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Predictability of the North Atlantic warming in the mid 1990s and its climate impacts

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Rowan Sutton and Doug Smith

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Mid 1990s North Atlantic warming

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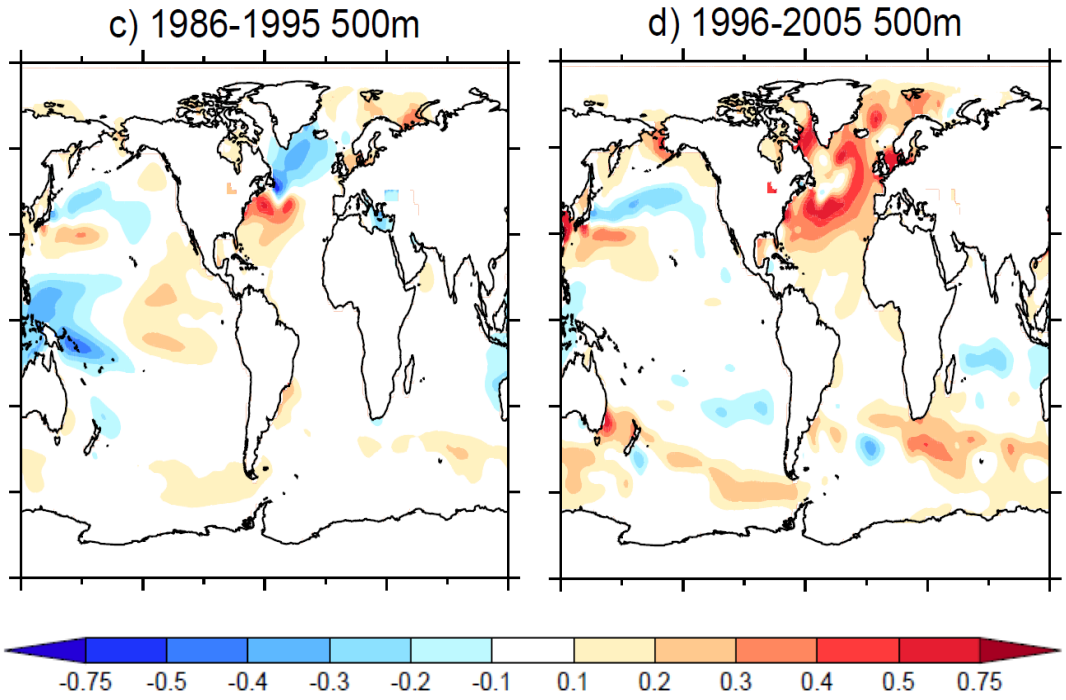

- Warming was largely due to ocean heat transport changes associated with increased overturning
- Consistent with a **lagged response of the buoyancy forced circulation** to the positive NAO that peaked in the late 1980s and early 1990

See Robson et al, 2012, JCLIM

- The mid 1990s Atlantic warming is an excellent case study for assessing decadal predictions

All anomalies relative to 1961-1990 climatology

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Two Questions

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1. **Was the warming of the North Atlantic subpolar gyre predictable?** (and what were the mechanisms?)
   - Robson et al, 2012, GRL (also see Yeager *et al*, 2012, J. Clim)

2. **Are predictions able to capture the wider climate impact?**
   - Robson et al, *In Press*, J. Clim

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Experiments and data

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- Predictions made with DePreSys PPE (Smith et al, 2010)
  - 9 member perturbed physics ensemble
  - Uses **anomaly assimilation** for 3D ocean T, and S, and atmospheric U,V,T and MSLP
  - Hindcasts initialised every November between 1960-2005
- Comparison ensemble that does not assimilate observed information (NoAssim PPE)

- Compare the predictions with observations
  - HadISST
  - CRU TS 3.0
  - HadSLP
  - NCEP reanalysis

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Subpolar Gyre heat content anomalies

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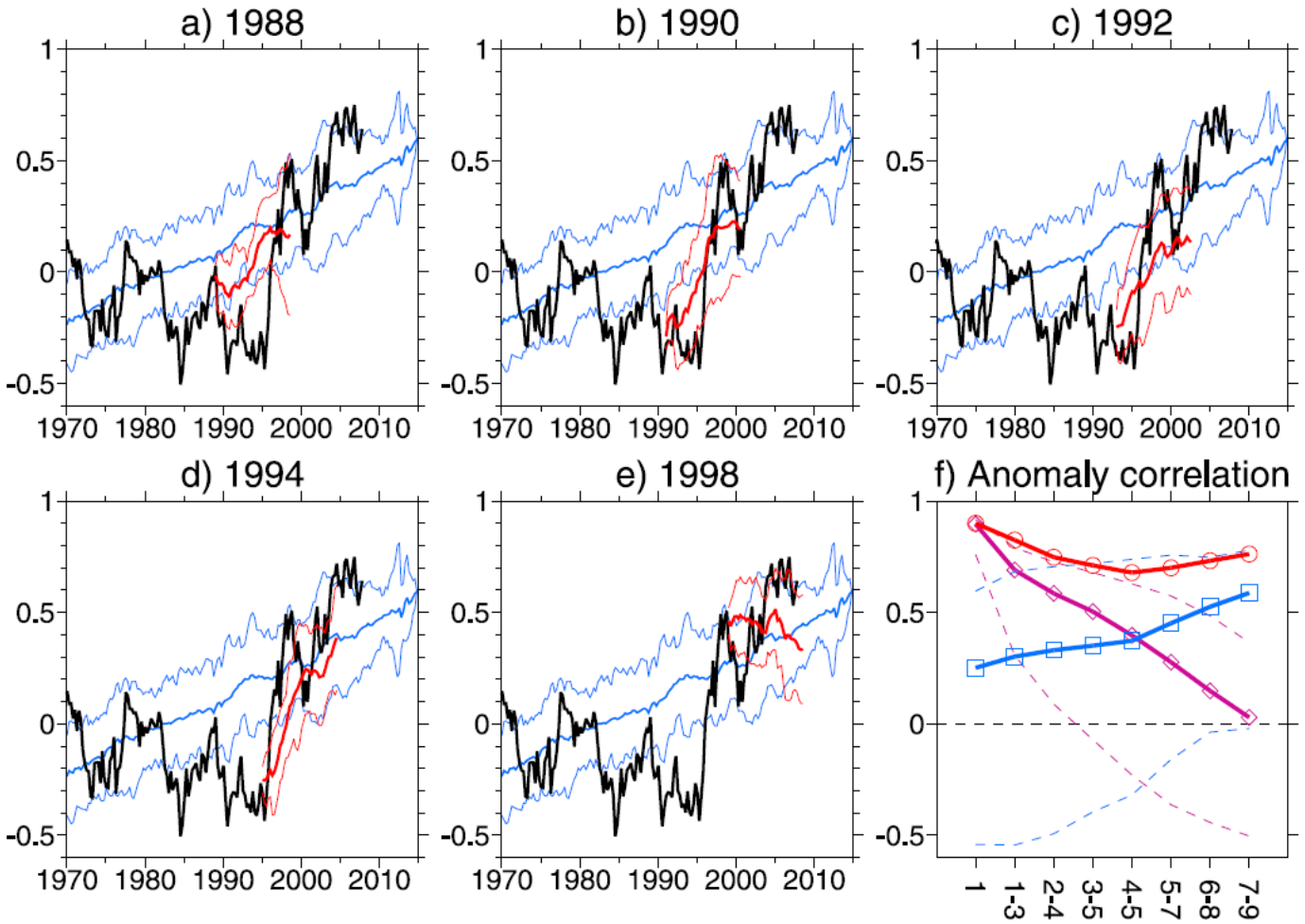

0-500m heat content anomaly

Obs
DePreSys
NoAssim
Persistance

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Subpolar heat budget Integrated over years 1-3

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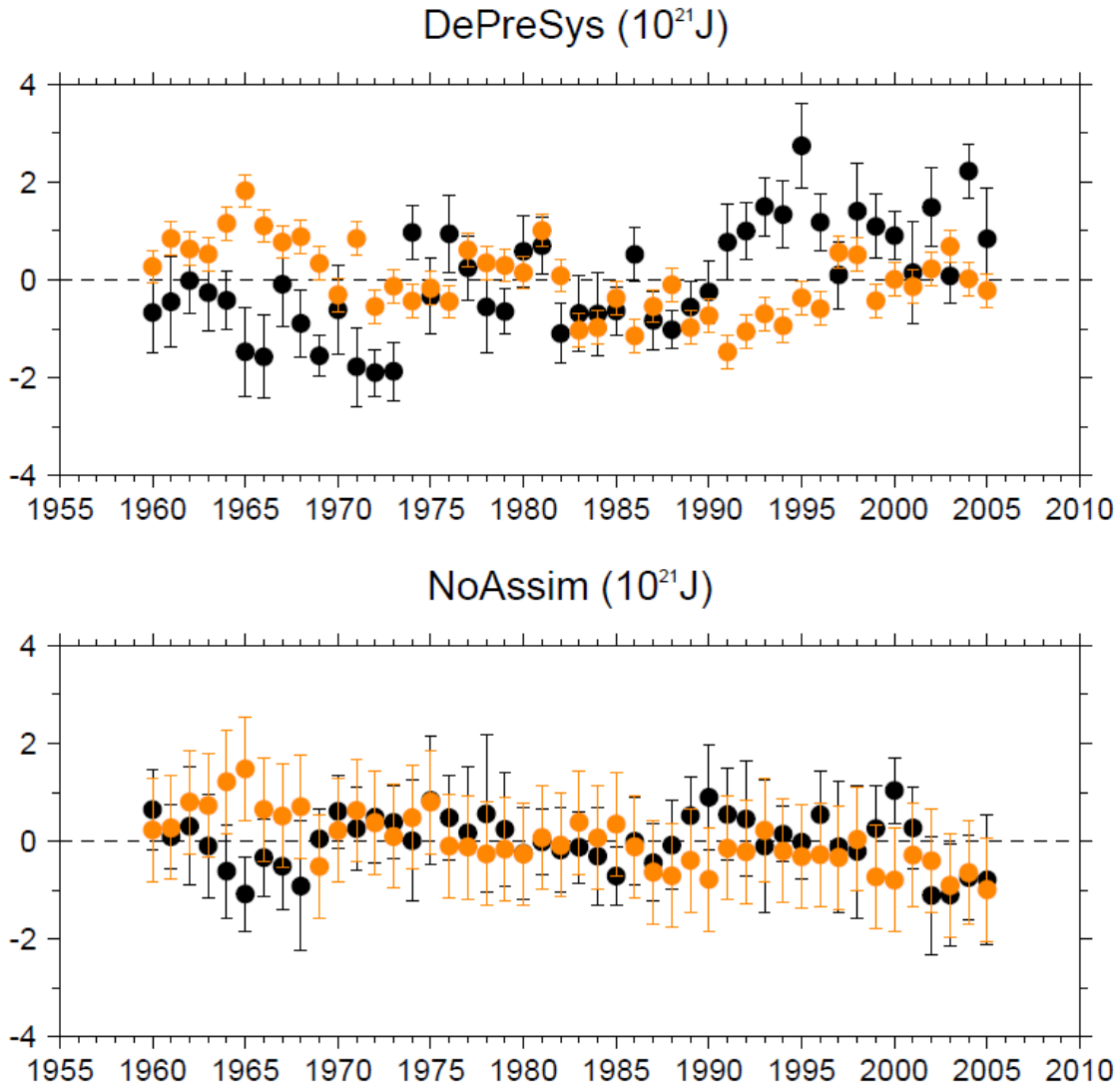
Ocean heat transport convergence and **atmospheric heat loss** integrated over the subpolar gyre (60W-10W, 50N-65N)

Ocean heat transport convergence plays a key role in the successful prediction of the SPG warming



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Subpolar heat budget Integrated over years 1-3

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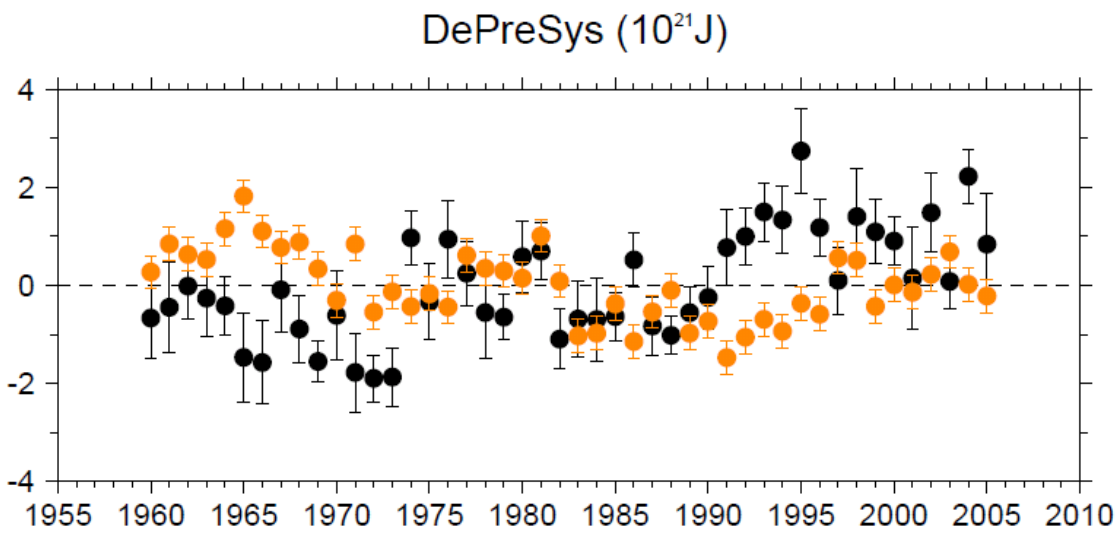
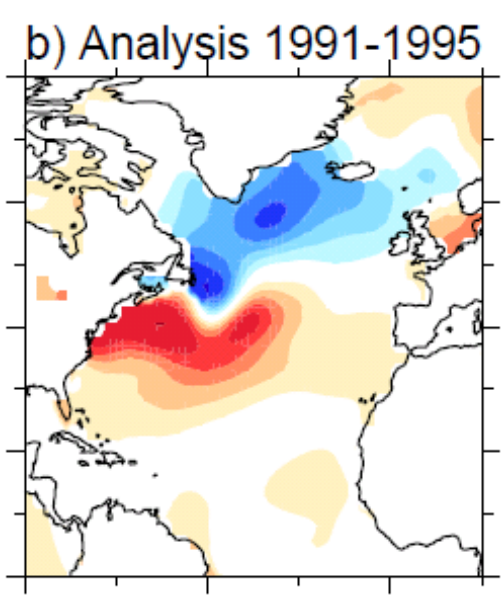
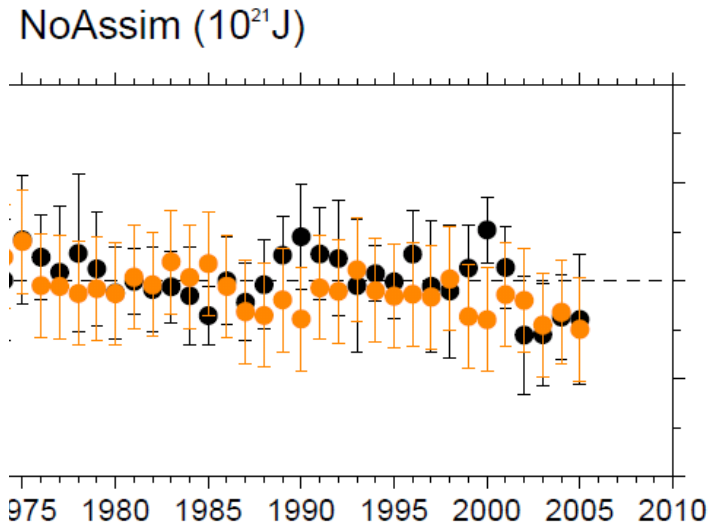
Ocean heat transport convergence and **atmospheric heat loss** integrated over the subpolar gyre (60W-10W, 50N-65N)

Ocean heat transport convergence plays a key role in the successful prediction of the SPG warming

What is the mechanism?







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Role of ocean heat transport changes

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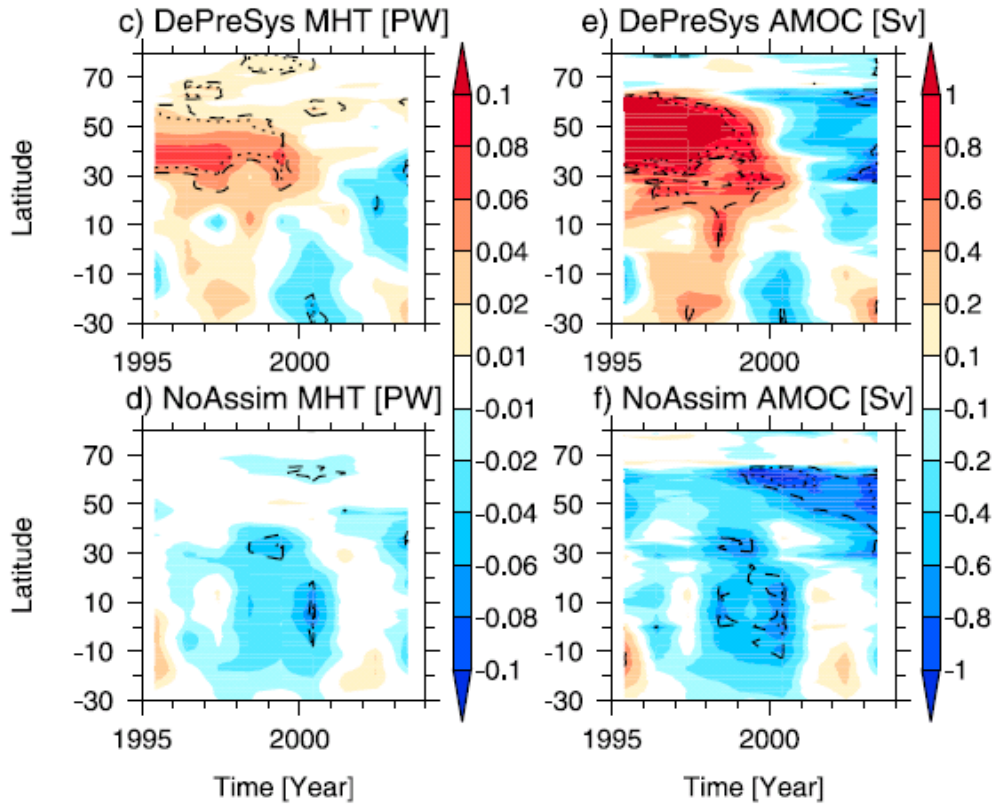

November 1994 hindcast

Initialisation of strong AMOC key to predict the warming

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Role of ocean heat transport changes

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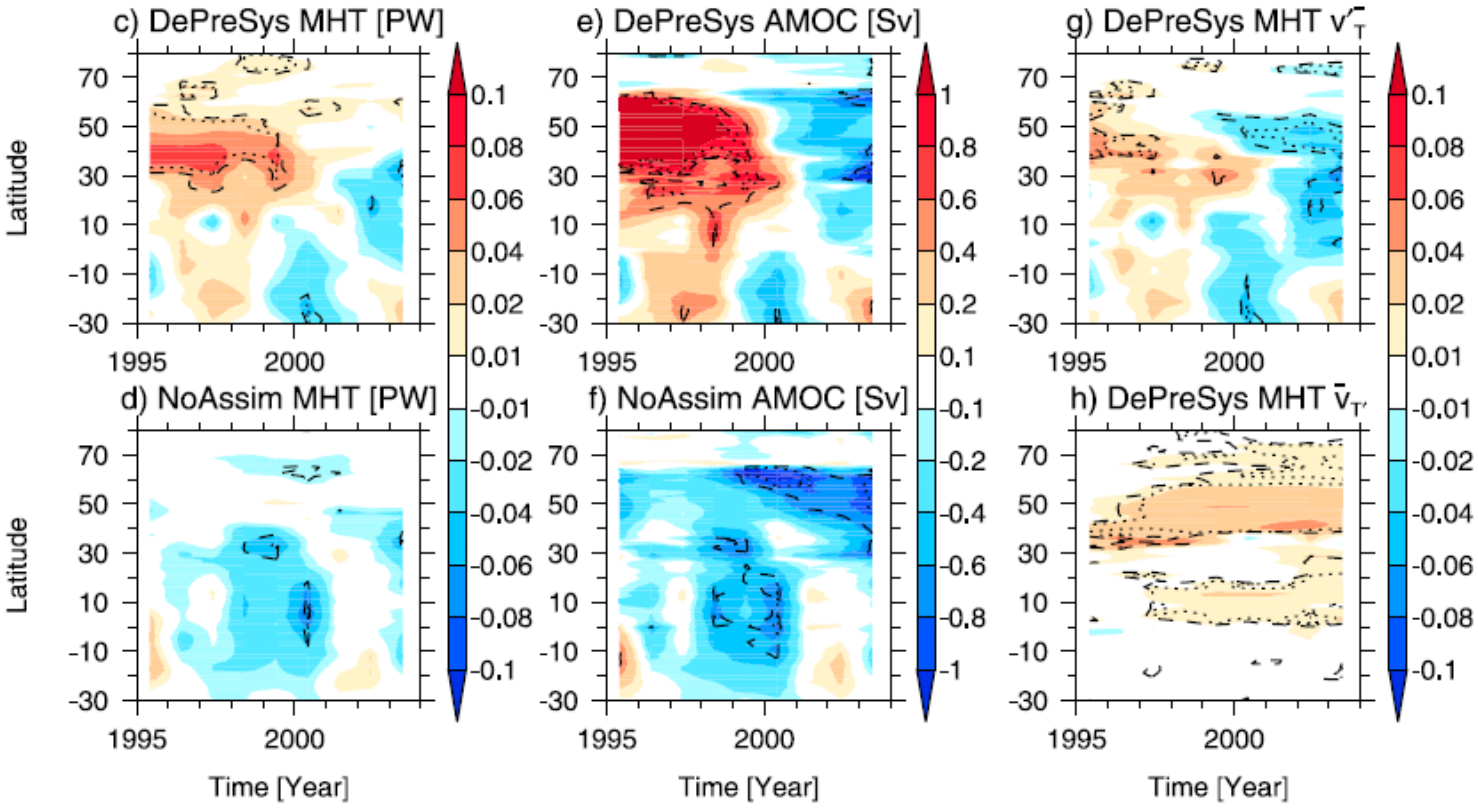

$\overline{v'T}$

$\overline{vT'}$

November 1994 hindcast

Initialisation of strong AMOC key to predict the warming

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What about the climate impact?

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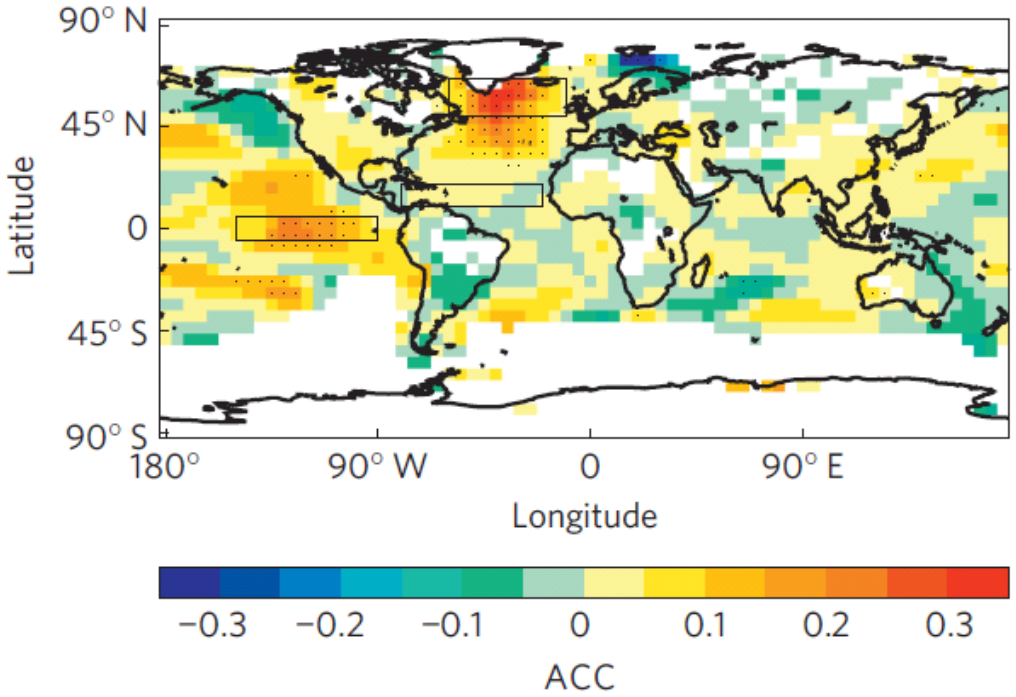
JJASON Temp Yrs 1-5 (DePreSys – NoAssim)



(from Smith et al, 2010)

- So far, there is much less evidence for initialisation improving predictions over land **– A surprise?**

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What about the climate impact?

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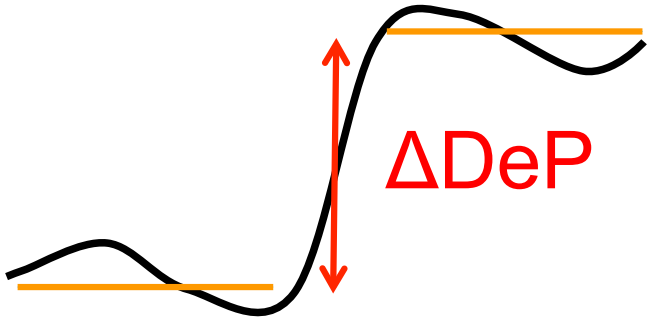
- There are problems for examining the skill of surface variables
  - Limited # hindcasts & ensemble members etc; initial shock; signal to noise
- **Is there an impact of initialisation in DePreSys?**



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

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What about the climate impact?

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- There are problems for examining the skill of surface variables
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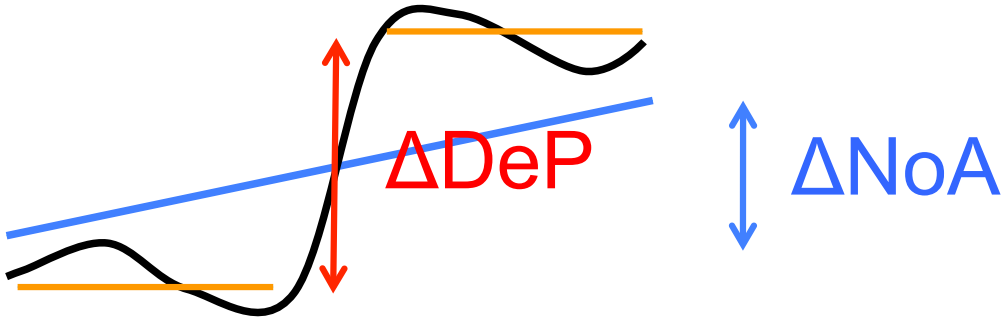

Examining difference relative to NoAssim removes forced trend

Impact of initialisation = ΔDeP – ΔNoA

Focus on years 2-6, comparing with detrended observations

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Predictions of SST

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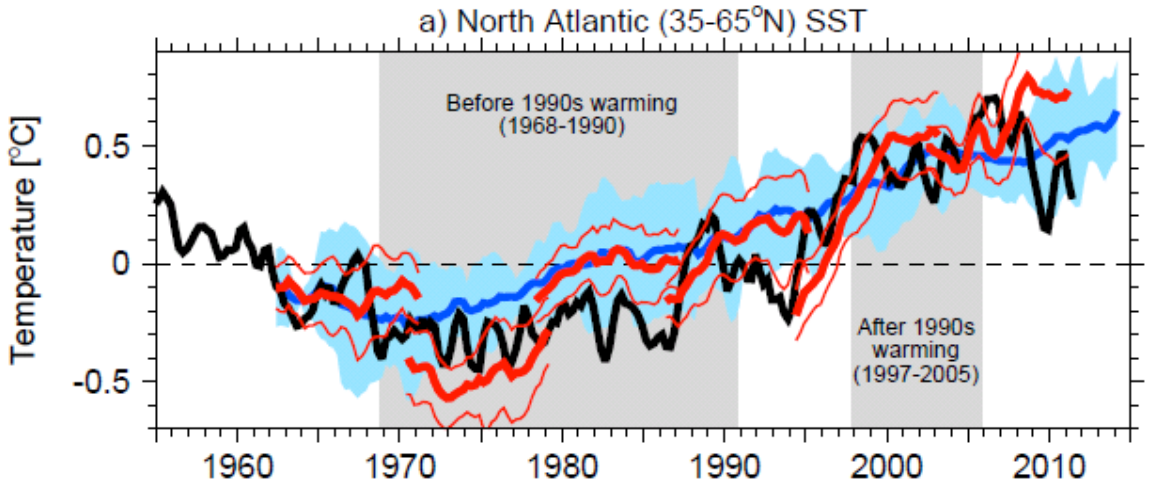

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Predictions of SST

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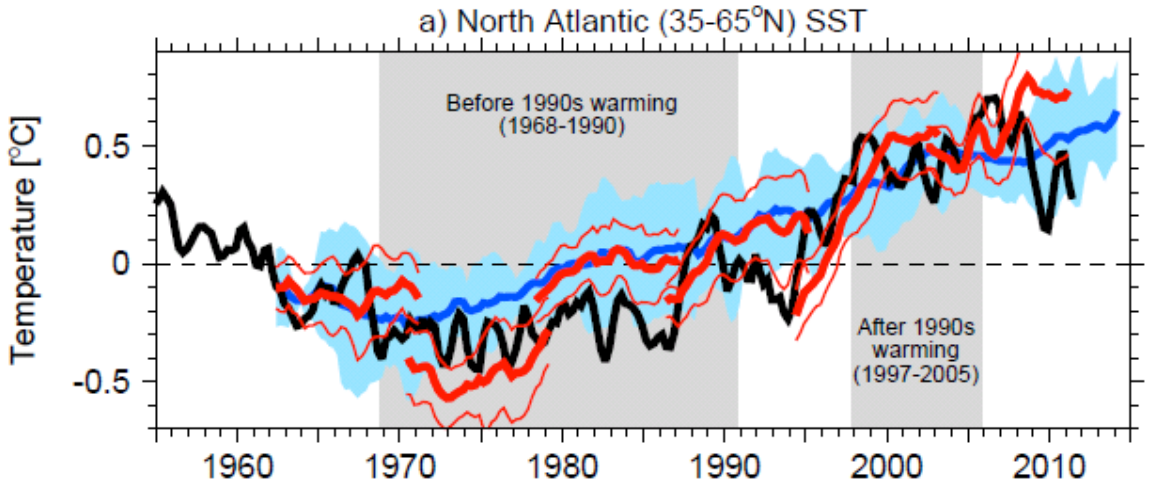

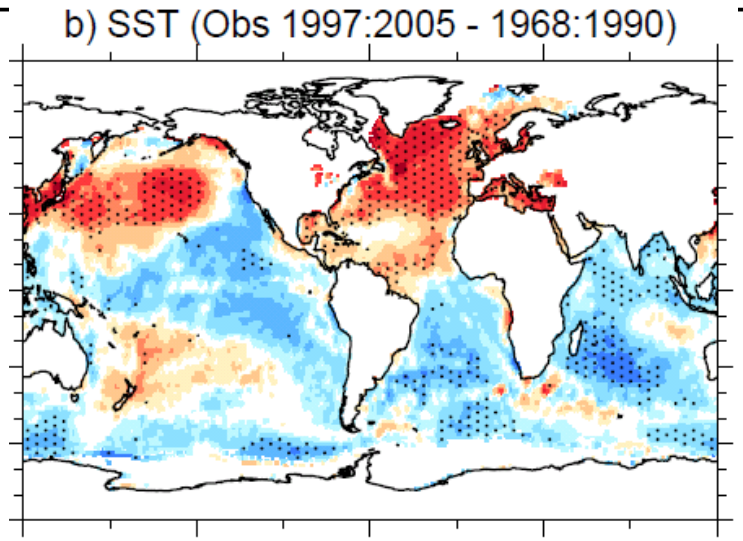

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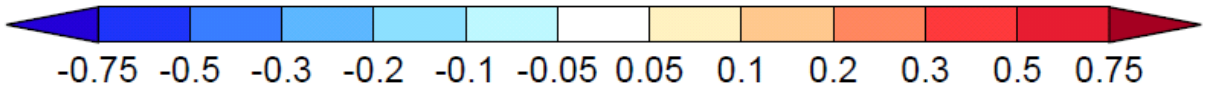

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Predictions of SST

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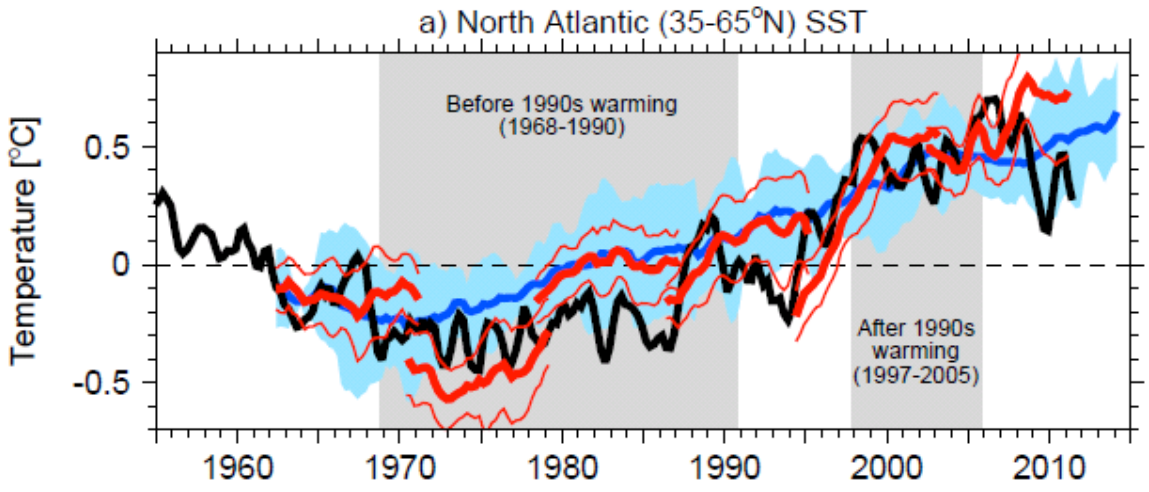

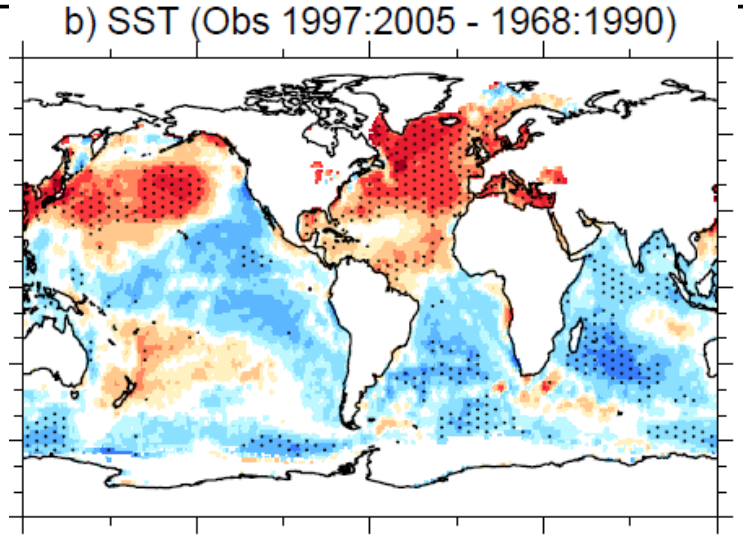

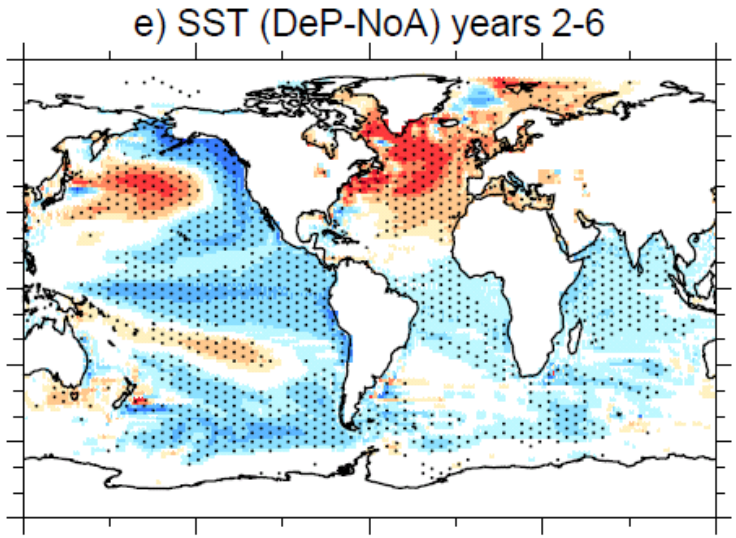

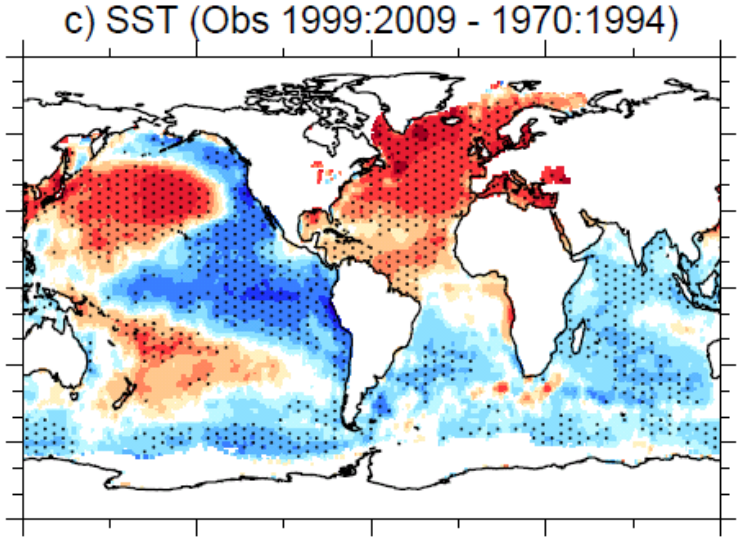

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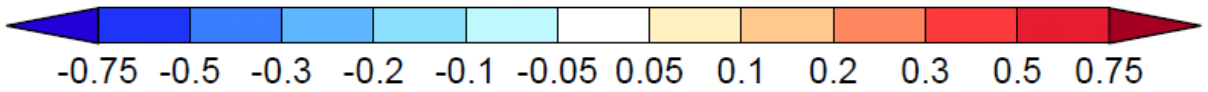

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Surface climate - MAM

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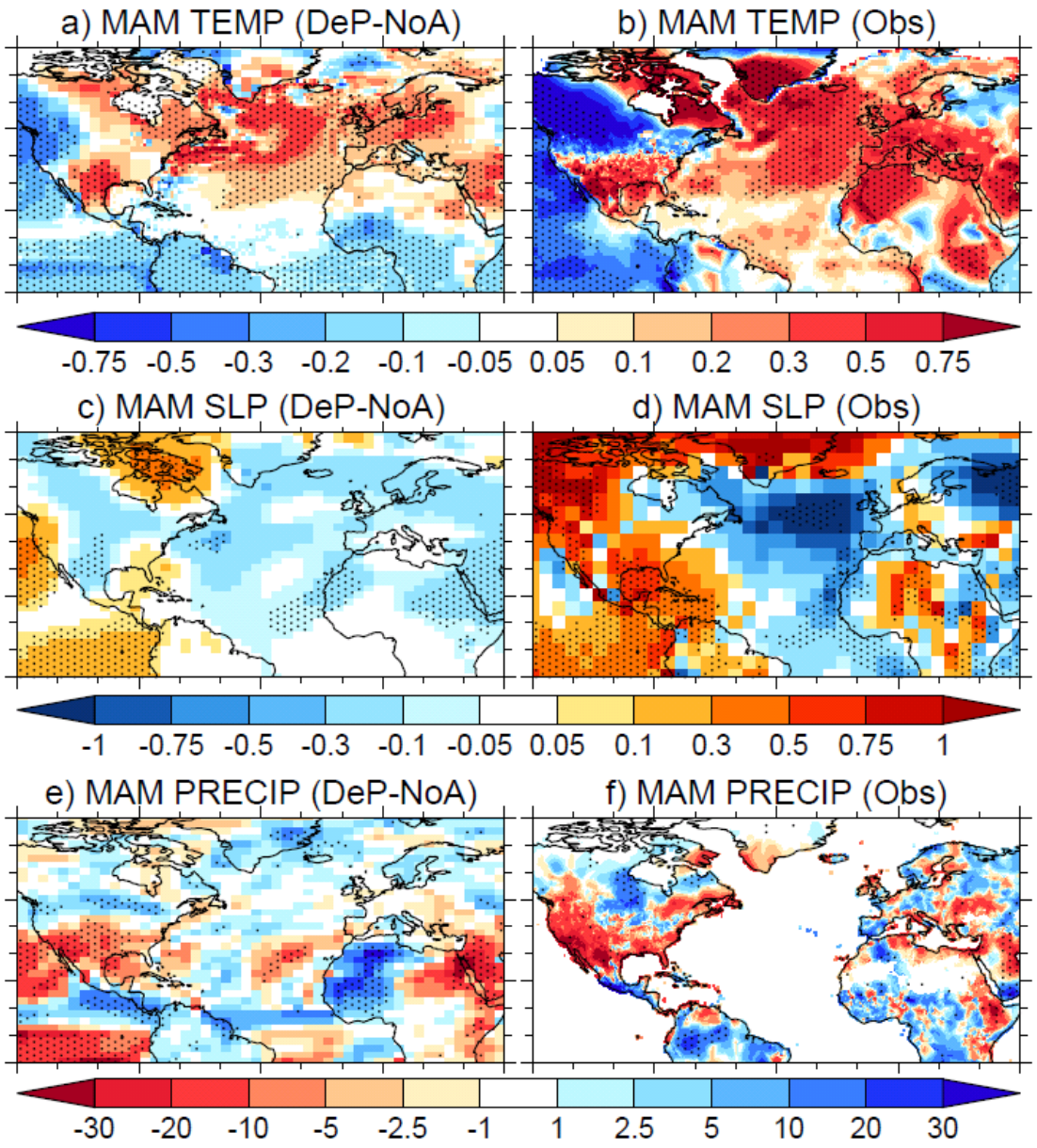
Model

(97-05) – (68-90)

Years 2-6

Obs

(99-09) – (70-94)



°C

hPa

% of the mean

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Surface climate - JJA

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Model

(97-05) – (68-90)

Years 2-6

Obs

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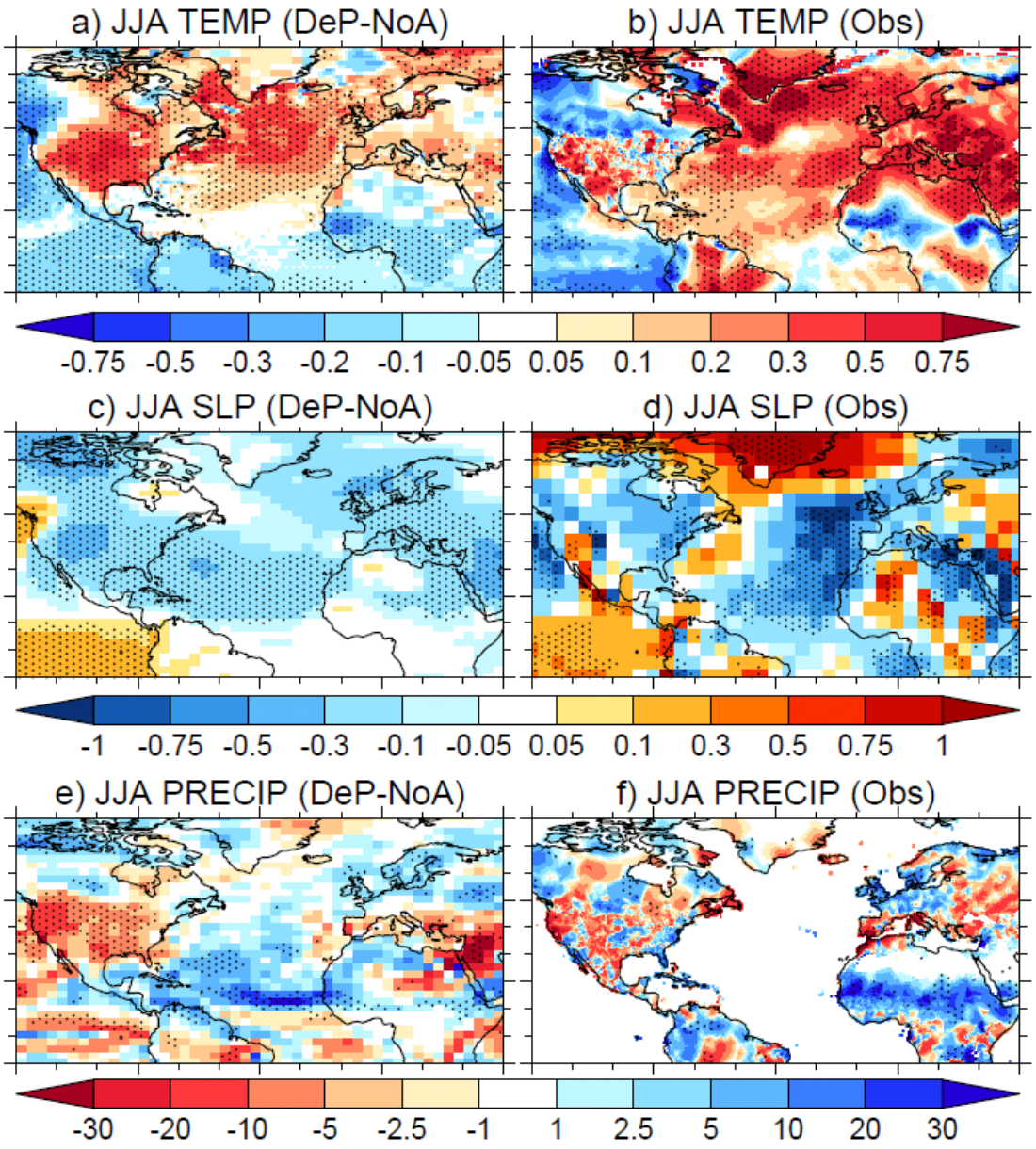

°C

hPa

% of the mean

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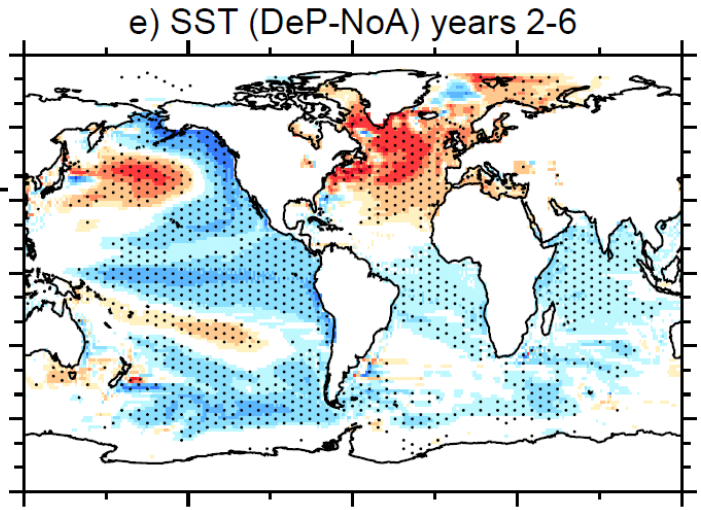
What about the role of the Pacific?



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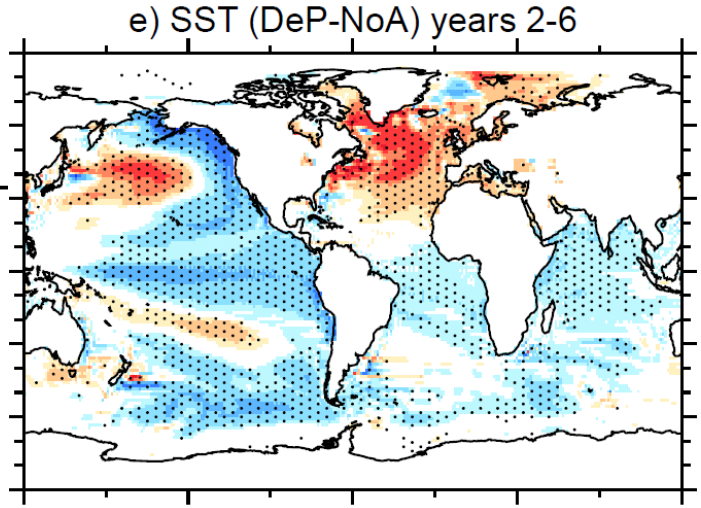
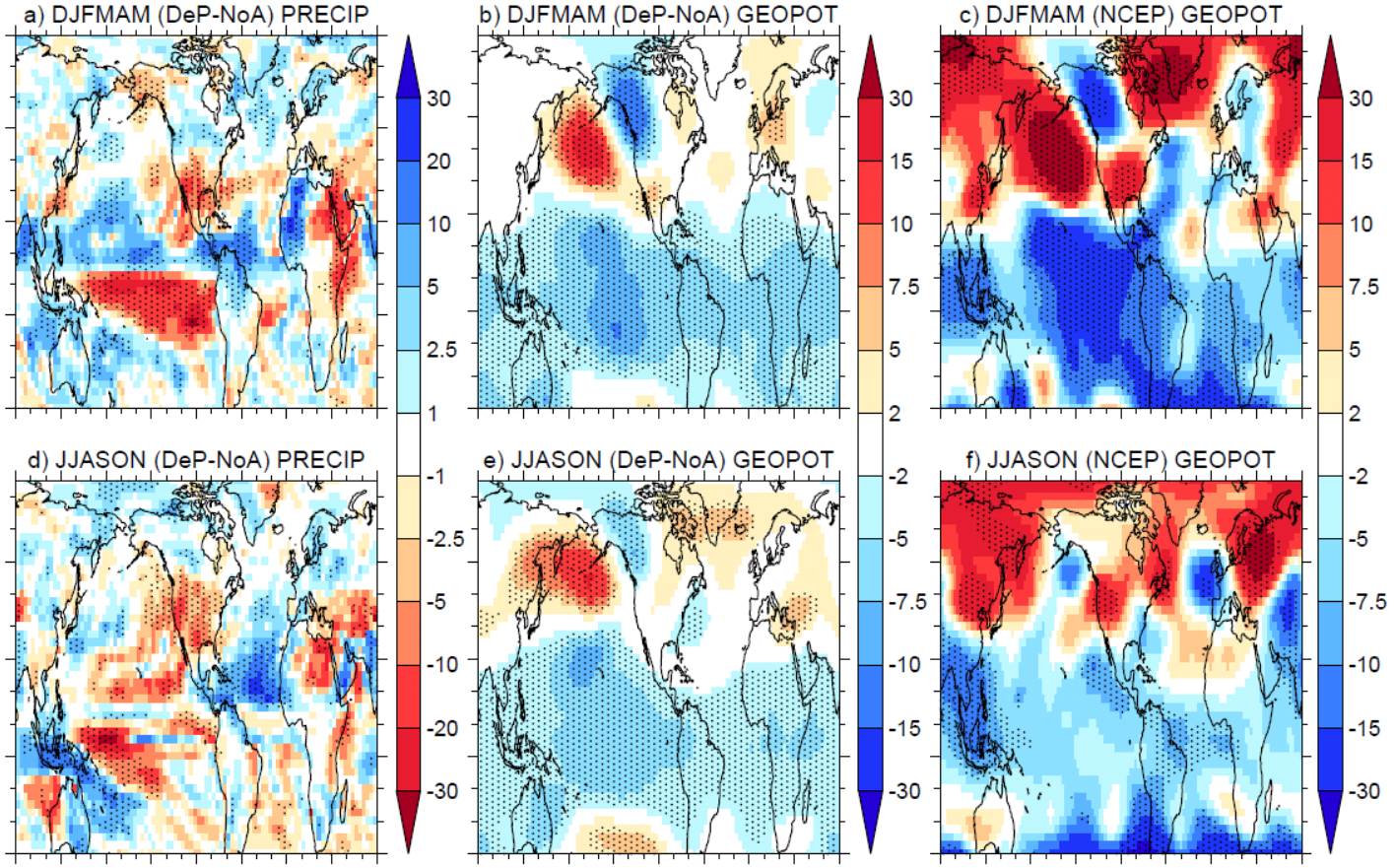
What about the role of the Pacific?

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)

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Conclusions

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- DePreSys PPE is able to predict the warming of the North Atlantic subpolar gyre in the mid 1990s.
- Anomalously strong **ocean heat transport**, which itself is due to the initialisation of the **dynamics**, i.e. a **strong AMOC**, is **key** - consistent with earlier work (e.g. Robson *et al*; 2012, Yeager *et al*; 2012)
- Initialisation does have an impact on the prediction of surface climate variables **over land** – "skill" over North America and Europe.
- The impact of initialisation **lasts beyond the first year.**
- DePreSys also predicts a **cooling of the tropical east Pacific** in the 2000s – The cooling appears important for predicting the climate impacts over North America

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Mid 1990s rapid warming

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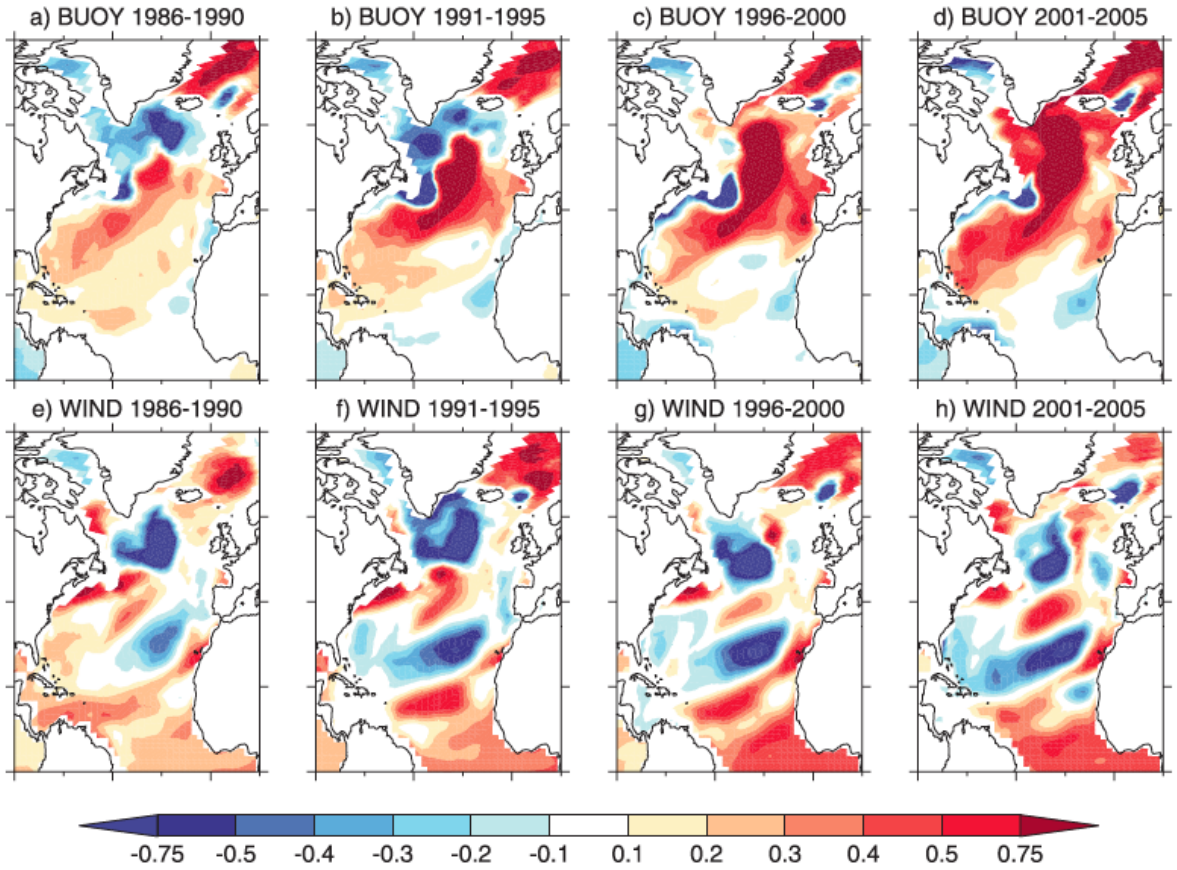

- Warming was largely due to ocean heat transport changes associated with increased overturning
- Consistent with a **lagged response** to the positive NAO that peaked in the late 1980s and early 1990
- The mid 1990s Atlantic warming is an excellent case study for assessing decadal predictions

Robson et al, 2012; J Clim

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All anomalies relative to 1961-1990 climatology

0-500m heat content anomaly

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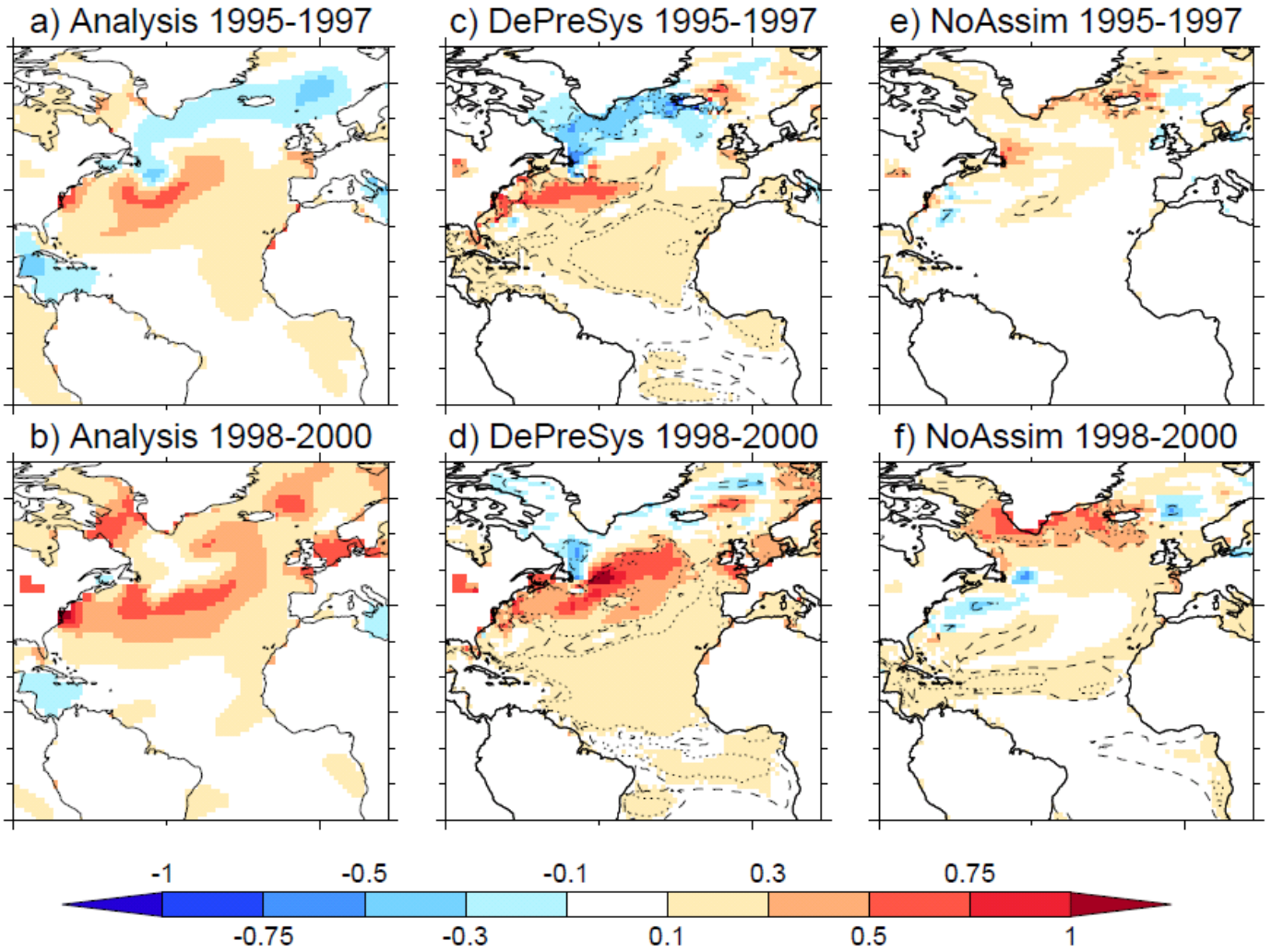

November 1994 hindcast

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1991-1996 hindcast prediction

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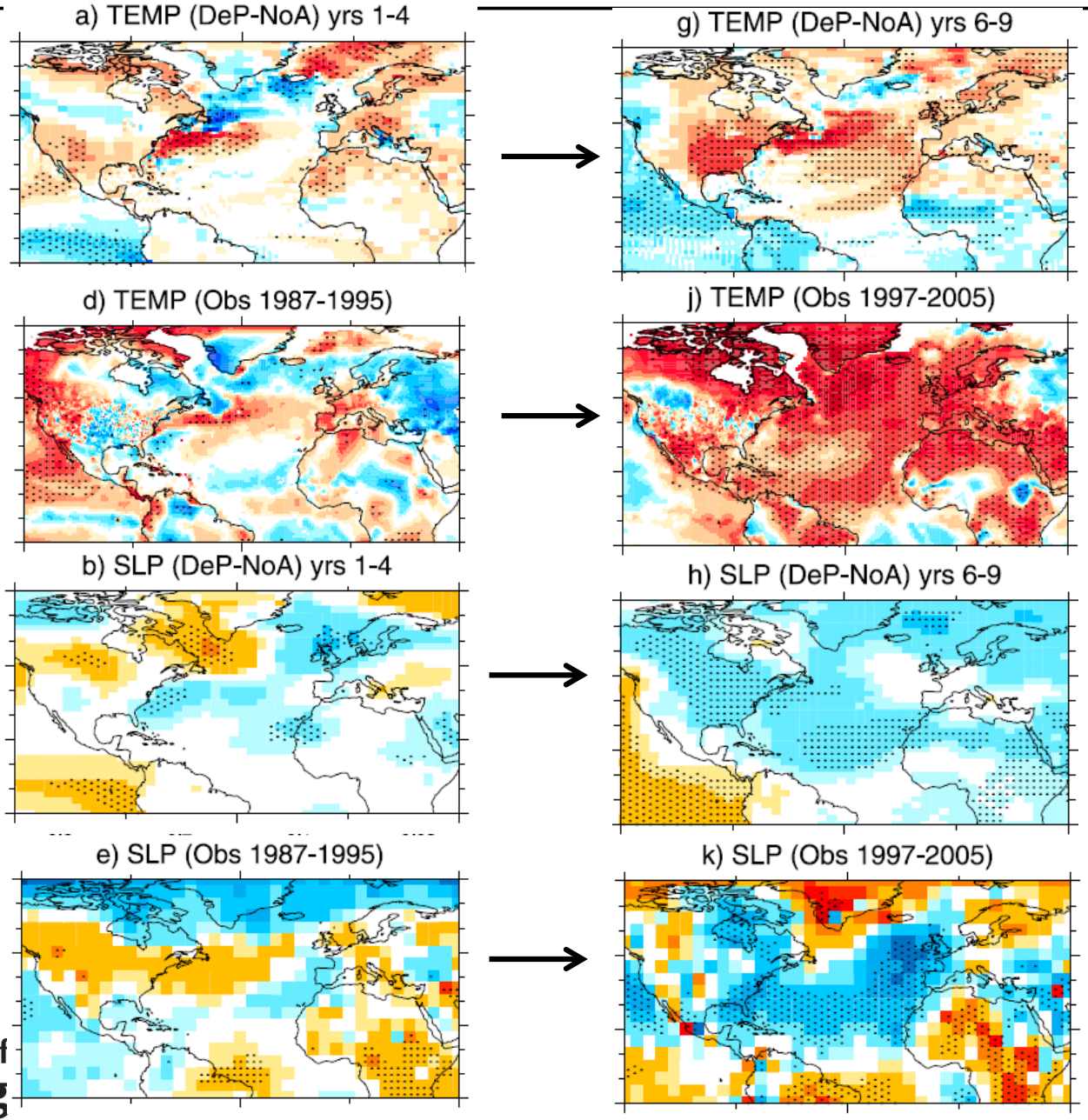

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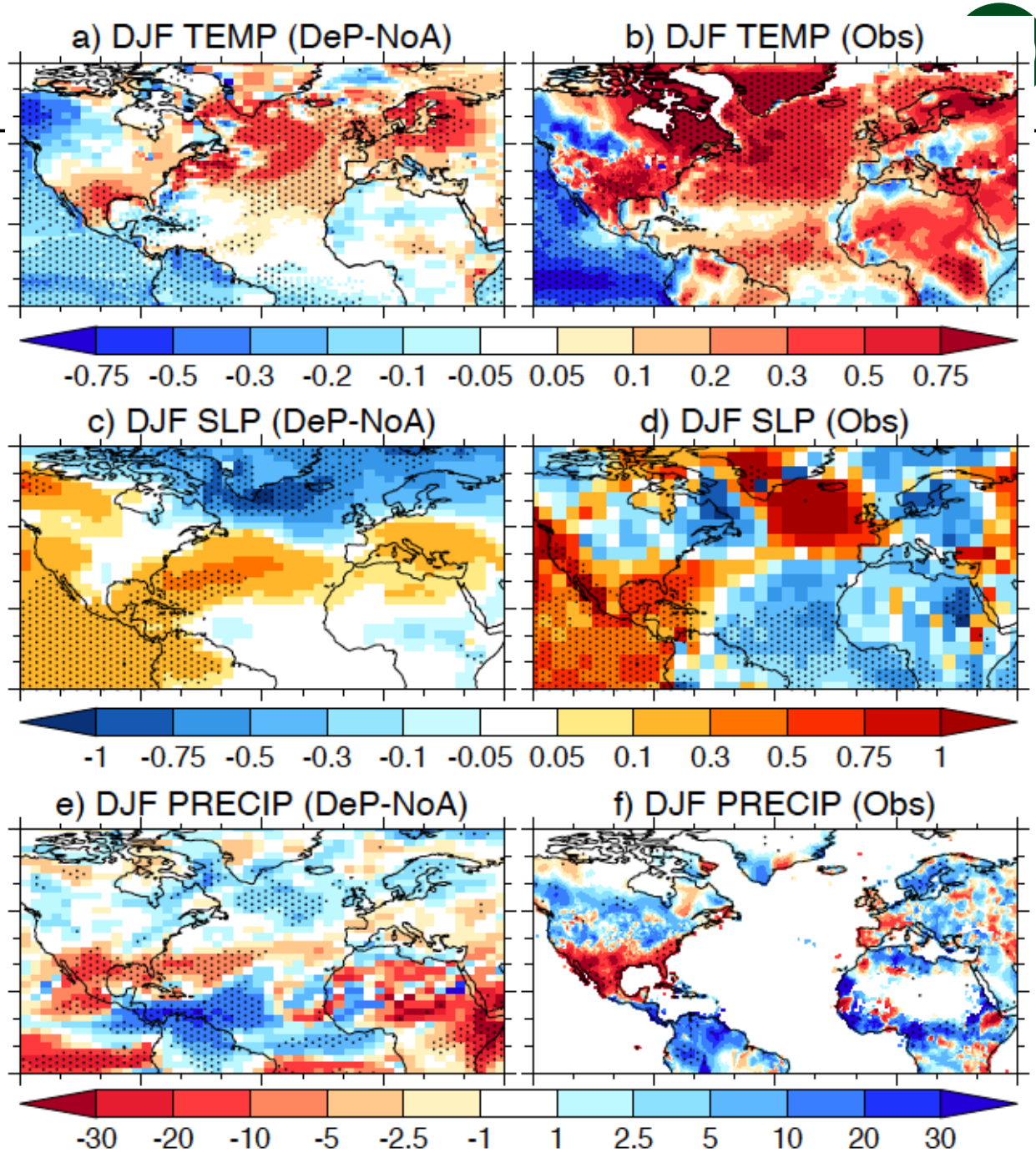

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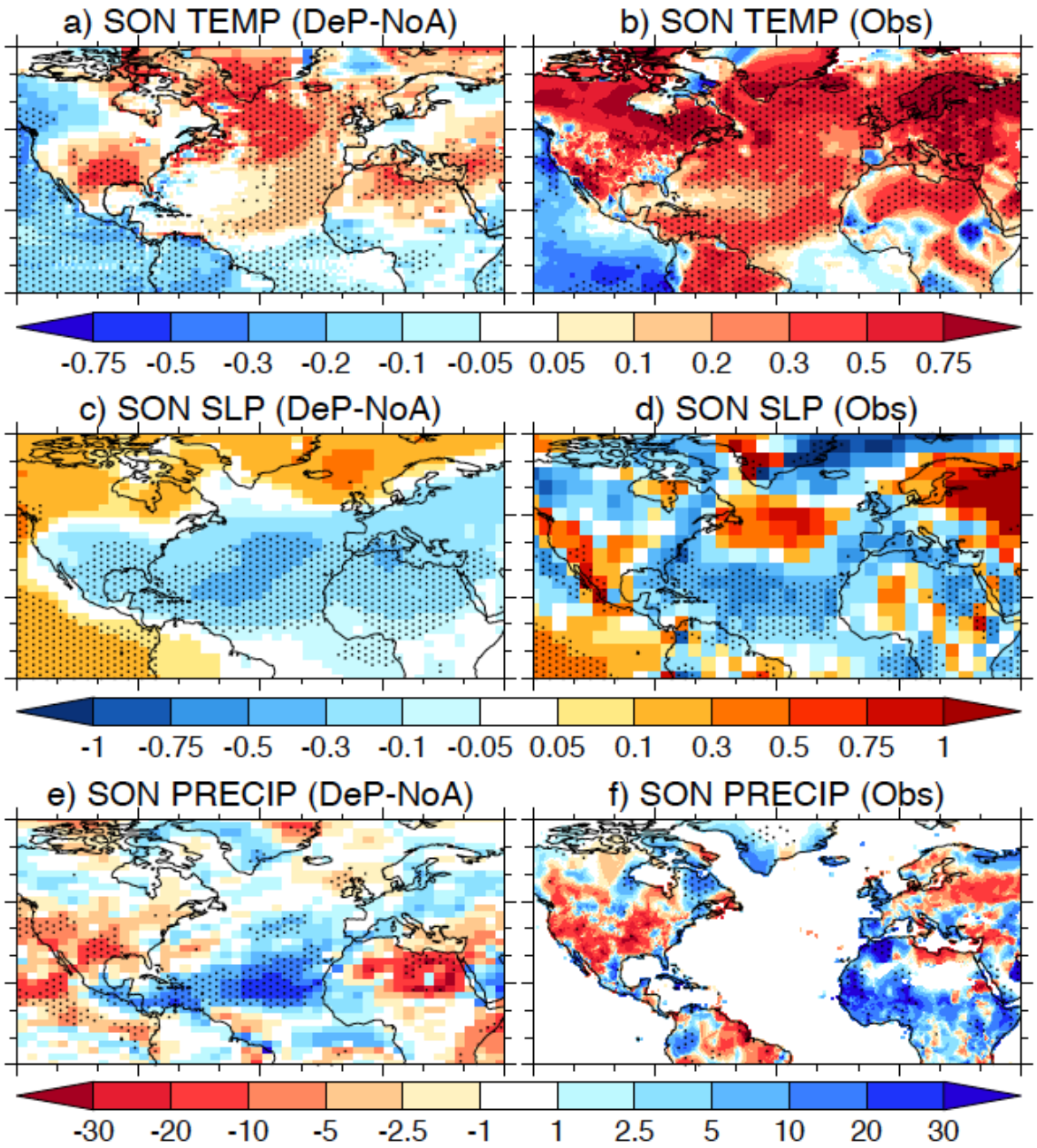

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Mean DePreSys - NoAssim

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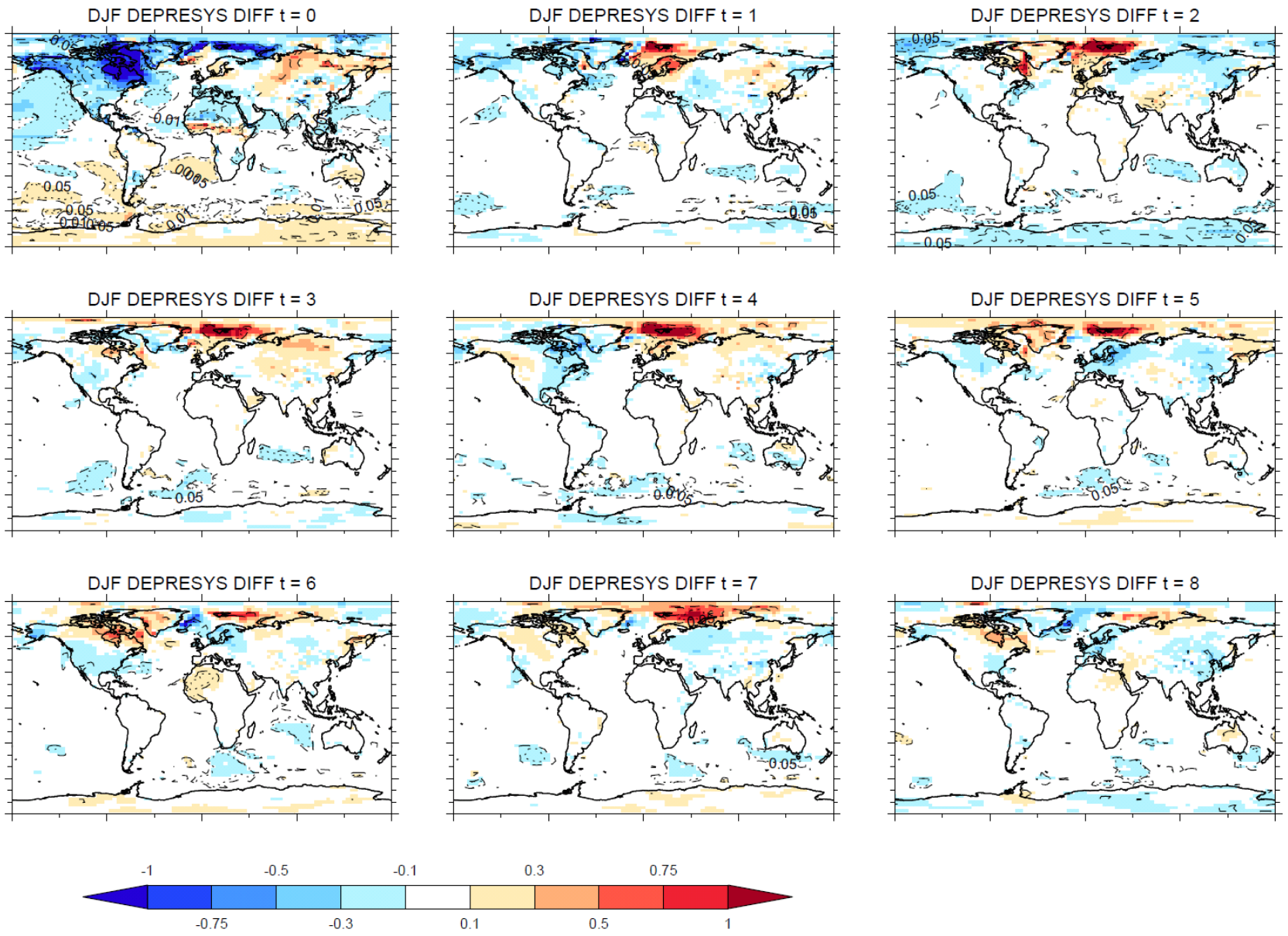

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MAM SAT 5yr

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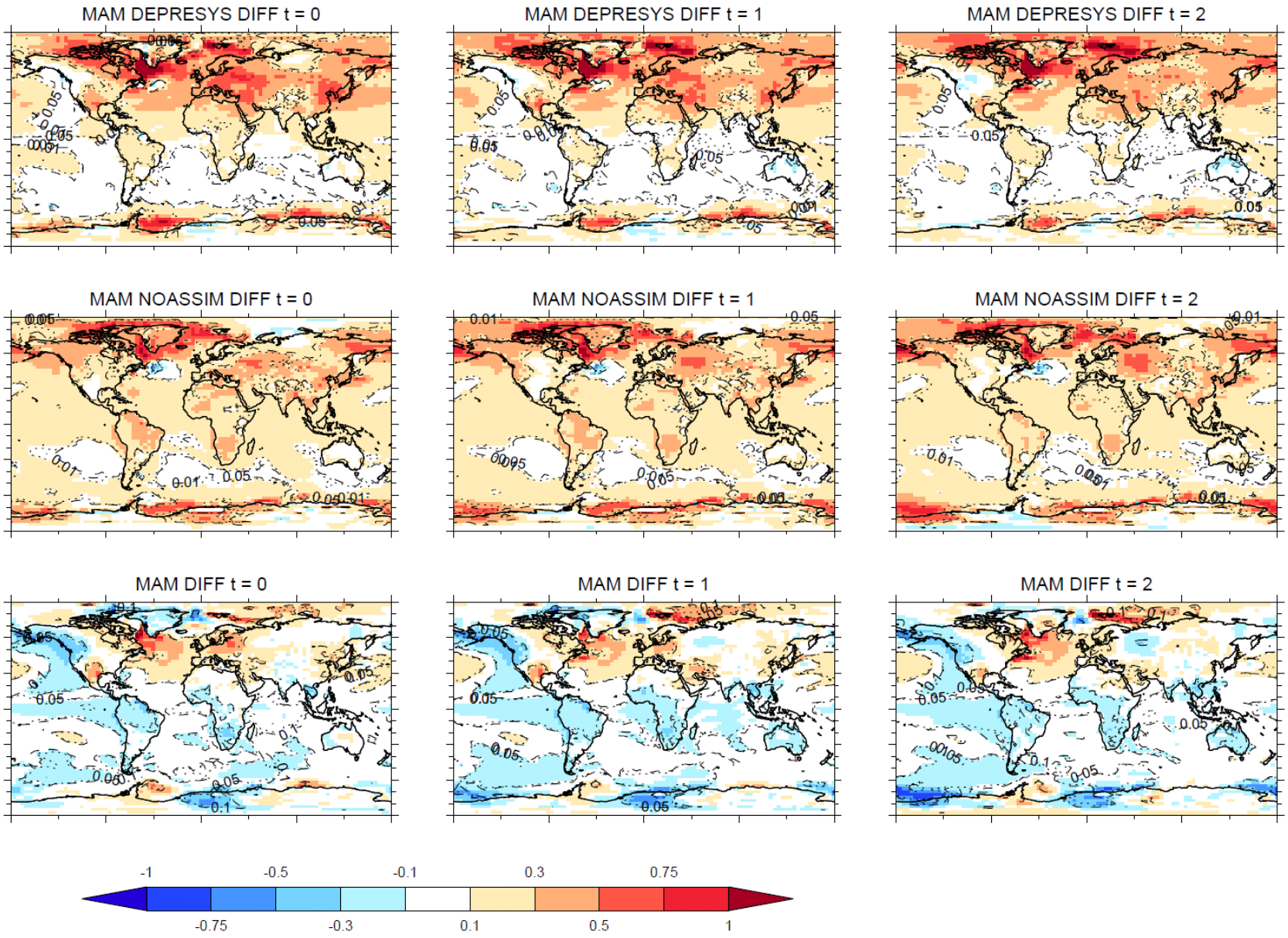

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MAM SAT 1yr

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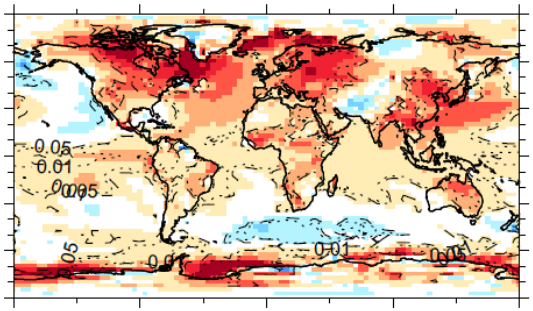
MAM DEPRESYS DIFF t = 0



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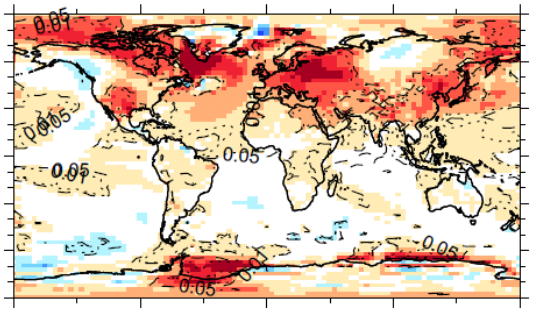

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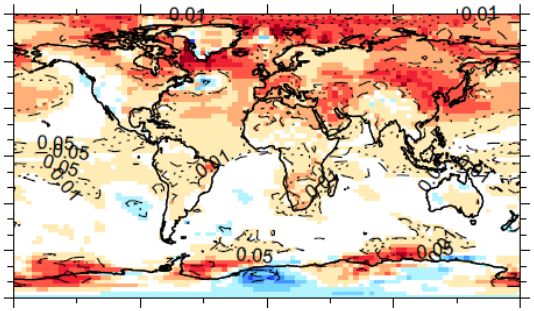

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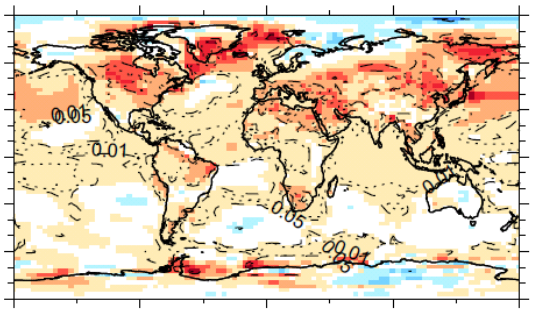

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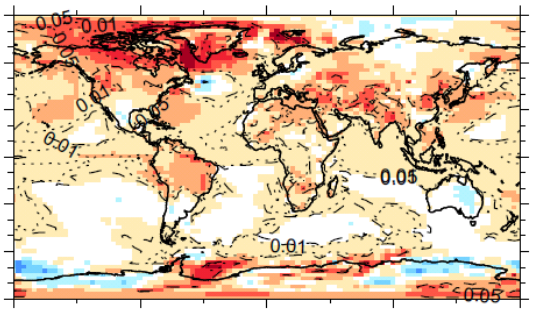

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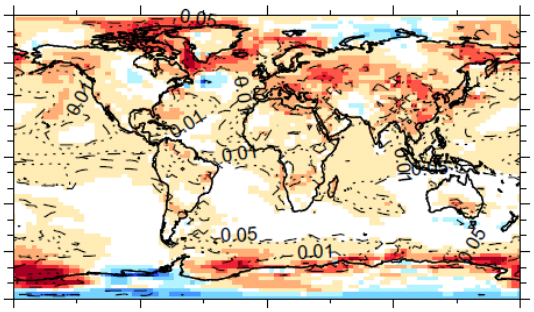

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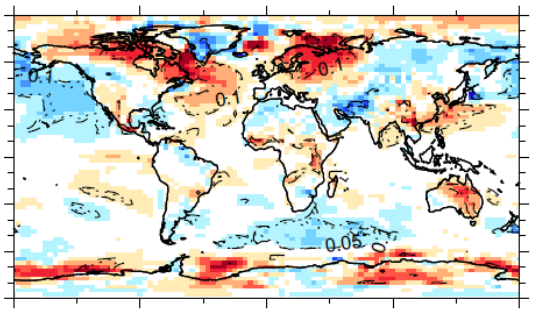

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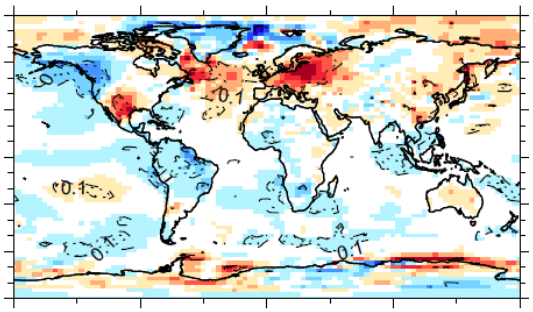

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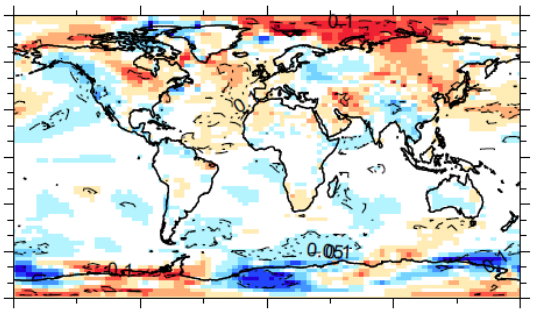

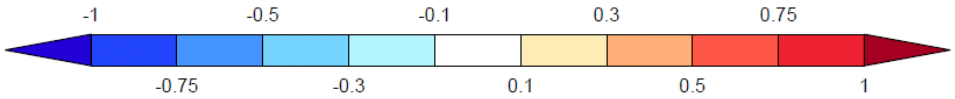

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