Multi-decadal variability of Arctic climate in CCSM3 mid-Cretaceous simulations

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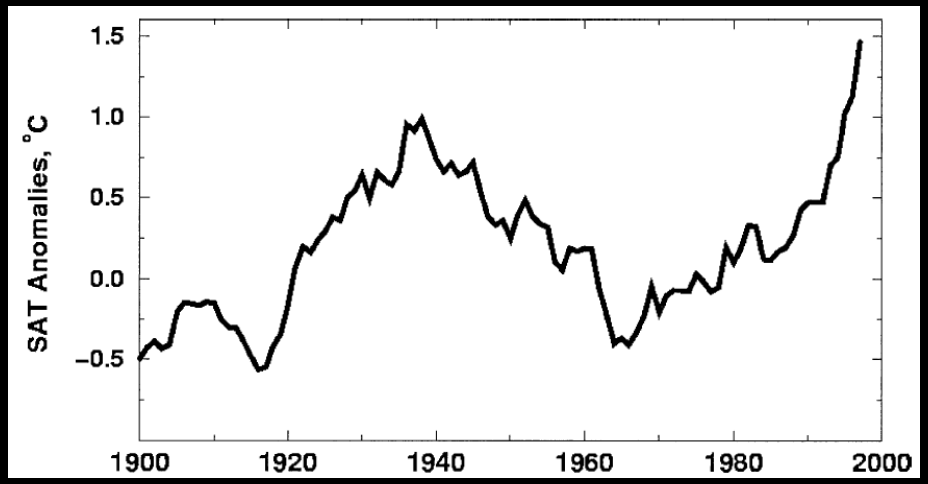
Recent Arctic variability and the potential causes



The warming in the early 20th is likely due to natural variability, and linked to sea-ice variability.

Bengtsson et al., 2004

Induced by modifications in the meridional heat transport between the Arctic and North Atlantic via:

- Atmospheric variability (NAO/AO)
- Wind-driven Arctic Ocean Oscillatory (AOO)
- Variability of the meridional overturning circulation (MOC)

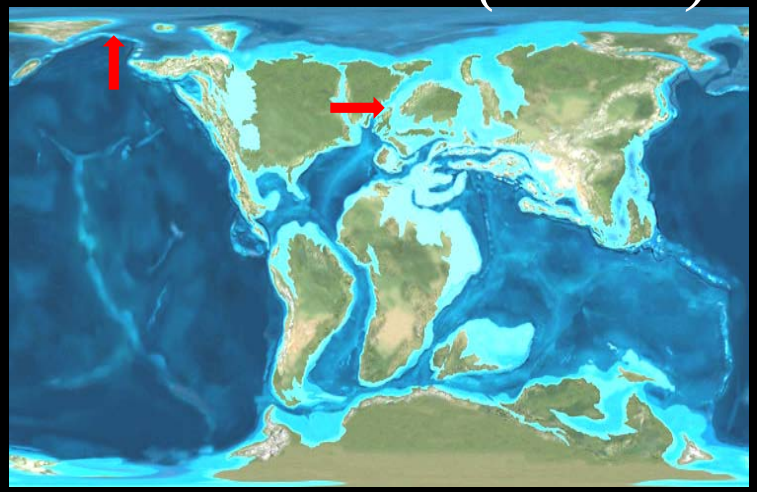
Goosse and Holland, 2005

Methodology

Model:

T31x3 CCSM3 with dynamic vegetation model

Mid-Cretaceous (100 ma)



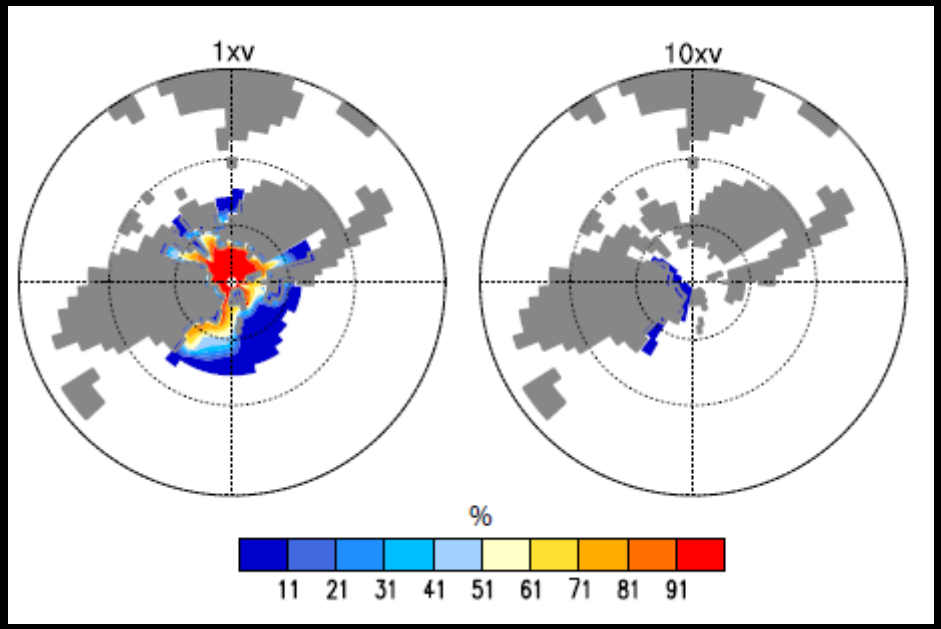
Source: Scotese PALEOMAP project)

Experiments:

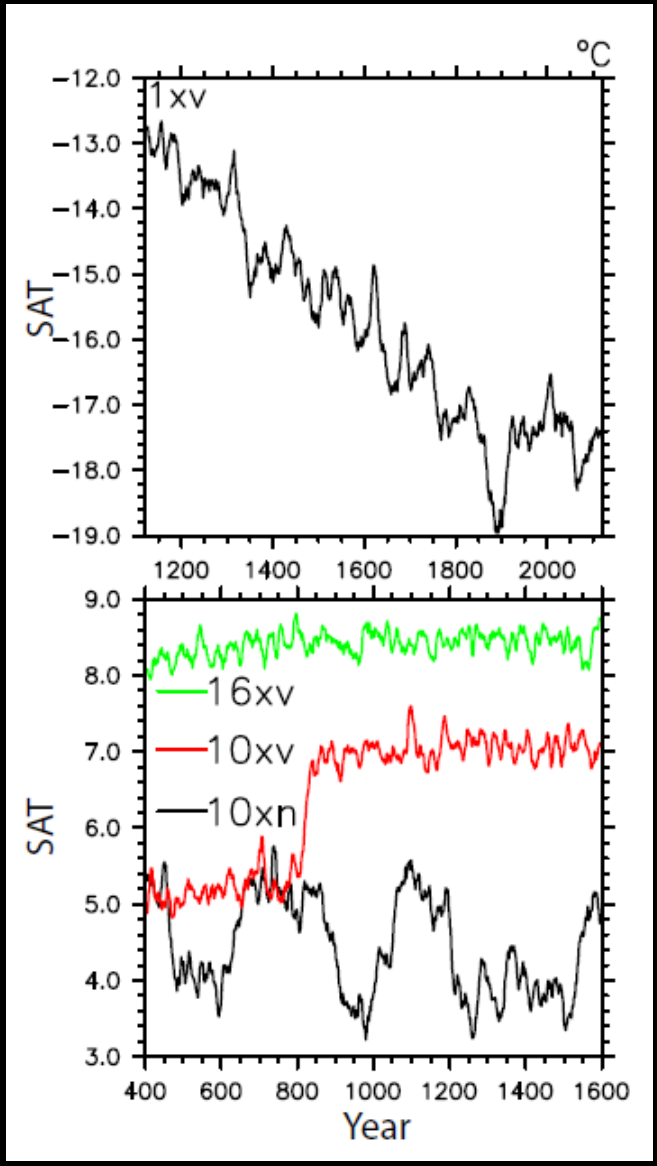
- Mid-Cretaceous paleogeography and bathymetry.
- 99% of modern solar constant
- Four experiments initialized from a previous Cretaceous simulation.

Simulated mean climate

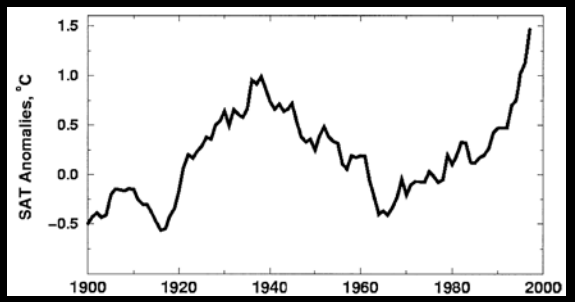
Exp.	Atm. CO_2 (ppmv)	Vegetation	Global SAT (°C)	MOC (Sv)	70-90 °N SAT (°C)	Sea ice ($10^6 km^3$)
1xv	280	DGVM	13.6	21.9	-17.6	15.7
10xn	2800	Bareground	23.1	20.4	4.9	0.1
10xv	2800	DGVM	24.0	18.2	7.0	0.06
16xv	4480	DGVM	25.6	9.6	8.4	0.01

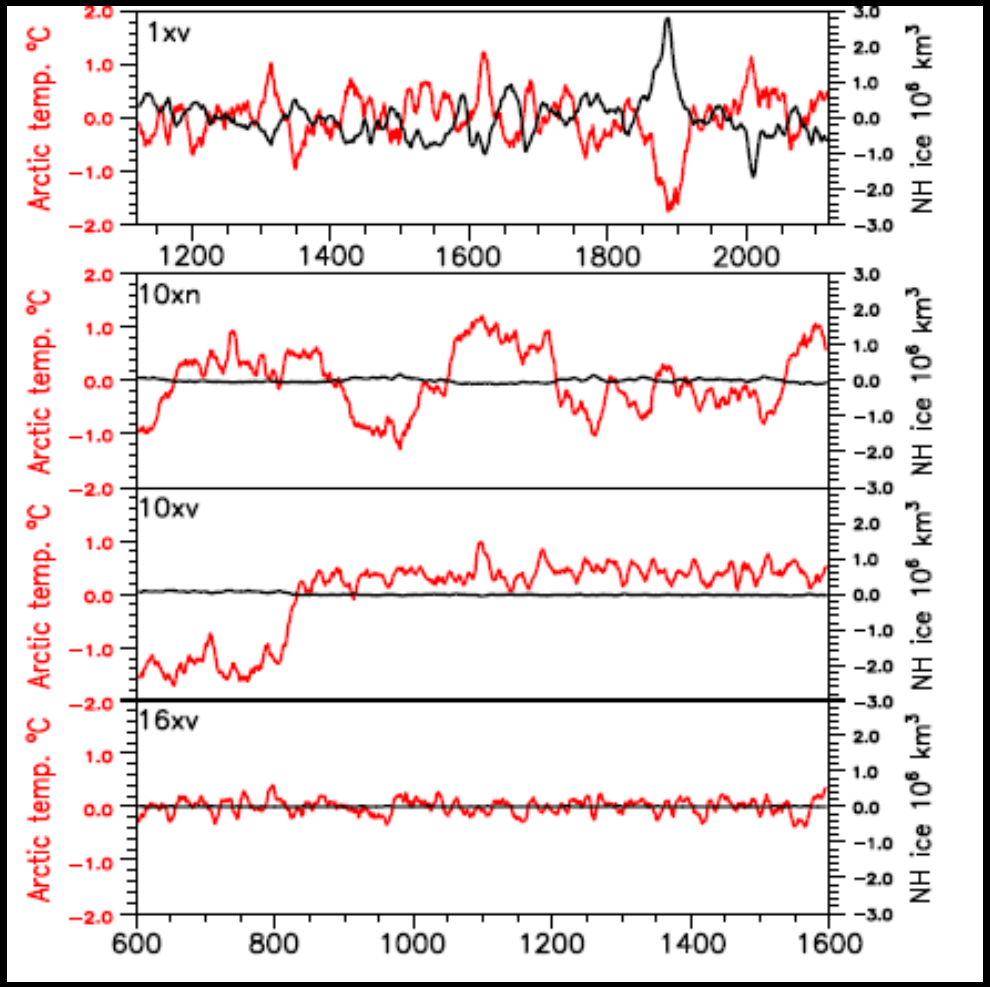


Time series of Arctic SAT

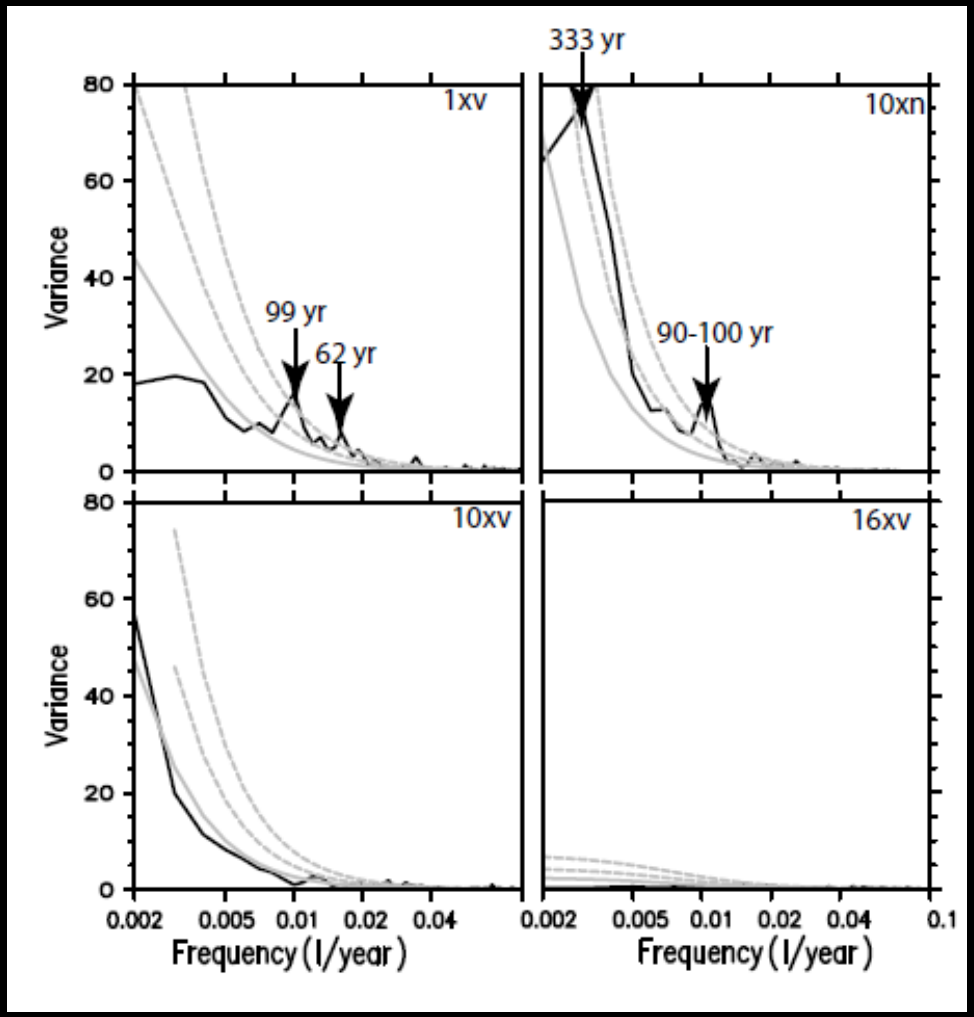


Variability of Arctic SAT

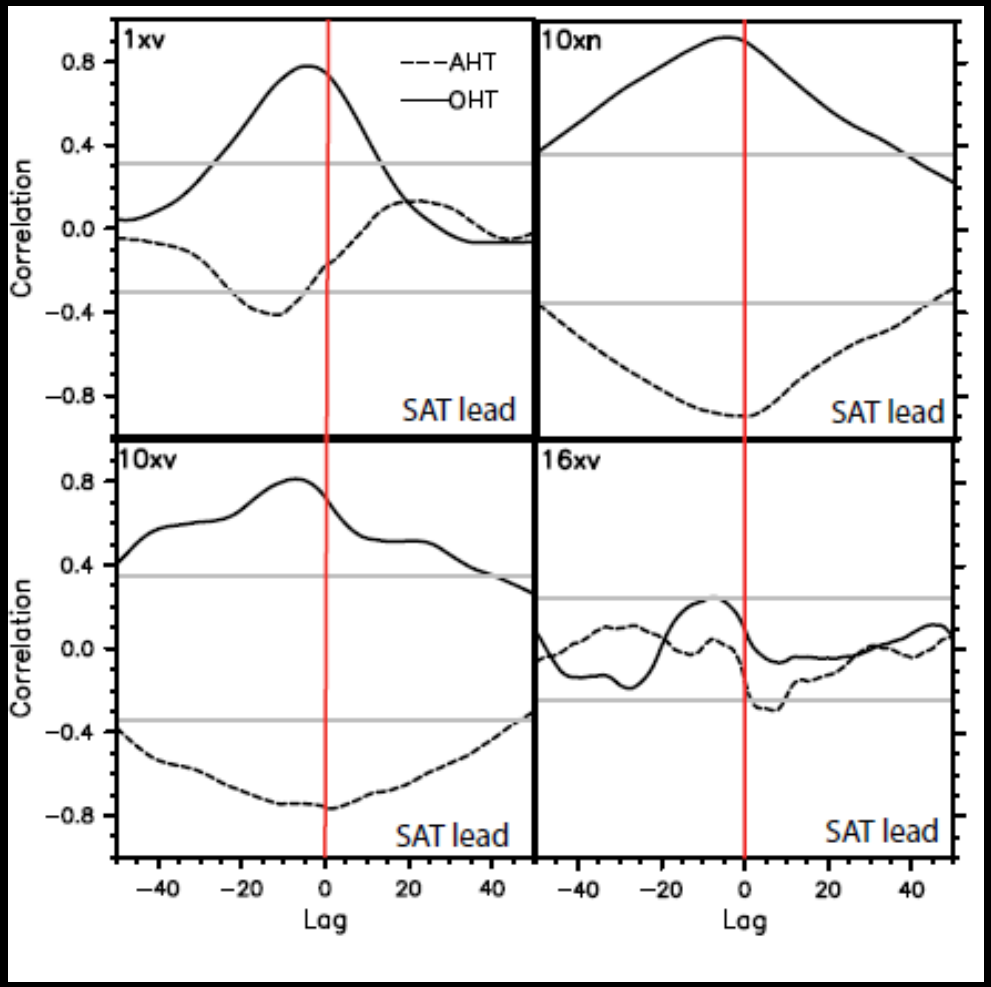




Simulated Arctic variability :spectrum of SAT

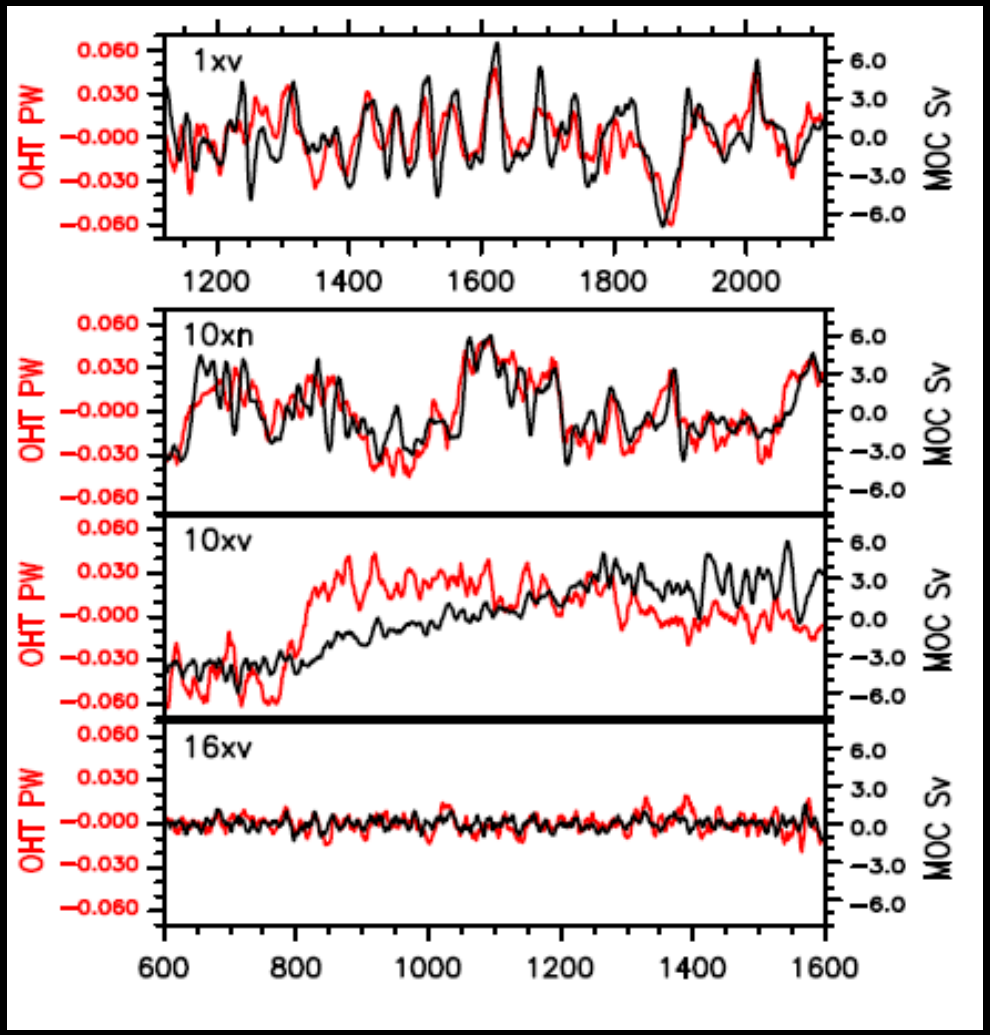


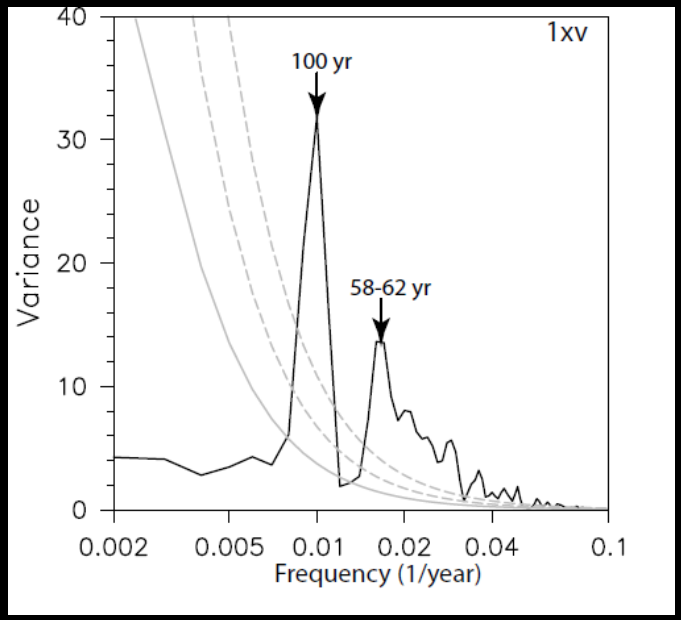
The role of meridional heat transport



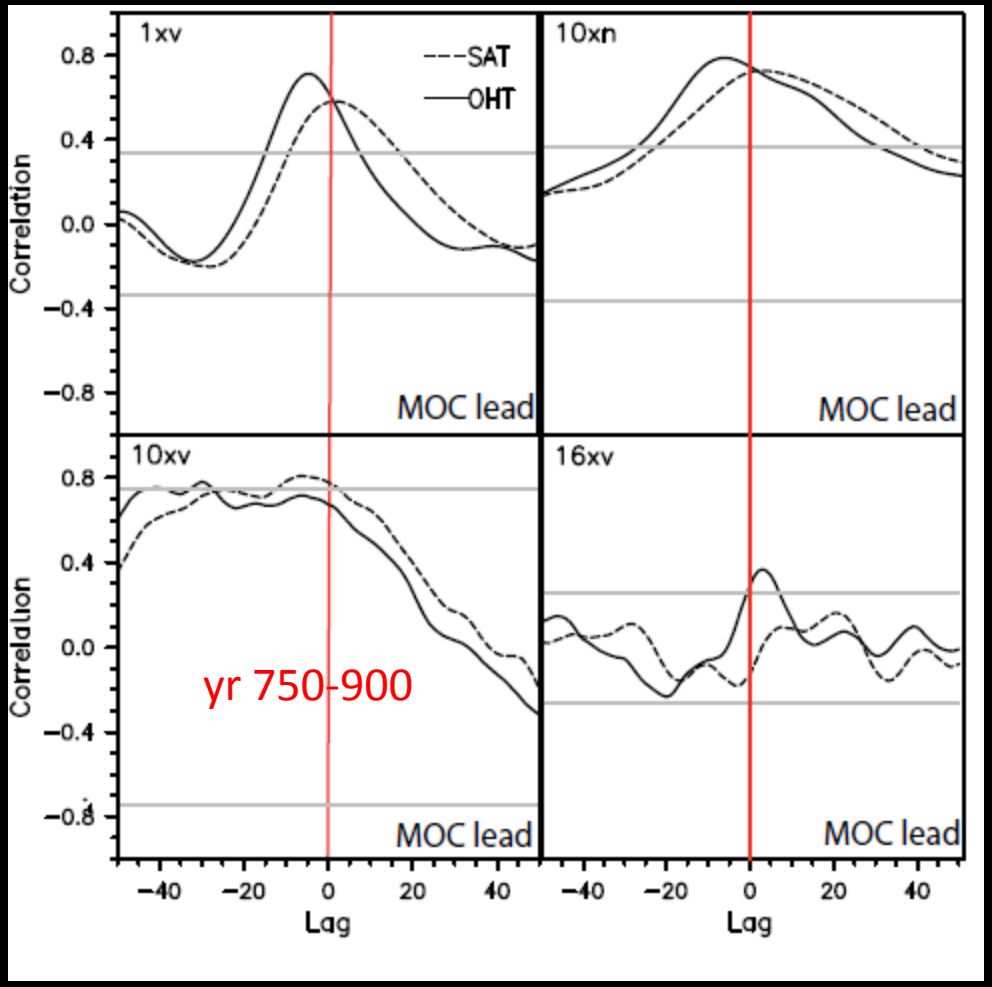
- The driving role of oceanic heat transport is persistent.
- The leading role of atmospheric heat transport decreases with warmer climate.

Variability of MOC



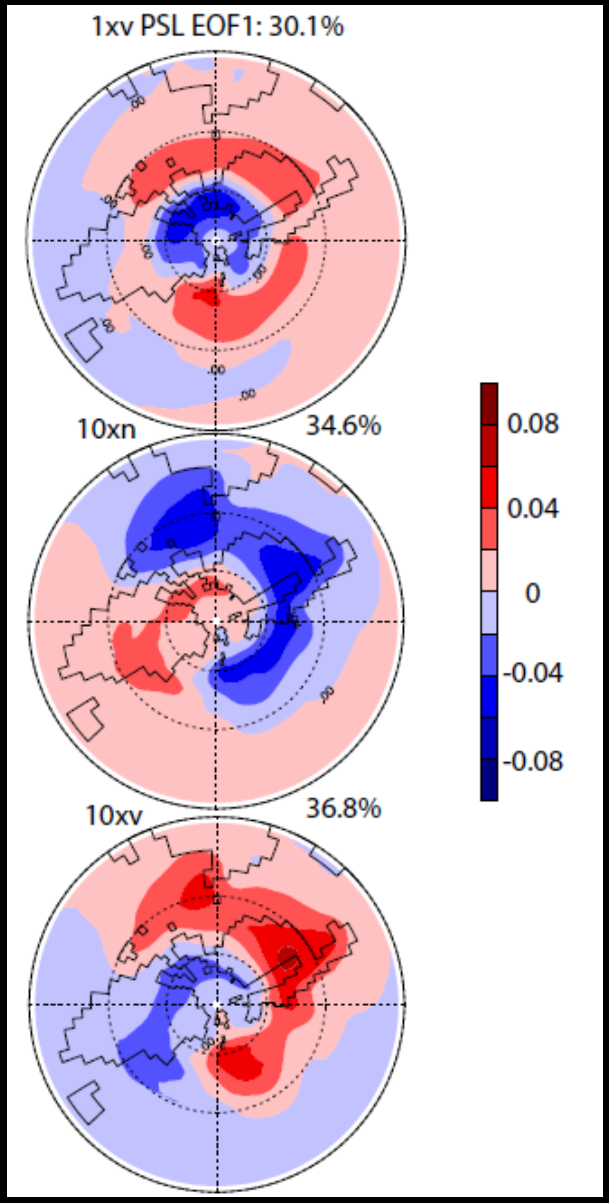


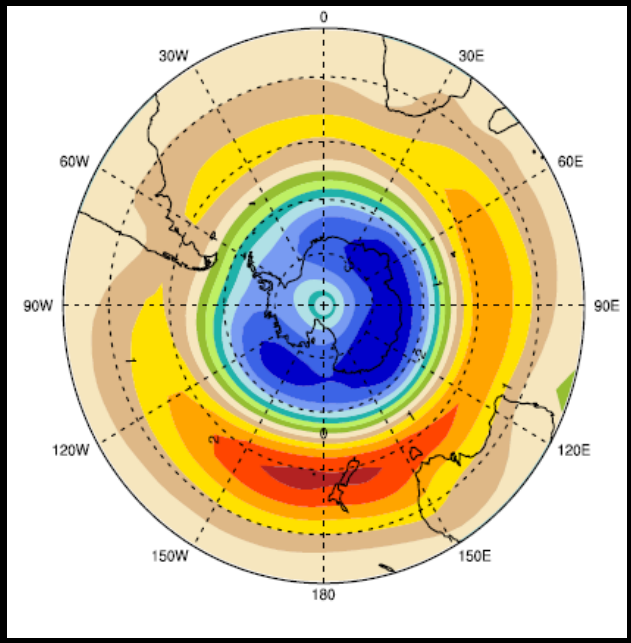
The role of MOC



MOC variation is a response rather than a driver of the anomalous OHT except in the 16xv experiment.

Atmospheric variability: PSL EOF1

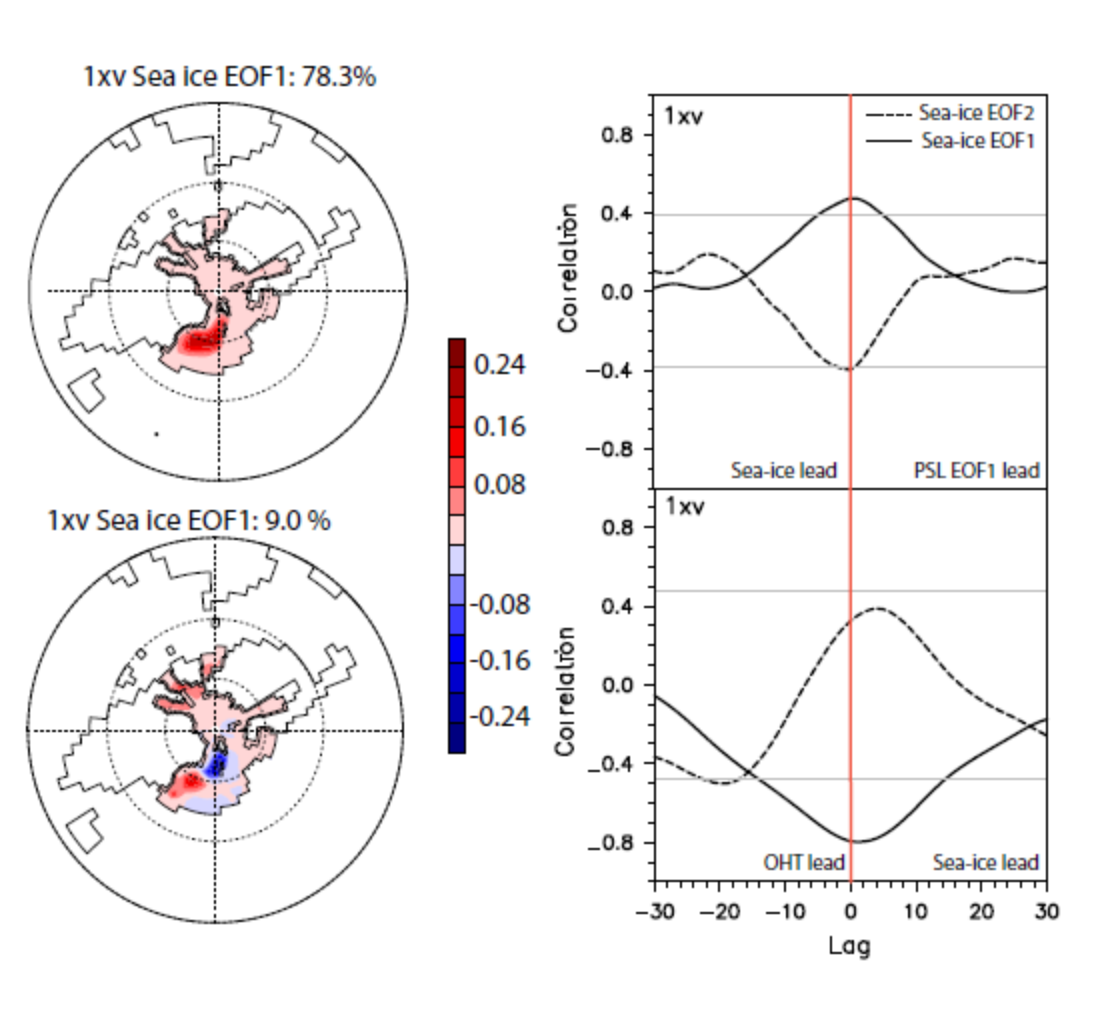




T41 modern CCSM3 simulation

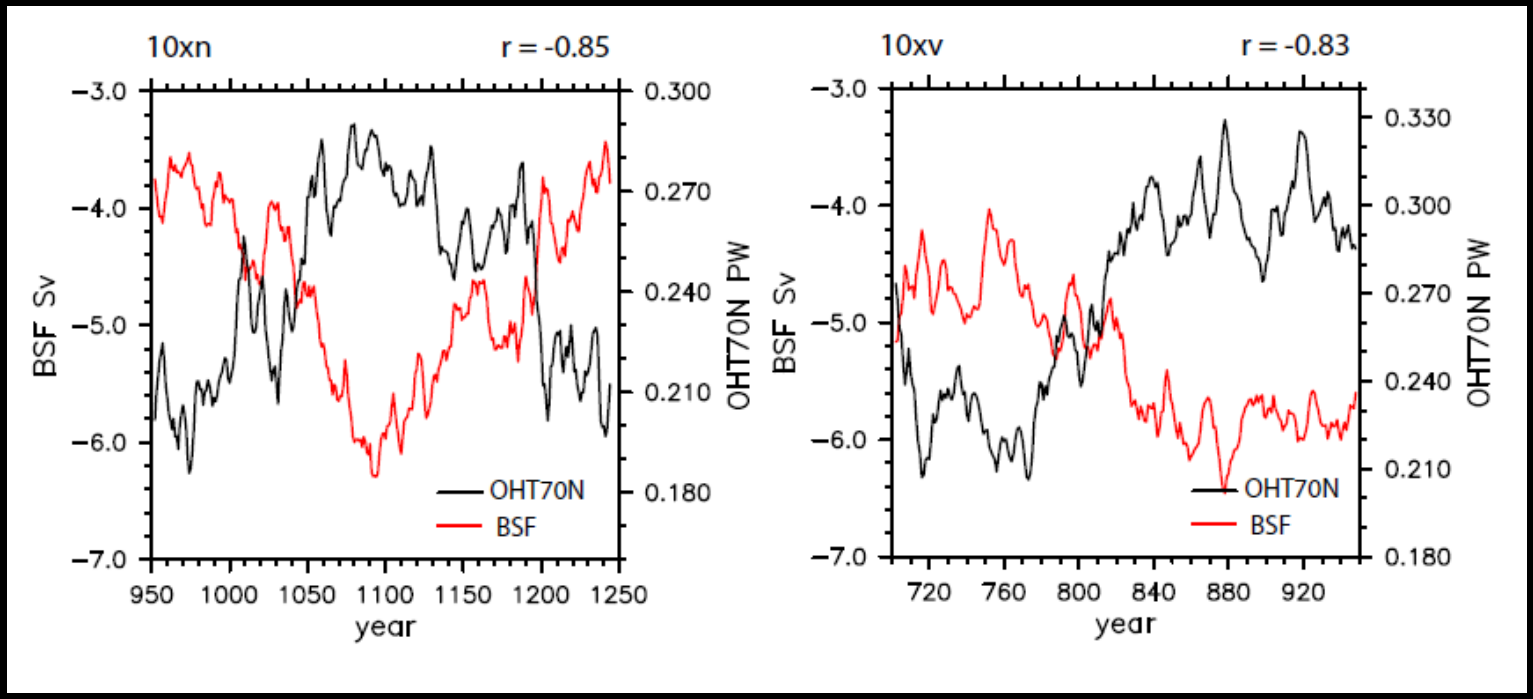
Yeager et al., 2006

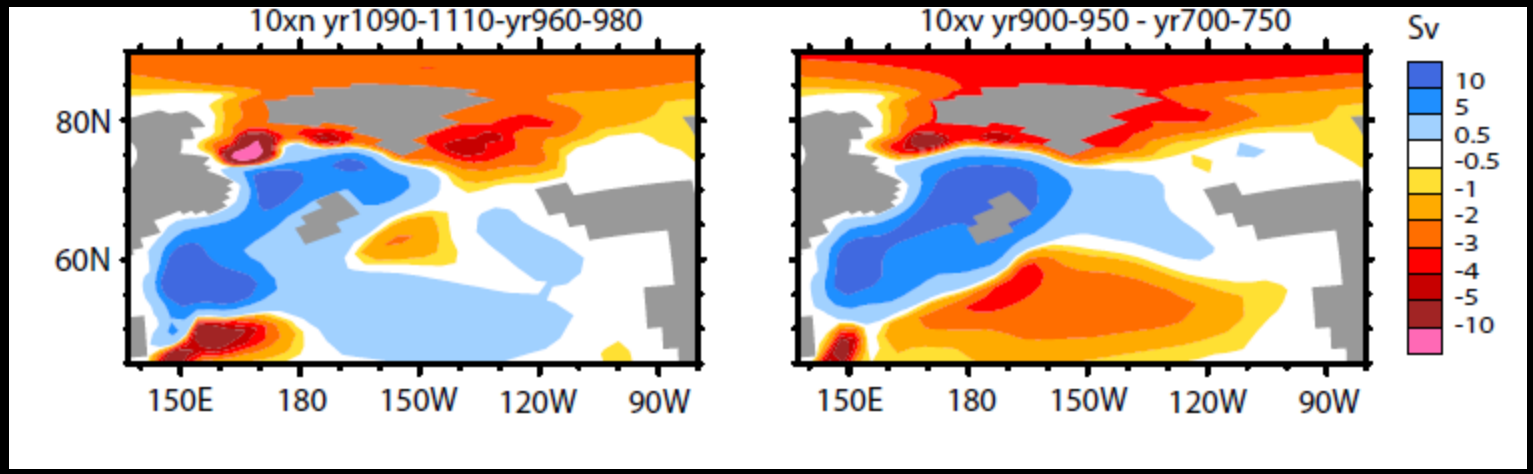
The role of sea-ice



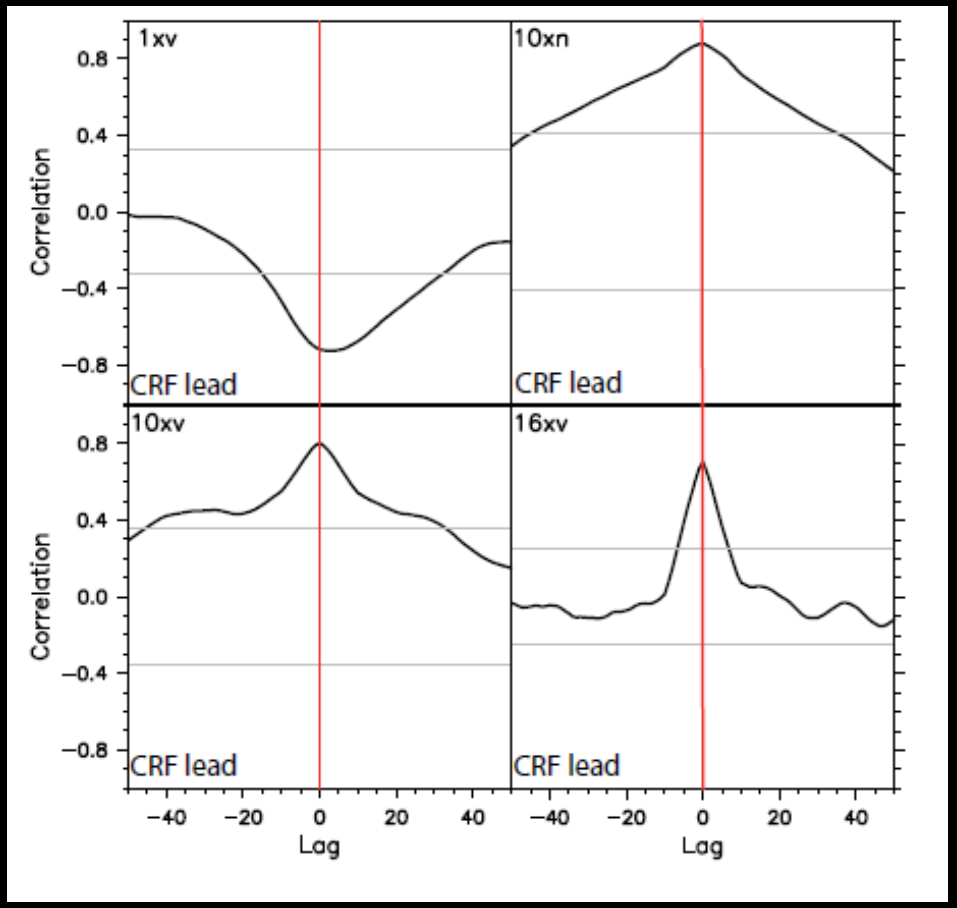
Atmospheric circulation triggers changes in sea-ice, which influences oceanic heat transport.

The role of BSF





The role of cloud radiative forcing



Positive cloud feedbacks in the ice-free simulations.

Summary:

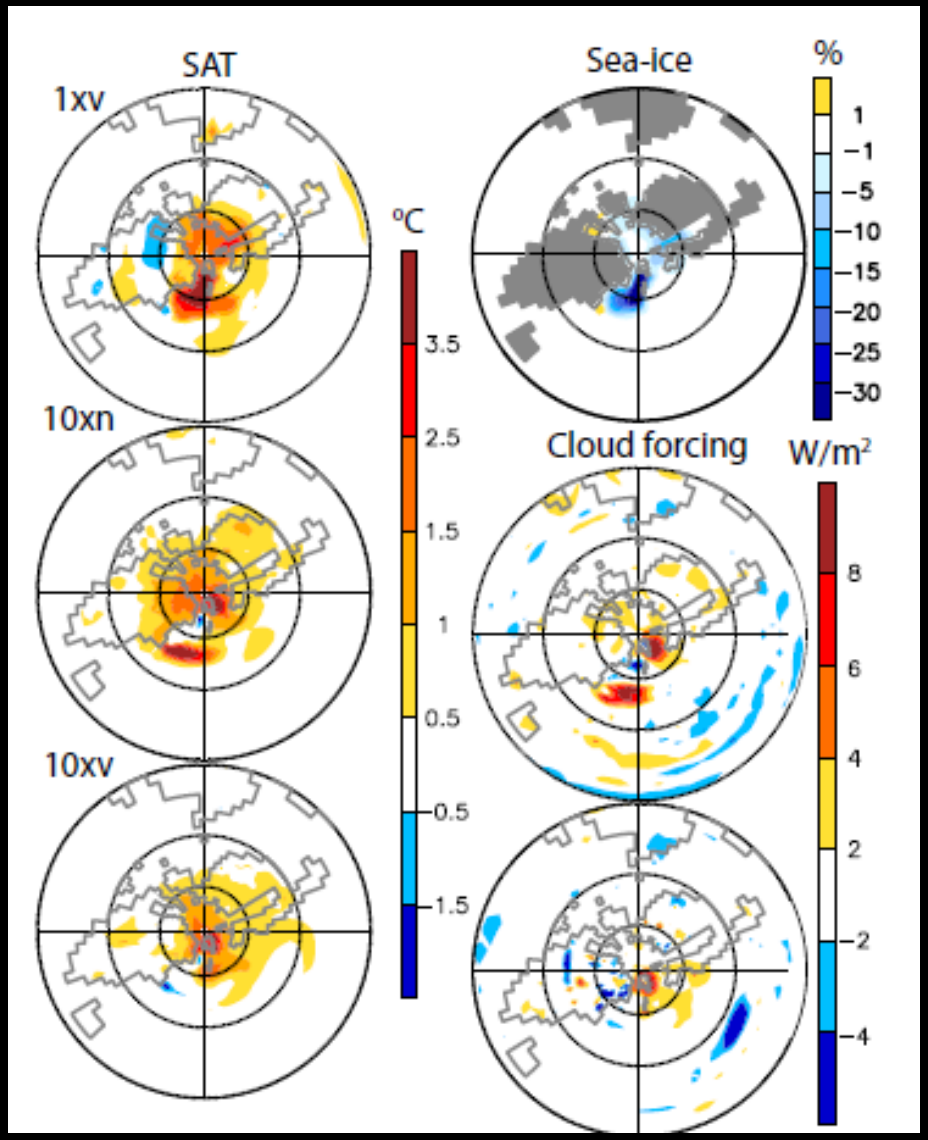
- The multi-decadal Arctic variability varies with mean climate in terms of regularity and magnitude.

- Anomalous oceanic heat transport acts as a driver for the Arctic multi-decadal variability, which is due to atmosphere-sea ice interaction in the 1xv experiment, and due to changes in BSF in the ice-free 10xn and 10xv experiment. In contrast, MOC variation can be only considered a response to the Arctic change.

- Anomalous atmospheric circulation leads to the Arctic multi-decadal variability when sea-ice feedback is significant.

- Cloud feedbacks tend to damp the variability in the 1xv experiment, yet to reinforce the variability in the rest ice-free warm simulations.

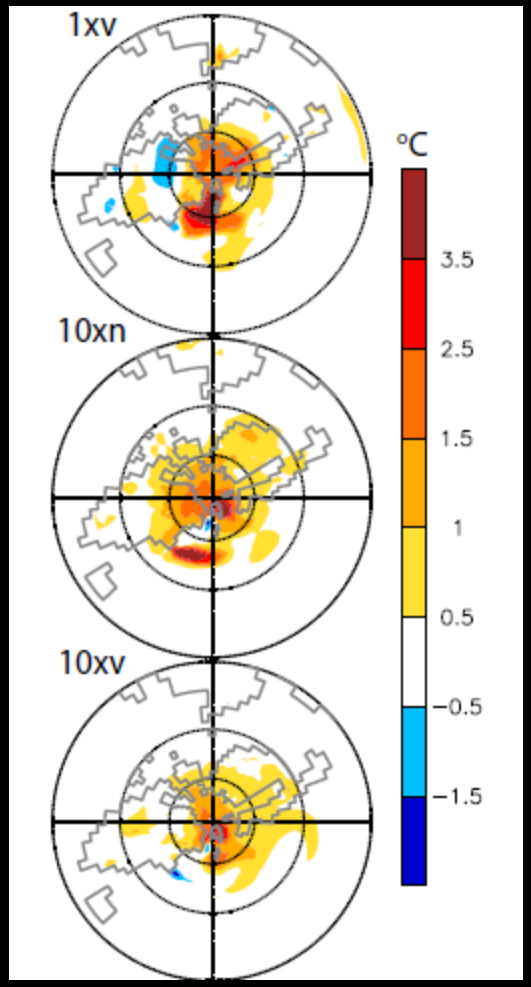
Examples of warming events

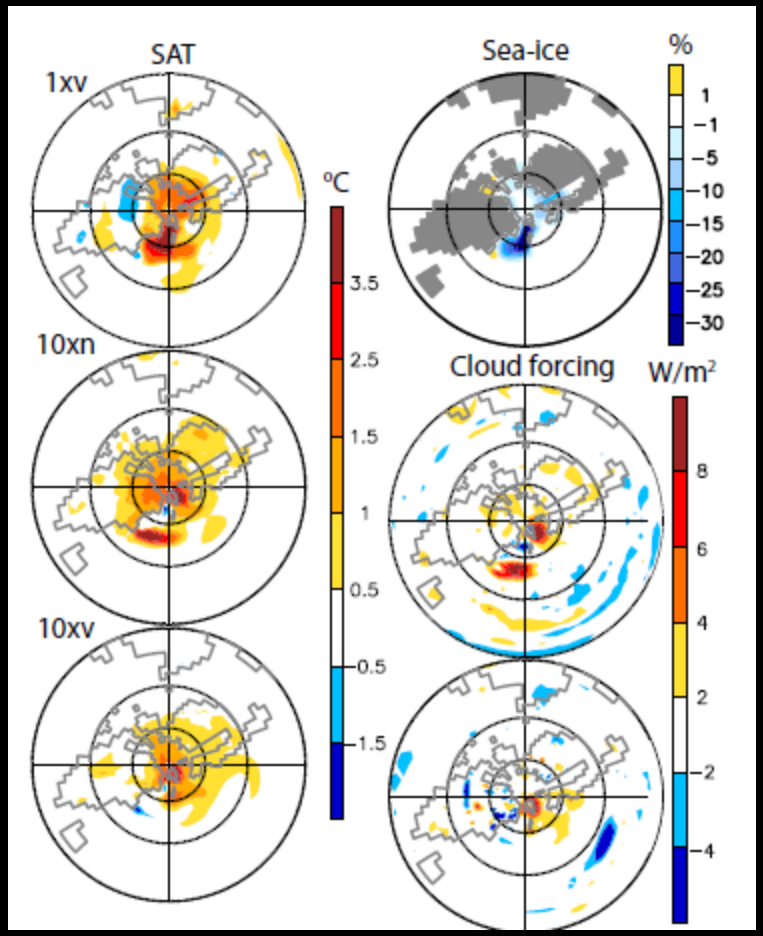


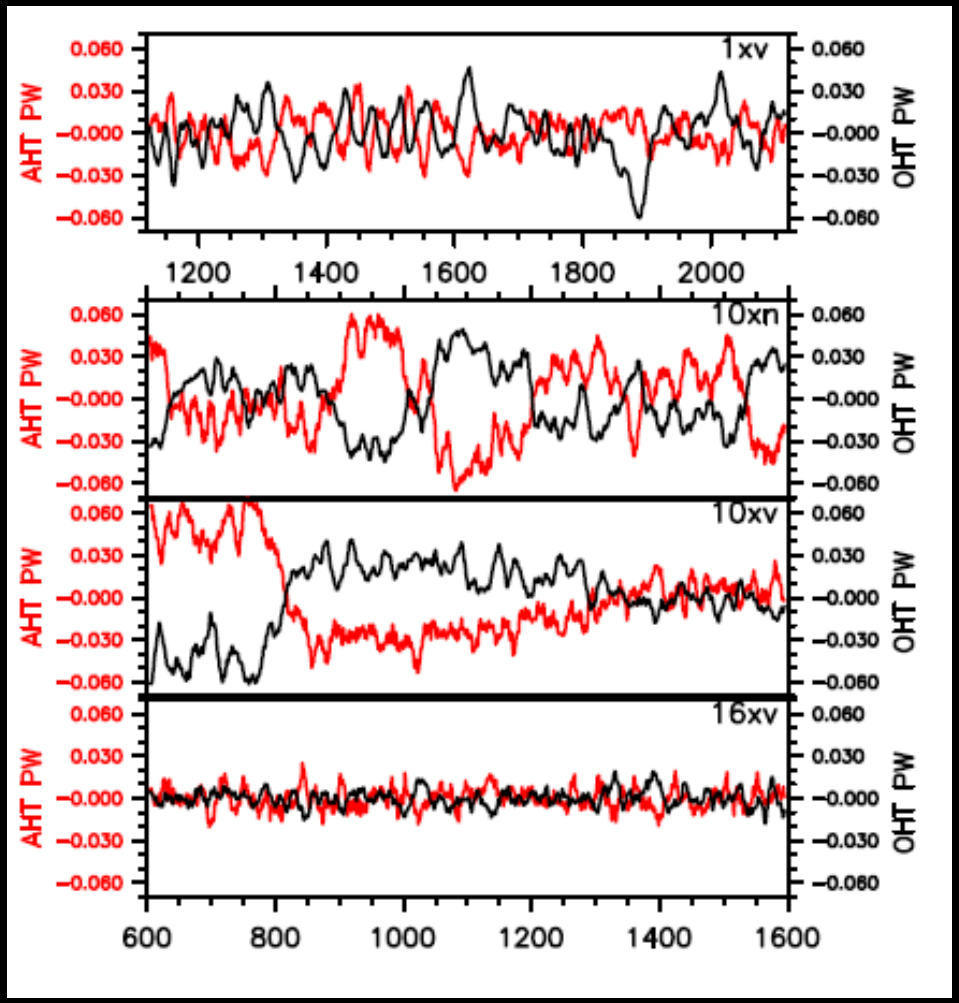
Methods

- Remove least-squared quadratic trend
- Hanning-window with a bandwidth of 11 applied prior to spectrum
- 10-year running mean is applied prior to regression/correlation
-

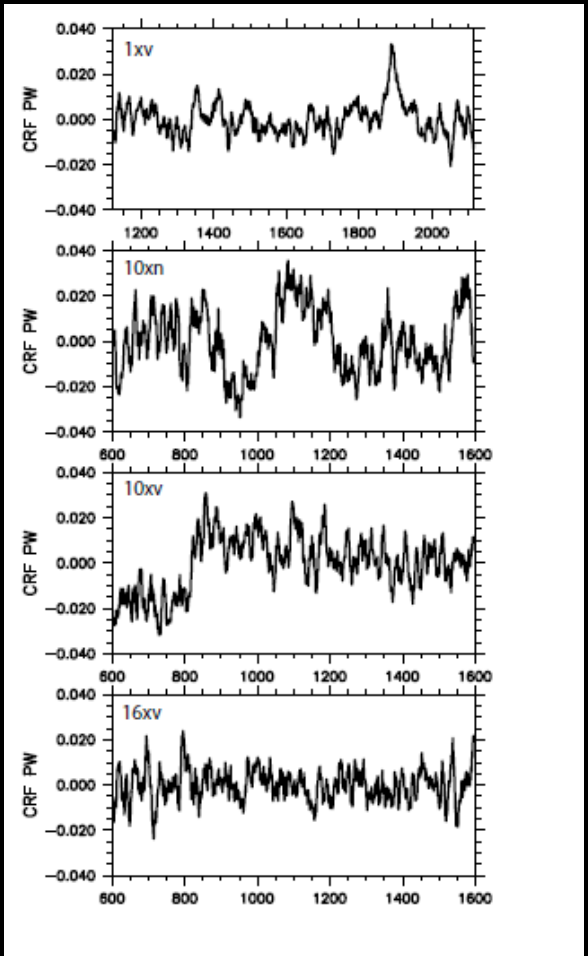
Warming events






1xv
10xn
10xv
16xv
AHT PW
OHT PW
0.060
0.030
−0.000
−0.030
−0.060
1200
1400
1600
1800
2000
600
800
1000
1200
1400
1600

CRF


1xv
10xn
10xv
16xv
CRF PW
0.040
0.020
0.000
−0.020
−0.040
1200
1400
1600
1800
2000
600
800
1000
1200
1400
1600