Interference Between Forced and Unforced Climate Variability: Implications for the North Atlantic and the Arctic

Neil F. Tandon
& Paul J. Kushner
University of Toronto

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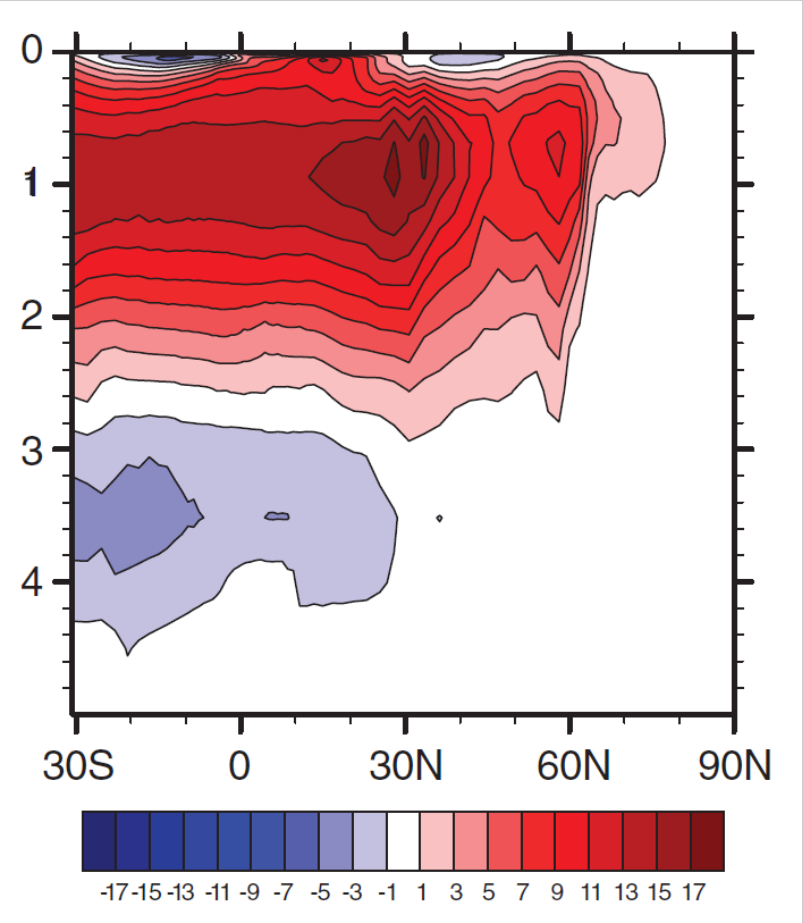
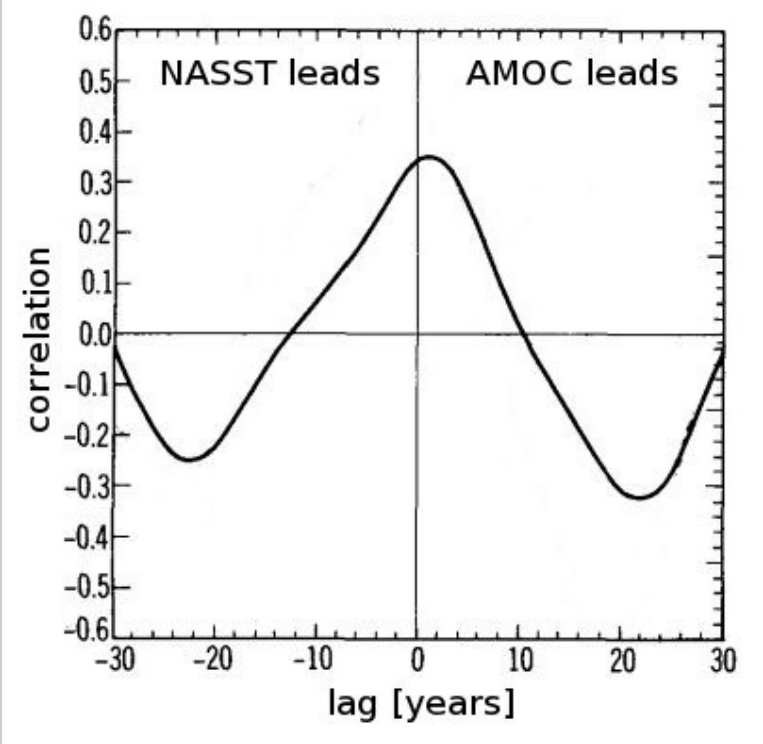
BNP PARIBAS FOUNDATION

CANSISE
Canadian Sea Ice and Snow Evolution Network

AMOC-NASST Relationship



Liu et al., *Science* (2009)



schematic adaptation from
Delworth et al., *J. Clim.* (1993)

(AMOC = Atlantic meridional overturning circulation
NASST = North Atlantic sea surface temperature)

Models are highly inconsistent!

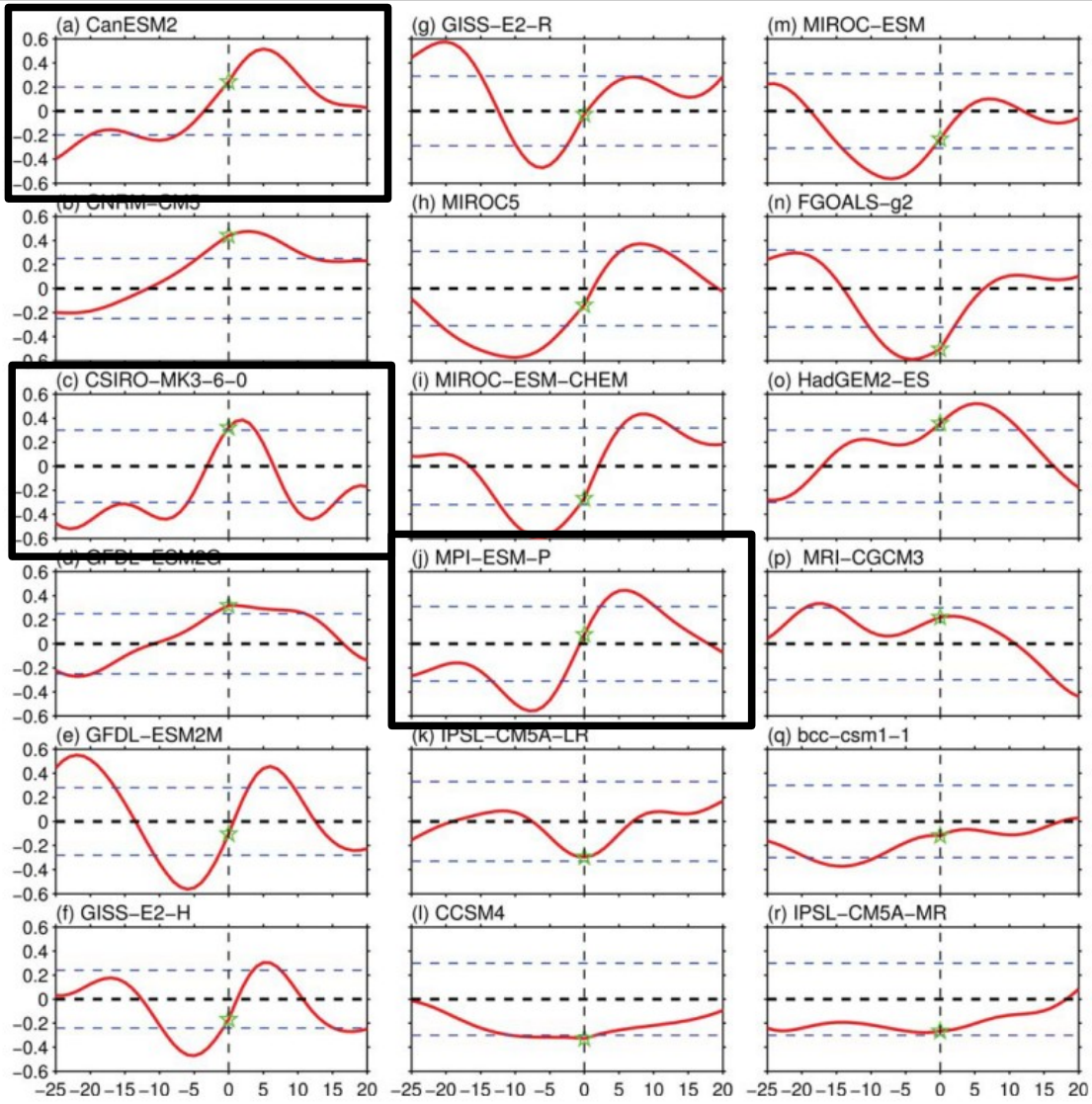


Figure 10. Lead-lag correlation between the AMO and the AMOC indices in CMIP5 historical simulations. The unit of value in *x* axis is year. Positive (negative) years in *x* axis mean the AMOC leads (lags) the AMO. The dash lines are the 80% confidence level.

Historical simulations (1850-2005) from CMIP5, Linearly detrended

Zhang and Wang, *JGR* (2013)
cf. Medhaug and Furevik (2011)

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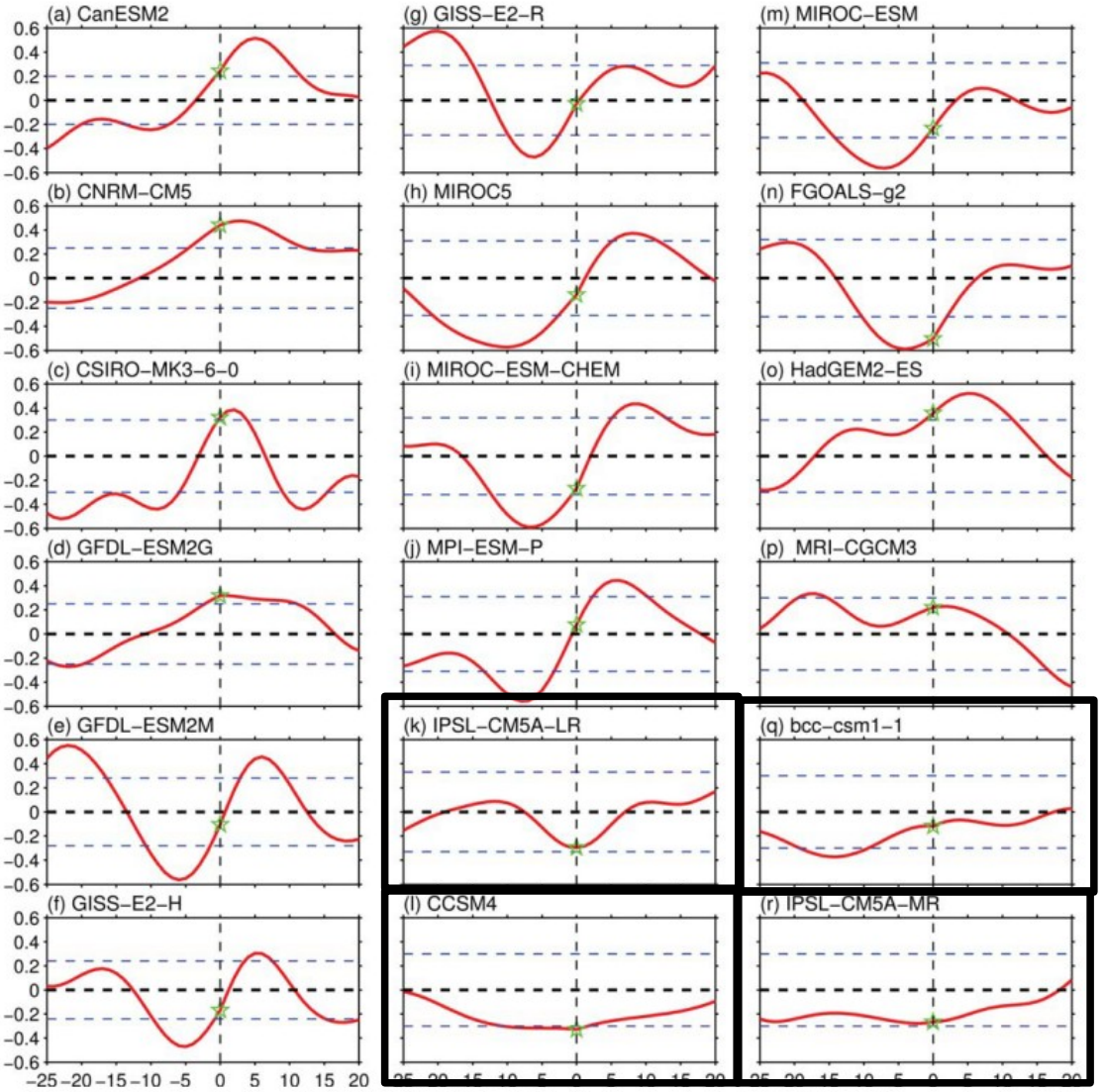

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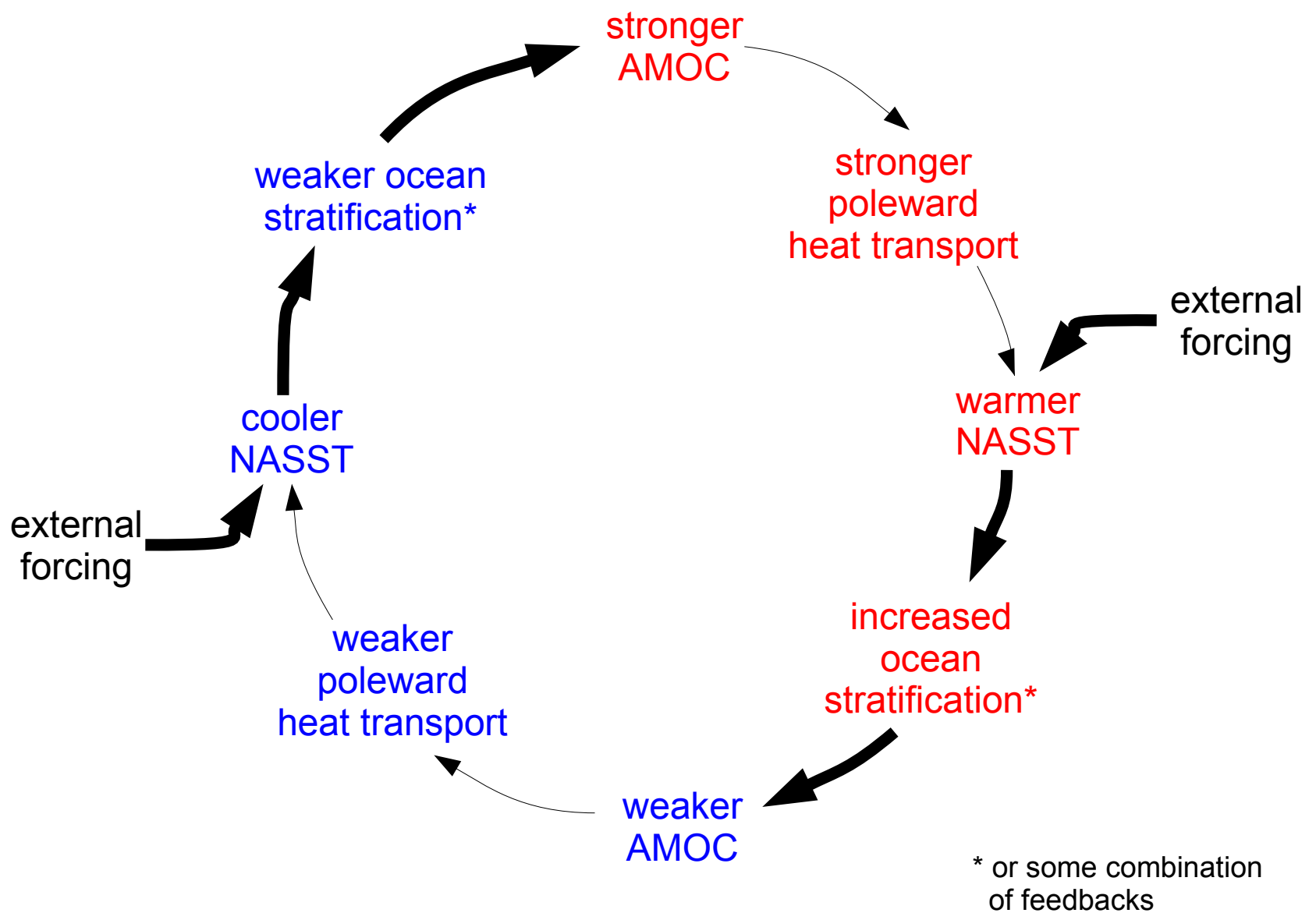
Key question #1: Why do models seem so inconsistent in how they represent the AMOC-NASST relationship?

Our answer: Forced variations are interfering with unforced variations.

Key question #2: Does such interference occur in the Arctic?

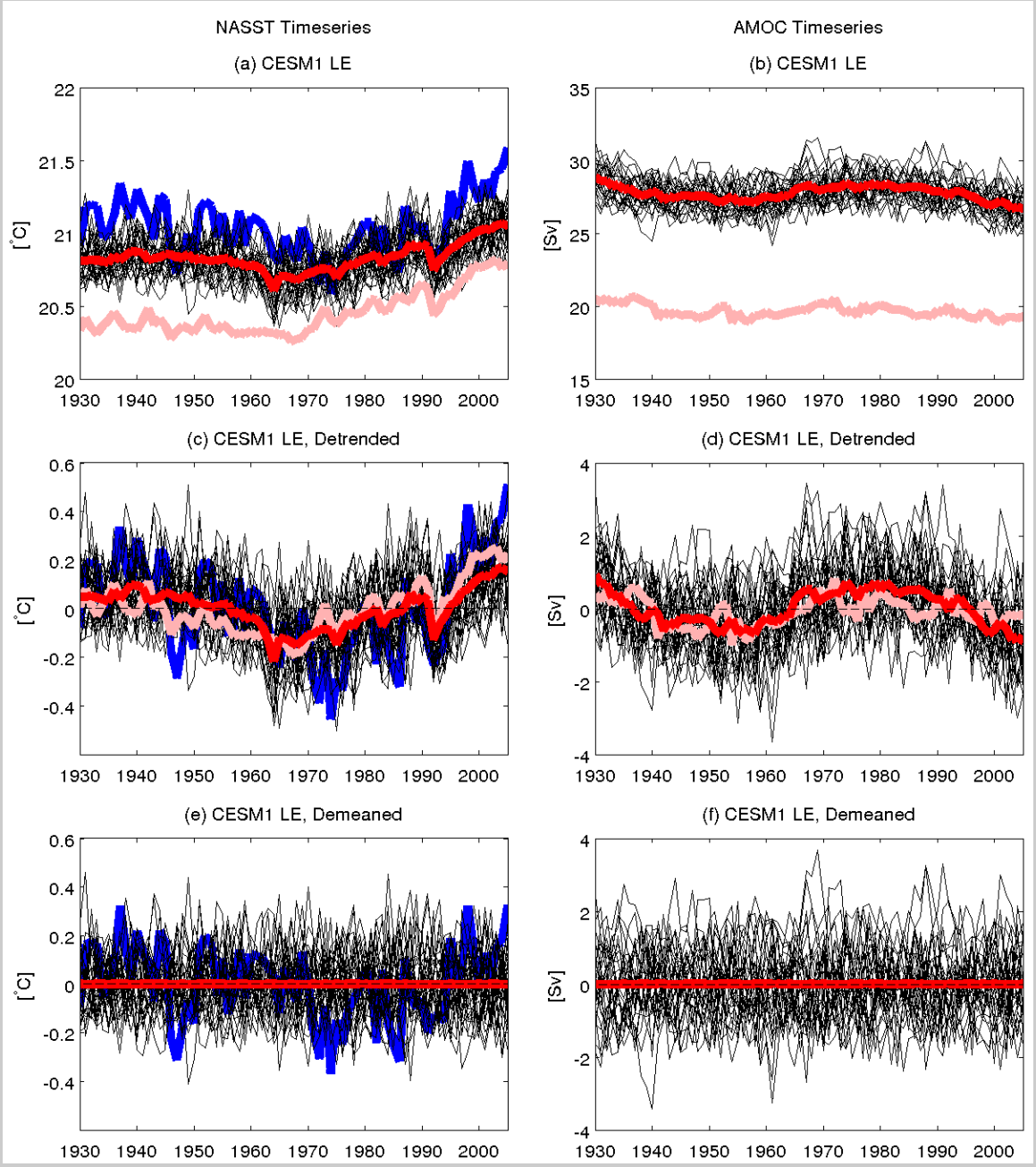
Our answer: Apparently yes, but the effect is more regional, e.g. East Atlantic Pattern's relationship to Arctic sea ice.

Role of External Forcing



CESM1 Large Ensemble

(Described in Kay et al., *BAMS,* 2014)



29 realizations
1920-2005

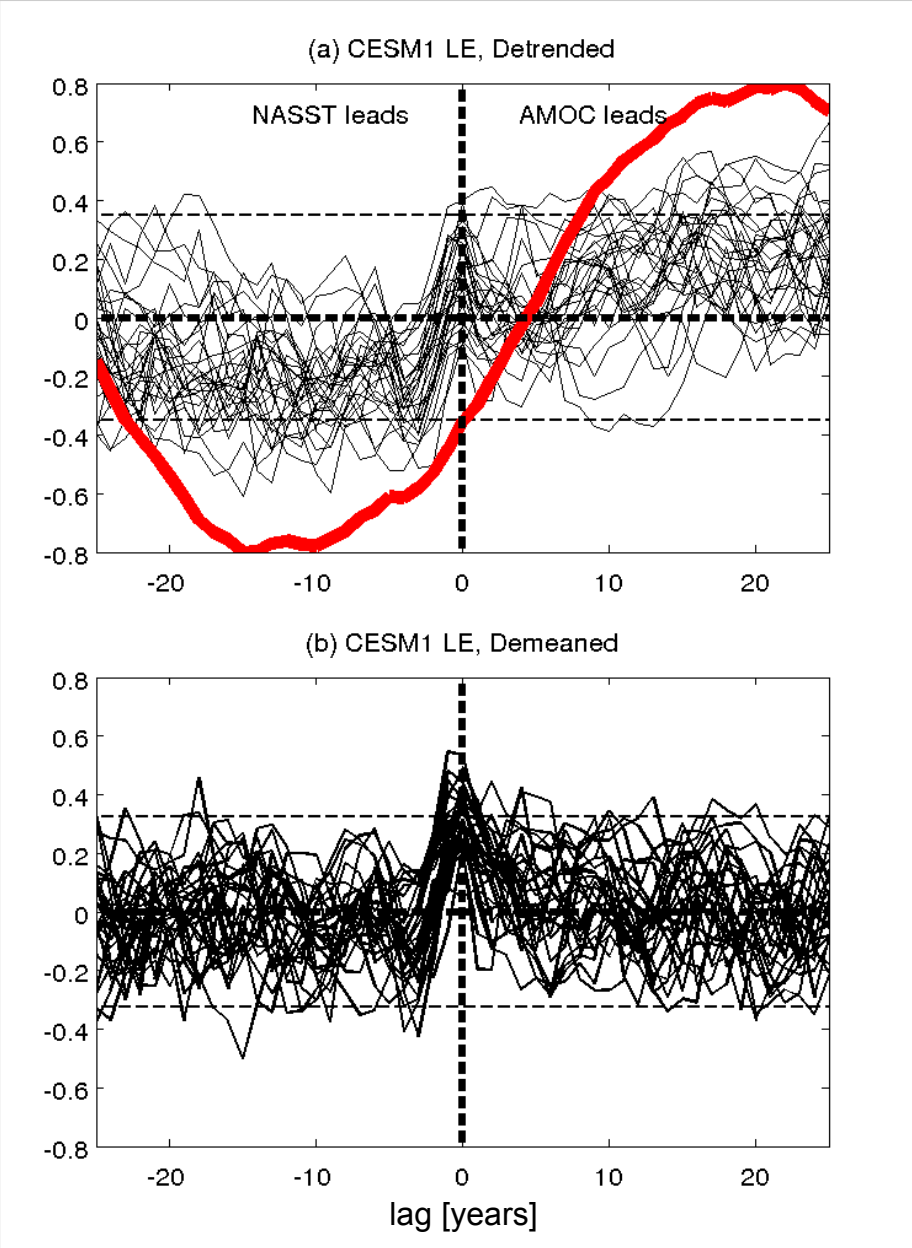
— ensemble mean
— CMIP5 mean
— ERSSTv3

Possible role of aerosols?

Implications for NASST persistence

Tandon and Kushner, *J. Clim.* (2015)

CESM1 Large Ensemble



— individual realizations
— correlation between ensemble means

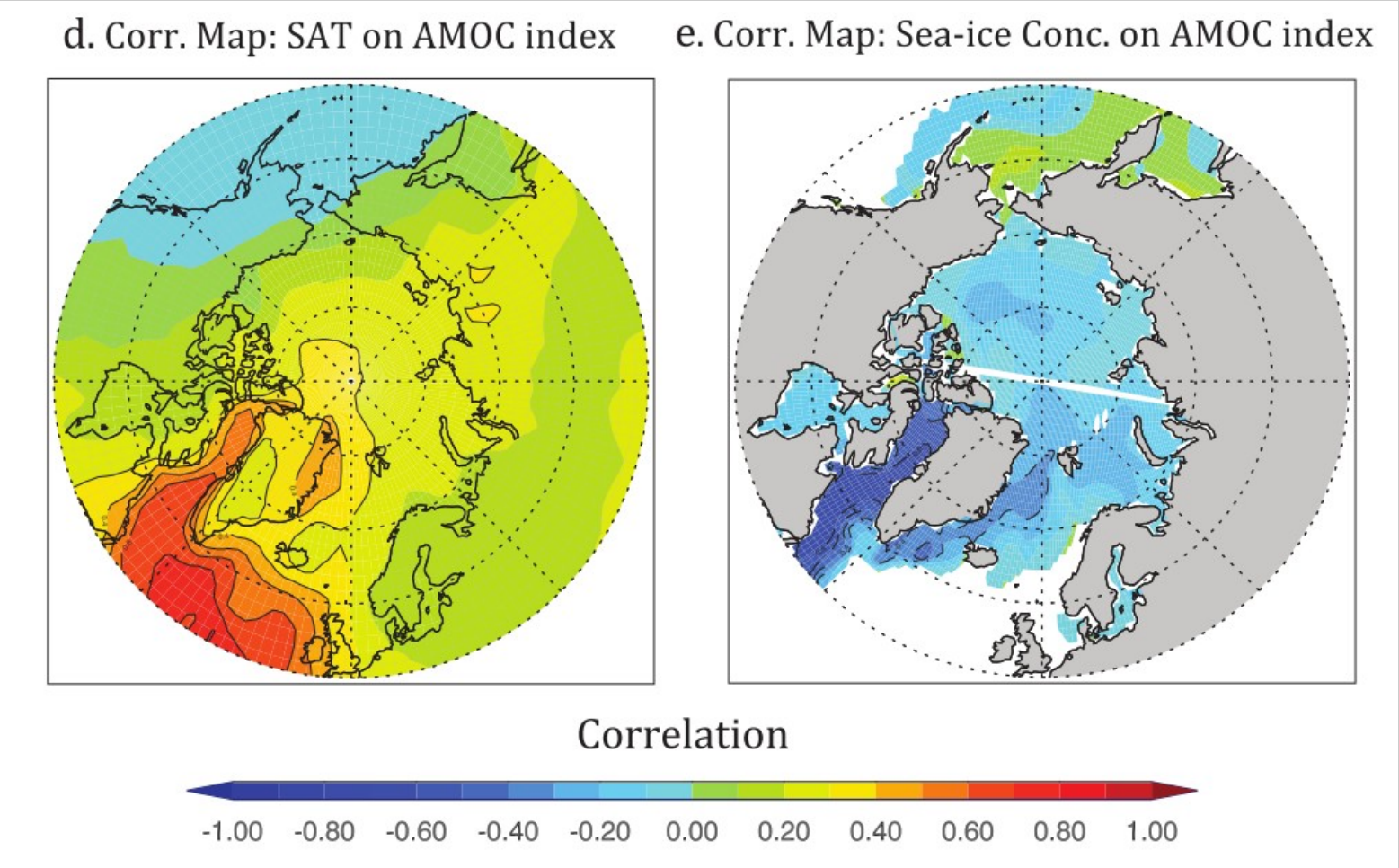
Implication for decadal predictability:
Don't expect the AMOC to tell you what will happen to NASST!

Similar behaviour in other models.

Tandon and Kushner, *J. Clim.* (2015)

Implications for the Arctic?

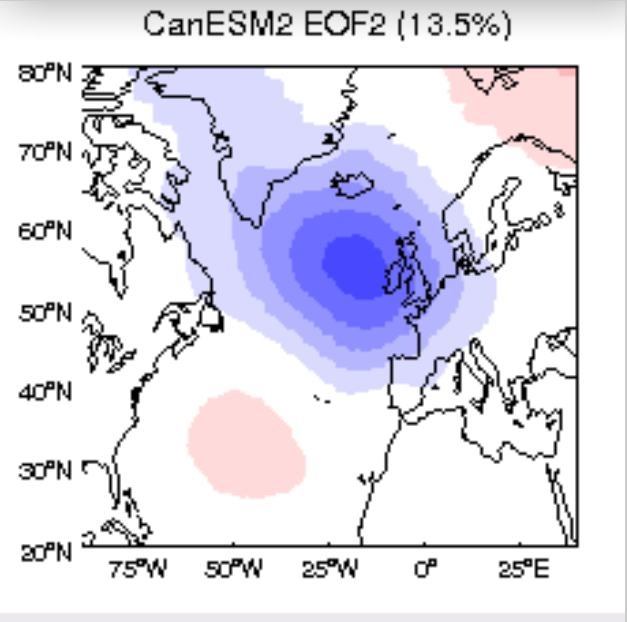
1000-year control run of GFDL CM2.1



Mahajan, Zhang, Delworth, *J. Clim.* (2011)

Key point: Fairly weak AMOC influence on Arctic sea ice.

East Atlantic Pattern (EAP)



(positive phase = cyclone
over Labrador Sea)

Unforced "Subpolar Gyre" effect:

positive EAP → stronger SPG → warmer Labrador Sea/colder Arctic
→ ice loss in Labrador Sea/ice gain in Arctic

Forced "Arctic melt" effect:

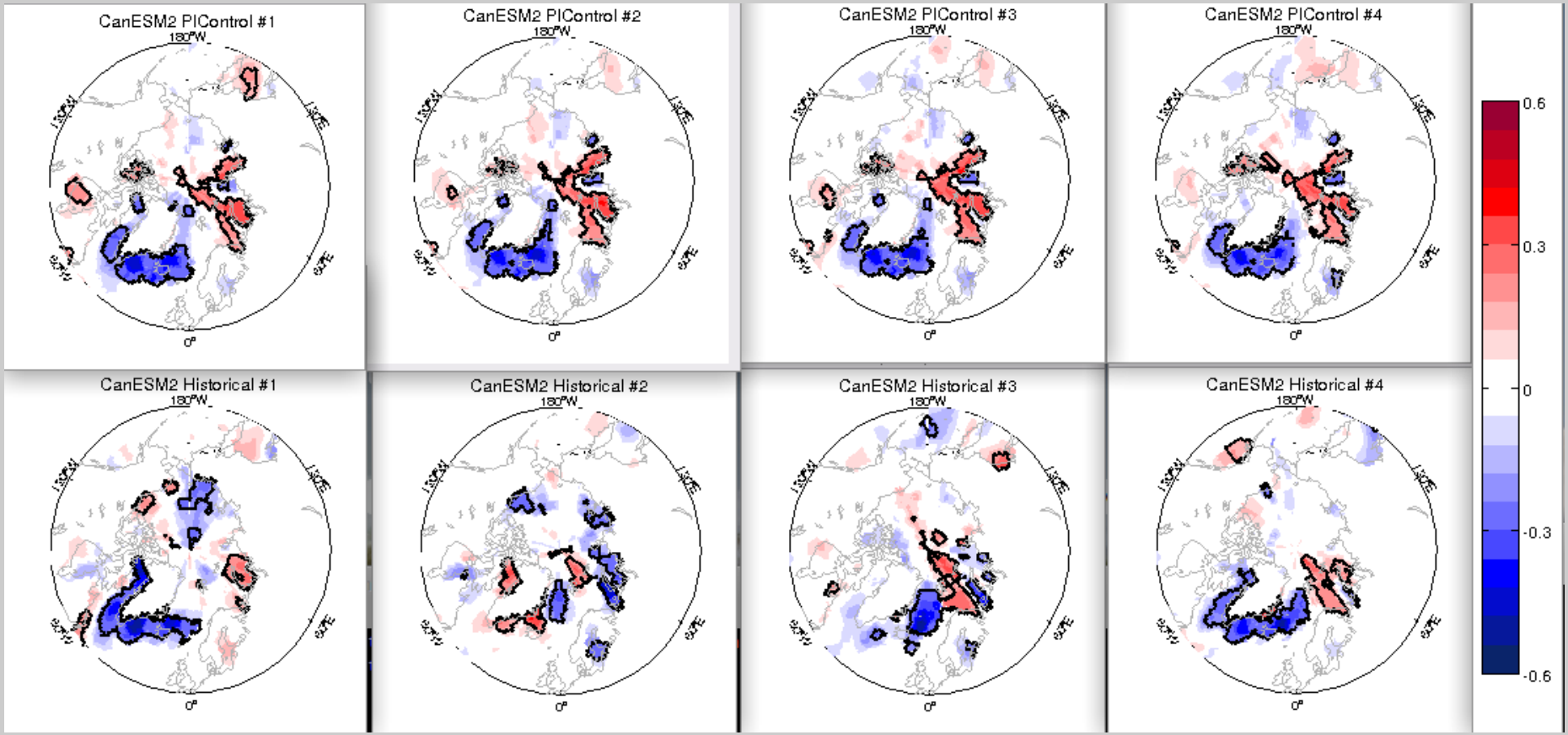
forced warming → ice loss in Arctic → equatorward shift of Atlantic eddy-driven jet
→ positive EAP

EAP-SIC Correlation

(CanESM2, Feb-Mar-Apr averages)

Control (145-year chunks)

Historical runs (detrended)



(SIC = sea ice concentration
thick contour = 95% statistically significant)

Summary

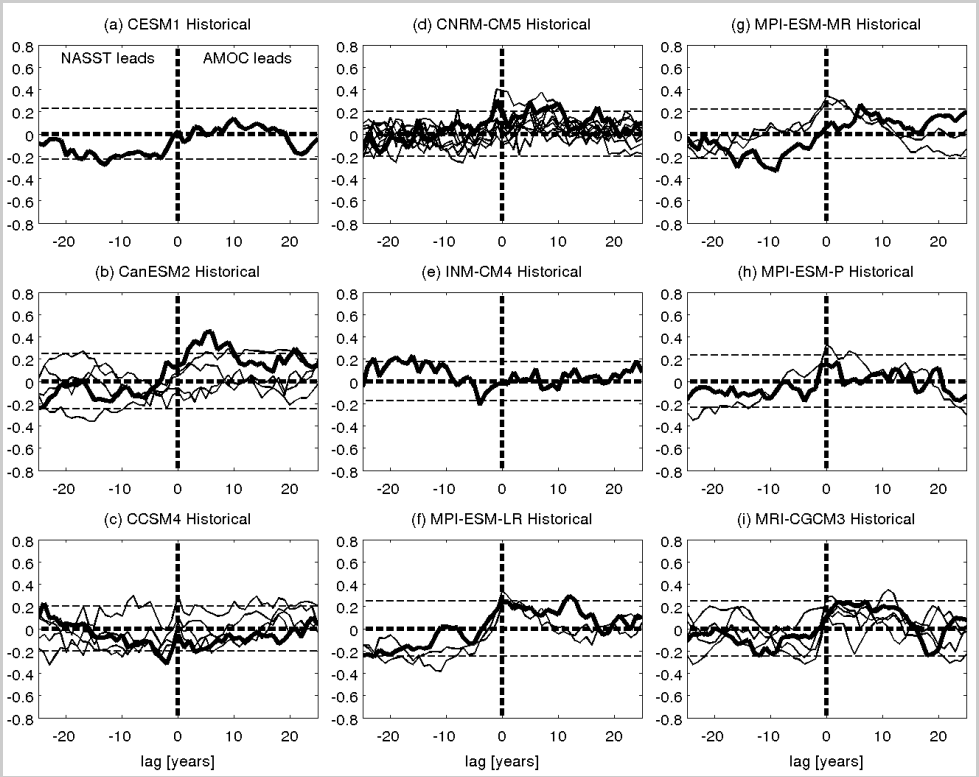
- External forcing can interfere with internally generated covariations of the AMOC and NASST.
- There is also evidence of forced-unforced interference in the relationship between the East Atlantic Pattern and Arctic sea ice.
- Thus, one needs to be careful if attempting to predict changes in SST and sea ice based on circulation changes in the atmosphere and ocean.
- Large initial-condition ensembles are extremely helpful for separating forced and unforced effects. (Linear detrending is **not** the way to go!)

N. F. Tandon and P. J. Kushner, 2015: Does external forcing interfere with the AMOC's influence on North Atlantic sea surface temperature? *J. Climate*, 28, 6309-6323, doi:10.1175/JCLI-D-14-00664.1.

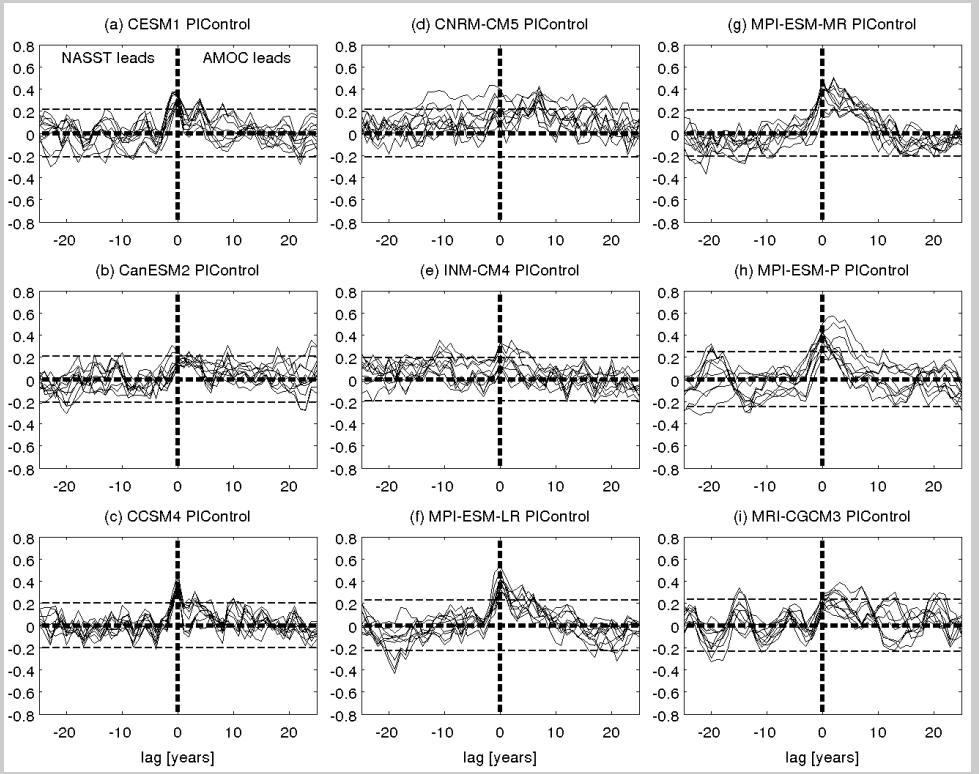
Extra slides

Evidence from Other Models

Historical simulations (1860-2005)
detrended annual mean



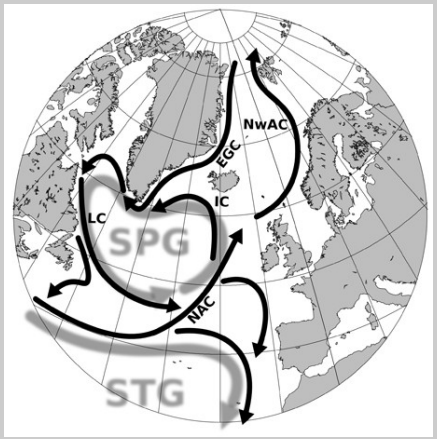
Pre-industrial controls (146-year chunks)
detrended annual mean



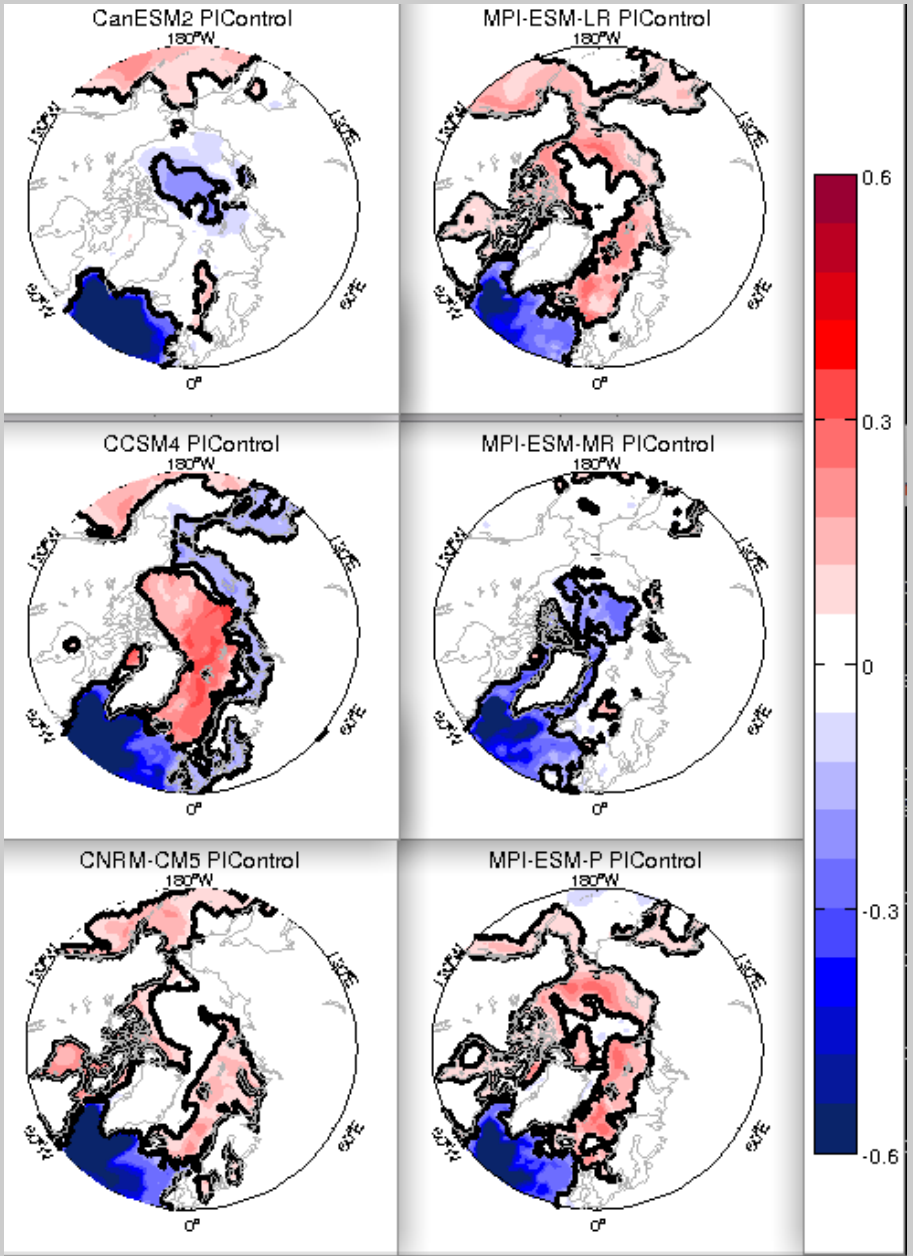
Tandon and Kushner, *J. Clim.* (2015)

Role of the Subpolar Gyre

SPG index correlation with barotropic streamfunction
(FMA)



A. Born



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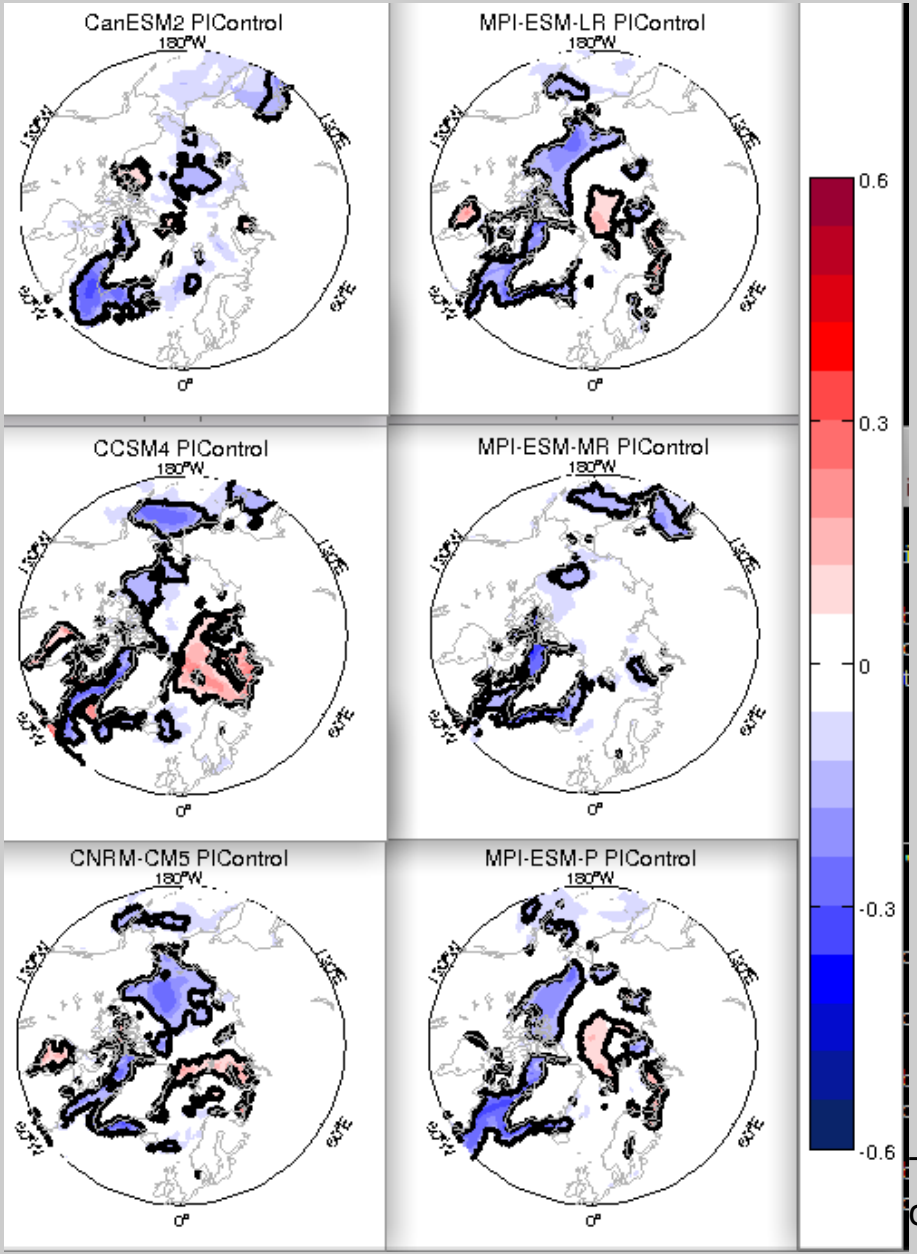
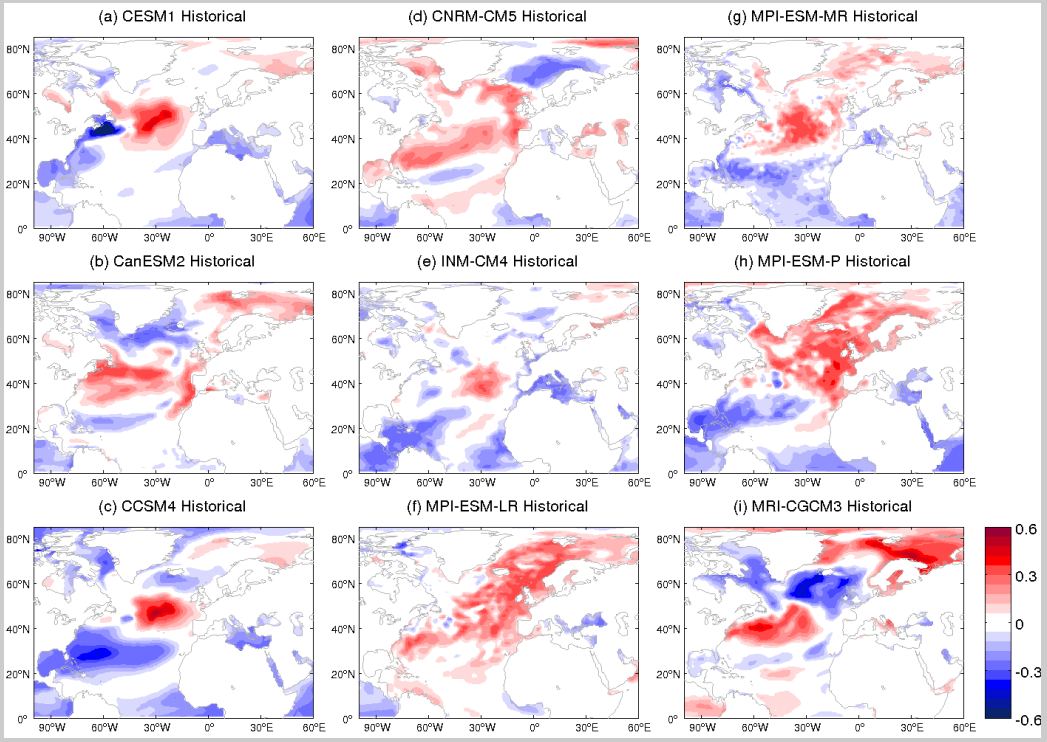


Tandon and Kushner, in prep.
cf. Hátún et al., *Science* (2005)

Regional Effects

AMOC-NASST simultaneous correlation
(Annual mean)

Historical simulations



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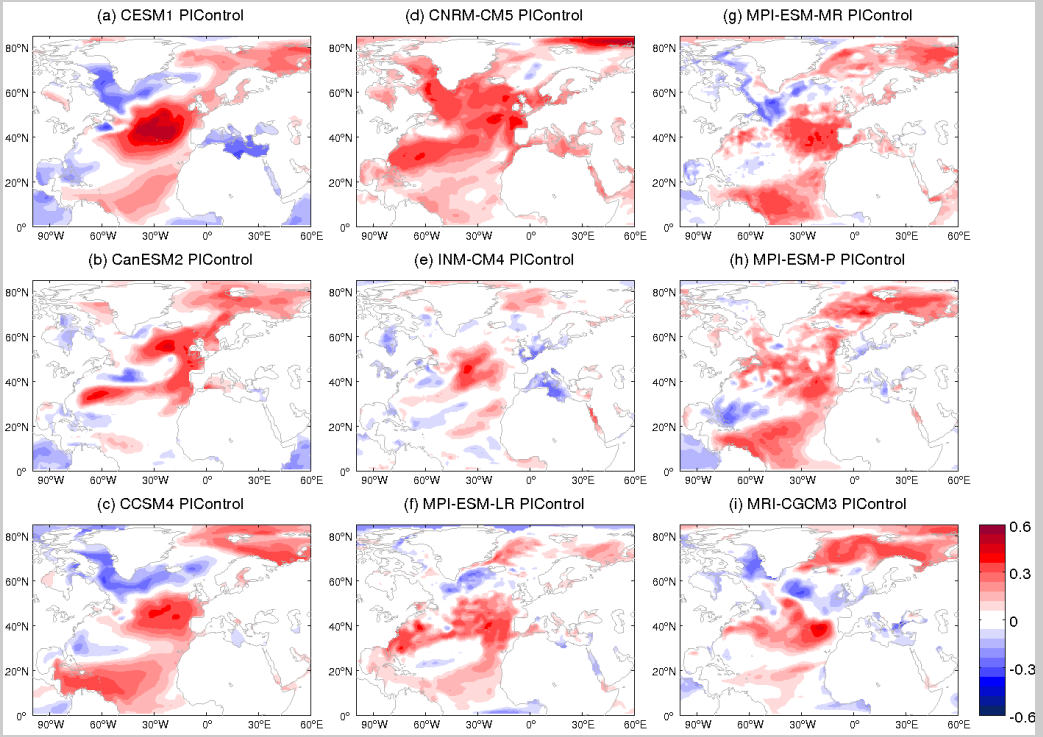
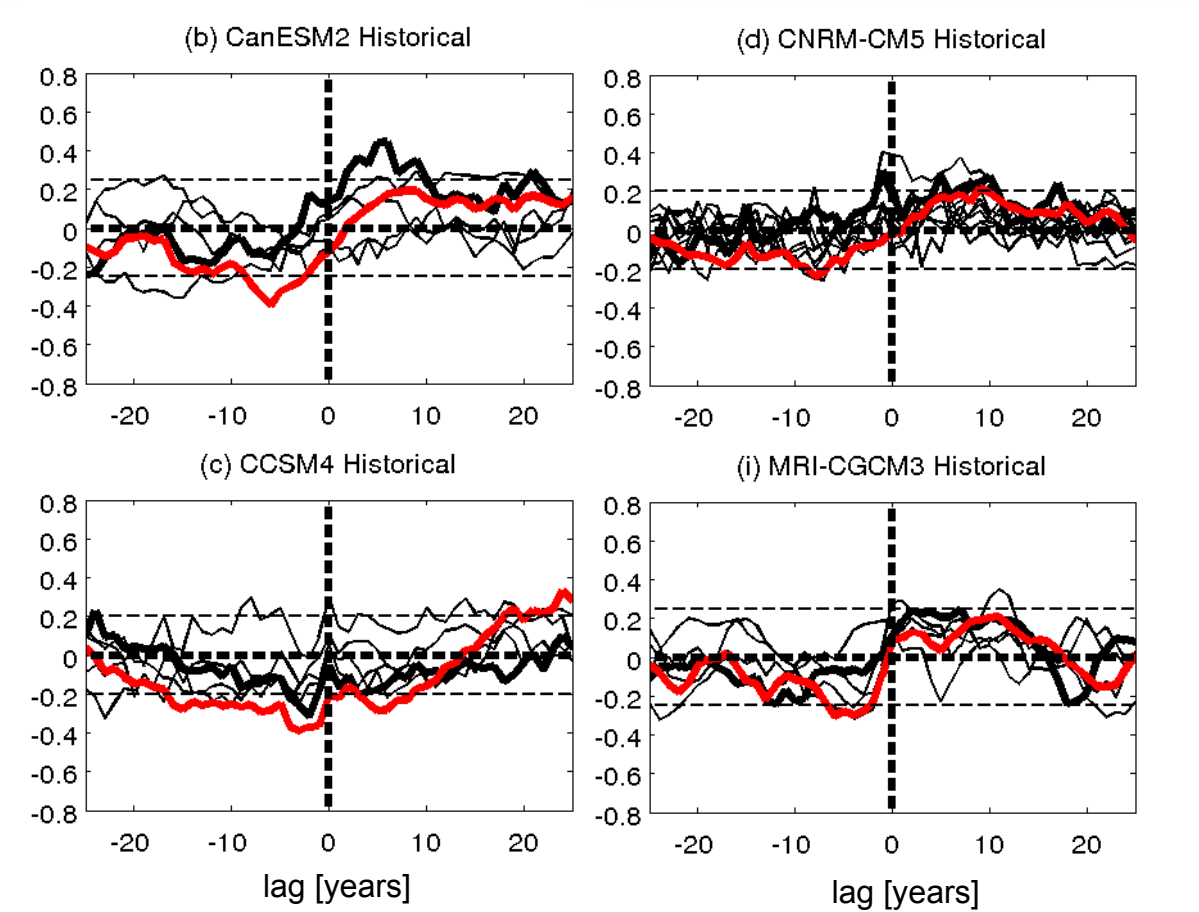
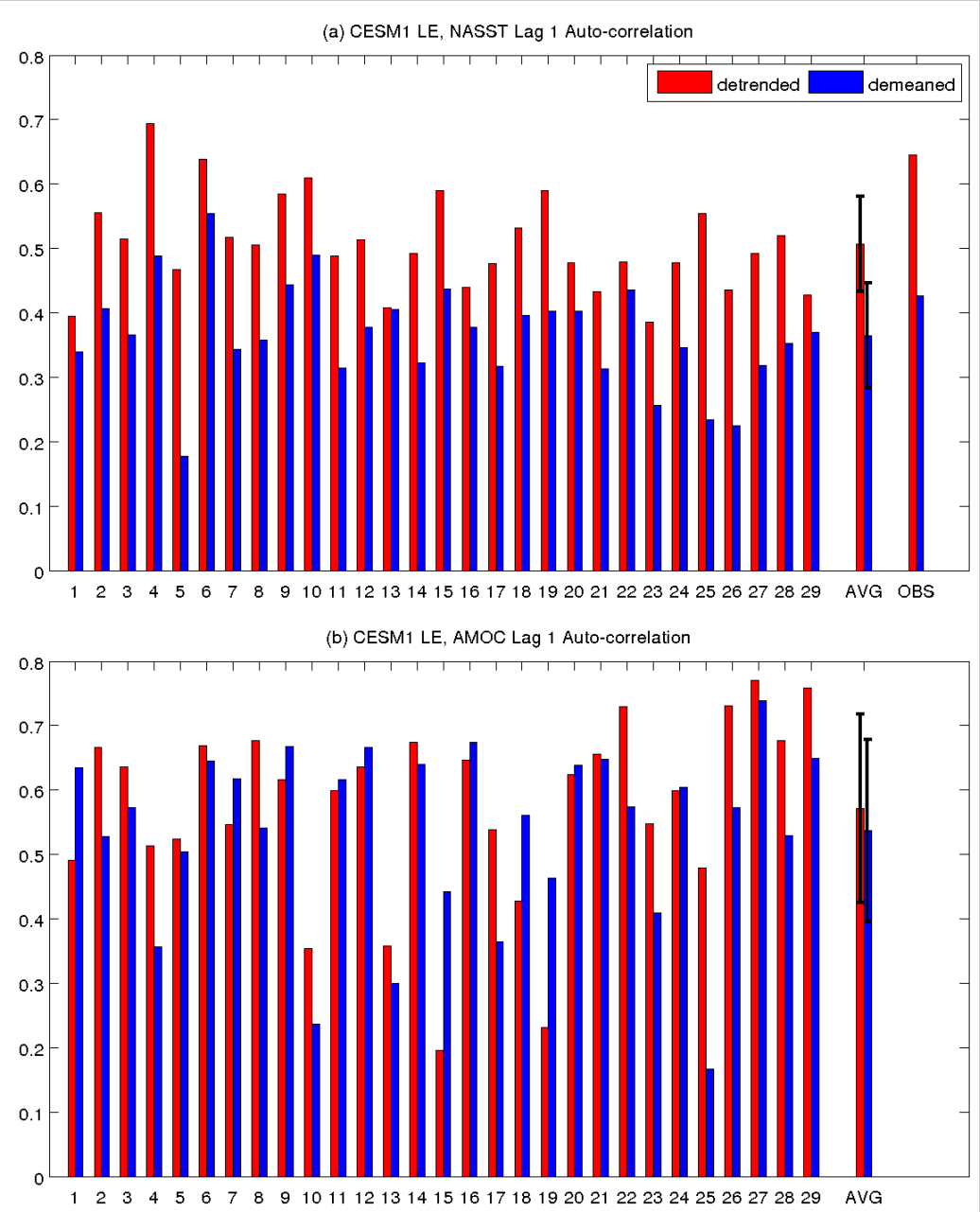


Effect of External Forcing



Implications for Predictability



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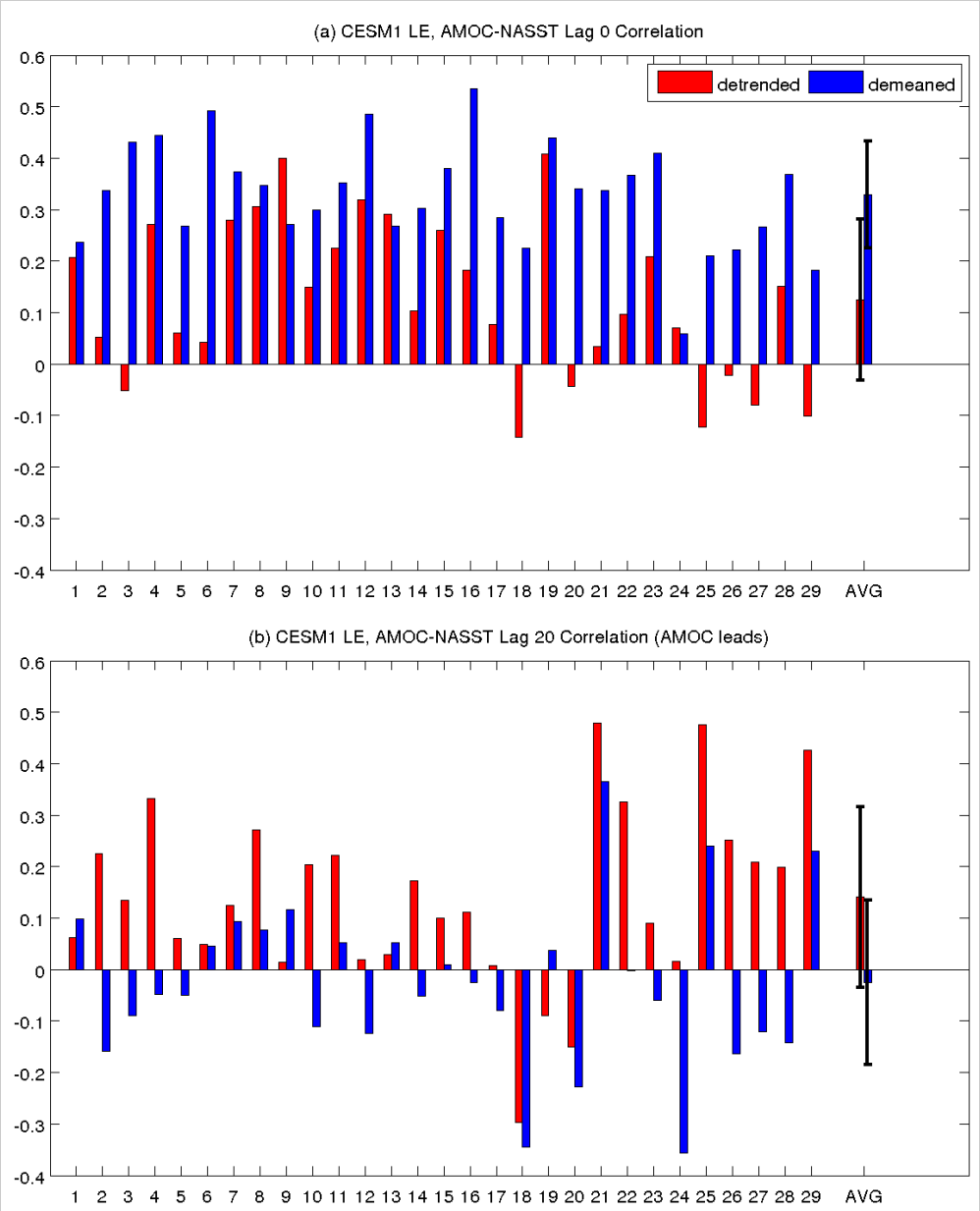
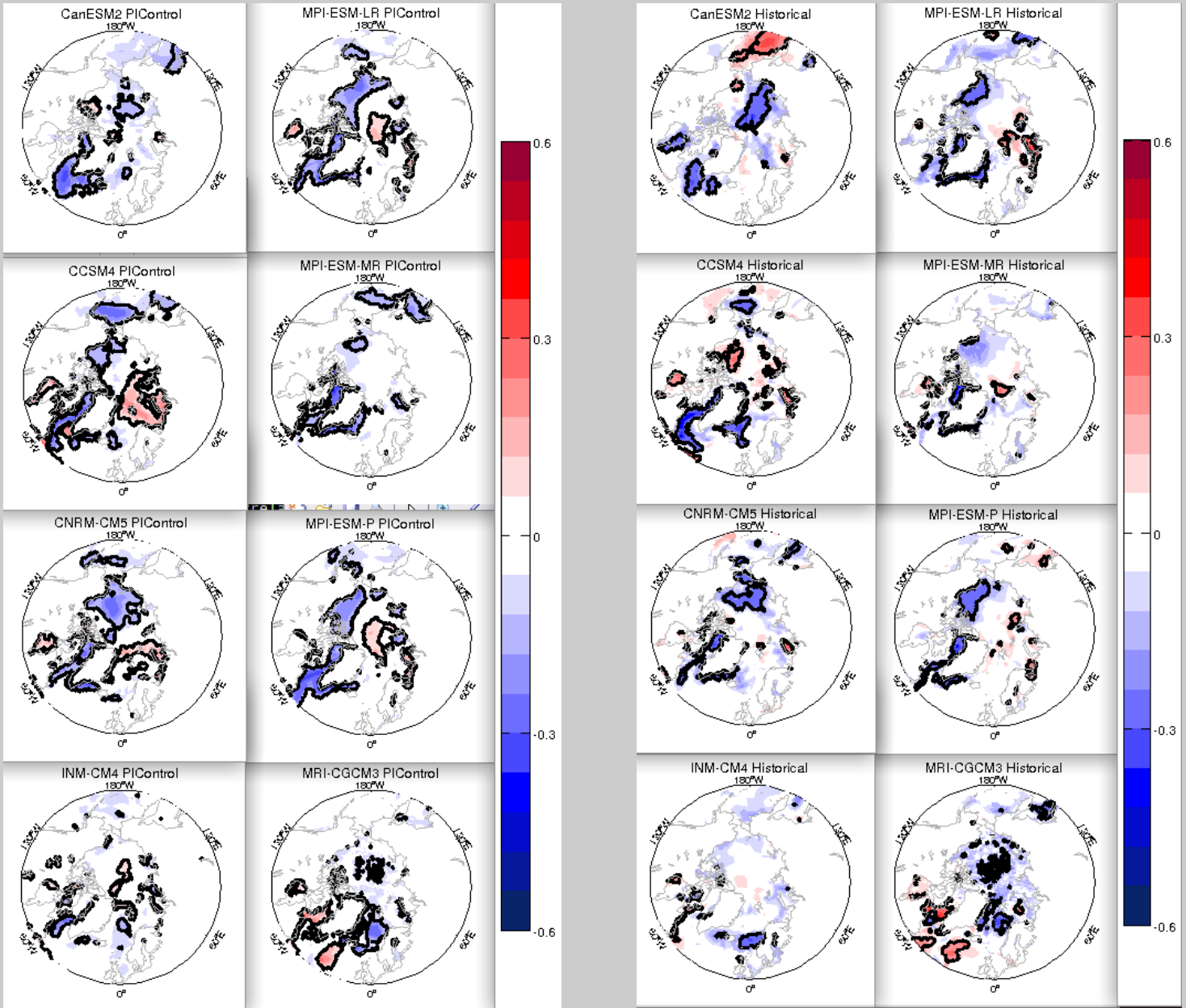


Interference of Forced Variations?

SPG-SIC correlation (FMA)

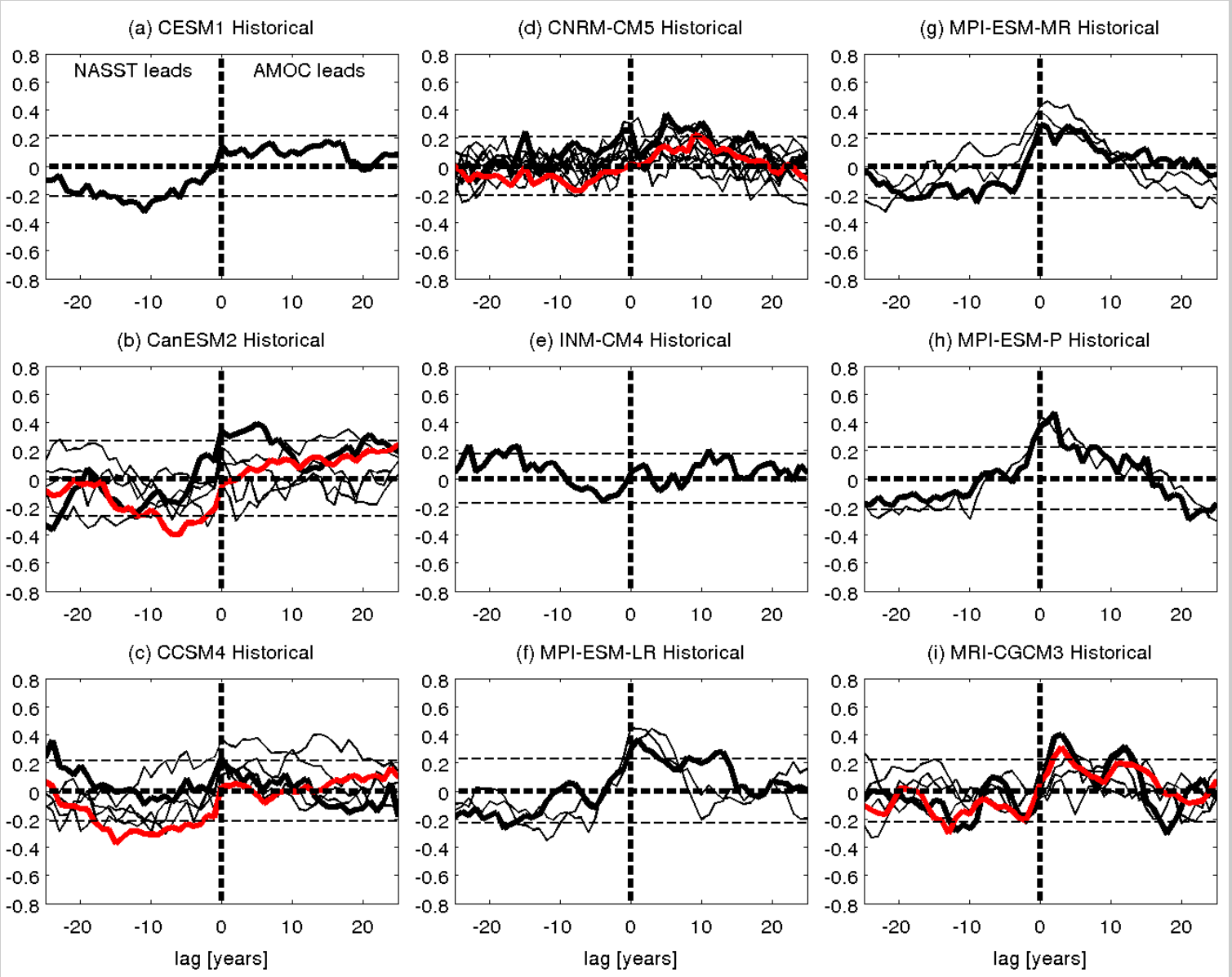
Pre-industrial controls

Historical simulations



...not strongly

AMOC & Extratropical NASST



Role of Atmospheric Circulation

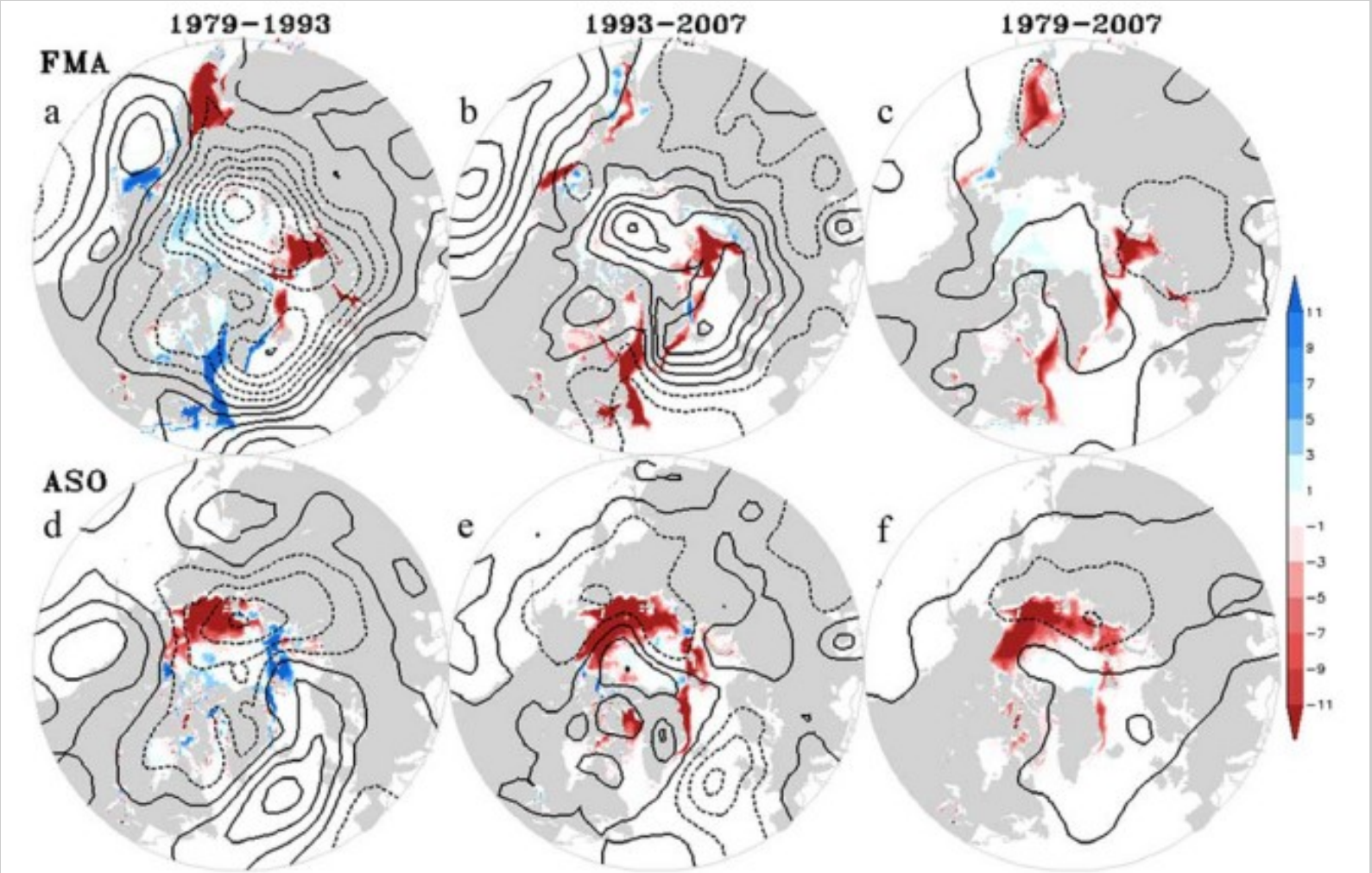


Figure 2. (top) Winter and (bottom) summer sea ice concentration (color shading; % per decade) and sea level pressure (contours; hPa per decade) trends during (a) and (d) 1979–1993, (b) and (e) 1993–2007, and (c) and (f) 1979–2007. The contour interval for sea level pressure is 1 hPa per decade, with negative values dashed, and the zero and positive values solid. Note that 2006 is the last year of data in summer.

Deser and Teng, *GRL* (2008)

Role of the Subpolar Gyre

SPG index correlation with SIC
(ASO)