Effect of Recent Sea Surface Temperature Trends on the Arctic Stratospheric Vortex

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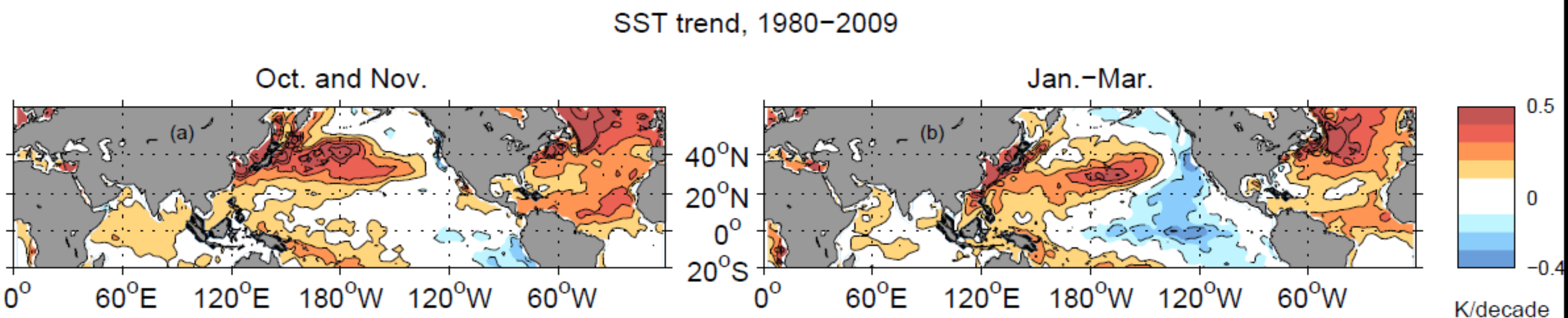
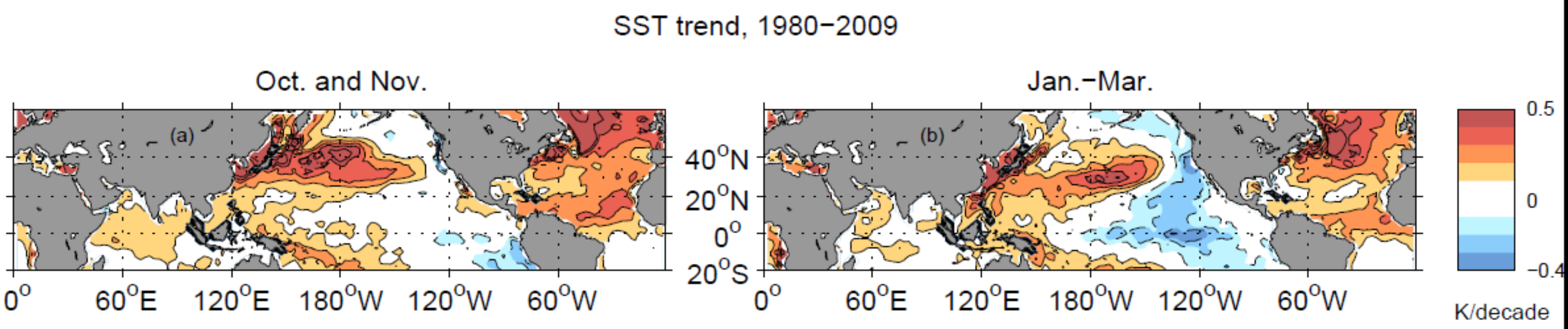


Sea surface temperature (SST) trends

Link between SSTs and Vortex on Interannual/ decadal Timescales

1. Warm phase of Atlantic multi-decadal variability leads to a weakened early winter vortex (Schimanke et al., 2011; Omrani et al., 2013).
2. Colder sea surface temperatures in the North Pacific lead to a weakened vortex (Jadin et al., 2010; Hurwitz et al., 2011, 2012).
3. El Nino leads to a weaker vortex, and La Nina (possibly) to a stronger vortex (Manzini et al., 2006, Garfinkel and Hartmann 2007).
4. Warmer Indian Ocean sea surface temperatures lead to a stronger vortex (Fletcher and Kushner 2011). As El Nino events typically include warmer Indian Ocean temperatures as well, this effect reduces the apparent impact of El Nino on the stratospheric vortex.

Trend in SSTs over the satellite era



Indian, North Pacific, and North Atlantic basins warm, while tropical Pacific SSTs shift towards La Nina.

Based on previous work, the first, second, and fourth of these lead to a stronger late winter vortex.

What is the net impact of changing SSTs in all of these basins on Arctic stratospheric temperature and ozone?

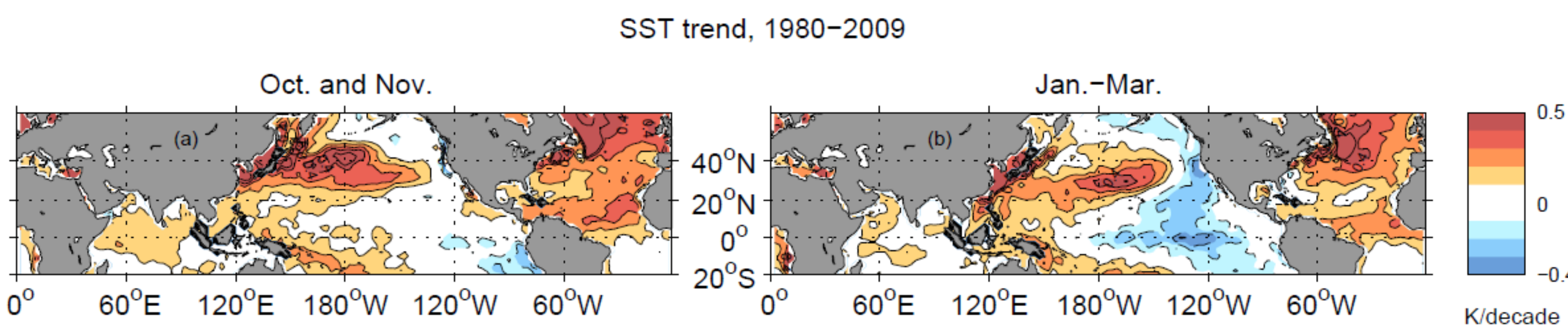
Methodology

Analyze two ensemble of GEOSCCM integrations, each contains 10 members:

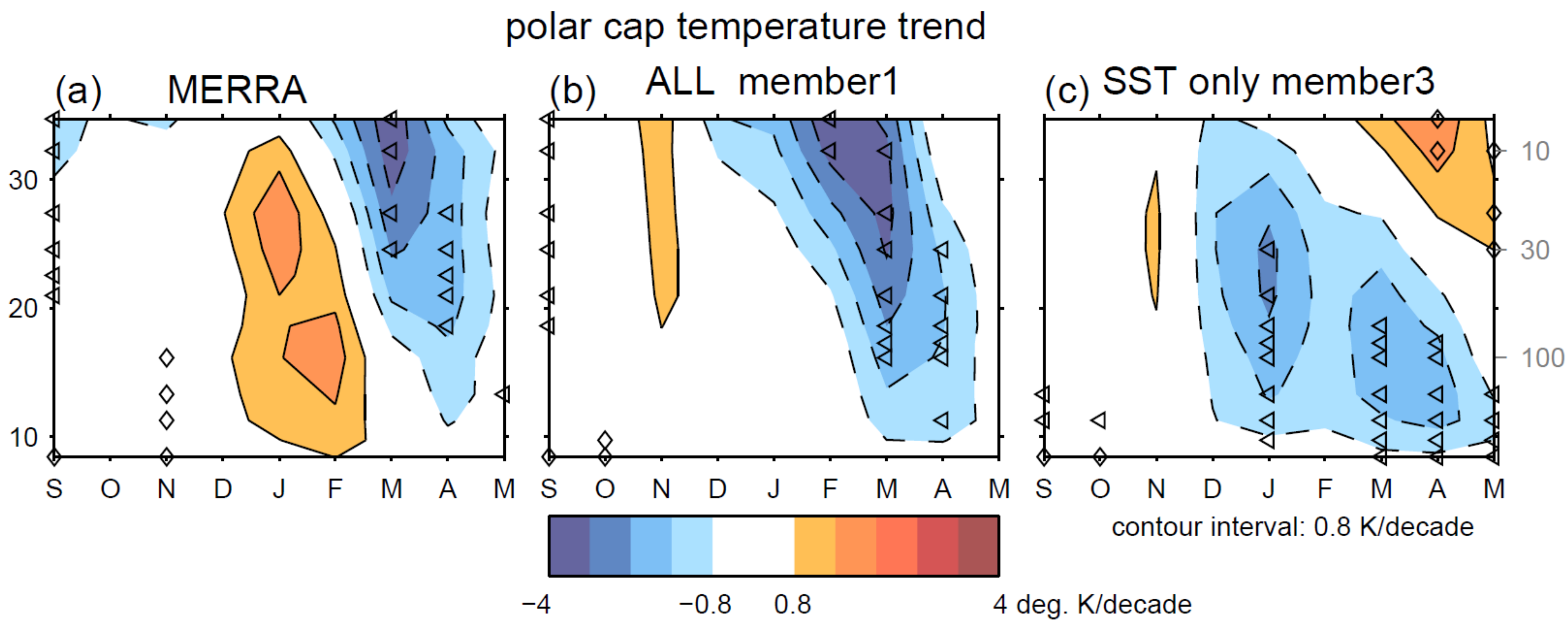
A) SST only The only externally imposed variability is that the SSTs simulate those observed during the years 1980 to 2009. ODS concentrations are fixed.

B) ALL forcings Both gas concentrations (CO_2, ODS, N_2O, CH_4, and others) and SSTs change to follow that observed from 1980 to 2009

We thus isolate the impact that changing SSTs have had on these temperature trends.

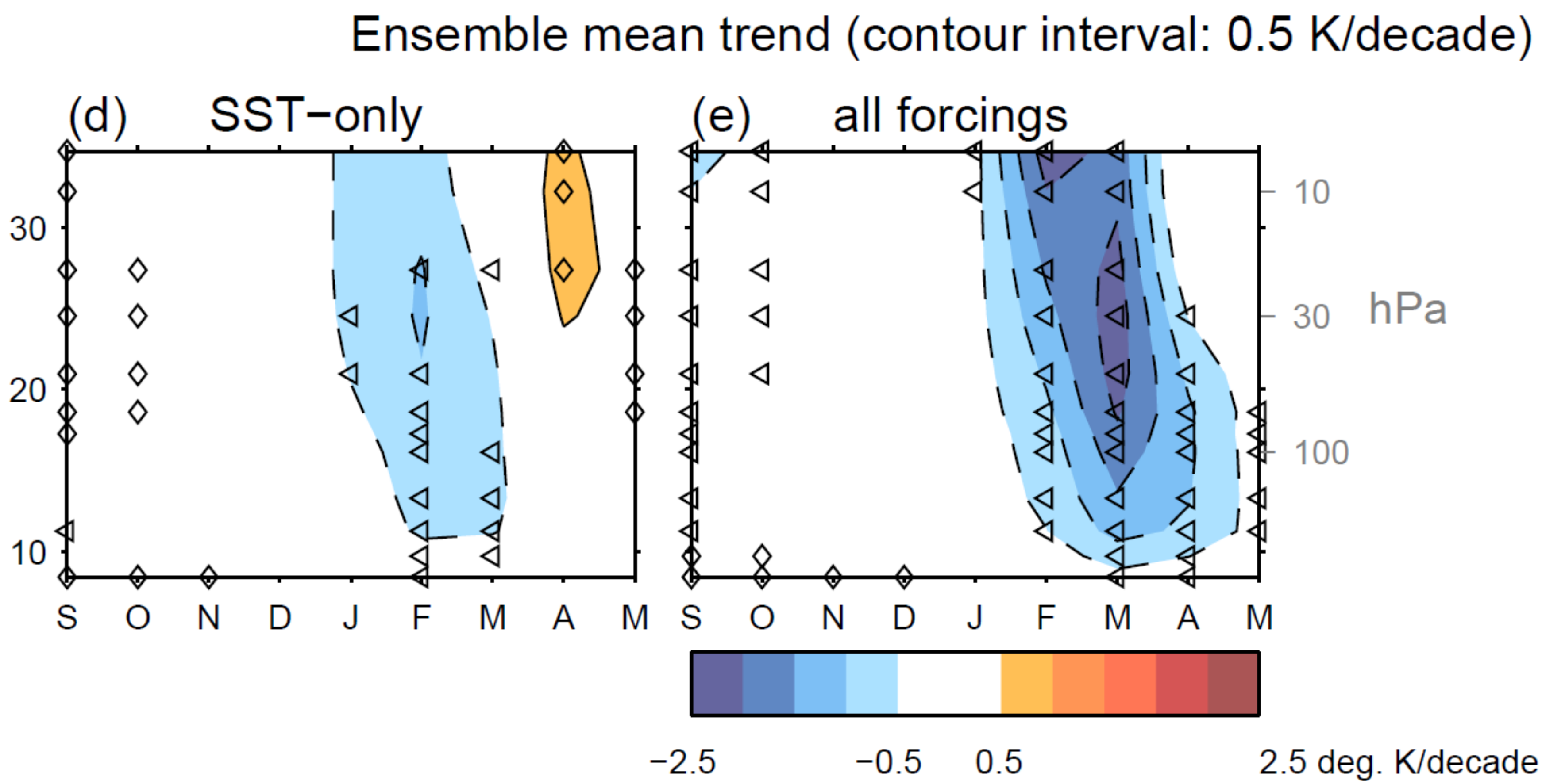


Polar Cap Temperature Trends



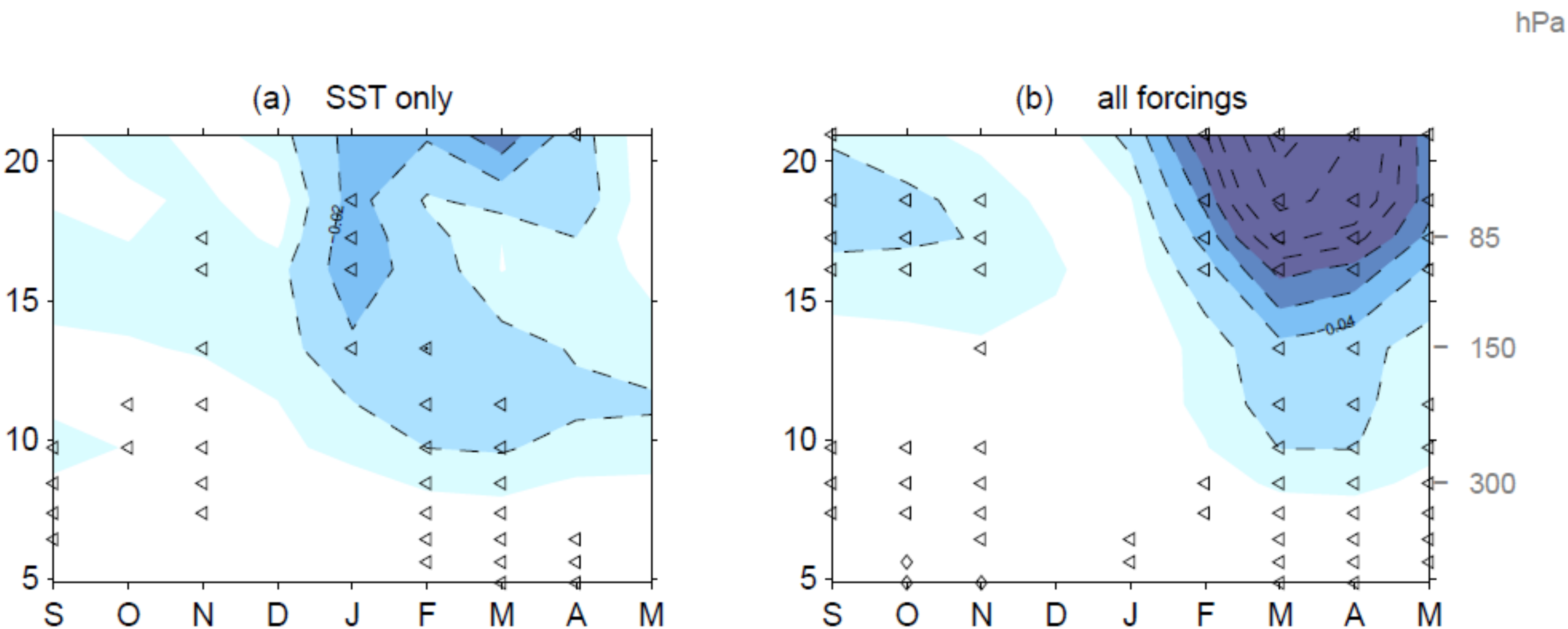
- Significant cooling trend in MERRA (and also in MSU data) in springtime (e.g Bohlinger et al 2014)
- This effect is captured by individual ensemble members in both ensembles

Polar Cap Temperature Trends



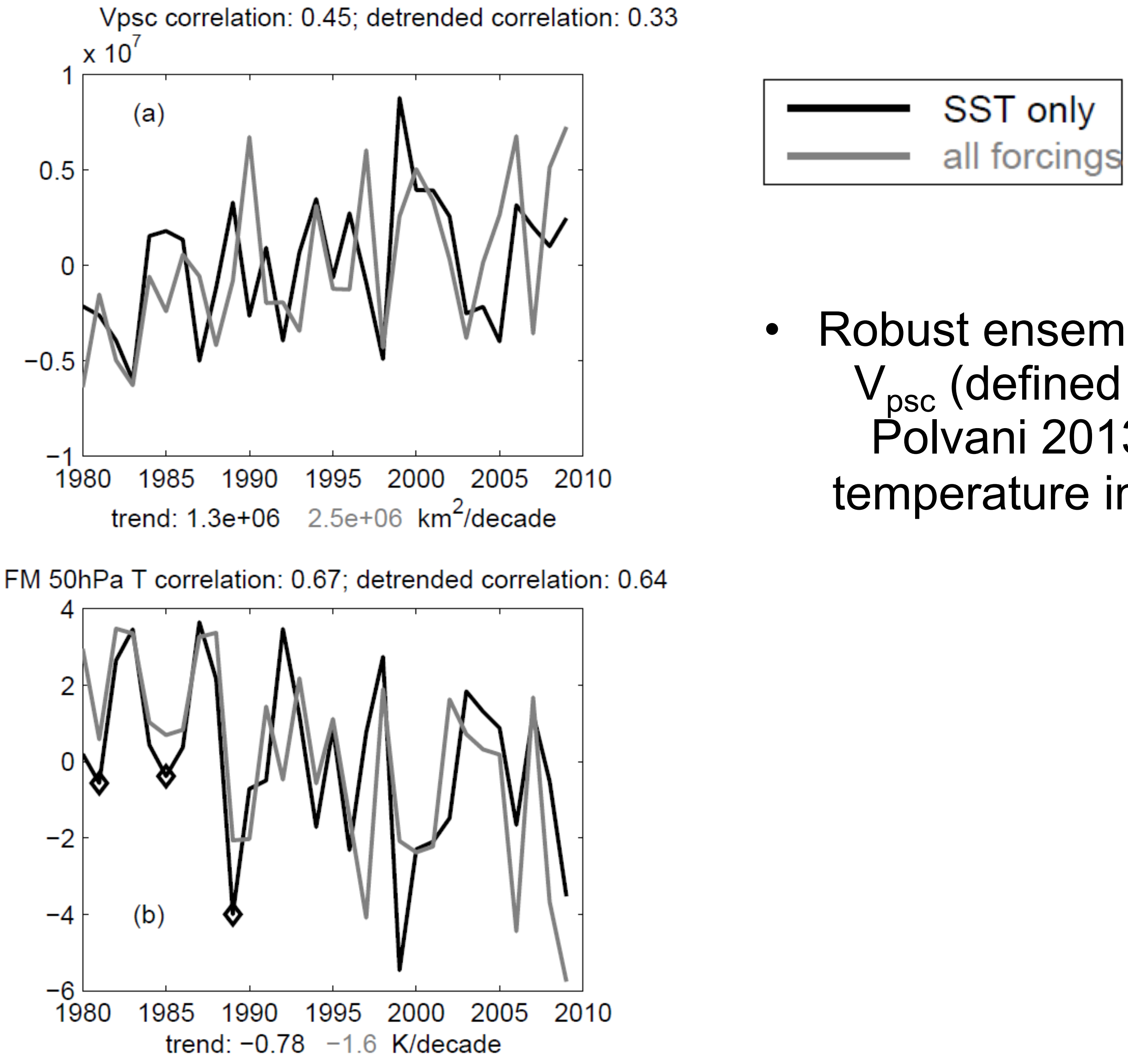
- Ensemble mean response reflects the forced response
- In both ensembles we find robust polar cap cooling (robustness indicated by the triangles).
- Up to half of the cooling is capture in the SST only ensemble.

Polar Cap Ozone Trends



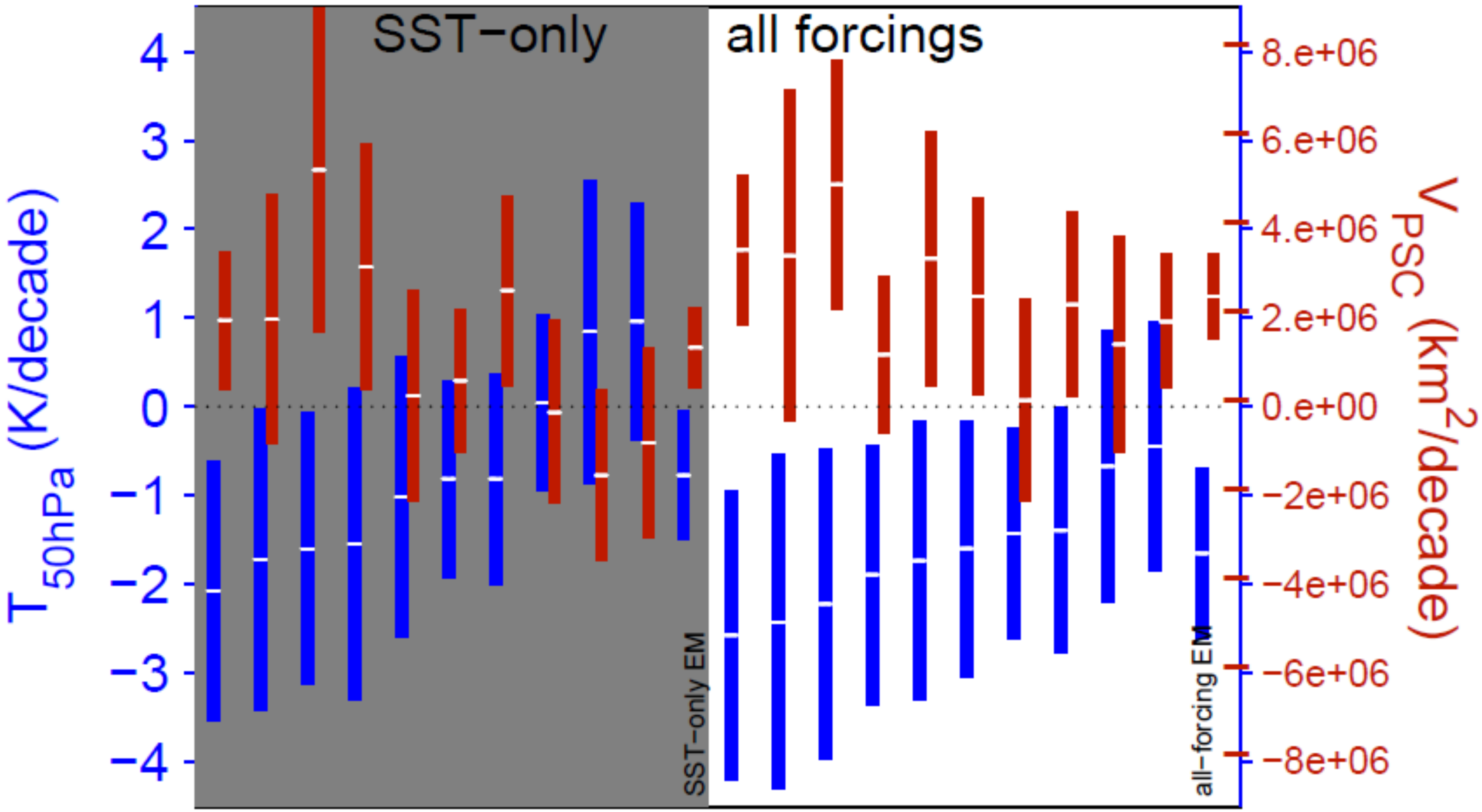
- Robust ensemble mean reduction in ozone in both ensembles (robustness indicated by the triangles).

Interannual Variability in Polar Cap T and V_{psc}



- Robust ensemble mean trends in V_{psc} (defined as in Rieder and Polvani 2013) and polar cap temperature in both ensembles.

Trends for Each Ensemble Member



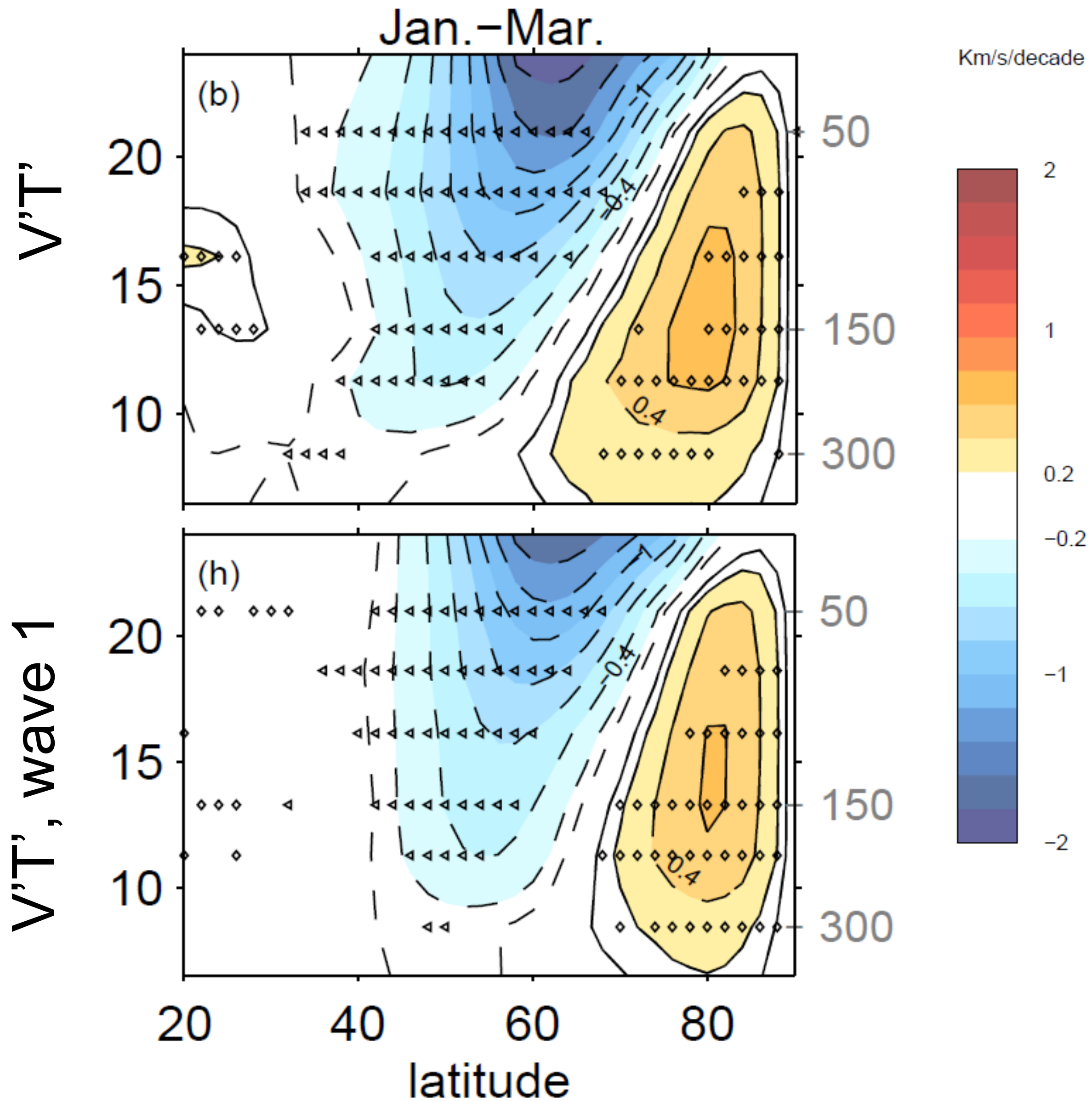
Length of bar represents 90% confidence interval

- Very important to consider large ensembles.

A) Individual ensemble members for both ensembles simulate no trend in either quantity

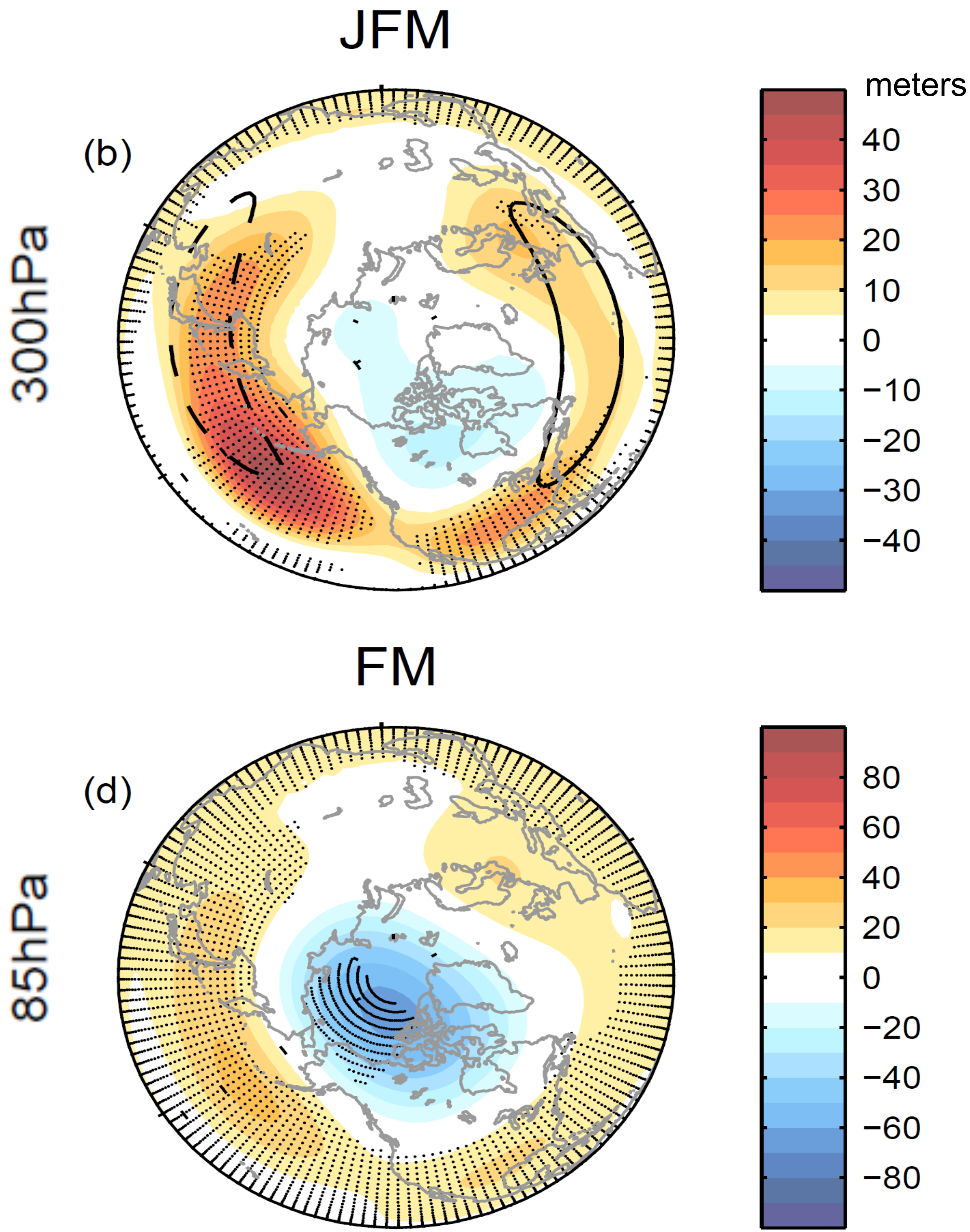
B) Other individual ensemble members for both ensemble simulate statistically significant trends

Trend in heat flux



- In ensemble mean, significantly less heat flux in JFM.
- This reduction is due to the wavenumber 1 component of the heat flux.

What drives the wavenumber 1 trends?

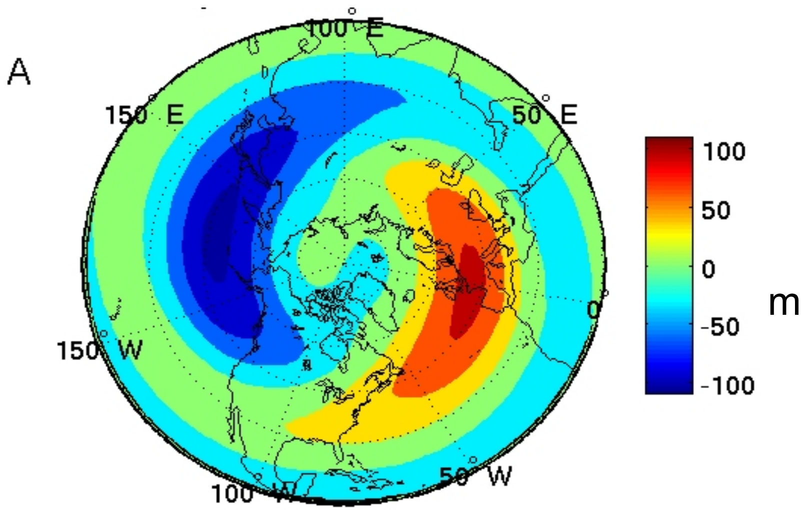


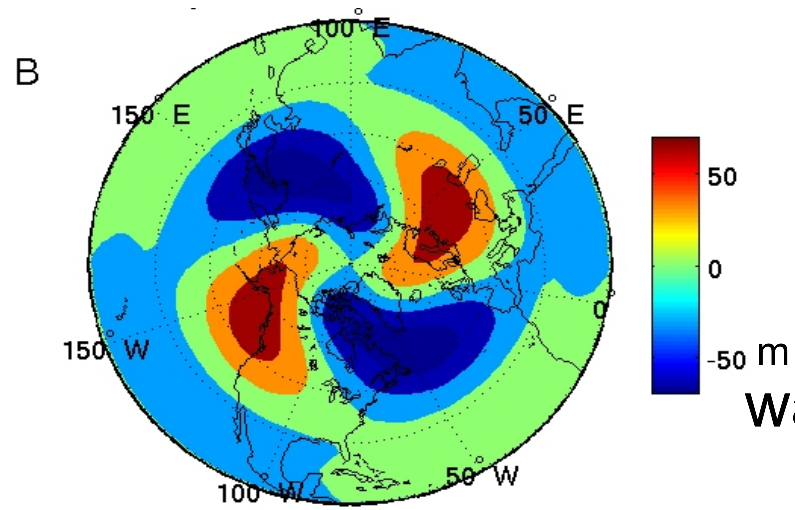
- Ridging develops over the North Pacific basin moreso than other regions
- Net effect projects strongly on wavenumber 1.
- This ridging is consistent with the La Nina tropical SSTs, warming of the Indian Ocean, and warming of the North Pacific

How does a North Pacific ridge weaken the vortex?

Climatology of NDJF Tropospheric Geopotential Height

wave 1



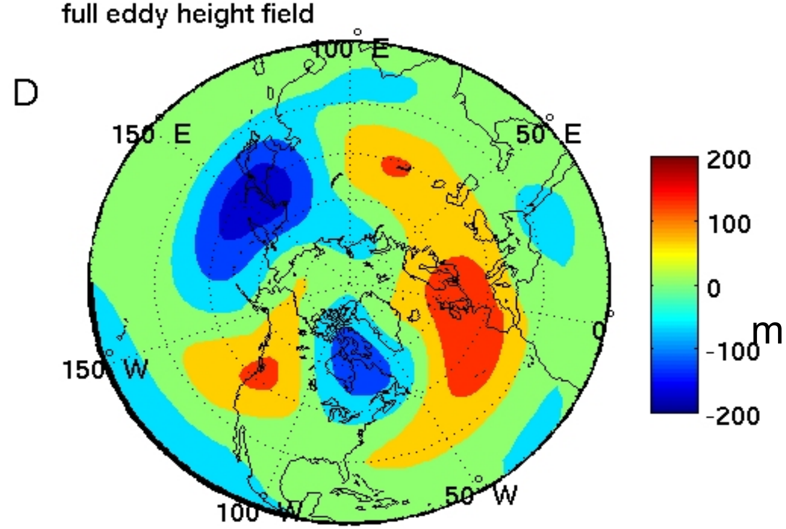


wave 2

geopotential height at 500.0 hPa

Stationary planetary waves that are generated by surface forcing can propagate upwards to the stratosphere.

full eddy height field



total

•A ridge collocated with these climatological regional asymmetries will reduce wave-1 EP flux leaving the troposphere and affecting the stratosphere, as we showed a few slides ago.

Conclusions

•Sea surface temperatures have warmed over most oceanic basins over the satellite era.

•These SST trends have led to cooling of the late winter vortex (as has been observed) and ozone depletion.

•Up to a half of the trend in the All forcing ensemble is associated with SST trends.

•The most important region appears to be the Pacific sector, where more frequent La Nina events, warming North Pacific SSTs, and warming Indian Ocean SSTs lead to a subpolar ridge which reduces wavenumber 1 heat flux.

Garfinkel, C. I. M. M. Hurwitz, and L. D. Oman (submitted to Journal of Geophysical Research: Atmospheres), Effect of Recent Sea Surface Temperature Trends on the Arctic Stratospheric Vortex**.

Garfinkel, C.I., D.L. Hartmann, and F. Sassi (2010), Tropospheric Precursors of Anomalous Northern Hemisphere Stratospheric Polar Vortices, J. Clim.

Thanks for listening!