

Why the Arctic Troposphere Has Warmed: An Assessment of Causes with Linkages to Lower Latitudes

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- **Don Murray** for putting the data into the NOAA FACTs data repository
- **Jon Eischeid** for general assistance with observational data.

Motivation: Research is motivated by the claim that Arctic sea ice loss and related Arctic Amplification is an important driver for occurrence of more persistent weather patterns in lower latitudes which lead to weather and climate related extremes.



“The cat did it.”

“Arctic sea ice decline did it”

“Weather Runs Hot and Cold, So Scientists Look to the Ice” NY Times regarding to March 2012 warm spell over US

“Winter 2013-2014: Sea Ice Loss Locks Jet Stream into Severe Winter Storm Pattern For Most of US”
robertscribblers.wordpress.com

“Loss of Arctic ice leads to drought in California” The Tribune, January 2014

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

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

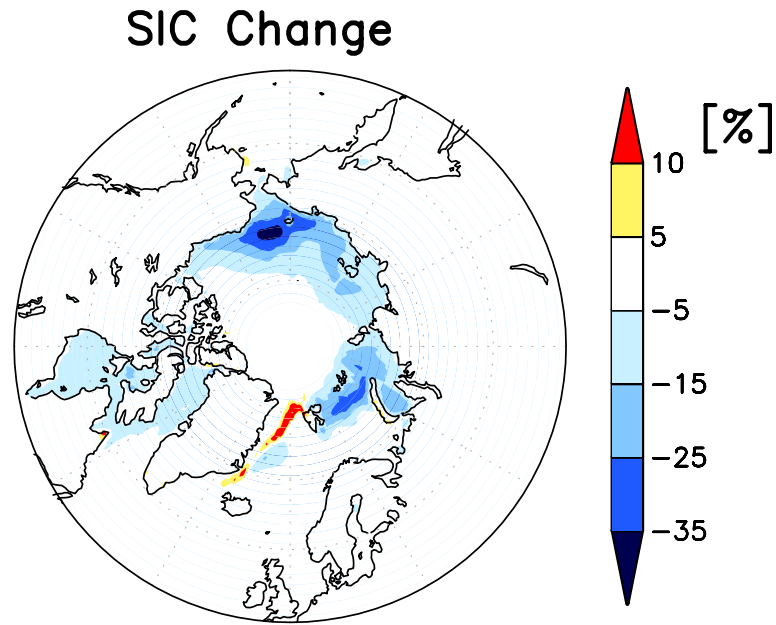
Experiments (1979-2012) using CAM4 and ECHAM5 model

- **PresentCTL** (300yrs) 1981-2010 climatology + RF
- **PastCTL** (300yrs) 1881-1910 climatology+RF
- **AMIP:** RF and observed SST and SIC
- **AMIP-noSIC:** 1979-2012 RF, 1979-1989 SIC climatology and 1979-1989 SSTs climatology where SIC has changed

(10 to 20 member ensembles)

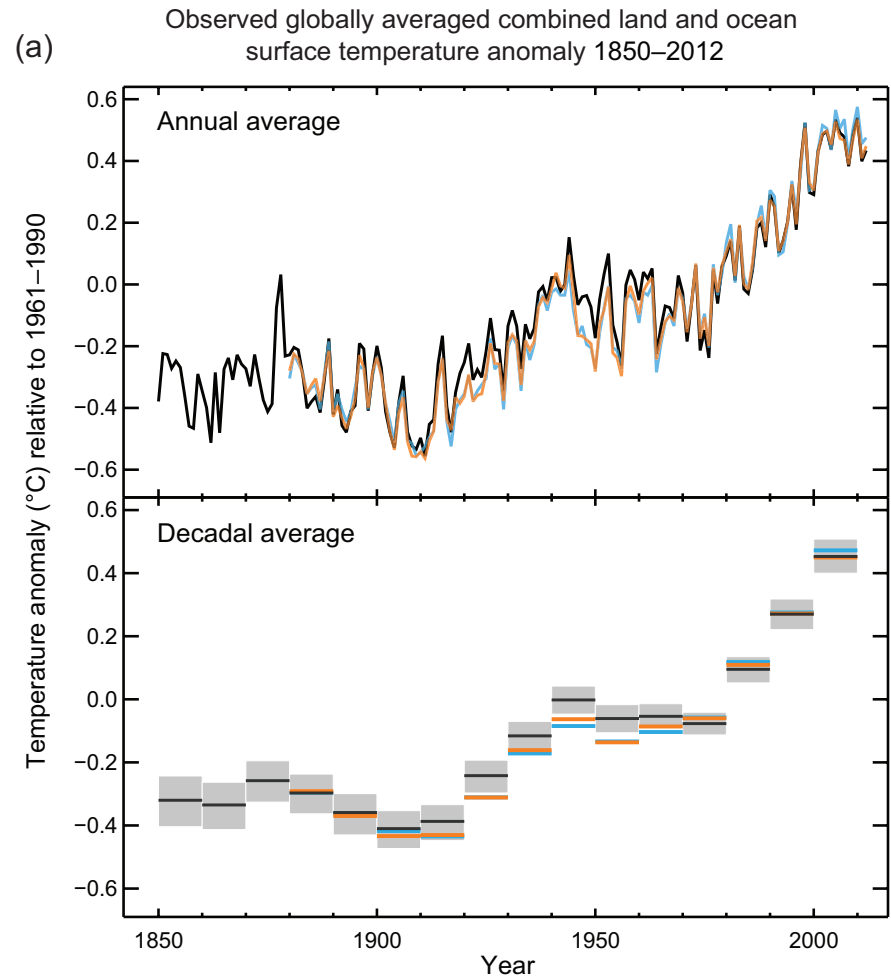
OND SST Change

2003-2012 minus 1979-1988



Estimate of long-term climate change contribution

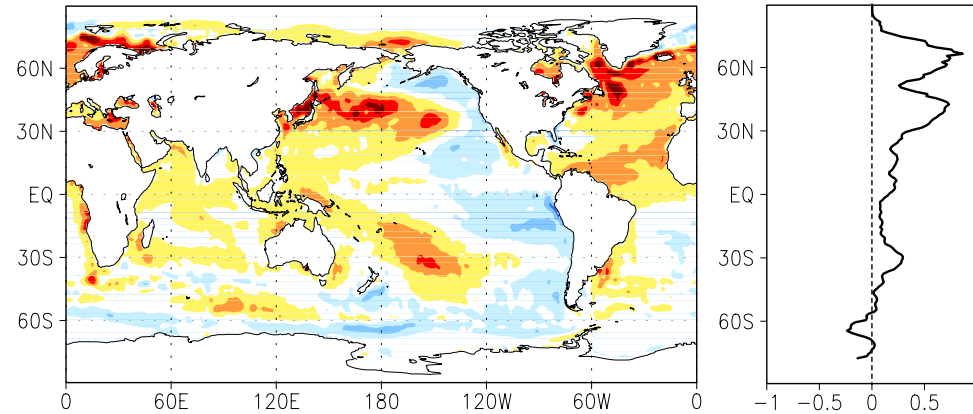
- Approach takes into account that RF and global mean SST did not increase linearly over the last century.
- Determined recent decadal (2003-2012 minus 1979-1988)/long-term (1981-2010 minus 1881-1910) global SST outside Arctic (scaling Factor 0.52)
- Utilize difference between PresentControl and PastControl runs and scale response



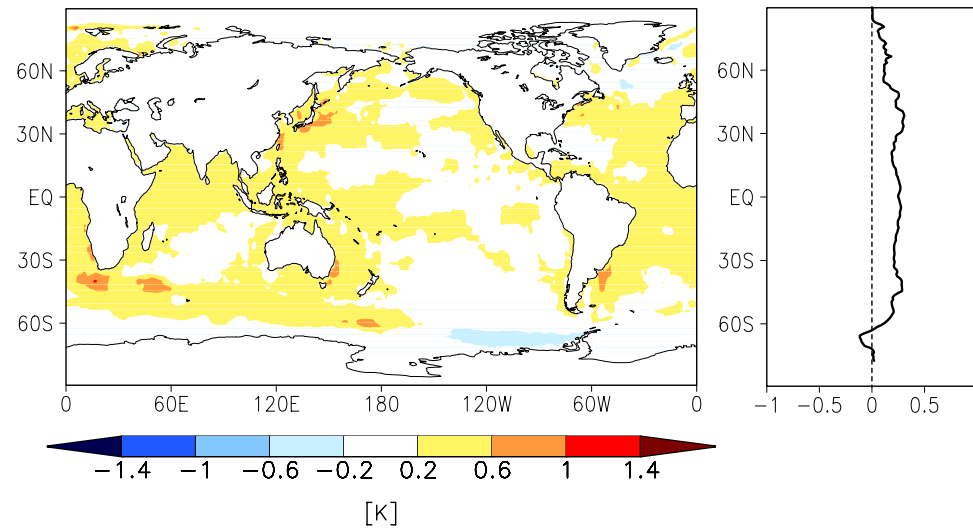
OND SST change

2003-2012 minus 1979-1988

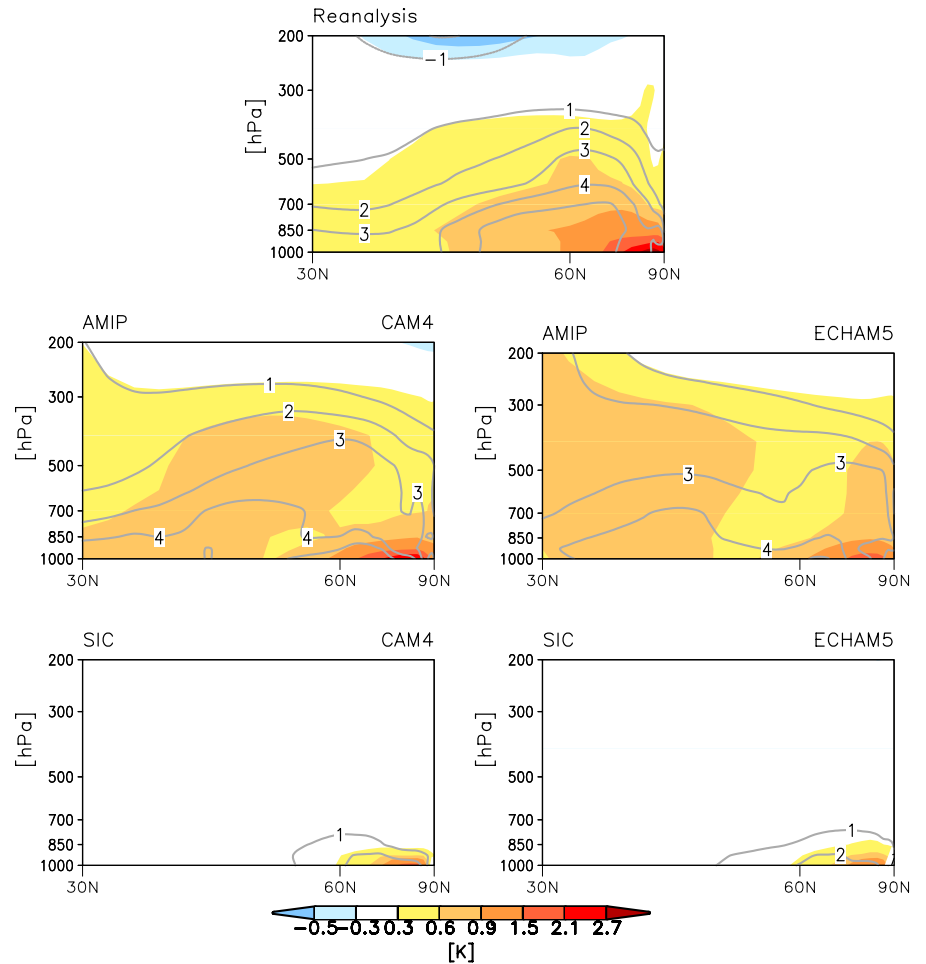
Decadal SST Difference



Long-term Trend Contribution to Decadal SST Difference

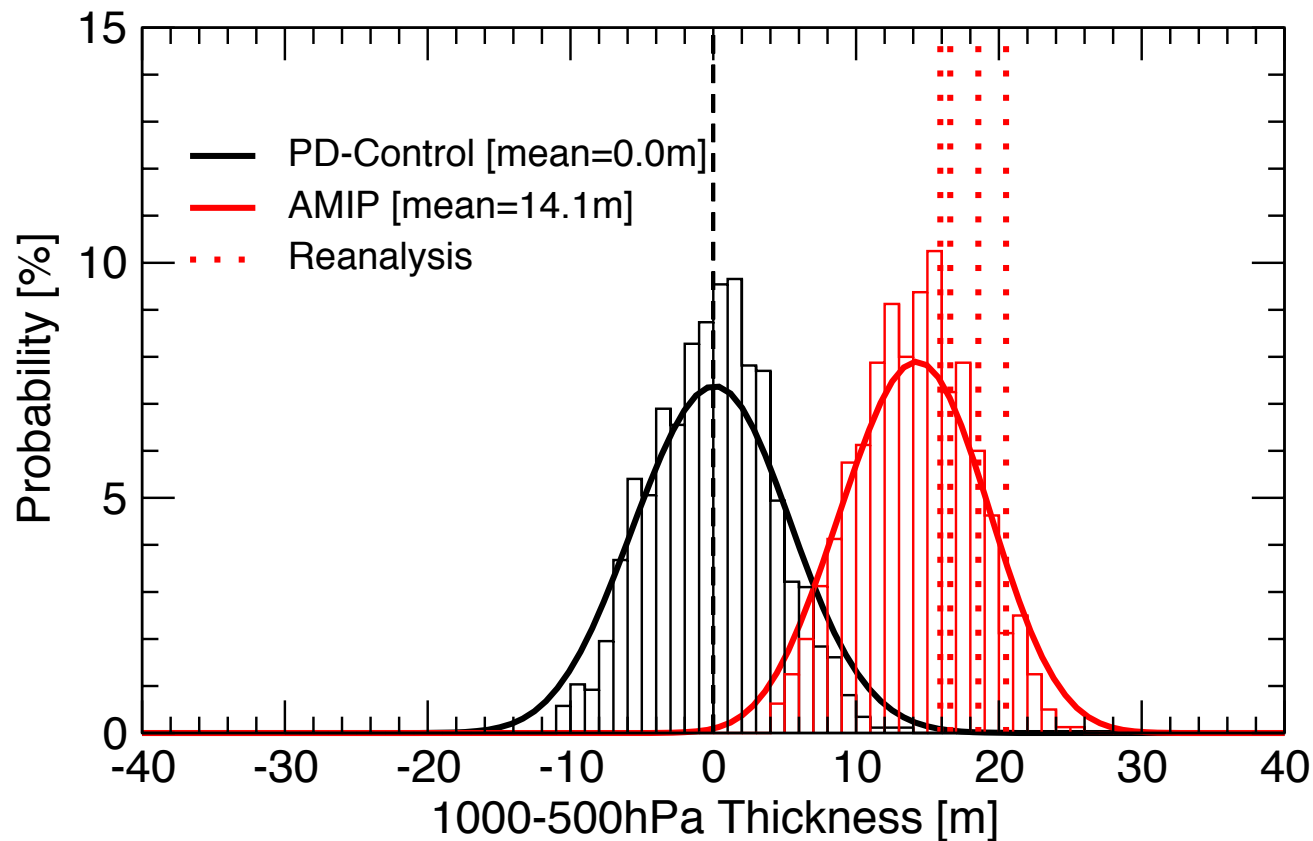


**Observed and
simulated OND
zonal mean
temperature difference
2003-2012 minus
1979-1988**

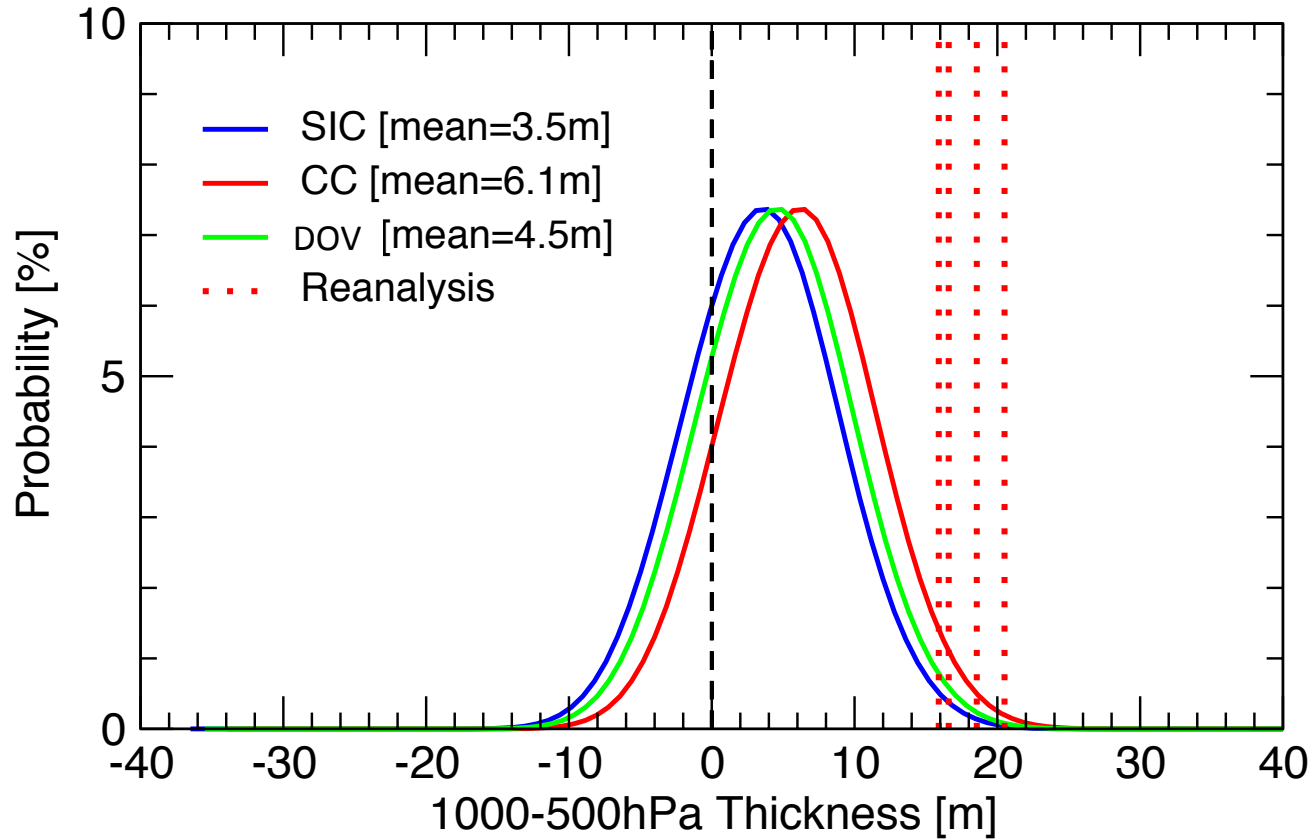


Polar Cap (60-90N) 1000-500hPa Thickness Difference during OND

2003-2012 minus 1979-1988



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



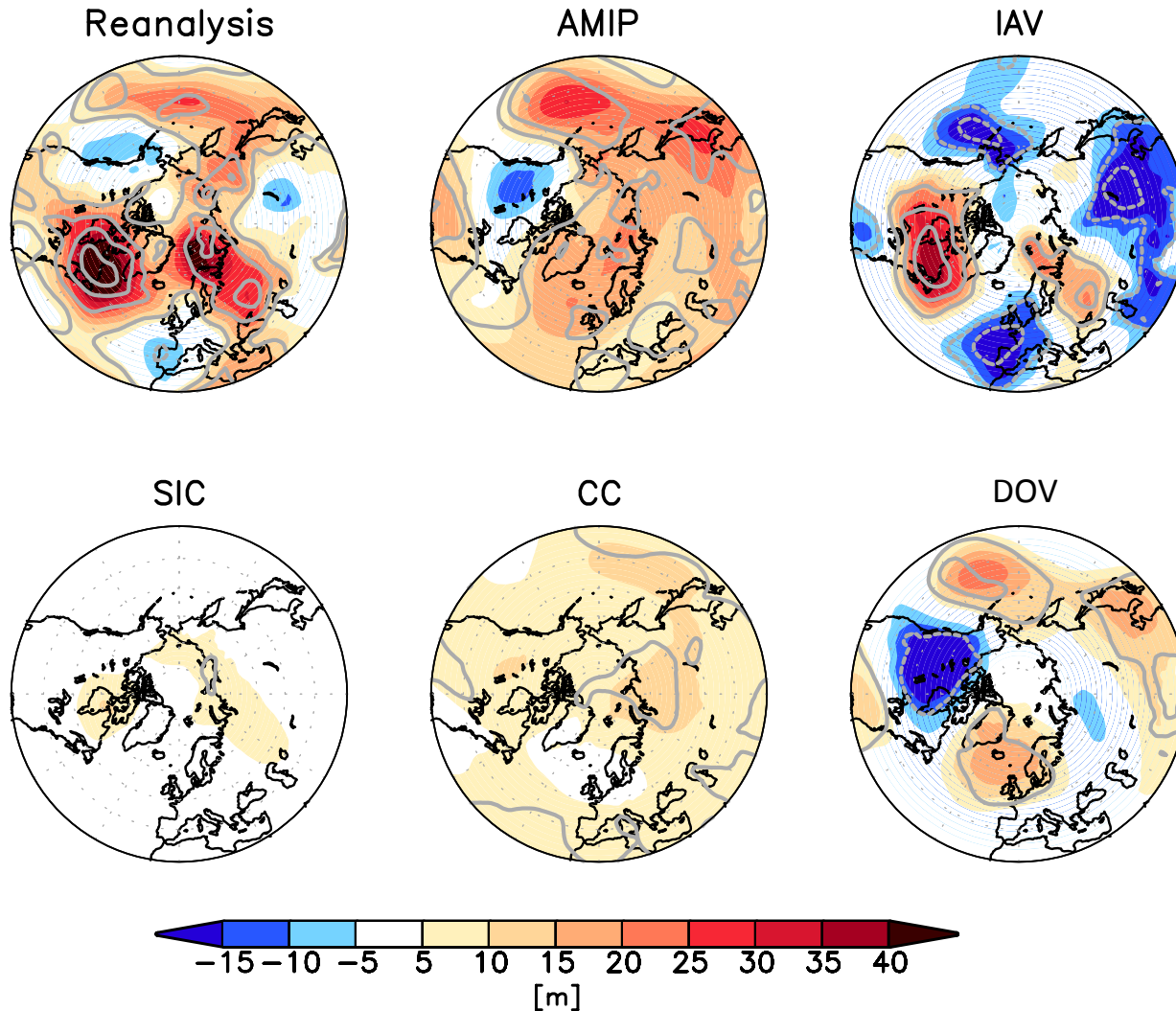
Contributions to Observed Arctic Tropospheric Warming

- **Sea ice decline:** about 20%
- **Long-term warming contribution from SST outside the Arctic:** about 34%
- **Decadal Ocean Variability:** about 25%
- **Internal atmospheric variability:** up to 25%

Regional Perspective

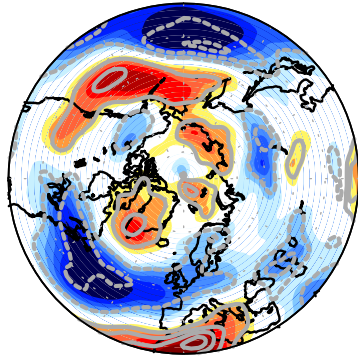
- Impact of sea ice loss on Arctic tropospheric temperature is only 20%.
- What about remote effects on lower latitude weather and climate?

1000-500hPa Thickness Change during OND 2003-2012 minus 1979-1988

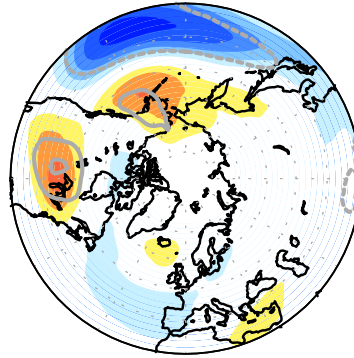


500hPa Zonal Wind Change during OND 2003-2012 minus 1979-1988

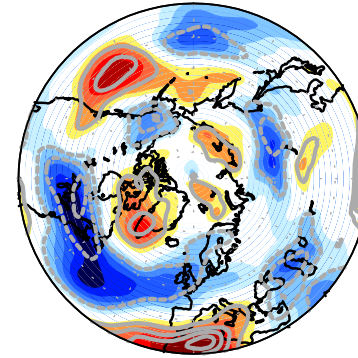
Reanalysis



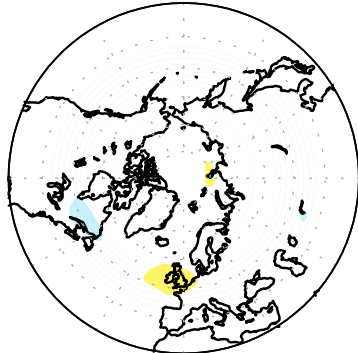
AMIP



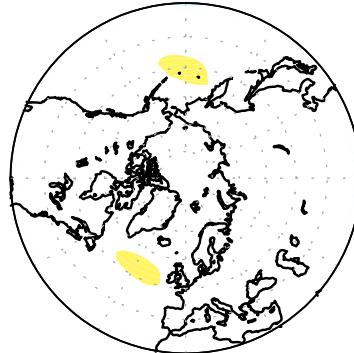
IAV



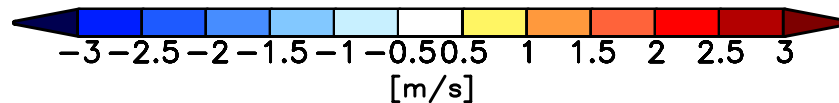
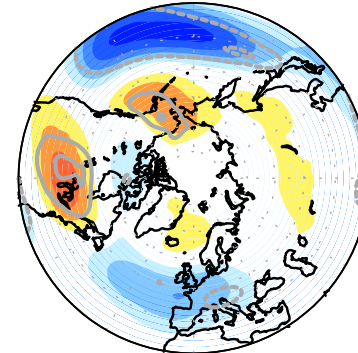
SIC



CC



DOV



Summary

- Sea ice decline is responsible for most of the near-surface Arctic warming, but contributed only about 20% to deep tropospheric warming.
- The Arctic troposphere warmed primarily due to remote, rather than in situ, forcings since 1979.
- The pronounced tropospheric thickness increases over the far North Atlantic region including a reduction in westerly flow over the mid-latitudes were mainly a large amplitude expression of internal atmosphere variability and decadal ocean variability and thus mostly unrelated to effects of sea ice loss.
- **In consequence: the Arctic troposphere has been mainly responding to rather than forcing mid-latitude weather and climate.**



“The cat did it.”

~~“Arctic sea ice decline did it”~~