Atlantic Multidecadal Oscillation influence on the Northern Hemisphere atmospheric circulation

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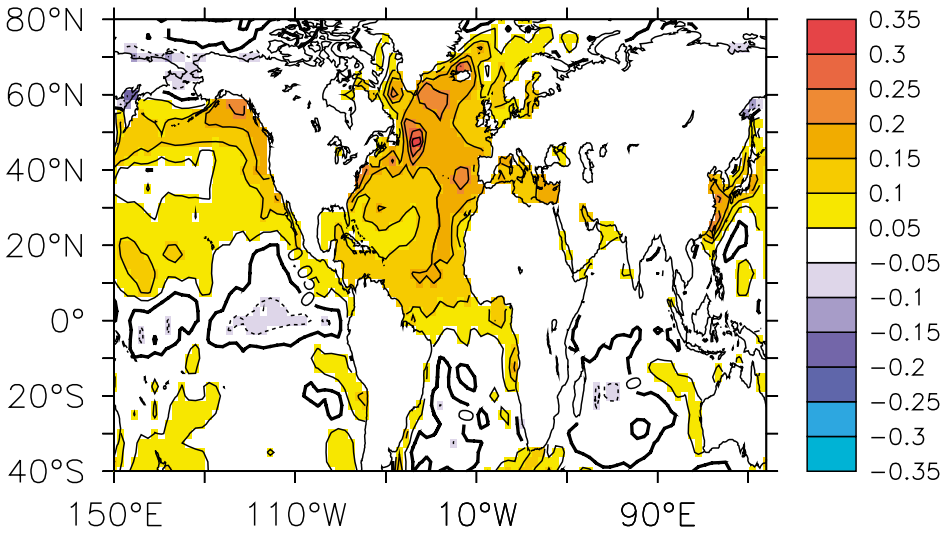
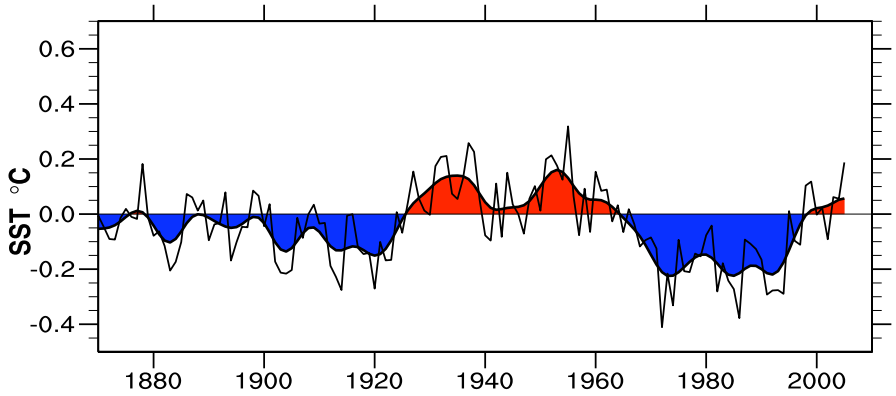
Altantic Multidedacal Oscillation (AMO)

Observed SST (K) mutlidecadal variability in the Atlantic Ocean

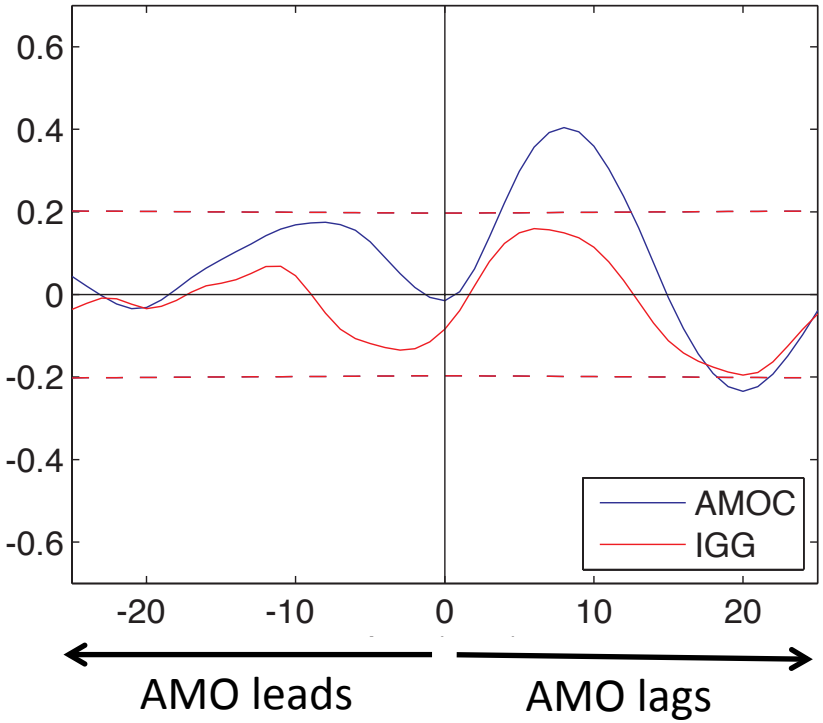


From Sutton and Hodson, 2005



From Trenberth and Shea, 2006

Correlation AMO / AMOC and AMOC / supolar gyre in IPSL-CM5A-LR



The AMO and its impacts might reflect the impact of the AMOC.

The Altantic Multidedacal Oscillation (AMO) and its climate effects

- AMO summer influence (Sutton and Hosdon 2005 ; Sutton and Dong 2012) :
  - N/S America rainfall (associated to ENSO and PDO)
  - Surface warming over N. Atlantic that extends to N Europe and N America; summer NAO (Folland et al., 2009).

- AMO winter influence : lower signal to noise ratio

Processes of the AMO influence :

- Response to tropical Atlantic warm SST over Caribbean basin (Hodson et al. 2010) that forces a summer NAO
- Midlatitude SST were shown to influence the atmospheric circulation (Watanabe and Kimoto, 2000 ; Czaja and Frankignoul, 2001 ; Peng et al. 2003)

-> changes project on the NAO (*North Atlantic Oscillation*)

- *Is there a relation between the Atmospheric circulation and the AMO?*
- *What is the role of midlatitude and tropical SST anomalies?*

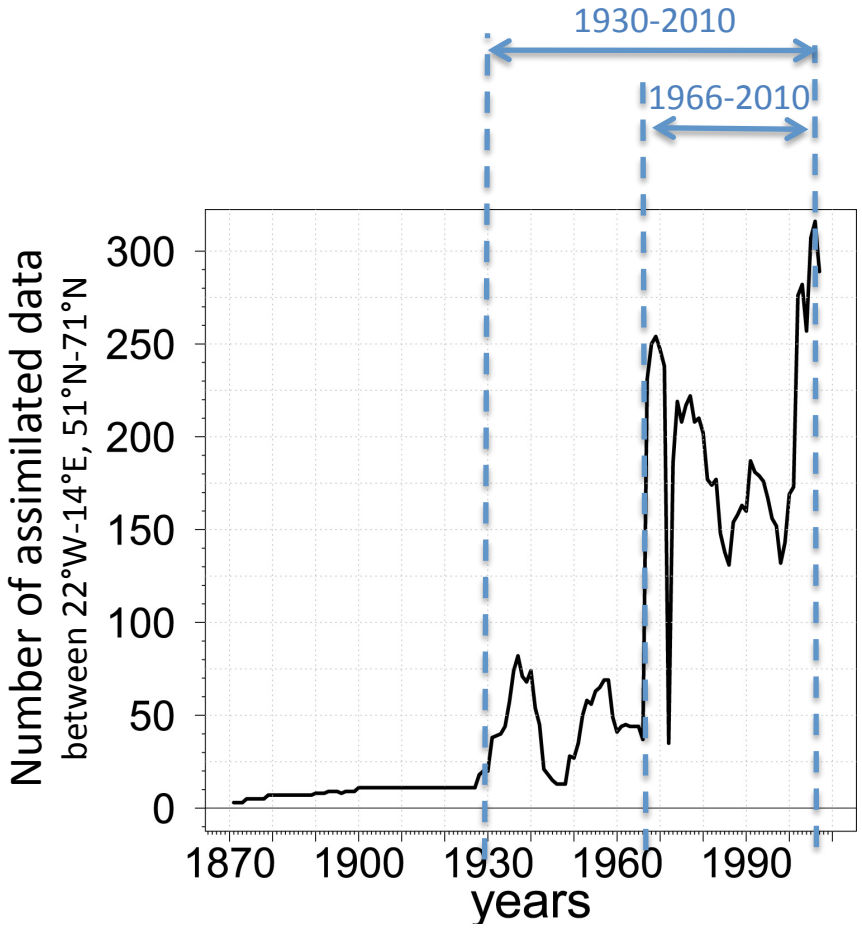
Data and Methods

Data:

- NOAA-CIRES 20CR reanalysis. Both ensemble mean and 56 members.
- HadISST as SST

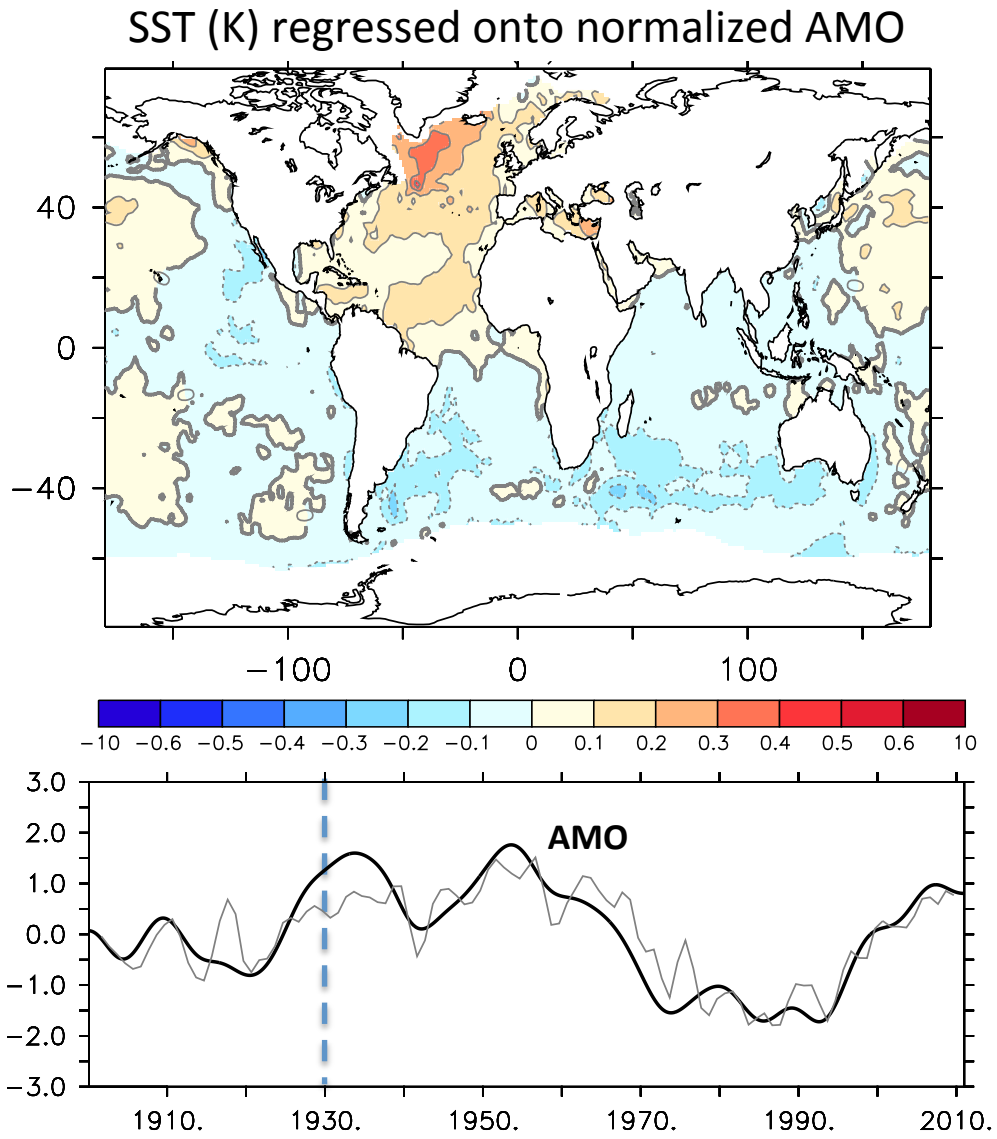
Processing :

- Seasonal three month mean,
- Global warming signal removed from SST by subtracting the regression with Global mean SST,
- Trend removed from atmospheric data,
- Tropical variability subtracted with asymmetric regression using the 3 PC of tropical SST (20S-20N).



Krueger et al., 2013

Multidecadal Variability of North Atlantic SST

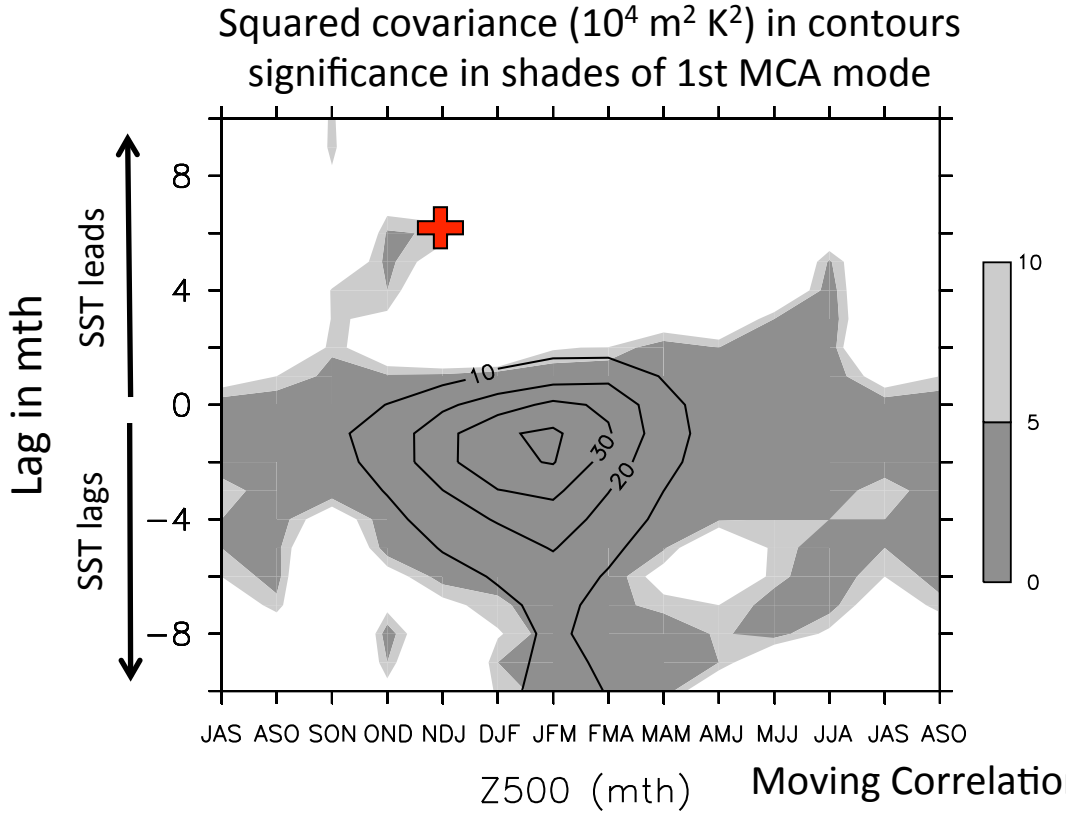


AMO = mean SST over N. Atlantic (75W-7.5E ; 0N-60N) low pass filtered with a 10 yr cutoff

We obtain:

- stong maximum in the subpolar gyre
- anomalies with opposite sign in the S. Atlantic
- Smaller anomalies in the Ind. Pac. Eq.

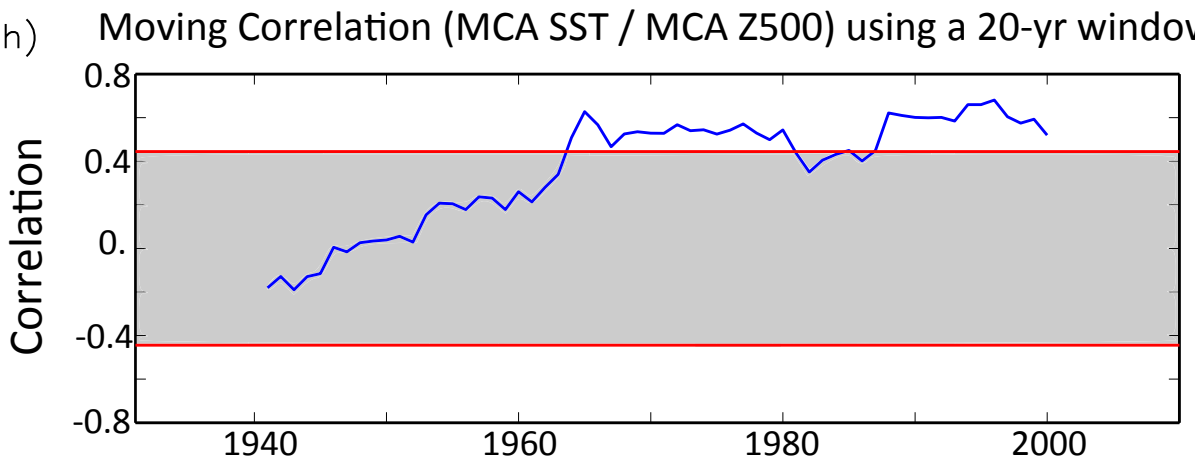
Can we detect the SST influence during the seasonal cycle?



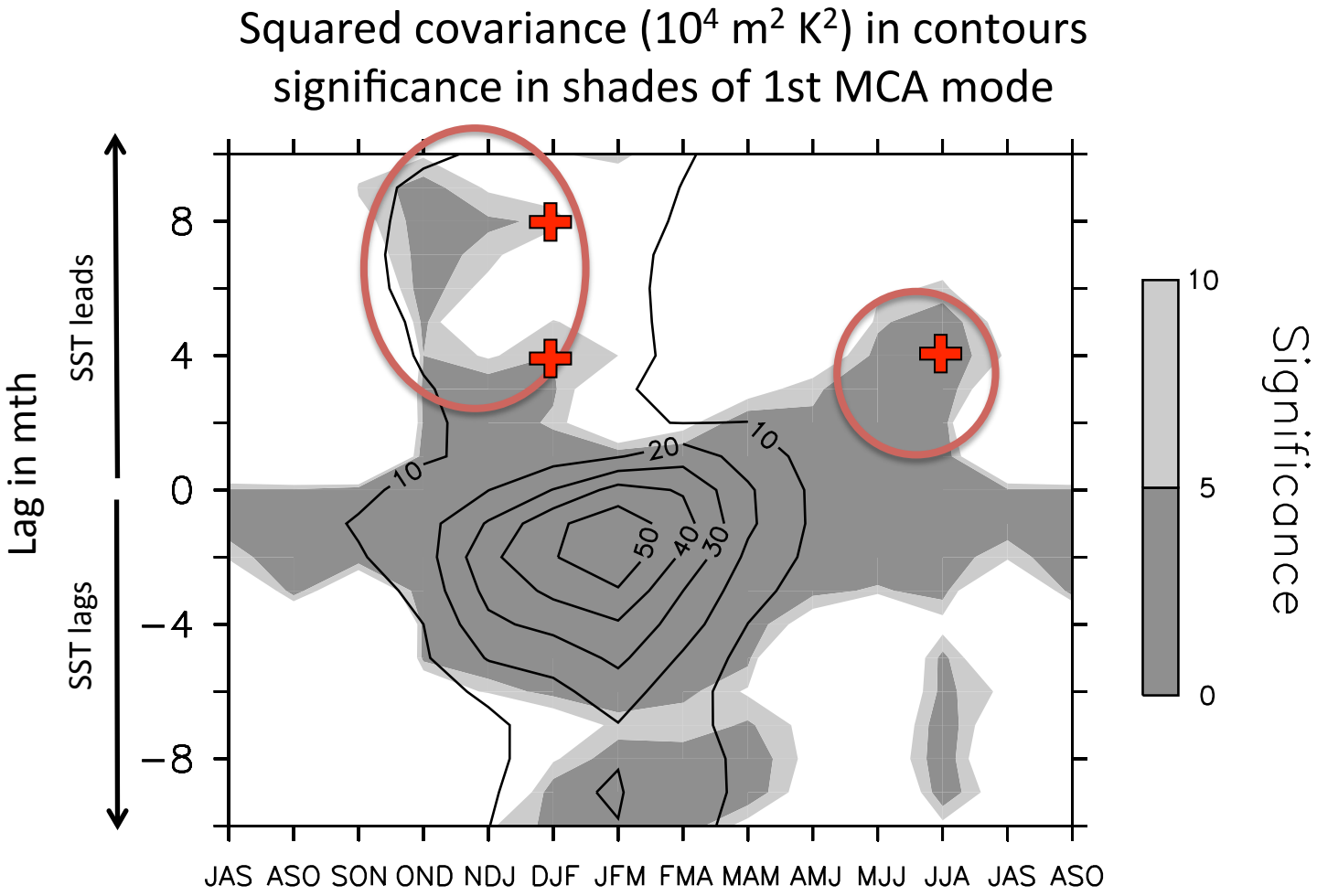
Maximum covariance analysis (MCA) between SST and Z500 (Bretherton et al. 1999).

A significant MCA mode when the SST leads shows the ocean influence onto the atmosphere.

Only the data after 1965 show a large correlation
-> correspond to the number of assimilated data



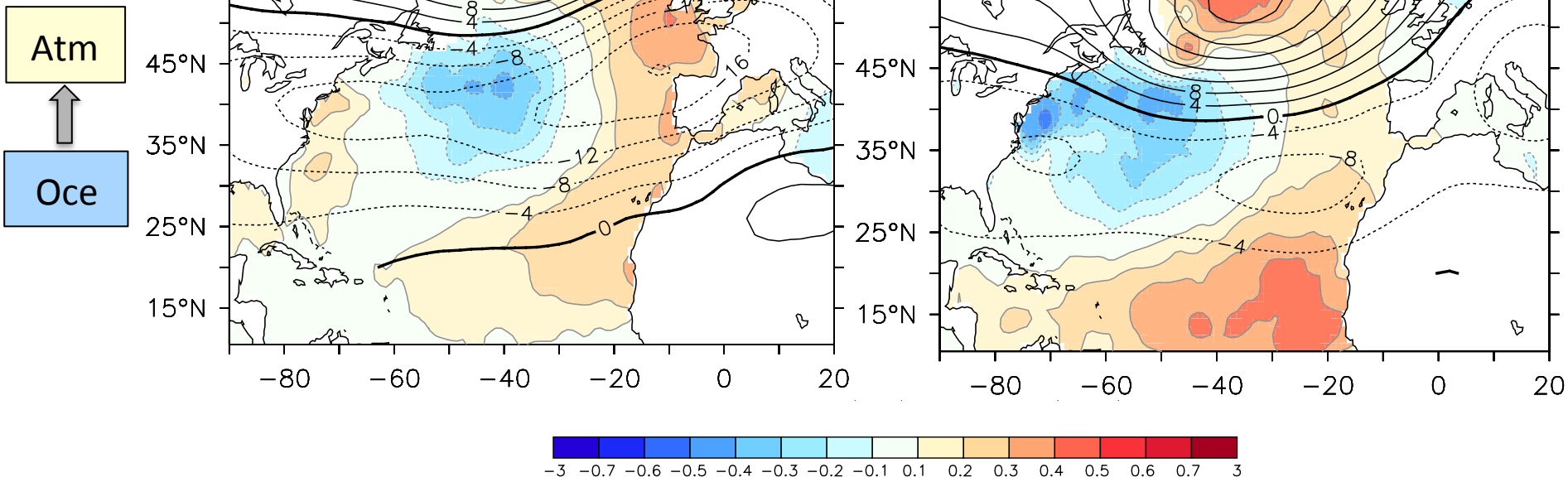
SST influence during the seasonal cycle using 1966-2010



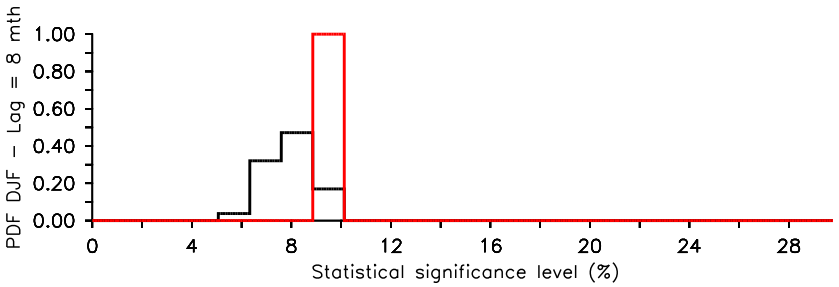
First MCA mode SST-Z500 DJF

SST (K) in SON and Z500 (m) in DJF, lag= 3 mth (SST leads)

SST (K) in AMJ and Z500 (m) in DJF, lag= 8 mth (SST leads)

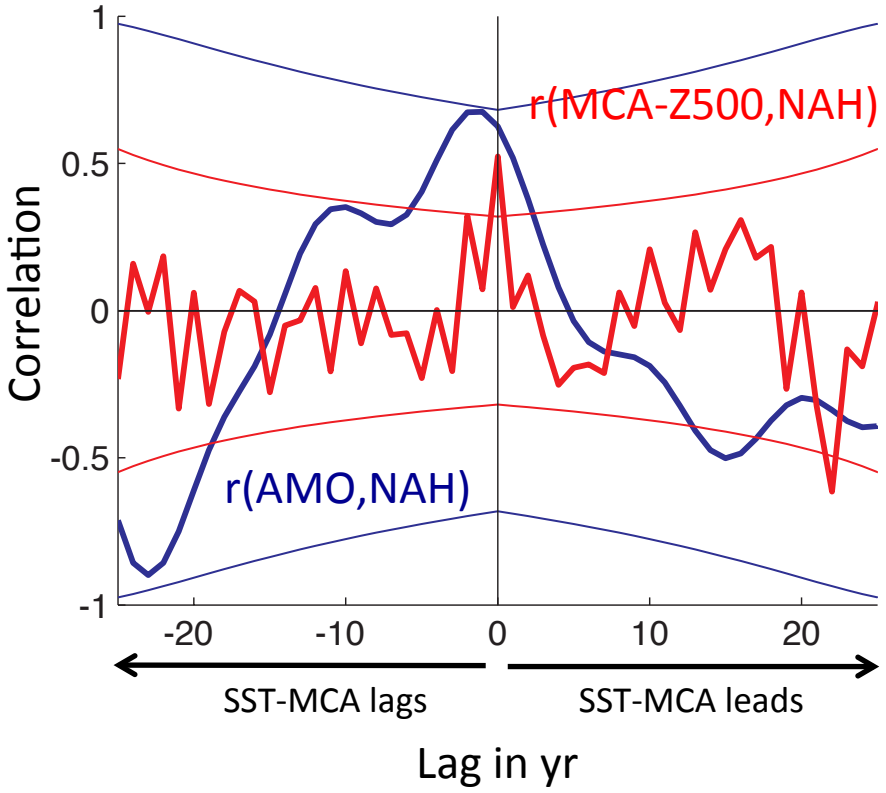


- Similar to OND.
- Note that the significance stay below 10% for SC and R in all ensemble member.

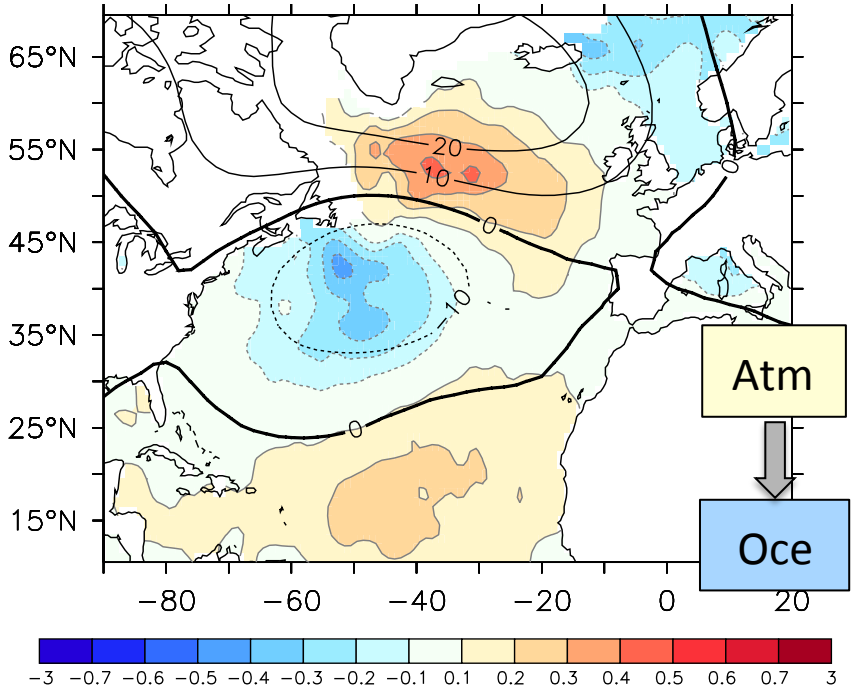


Link between AMO and winter North Atlantic Horseshoe

Correlation between NAH, AMO and Z500-MCA DJF time series



SST (K) in AMJ and Z500 (m) in MAM, lag= -1 mth (SST leads)

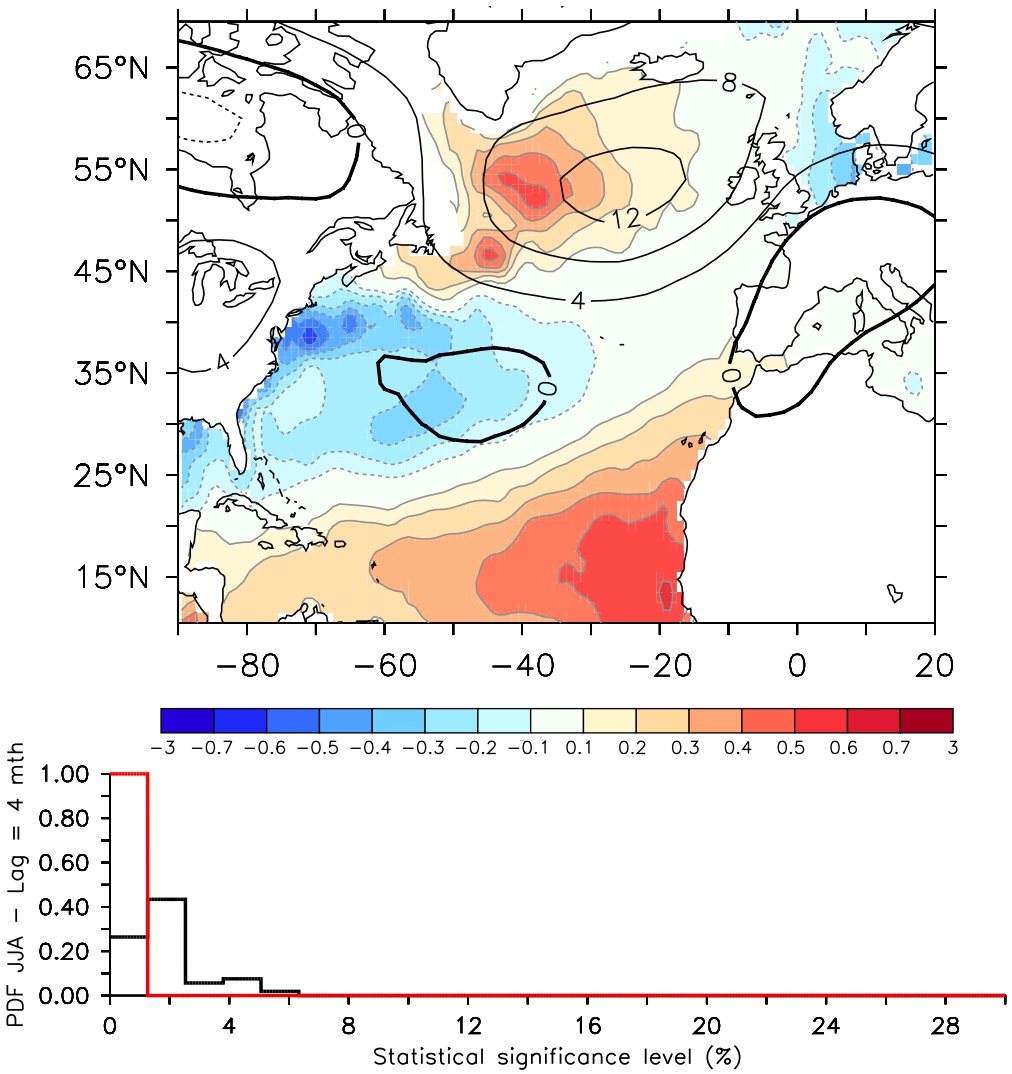


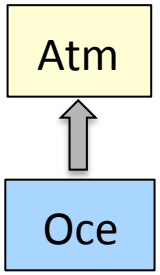
The NAH might be caused by :

- Processes linked to the AMO (AMOC, subpolar gyre variability)
- Atmospheric forcing in spring

Summer SST influence

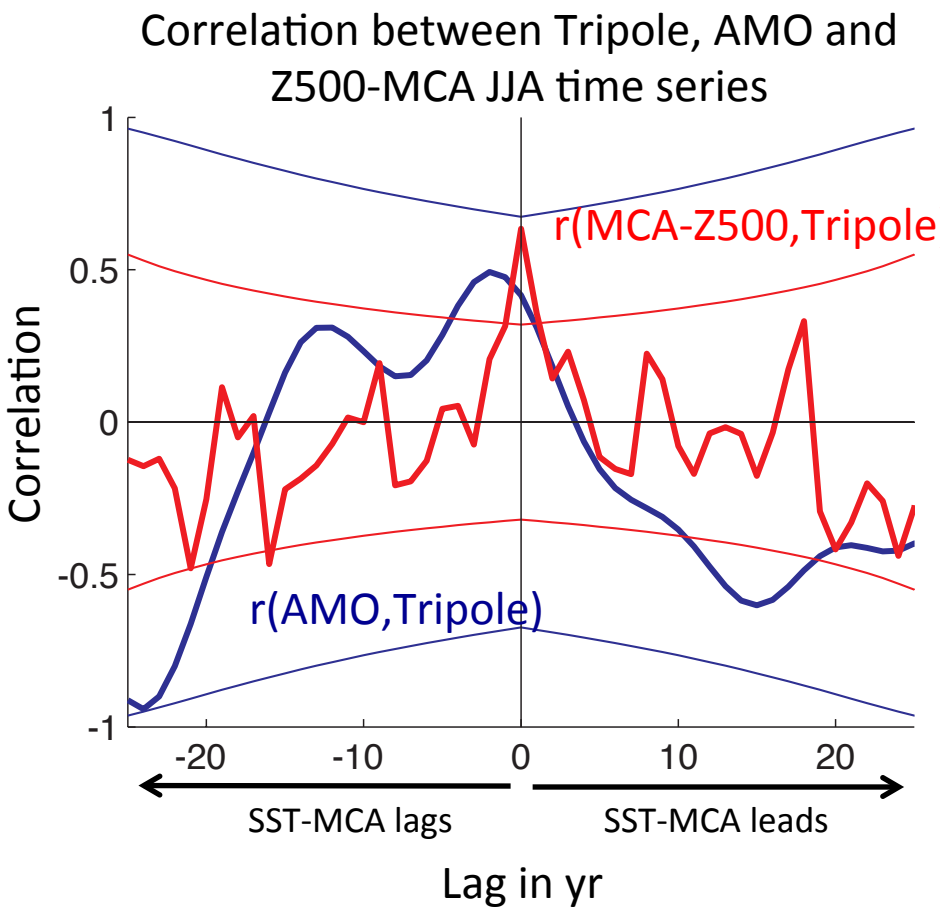
SST (K) in FMA and Z500 (m) in JJA,
lag= 4 mth (SST leads)

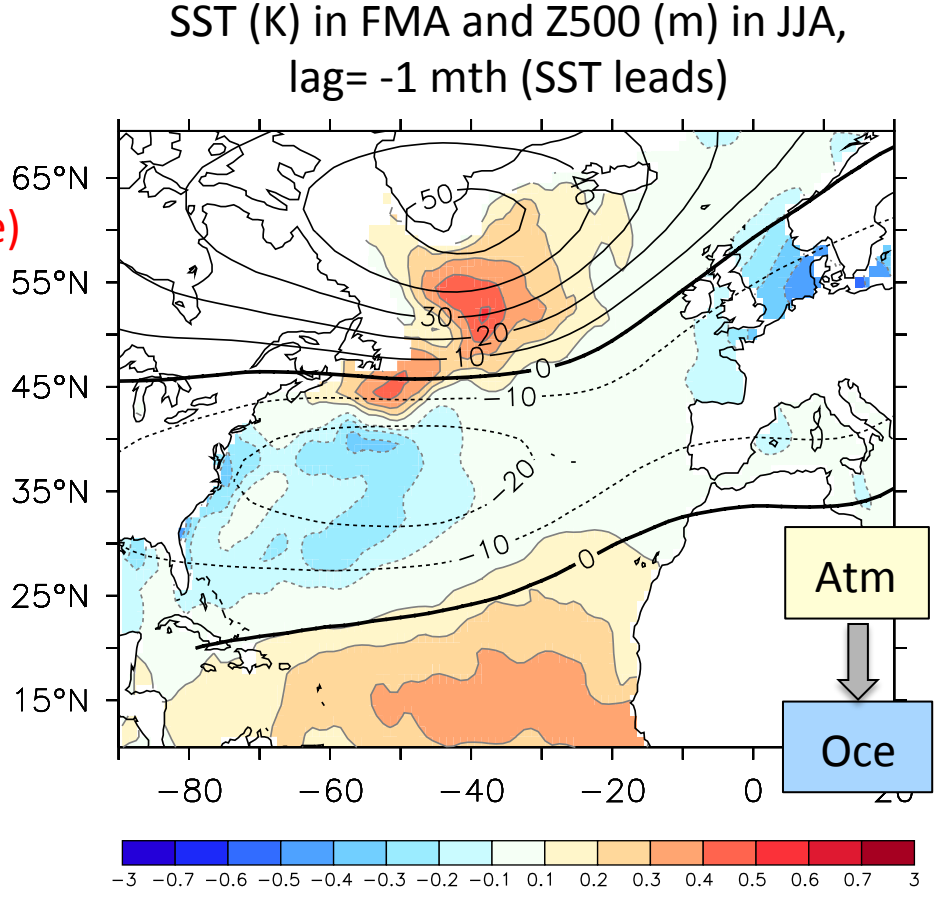




- Weaker pattern, sharing similarities with the summer NAO
- Response robust shown by all ensemble member.

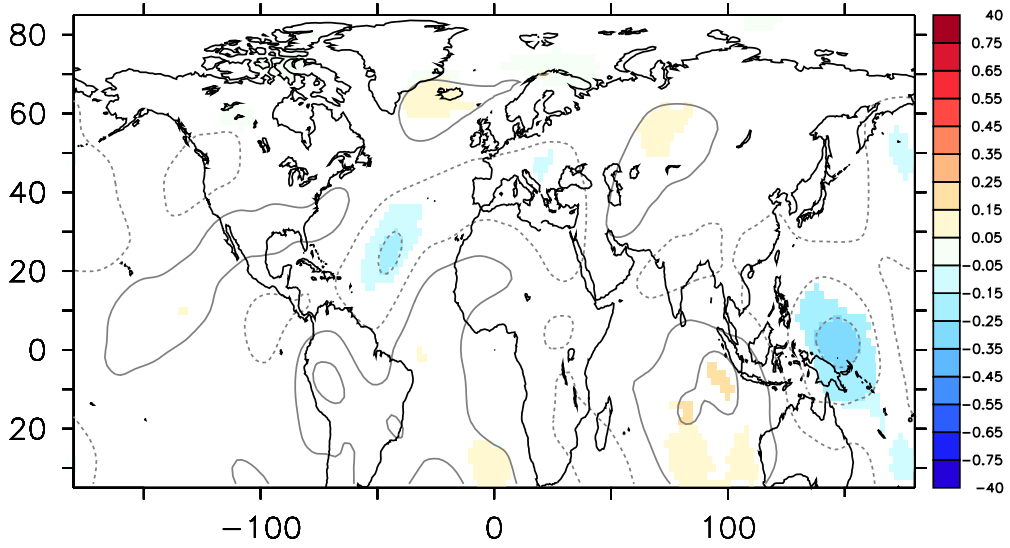
Link between AMO and summer tripole





Tropical influences

Regression φ, in 10^6 m^2 s^{-1}, at 200hPa onto normalized SST-MCA time series in DJF

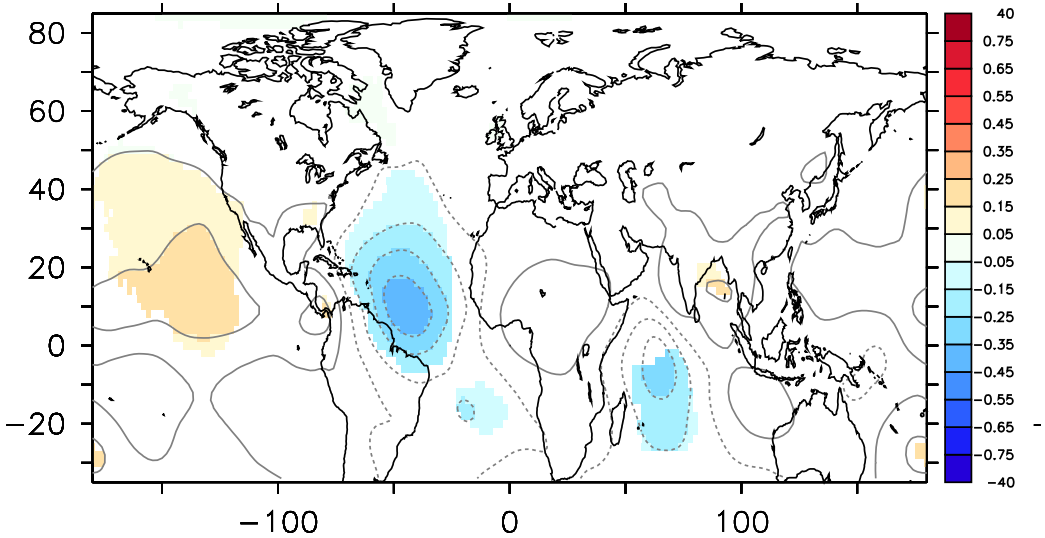


Velocity potential :
$\Delta \varphi = \text{div } \mathbf{u}$

Quantify the large scale tropical circulation.
It have a large effect on the Rossby wave source.

- In DJF some large scale ascent in the Western Pacific Ocean.
- In JJA large scale pattern due to ascending motion over Equatorial Atlantic.

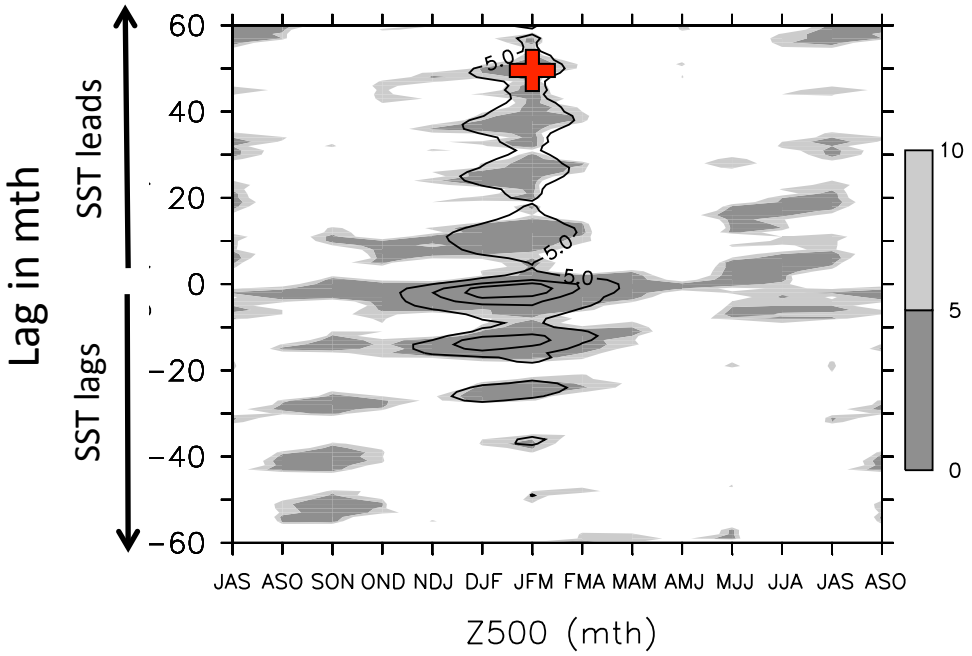
Same for SST-MCA in JJA



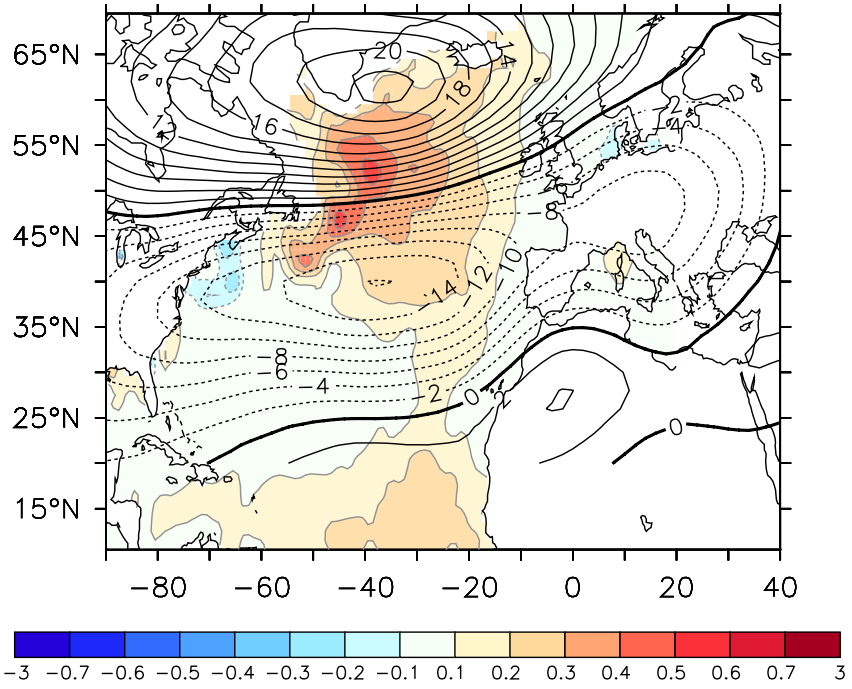
Maximum covariance analysis SST / Z500

- Low pass filter 0.25 0.5 0.25 applied to all seasonal data :
  for example : $Z500_{LPF\text{-}JFM}(n) = 1/4\ Z500_{JFM}(n+1) + 1/2\ Z500_{JFM}(n) + 1/4\ Z500_{JFM}(n-1)$

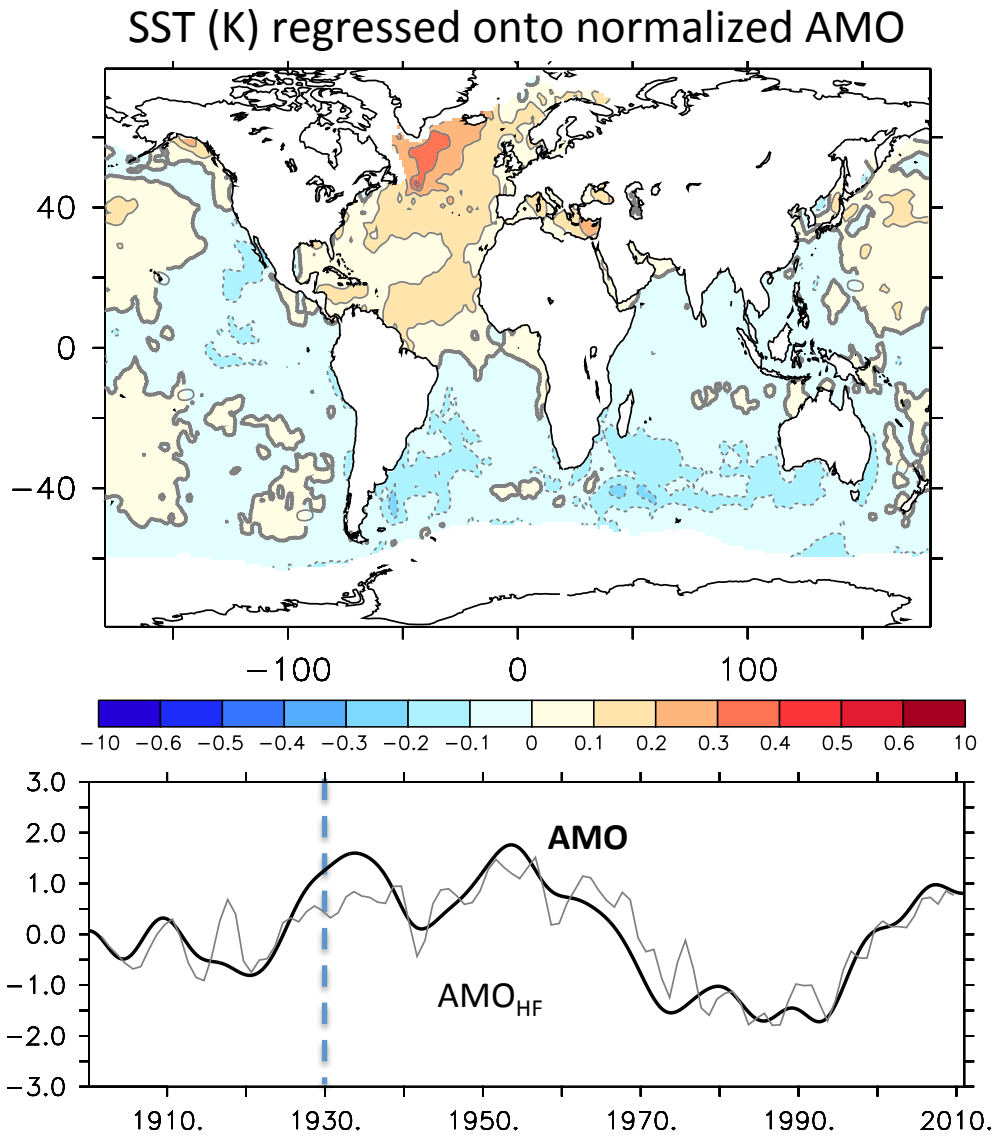
Squared covariance (10^4 m^2 K^2) in contour significance in shades of 1st MCA mode



SST (K) and Z500 (m), JFM, lag=4 yr (SST leads)



Multidecadal Variability of North Atlantic SST

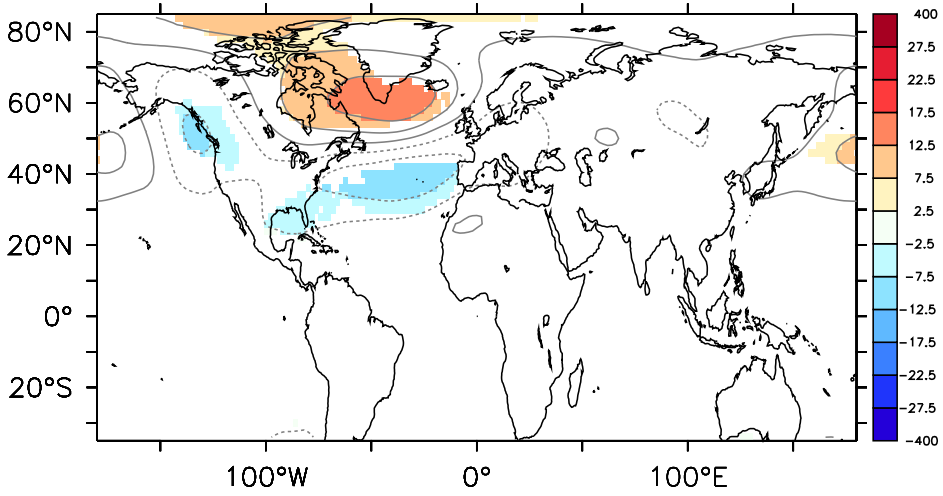


AMO_{HF} = projection the JFM SST onto the AMO structure, and ¼ ½ ¼ filter.

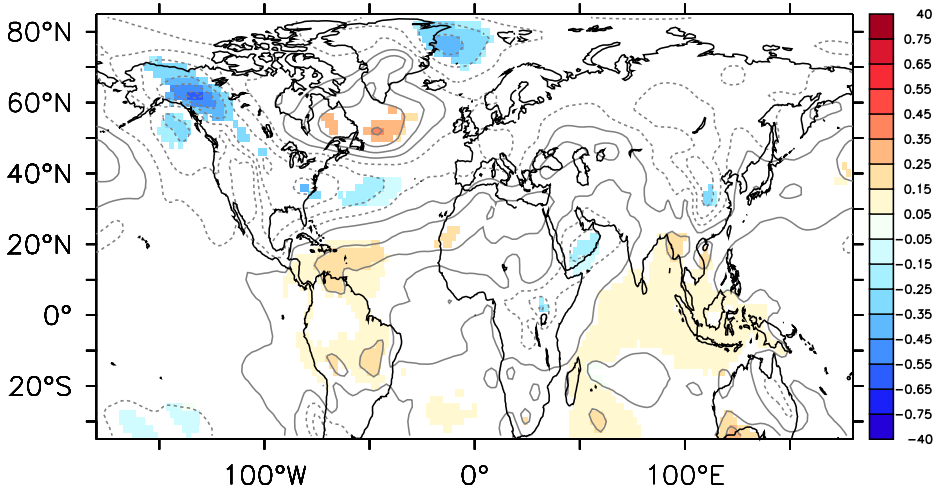
Period considered : 1930-2010

Regression onto AMO_{HF} : JFM

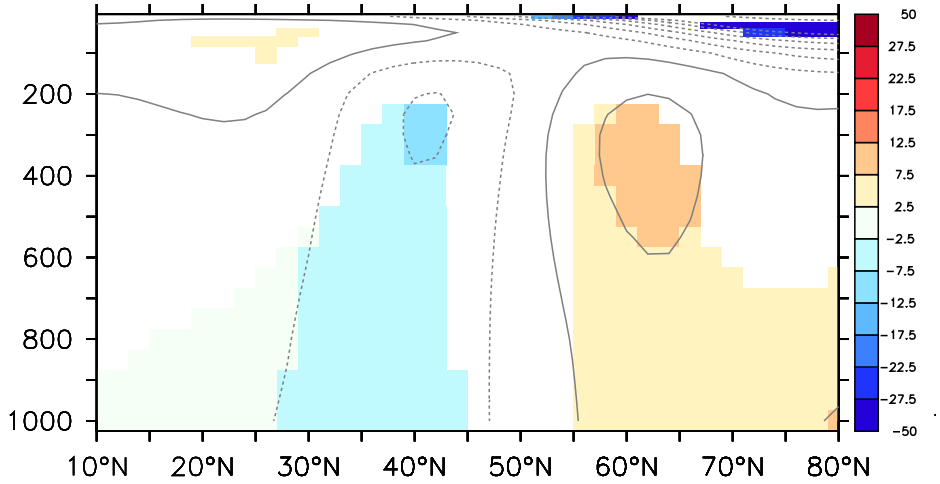
JFM Z500 (m) Lag 4 yr



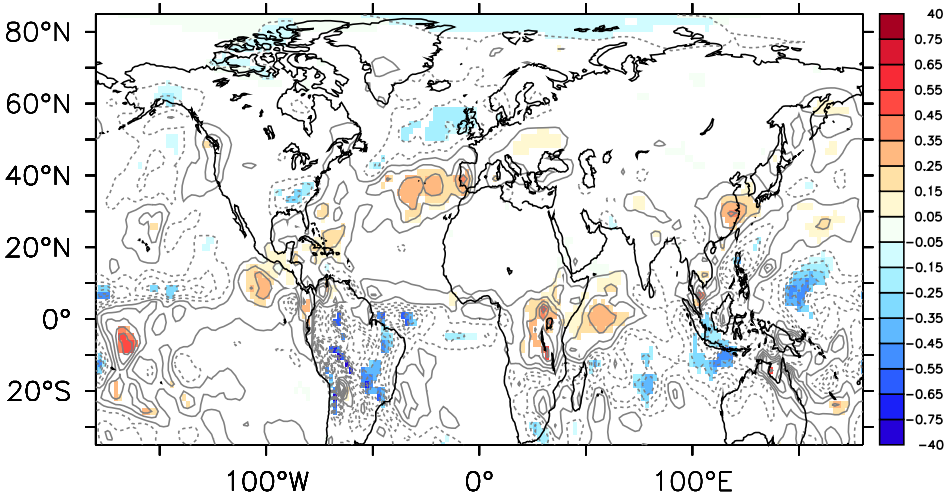
JFM T at 850hPa (K) Lag 4 yr



JFM zonal mean Z (m) N. Atl Lag 4 yr

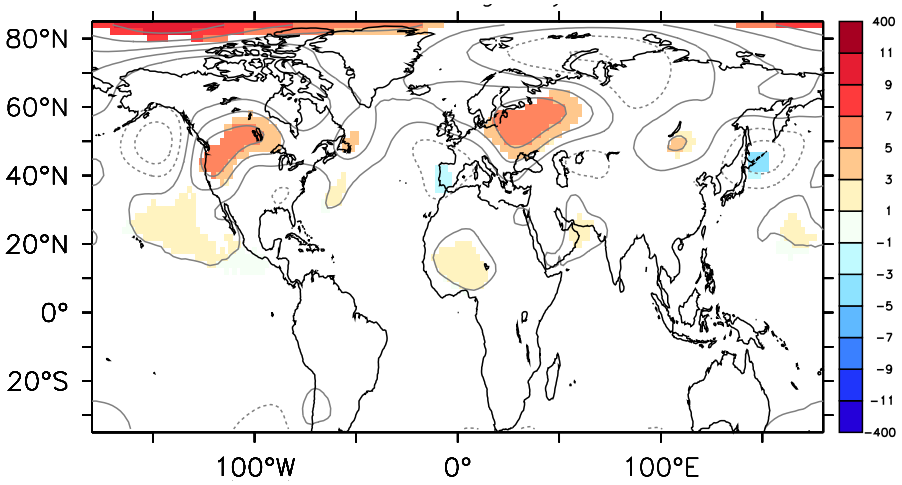


JFM Rainfall (mm d^{-1}) Lag 4 yr

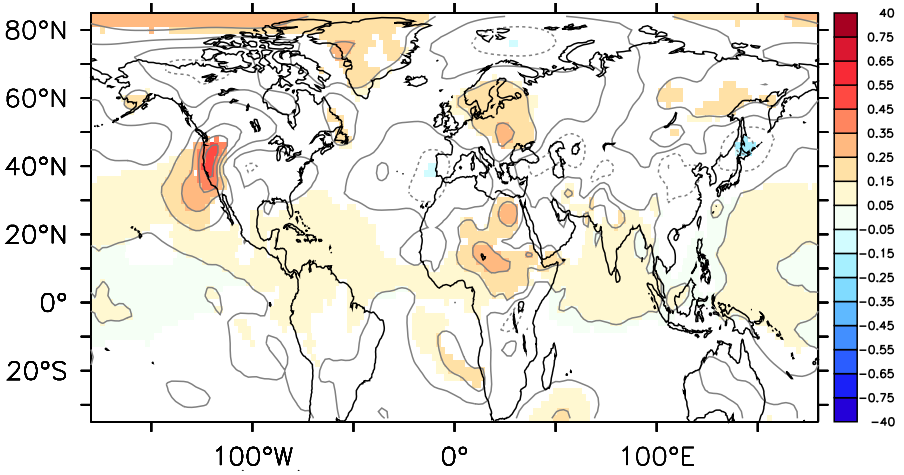


Regression onto AMO_{HF} : JAS

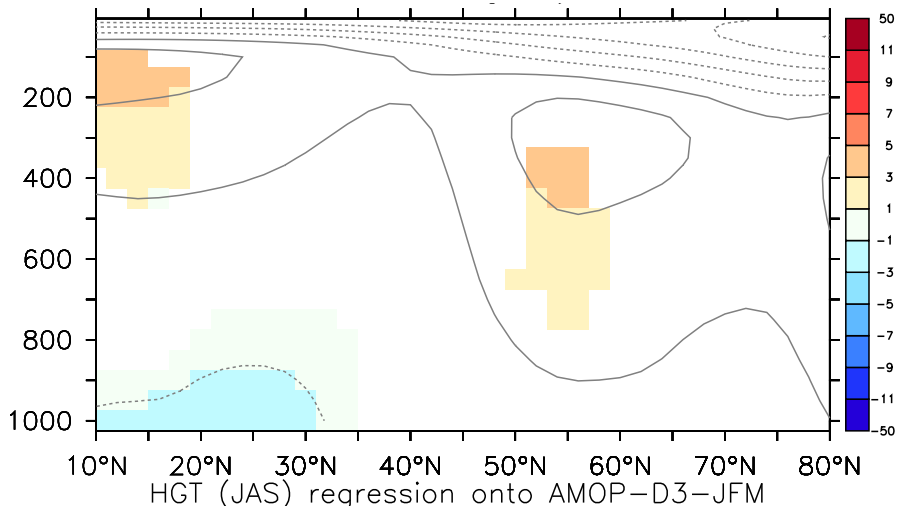
JAS Z500 (m) Lag 0 yr



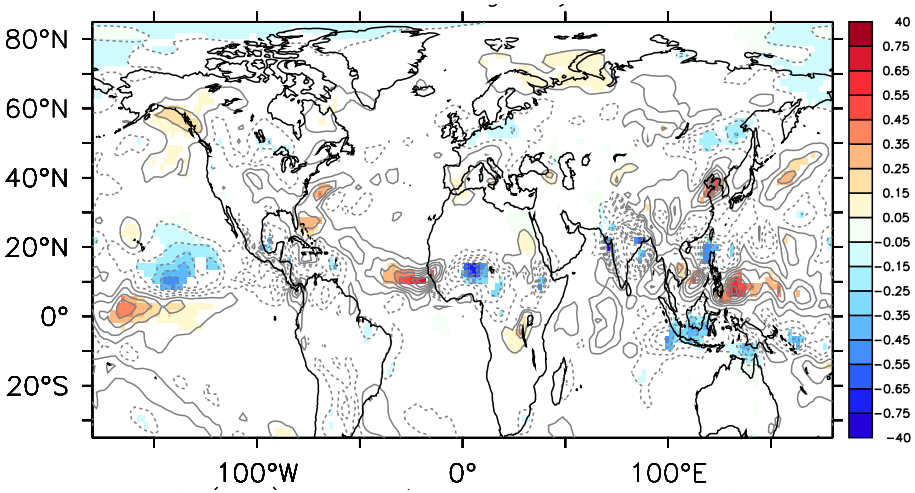
JAS T at 850hPa (K) Lag 0 yr



JAS zonal mean Z (m) N. Atl. Lag 0 yr



JAS Rainfall (mm d^{-1}) Lag 0 yr



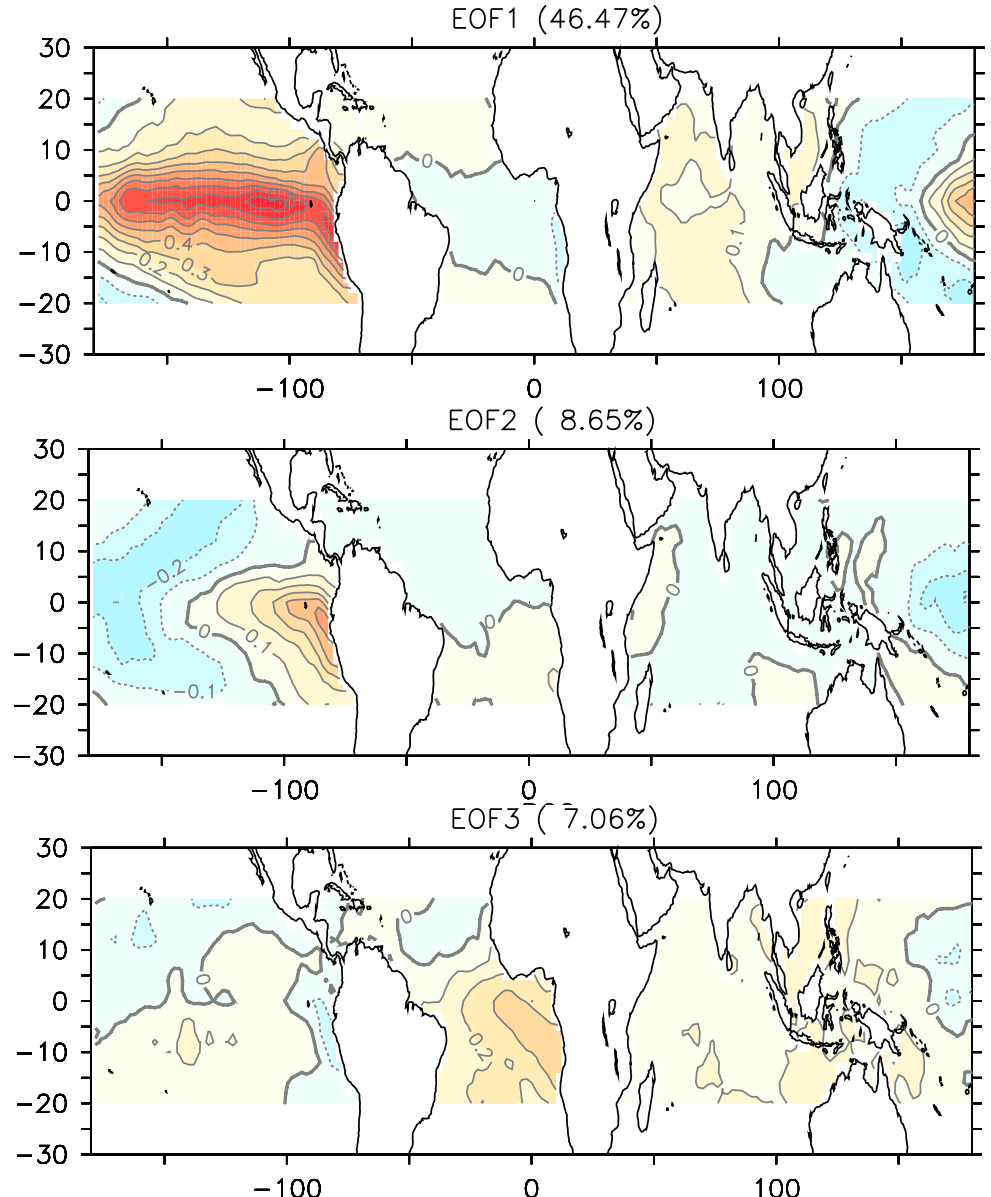
Conclusion

- The AMO seems to be associated *in winter* with the negative NAO. But :
  - > Possible influence of winter midlatitude SST, but role of tropical SSTs need to be clarifed.
  - > The role of the stratosphere variability need also to be clarified (Reichler et al. 2012)

- Mechanism responsible for the SST anomalies preceding the NAO needs also to be investigated.
  - Re-emergence (Cassou et al., 2007) ?
  - Role of ocean dynamics? AMOC (Gastineau and Frankignoul, 2011)?

- The SST seasonal influence in summer is more determined by the atmospheric forcing in winter (as found by Smirnov and Vimont, 2012). Different at lower frequencies.

Tropical SST EOF



Atmospheric tropical influence removed by :

$$X(t) = X(t) - a_{1+}\, PC_{1+}(t) - a_{1-}\, PC_{1-}(t) - a_{2+}\, PC_{2+}(t) - a_{2-}\, PC_{2-}(t) - a_{3+}\, PC_{3+}(t) - a_{3-}\, PC_{3-}(t)$$

Separately for each season