Mechanisms for Linkages between Arctic Amplification and Mid-Latitude Weather, and Their Representation in Models

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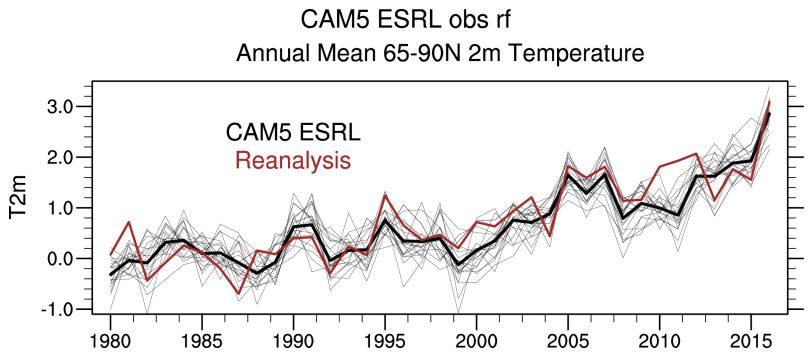
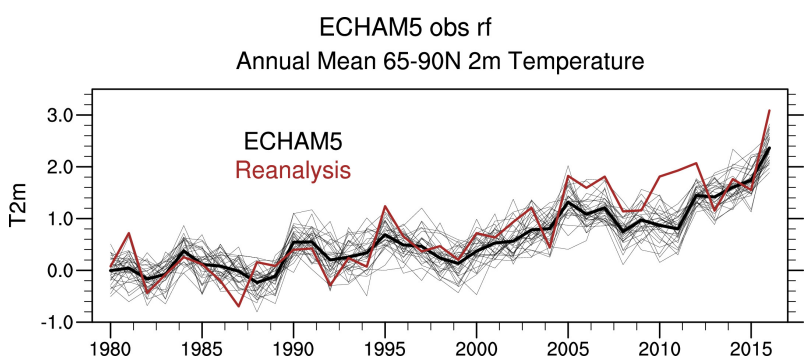
- **Arctic tropospheric warming and its causes**
- **Stratospheric pathway of Arctic change-lower latitude linkages**

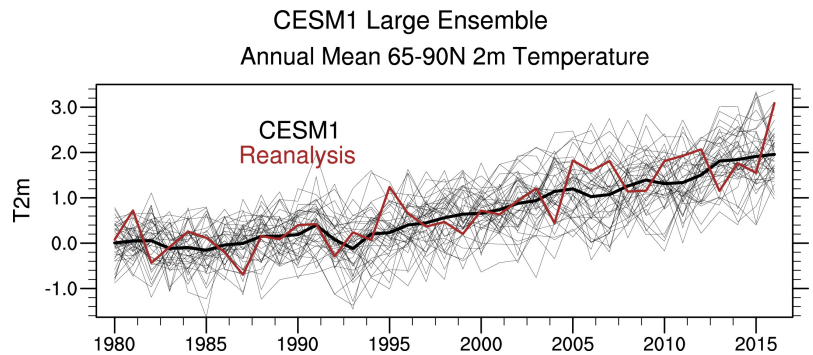
Models capture "observed" changes in Arctic Near Surface Warming since 1980

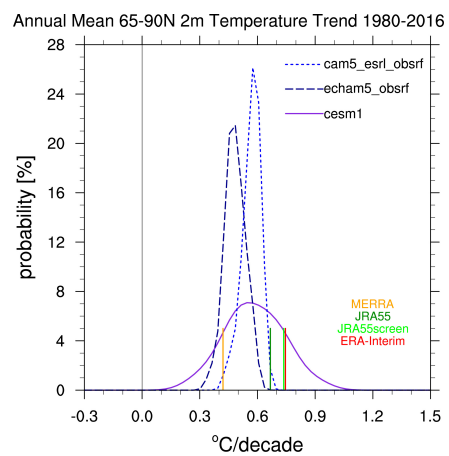
Atmospheric Model Simulations forced with observed changes in SIC, SST and radiative forcings





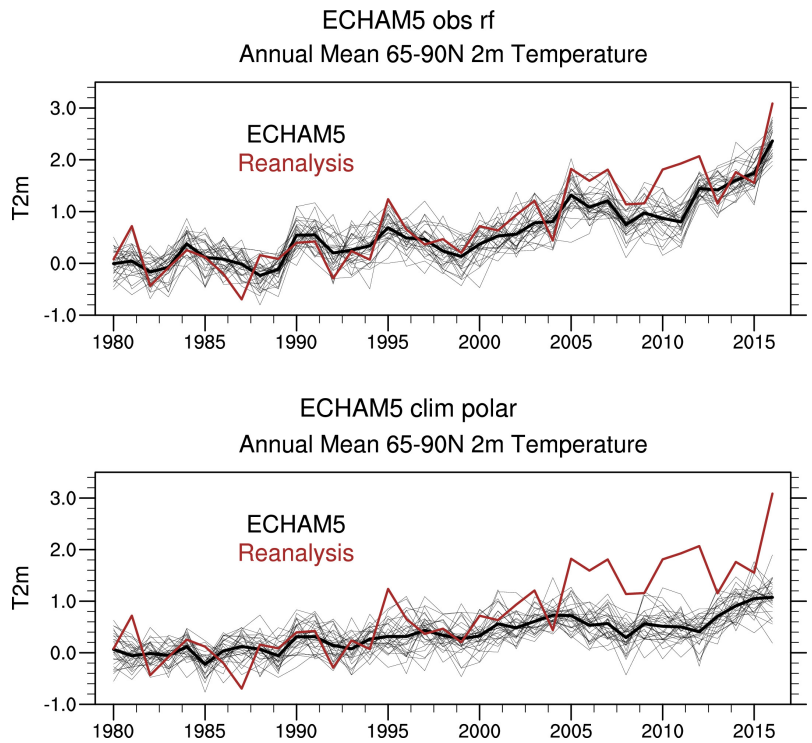
Coupled Model Simulation forced with observed radiative forcings/RCP8.5

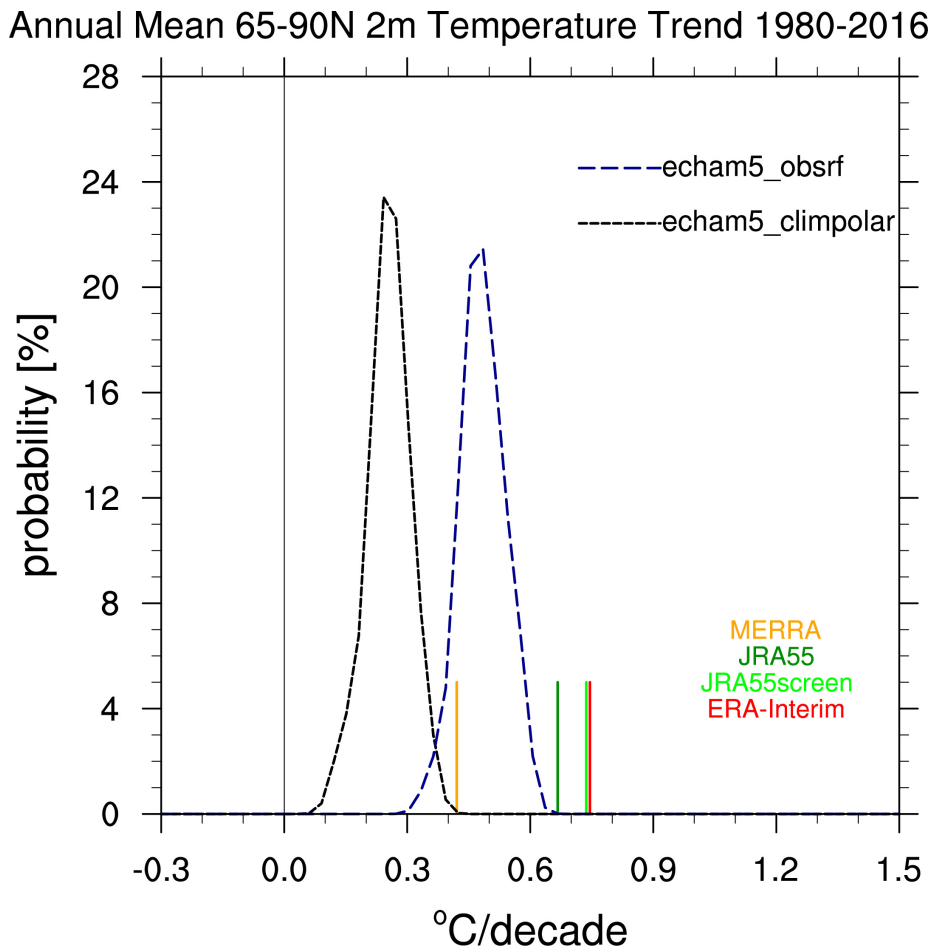




Arctic sea ice loss is an important driver of near surface temperature change in the Arctic

Atmospheric Model Simulations forced with observed changes in SIC, SST and radiative forcings

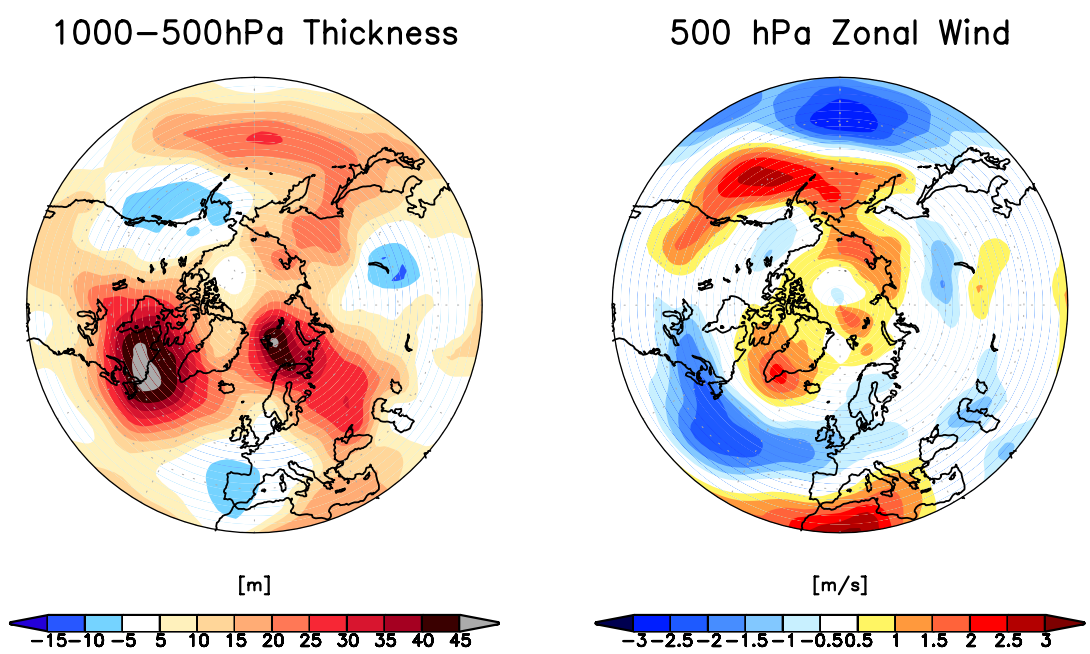




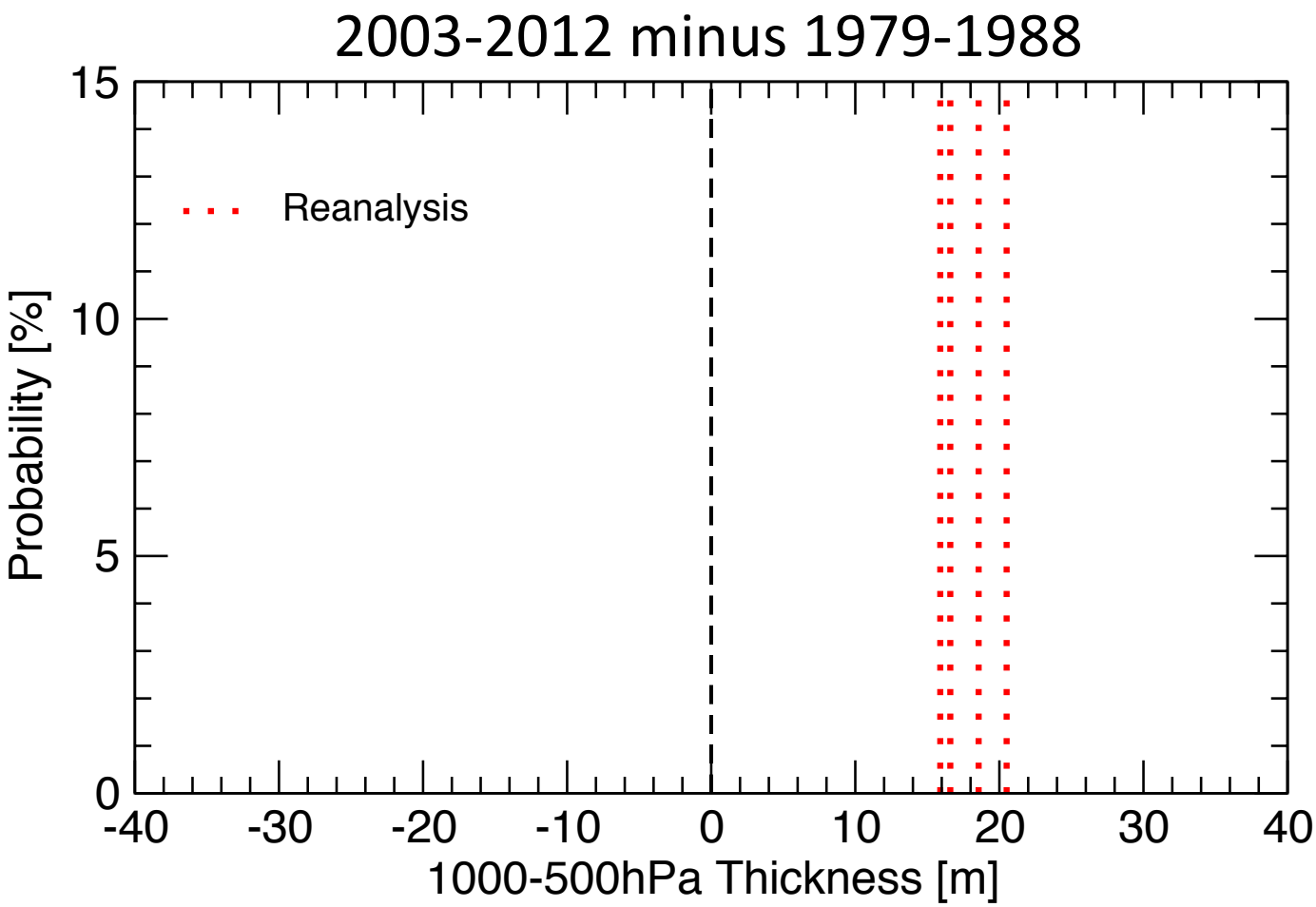
What are the Causes of Arctic Tropospheric Warming?

Decadal change in OND 1000-500hPa Thickness and Zonal Mean Zonal Wind

2003-2012 minus 1979-1988



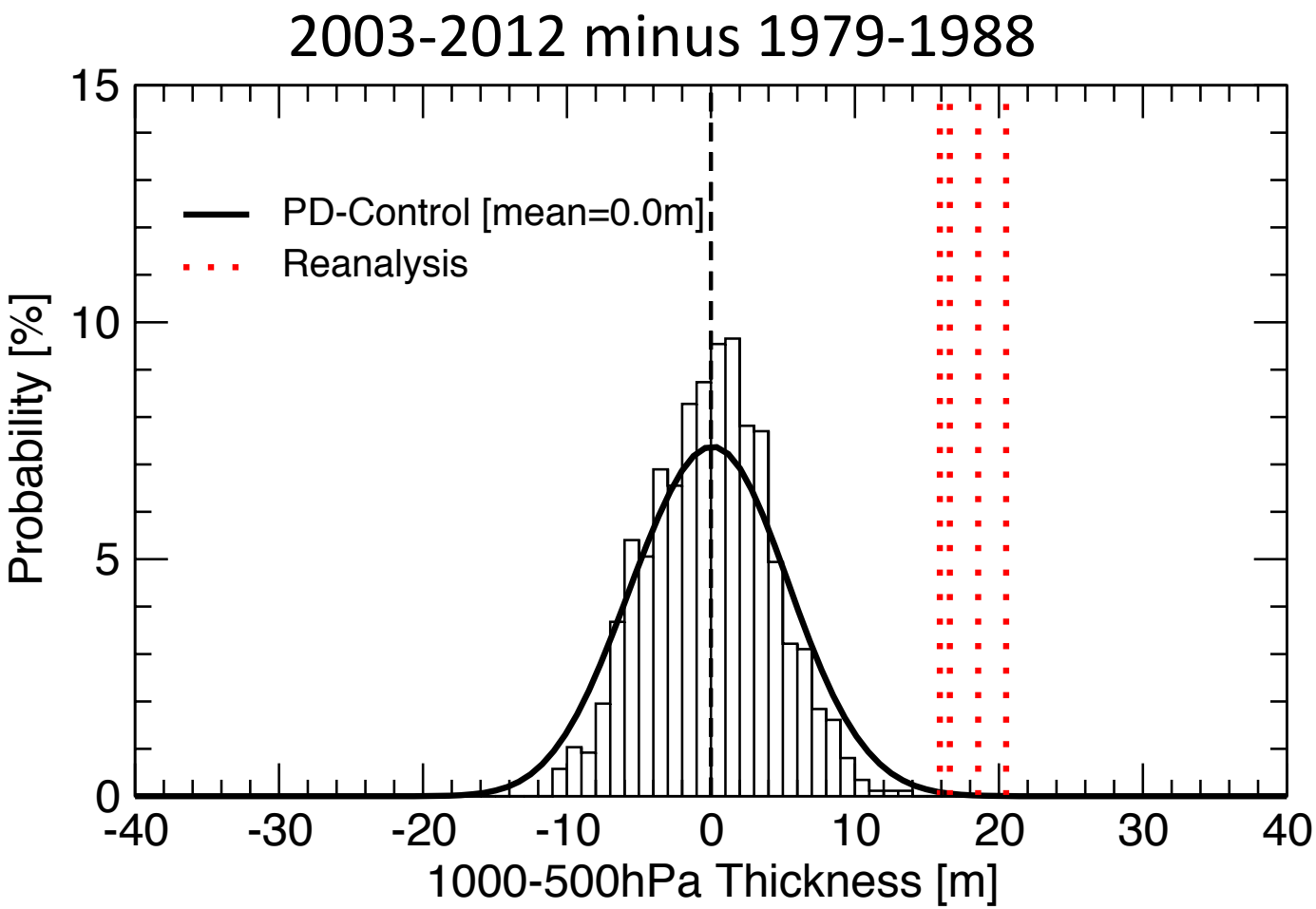
Polar Cap (60-90N) 1000-500hPa Thickness Difference during OND



Observed polar cap thickness change amounts to about 18m which corresponds to a deep tropospheric warming of about 1K.

Perlwitz et al. 2015

Polar Cap (60-90N) 1000-500hPa Thickness Difference during OND

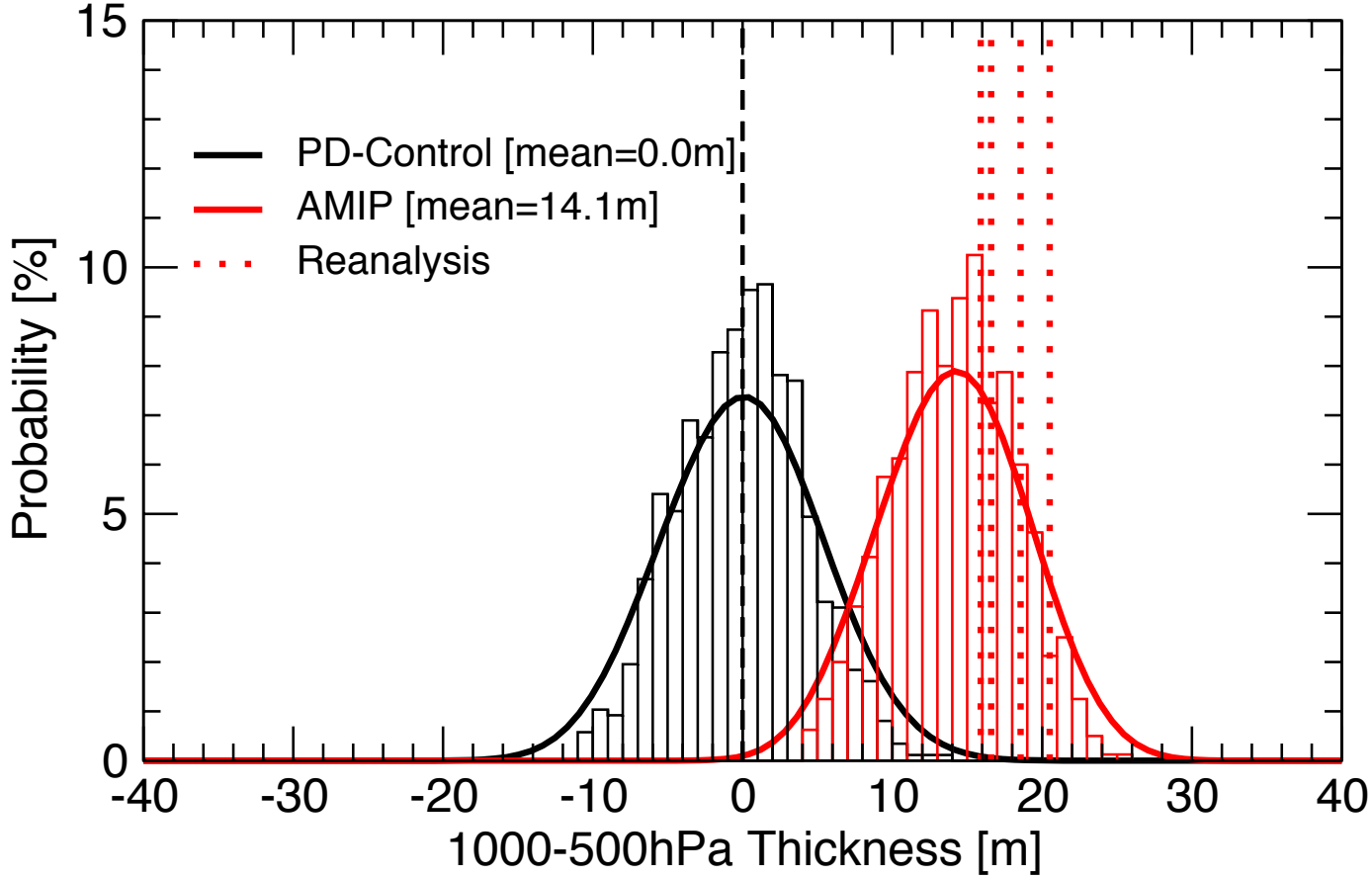


Observed thickness change amounts to about 5 standard deviations of internal atmospheric variability estimated from Present-Day control run suggesting that Arctic tropospheric warming is mainly forced.

Perlwitz et al. 2015

Polar Cap (60-90N) 1000-500hPa Thickness Difference during OND

2003-2012 minus 1979-1988

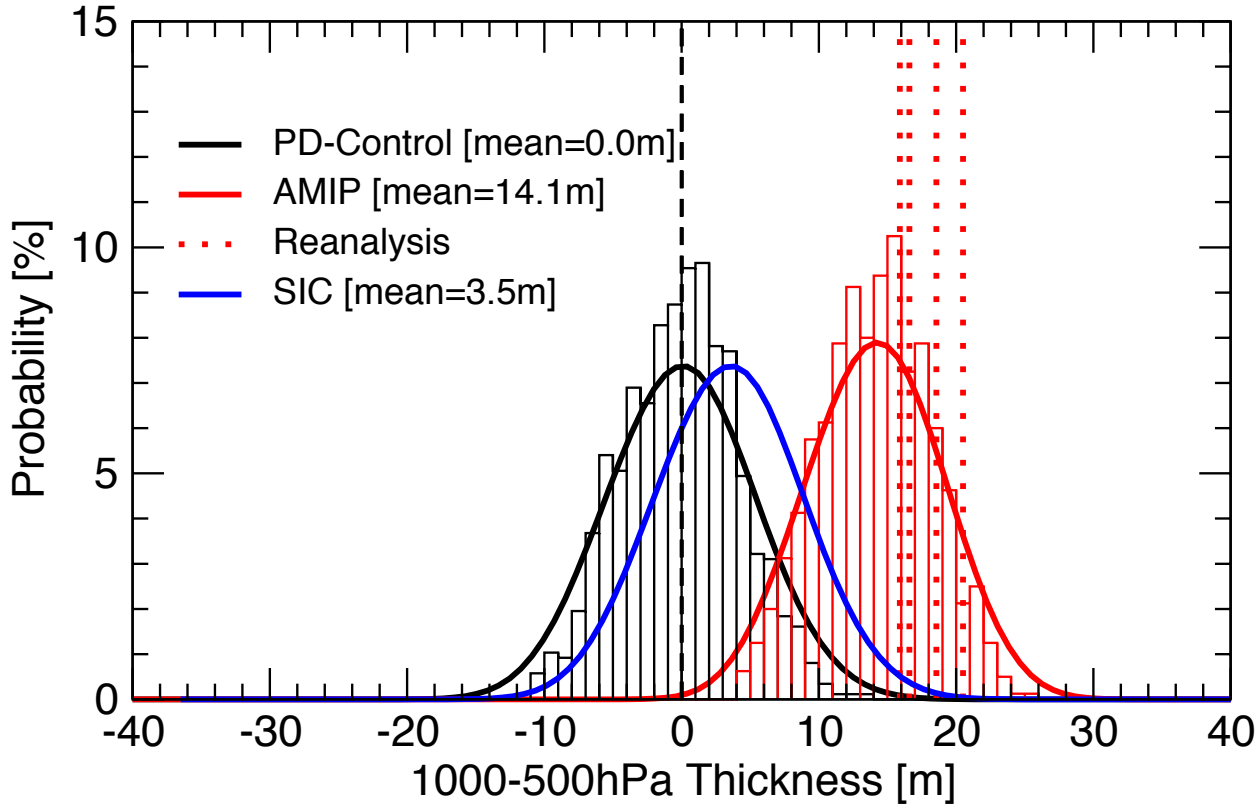


Observed polar cap thickness change is consistent with a combined impact of observed lower boundary changes and changes in radiative forcings.

Perlwitz et al. 2015

Polar Cap (60-90N) 1000-500hPa Thickness Difference during OND

2003-2012 minus 1979-1988

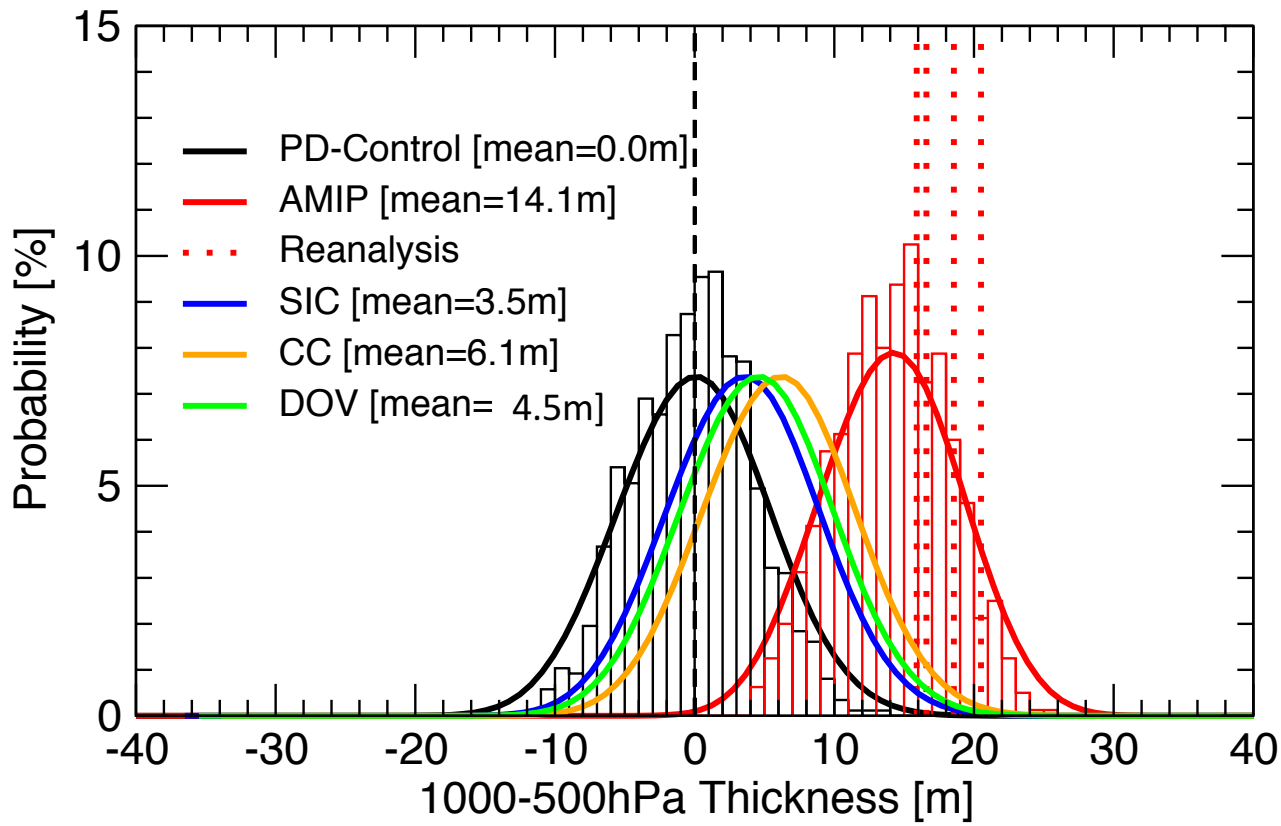


Effect of sea ice loss on polar cap thickness change is of the magnitude of internal atmospheric variability and thus its effect on Arctic deep tropospheric warmings is not detectable. ***(~20%)***

Perlwitz et al. 2015

Polar Cap (60-90N) 1000-500hPa Thickness Difference during OND

2003-2012 minus 1979-1988



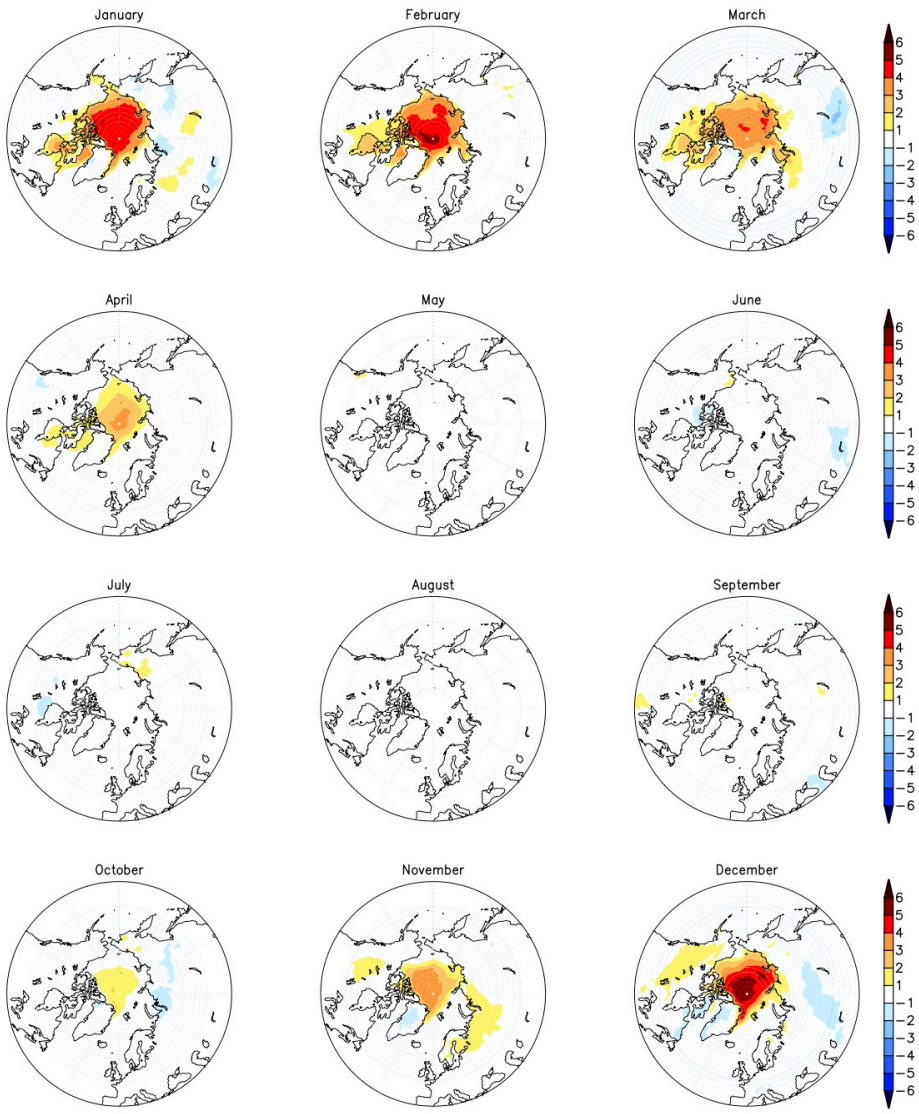
SST changes outside the polar cap are the main contributor to observed Arctic polar cap thickness change. These SST changes result from recent decadal ocean variability and a long-term climate change contribution. ***(~60%)***

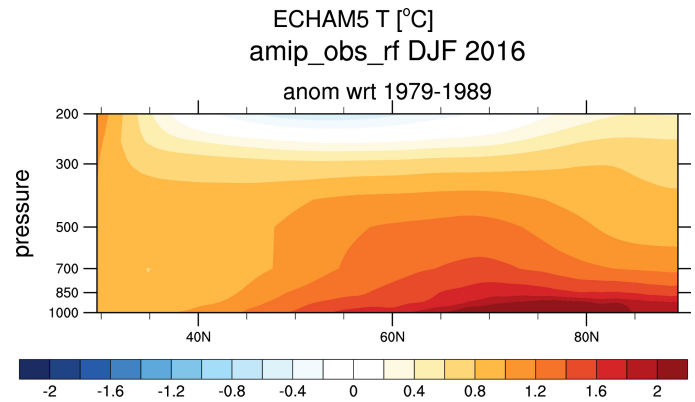
Perlwitz et al. 2015

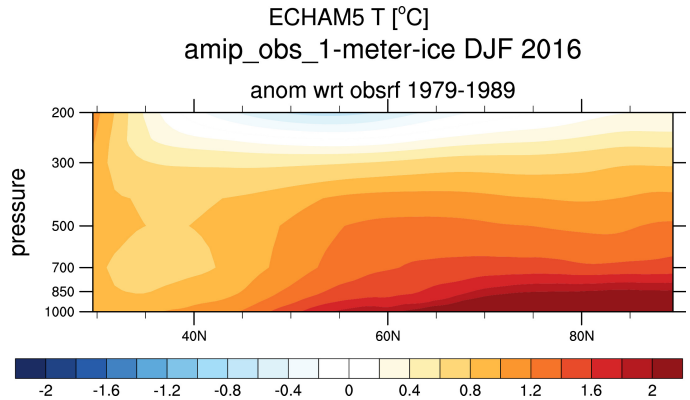
Model Errors Potentially Affecting Proper Simulation of Arctic Lower Latitude Linkages

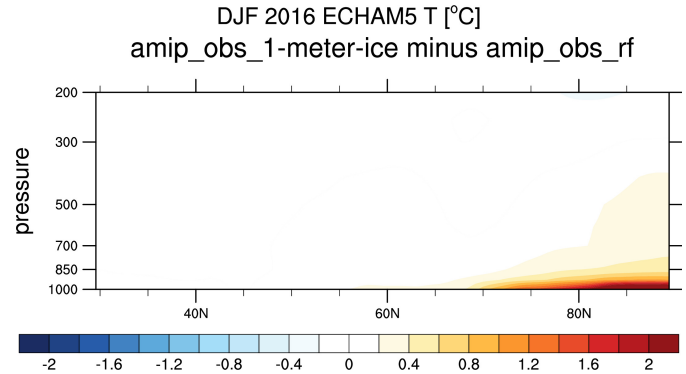
- Sea-ice–atmosphere coupling
- Energy fluxes and cloud properties
- Attribution studies do not account for changes in Arctic sea ice thickness
- Stratosphere-troposphere coupling

Sensitivity to Sea Ice Thickness Change- Strong Impact on Arctic Near Surface Temperature in Cold Season, Impact is Confined to the Lowermost Troposphere

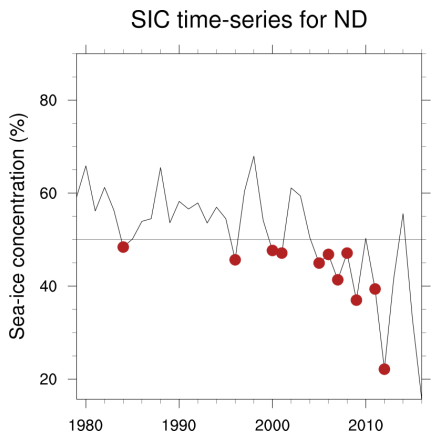


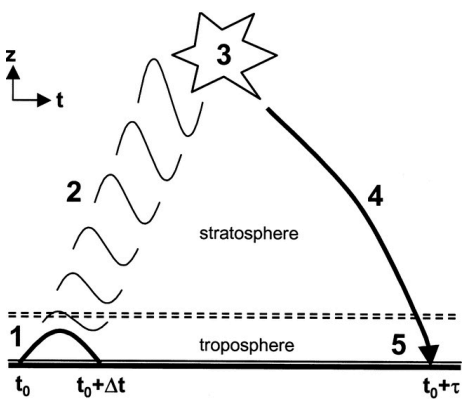




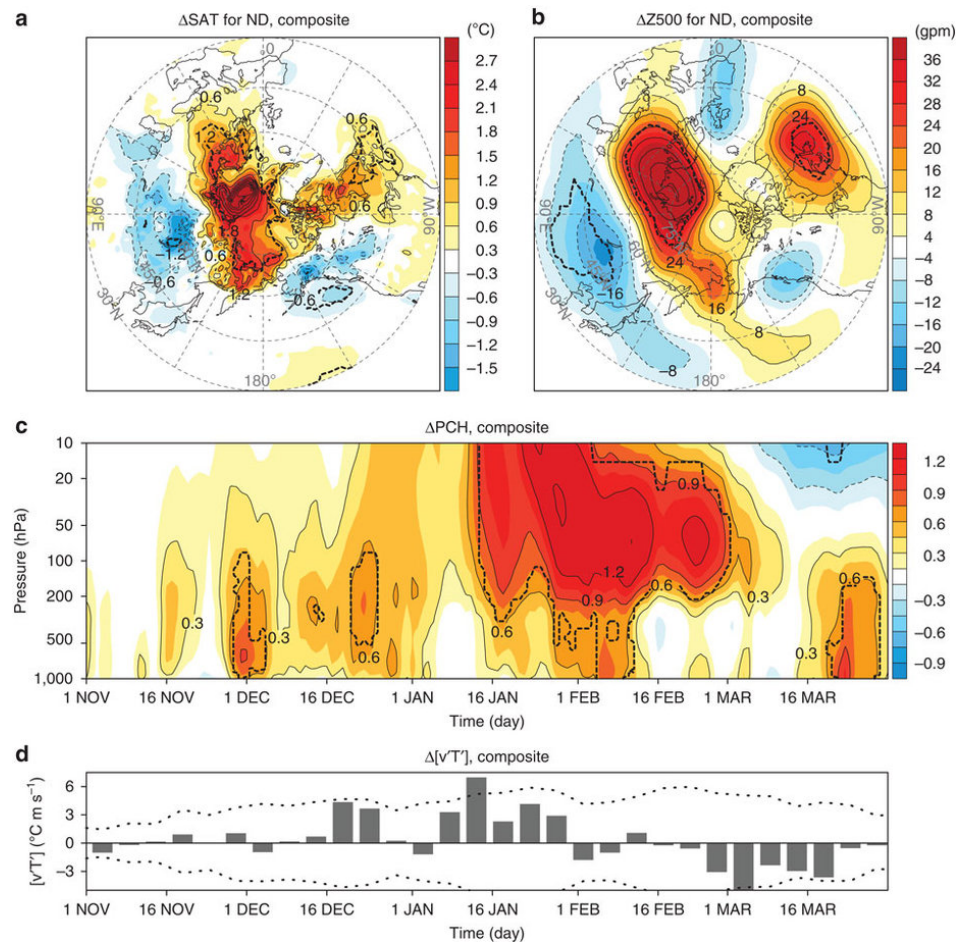


On the Stratospheric Pathway of Arctic Change-Lower Latitude Linkages





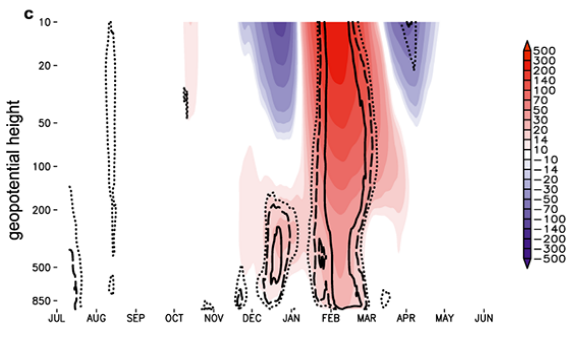
Reichler et al. 2005



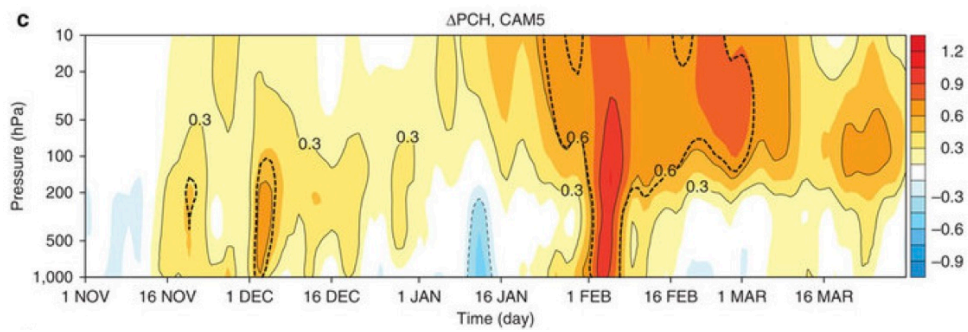
Kim et al. 2014

Atmospheric winter response to Arctic sea ice changes in reanalysis data and model sensitivity experiments

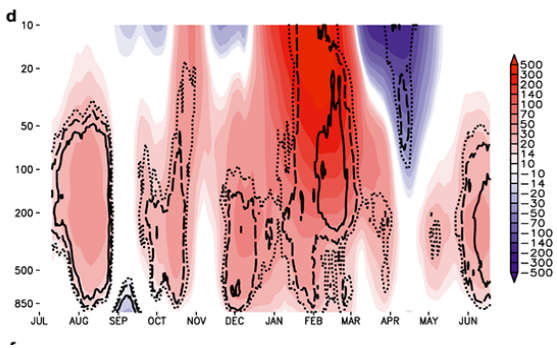
AFES NICE-CNTL



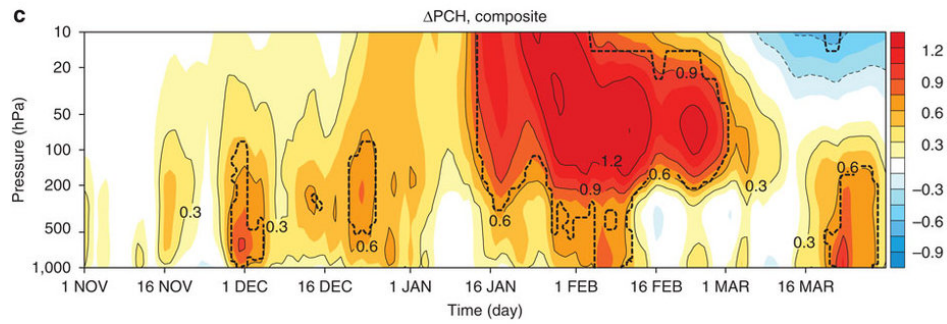
CAM5 with modified formula for calculating the fraction of low-level stratiform clouds



ERA-Interim Low-High



Era-Interim Barents-Kara sea

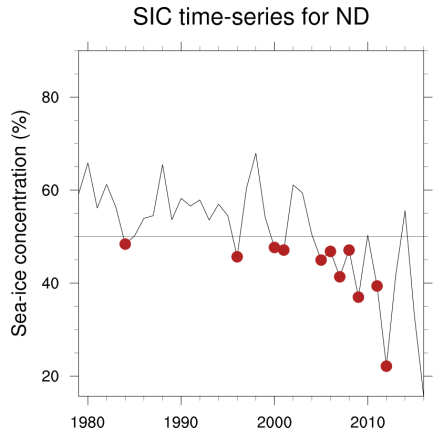


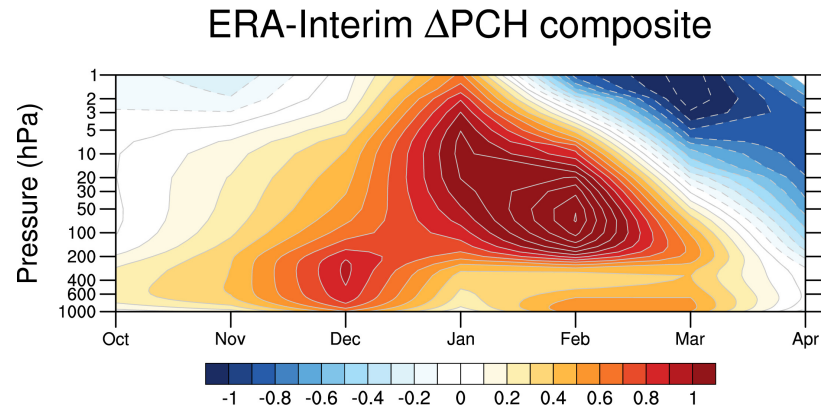
Jaiser et al. 2016

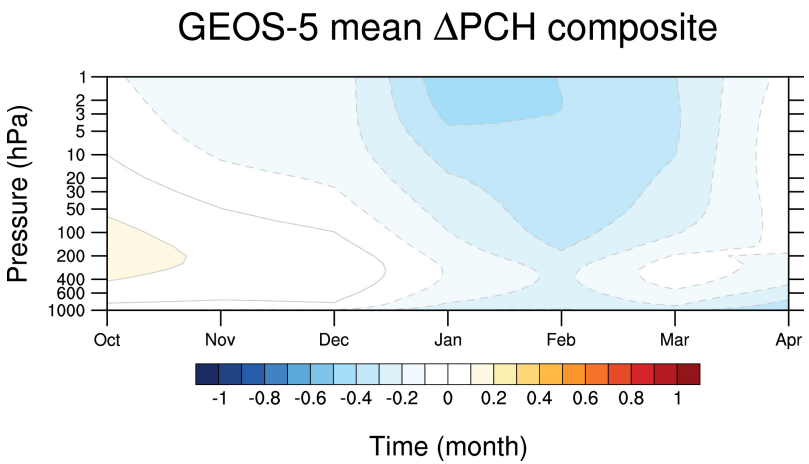
Kim et al. 2014

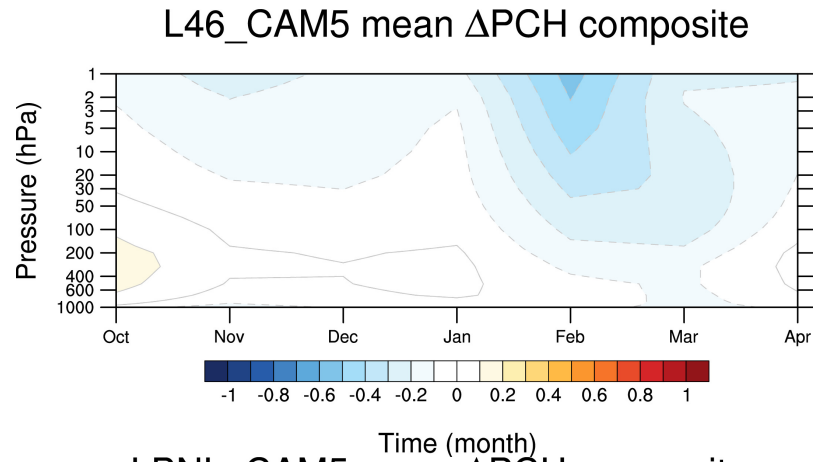
Model sensitivity experiments support the relevance of a stratospheric pathway

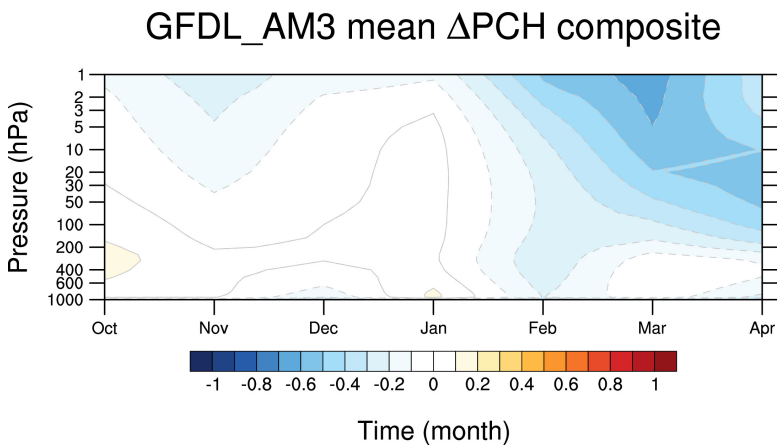
Low SIC Barents-Kara Seas Composites in AMIP simulations

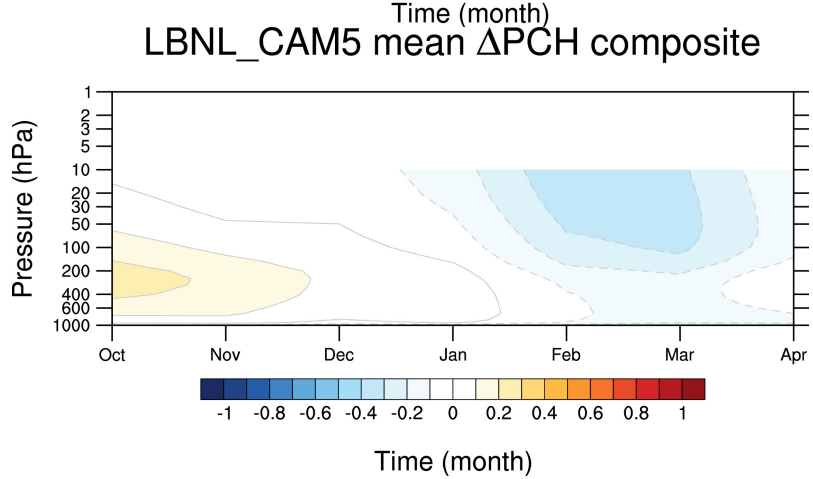








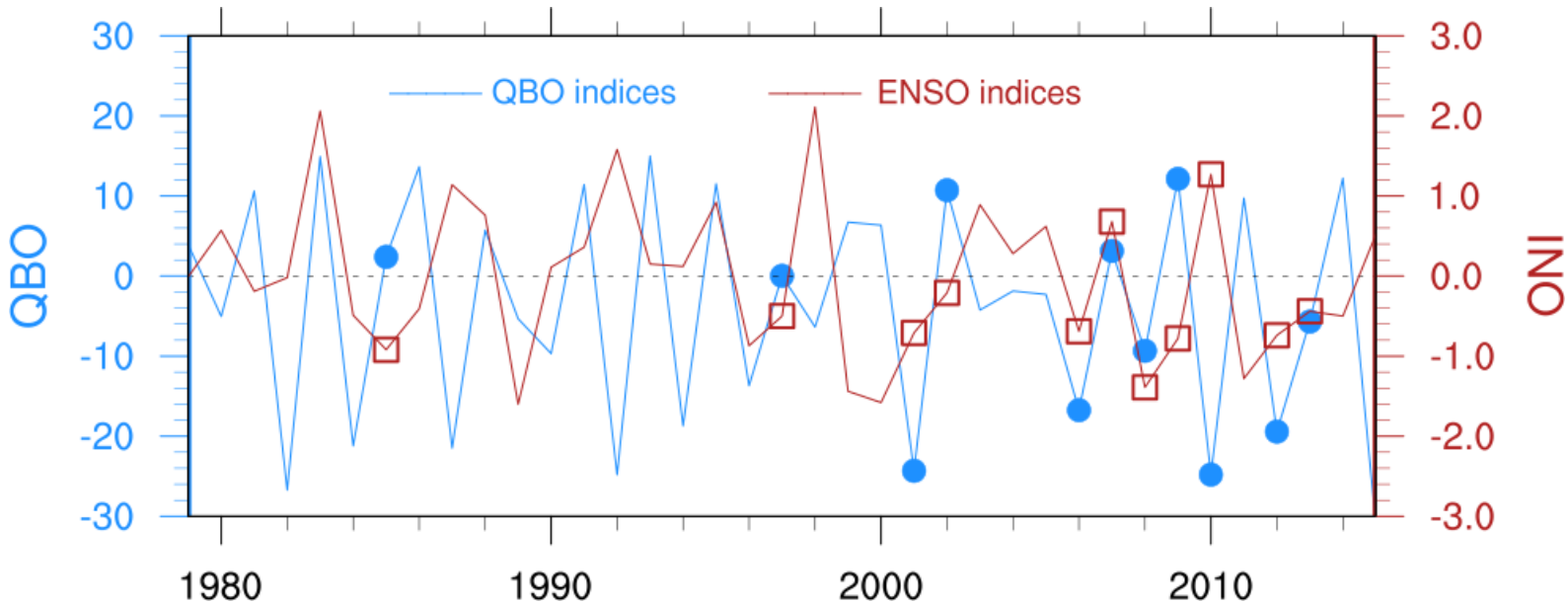




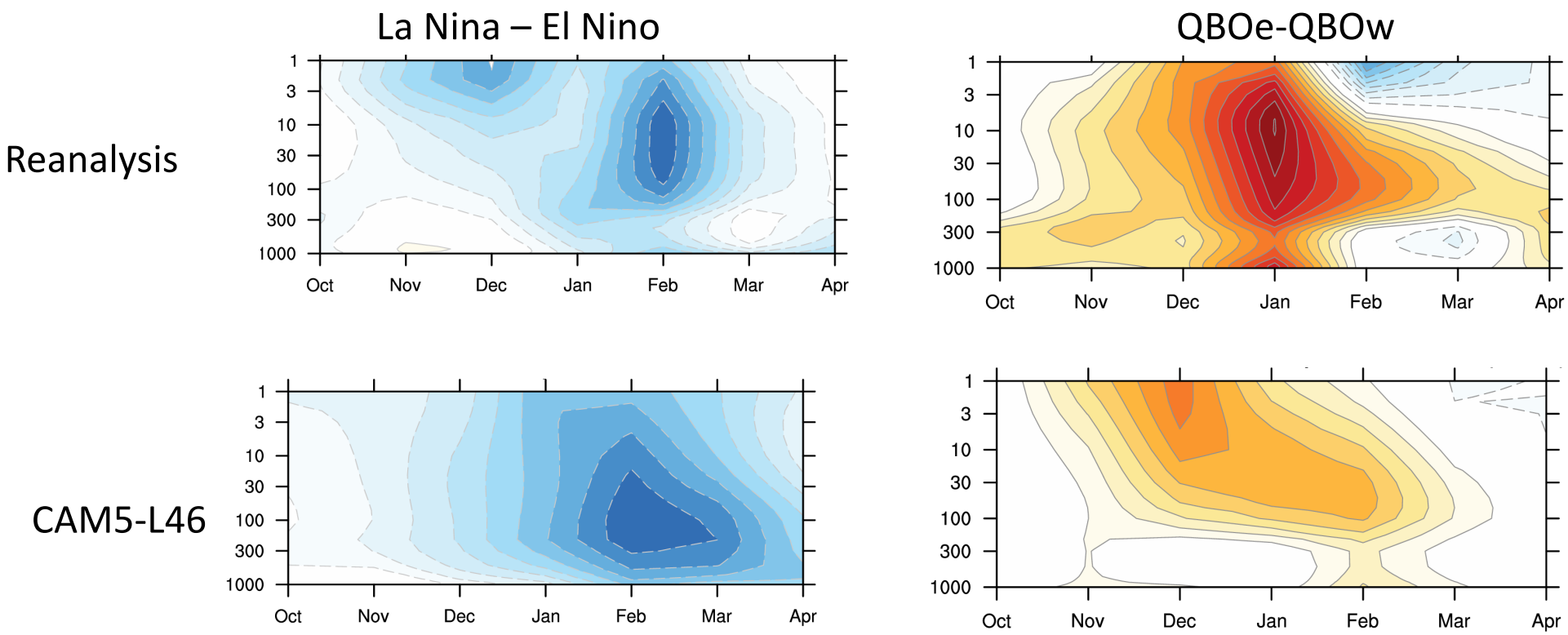
Large difference between forced response in models and observational composite even in high-top models

These 11 Low Arctic Sea Years Had

- Prevailing Cold-Phase of ENSO (projects on strong polar vortex)
- Prevailing East-Phase of the QBO (projects on weak stratospheric polar vortex)



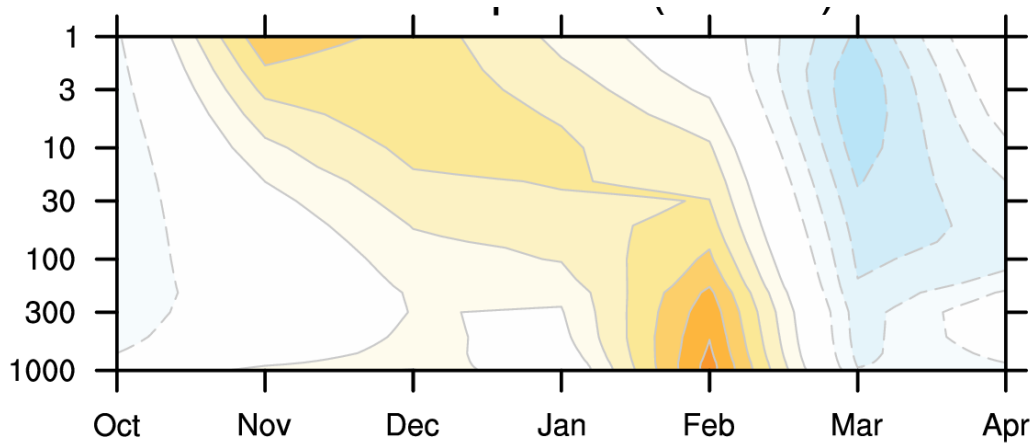
Impact of Forcings on Polar Cap Heights in Reanalysis and L46-CAM5



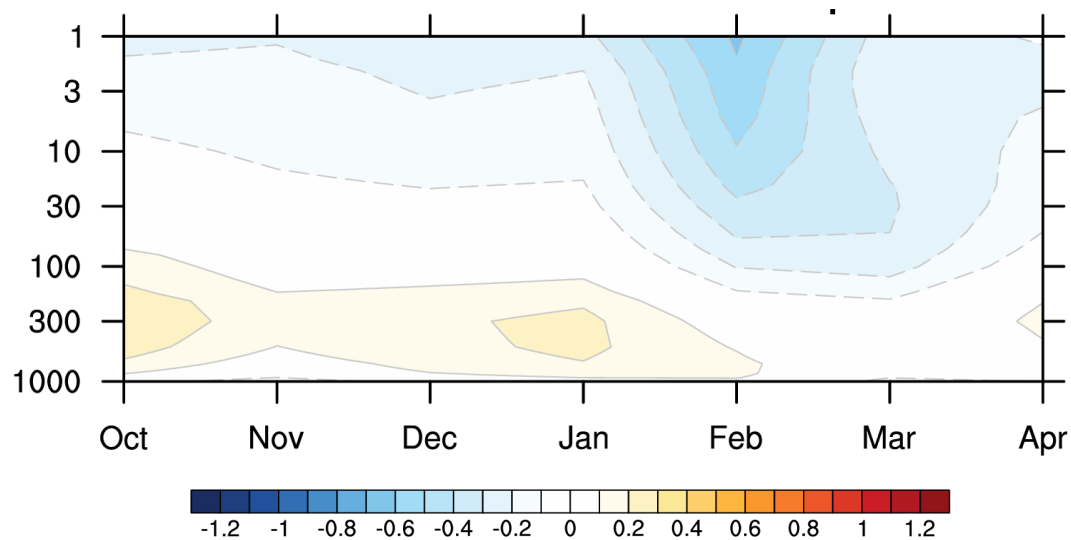
11 years of low sea ice in the Barents-Kara Seas using L46-CAM5

East QBO

Conditioned



Unconditioned



Conclusions

- Influence of SIC change on Arctic surface warming is highly detectable.
- Influence of Arctic SIC change on tropospheric warming is not detectable, and contributions of factors outside the Arctic might dominate.
- 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.
- More work is needed to better understand the potential role of model errors on simulating proposed Arctic-lower latitude linkages.

Backup Slides

Chain of Events Linking Arctic Amplification (AA) with Increased Extreme Weather in Mid-Latitudes

J. Francis (NAS Workshop)

AA: Arctic warming 2-3 times faster than N. hemisphere

Poleward temperature gradient weakening

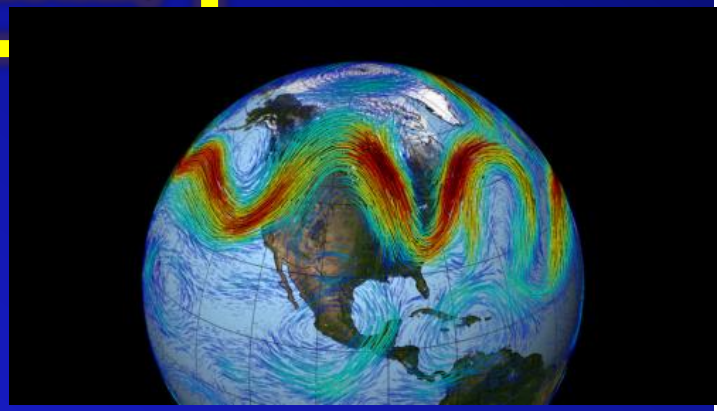
500 mb zonal winds decreasing where gradient weakens

Upper-level flow becoming more meridional

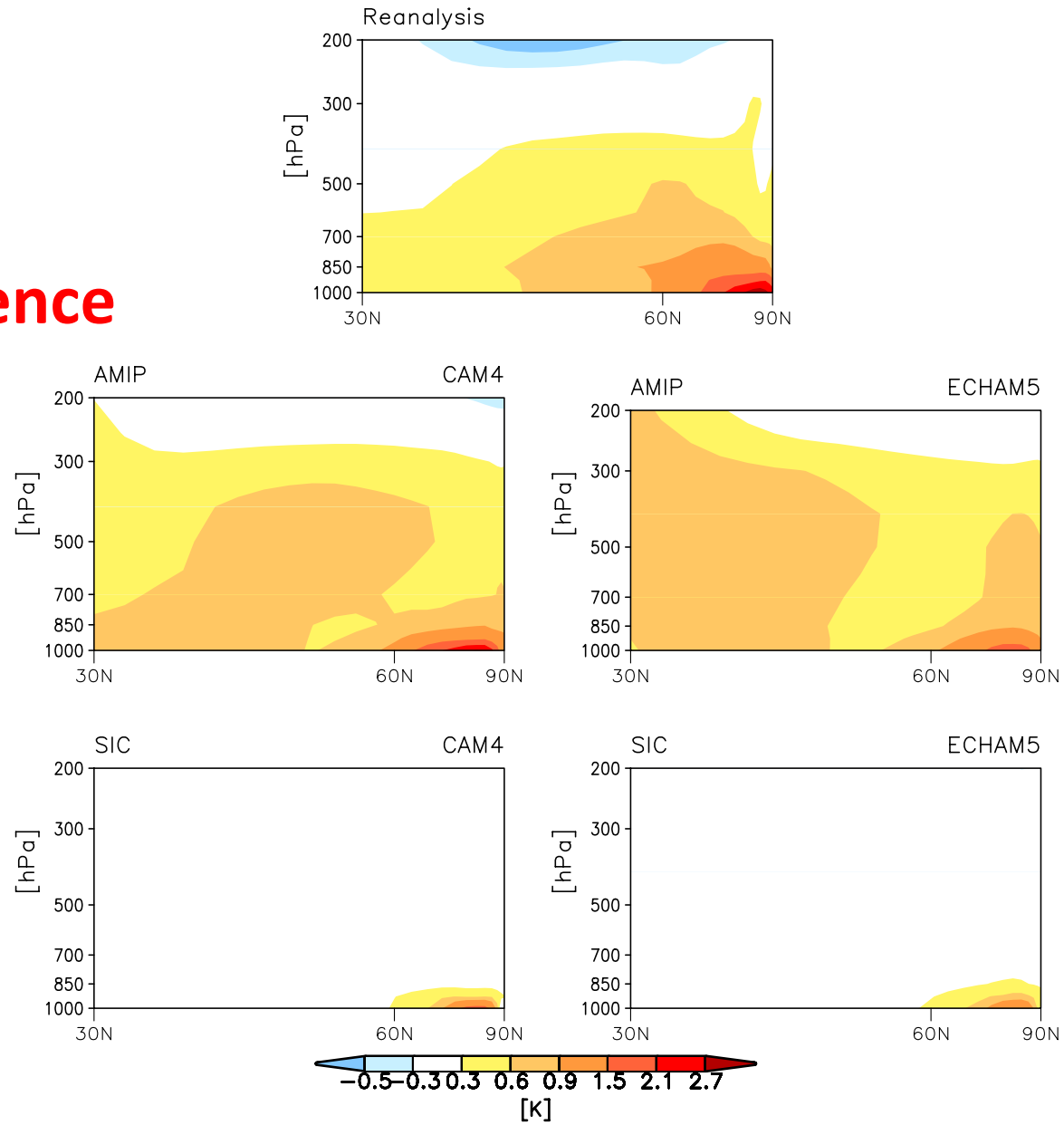
Amplitude of Rossby waves increasing, blocking more likely

Large-scale waves progress more slowly eastward

More persistent weather patterns, extremes more likely



Observed and simulated OND zonal mean temperature difference 2003-2012 minus 1979-1988



Impact of SIC change
is confined to lowermost stratosphere