

Why has the Arctic Warmed?

Judith Perlwitz, Martin Hoerling and
Randall Dole

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- **Don Murray** for putting the data into the NOAA FACTs data repository
- **Jon Eischeid** for determining the natural sea surface temperature forcing.

Motivation

- Research is motivated by the claim that Arctic sea ice loss and related Arctic Amplification are a principal driver for occurrence of more persistent mid-latitude weather patterns which lead to weather and climate extremes.

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

J. Francis (NAS Workshop)

Goal: Quantify the magnitude of tropospheric Arctic warming resulting from various factors

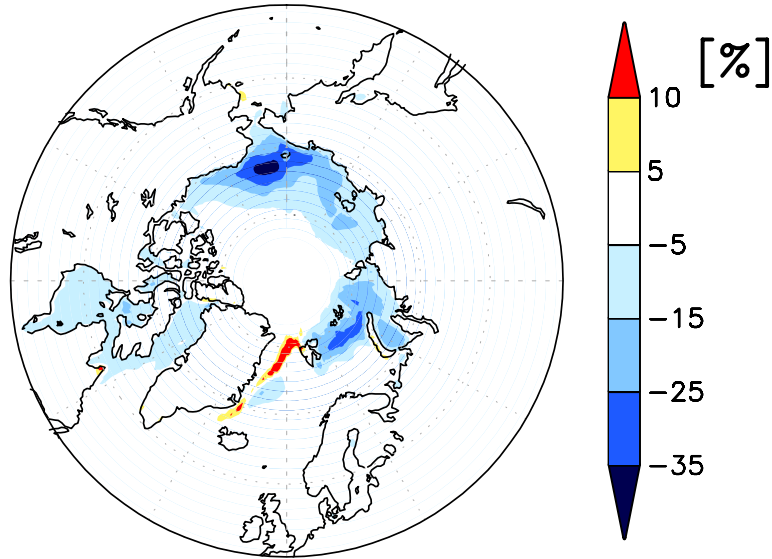
Experiments (1979-2012) using CAM4 and ECHAM5 model (10-20 member ensembles)

- **CTL** (300yrs) 1981-2010 climatology
- **Fully Forced:** RF and observed SST and SIC
- **FixedSIC:** 1979-2012 RF, 1979-1989 SIC climatology and 1979-1989 SSTs climatology where SIC has changed
- **NatSST:** 1880 RF, 1979-2012 SST with zonal mean climate change component removed which is determined based on century long SST trends, SIC 1979-1989 climatology

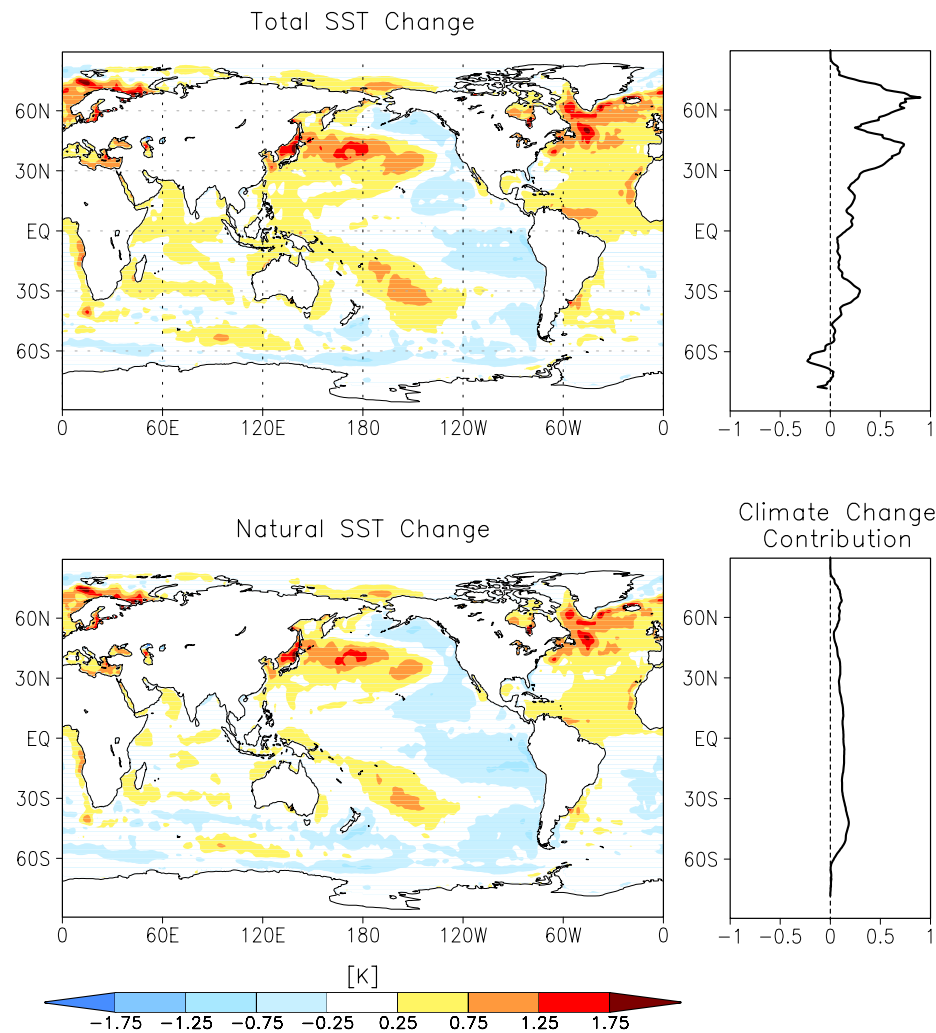
OND SST Change

2003-2012 minus 1979-1988

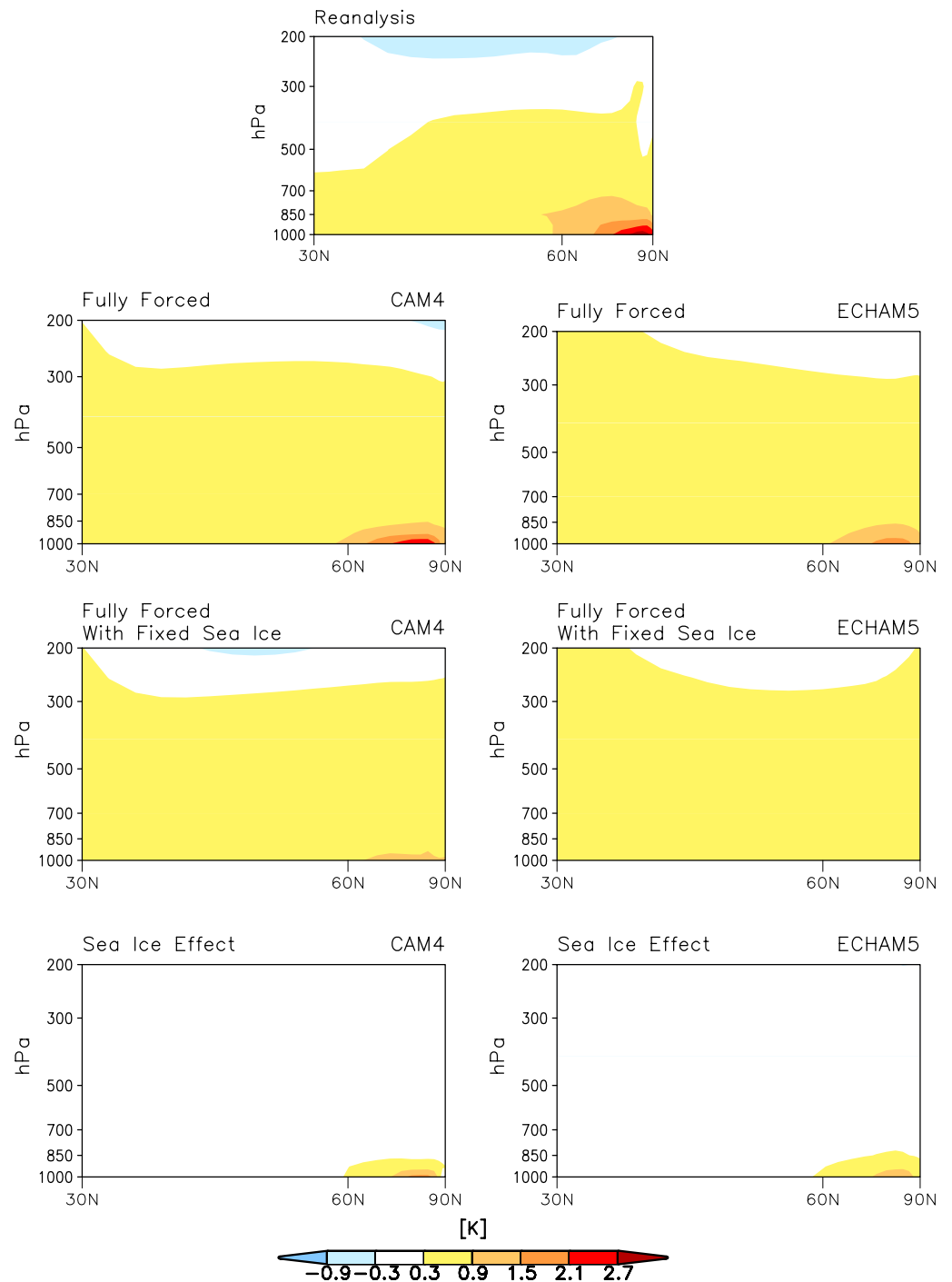
SIC Change



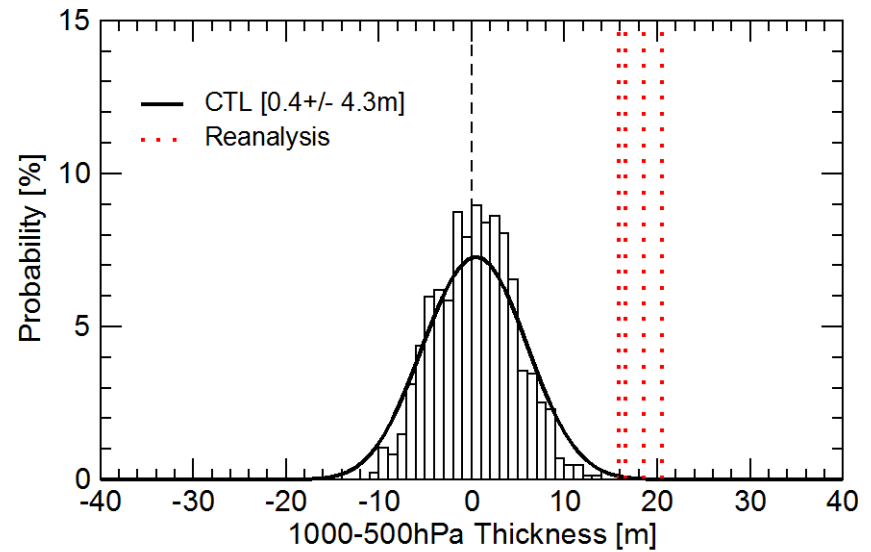
OND SST change 2003-2012 minus 1979-1988



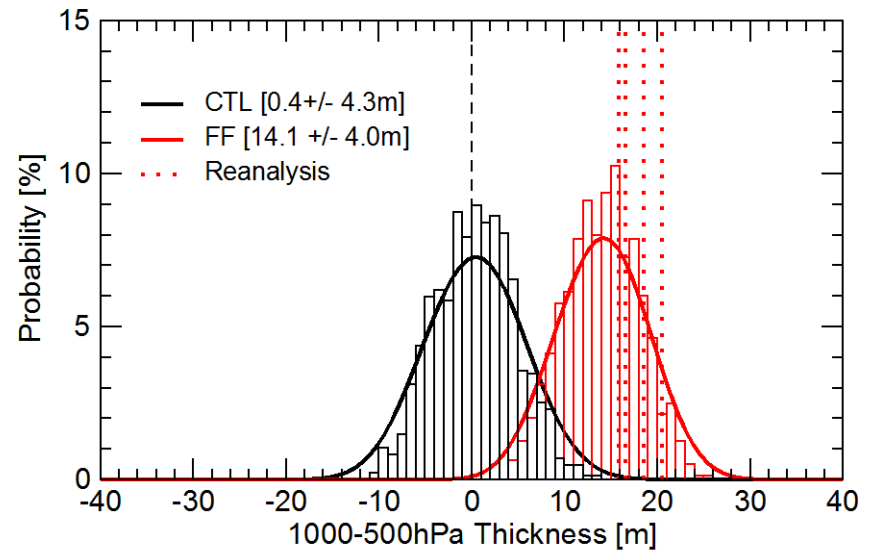
Observed and simulated OND zonal mean temperature change 2003-2012 minus 1979-1988



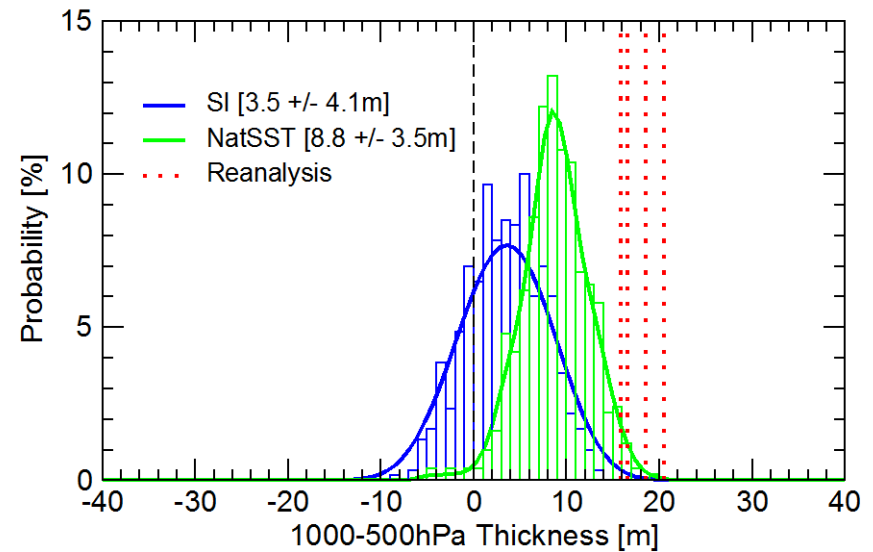
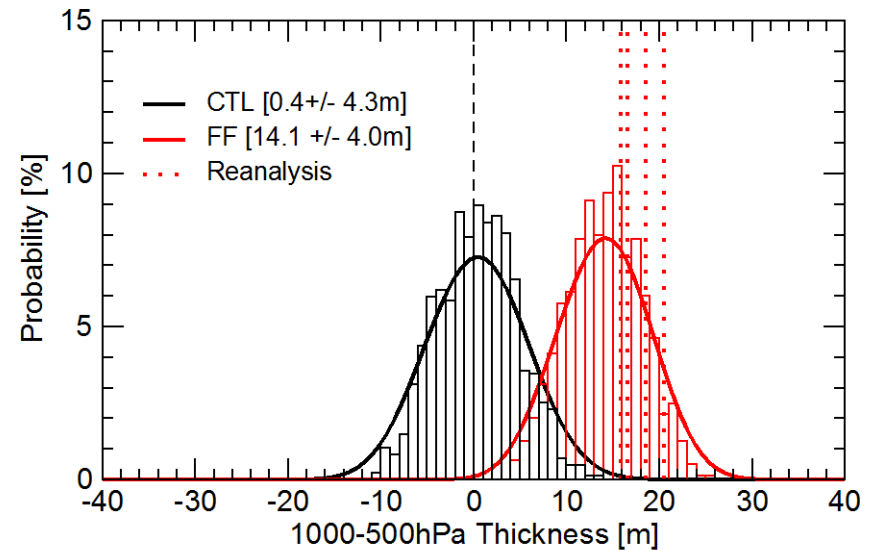
OND 1000-500hPa Thickness Change over Polar Cap (60-90N)



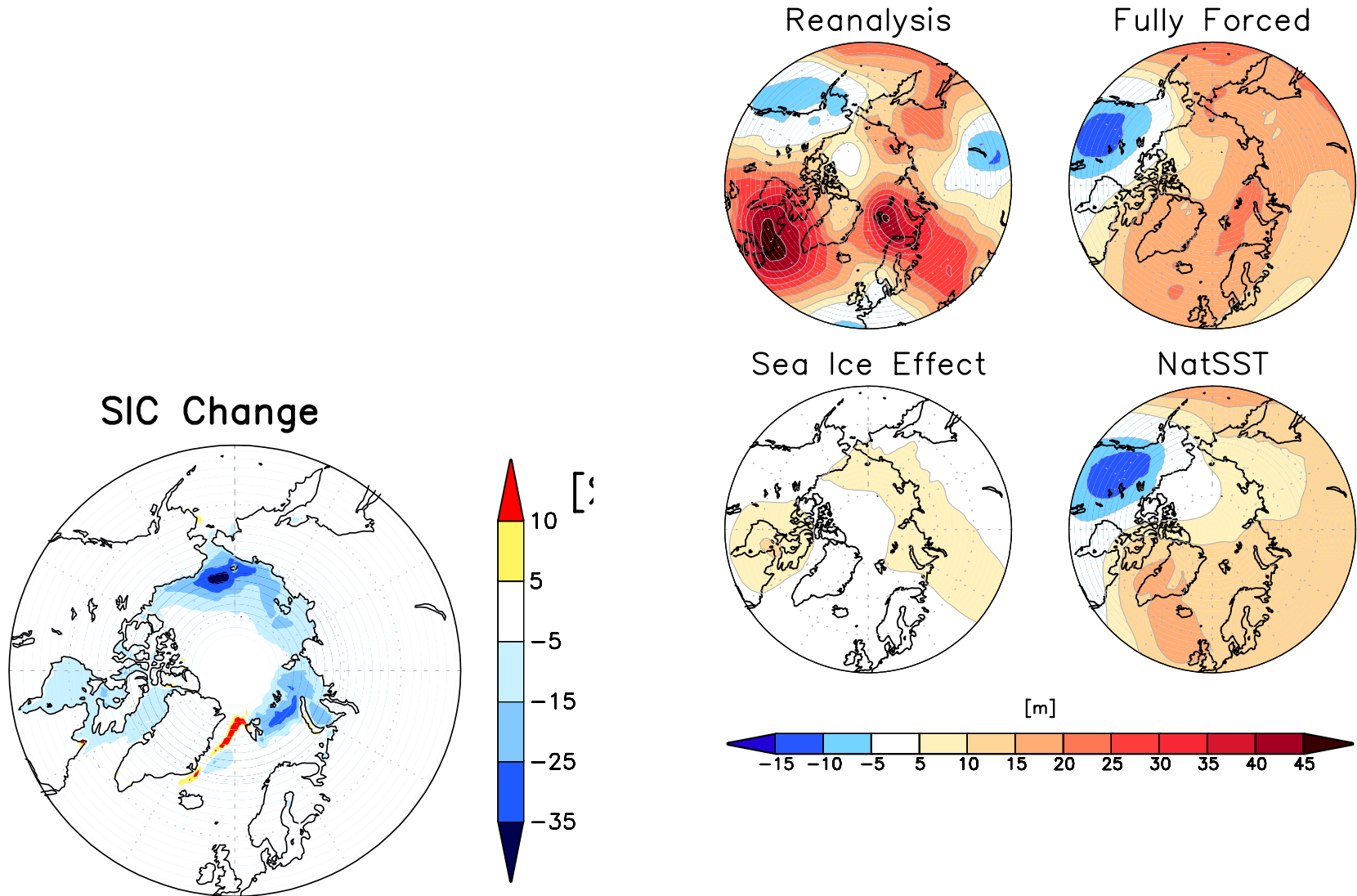
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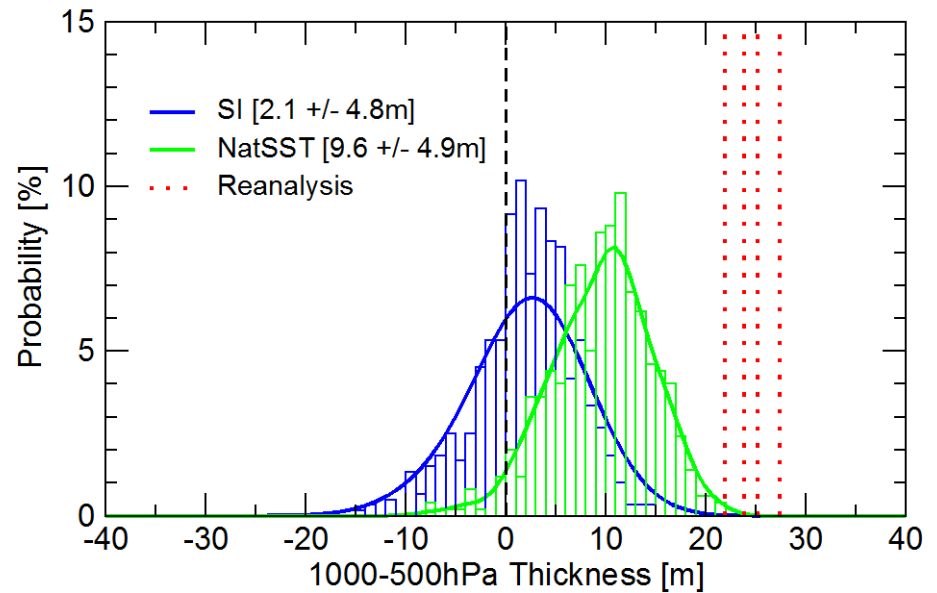
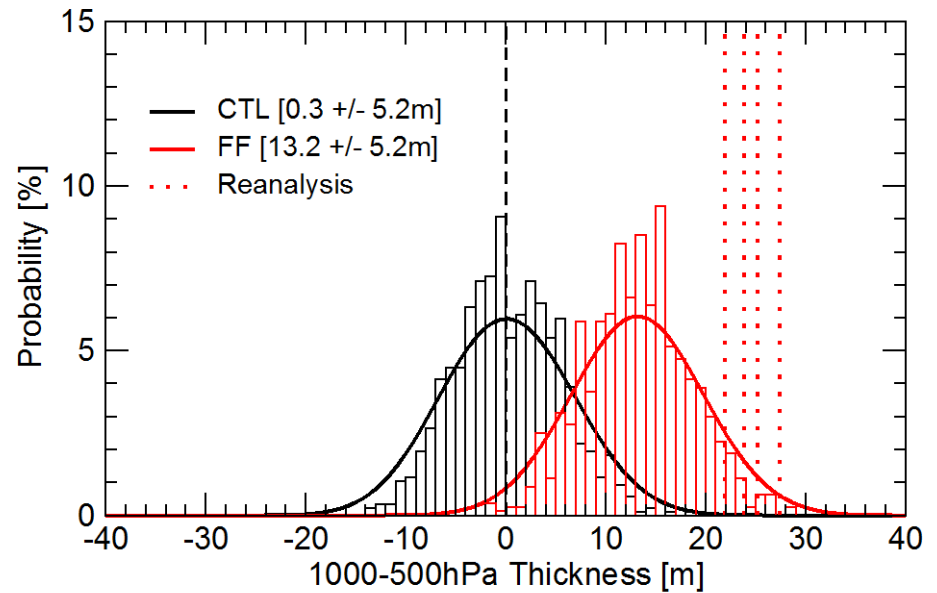
OND 1000-500hPa Thickness Change over Polar Cap (60-90N)



OND 1000-500hPa Thickness Change



OND 1000-500hPa Thickness Change over North Atlantic Region (90W-0,45- 80N)



Contributions to Observed Tropospheric Arctic Warming

- **Remote forcing by natural fluctuations in sea surface temperatures mainly outside the polar cap: about 50%**
- **Sea ice decline: about 20%**
- **Unforced random atmospheric variability: up to 25%**

Implications

- Arctic troposphere has been mainly responding to rather than forcing mid-latitude weather and climate.
- A reduced rate of tropospheric warming or even short-term cooling may occur in the Arctic in the future in response to remote forcing by natural decadal modes of variability.