Low Frequency Variability in the Atlantic-Arctic Sector
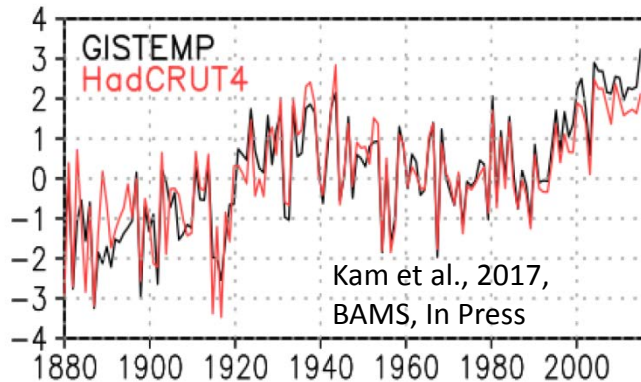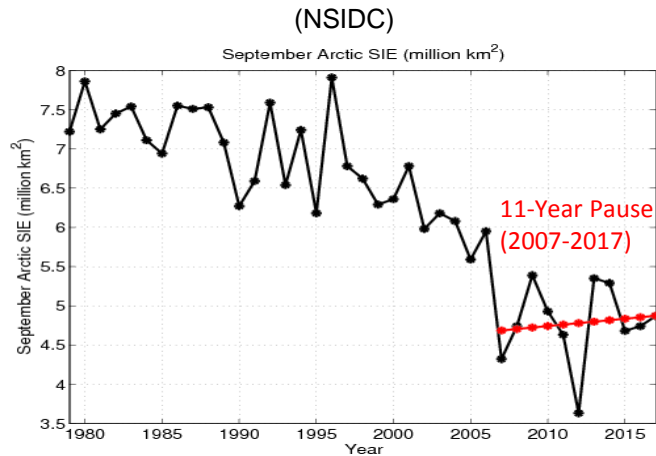
Presented by
Rong Zhang

Geophysical Fluid Dynamics Laboratory Fall Science Symposium
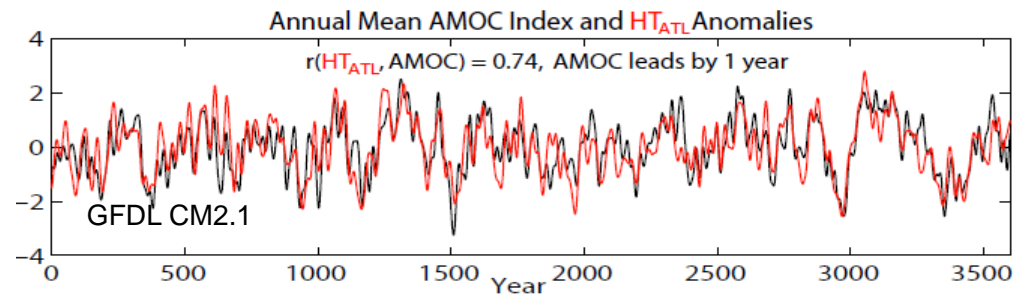
November 2, 2017

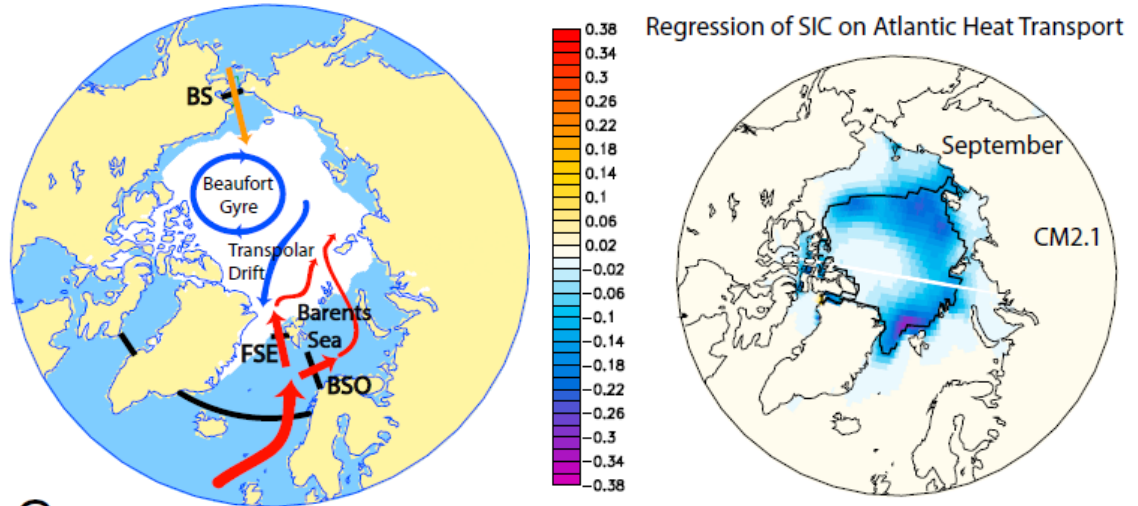# Low Frequency Variability of Summer Arctic Sea Ice
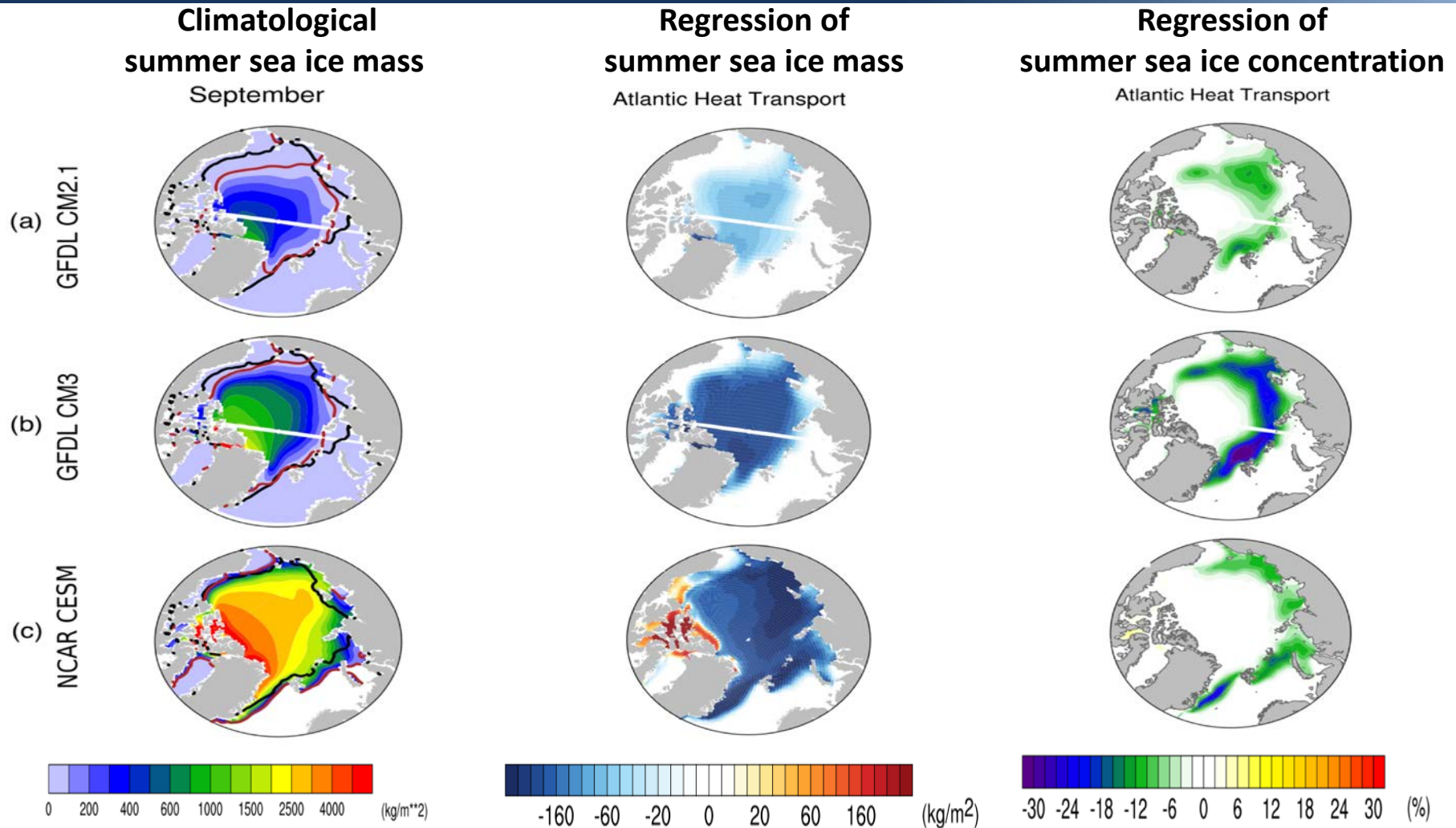
Observed
Summer Arctic Sea Ice Decline

(NSIDC)

September Arctic SIE (million km²)

11-Year Pause
(2007-2017)

Kam et al., 2017,
BAMS, In Press

Observed Multidecadal Variations in
Arctic winter Surface Temperature

Impact of AMOC on
Summer Arctic Sea Ice Variability

Regression of SIC on Atlantic Heat Transport

September

CM2.1

Annual Mean AMOC Index and HT$_{ATL}$ Anomalies

r(HT$_{ATL}$, AMOC) = 0.74, AMOC leads by 1 year

GFDL CM2.1

The AMOC variability and associated Atlantic heat transport into the Arctic also play a significant role in the low frequency variability of summer Arctic sea ice extent

Low Frequency Variability of Summer Arctic Sea Ice

Climatological summer sea ice mass
September

Regression of summer sea ice mass
Atlantic Heat Transport

Regression of summer sea ice concentration
Atlantic Heat Transport

(a) GFDL CM2.1

(b) GFDL CM3

(c) NCAR CESM

0 200 400 600 1000 1500 2500 4000 (kg/m**2)

-160 -60 -20 0 20 60 160 (kg/m^2)

-30 -24 -18 -12 -6 0 6 12 18 24 30 (%)

The response of sea ice mass to enhanced Atlantic heat transport increases with mean state sea ice thickness, while the response in sea ice concentration is largest in the model with intermediate mean state sea ice thickness
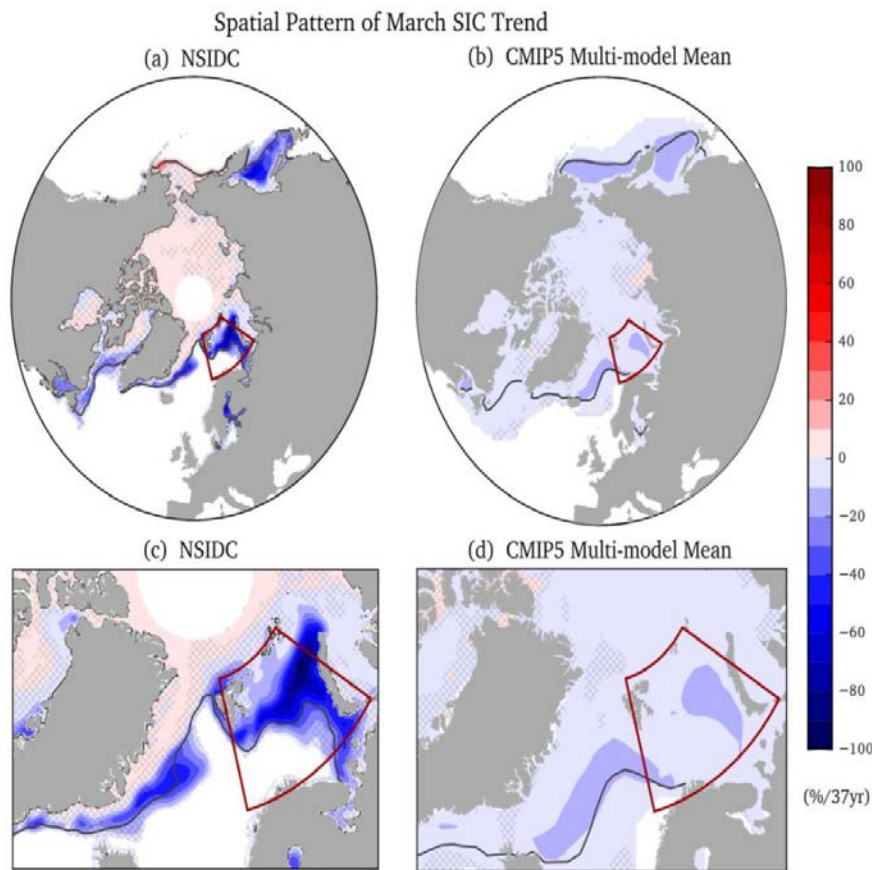
CMIP5 externally forced winter SIC trend (1979-2015) in individual regions (especially in Barents Sea) differs substantially from that observed.
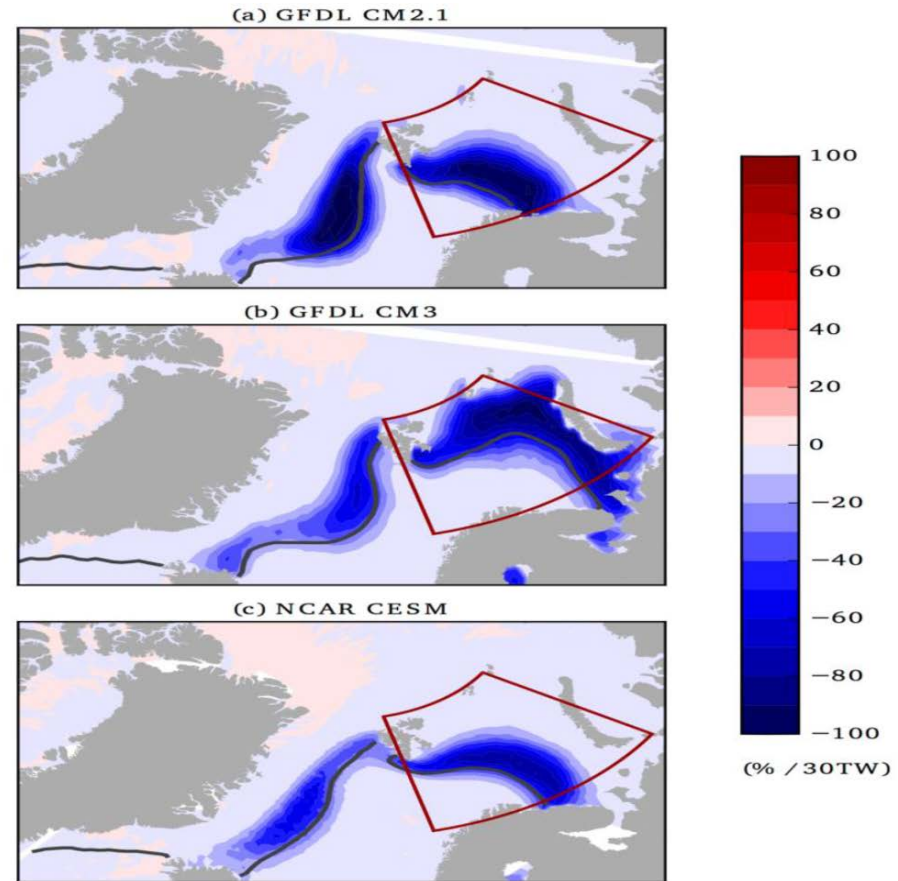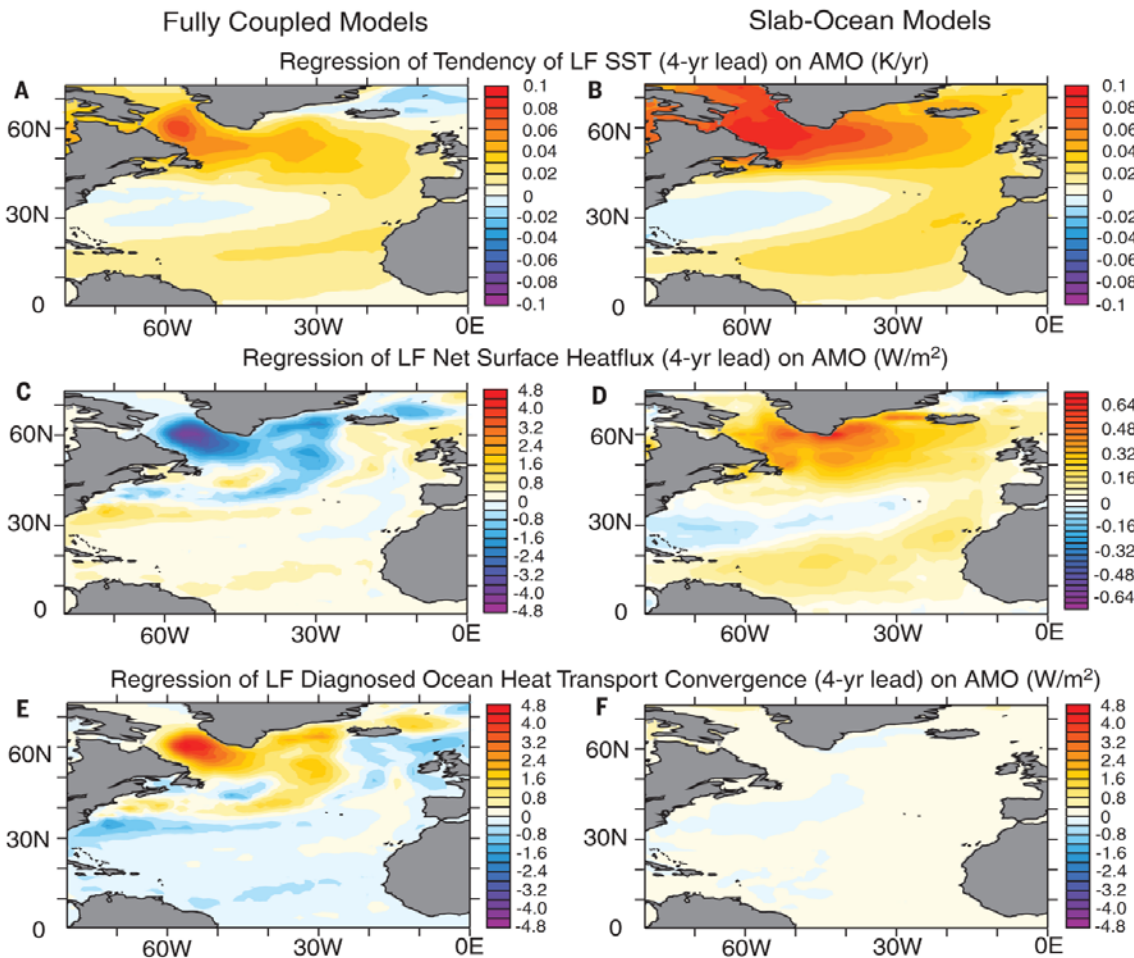
Internal variability may have played a leading role in the observed winter Barents Sea SIC decline over the satellite period.

Recent Debate on Mechanisms of the Atlantic Multidecadal Variability (AMV)

Comment on "The Atlantic Multidecadal Oscillation without a role for ocean circulation"

Rong Zhang[1*], Rowan Sutton[2], Gokhan Danabasoglu[3], Thomas L. Delworth[1], Who M. Kim[3], Jon Robson[2], Stephen G. Yeager[3]

Fully Coupled Models   Slab-Ocean Models

Regression of Tendency of LF SST (4-yr lead) on AMO (K/yr)

Regression of LF Net Surface Heatflux (4-yr lead) on AMO (W/m²)

Regression of LF Diagnosed Ocean Heat Transport Convergence (4-yr lead) on AMO (W/m²)

Recent study (Clement et al. 2015, Science) concludes that the AMV in fully coupled models is generated by the red noise process as found in slab ocean models without ocean dynamics

Zhang et al., 2016 shows that the fundamental equation and mechanisms for the AMV are quite different between fully coupled models and slab-ocean models
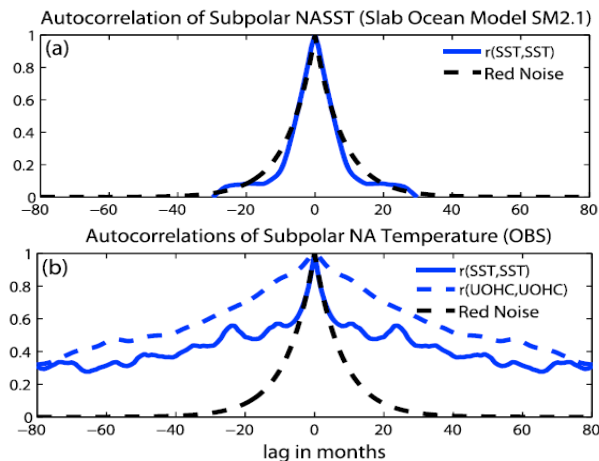
The negative regression between net downward surface heat flux and SST in subpolar NA in fully coupled models indicate the important role of ocean dynamics in the AMV

Recent Debate on Mechanisms of the AMV

$$\frac{cov(f_O', T')}{cov(f_A', T')} \approx \frac{\lambda_O - \dfrac{r(F_{Net}', T')\sigma_{F_{Net}'}}{\sigma_{T'}}}{\lambda_A + \dfrac{r(F_{Net}', T')\sigma_{F_{Net}'}}{\sigma_{T'}}}$$

The correlation/regression between net surface heat flux and SST at low frequency are key indicators for the relative roles of oceanic vs. atmospheric forcing

In observation, $\dfrac{cov(f_O', T')}{cov(f_A', T')} \gg 1$, f_O' has a dominant role in subpolar AMV. The red noise model without oceanic damping ($\lambda_O = 0$) leads to unrealistic interpretation $\dfrac{cov(f_O', T')}{cov(f_A', T')} \ll 1$

Autocorrelation of Subpolar NASST (Slab Ocean Model SM2.1)
Autocorrelations of Subpolar NA Temperature (OBS)

Observed AMOC Fingerprint: EOF1 of Upper Ocean Heat Content
Squared Coherence with AMOC Fingerprint (OBS)

The observed decadal persistence of Subpolar NASST will lead to much higher decadal prediction skill than that obtained from the slab ocean models/red noise process
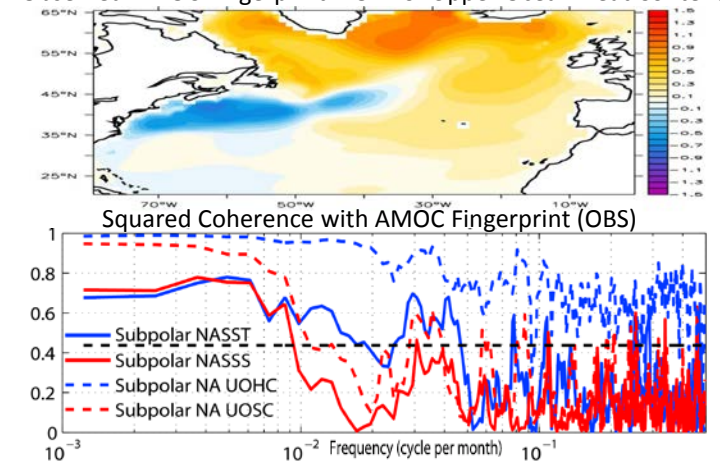
High coherence among observed Subpolar SST/SSS, UOHC/UOSC, and AMOC fingerprint at low frequency cannot be explained by slab ocean models/ red noise process, but is consistent with the ocean dynamics mechanism

The Role of AMOC in the Multidecadal Variability of Atlantic Major Hurricane Frequency
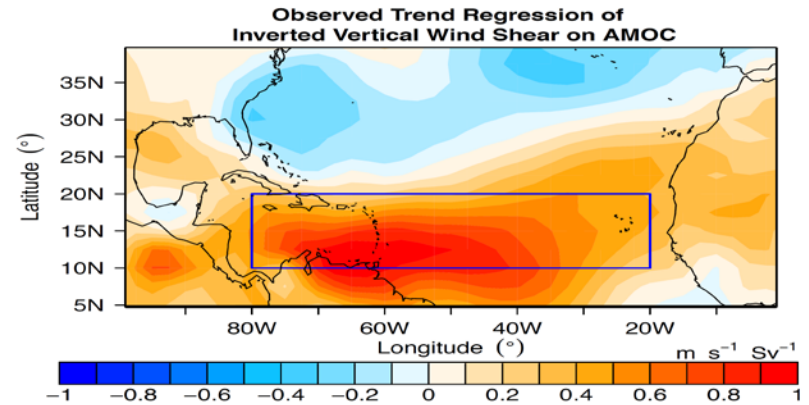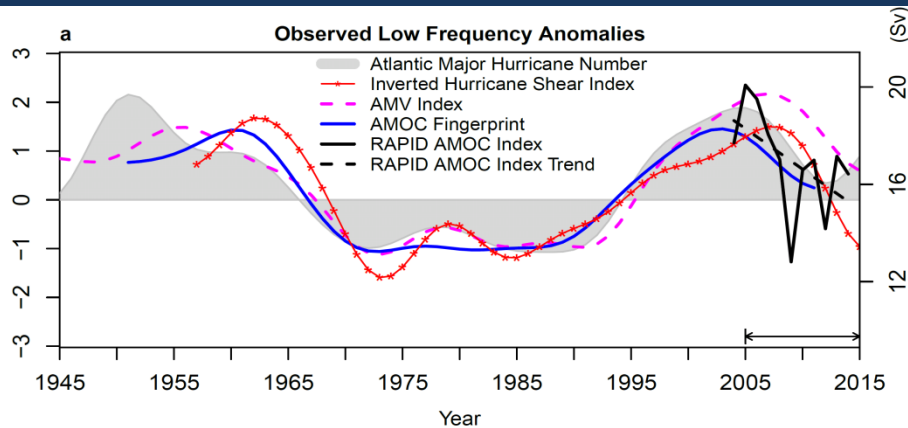
Observations show coherent multidecadal variations among the Atlantic major hurricane frequency, AMOC fingerprint, AMV Index, and Inverted Hurricane Shear Index .
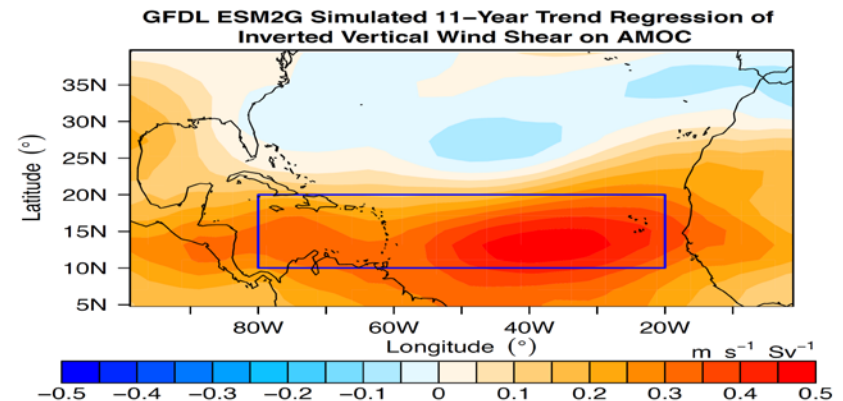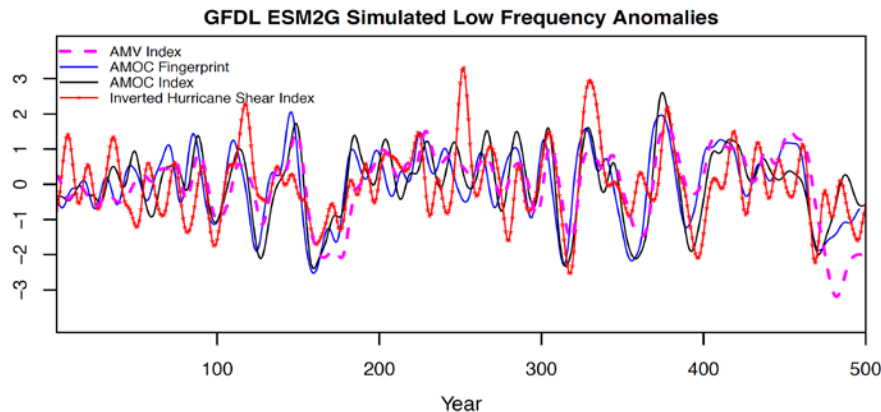
Coherent variations among AMOC Index/fingerprint, AMV Index, and Inverted Hurricane Shear Index in GFDL-ESM2G control simulation suggest an important role of AMOC in the AMV and the multidecadal variability in the Atlantic major hurricane frequency.

Summary

- The AMOC variability and associated Atlantic heat transport have played an important role in the low frequency variability of both winter and summer Arctic sea ice.

- Many key observed AMV features cannot be explained by a direct response to stochastic atmospheric forcing, but are consistent with the ocean dynamics mechanism. AMOC variability is a major source for enhanced decadal prediction skill in subpolar NA.

- Both observations and modeling results suggest an important role of the AMOC in the AMV and the multidecadal variability of Atlantic major hurricane frequency.