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NATURAL ENVIRONMENT RESEARCH COUNCIL

Capturing shifts of the Atlantic multi-decadal variability in the Met Office Decadal Prediction System

Jon Robson

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Thanks to Rowan Sutton and Doug Smith

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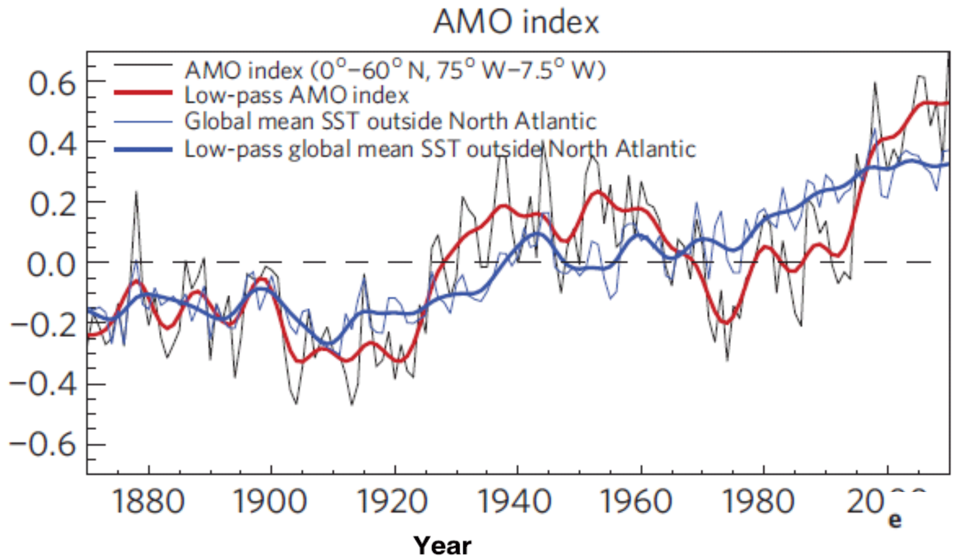
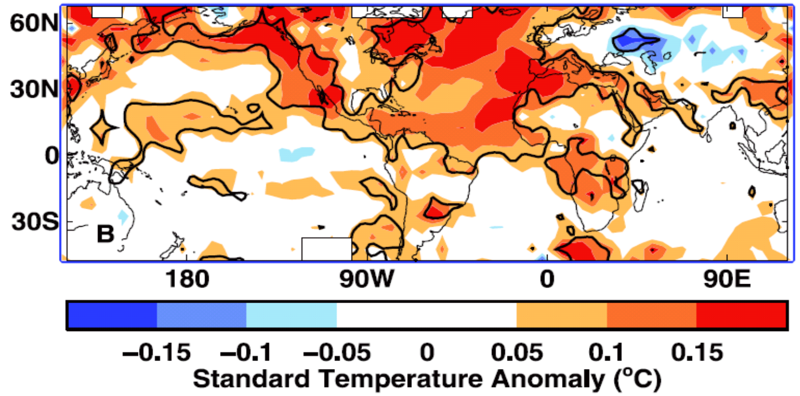
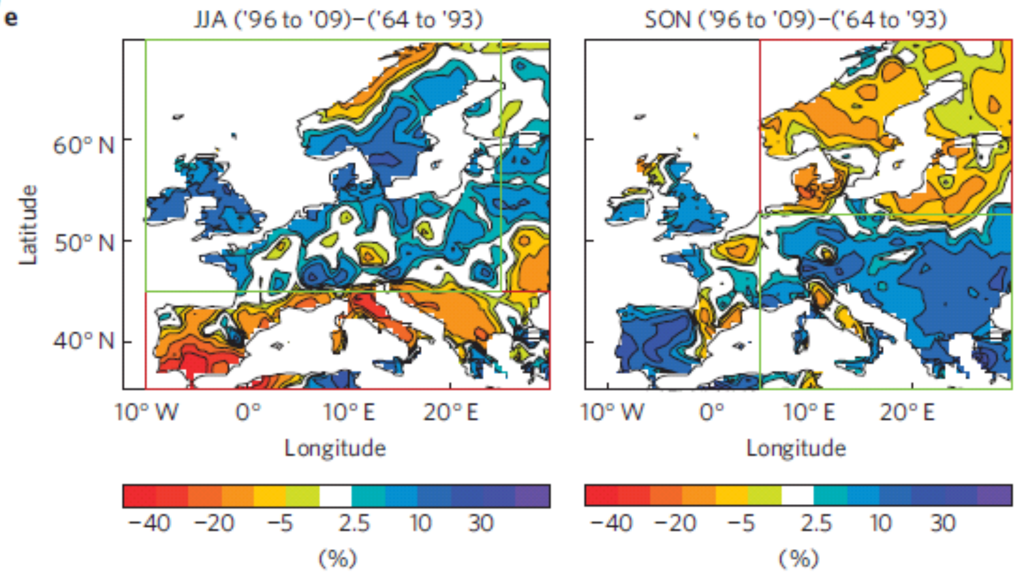
Atlantic Multidecadal Variability (AMV) and its climate impacts





Knight et al, 2005

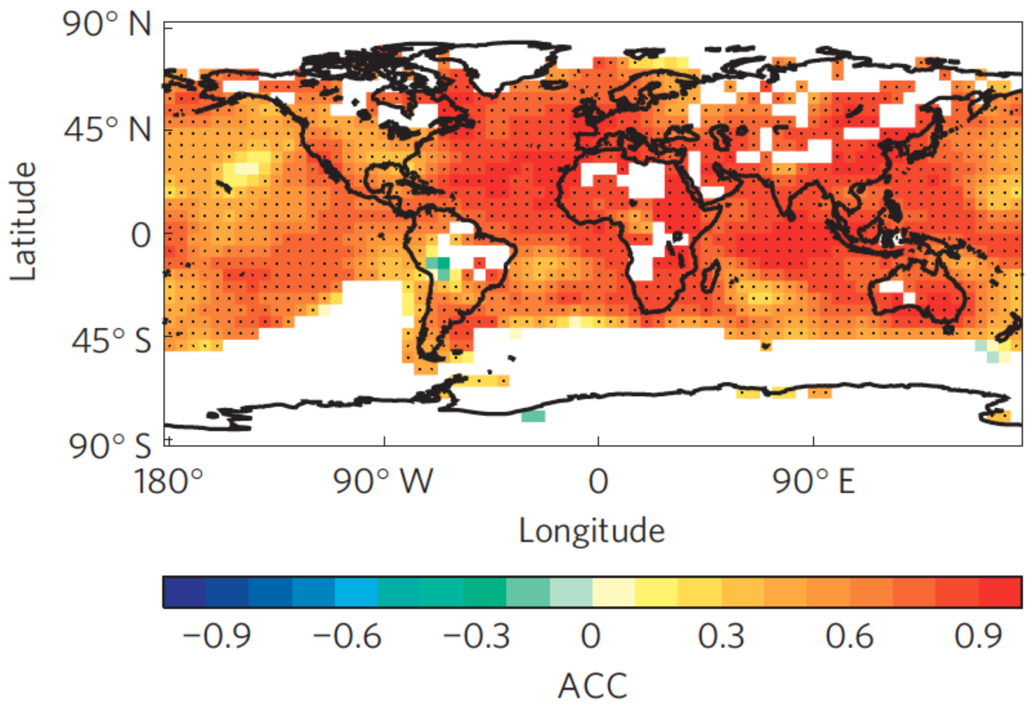
Evidence that North Atlantic SSTs can affect the surface climate across the Americas, Europe and Africa



Sutton and Dong, 2012

Is there skill in decadal predictions?

JJASON Temp Yrs 1-5 (DePreSys)



(from Smith et al, 2010)

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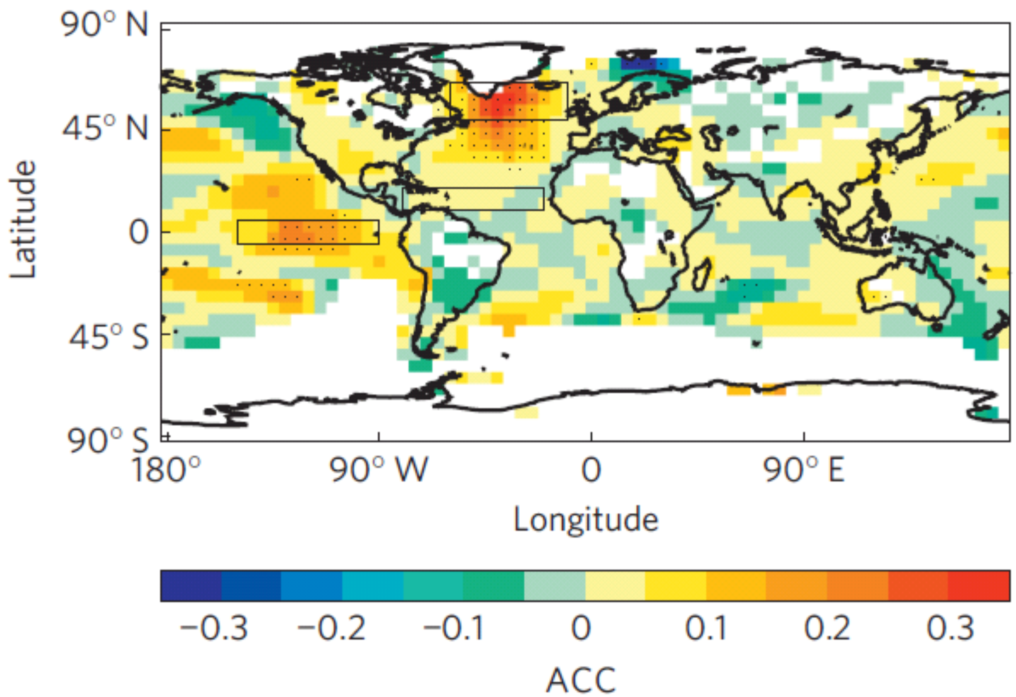

(from Smith et al, 2010)

- Only skill in a few regions
  - Mainly in the North Atlantic – Why?
  - Is the skill just persistence?
- Also, there is much less evidence for initialisation improving predictions over land **– A surprise?**

AMV shifts: case studies for prediction

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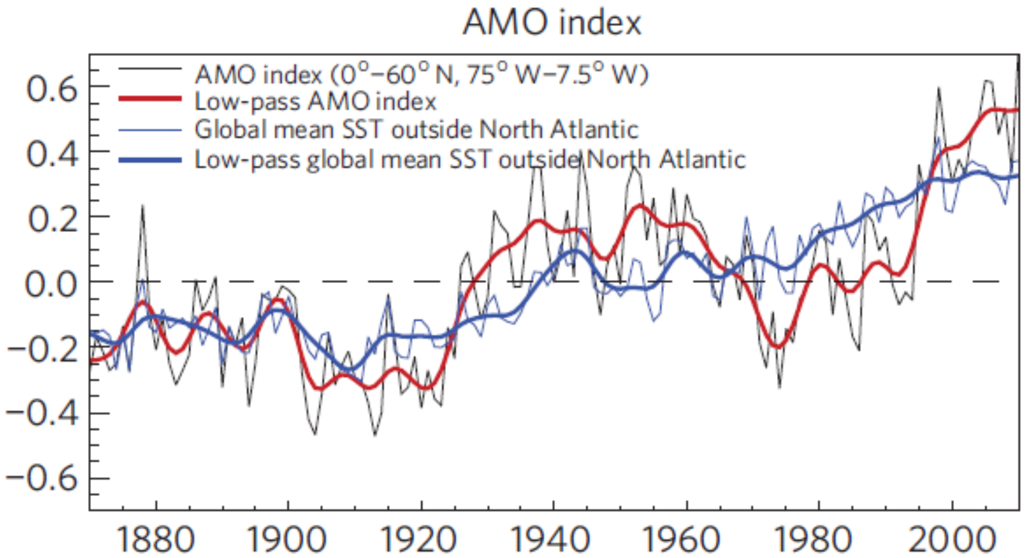
- We have focused on understanding the observed shifts in Atlantic SST



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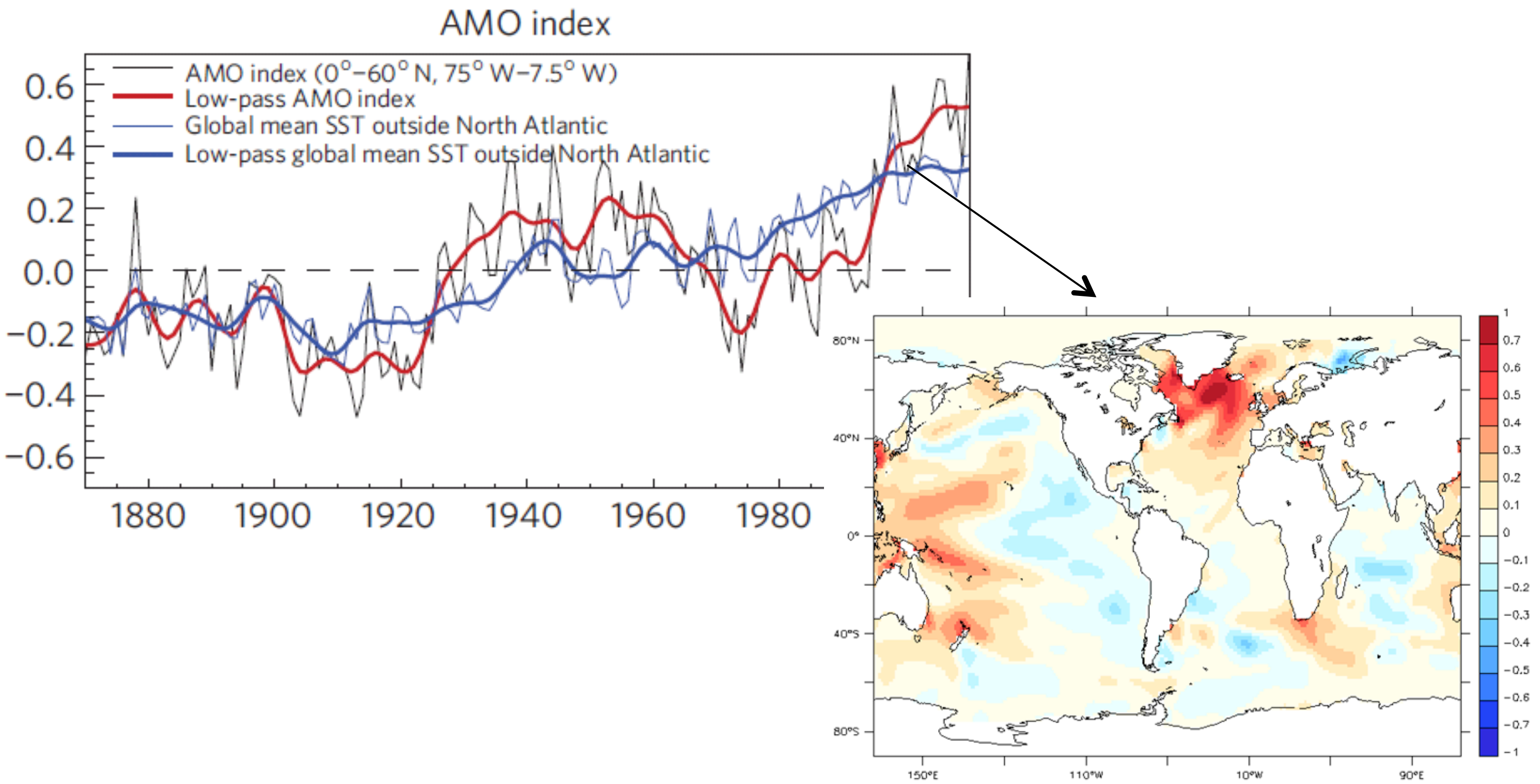

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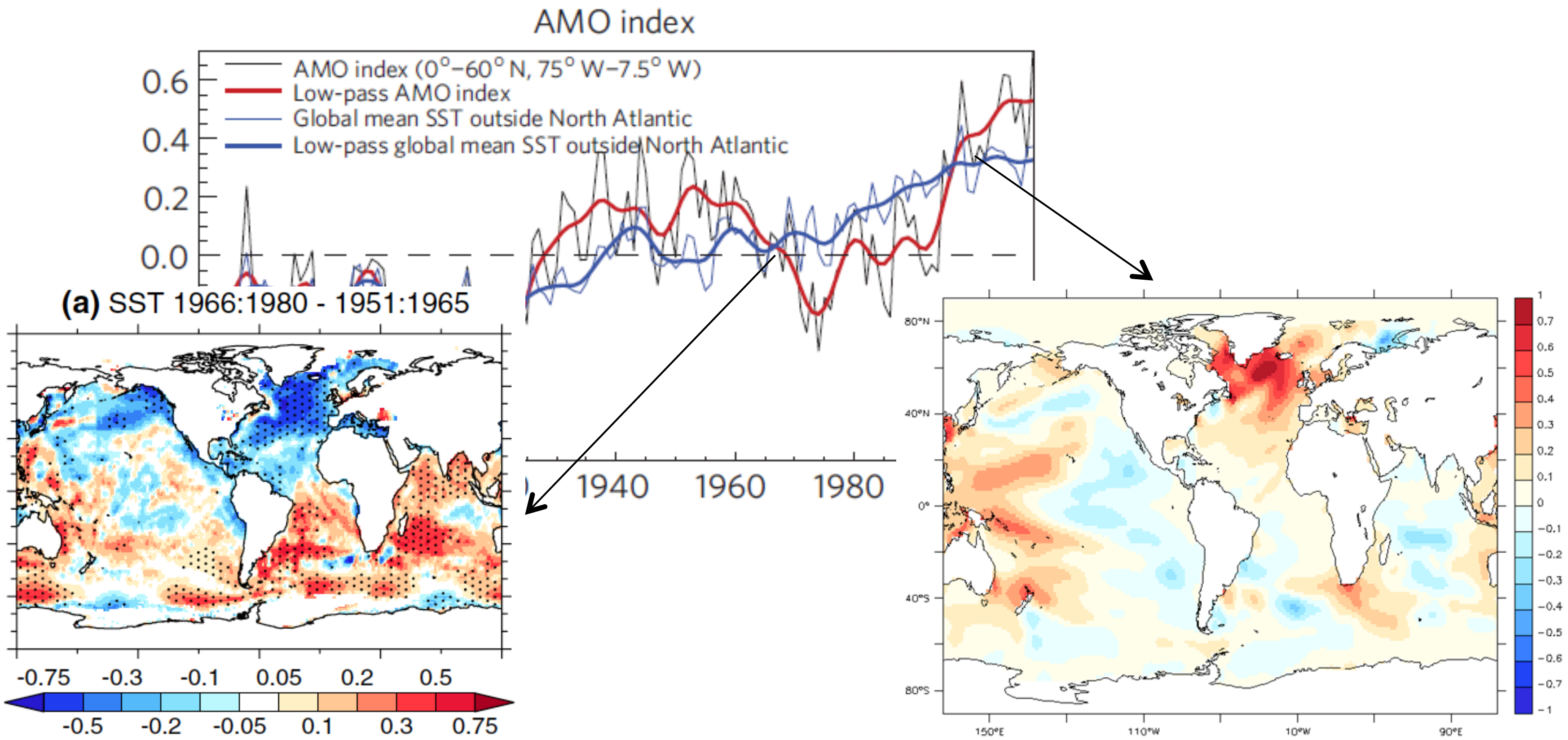

Were these events predictable?
Why?

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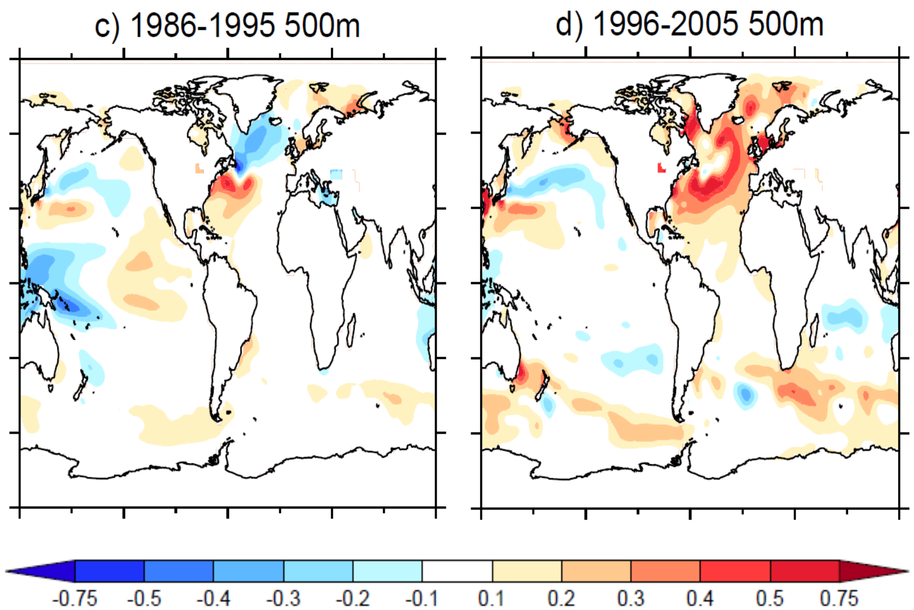
Experiments and data

- We will be looking at predictions made with DePreSys PPE
  - Based on HadCM3 (1.25° Ocean, 3.75 x 2.5° Atmosphere)
  - 9 member perturbed physics ensemble
  - Uses **anomaly assimilation** for 3D ocean T, and S, and atmospheric U,V,T and MSLP
  - Hindcasts start every November between 1960-2005
  - Forced with historical anthropogenic, and projected natural forcings
- Comparison ensemble that does not assimilate observed information (NoAssim PPE)
- Compare the predictions with observations
  - Met Office ocean analysis
  - HadISST
  - CRU TS 3.0
  - HadSLP

Mid 1990s North Atlantic warming



- Model experiments suggest warming was largely due to ocean heat transport changes
- **A lagged response of the buoyancy forced circulation** to the positive NAO that peaked in the late 1980s and early 1990

See Robson et al, 2012a,b; Yeager et al, 2012

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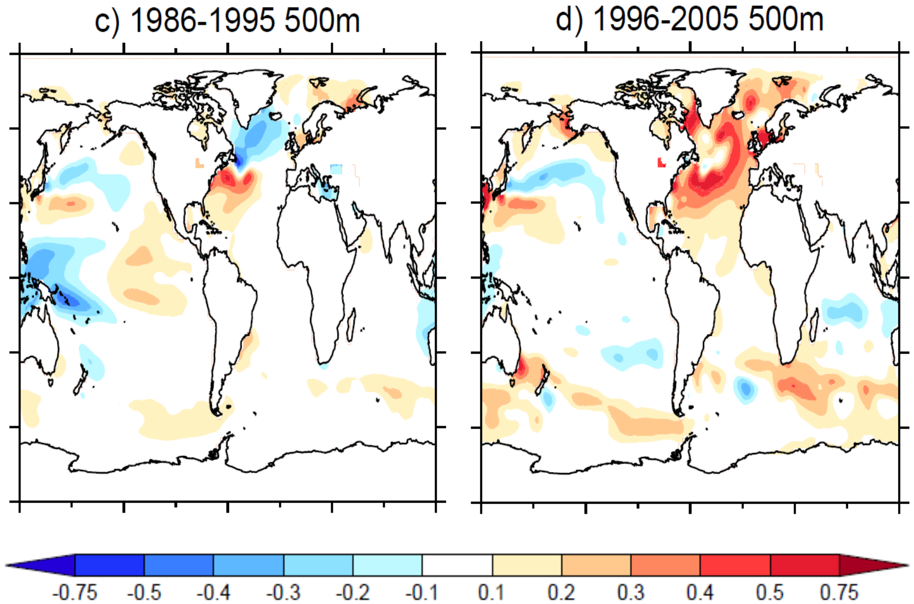

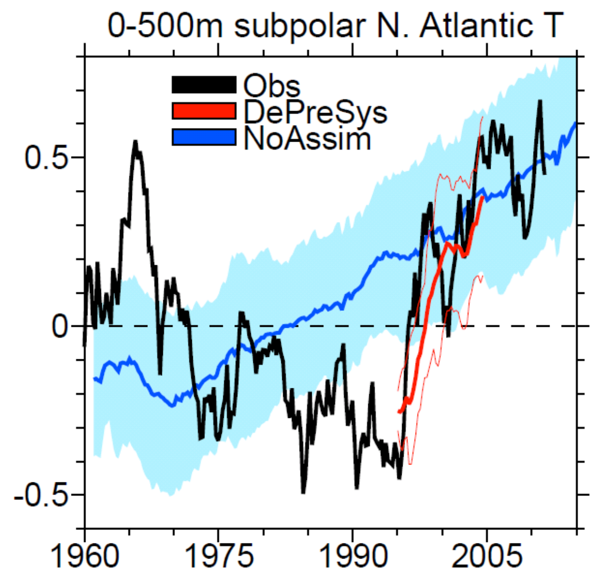

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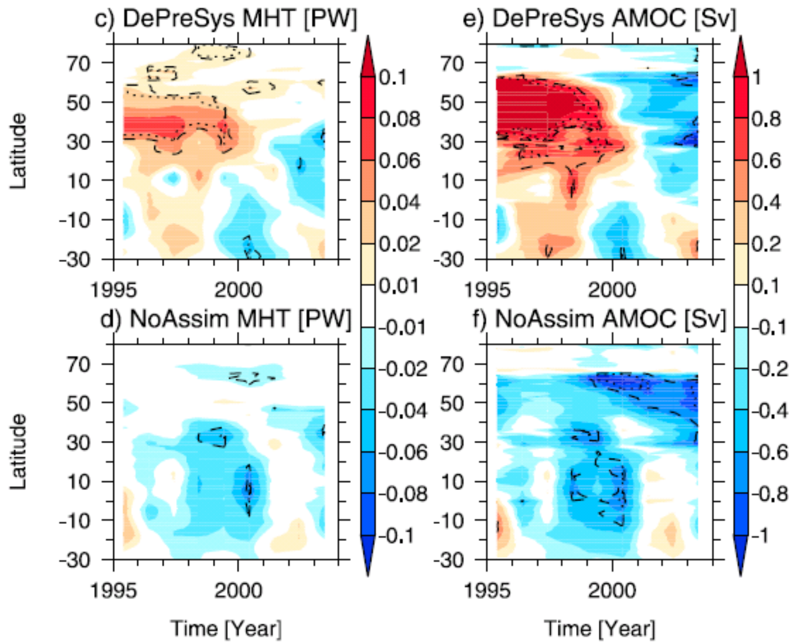

What about the climate impact?

- There are problems for examining the skill of surface variables
  - Initial shocks and biases
  - Limited number of hindcasts & ensemble members. i.e. signal to noise
- **Is there an impact of initialisation in DePreSys?**

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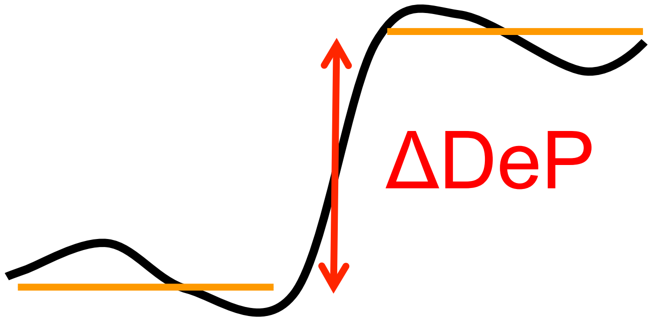

- Compare anomalies from many predictions made before and after the warming event
  - No need to define a climatological period, or remove mean bias

What about the climate impact?

- There are problems for examining the skill of surface variables
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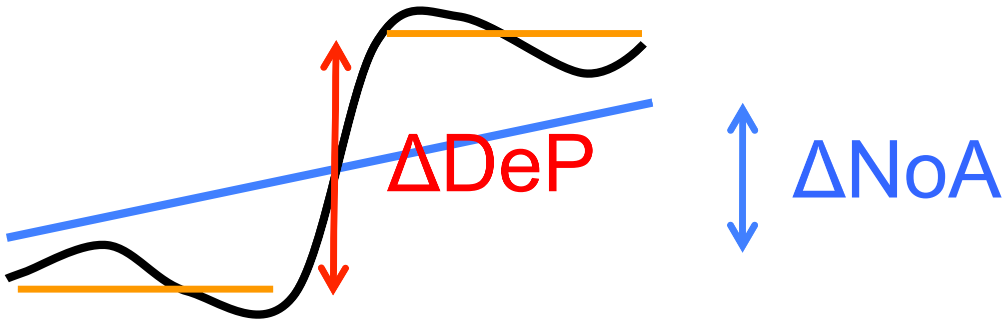
- Is there an impact of initialisation in DePreSys?

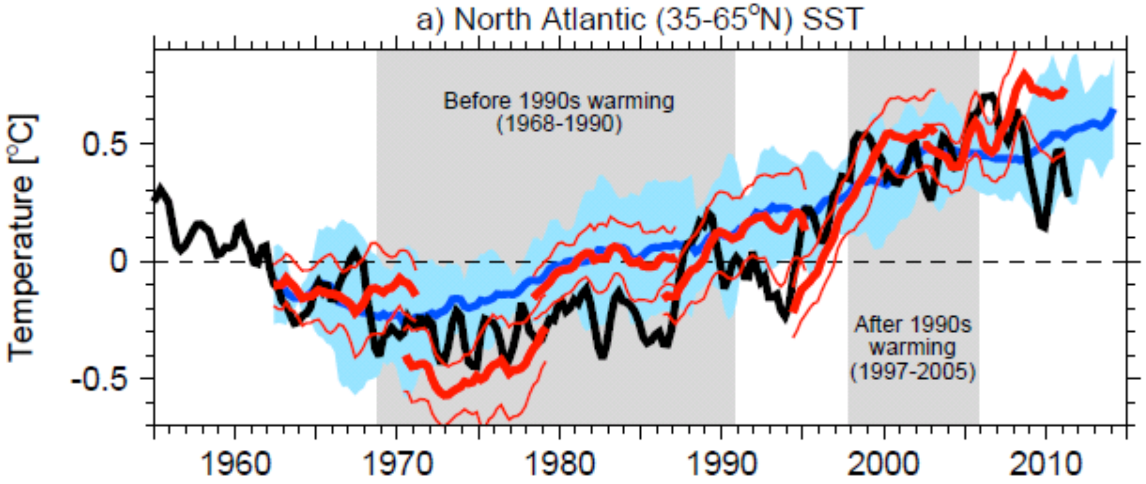


Examining difference relative to NoAssim removes forced trend

Impact of initialisation = ΔDeP – ΔNoA

Focus on years 2-6, comparing with detrended observations

Predictions of SST



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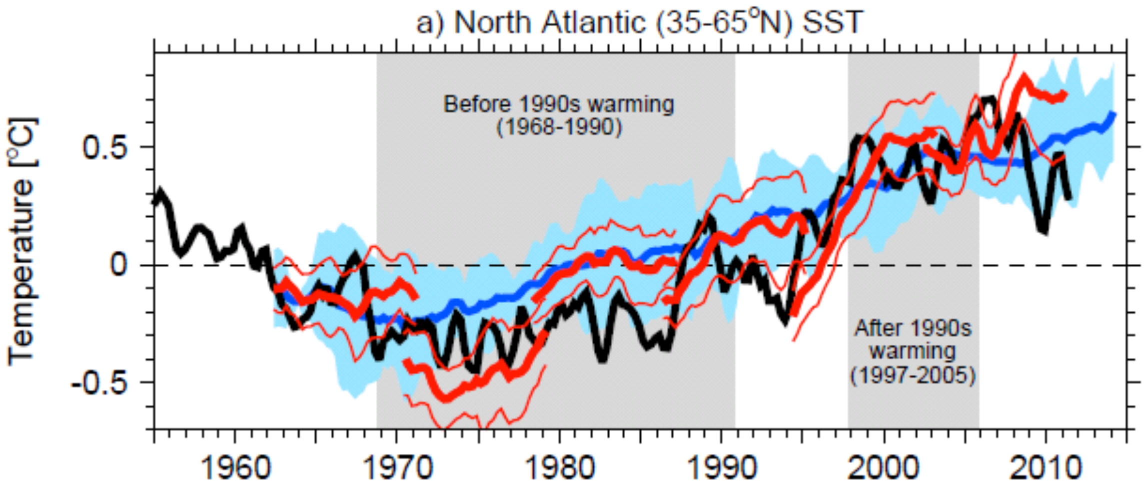

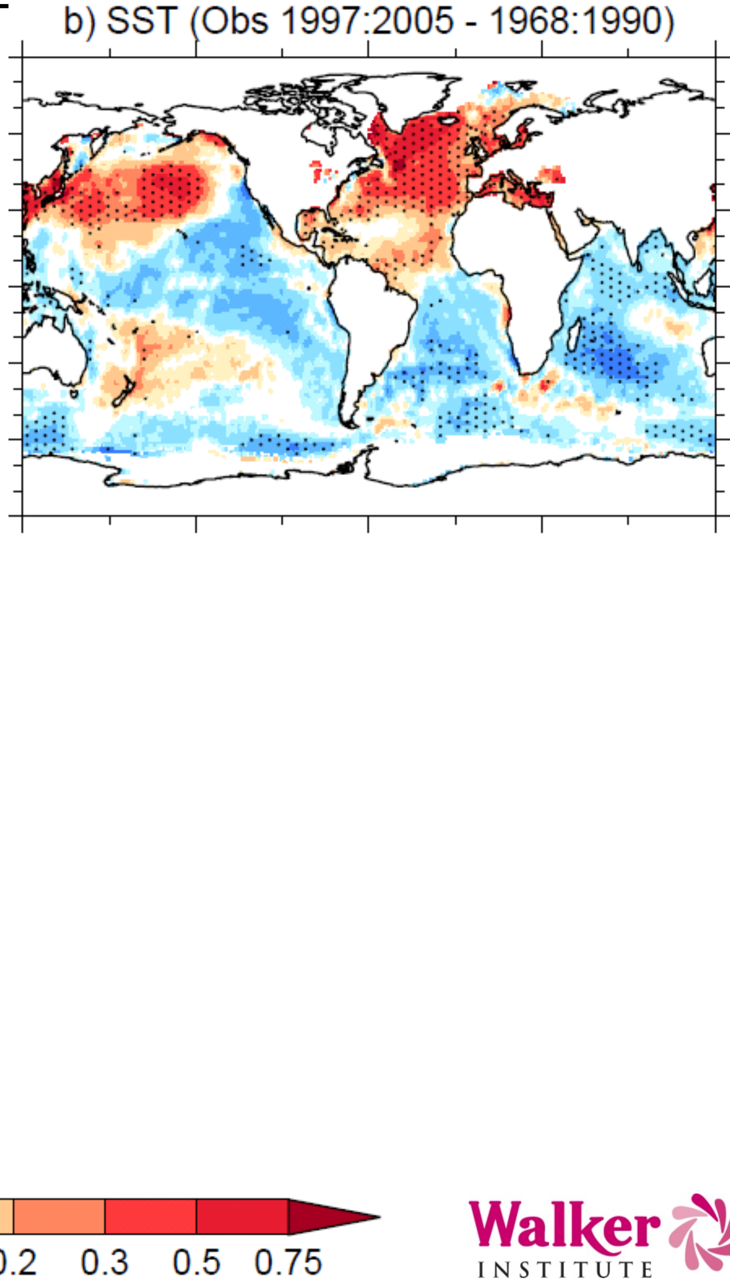

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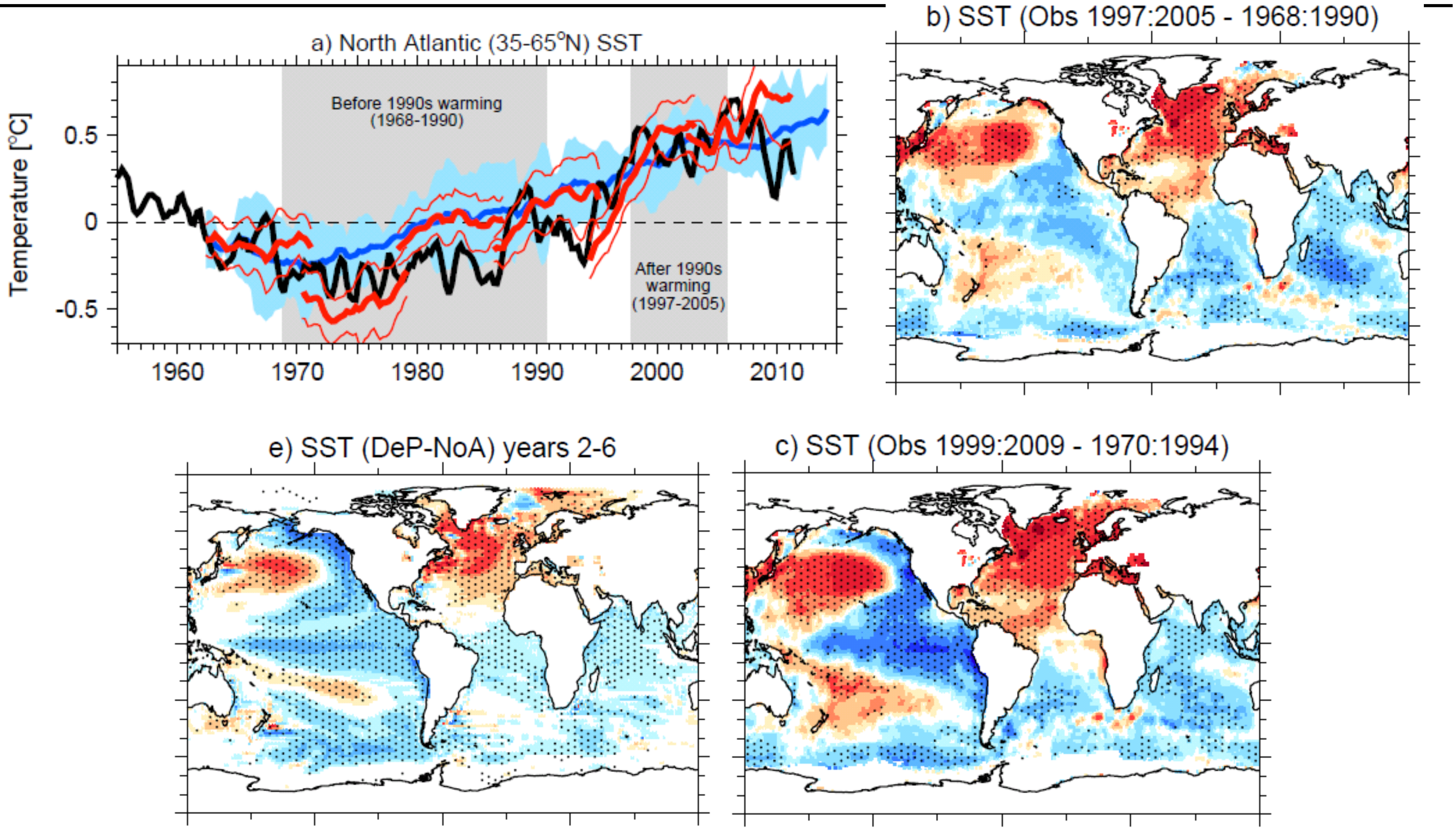
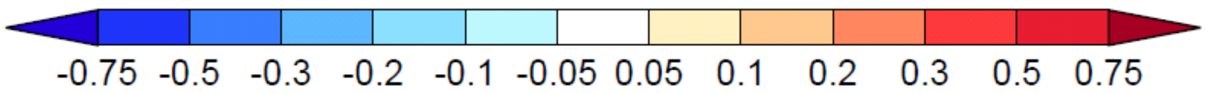




Surface climate - MAM

<u>Model</u>

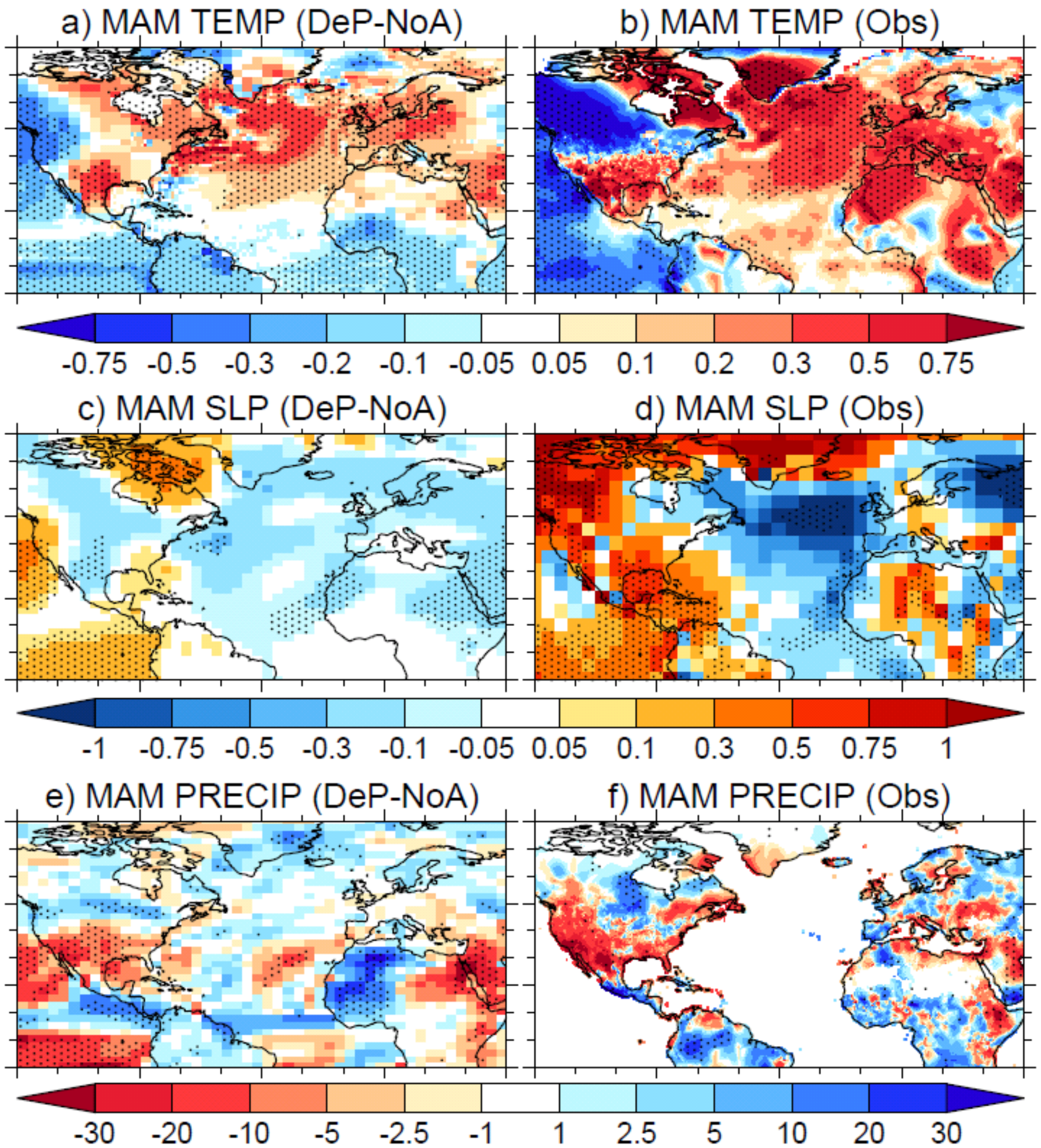
(97-05) – (68-90)

Years 2-6

<u>Obs</u>

(99-09) – (70-94)

Robson et al, 2013



^oC

hPa

% of the mean

Surface climate - JJA

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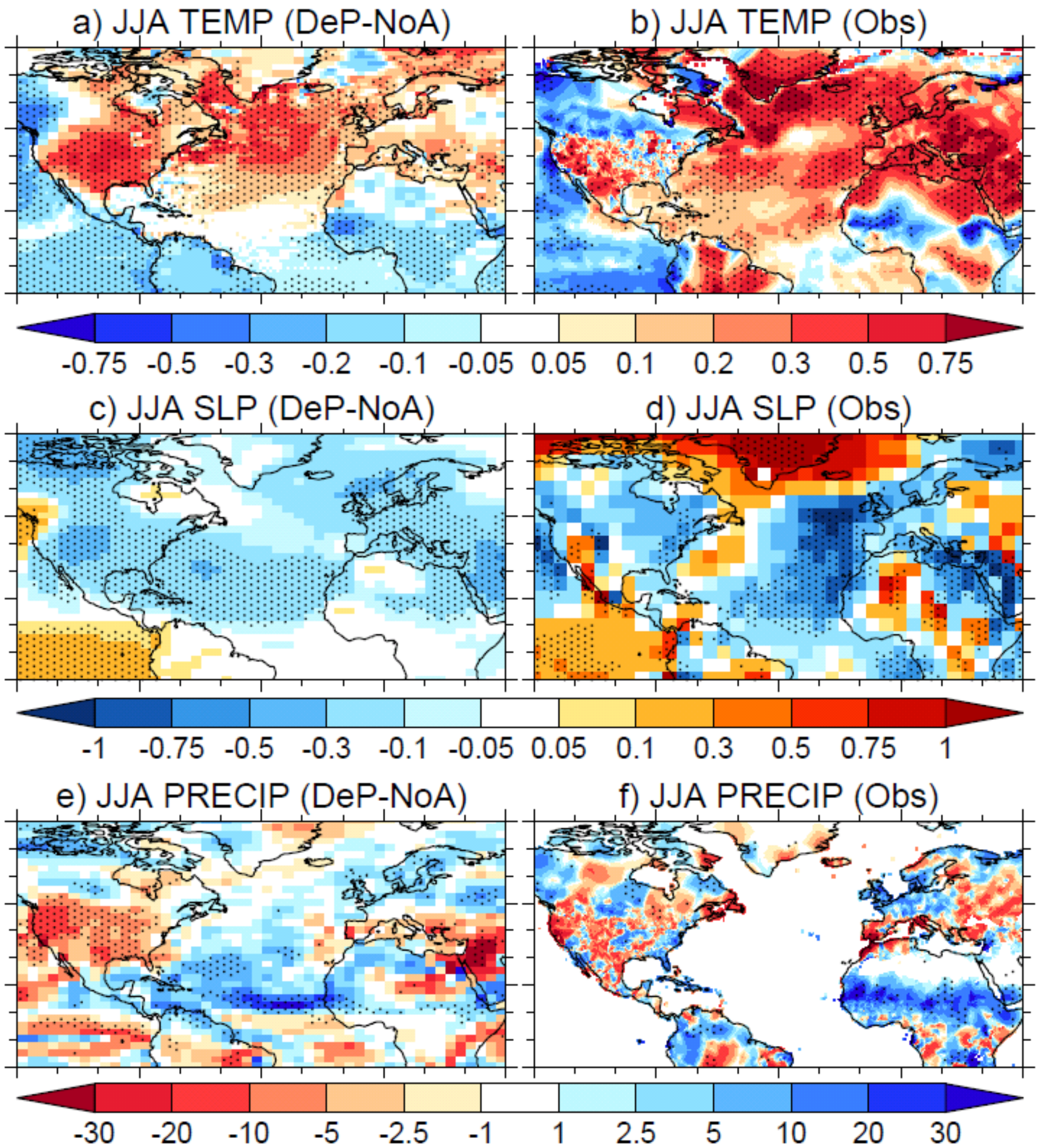

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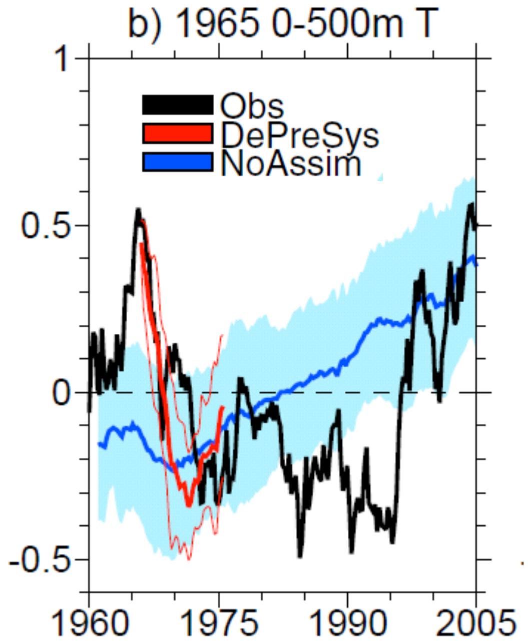
Predictions of the 1960s cooling



Robson et al, 2014, Climate Dynamics

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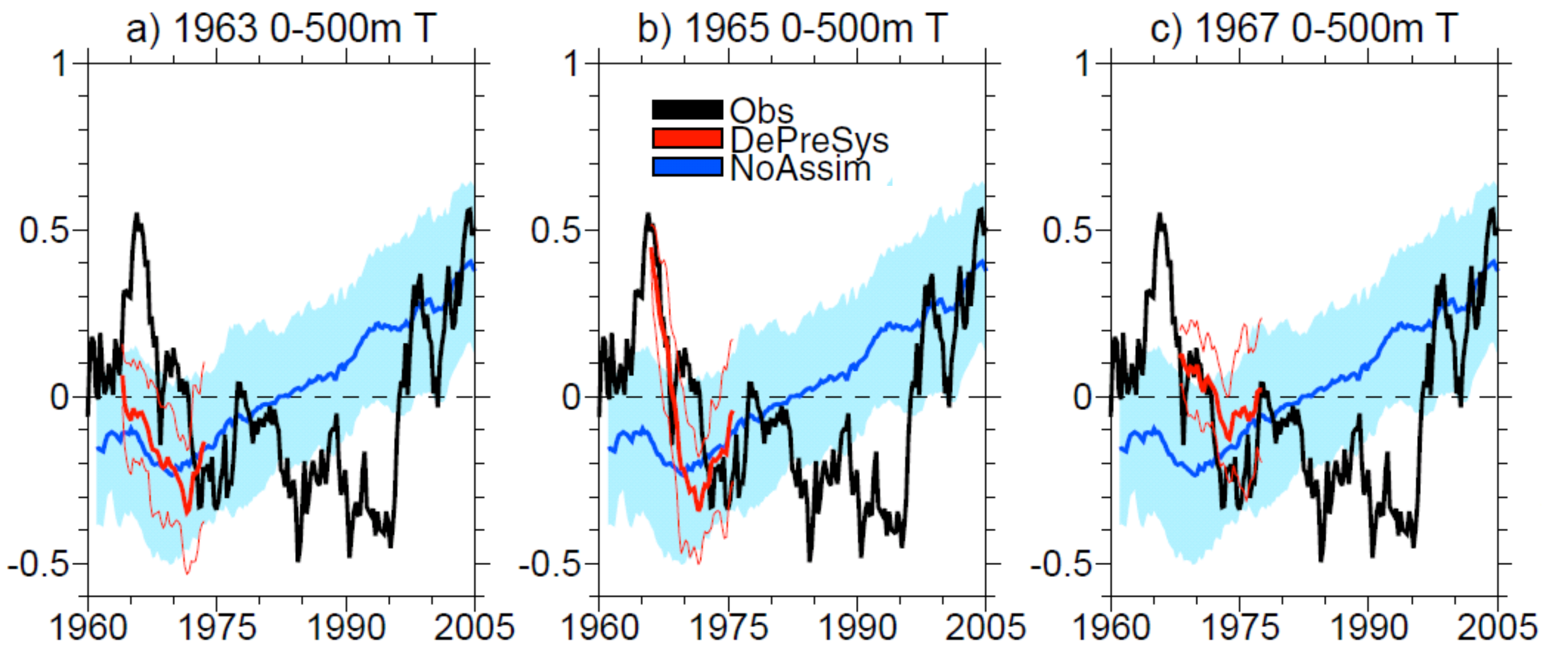

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Predictions of the 1960s cooling

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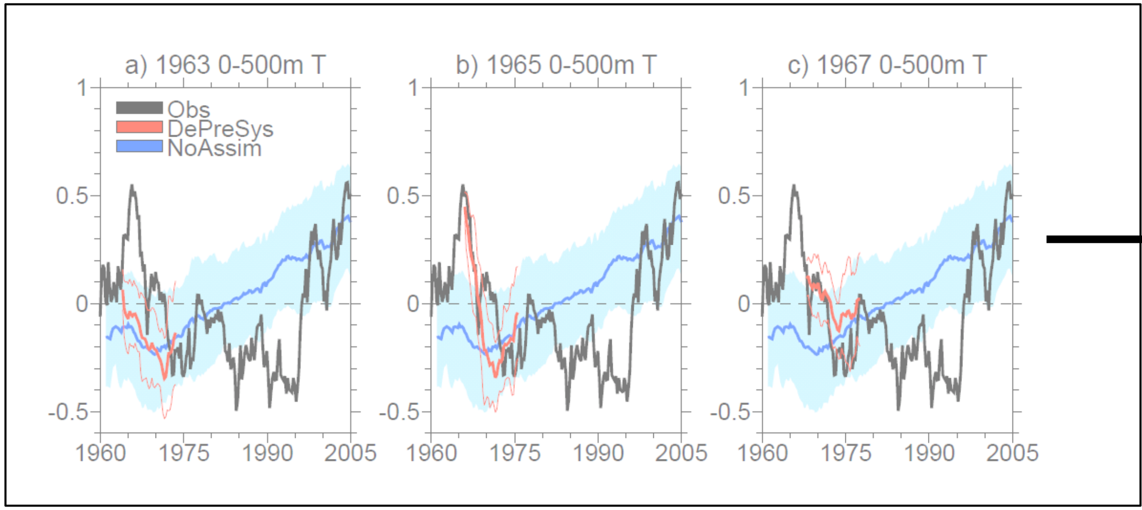
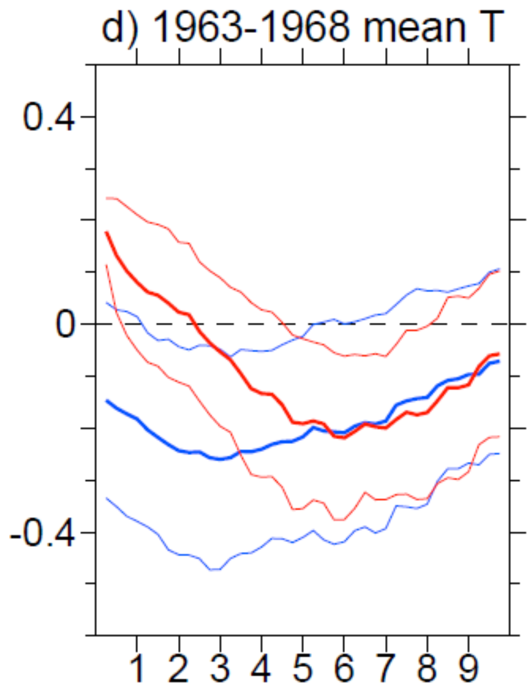
Mean over all hindcasts 1963-1968





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Robson et al, 2014, Climate Dynamics

SPG energy budget

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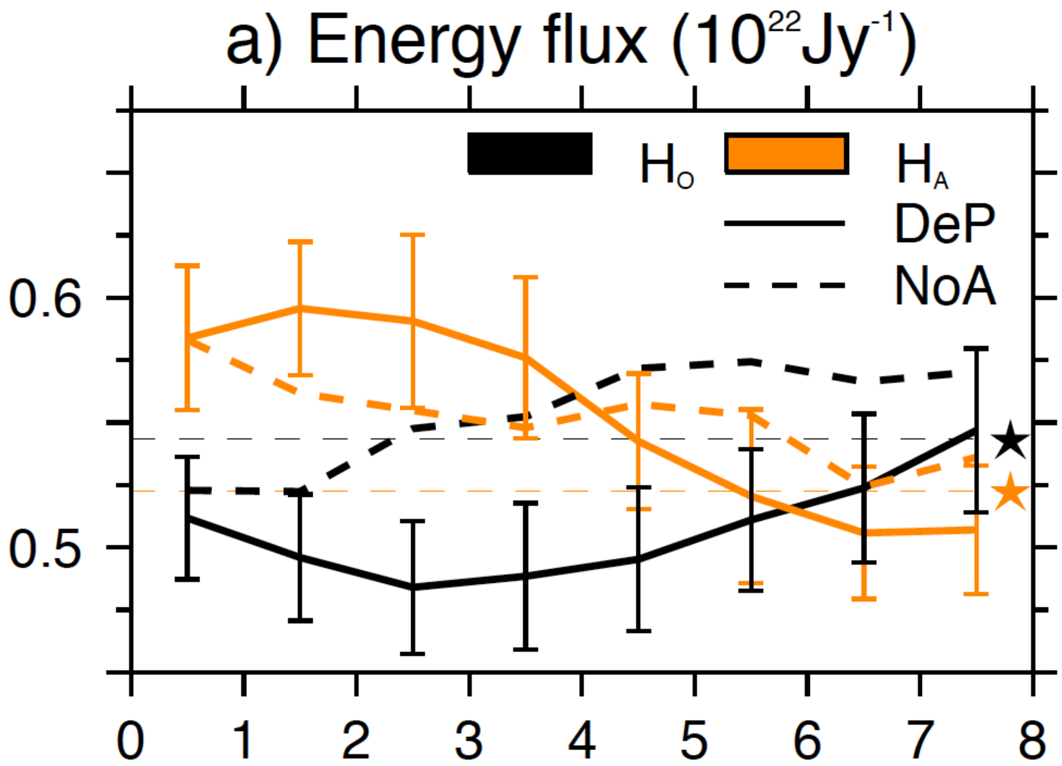
$\Delta E = H_O - H_A$

H_O = Ocean heat transport convergence
And
H_A = Atmospheric heat loss integrated over the latitude of the subpolar gyre (50N-65N)



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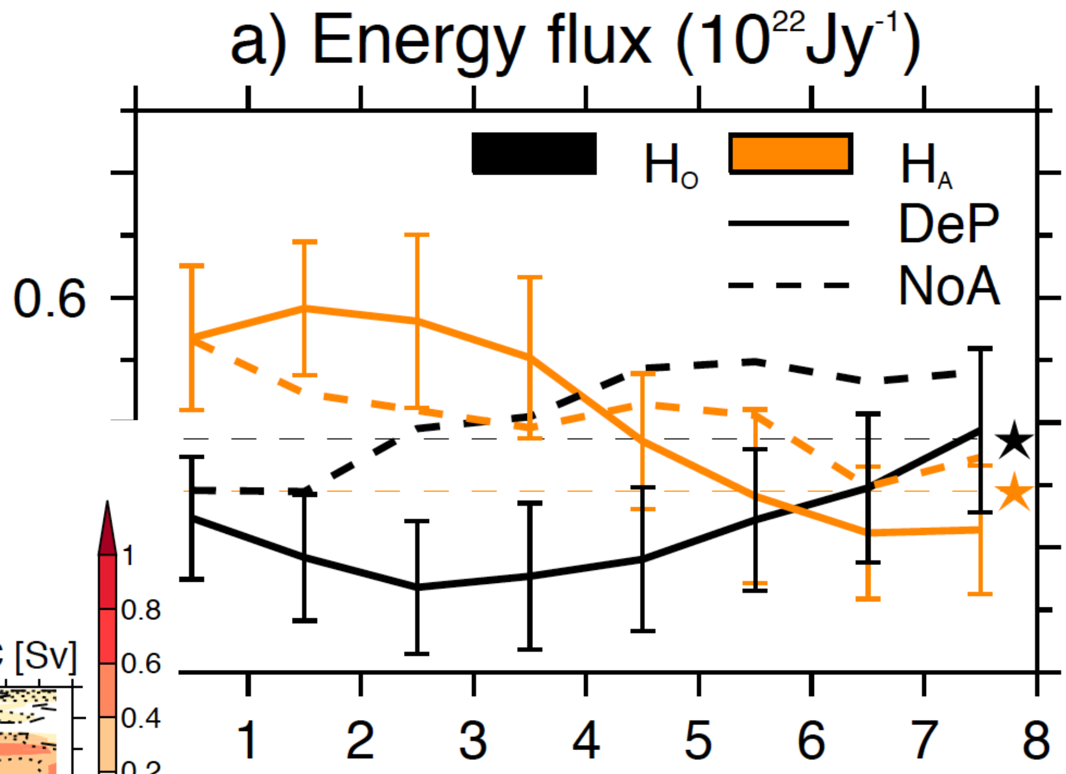
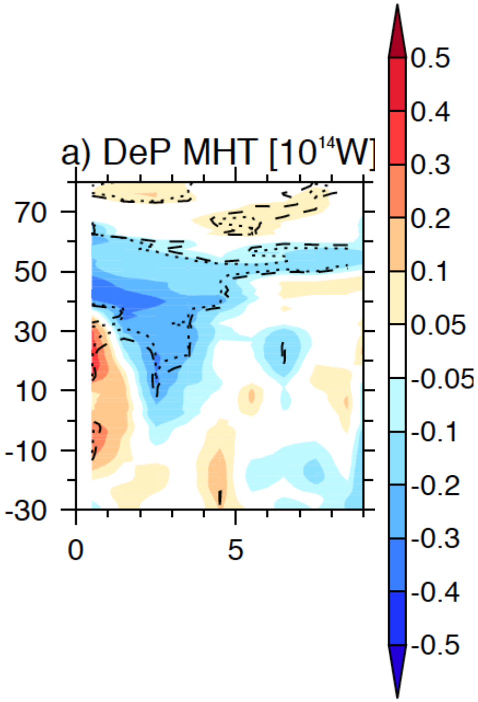
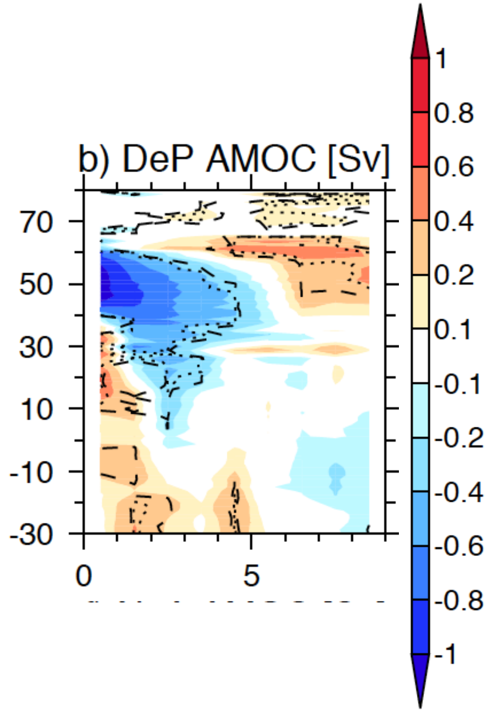
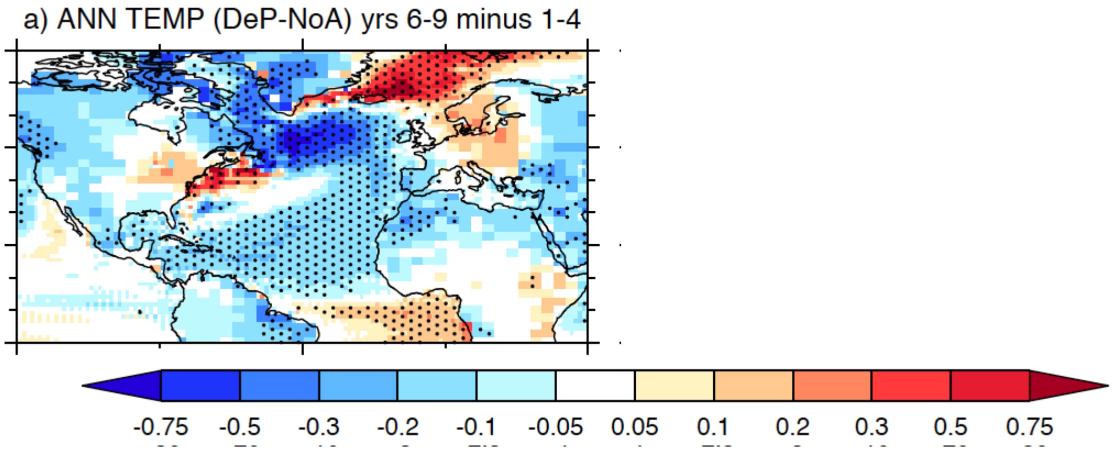
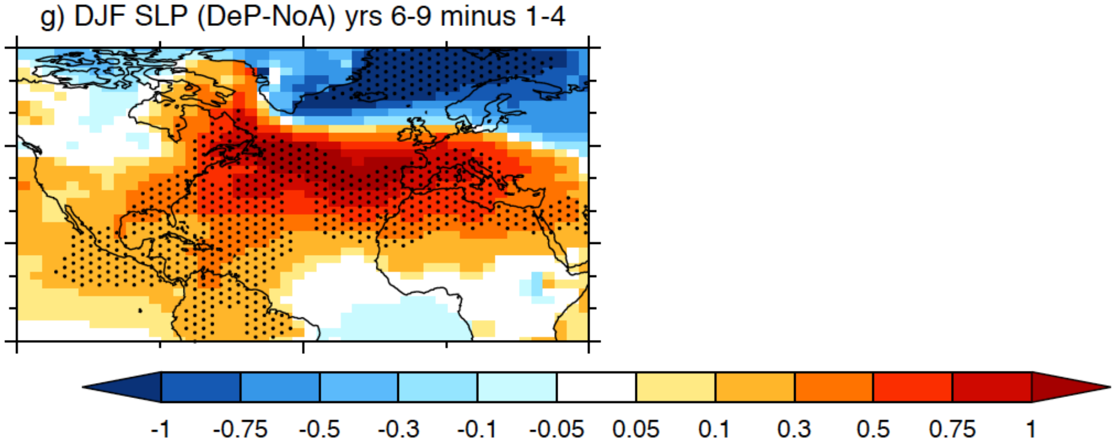






1960s surface climate impact





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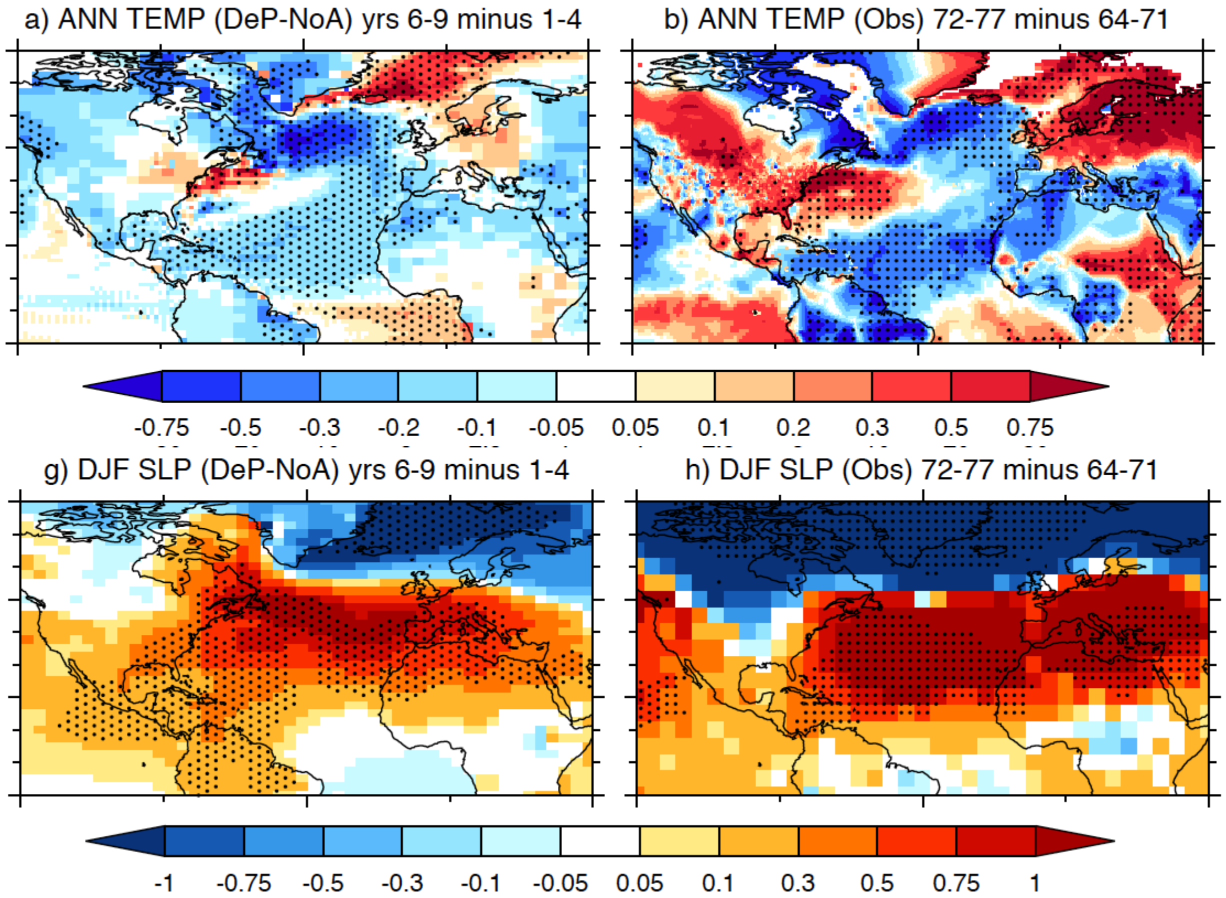

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Conclusions

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- Results from DePreSys suggests that:-
  - The shifts in AMV in the 1960s and 1990s could have been predicted in advance – there is skill *beyond persistence*
  - Both events were primarily caused by changes in ocean circulation and ocean heat transport convergence anomalies in the subpolar gyre
  - The AMOC played a key role in both shifts
  - The changes in ocean temperature also led to predictable impacts on surface climate – *even over land*
- The results are therefore encouraging for the prospects of predicting future changes in North Atlantic climate

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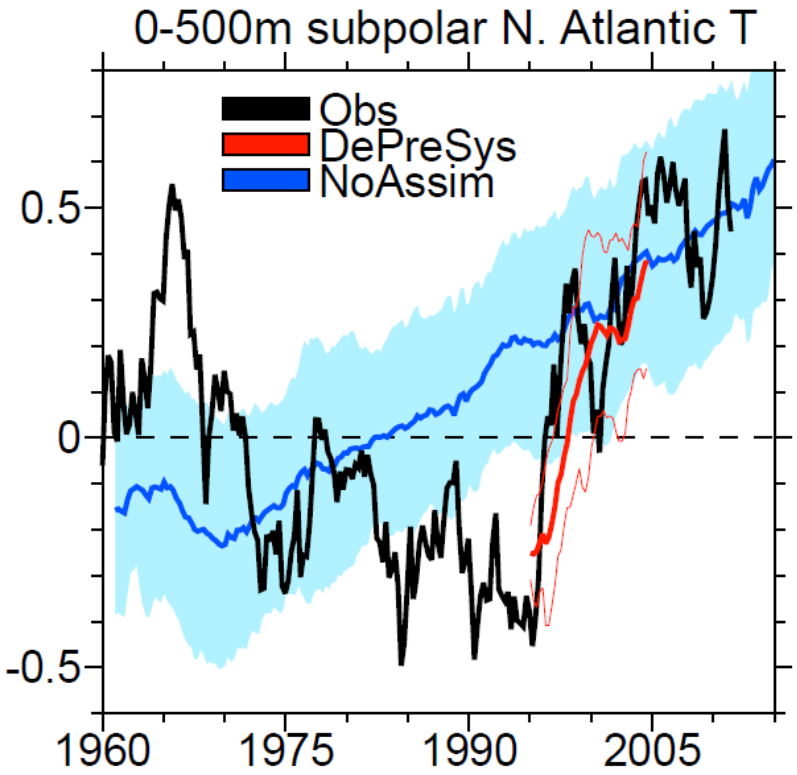
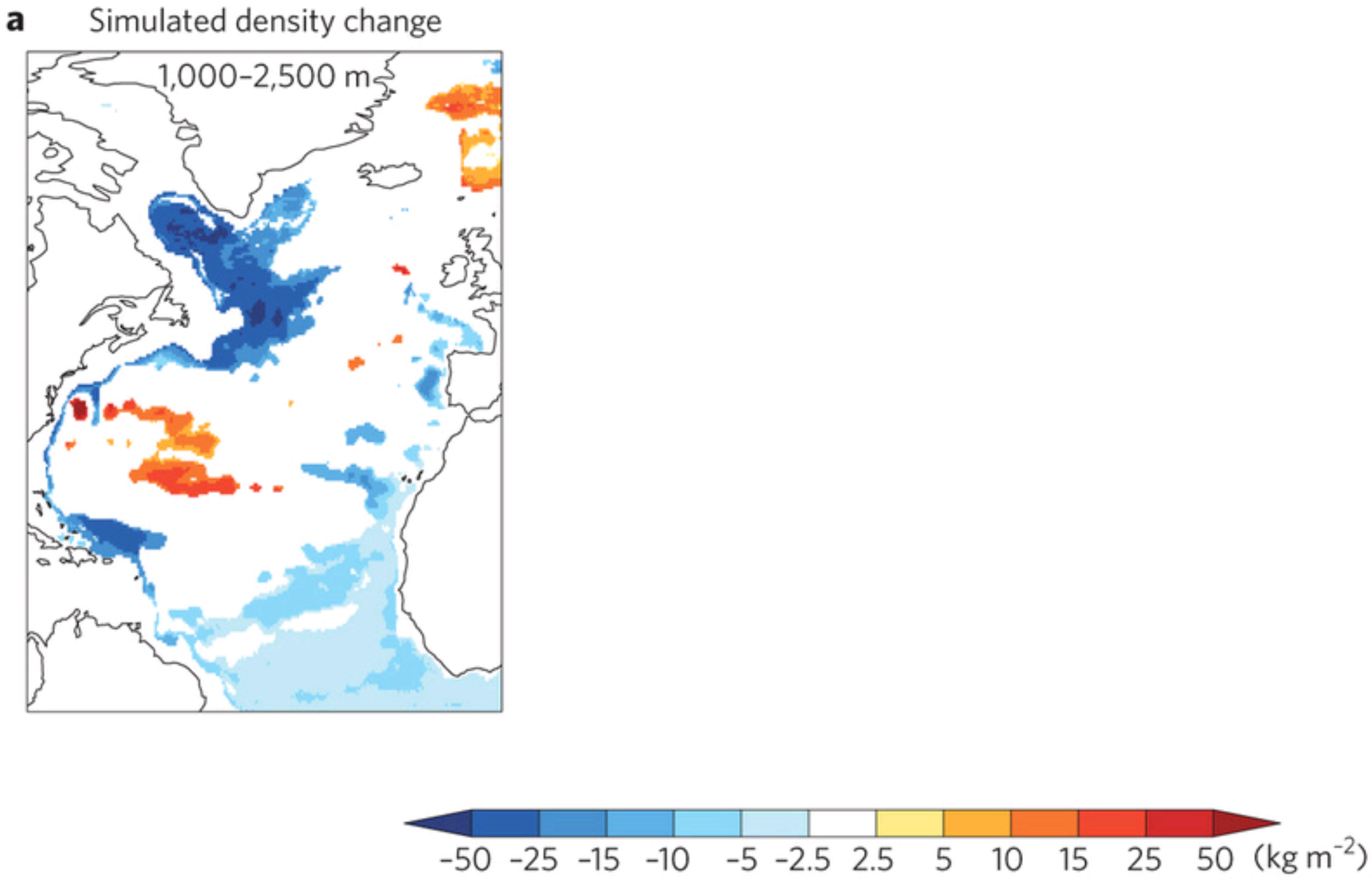
  - The changes in ocean temperature surface climate – *even over land*
- The results are therefore encouraging f changes in North Atlantic climate
- **BUT, Only two case studies….**
  ….with a low-resolution model



AMOC in decline?



Robson et al, 2014, Nat Geo

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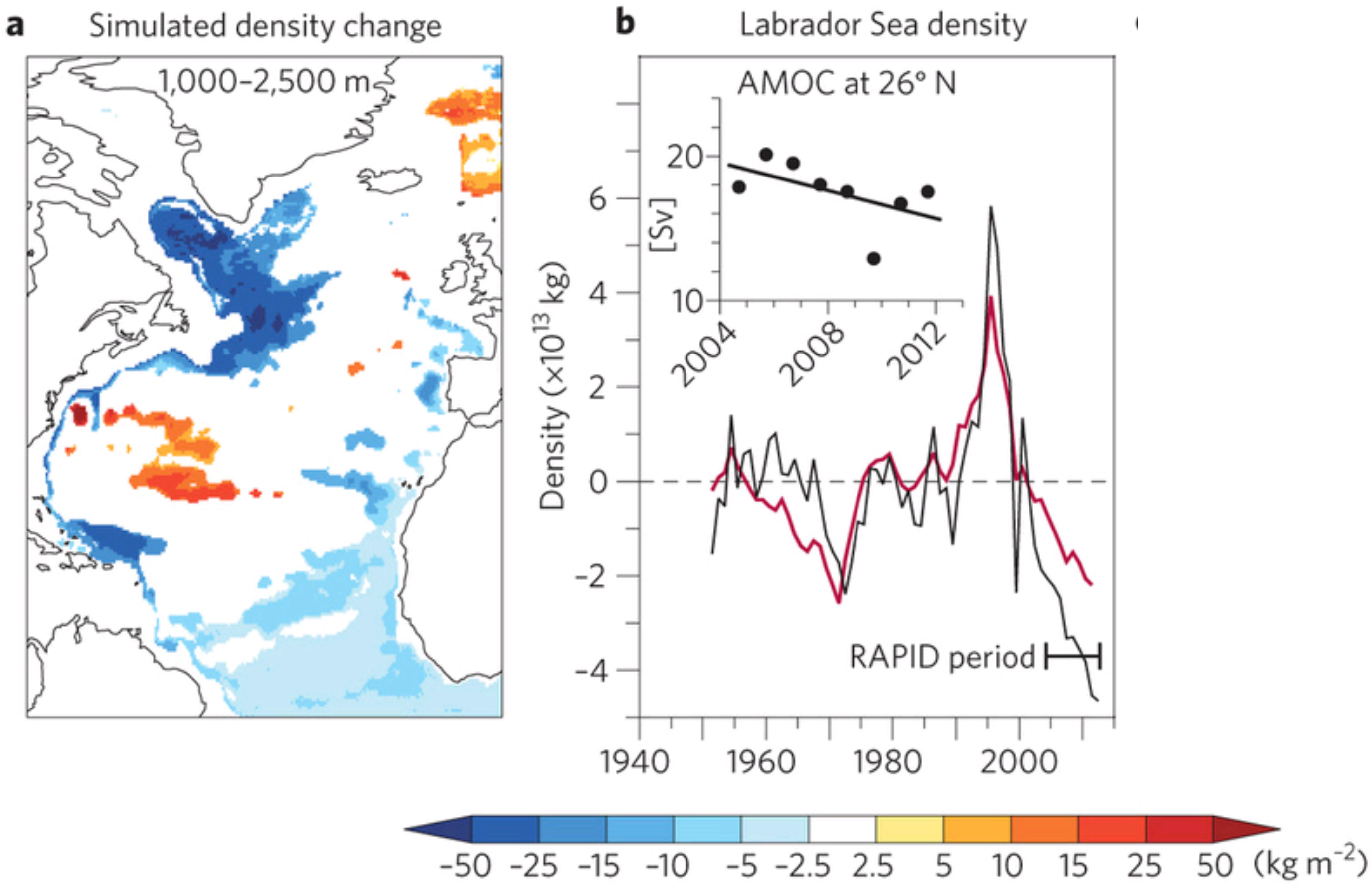

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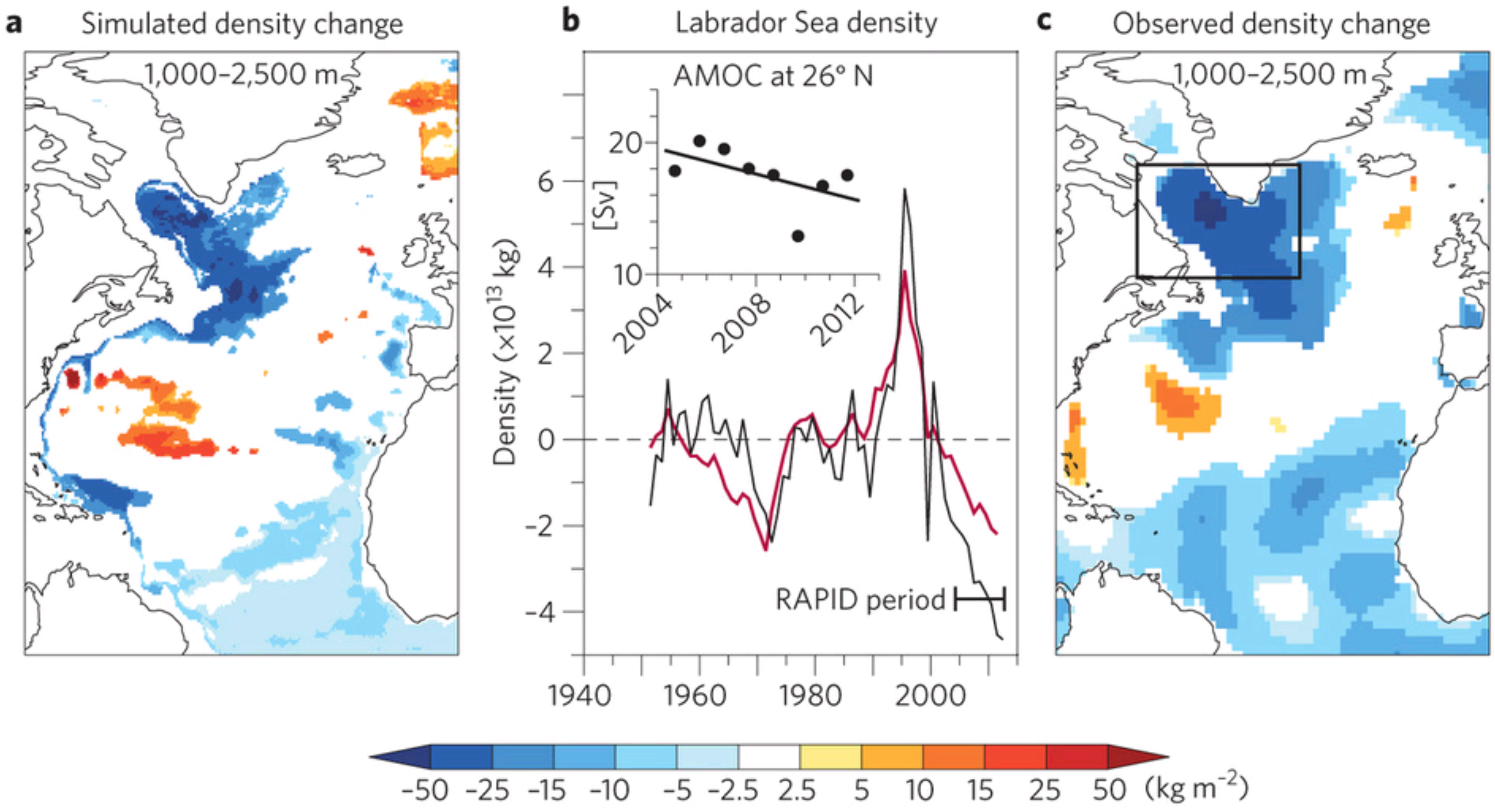

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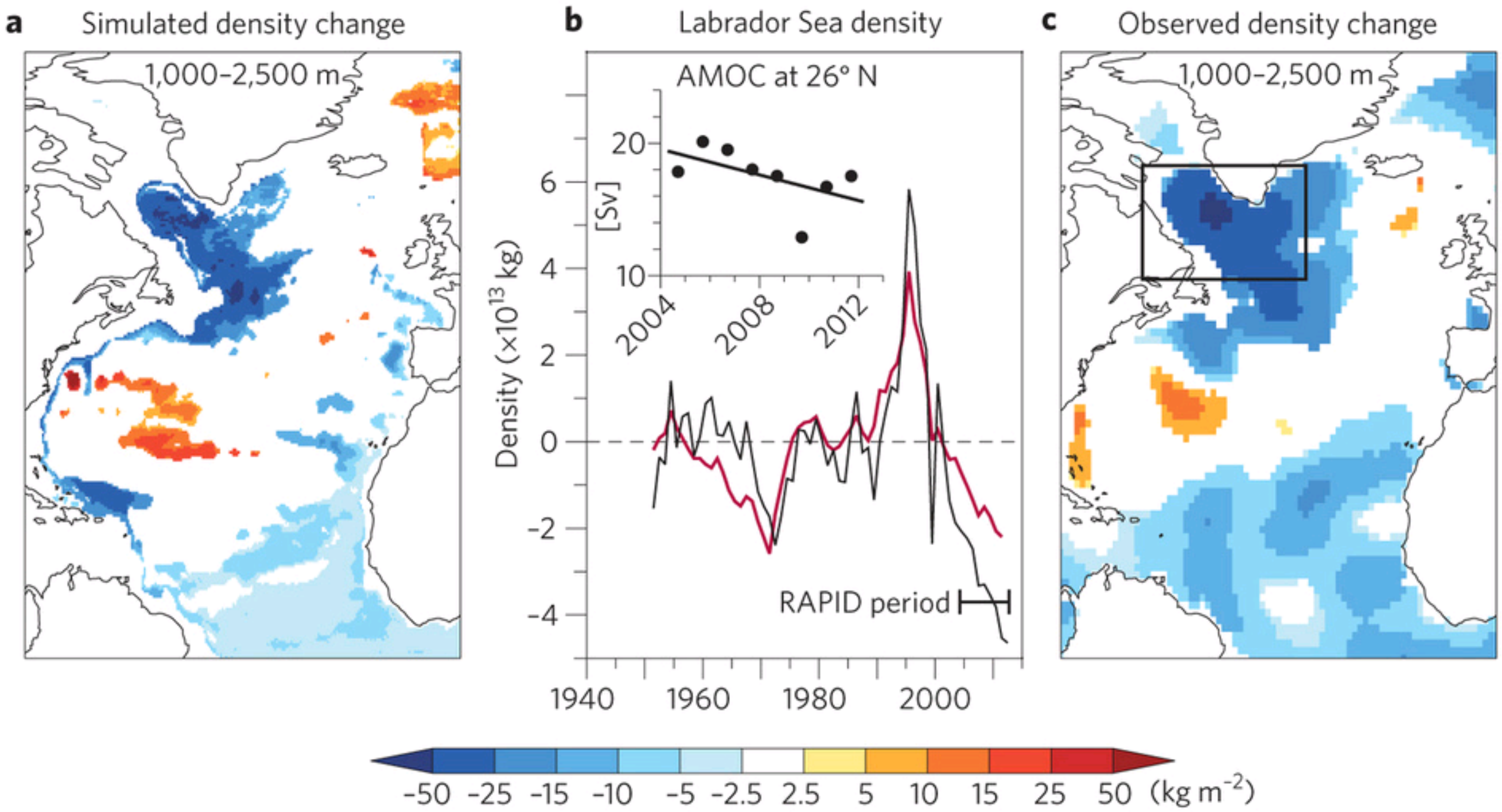
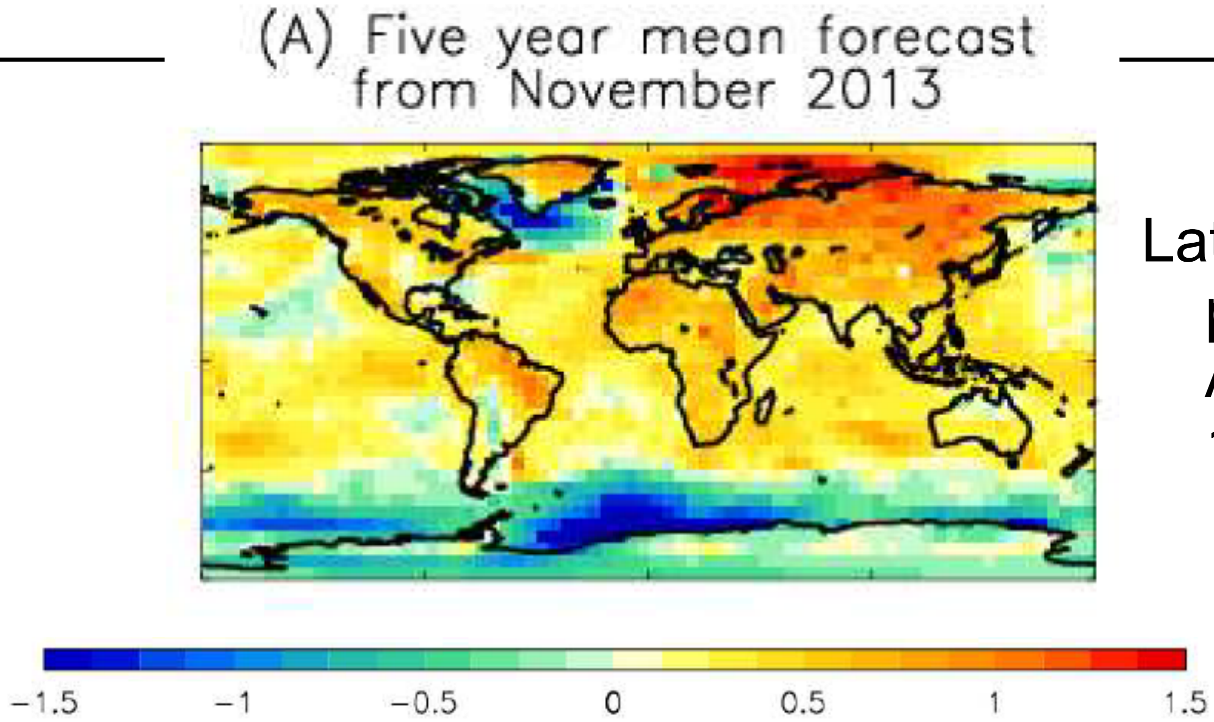


Model relationship suggests we should expect a further weakening of the AMOC

Excellent opportunity to test the understanding of the AMOC and, importantly, its role in climate

Robson et al, 2014, Nat Geo



Latest Met Office decadal prediction for SST. Anomalies relative to 1981-2010

Thanks!

Historical changes in the Subpolar gyre

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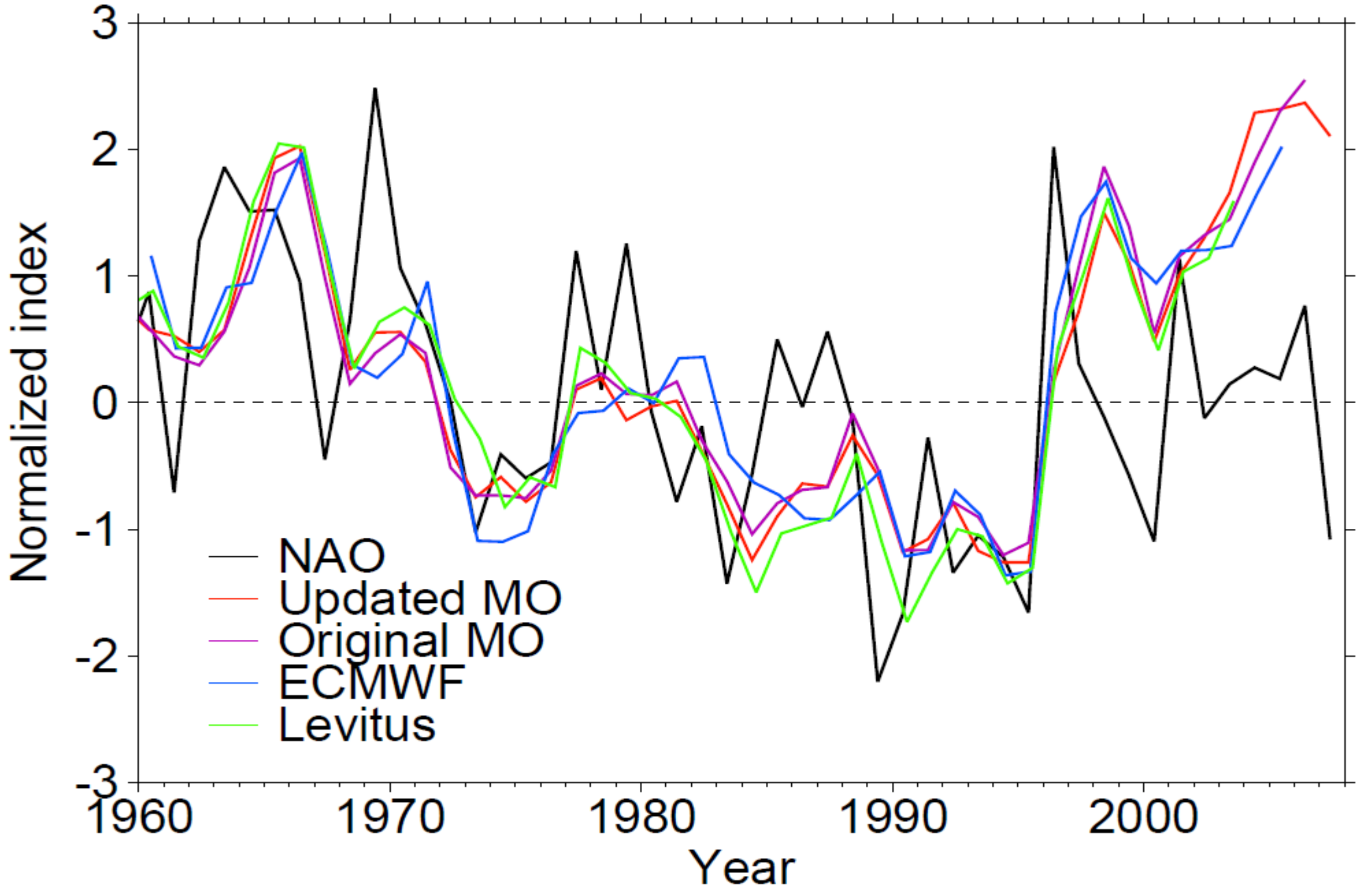

BLACK: *Inverted* NAO

Temp anomaly of Subtropical gyre (60W-10W,50N-66N) from Levitus, ECMWF and Met Office

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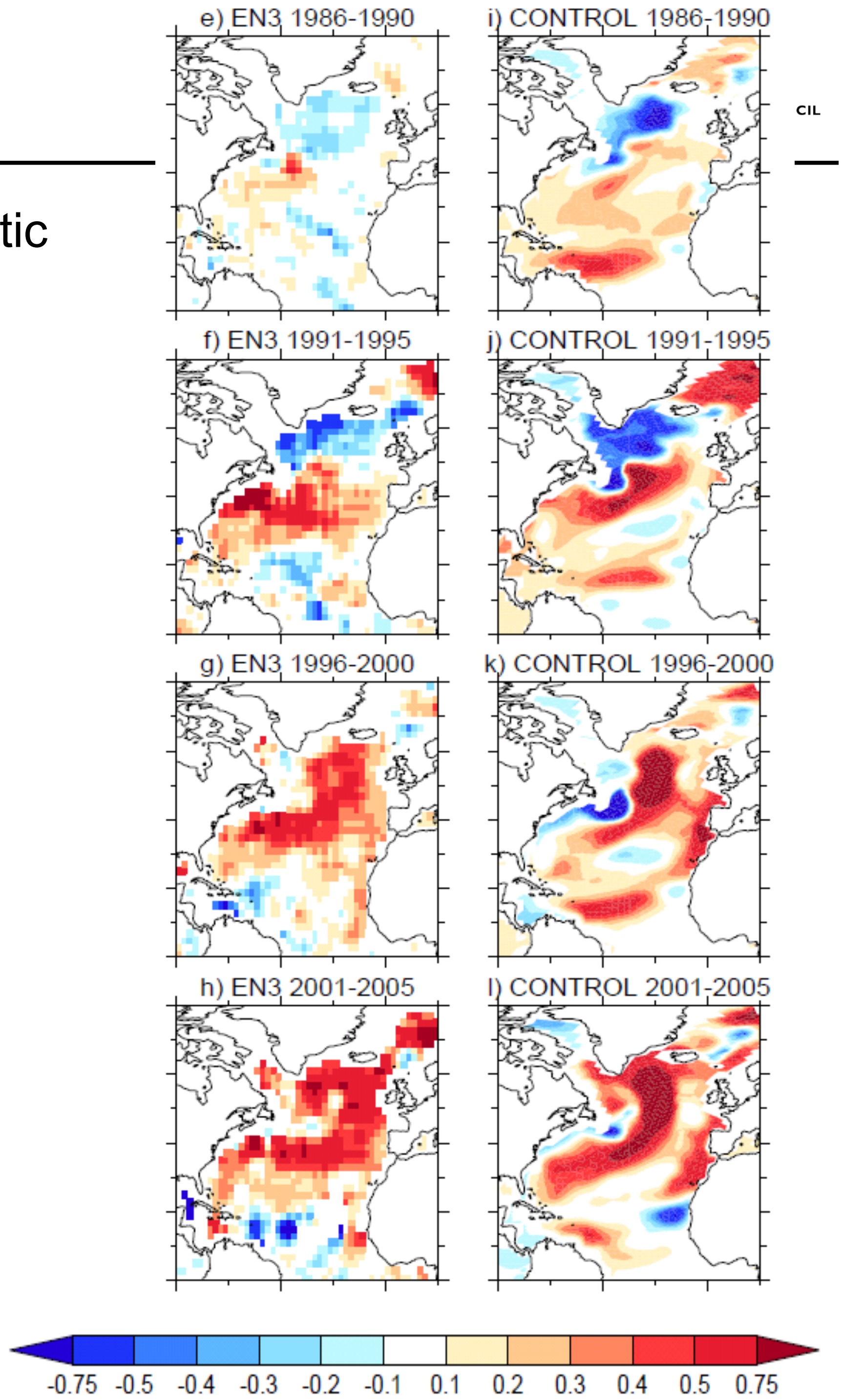
Ocean only experiments

- MICOM *2.4°* resolution, ~150km in the Atlantic

Historical experiments

- **CONTROL** - Ocean forced with daily fluxes taken from NCEP reanalysis

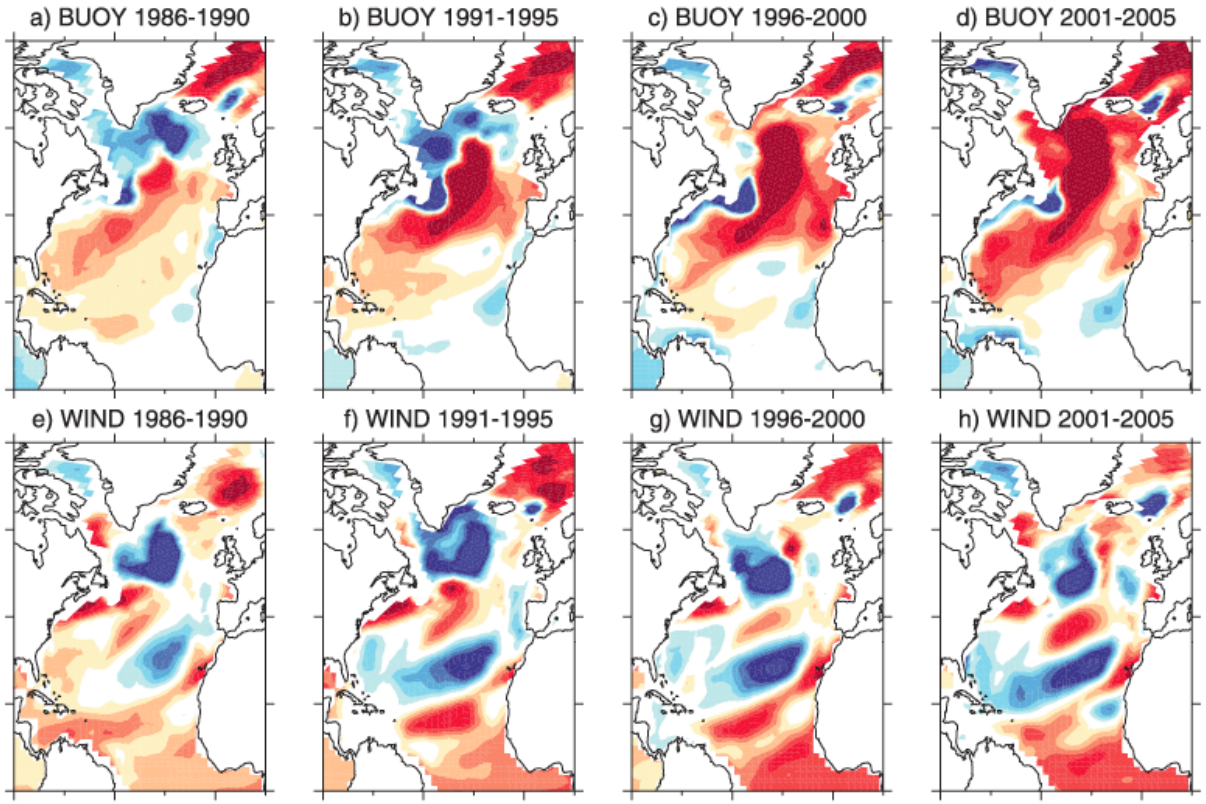


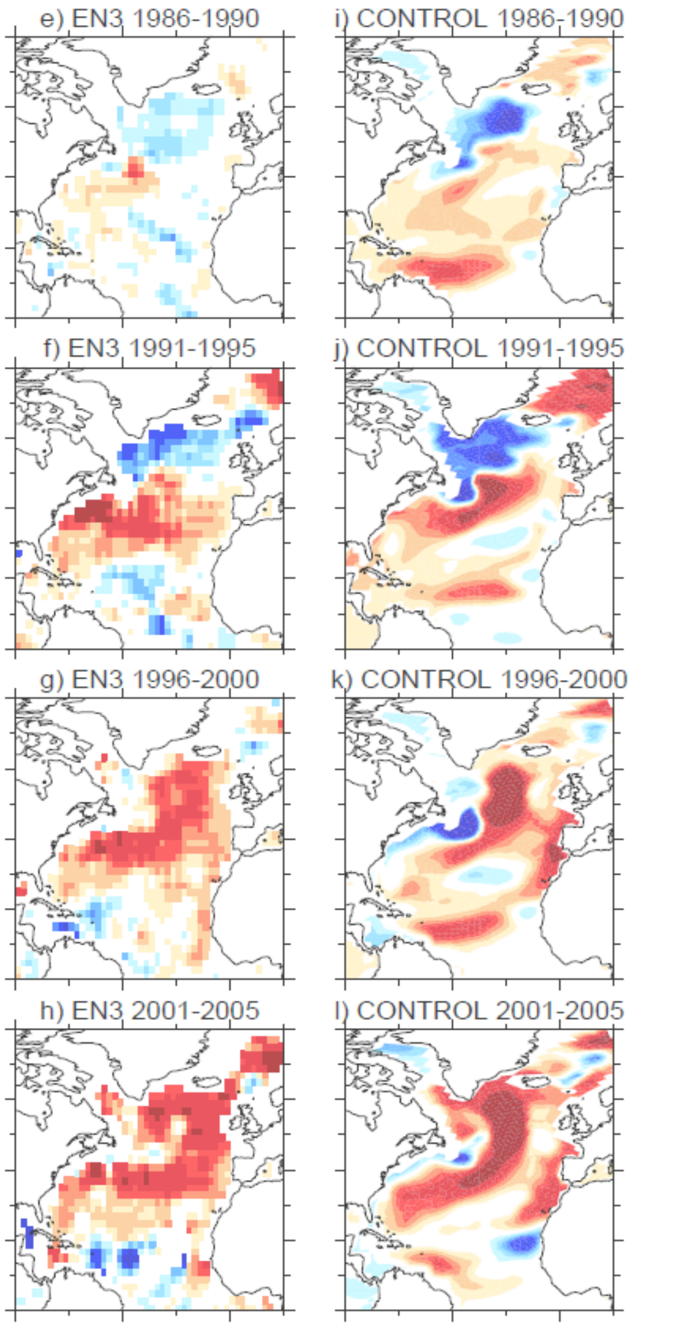
Robson et al, 2012, JCLIM

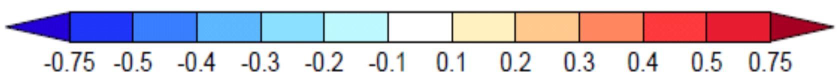
Ocean only experiments

Model only captures evolution of heat content anomalies when forced with changes in **buoyancy fluxes.**

Changes in ocean circulation are the key driver







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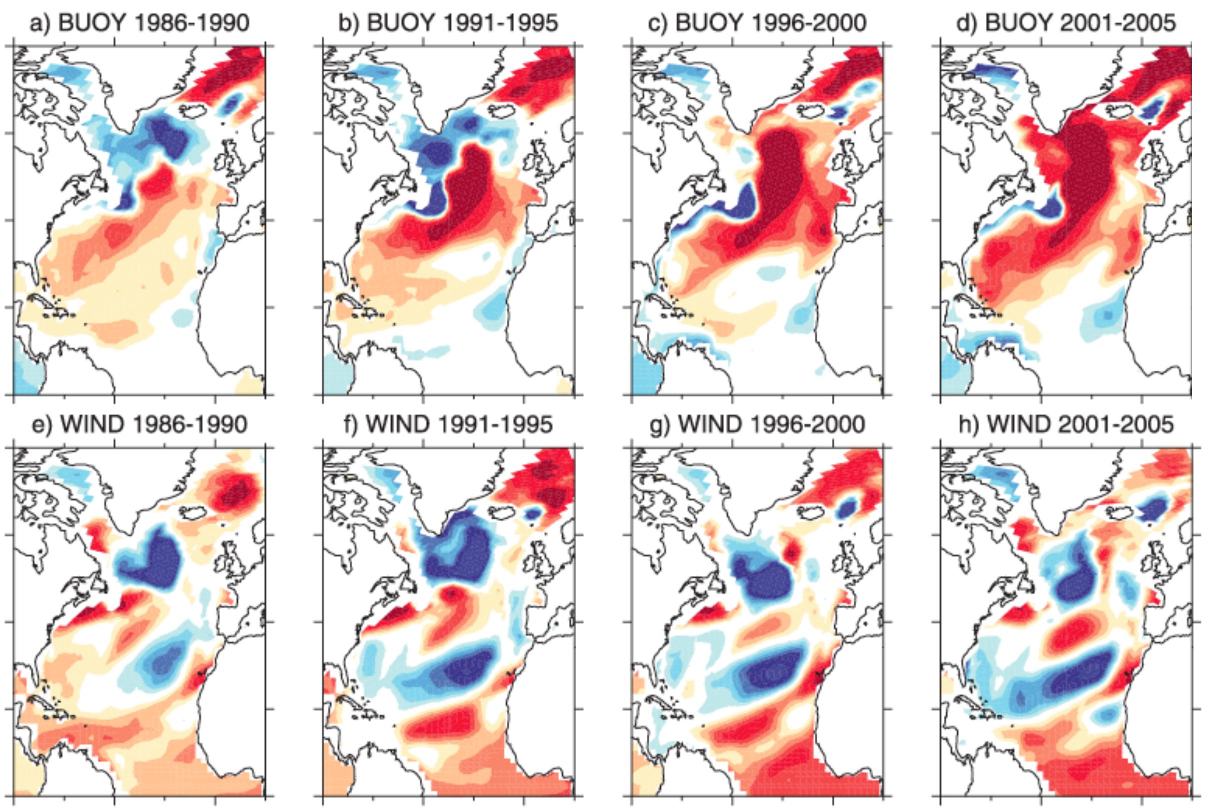
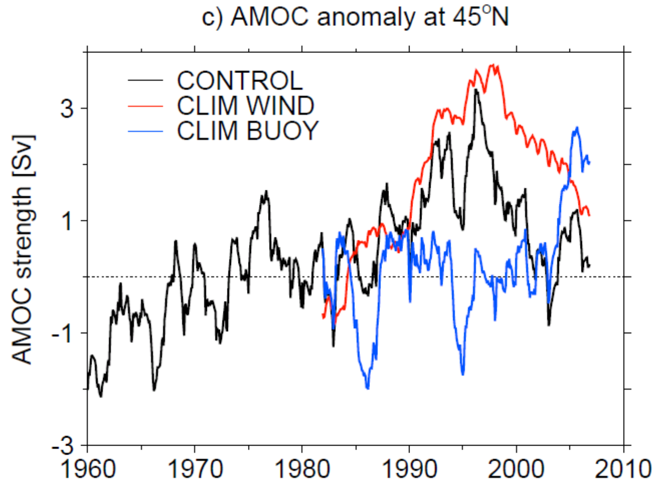
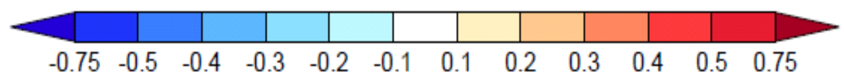
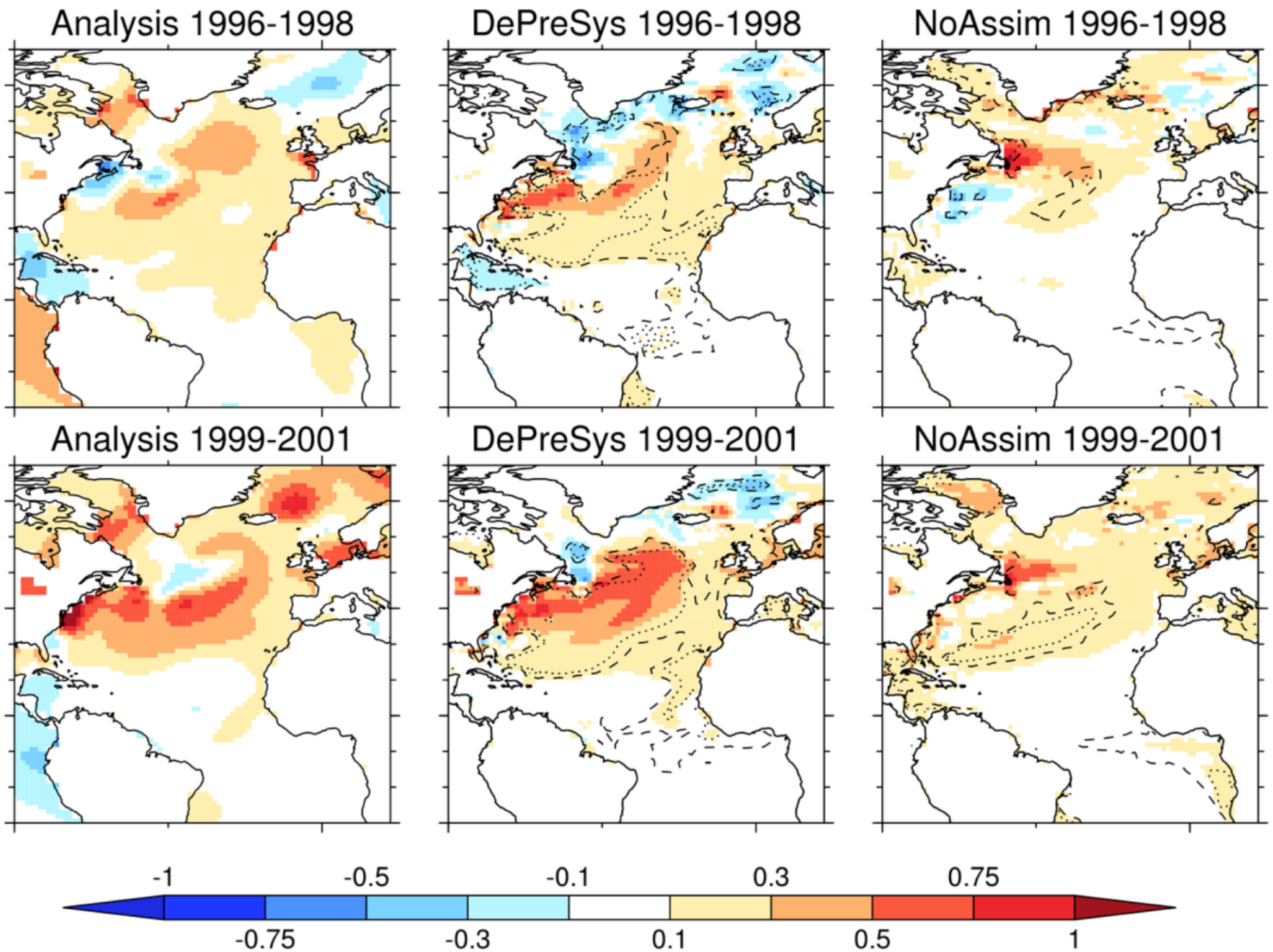






0-500m heat content anomalies



Role of ocean heat transport changes

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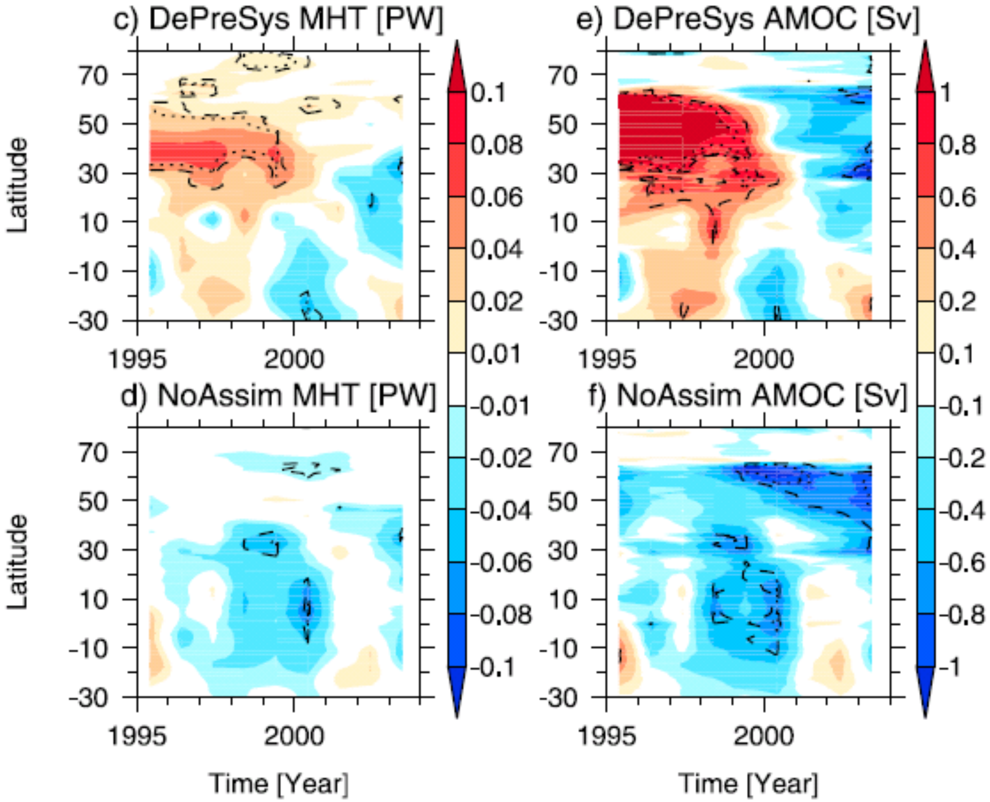

Initialisation of strong AMOC key to predict the warming

November 1994 hindcast

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Mean DePreSys PPE – NoAssim PPE

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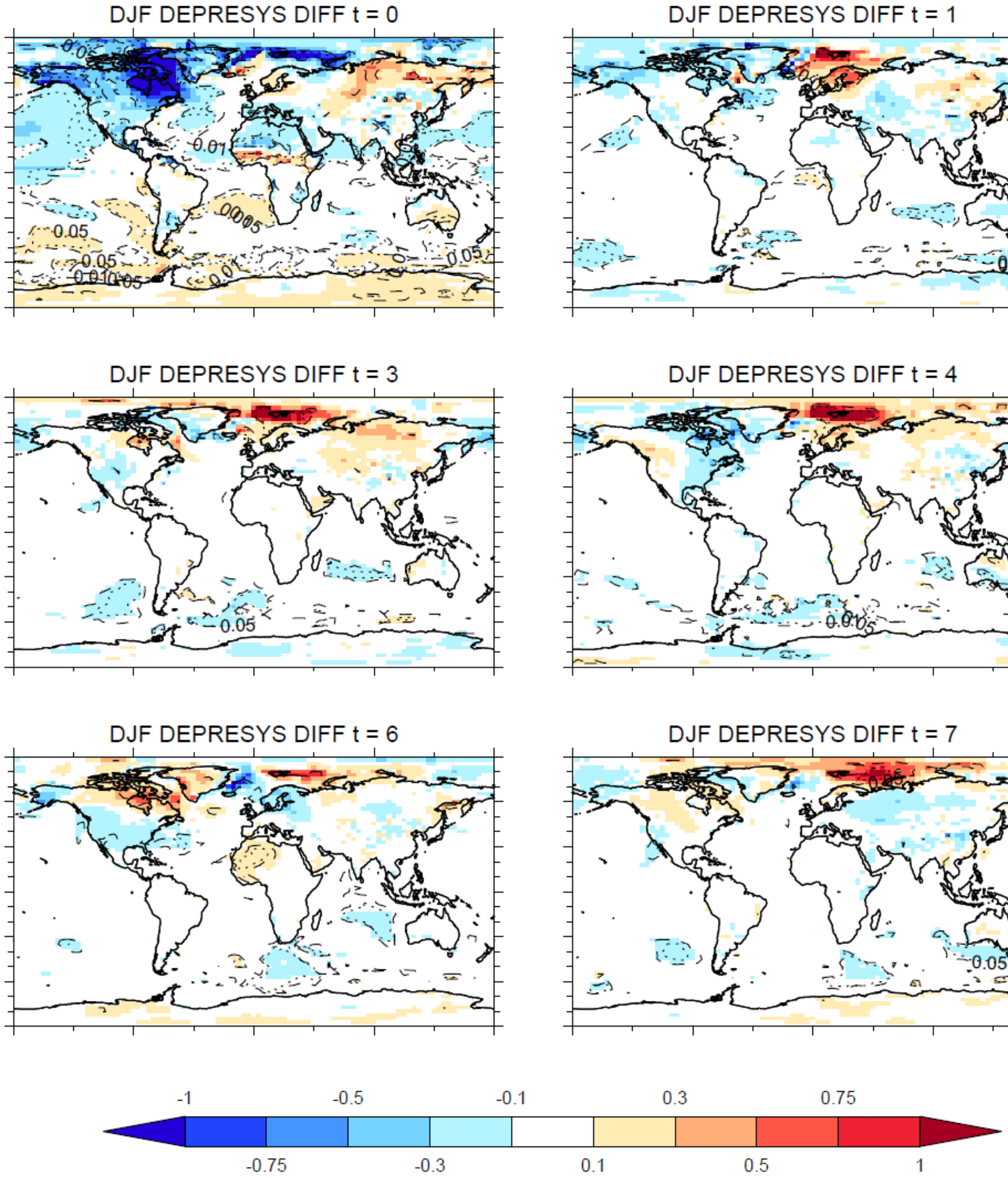
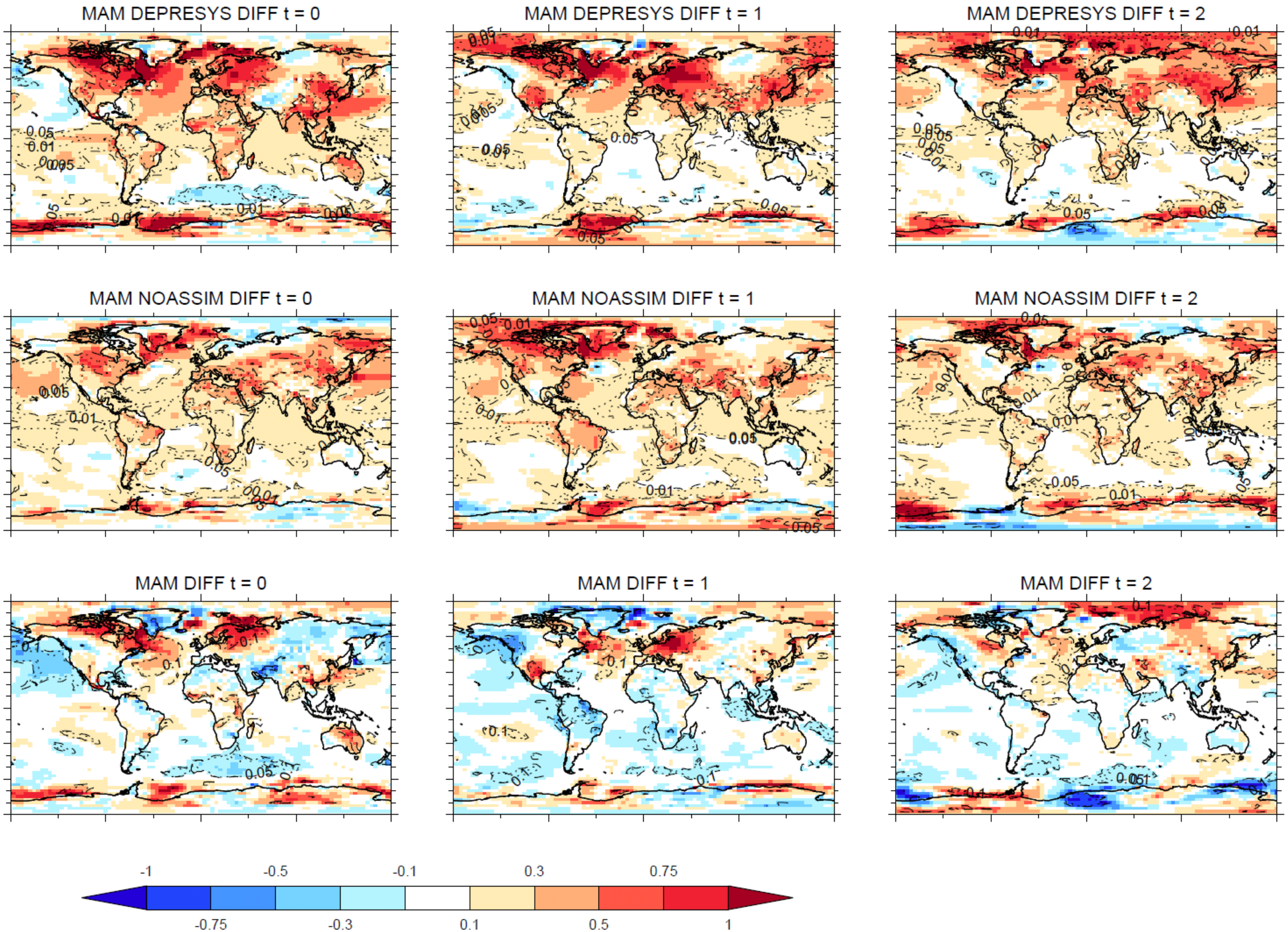
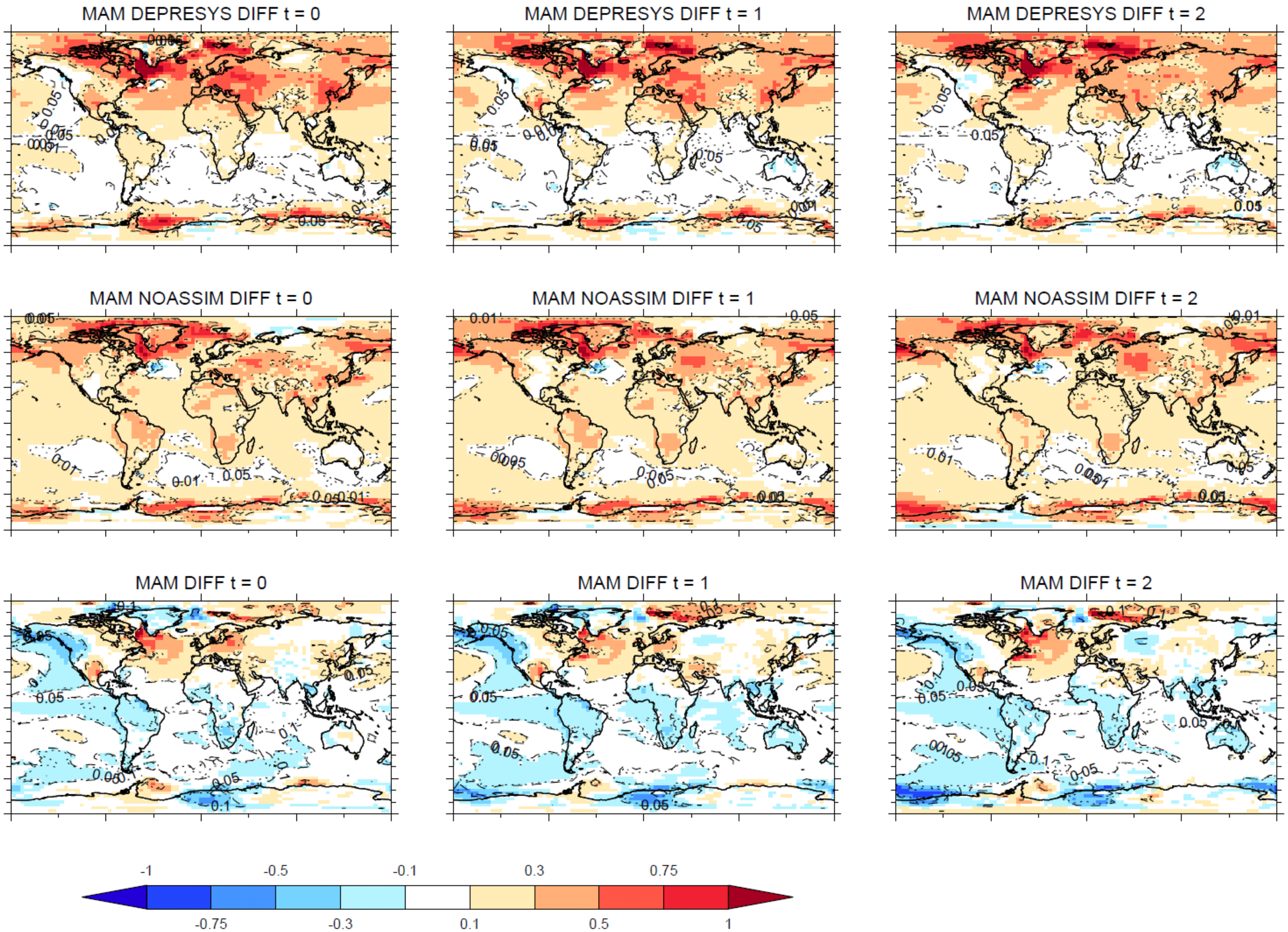


MAM SAT 1yr


MAM DEPRESYS DIFF t = 0
MAM DEPRESYS DIFF t = 1
MAM DEPRESYS DIFF t = 2
MAM NOASSIM DIFF t = 0
MAM NOASSIM DIFF t = 1
MAM NOASSIM DIFF t = 2
MAM DIFF t = 0
MAM DIFF t = 1
MAM DIFF t = 2
-1
-0.5
-0.1
0.3
0.75
-0.75
-0.3
0.1
0.5
1

MAM SAT 5yr


MAM DEPRESYS DIFF t = 0
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MAM NOASSIM DIFF t = 0
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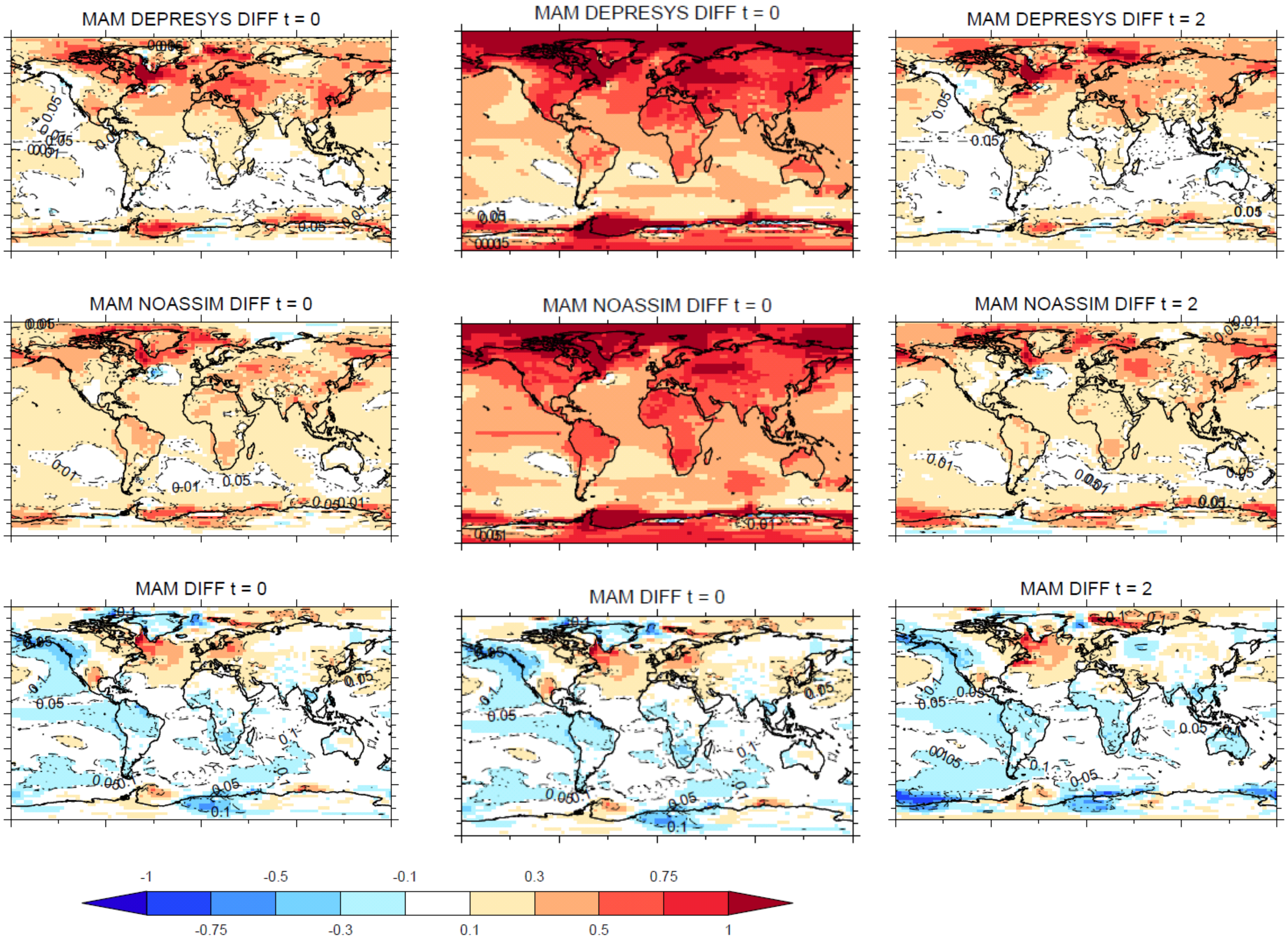
MAM NOASSIM DIFF t = 2
MAM DIFF t = 0
MAM DIFF t = 1
MAM DIFF t = 2
-1
-0.5
-0.1
0.3
0.75
-0.75
-0.3
0.1
0.5
1

MAM SAT 5yr



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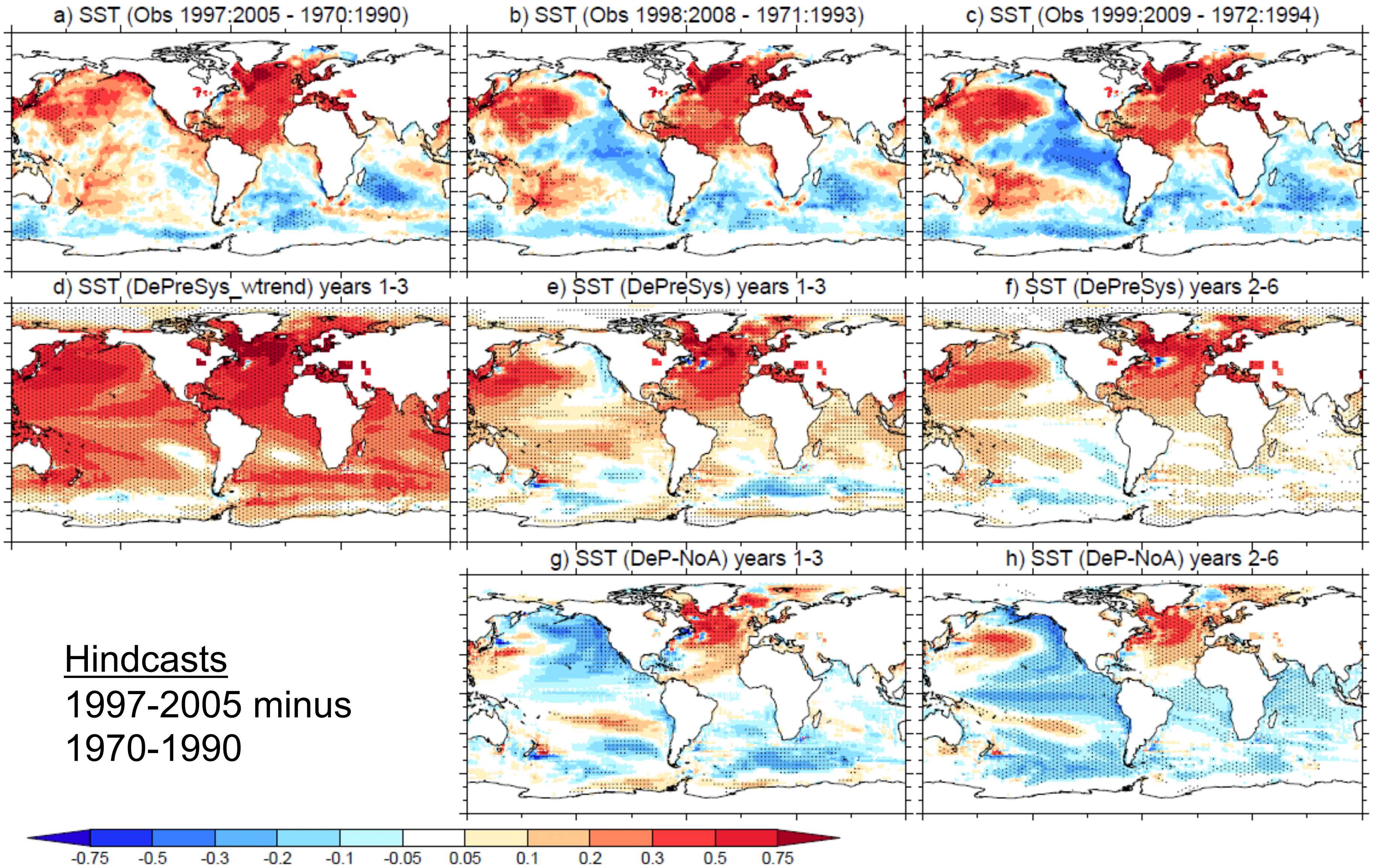
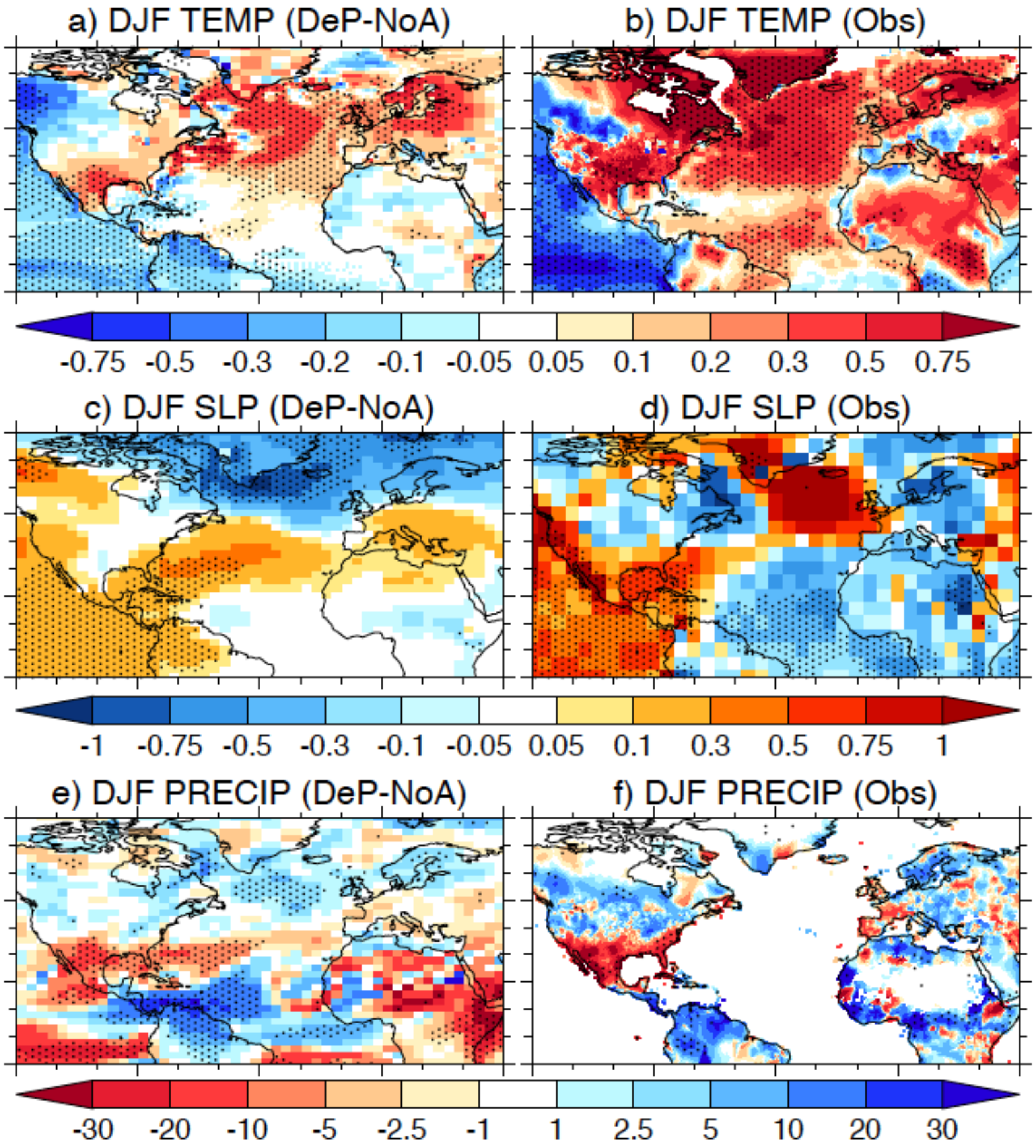
SSTs



<u>Hindcasts</u>
1997-2005 minus
1970-1990



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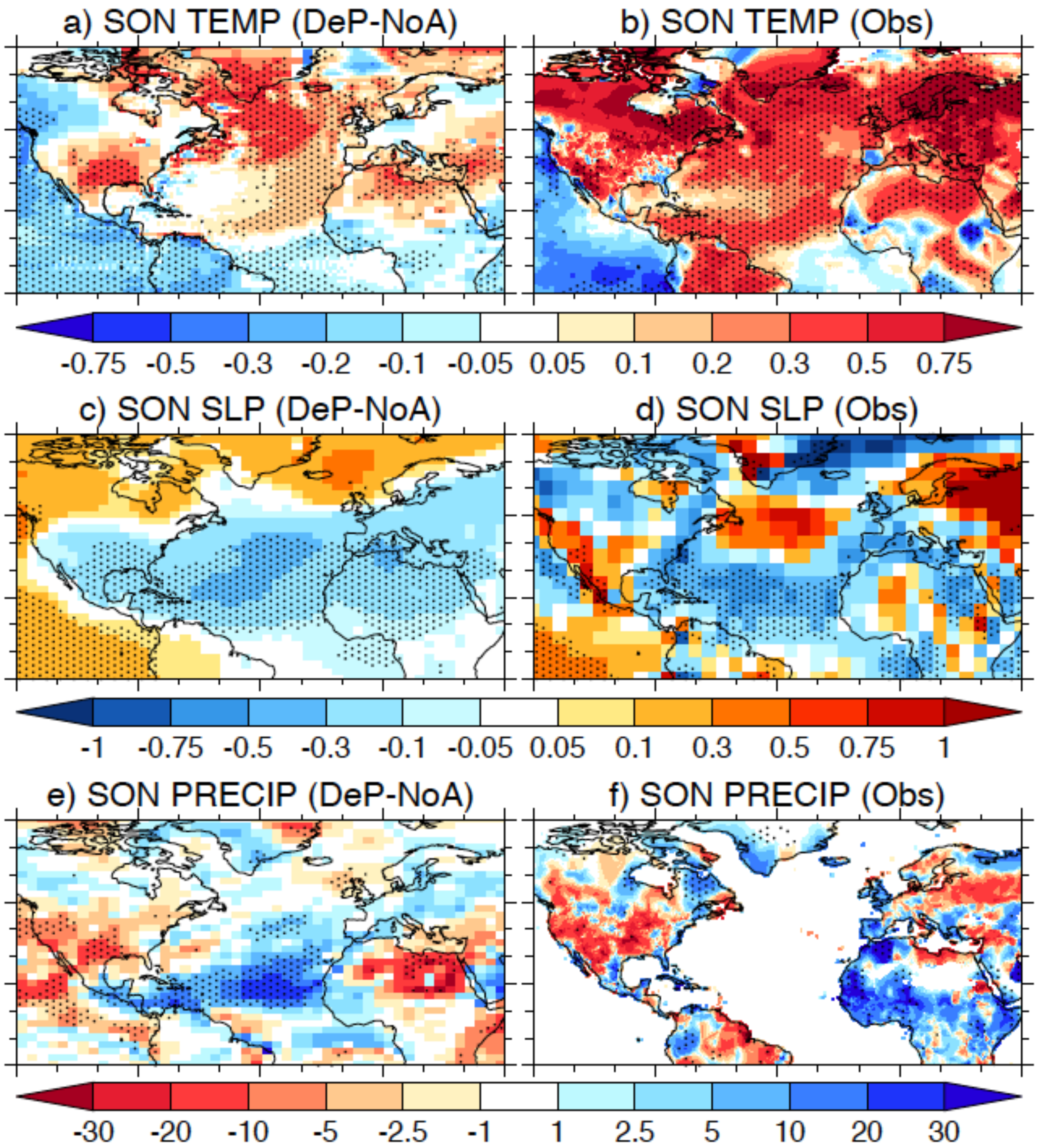

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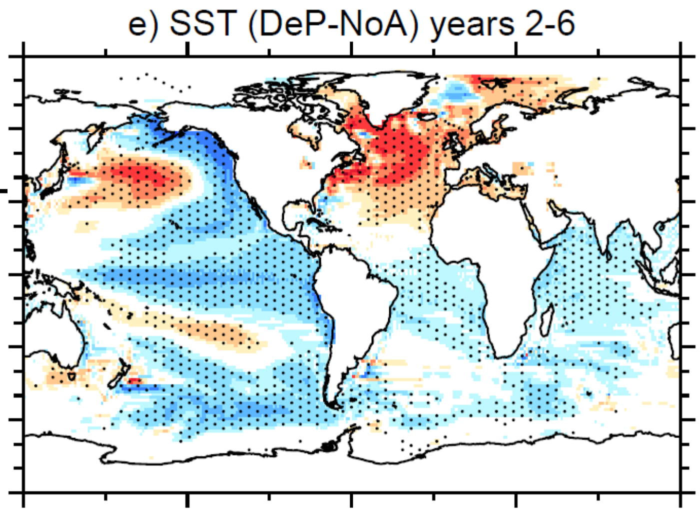
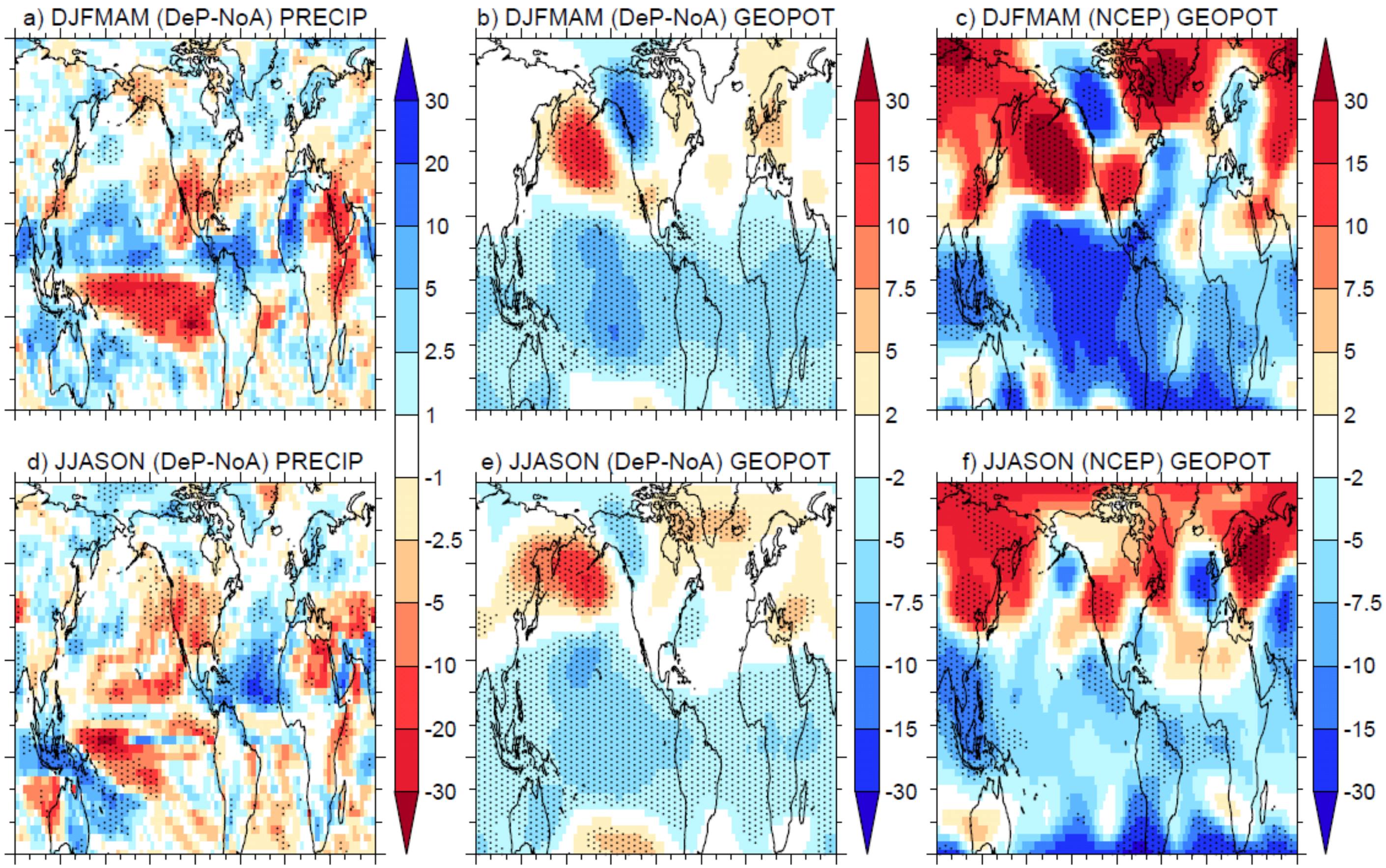
What about the role of the Pacific?

Predicted cooling of the Tropical East Pacific likely to be important for predictions over North America





Model

(97-05) –
(68-90)

Years 2-6

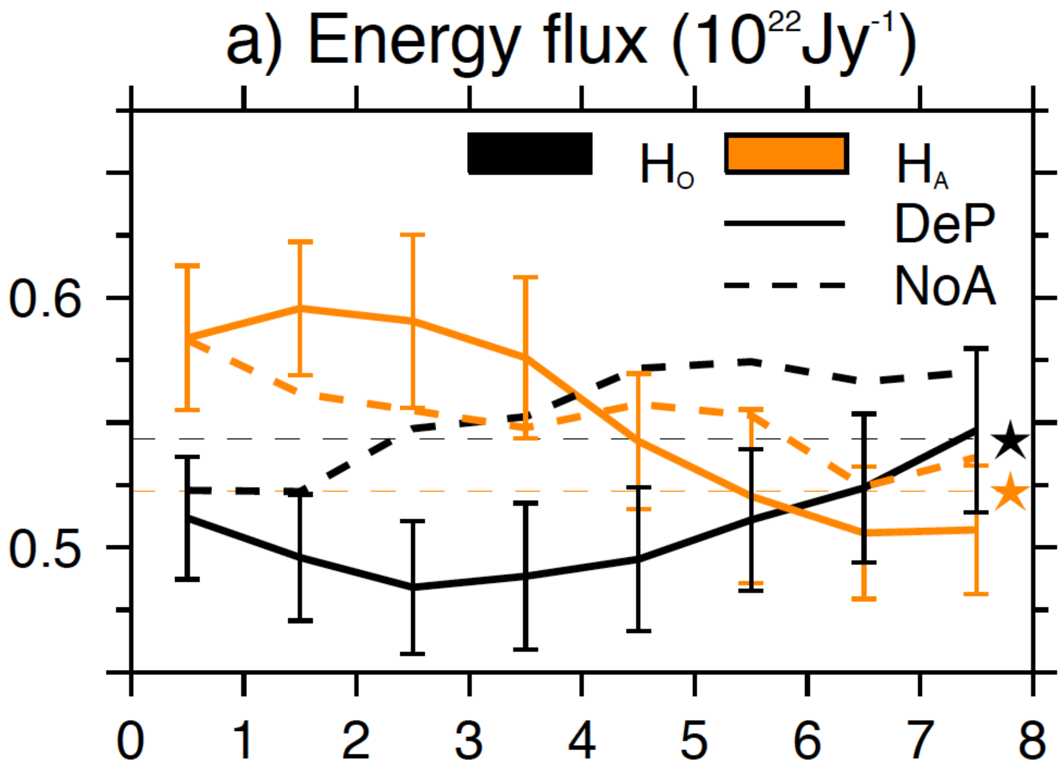
Obs

(99-09) –
(70-94)

SPG energy budget

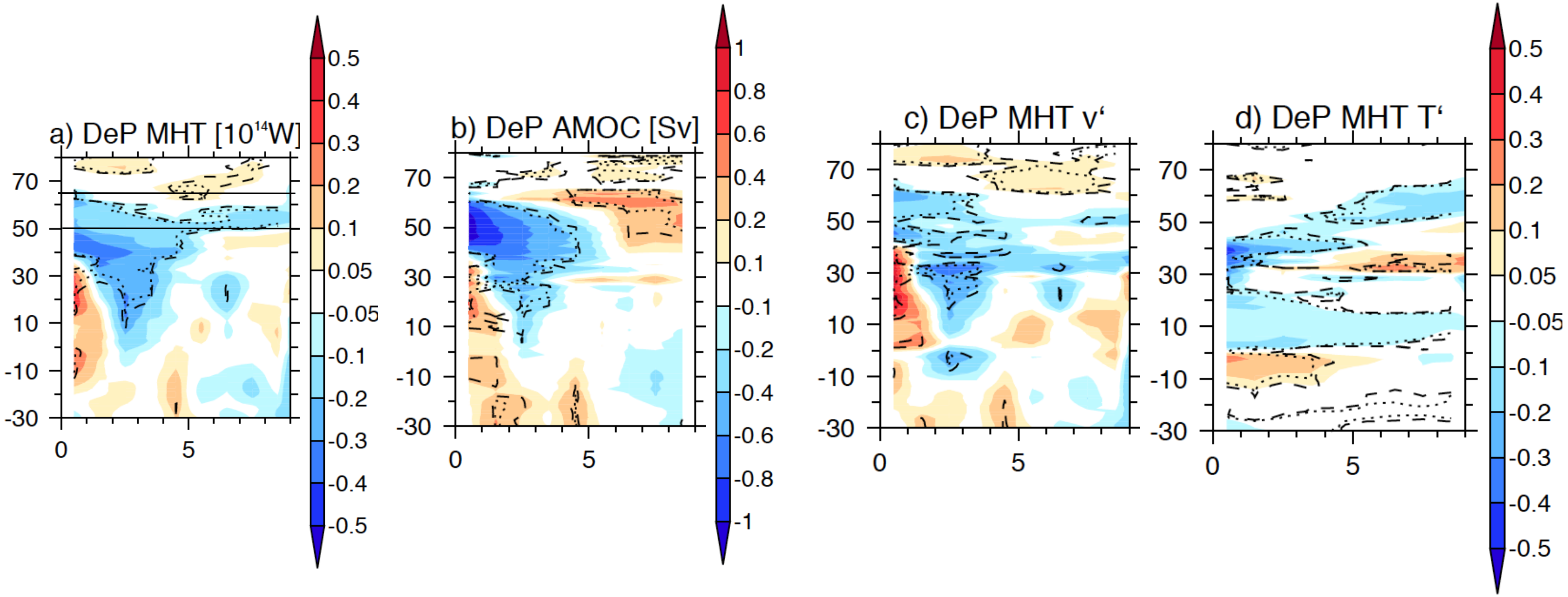
$\Delta E = H_O - H_A$

H_O = Ocean heat transport convergence
And
H_A = Atmospheric heat loss integrated over the latitude of the subpolar gyre (50N-65N)



Robson et al, 2014, Climate Dynamics

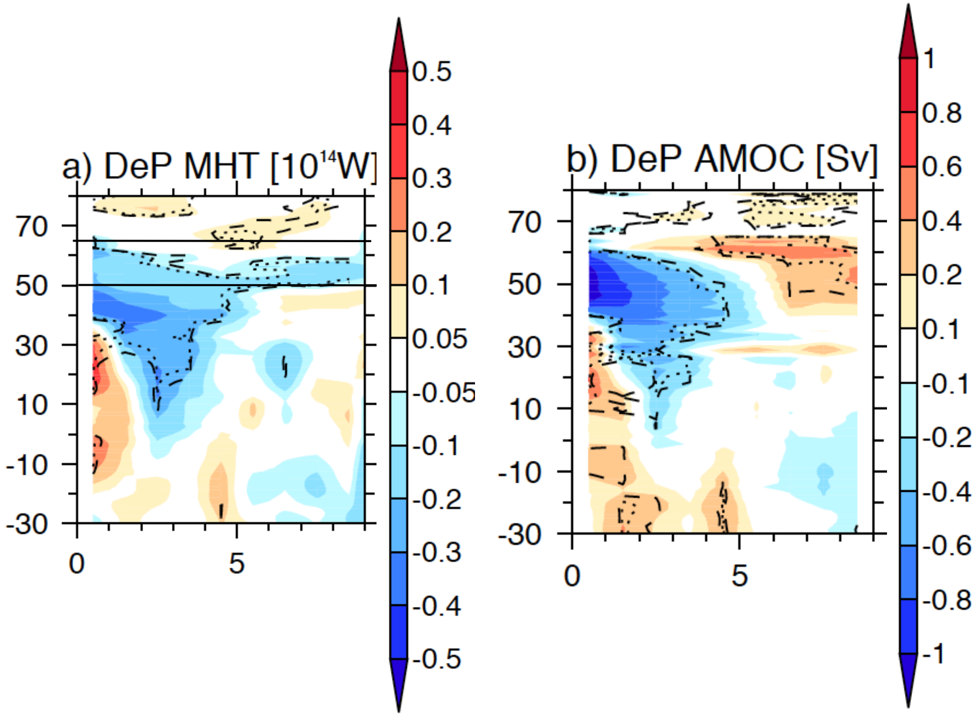
Ocean heat transport



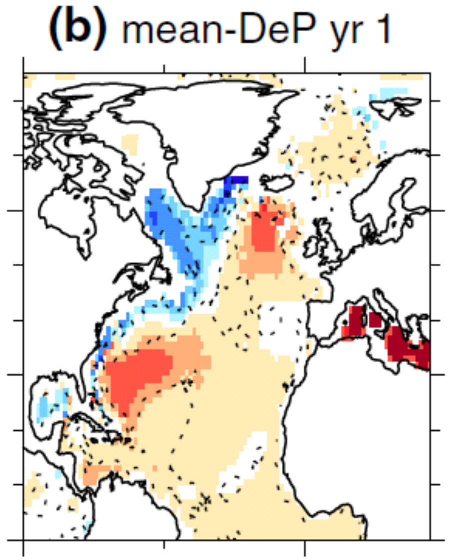
Weak ocean circulation → weak northward heat transport

Robson et al, 2014, Climate Dynamics

But why a weak AMOC?



1200-3000m Density anomalies



Robson et al, 2014, Climate Dynamics

1200-3000m Density anomalies

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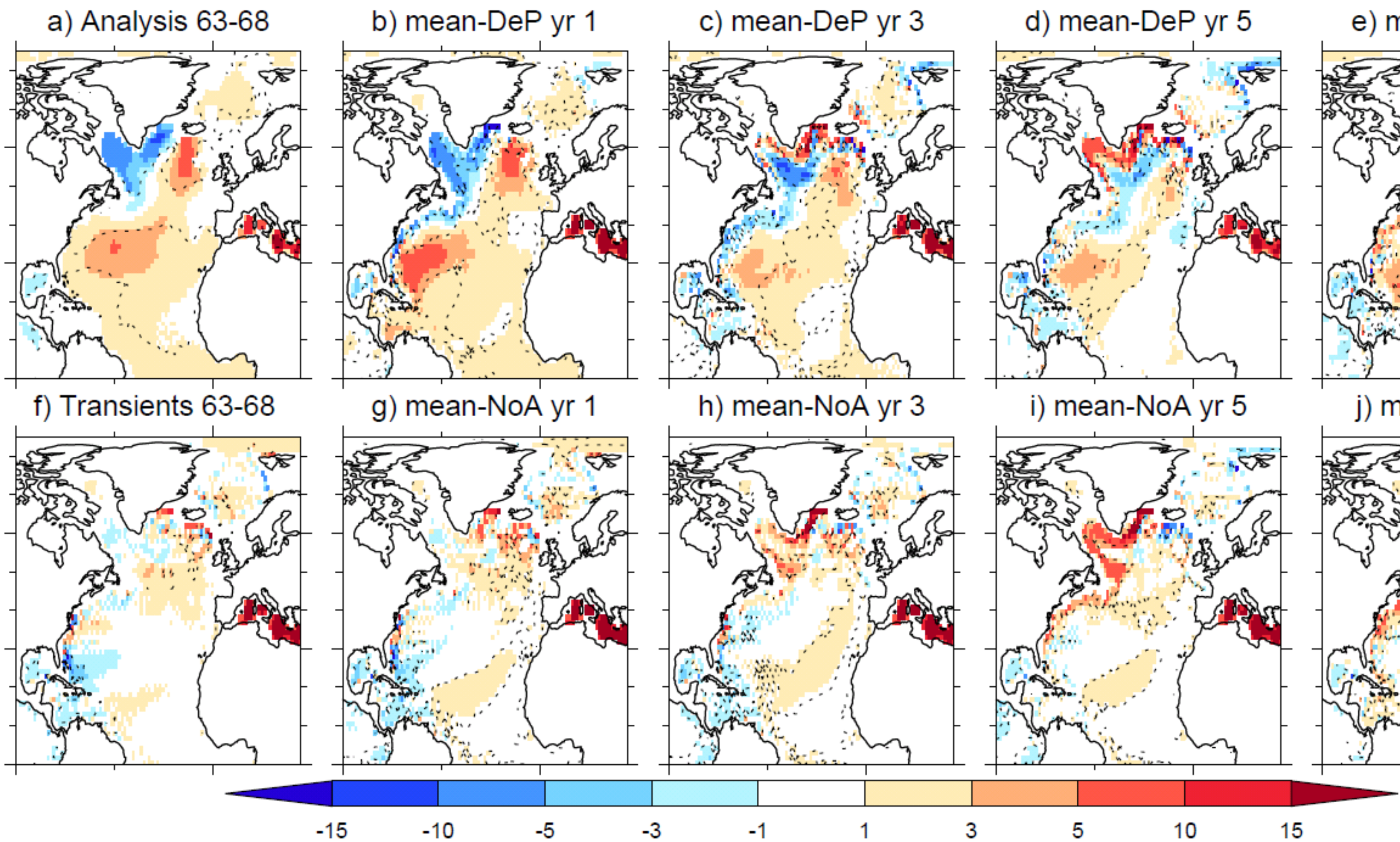

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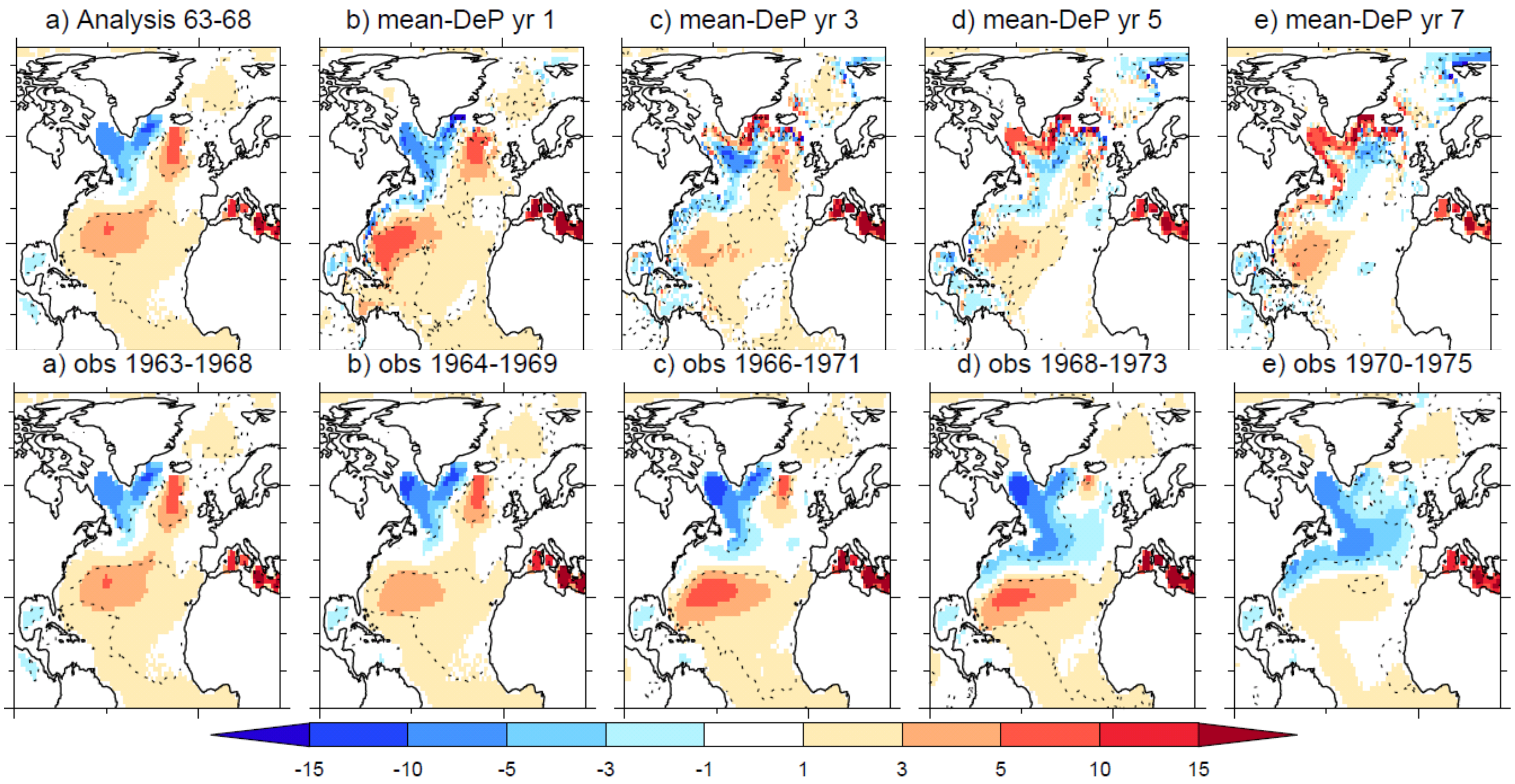
1200-3000m Density anomalies



Prediction of the GSA

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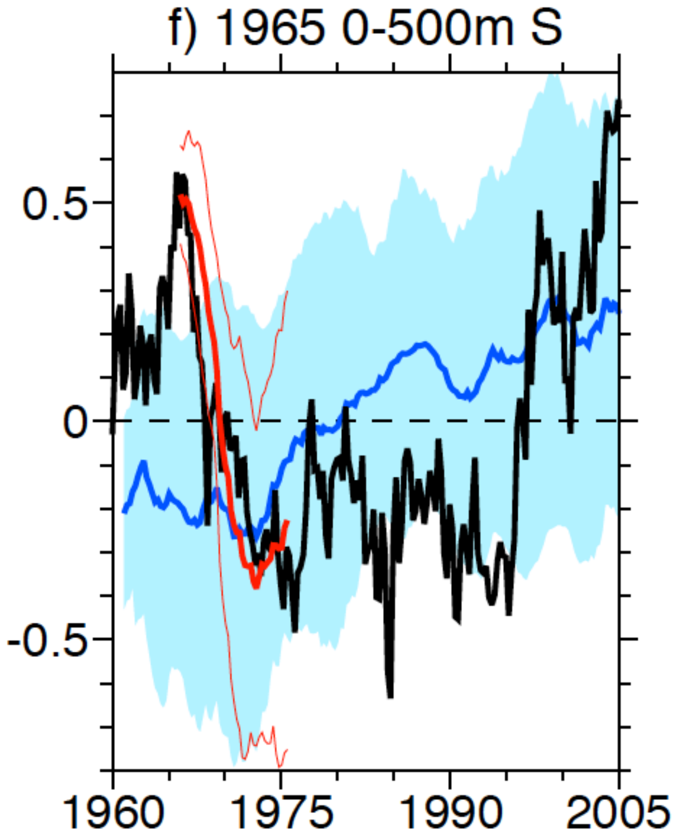
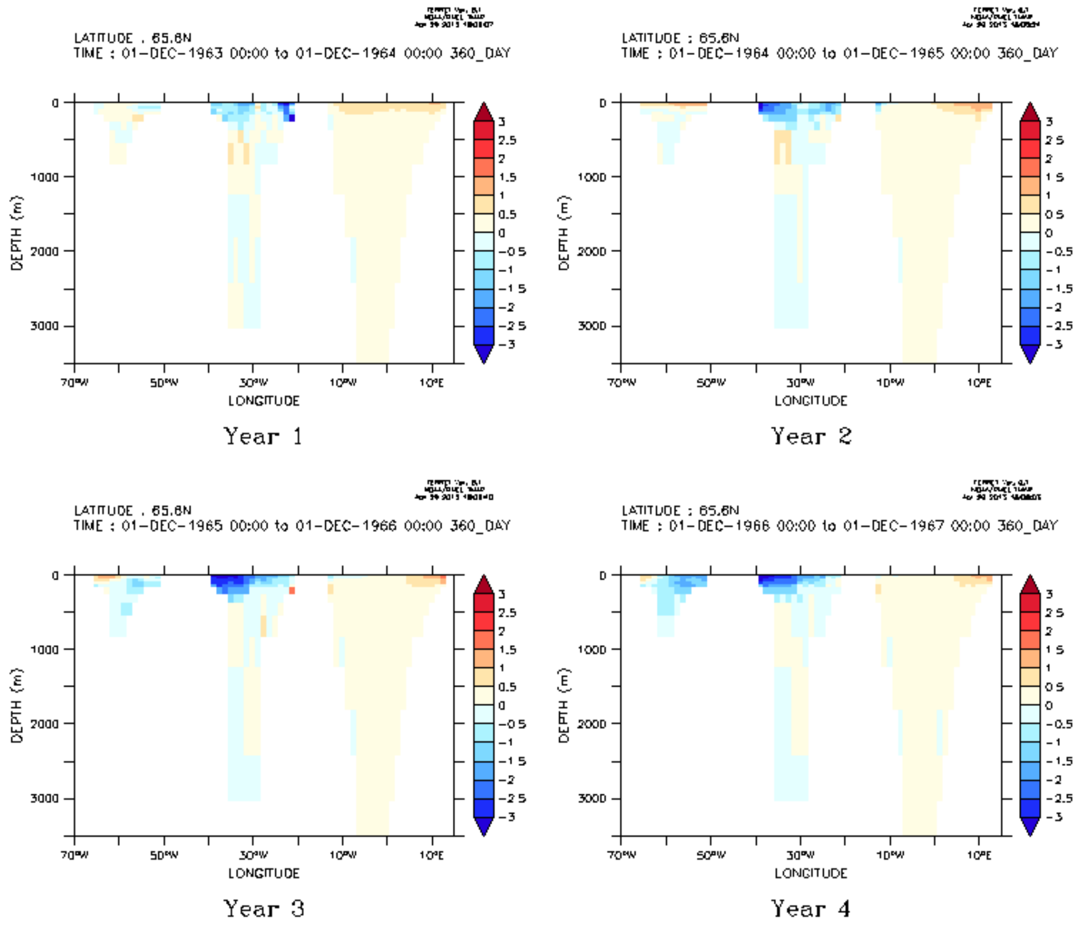


DePreSys also successfully predicts the Great Salinity anomaly



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Surface climate impact