NOAA CVP
2015 Decadal Variability and Predictability Webinar Series
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Multidecadal Variability of the Atlantic Meridional Overturning Circulation and Its Impact on the Atmospheric Circulation

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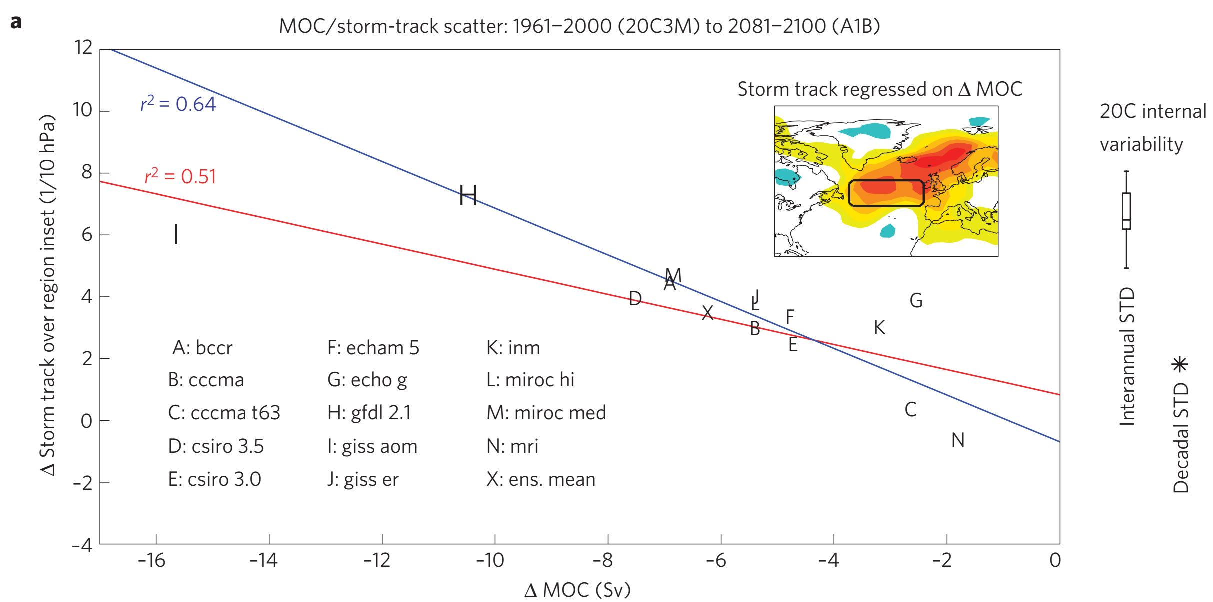
Why do we study the AMOC's impact on the atmospheric circulation?

- Climate models exhibit significant multidecadal AMOC variability and suggest the AMOC drives the SST Atlantic multidecadal variability (AMV).
- Previous studies suggest the AMOC as one of the leading source of the decadal predictability.
- AMOC change may influence the atmospheric circulation change in the future climate.



Woollings et al. (2012)

Community Climate System Model 4 (CCSM4)
Pre-industrial (1850) control simulation

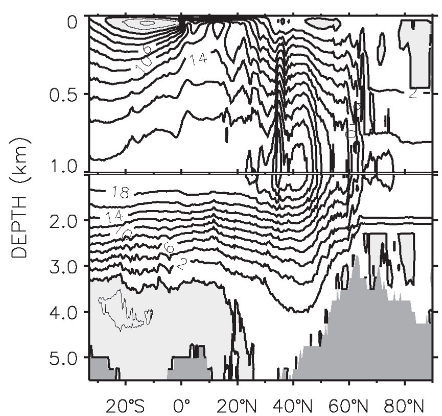
- One of the NCAR simulations for the CMIP5/IPCC AR5

- Community Atmosphere Model 4 (CAM4)
- Parallel Ocean Program 2 (POP2)
- Community Land Model 4 (CLM4)
- Sea Ice Model 4 (CICE4)

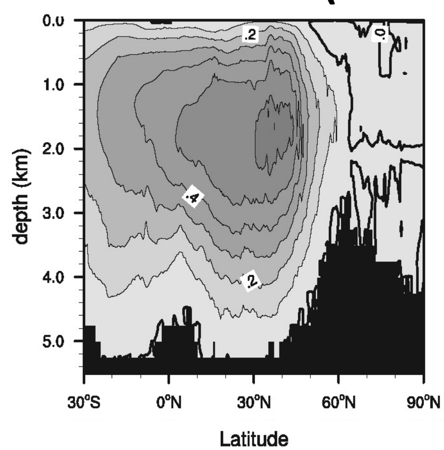
~1° resolutions

- Last 600 yrs are analyzed from 1300-yr integration.

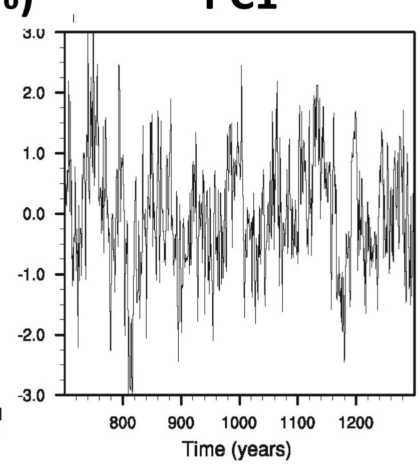
Mean AMOC



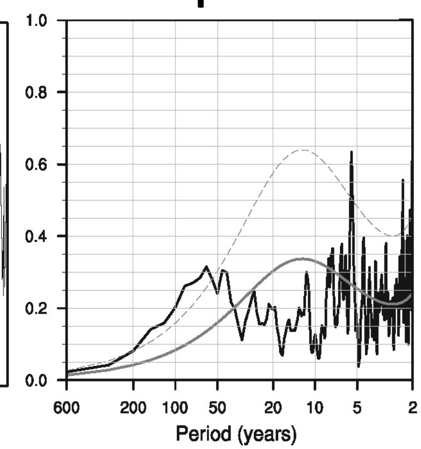
AMOC EOF1 (38.0%)



PC1



PC1 spectrum



Estimating ocean influence on atmosphere statistically

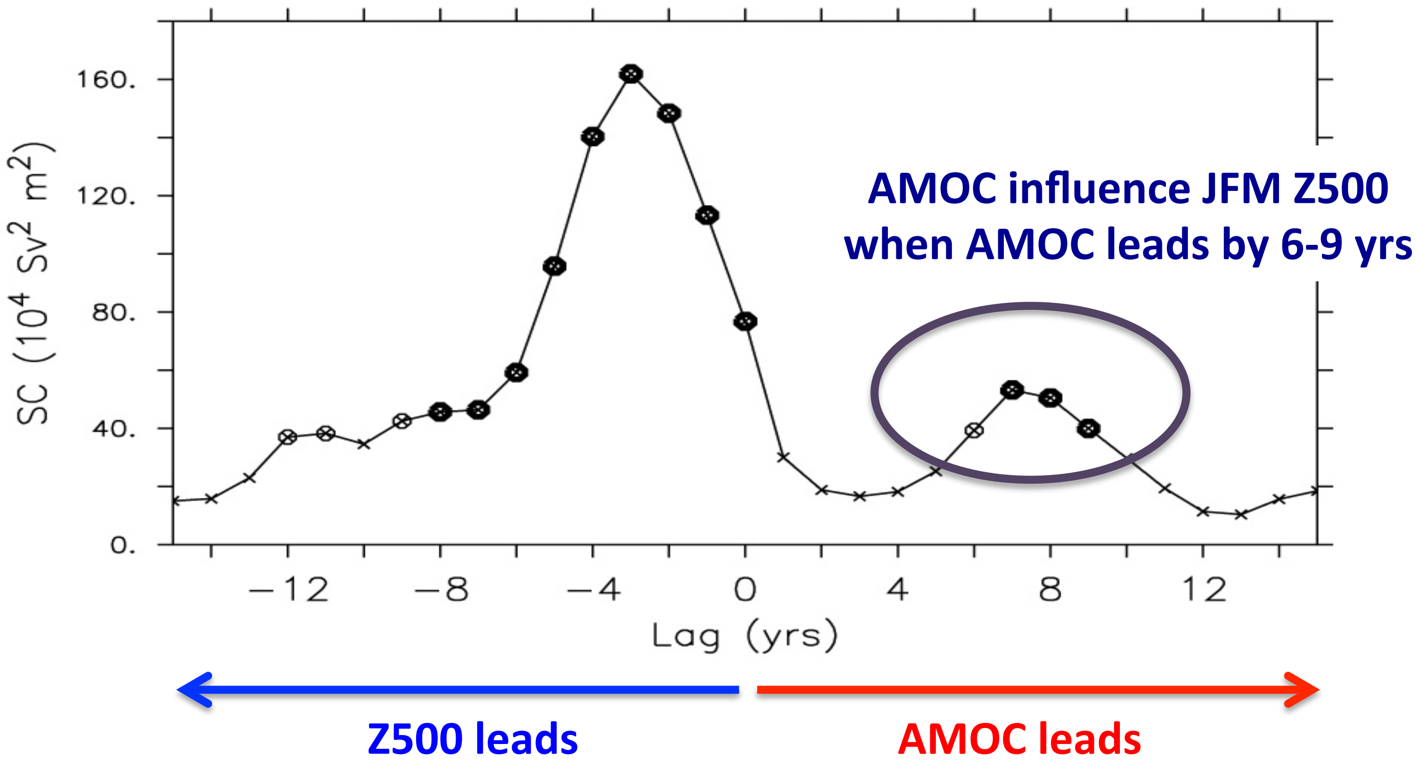
- Atmospheric timescale << oceanic timescale
- Relation between the atmosphere and preceding oceanic anomalies is indicative of oceanic boundary forcing on atmosphere, ***if***
  - the lag is longer than atmospheric intrinsic persistence
  - there is no other source of persistence in the atmosphere
    (e.g. low-frequency trends or ENSO variability)

Maximum Covariance Analysis (MCA) between AMOC and Z500 in the North Atlantic

- Annual mean AMOC vs. 3-month mean Z500 (after removing mean seasonal cycle)
- Quadratic trend and tropical impact are removed from all variables before MCA

When is relationship between AMOC & Z500 significant?

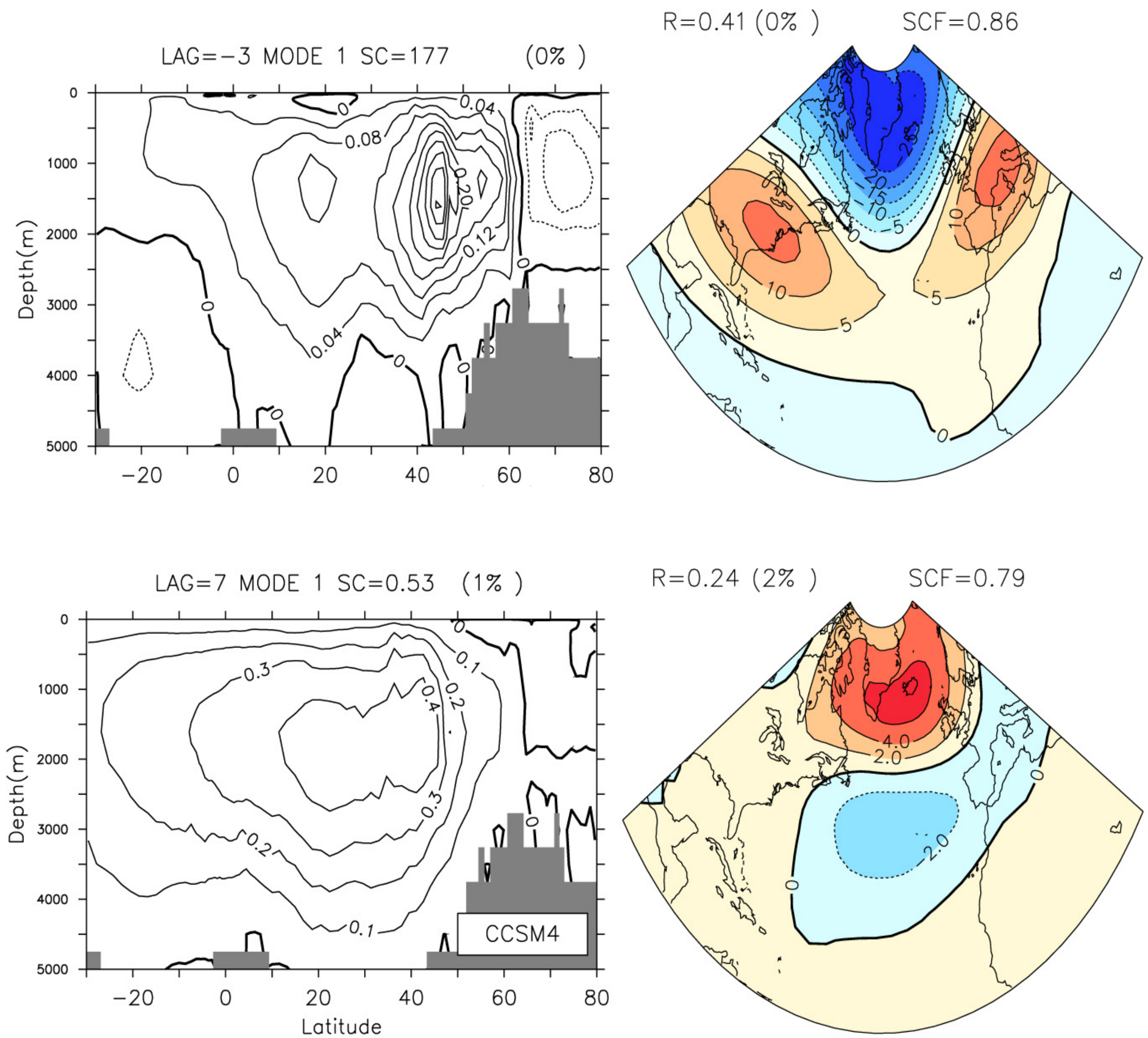
Squared covariances of the leading MCA modes between *annual AMOC* and *JFM Z500* at different lags



Filled circle: significant at 5% / open circle: significant at 10% (based on 100 Monte Carlo iterations)

Spatial patterns of the leading MCAs: lag -3 vs. lag +7

Z500 leads by 3 yrs



AMOC leads By 7 yrs

NAO+ drives AMOC intensification

Weak negative feedback

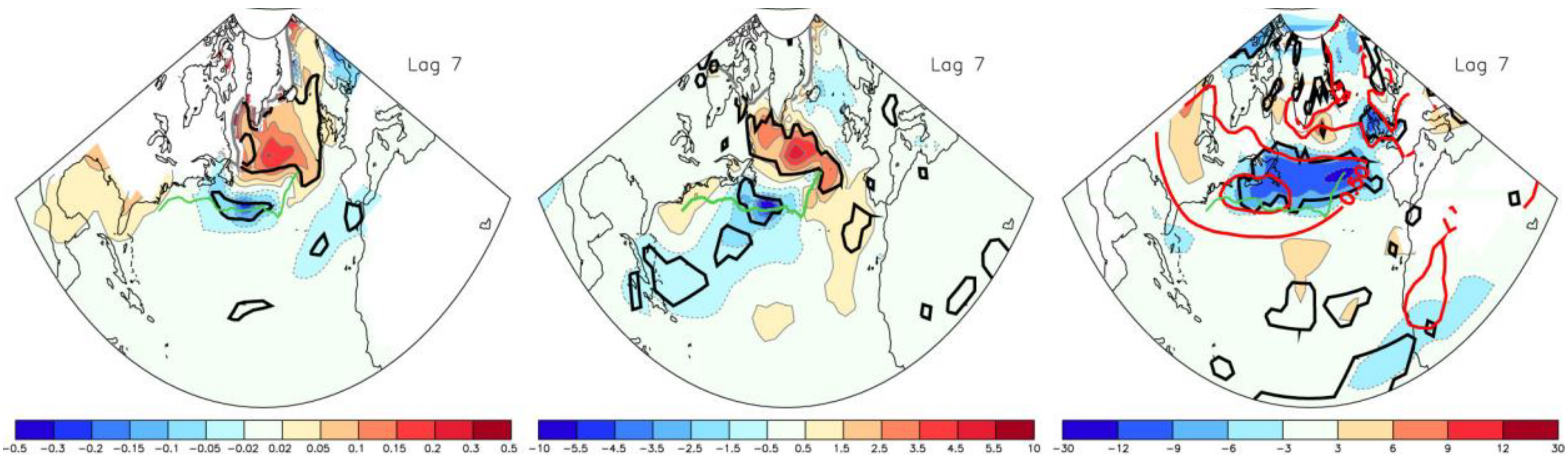
Intensified AMOC drives NAO-

How does the AMOC influence the atmosphere?

Lag-regressions on the lag+7 MCA AMOC time series

= anomalies associated with JFM Z500 response to AMOC intensification

JFM SST (°C) | **OND Surface heat flux (Wm^{-2})** | **JFM Eady growth rate at 850 hPa (10^{-2} day^{-1})**



Green curves: mean GS-NAC position

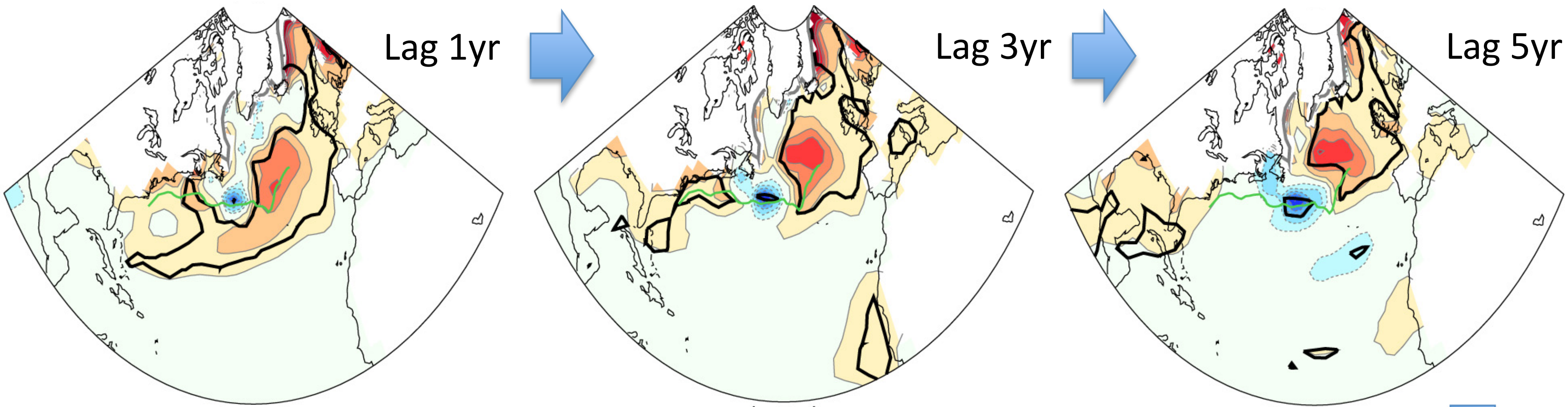
Red contours: climatology

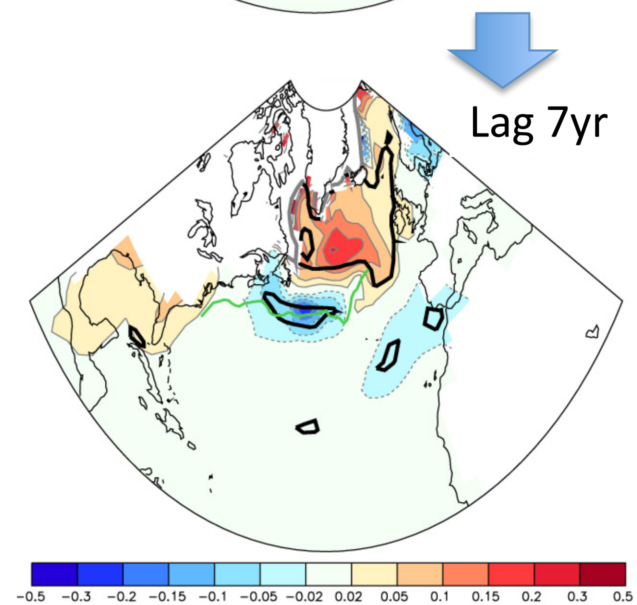
Meridional SST dipole (reduced dSSTdy) → **Damped by surface heat flux** → **Southward shift of storm track**

Why does it take 6-9 years for AMOC to impact Z500?

JFM SST lag-regressions on the lag+7 MCA AMOC time series

= Evolution of SST anomalies following the maximum AMOC intensification





Initially,

cooling along GS near the Tail of Grand Banks

+

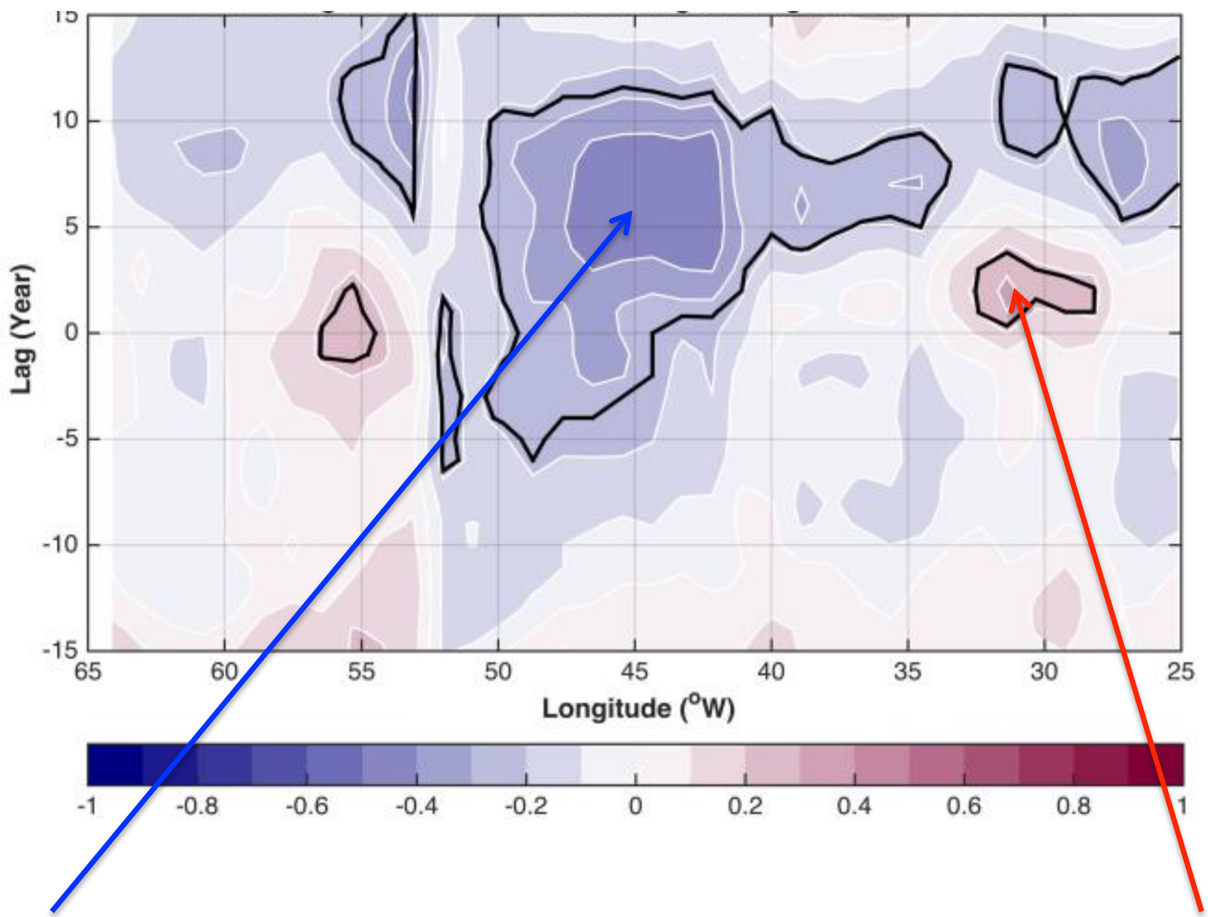
warming along NAC near the Mid-Atlantic Ridge

Green curves: mean GS-NAC position

Black contours: 5% significance

Why do SST anomalies appear near GS-NAC?

Lag-correlation between GS-NAC latitude (at each longitude) and AMOC PC1
(Positive lag when GS-NAC lags the AMOC PC1)

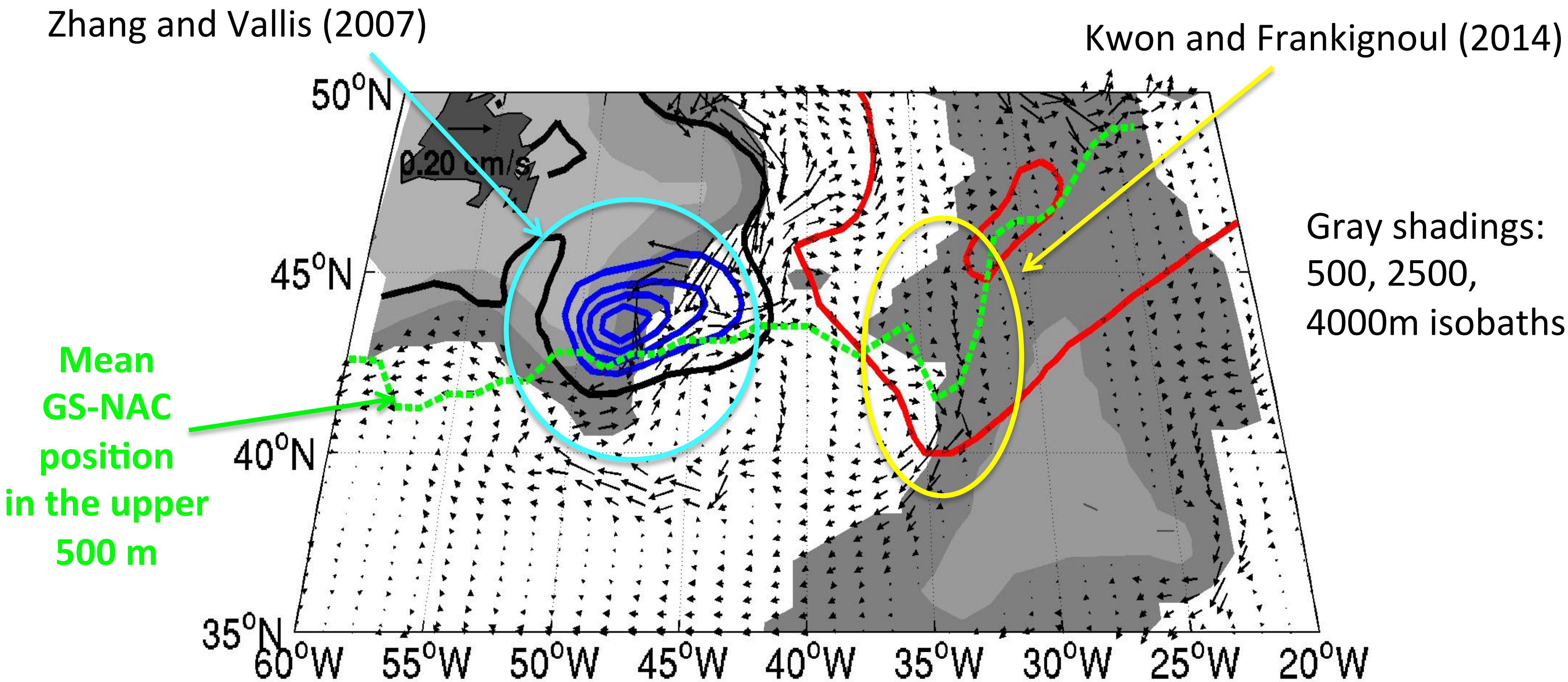


Southward shift of GS following AMOC intensification

Northward shift of NAC following AMOC intensification

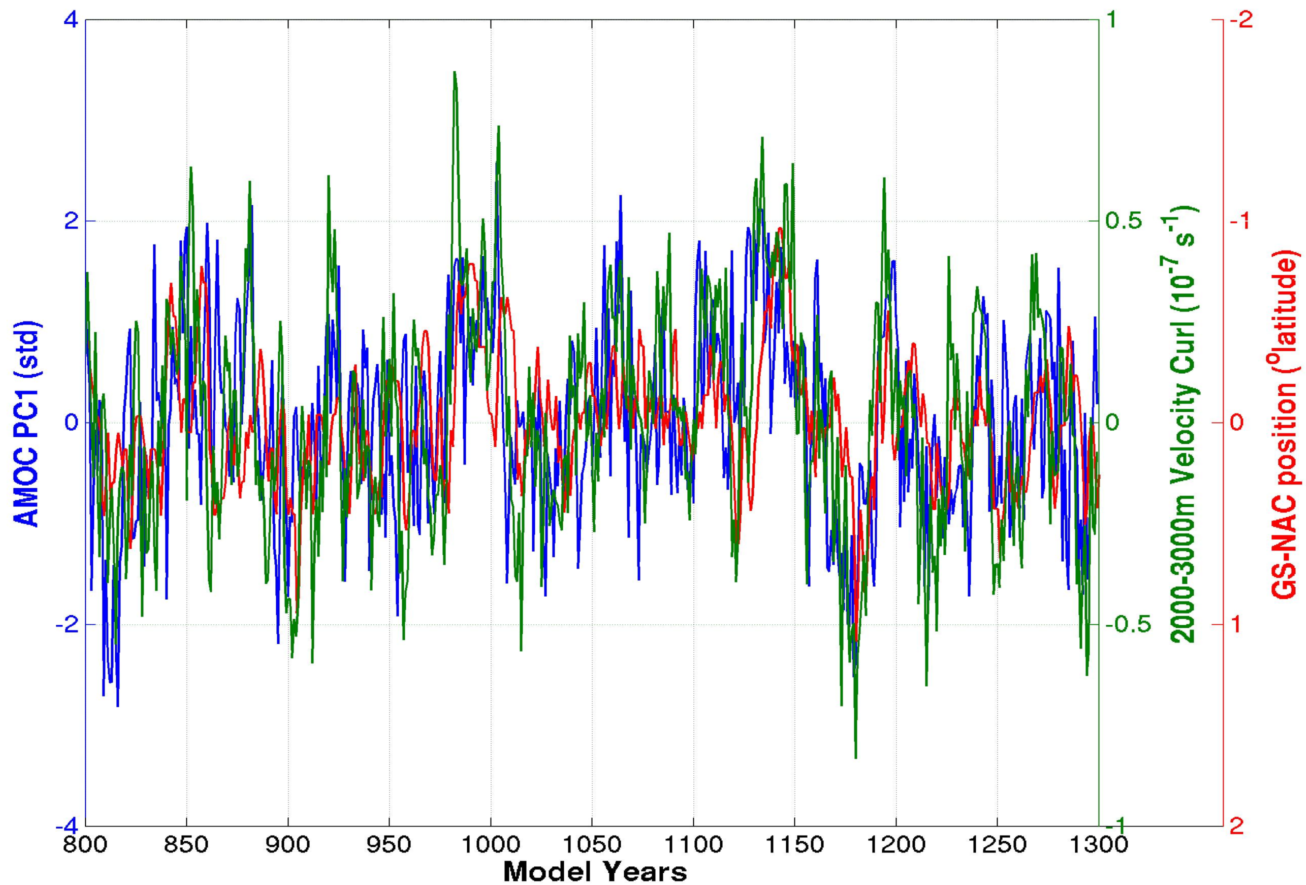
2000-3000m velocity and SST regressions on AMOC PC1

(one year following the maximum AMOC intensification)



Deep equatorward flow increases associated with AMOC intensification
primarily along the western boundary near the Tails of Grand Banks
but also along the interior pathway near the western flank of the Mid-Atlantic Ridge

DWBC and GS near the Tail of Grand Banks
(44°-45°N, 42°-47°W)

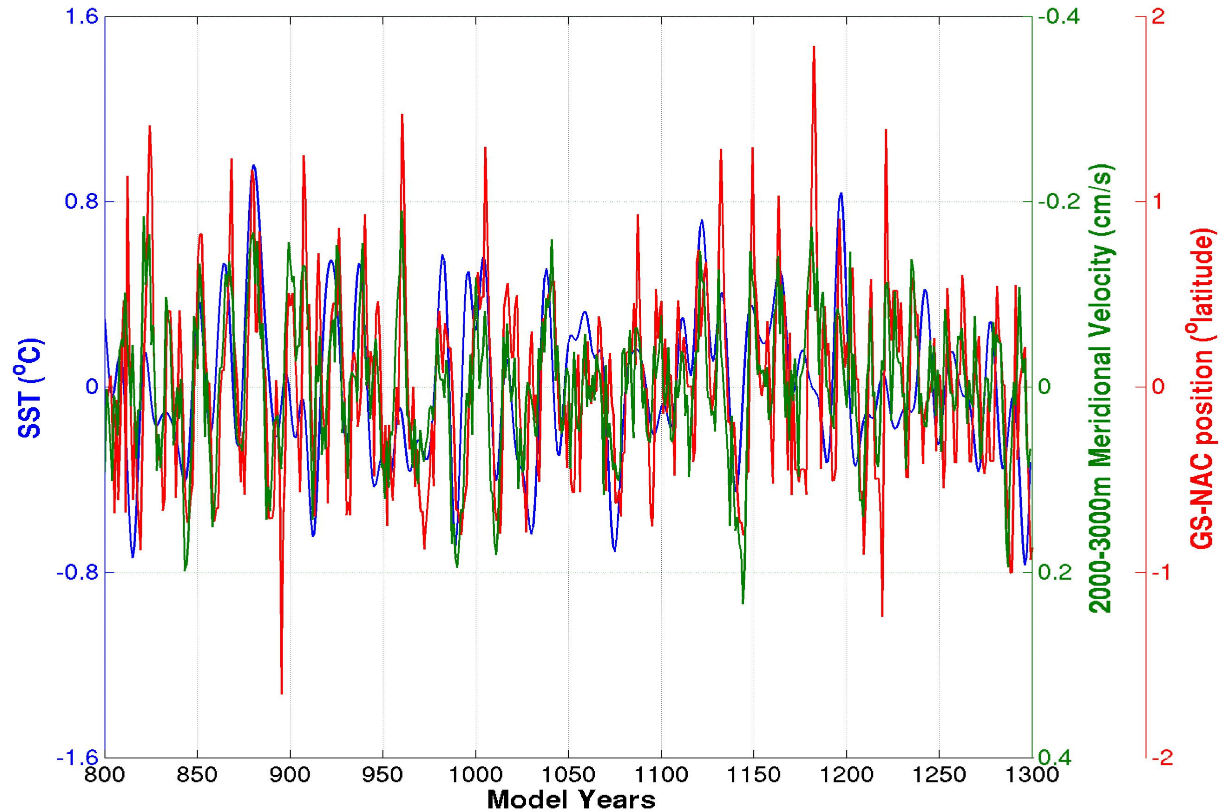


AMOC PC1 → **Deep velocity curl** → **GS latitude**

r=~+0.7 when AMOC leads by 0-5 yrs

r=~-0.65 when deep curl leads by 0-1 yrs

Deep flow and NAC near the western flank of MAR
(44°-48°N, 27°-33°W)



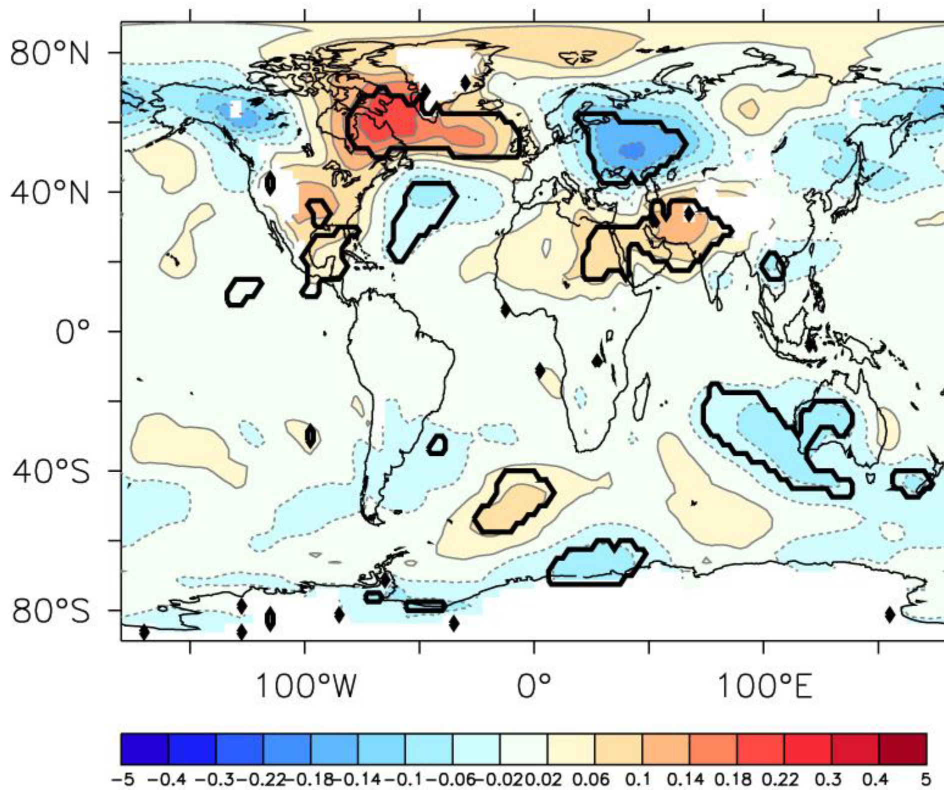
Deep meridional velocity → **NAC latitude** → **SST**

***r*=-0.88 at lag 0**   ***r*=+0.57 at lag 0**

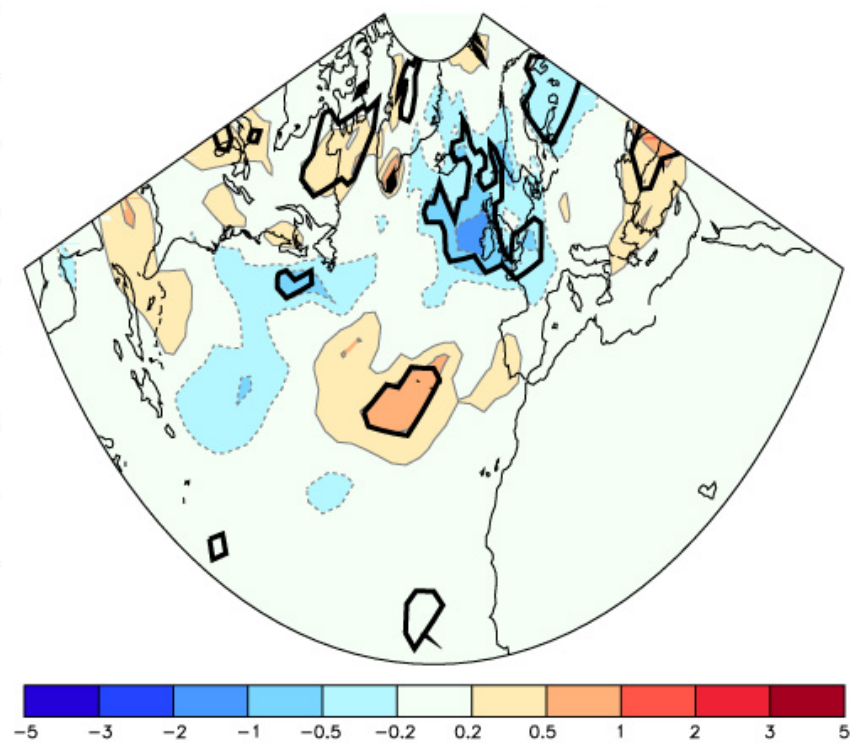
AMOC impact on winter climate

Lag-regressions on the lag+7 MCA AMOC time series

JFM Temperature at 850 hPa (K)



JFM Precipitation (0.1 mm day^{-1})



Climate impacts are mostly found in North America, North Atlantic and Europe

Summary

- ***NAO+ → Stronger AMOC → NAO-***

  : weak negative feedback between NAO and AMOC, consistent with 7 other CMIP3/5 models

- 6-9 yr lag between the AMOC and atmospheric response is associated with the time scale of SST anomaly advection along the subpolar gyre to form a meridional SST dipole starting from the zonal dipole along the GS-NAC.

- SST anomalies are initiated by the subpolar gyre strengthening and the interaction between the AMOC deep branch and the GS-NAC near the topographic slope in two locations near the Tail of Grand Banks and the western flanks of the Mid-Atlantic Ridges.

- Meridional SST dipole drives shift of the regions of maximum dT/dy, Eady grow rate, and thus storm track.

For the further details

Frankignoul, C., G. Gastineau, and Y.-O. Kwon: Wintertime atmospheric response to North Atlantic ocean circulation variability in a climate model. *J. Climate*, in-press. http://dx.doi.org/10.1175/JCLI-D-15-0007.1.

Kwon, Y.-O., and C. Frankignoul, 2014: Mechanisms of Multidecadal Atlantic Meridional Overturning Circulation Variability Diagnosed in Depth versus Density Space. *J. Climate*, **27**, 9359-9376. doi: http://dx.doi.org/10.1175/JCLI-D-14-00228.1.

Danabasoglu, G., S.G. Yeager, Y.-O. Kwon, J.J. Tribbia, A.S. Phillips, and J. Hurrell, 2012: Variability of the Atlantic Meridional Overturning Circulation in CCSM4. *J. Climate*, **25**, 5153-5172, doi:10.1175/JCLI-D-11-00595.1.