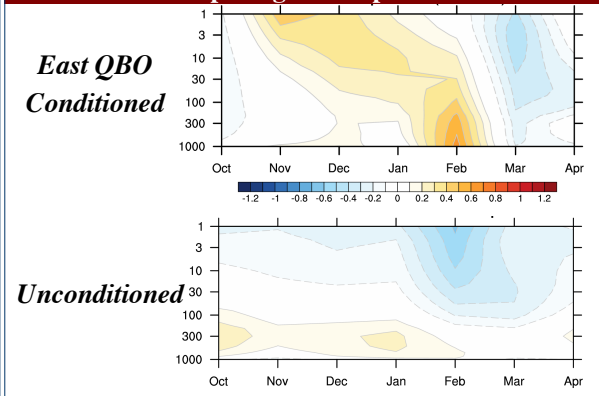

Figure 4. (Top) Composite of the standardized polar-cap geopotential height based on 11 years of low sea ice in the Barents-Kara Seas using L46-CAM5 data conditioned by East QBO. **(Bottom)** As in Top, but for all simulations (110 samples) for low ice years in the Barents-Kara Seas.

5. Key Points

- The weakened stratospheric polar vortex during recent low Arctic sea ice years is mostly due to atmospheric variability, linked especially to a prevailing east-phase QBO in those years.
- The forced signal is of a strengthened stratospheric polar vortex during recent low Arctic sea ice years due to the La Niña signal, whose impact is opposite in sign to the observed composite.
- A forced signal of sea ice loss impact on stratospheric polar vortex alone is judged to be small compared to other forced signals, and especially small compared to atmosphere internal variability.

6. References

- Kim, B.-M., S.-W. Son, S.-K. Min, J.-H. Jeong, S.-J. Kim, X. Zhang, T. Shim, and J.-H. Yoon, 2014: Weakening of the stratospheric polar vortex by Arctic sea-ice loss. *Nature Communication*., 5, 4646, doi:10.1038/ncomms5646.
- Reichler, T., P. Kushner and L. Polvani, 2005: The Coupled Stratosphere–Troposphere Response to Impulsive Forcing from the Troposphere, *Journal of the Atmospheric Sciences*, 62, 3337-3352.
- Richter, J. H., Clara Deser and Lantao Sun, 2015: Effects of Stratospheric Variability on El Nino Teleconnections, *Environ. Res. Lett.*, doi: http://dx.doi.org/10.1088/1748-9326/10/12/124021

Box: Polar-cap Height Composite with Respect to ENSO and QBO

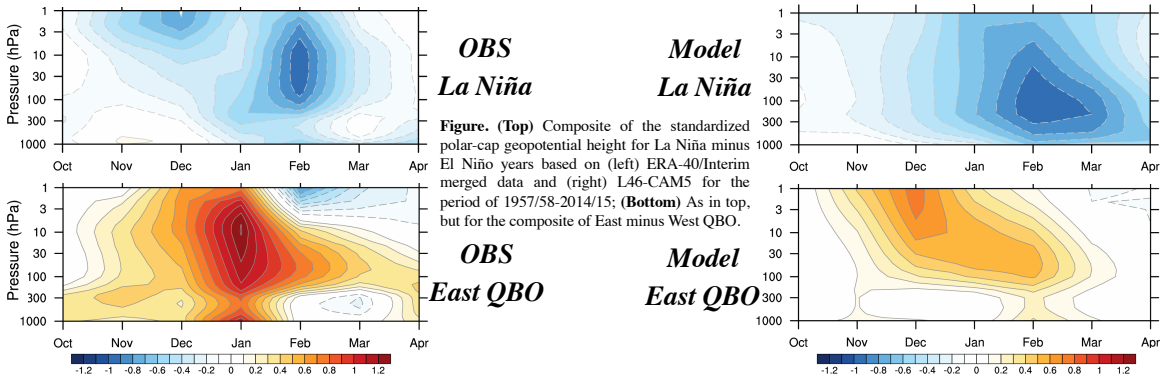

Figure. (Top) Composite of the standardized polar-cap geopotential height for La Niña minus El Niño years based on (left) ERA-40/Interim merged data and (right) L46-CAM5 for the period of 1957/58-2014/15; **(Bottom)** As in top, but for the composite of East minus West QBO.