# The influence of the AMOC variability on the atmosphere in CCSM4

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## Estimating oceanic influence on the atmosphere

- Intrinsic atmospheric persistence is small

- Relation between ocean and atmosphere with the ocean leading is indicative of boundary forcing

  if external forcing and anthropogenic changes are removed

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  if external forcing and anthropogenic changes are removed

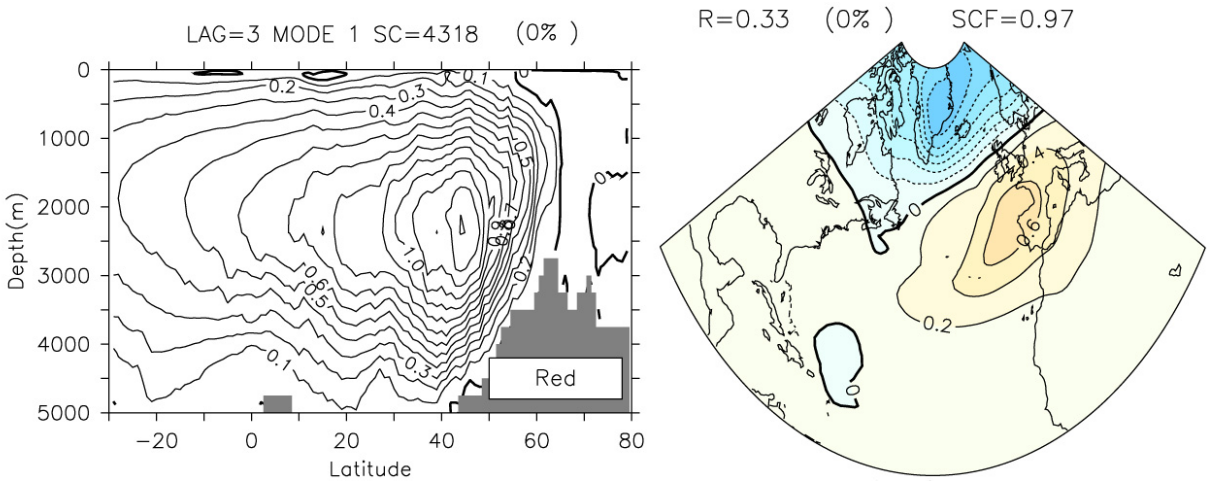
- AMOC influence in climate models best seen in control simulations

- AMOC impact may vary with atmospheric or oceanic climatology

- AMOC influences the atmosphere via its SST footprint and heat flux modulation

# CCSM3 T85 Control simulation, year 450 – 700 (red noise regime)

Maximum covariance analysis between yearly meridional streamfunction and SLP




First MCA mode when AMOC (in Sv) leads JFM SLP (in hPa) by 3 years

AMOC intensification leads a positive NAO in winter

Frankignoul et al. 2013

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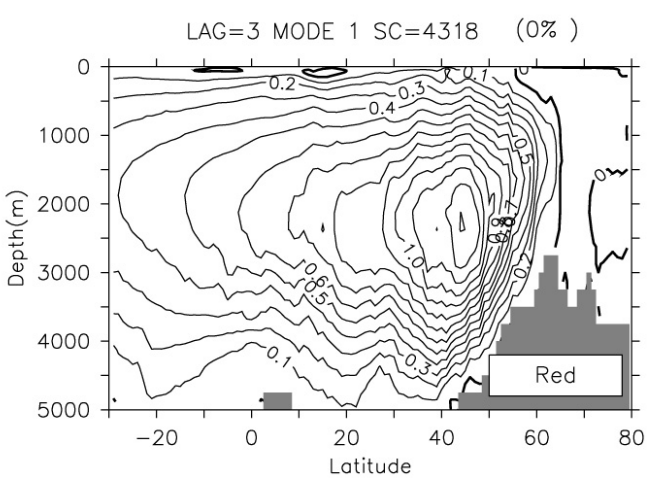
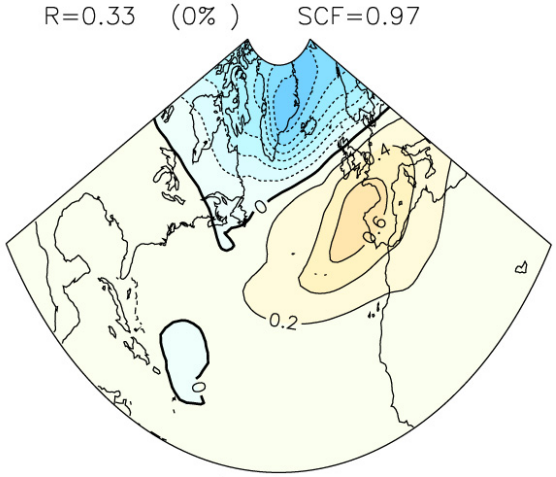
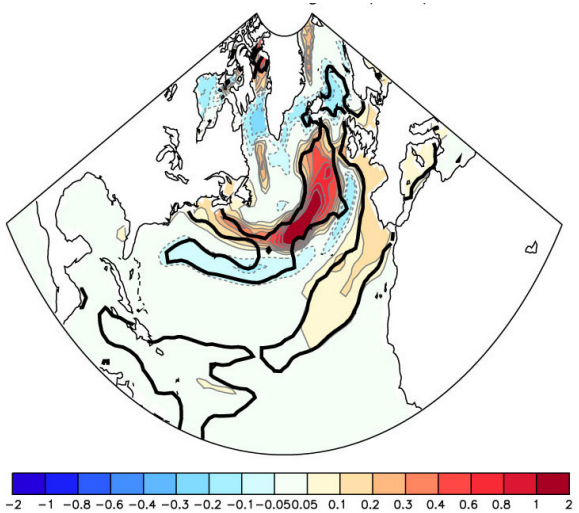



AMOC intensification leads a positive NAO in winter




Associated SST following AMOC intensification by 3-yr

No resemblance with the observed North Atlantic SST influence on the winter atmosphere, nor with the observed AMO

(too strong SST along GS/NAC )

Frankignoul et al. 2013

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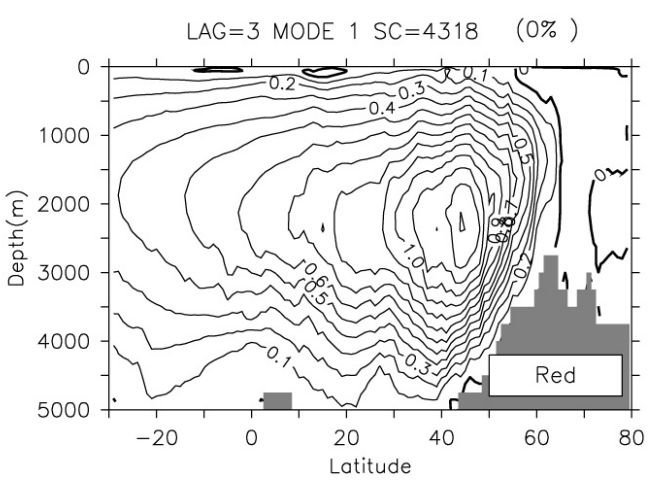


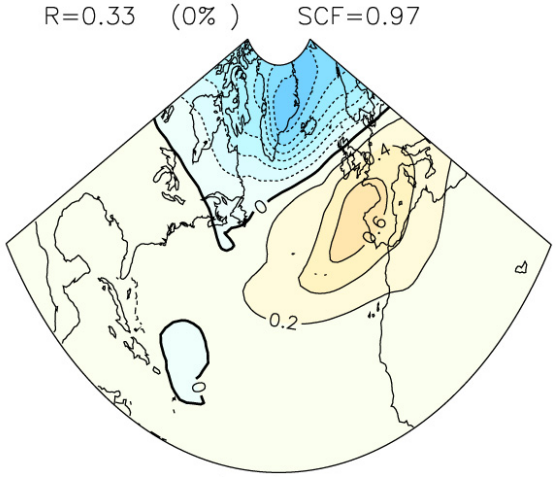


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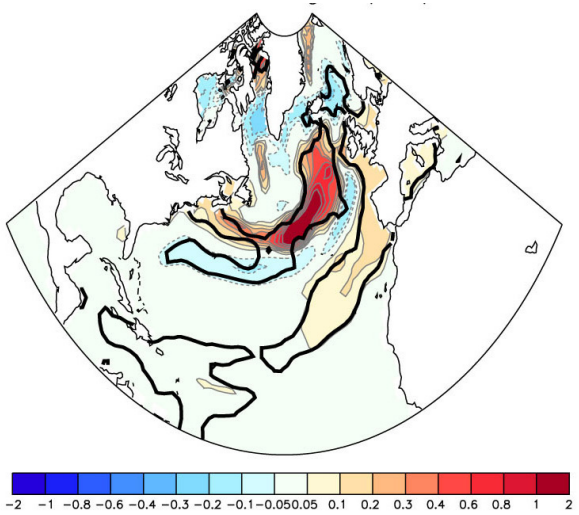


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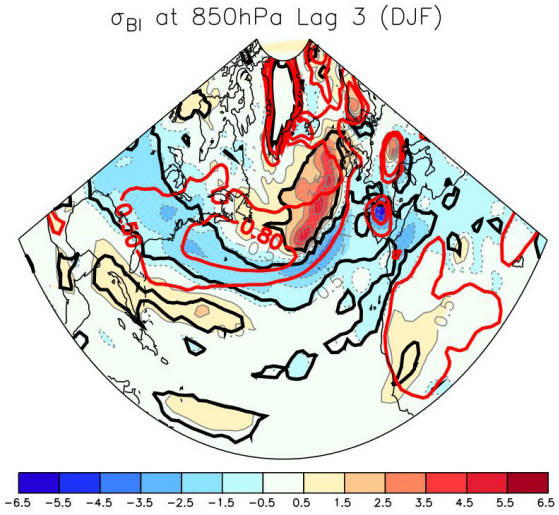



Associated Eady growth rate
Climatology in red

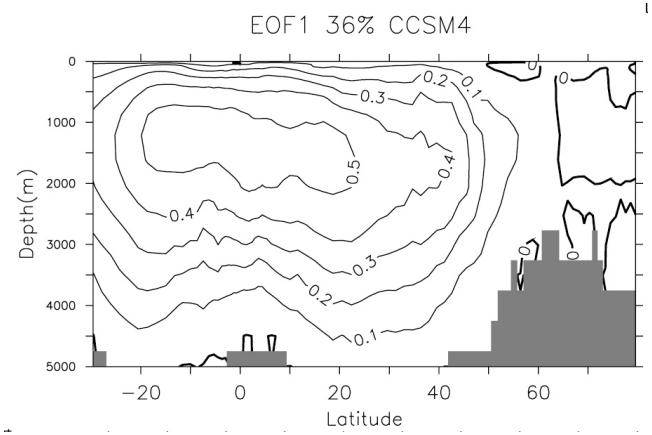
Mechanism:

Northward shift of SST along GS/NAC

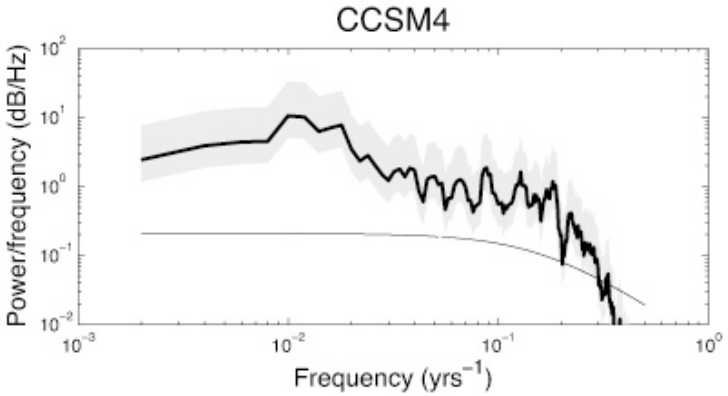
Northward shift of region of maximum cyclogenesis

Frankignoul et al. 2013

# CCSM4 700-yr control simulation

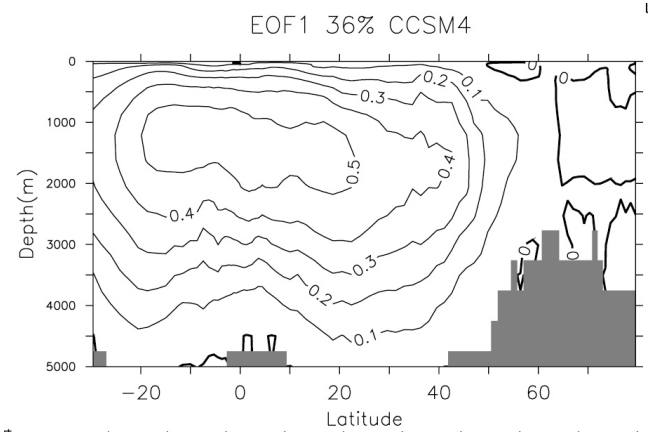


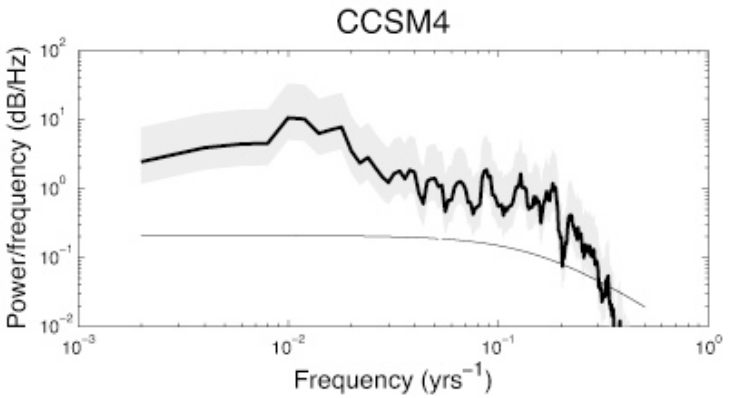

First EOF of AMOC




Power spectrum

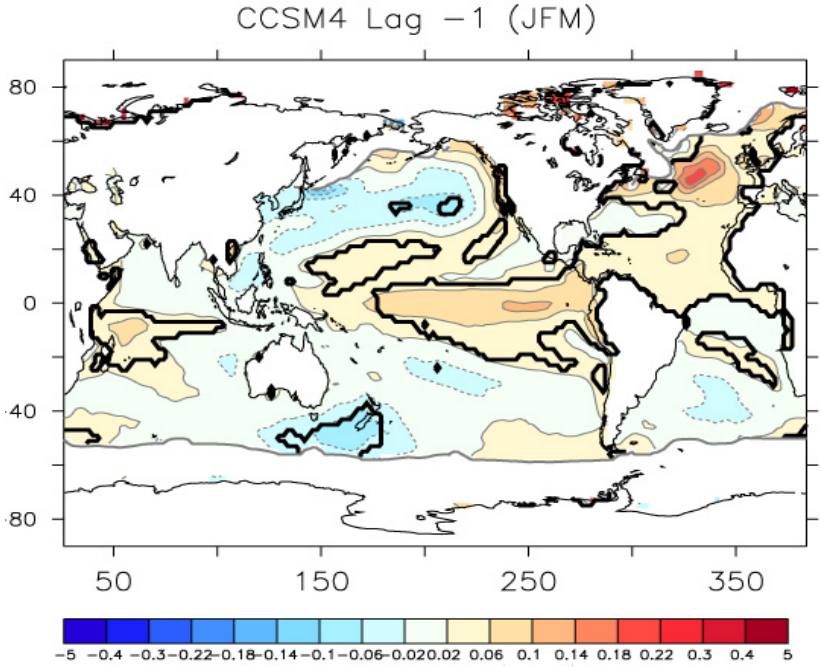
# CCSM4 700-yr control simulation




Regression of SST in JFM onto yearly AMOC PC-1

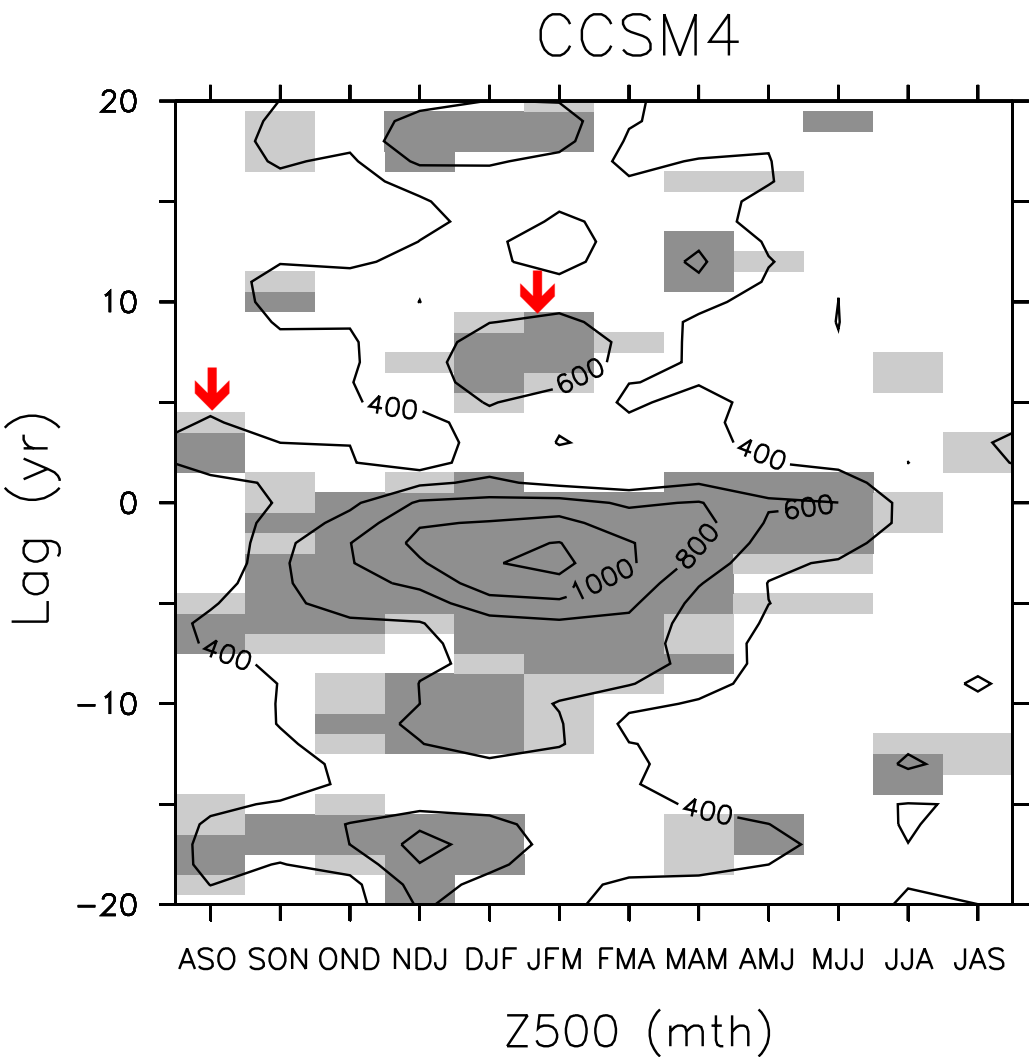
SST leads by 1 yr




Link between AMOC and ENSO

ENSO influence must be removed to detect direct AMOC influence

# CCSM4 700-yr control simulation




**AMOC leads at positive lag**

MCA between yearly AMOC and 3-month running mean geopotential height at 500 hPa

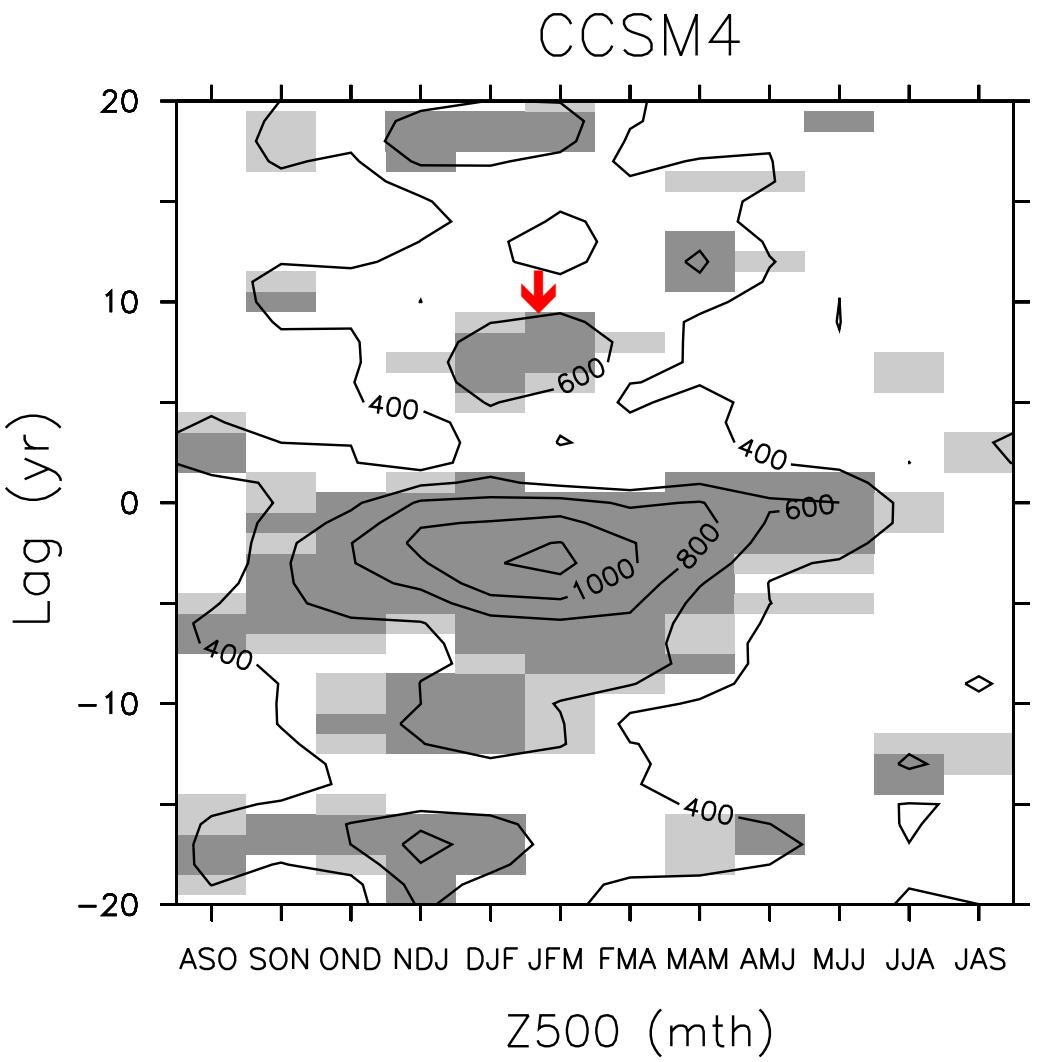
¼ ½ ¼ smoothing
Quadratic trend removed, ENSO removed
Seas. asym. 3 PCs

Dark grey 5%
Light grey 10%

Winter response DJF - JFM

Summer response JAS - ASO

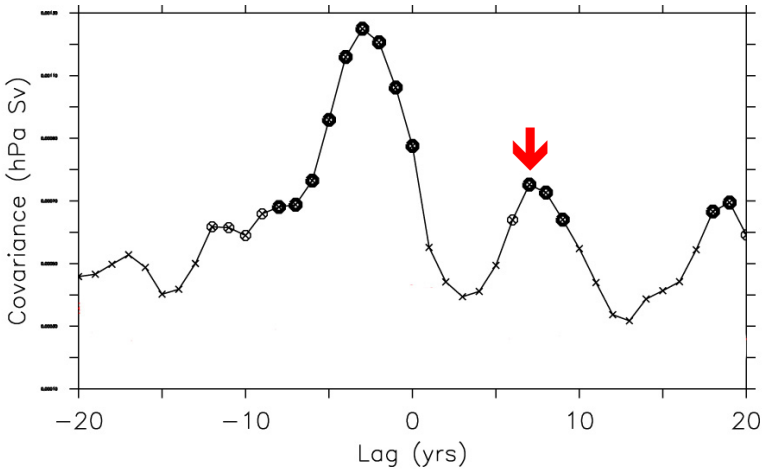
# CCSM4 700-yr control simulation




AMOC leads at positive lag

MCA between yearly AMOC and 3-month running mean geopotential height at 500 hPa

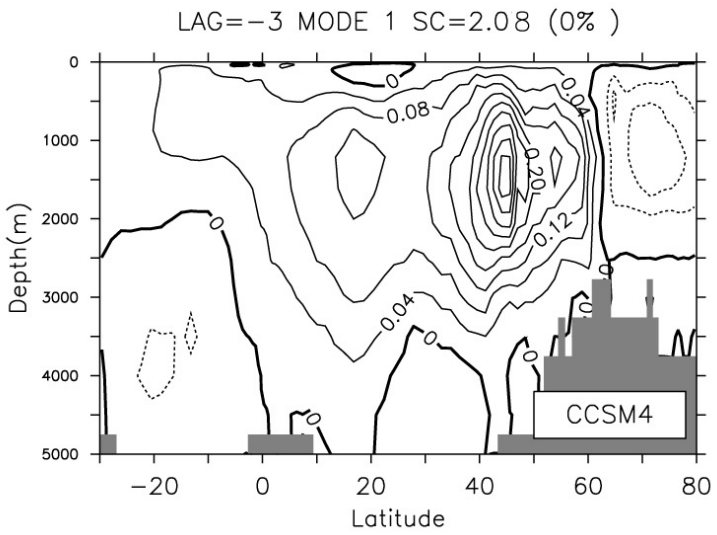
**Winter response** Z500 in JFM

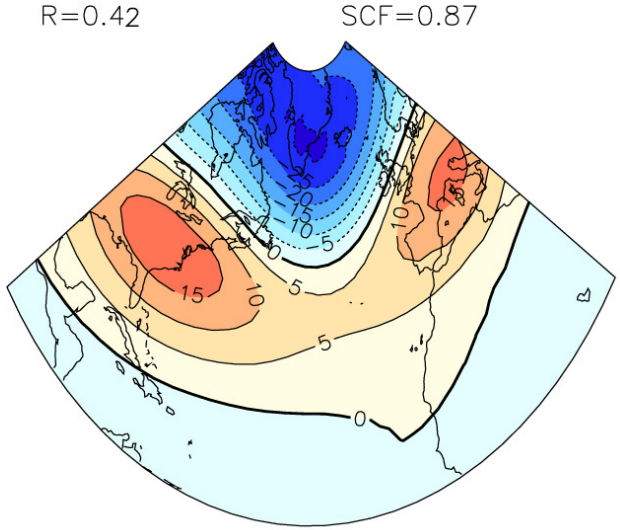



AMOC lags AMOC leads Z500

Black circle 5% open 10%

# Winter air-sea interactions




**AMOC response**

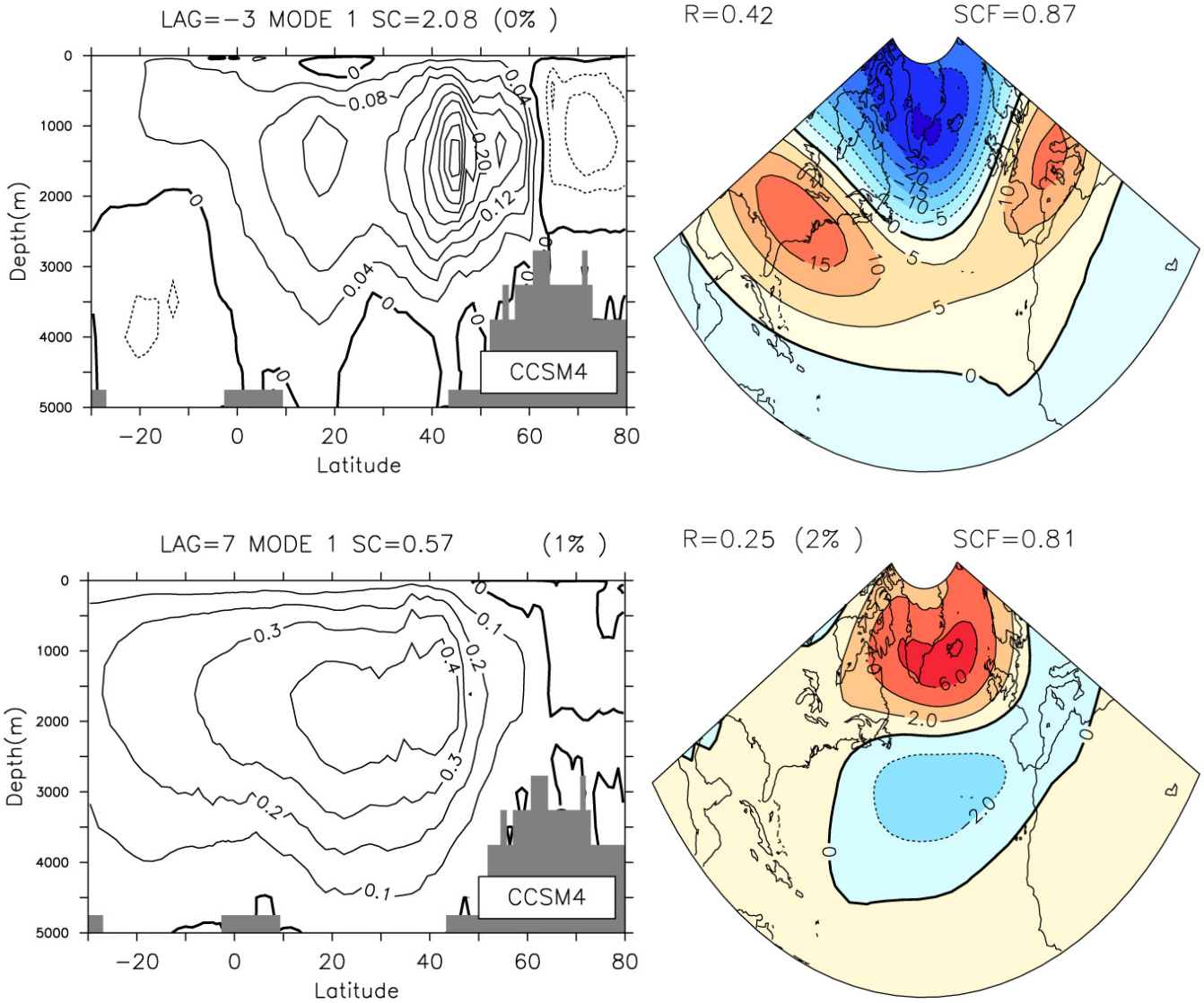
Z500 in JFM leads by 3 yr

NAO drives the AMOC

Similar to AMOC EOF1 (r=0.82)

Resemblance with NAO- shifted southward

# Winter air-sea interactions




**AMOC response**

Z500 in JFM
leads by 3 yr

NAO drives the
AMOC

**AMOC impact**

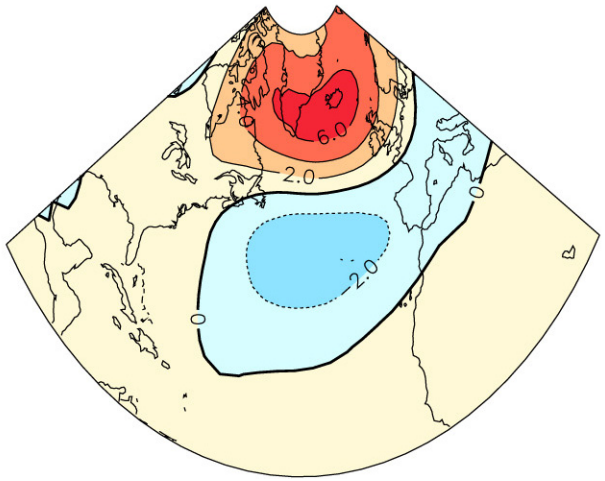
Z500 in JFM
lags by 6 to 9 yr

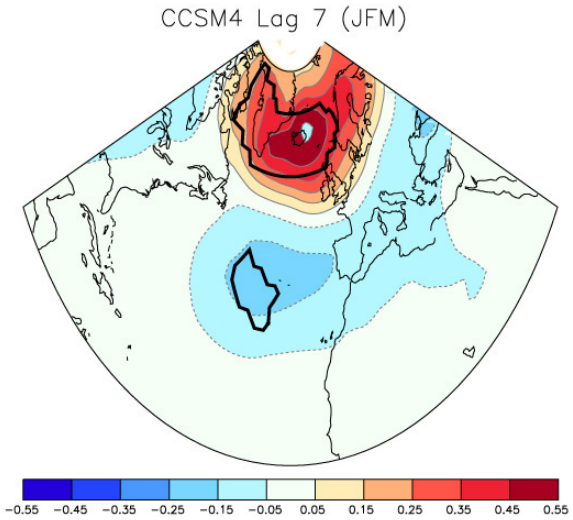
The AMOC drives NAO-

Negative feedback

# JFM patterns associated with the atmospheric response

Z500




SLP
hPa

NAO-

Barotropic

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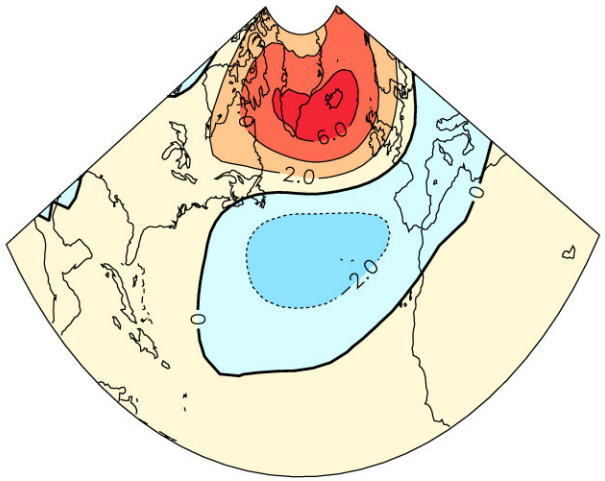
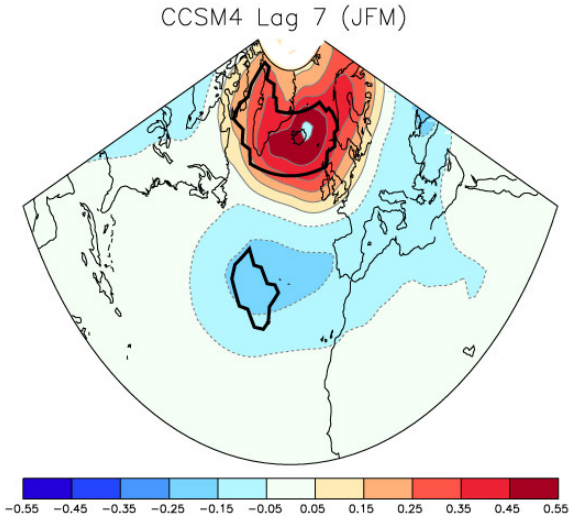


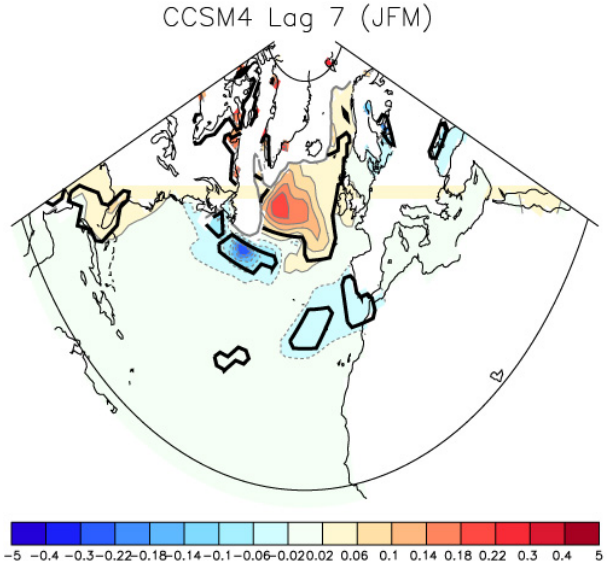

SLP
hPa

NAO-

Barotropic

SST

Similar
to AMO
but for
GS cooling



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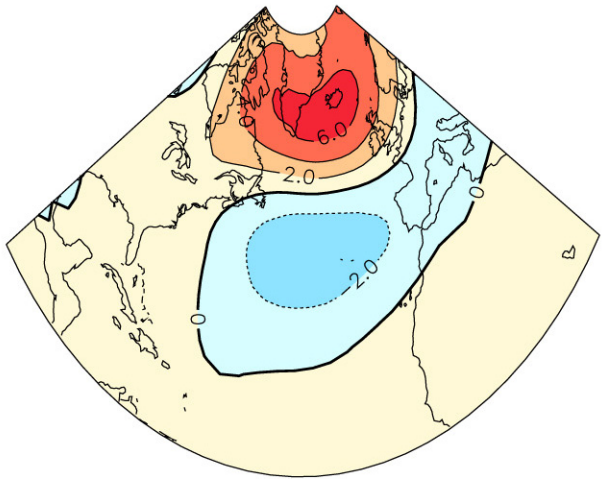


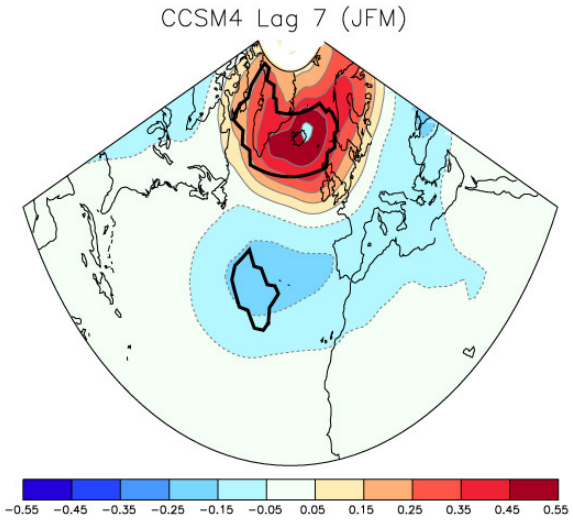


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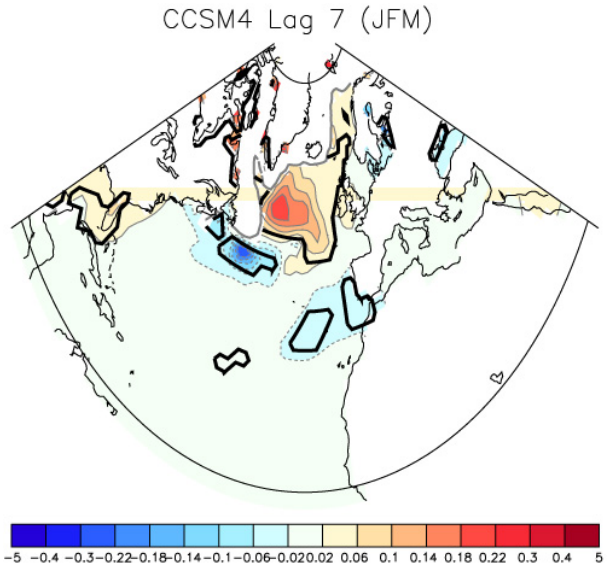
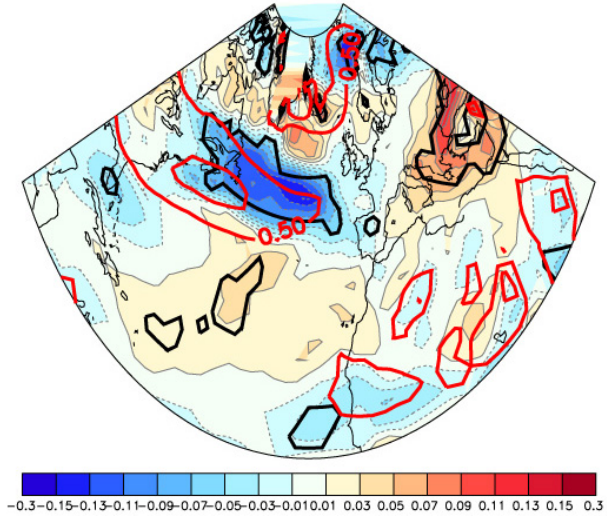


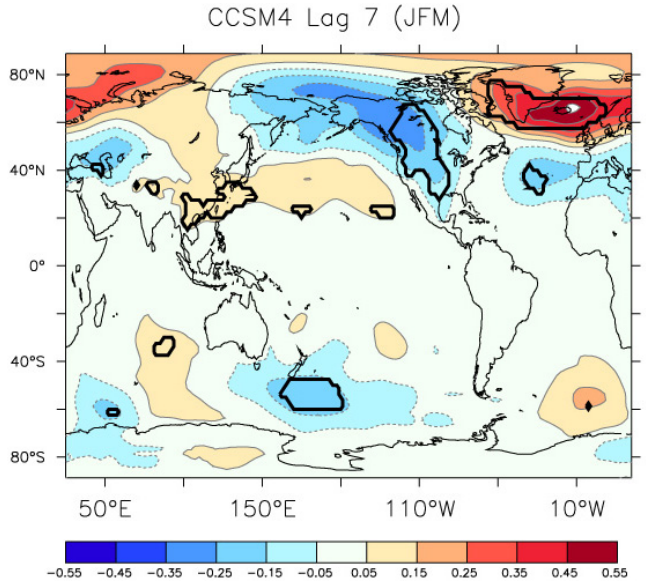

Eady
growth
Rate
0.1 $d^{-1}$

Southward
shift

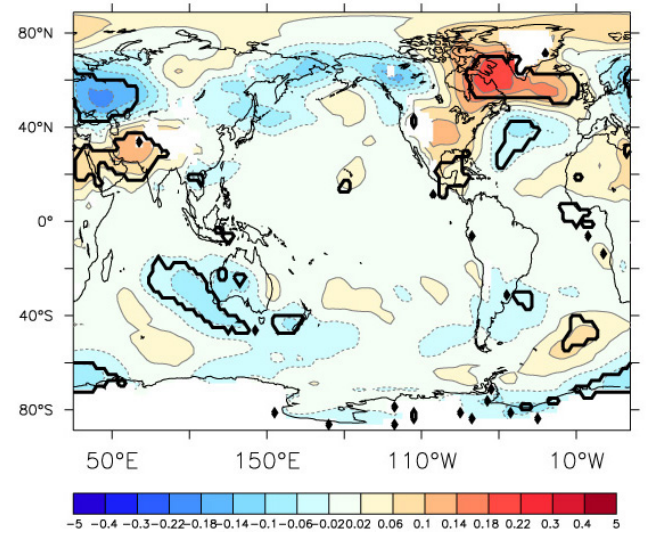
Cooling in
GS region

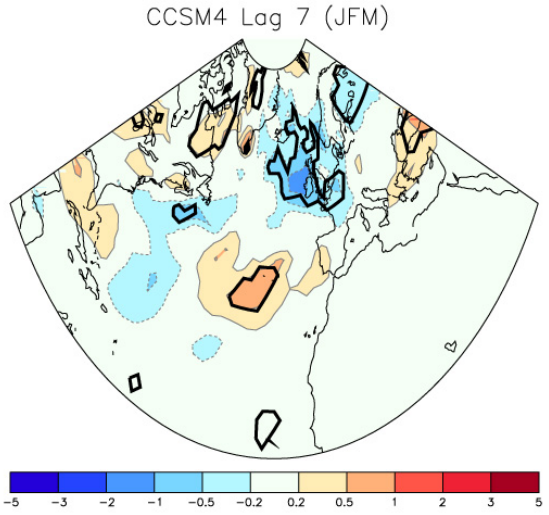
# AMOC winter impact

SLP
hPa

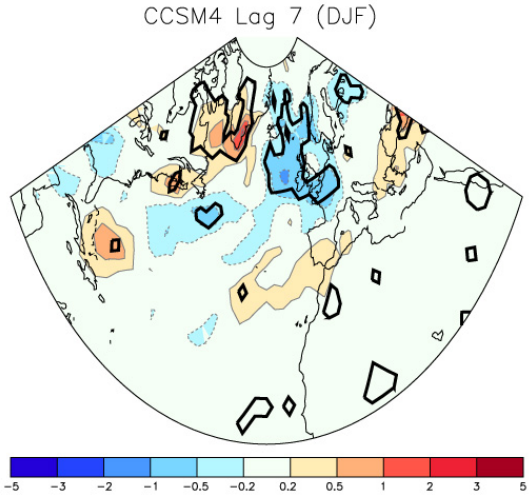



$T_{850}$
°C



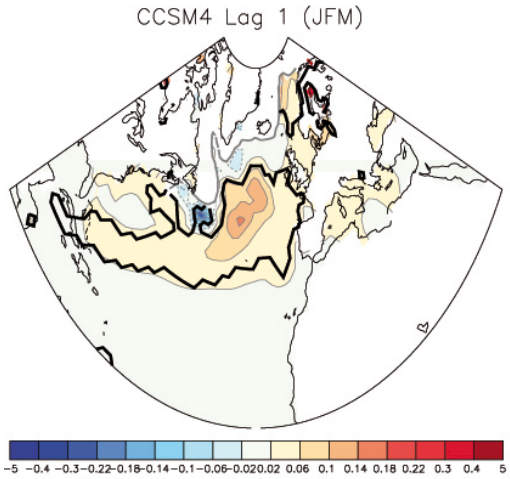

Precipitation
0.1 mm $d^{-1}$




Climatic impact mostly in North America, North Atlantic, and Europe

Why is the response only seen at lag 5 – 9?

1 yr




Regression of JFM SST onto AMOC PC1

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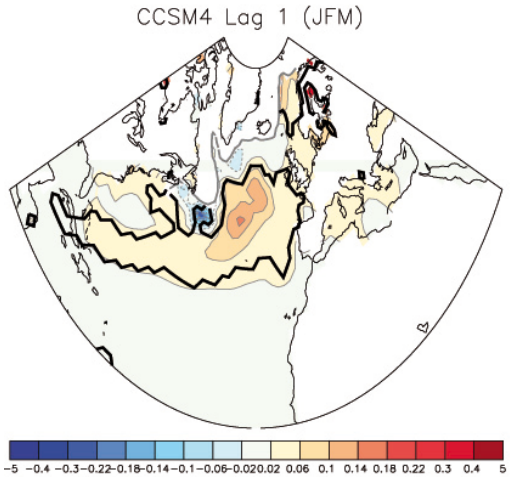
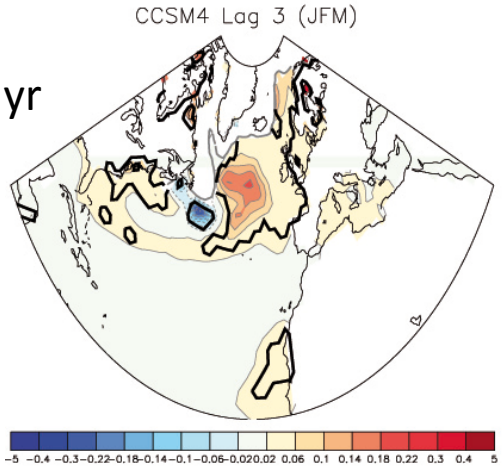



3 yr




Regression of JFM SST onto AMOC PC1

Cyclonic SST rotation
In subpolar gyre

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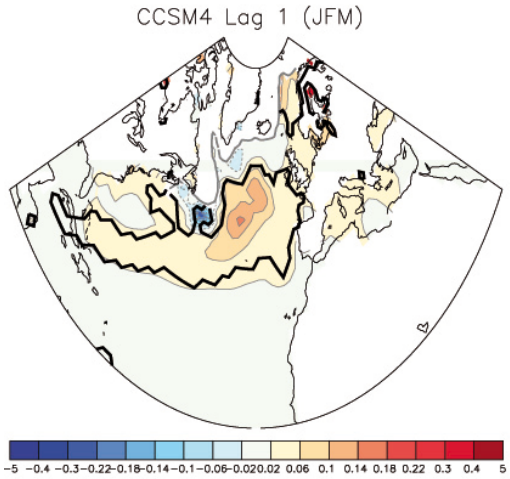


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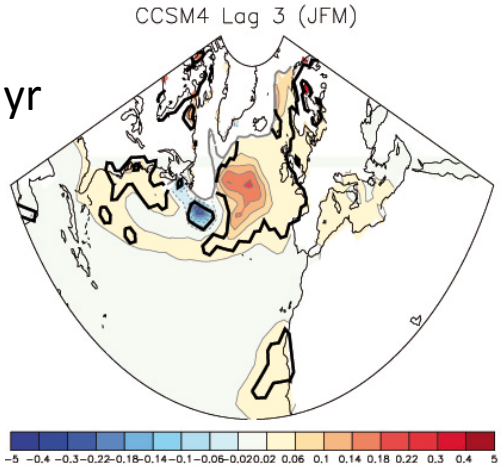


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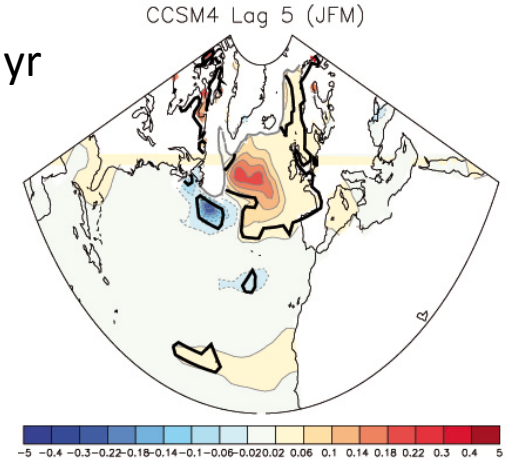

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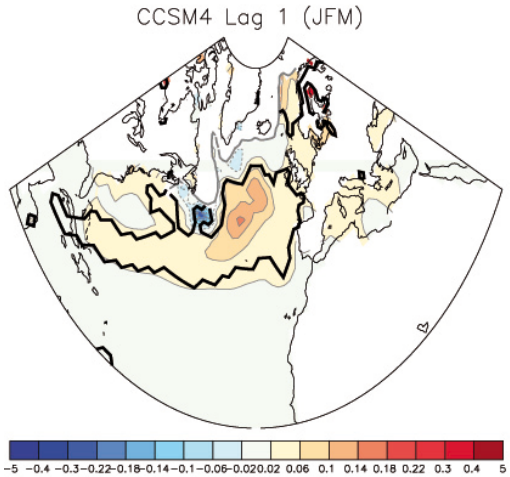
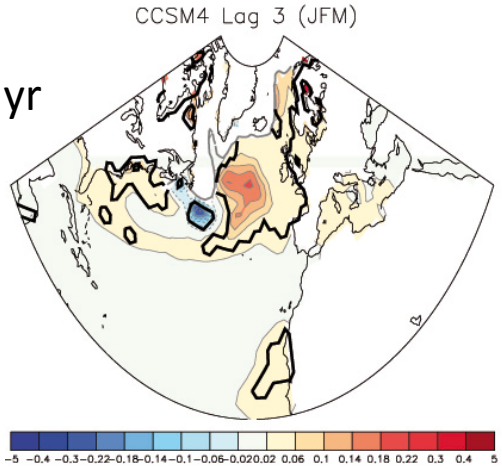



3 yr

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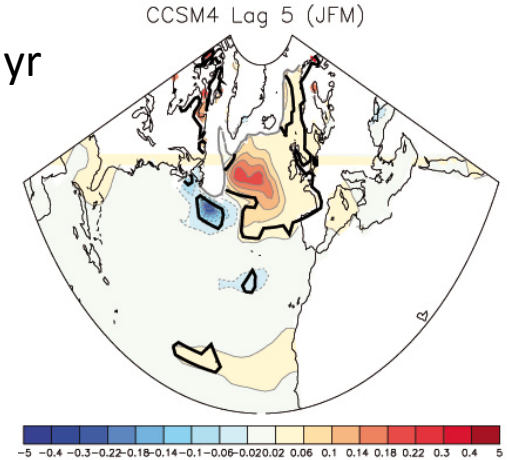
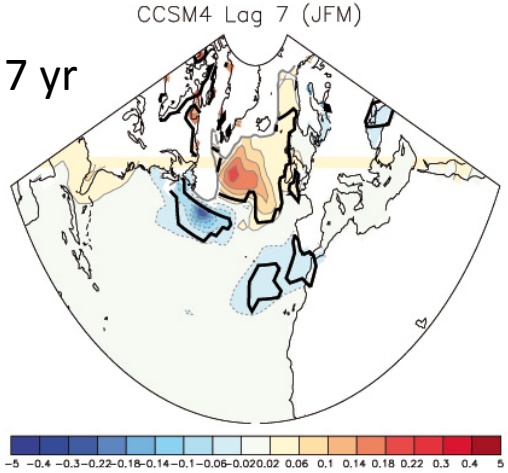


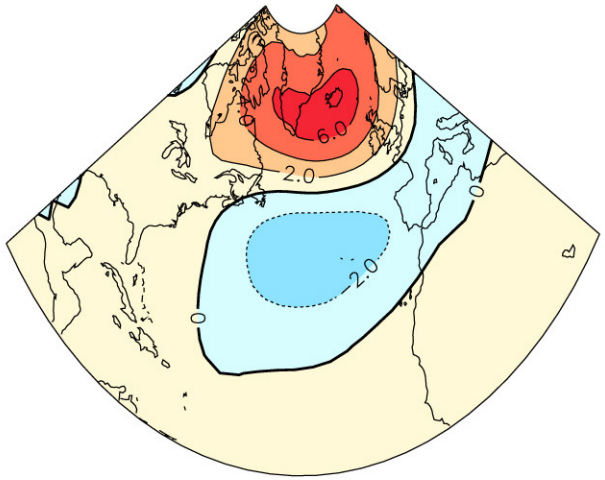

7 yr




Cooling in GS region intensifies with increasing lag (southward shift), shifting cyclogenis southward?

# Does the signal resemble the observed North Atlantic SST influence?

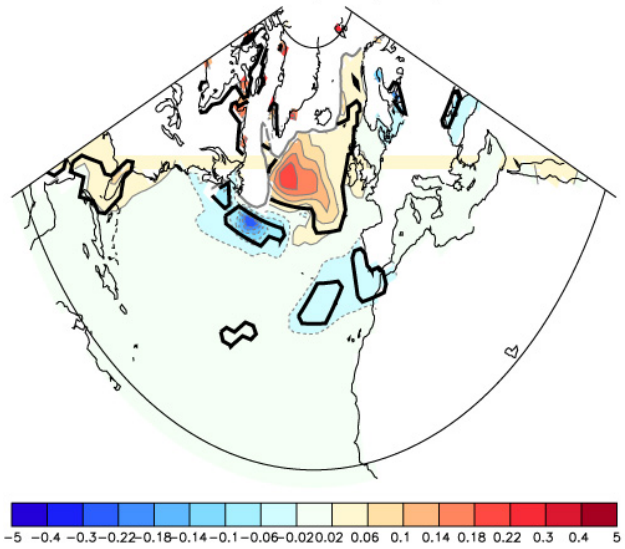
Z500




CCSM4 Lag 7 (JFM)

SST

Similar
to AMO
but for
GS cooling




AMOC impact could not be detected
in seasonal air-sea interactions

# Does the signal resemble the observed North Atlantic SST influence?

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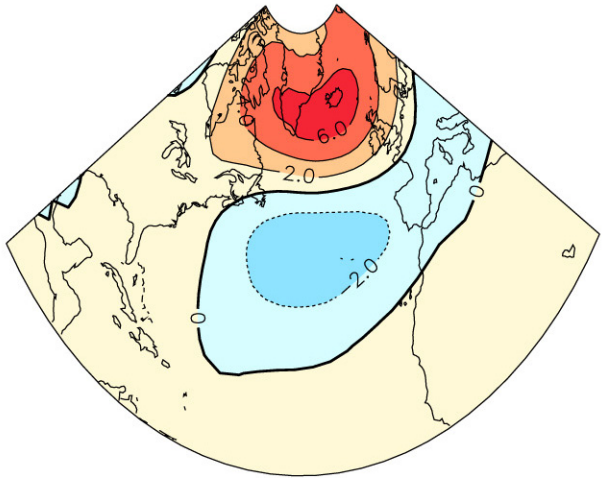
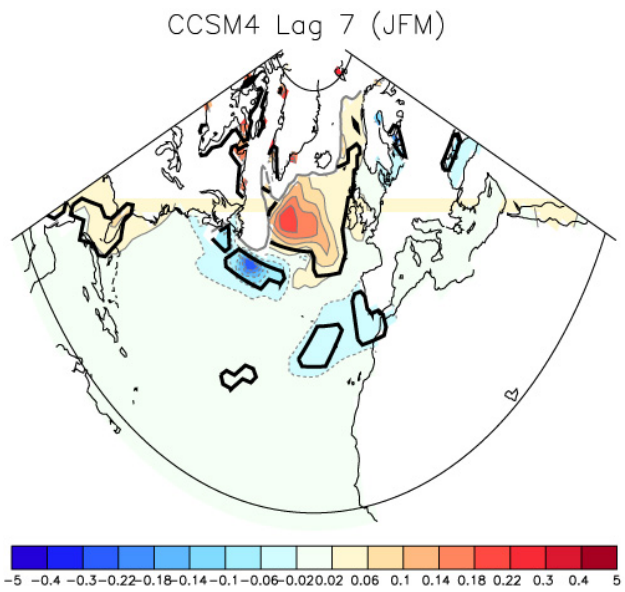


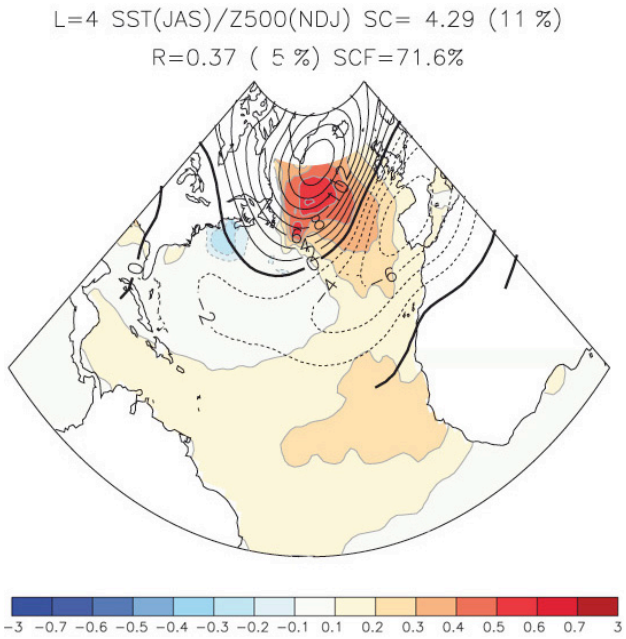

SST




Similar to AMO but for GS cooling

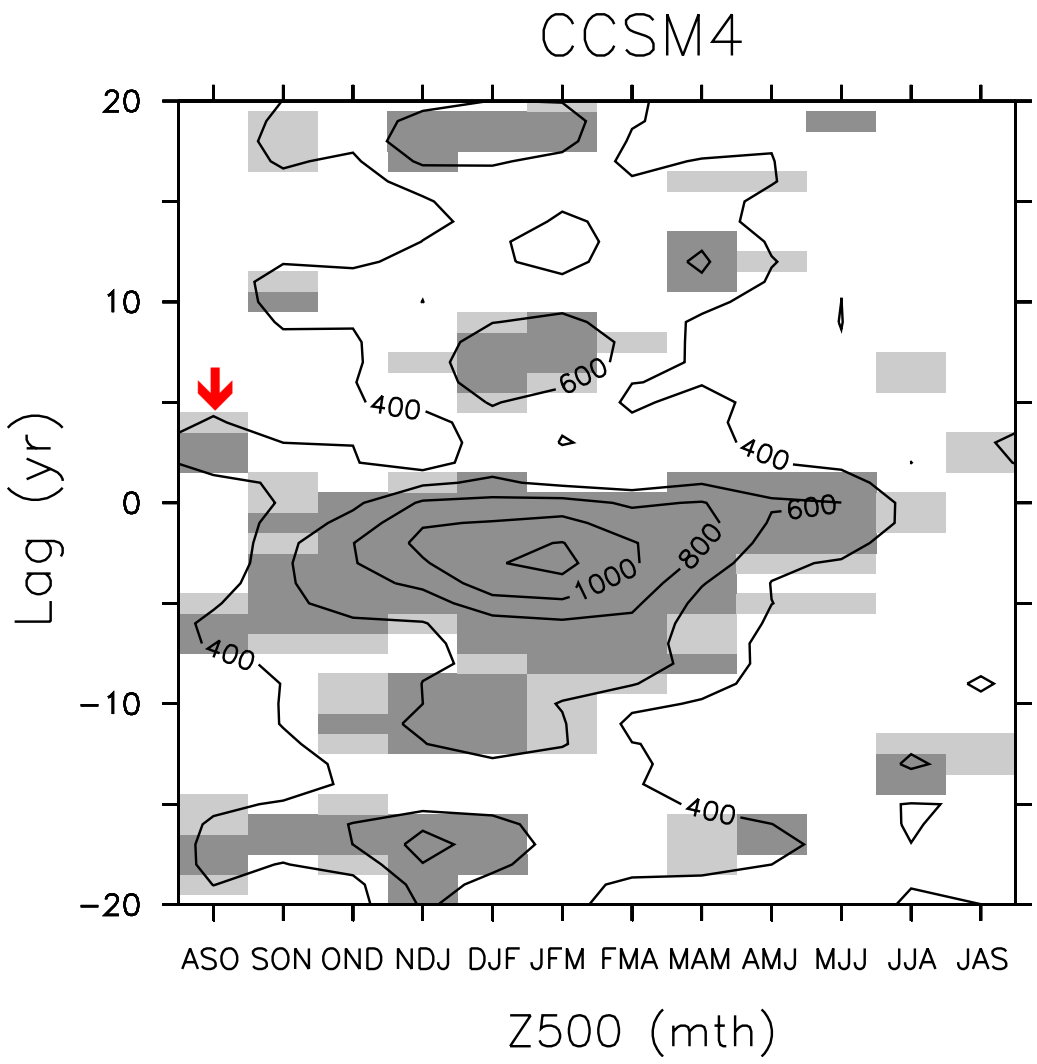
20th century reanalysis (1901-2005)

First MCA mode between JAS SST and NDJ Z500 (SST leads)




Some similarity with the observed patterns

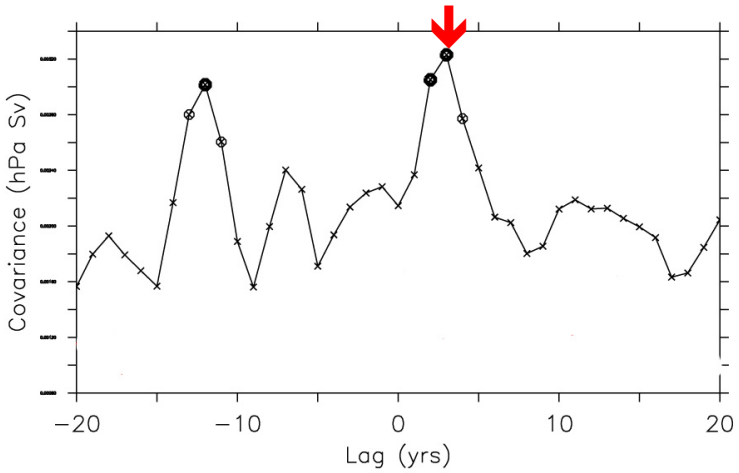
# CCSM4 700-yr control simulation




AMOC leads at positive lag

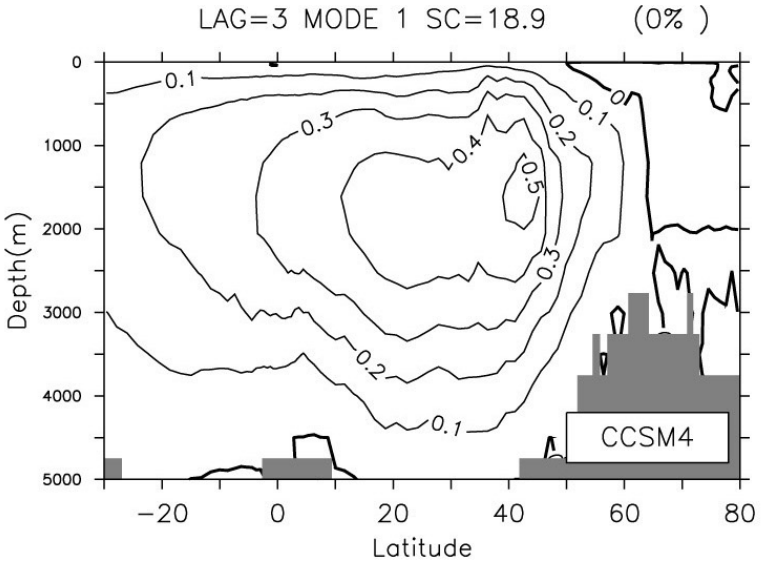
MCA between yearly AMOC and 3-month running mean geopotential height at 500 hPa

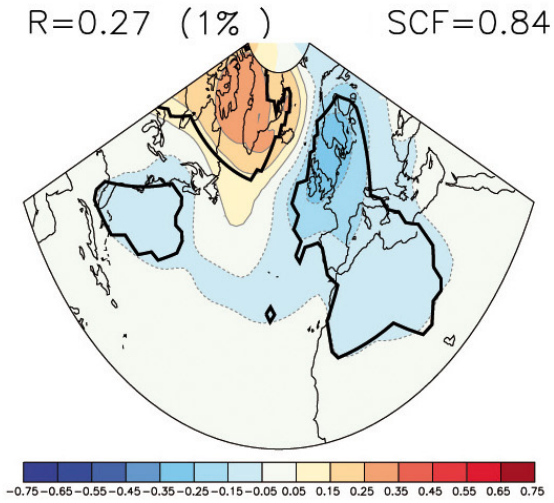
**Summer response** SLP in ASO




AMOC lags AMOC leads SLP

# Summer response to the AMOC




SLP follows the AMOC by 3 yr

Summer NAO-?

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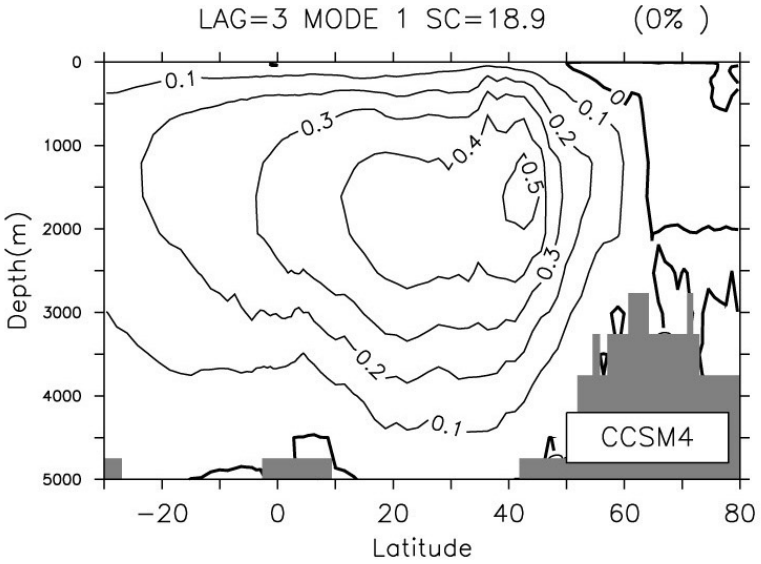
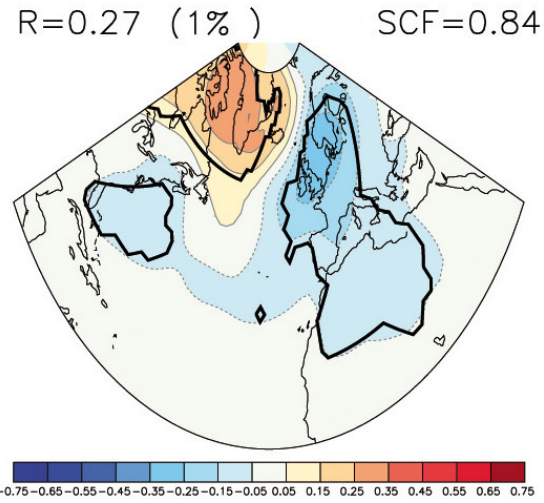


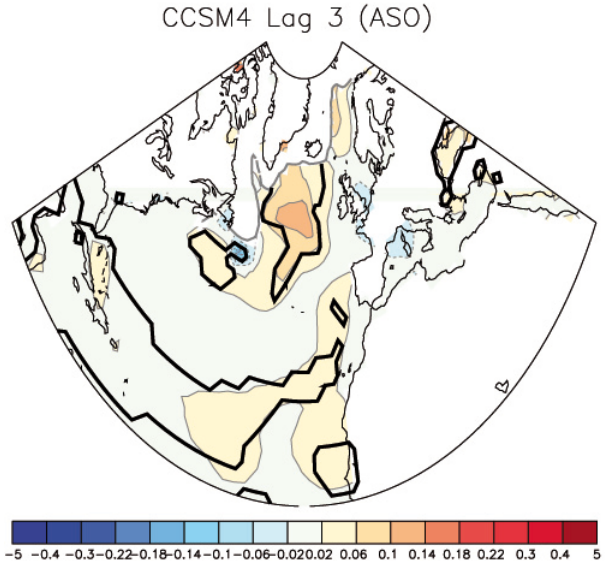




SLP follows the AMOC by 3 yr

Summer NAO-?

SST

°C




No significant change in cyclogenesis

Dynamics under investigation

Different from “classical” response

**Summary (work in progress)**

In winter, a negative NAO-like signal follows an AMOC intensification

The mode broadly resembles the observed winter NAH impact

The atmospheric response seems driven by the same mechanism as in CCSM3 and other climate models (Gastineau and Frankignoul 2012)
(meridional shift in SST and Eady growth rate in North Atlantic cyclogenesis region)

Role of sea-ice changes?

CCSM4 is more realistic than CCSM3

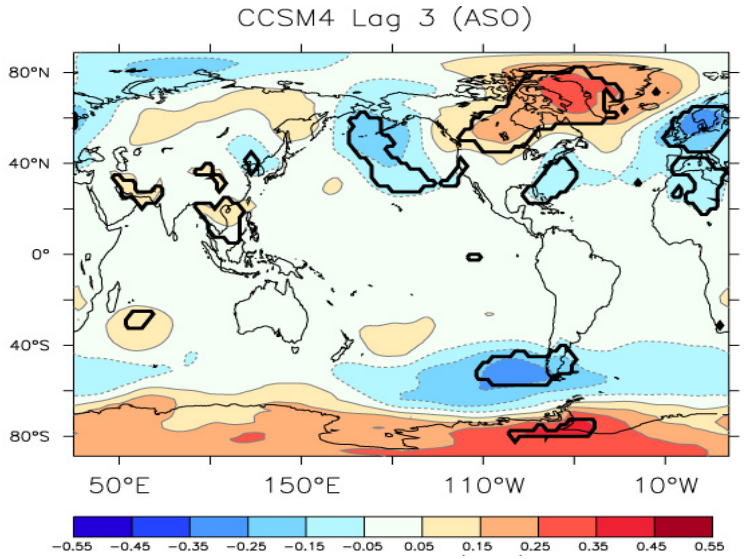
In late summer, the AMOC also drives a NAO- tropospheric response

Dynamics? Influence of tropical Atlantic?

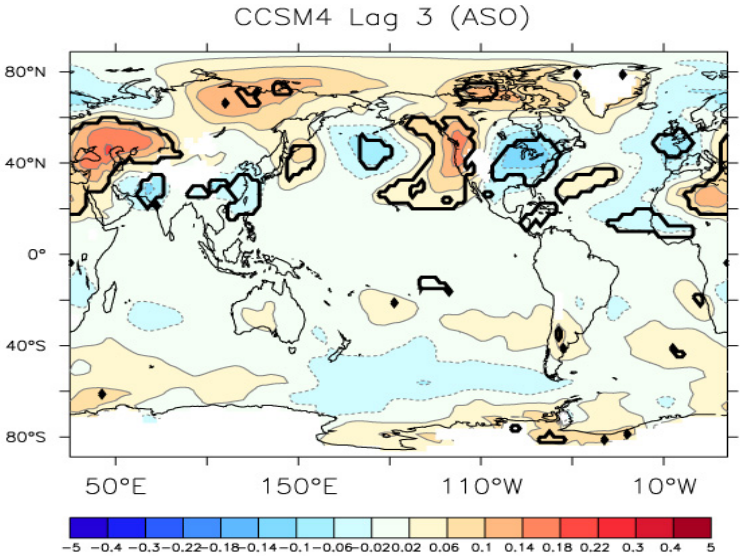
The Pacific – Atlantic connections must be understood

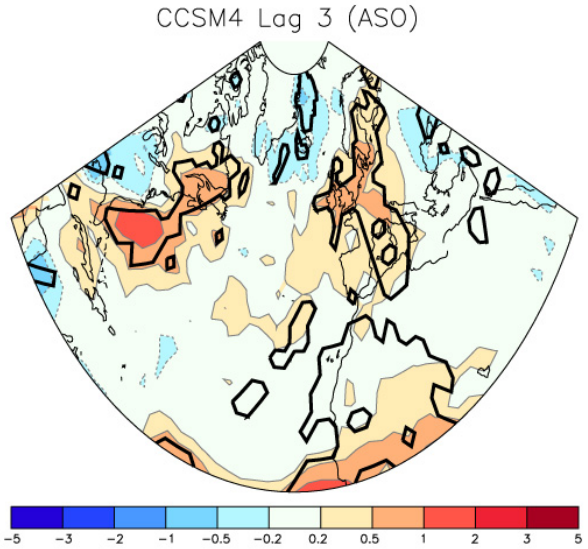
# Summer signal has hemispheric scale

SLP
hPa




$T_{850}$
°C

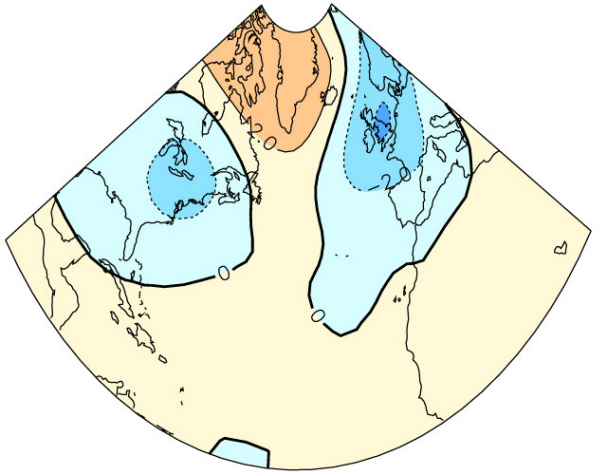


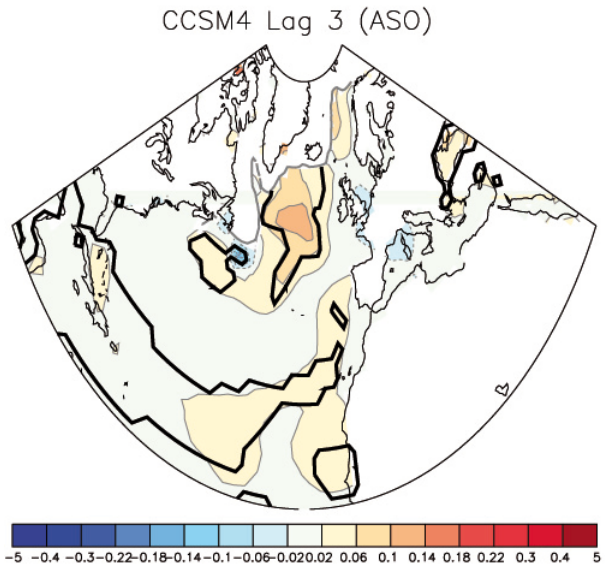

P
0.1 mm $d^{-1}$

# Summer AMOC impact seen in seasonal air-sea interactions

Z500
m

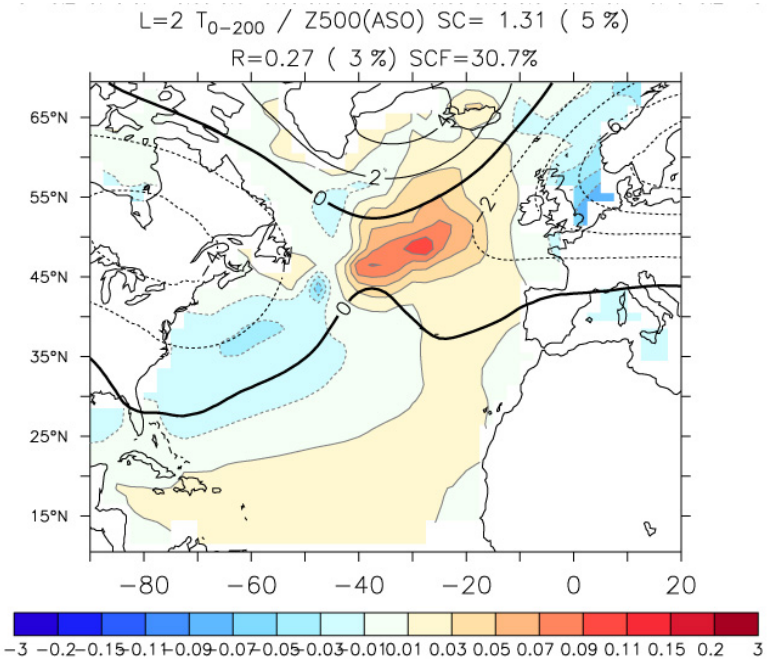


SST
°C




Lag MCA between
Z500 and $T_{0\text{-}200}$

Ocean leads




Response shifted south compared to observed pattern