The Impact of Multidecadal NAO Variations on Atlantic Ocean Heat Transport and Rapid Changes in Arctic Sea Ice

Thomas L. Delworth, Fanrong Zeng, Gabe Vecchi, Xiaosong Yang, Liping Zhang, Rong Zhang
GFDL/NOAA
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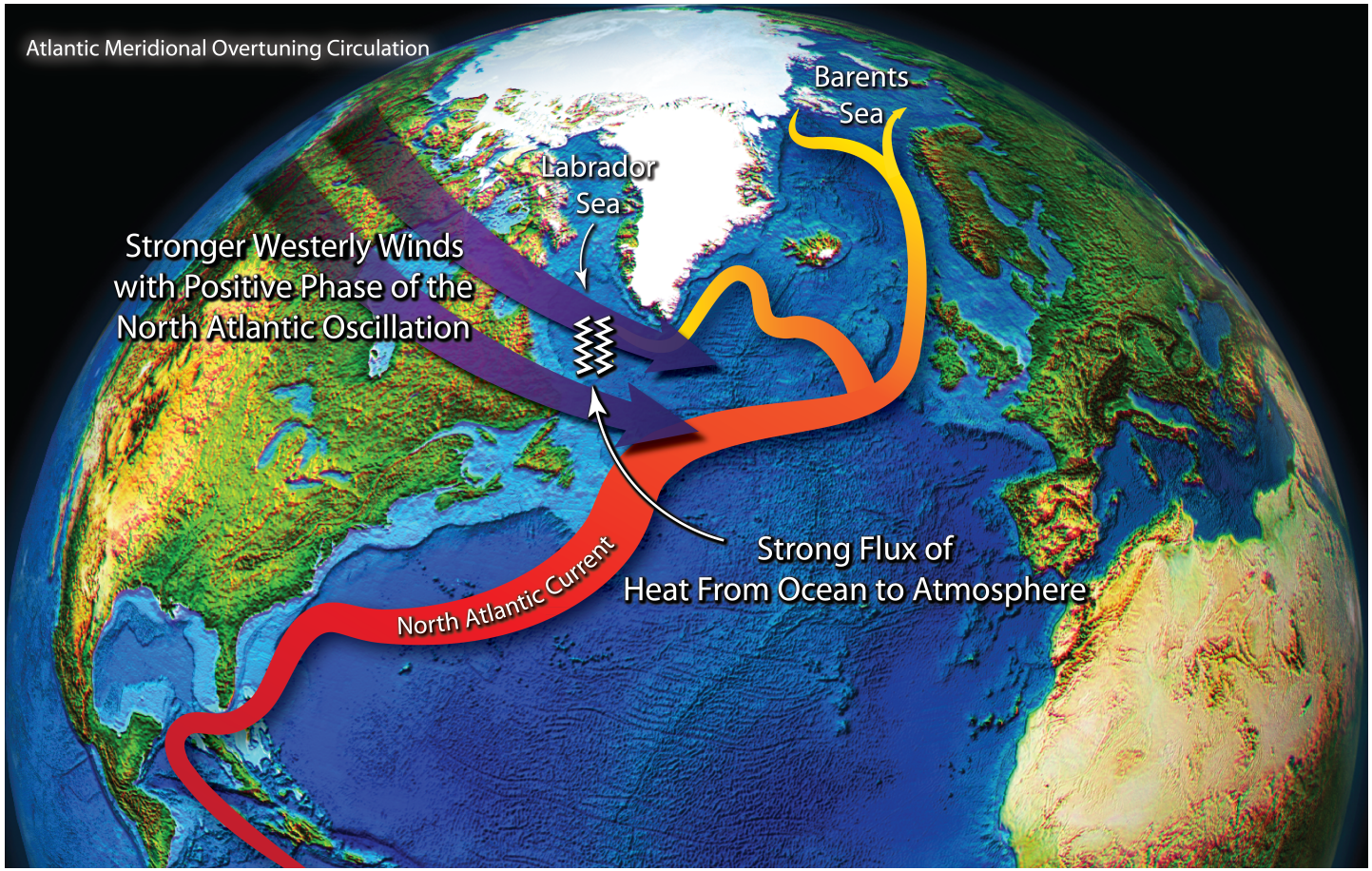
Motivations:

- **Observed rapid changes in the Arctic and Northern Hemisphere**
  - anthropogenic forcing and natural variability
- **North Atlantic Oscillation (NAO) is dominant mode of atmospheric variability**
- **Atlantic Meridional Overturning Circulation (AMOC) is dominant process for ocean heat transport in Atlantic**

Goal:

- **Explore the role of NAO variations in driving AMOC/ocean heat transport variations, and their impact on NH climate**

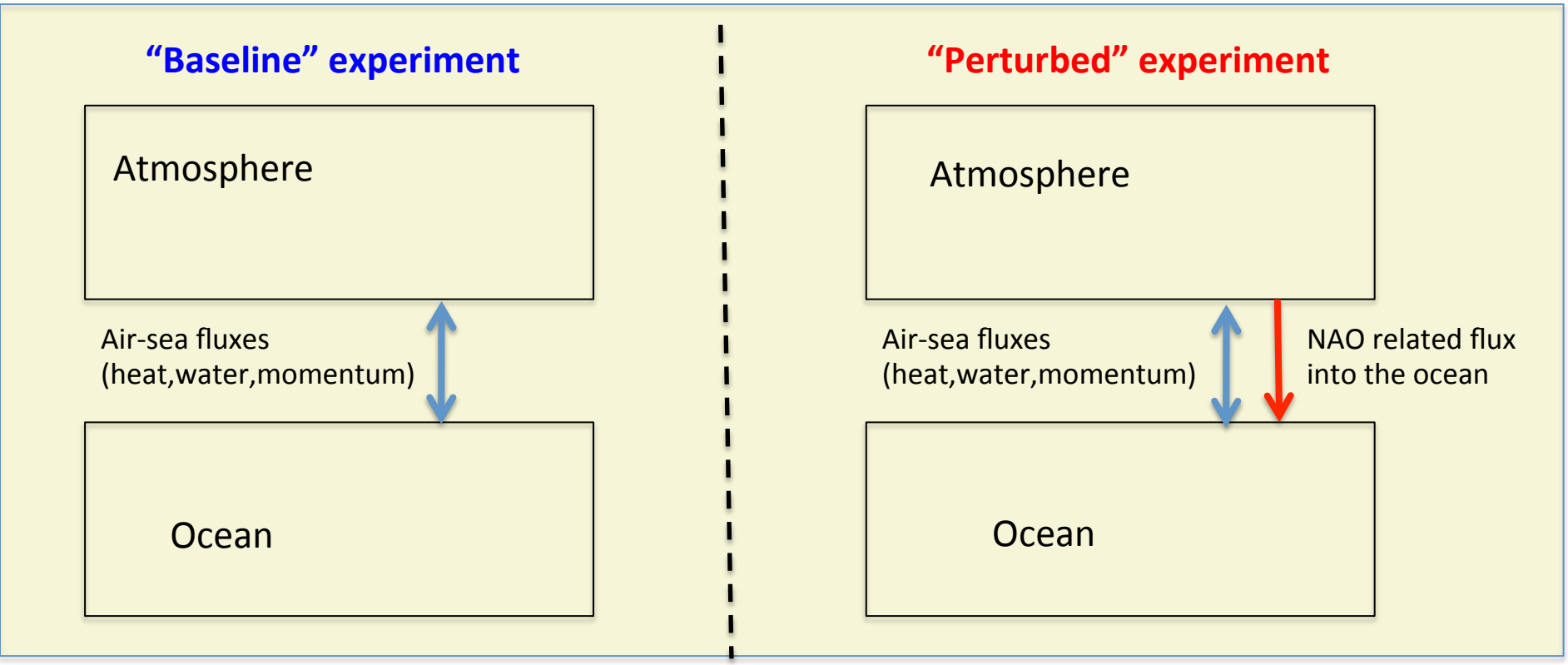


Transports ~1.3 PW of heat poleward in the Atlantic at 26°N

QUESTIONS TO ADDRESS:

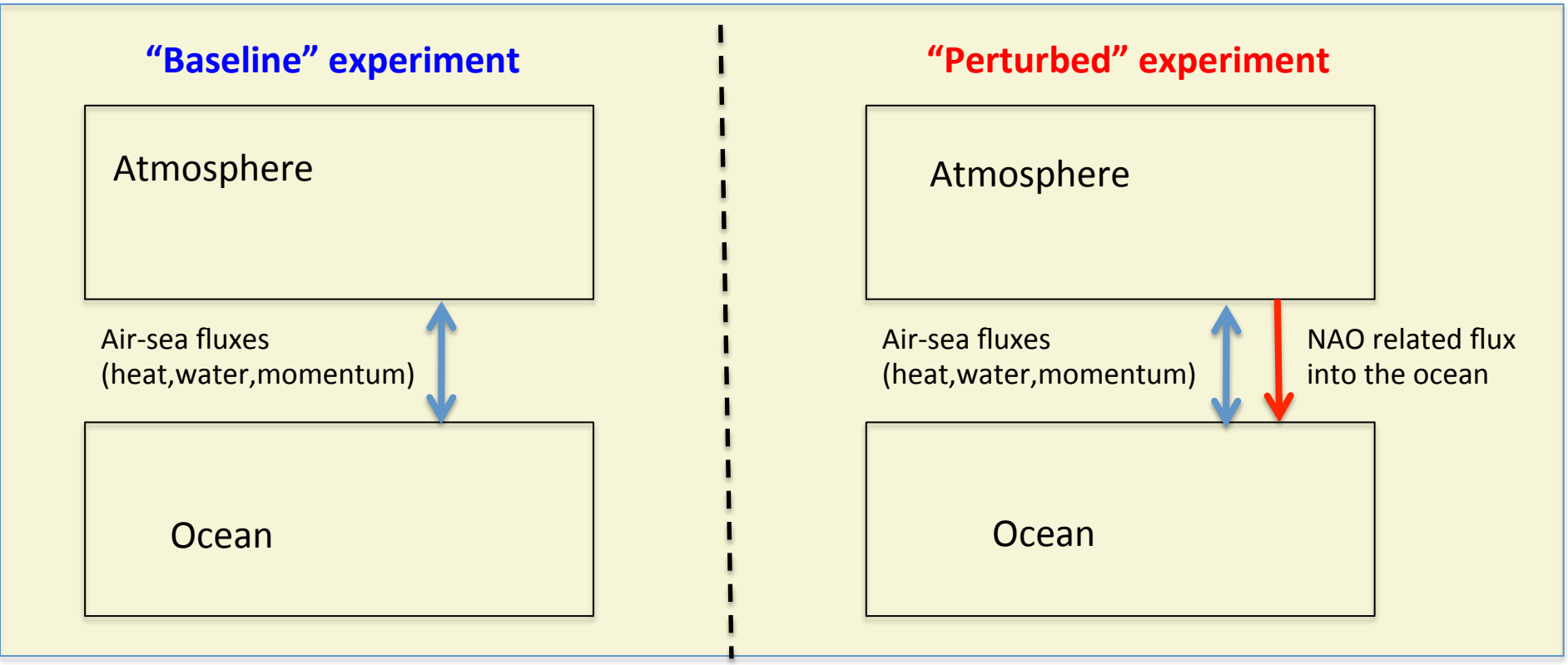
- How does the NAO influence the AMOC?
- What are the climatic impacts of NAO-induced AMOC variations?
- What role might NAO-induced AMOC changes play for understanding 20th/ 21st century decadal climate variability and change?

EXPERIMENTAL DESIGN



- *"Perturbed" minus "Baseline" is response to NAO-related fluxes.*
- *Use same radiative forcing in "Baseline" and "Perturbed" experiments (could be constant radiative forcing or time-varying radiative forcing)*
- *Use ensembles to increase signal to noise ratio.*

EXPERIMENTAL DESIGN

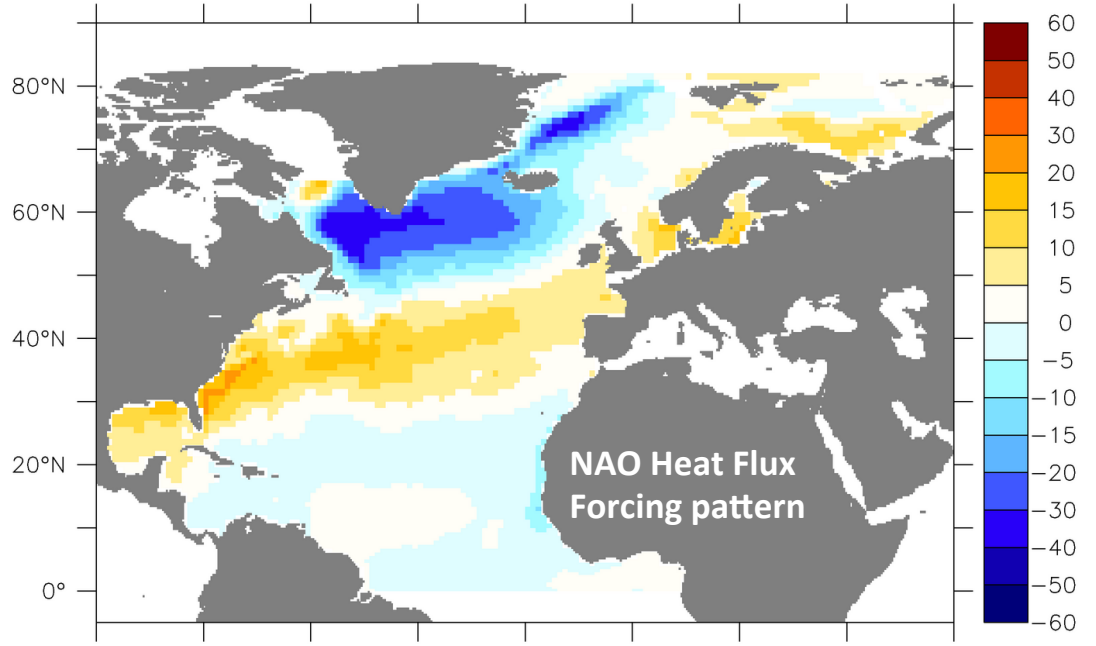


- *"Perturbed" minus "Baseline" is r*
- *Use same radiative forcing in "Ba*
  constant radiative forcing or time
- *Use ensembles to increase signal*

GFDL Coupled Models used:

CM2.1 - 2° atmosphere (24 levels), 1° ocean
CM3 - 2° atmosphere (48 levels), 1° ocean
FLOR – 0.5° atmosphere (32 levels), 1° ocean
CM2.5 – 0.5° atmosphere (32 levels), 0.25° ocean

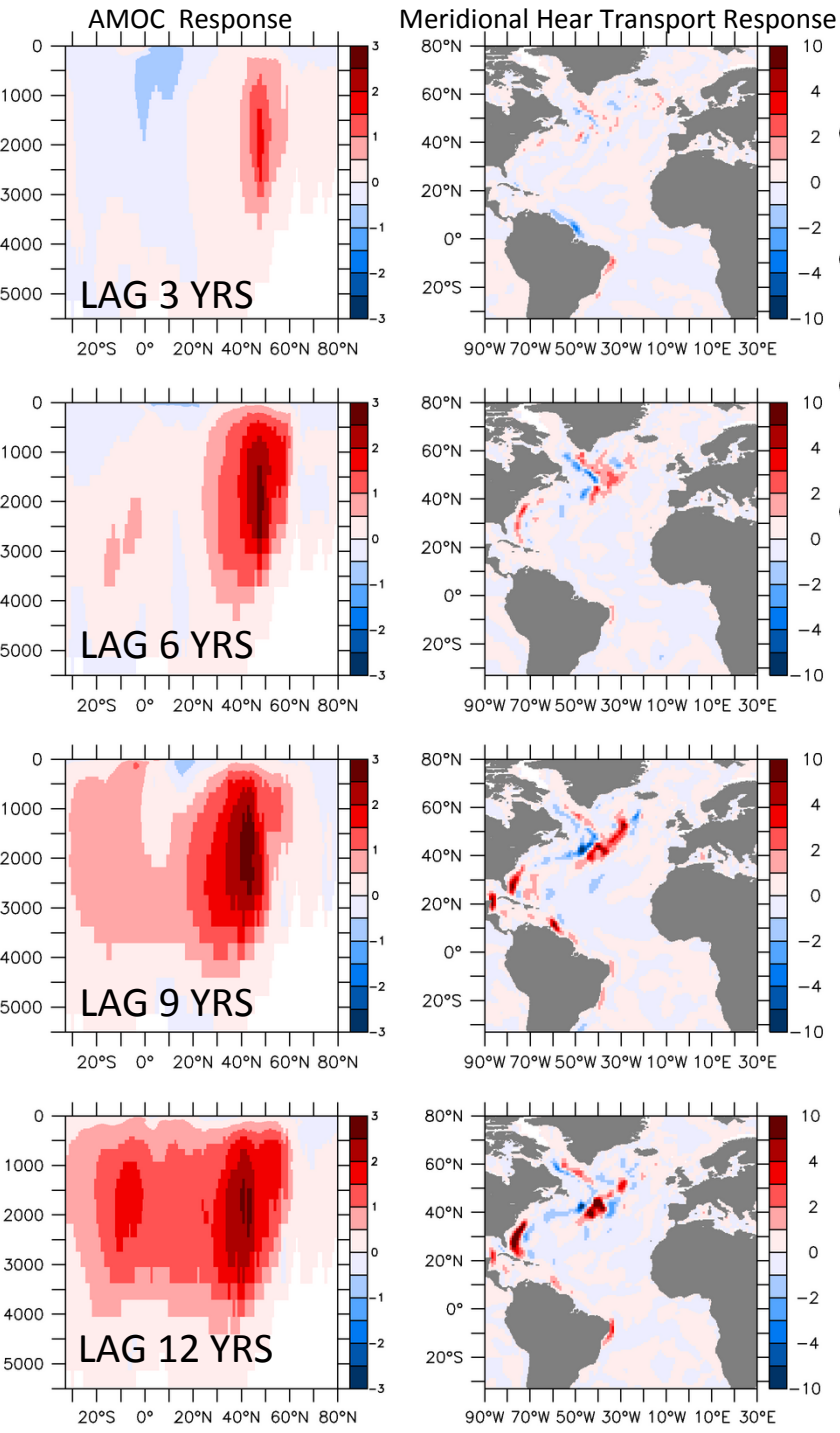
Pattern of surface heat flux associated with NAO

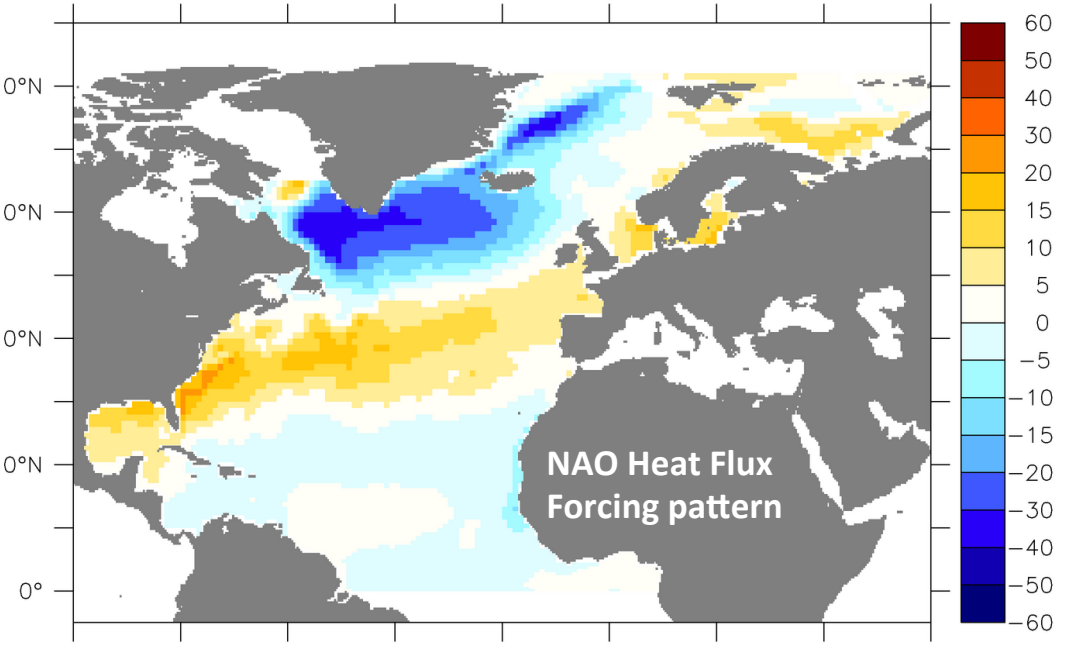


- Derived by regressing ECMWF fluxes versus observed NAO Index (Hurrell Station Index)
- Constrained to have zero spatial integral
- Only applied in North Atlantic, Nordic and Barents Sea

Conduct simulations applying this pattern, modulated in time:

- Switch on and hold constant
- Vary sinusoidally (separate experiments with NAO periods of 2,5,10,20,50,100,200 years)
- Vary over 20th/21st centuries with scaling to observed NAO





Experiments

a. "Switch on" of NAO forcing – adjustment process to NAO
b. "Sinusoidal" NAO forcing with periods from 2 to 100 years
c. "Realistic" 20th century NAO forcing

Delworth and Zeng, Feb, 2016
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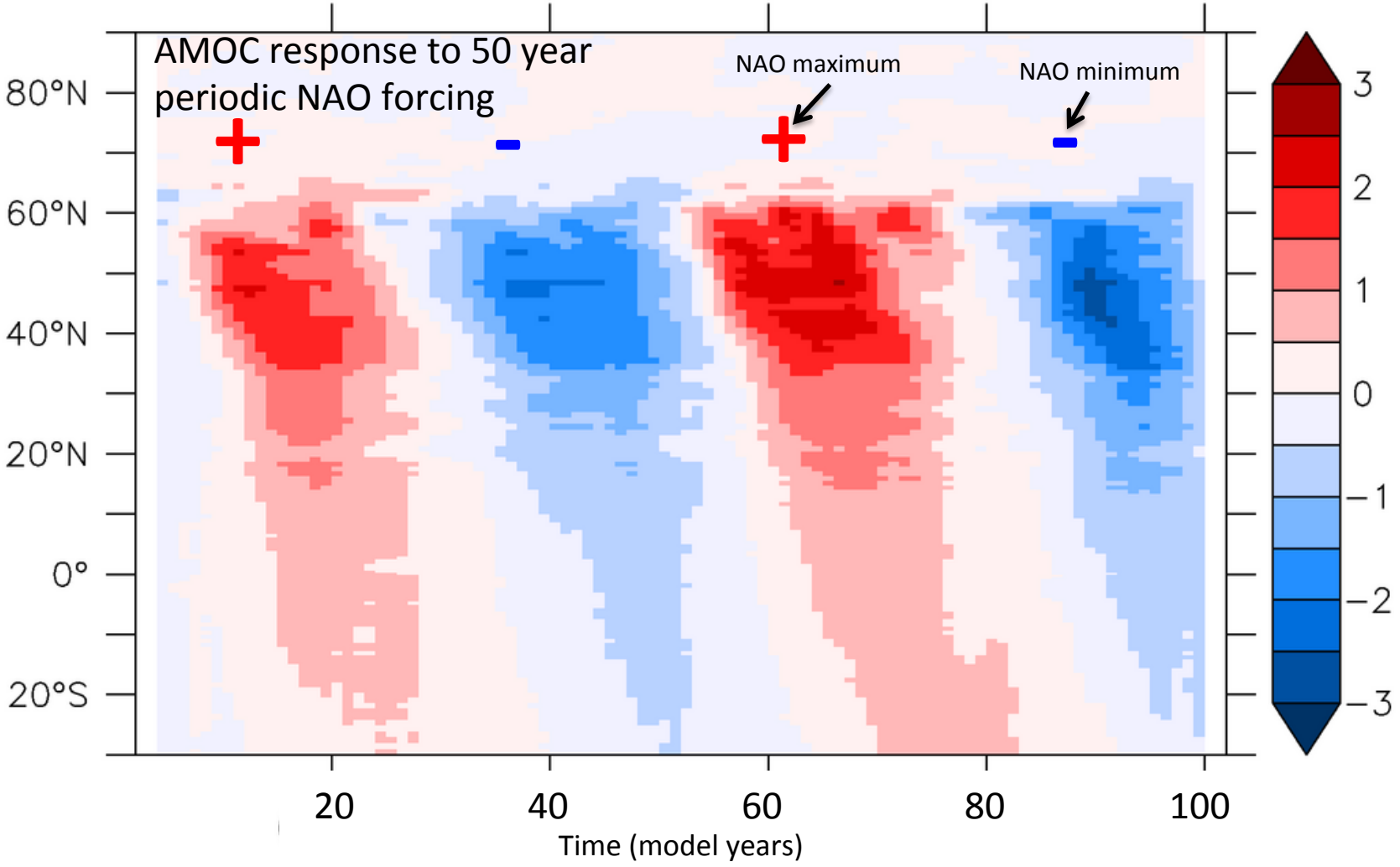
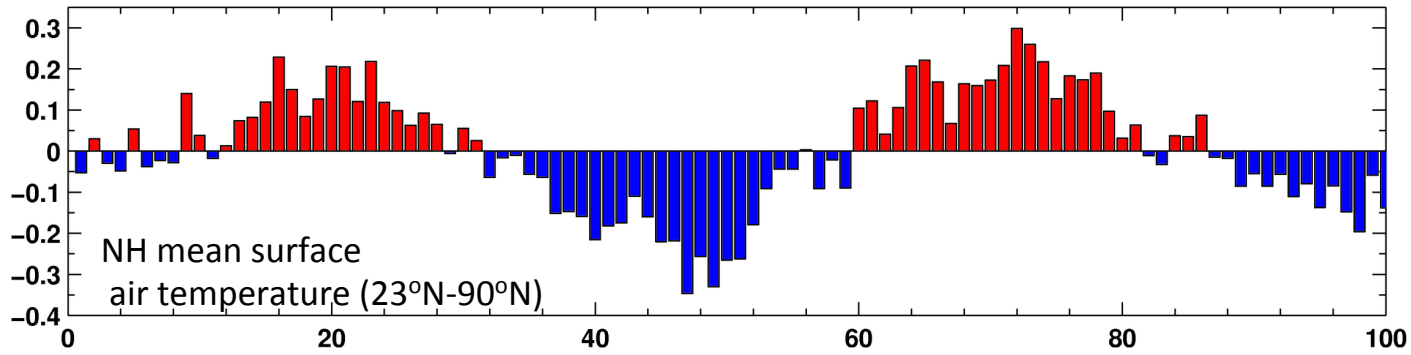
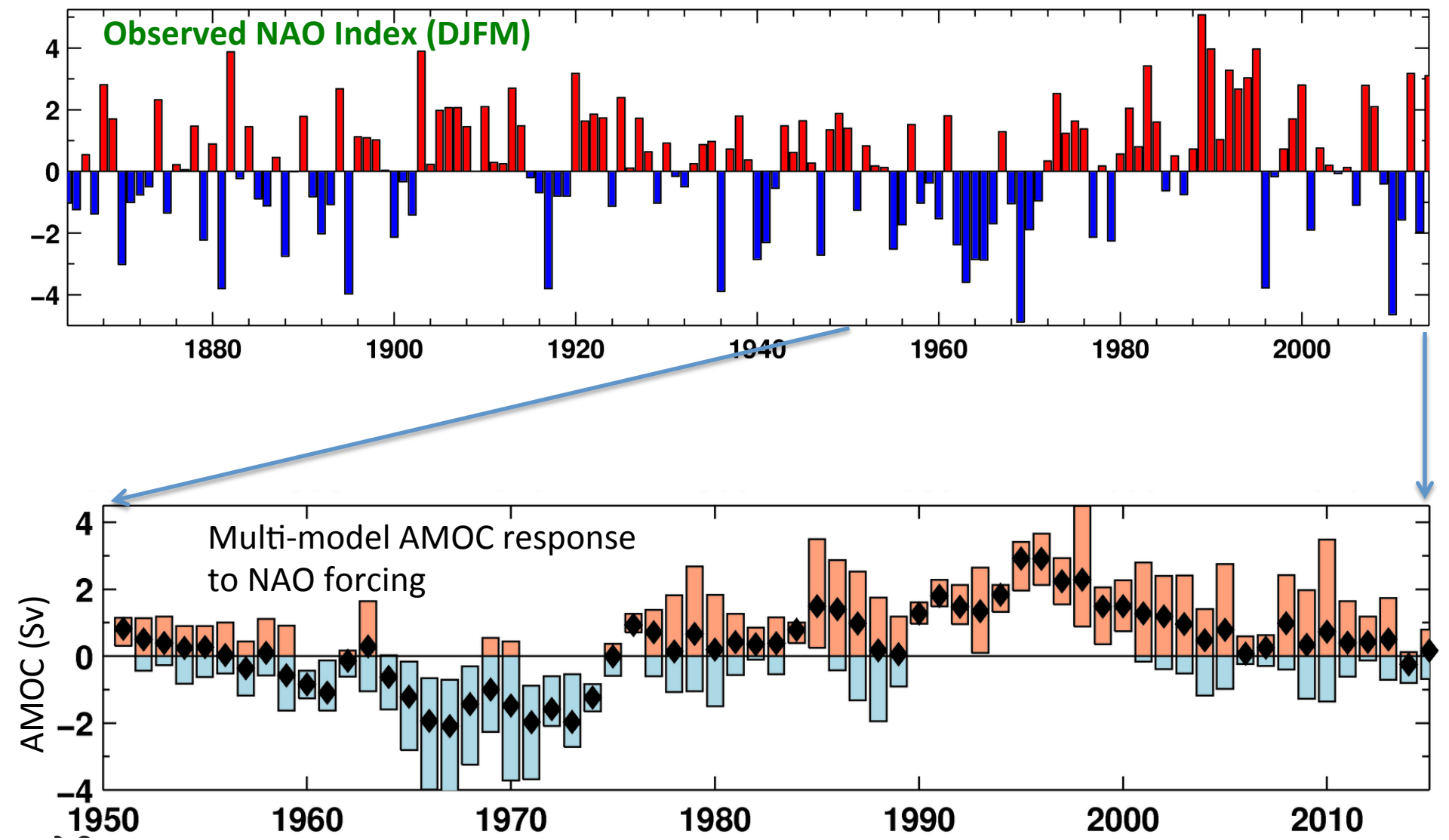
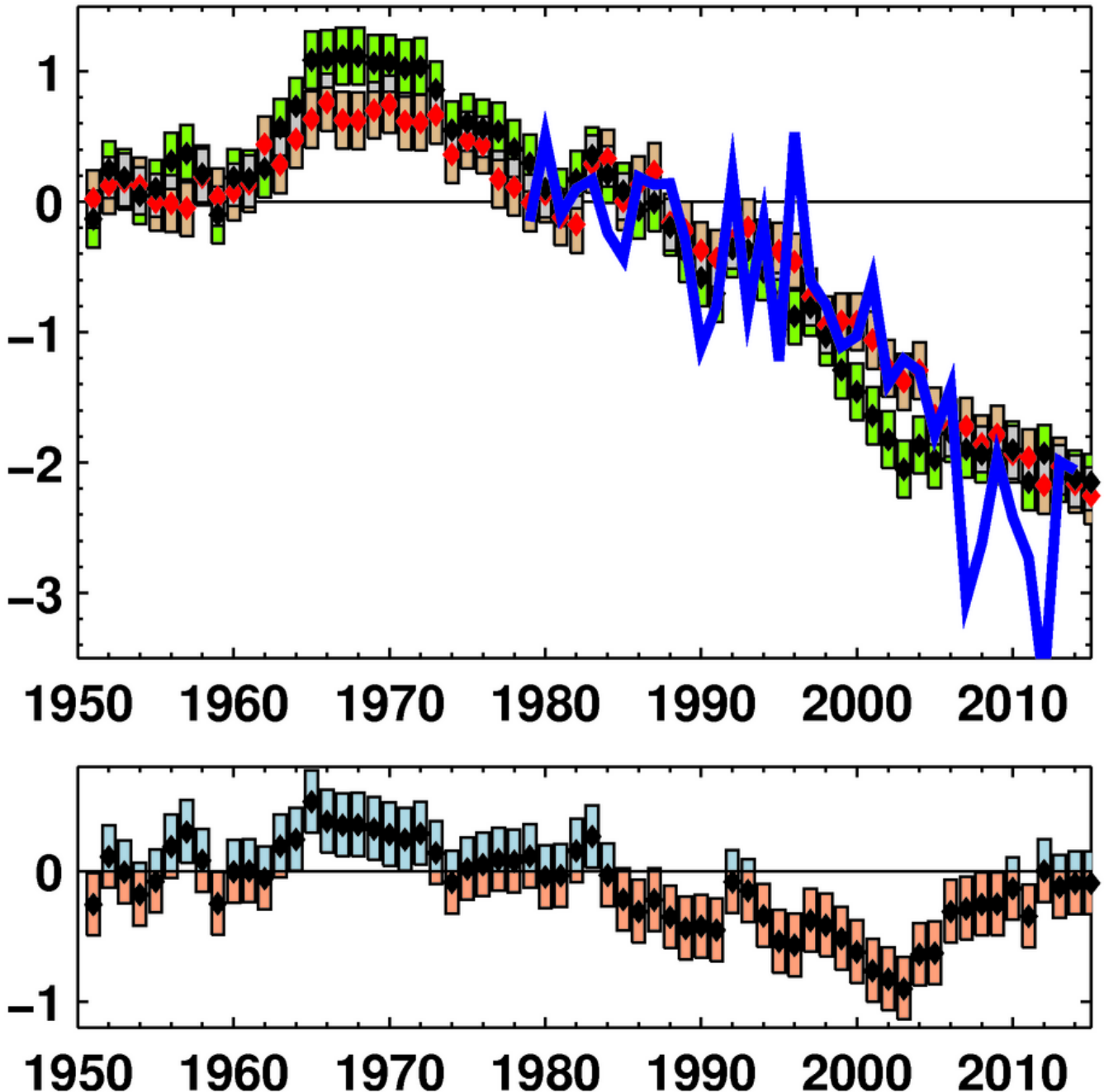

AMOC response to 50 year
periodic NAO forcing
NAO maximum
NAO minimum
+
-
+
-
80°N
60°N
40°N
20°N
0°
20°S
3
2
1
0
−1
−2
−3
20
40
60
80
100
Time (model years)


0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
NH mean surface
air temperature (23°N-90°N)
0
20
40
60
80
100



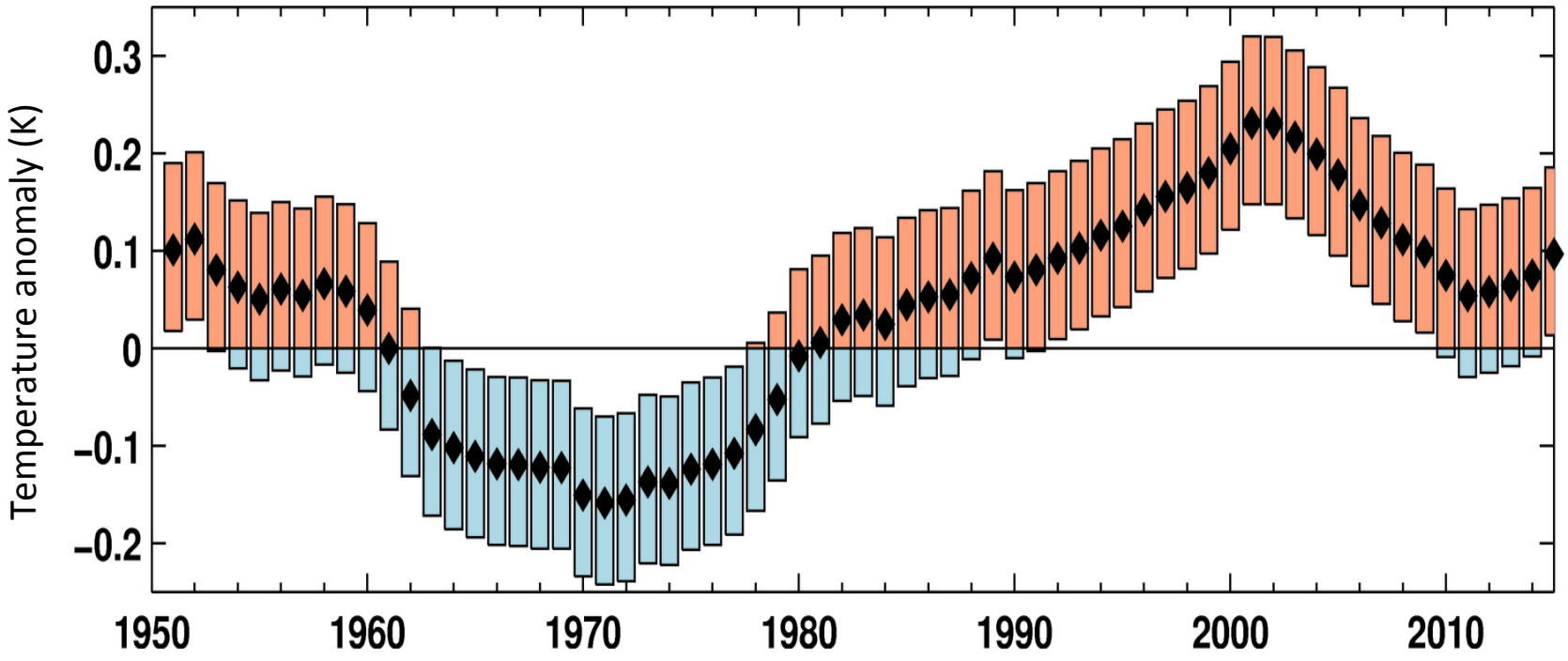
Delworth et al, Nat Geo, 2016

Impact of NAO-induced heat transport on Arctic Sea Ice Areal Extent

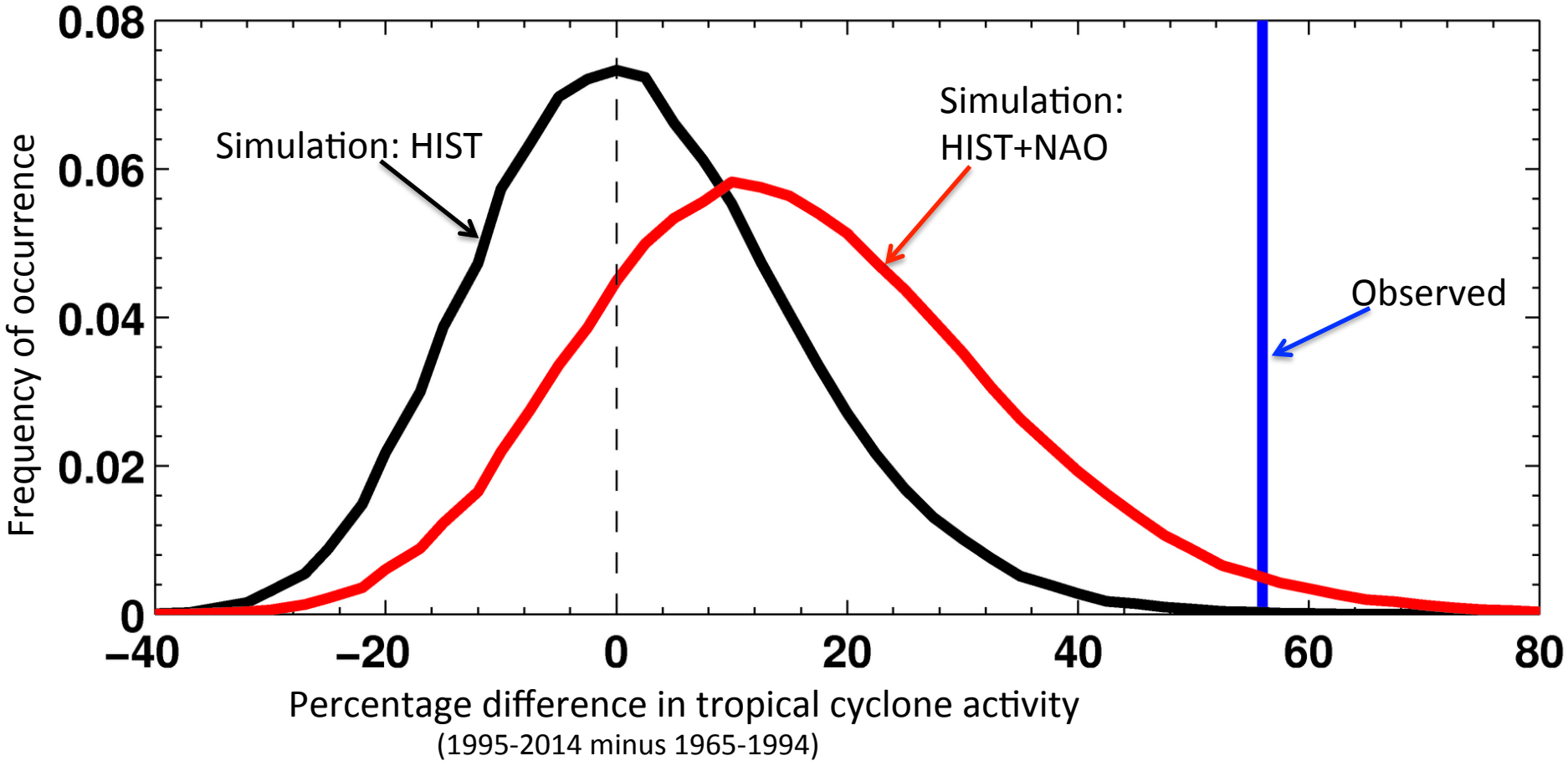


September

Response of Northern Hemisphere Extratropical Temperature to NAO Impact on Ocean



Impact of NAO-induced heat transport on Atlantic Tropical Storm Frequency



Summary and Discussion

- NAO variations drive simulated AMOC variability
- Models simulate NAO-induced AMOC changes over the historical record, with large-scale climatic impacts
  - Temperature, sea ice, Atlantic tropical storms, Southern Ocean
- NAO-induced variations are in addition to trends due to anthropogenic forcing

Challenges:

- What generates multidecadal NAO variability? White noise or more complicated? Response to radiative forcing?
- How widely do models differ in their response to the NAO? How can we know which models are "better"? What are the mechanisms determining this?
- Model predictions suggest weakening AMOC over the next decade … consistent with response to observed NAO trends and anthropogenic forcing … what will be the climatic impacts (sea ice, temperature, etc)?