Met Office
Hadley Centre

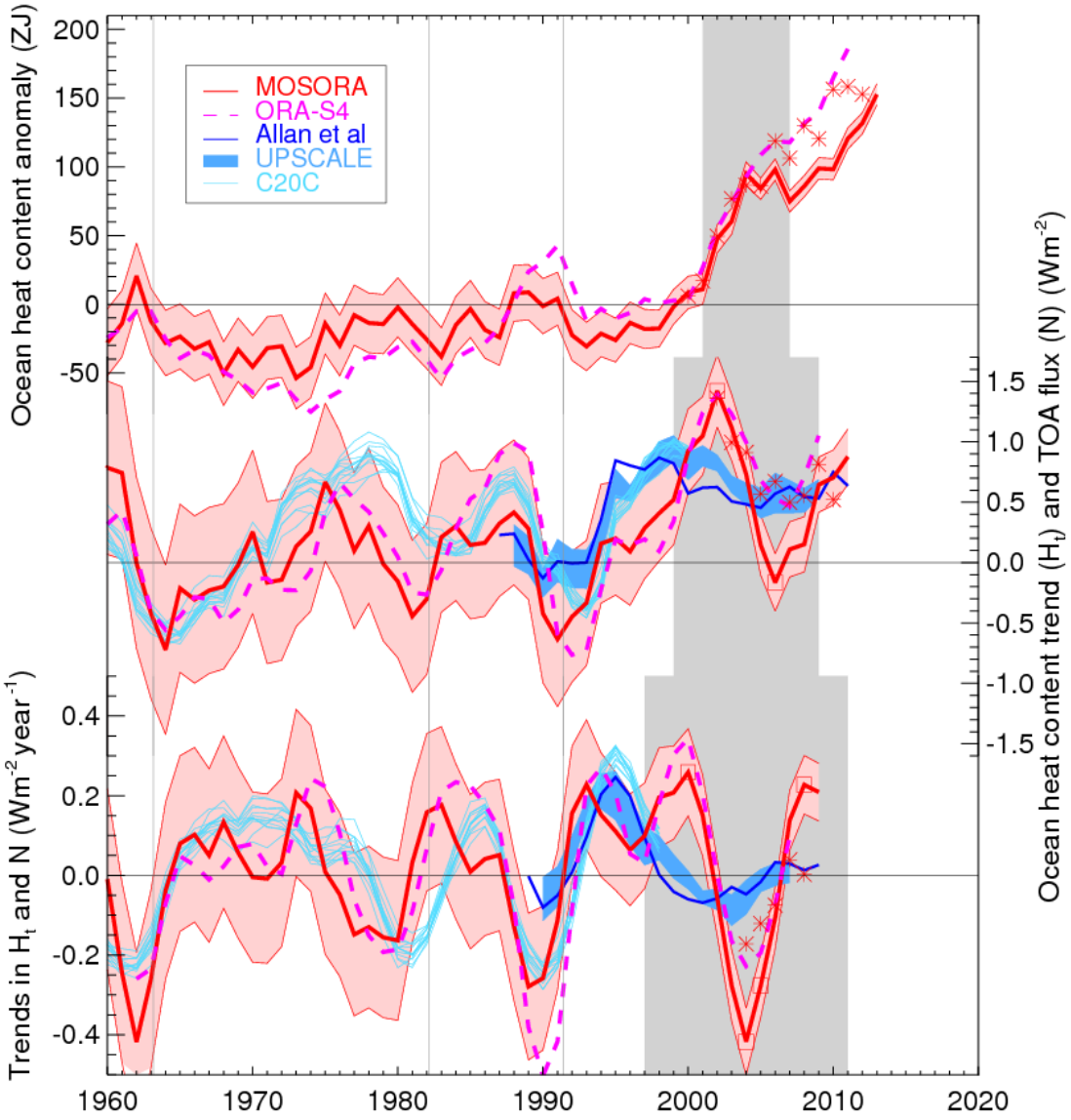
SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

What can we say about the coming decade?

Doug Smith, Nick Dunstone, Rosie Eade, Leon Hermanson, Adam Scaife, …

Observed energy budget

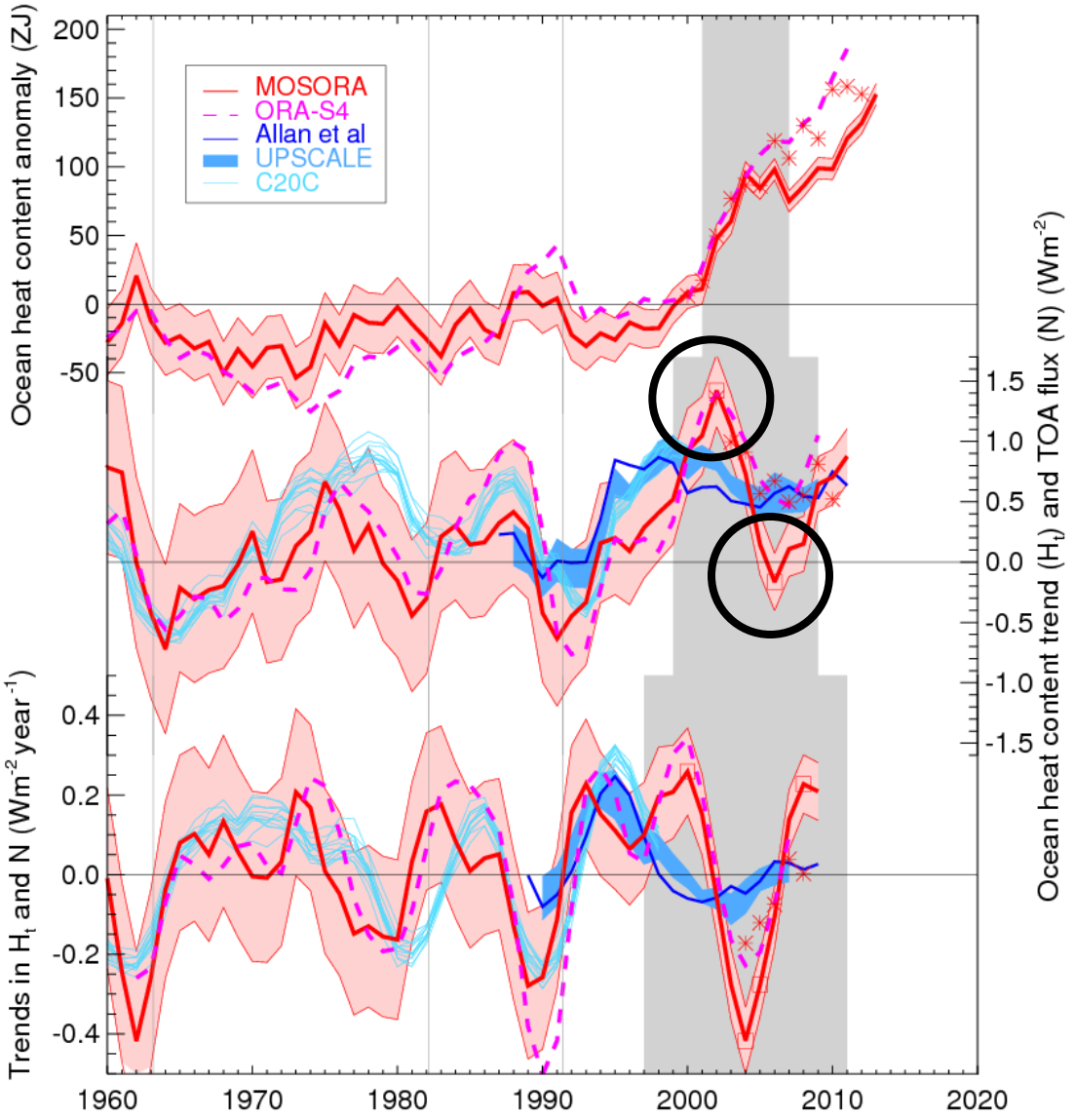
- **Good agreement (r=0.8) between Met Office (MOSORA) and ECMWF (ORA-S4) H_t**
- **Reasonable agreement (r=0.6) between H_t and N from 1960 to 1999**
- **Also seen in gradients (N_t vs H_{tt})**



(Smith et al. 2015)

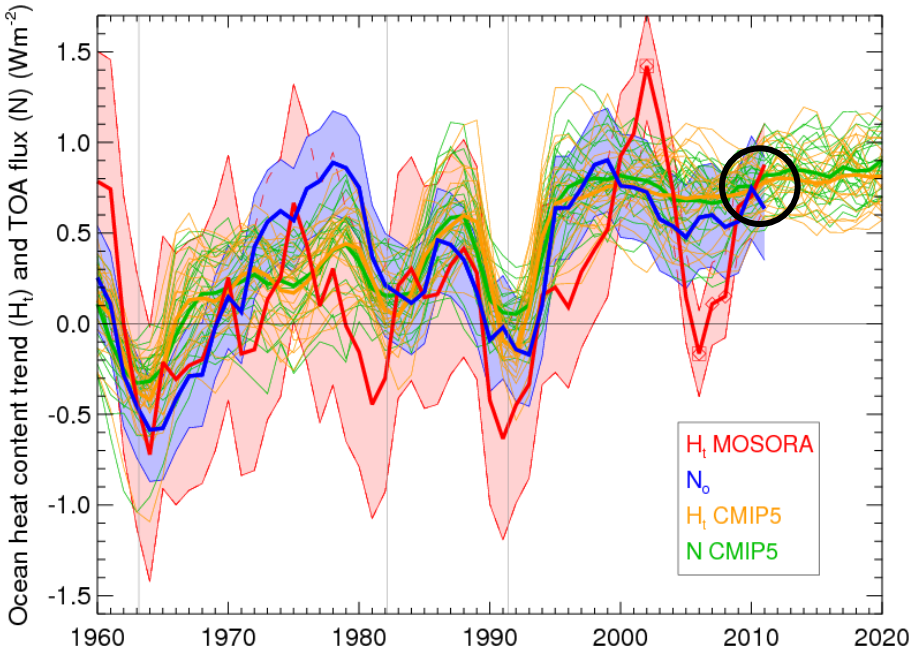
Observed energy budget

- **Maximum H_t in 2002 is inconsistent with N from satellites and AMIP simulations, so likely to be spurious**
- **Ocean analyses between 2000 and 2007 (grey shading) may be unreliable**
- **Also seen in analyses without Argo (red asterisks)**

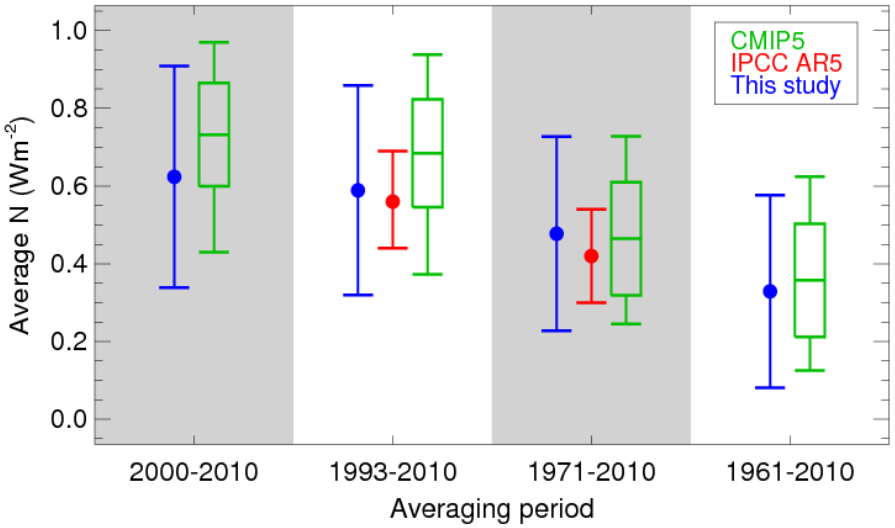


(Smith et al. 2015)

Comparison with CMIP5 coupled models



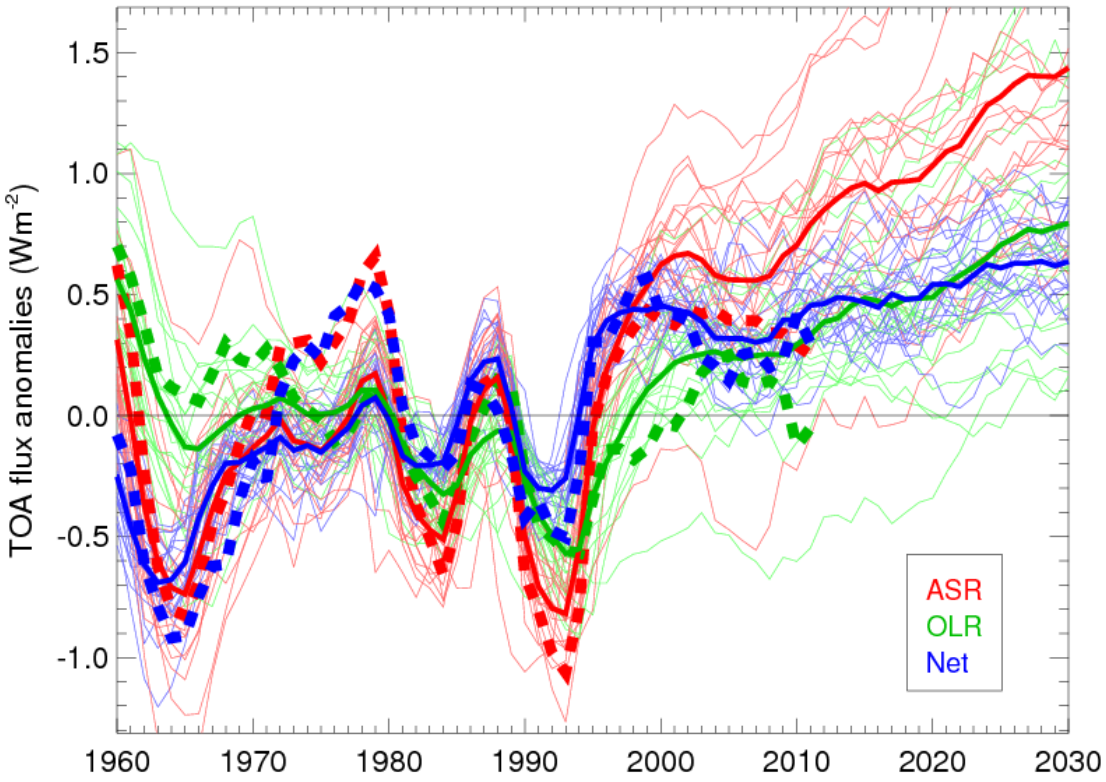
- **Observation-based estimate N_o created by averaging satellite and AMIP simulations**
- **Goes back to 1960**
- **Compare with CMIP5 coupled models**
  - ➢ **Need to remove CMIP5 control run values because of drifts**
- **Good agreement (r=0.82) with ensemble mean of CMIP5 coupled models**
- **Variations dominated by volcanic eruptions (Agung 1963, El Chichon 1982 and Pinatubo 1991)**



- **Absolute values of N for different periods in reasonable agreement with CMIP5 and IPCC**
- **BUT large uncertainties, dominated by estimates of H_t needed to anchor N – note disagreement in changes in N and U even in the most recent estimates**

(Smith et al. 2015)

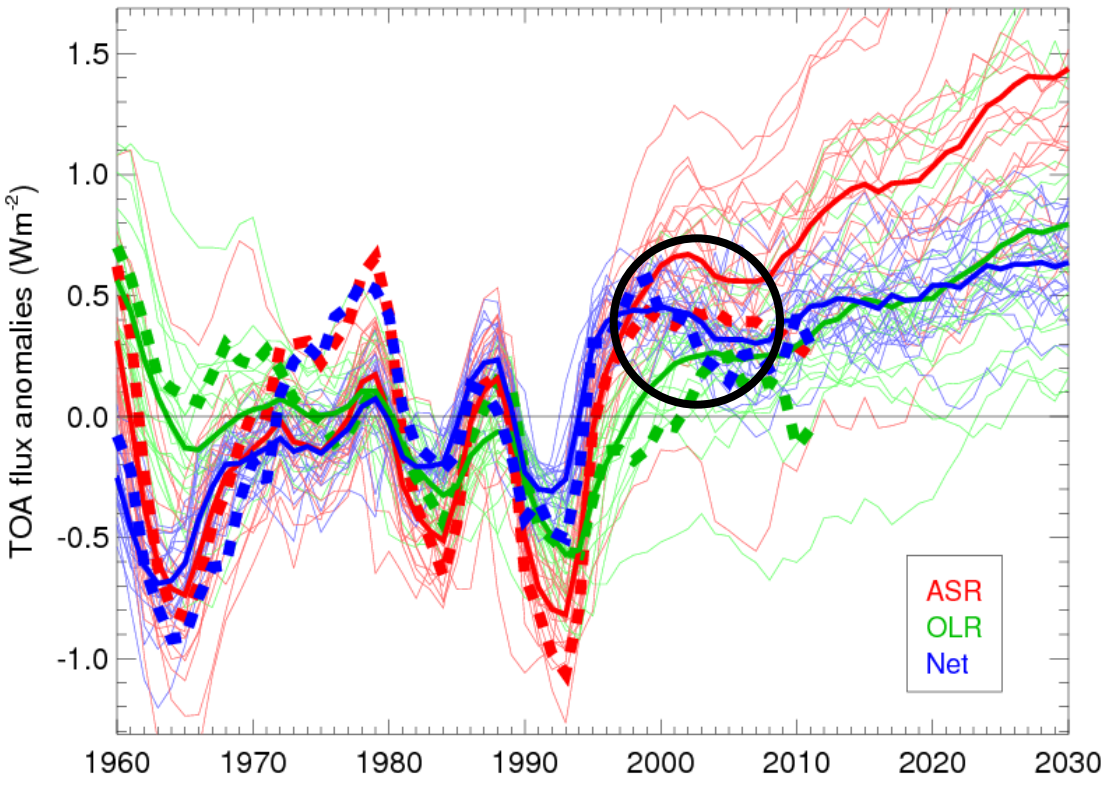
Observation-based and model anomalies



- **Anomalies wrt 1960-2011 → overcomes anchoring uncertainties**
- **Radiative components: absorbed shortwave (ASR, red), outgoing longwave (OLR, green)**
- **N = ASR - OLR**
- **Good agreement between models (solid) and obs (dashed) for ASR (red, r=0.87) and OLR (green, r=0.80)**
- **Models simulate response to volcanoes reasonably well (at least in ensemble mean)**

(Smith et al. 2015)

Observation-based and model anomalies



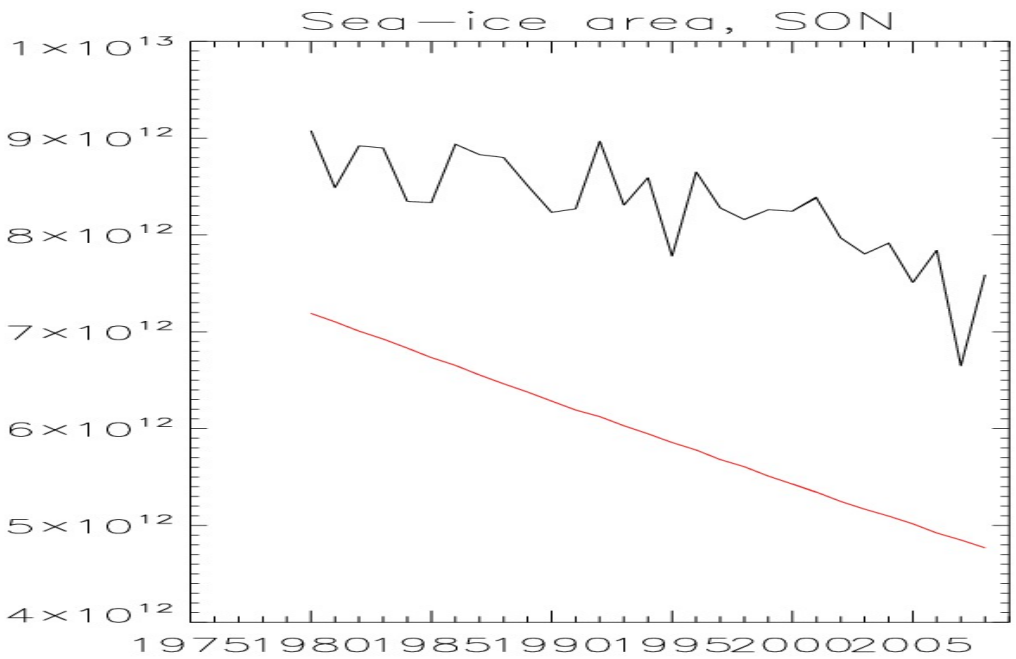
- **Observation-based decline in N of 0.31±0.21 Wm^{-2} between late 1990s and mid-2000s**
- **Spans different satellites – but also seen in AMIP simulations**
- **Role in warming pause?**
- **Consistent with minor volcanoes, reduced solar activity**
- **But driven by increasing OLR rather than reduced ASR? – though ASR lower than models**
- **N may also change through internal variability**

➢ **Hence relative roles of external forcing and internal variability remain unclear**

➢ **Increased uptake of heat by the ocean might not be crucial for explaining the hiatus**

(Smith et al. 2015)

Role of Arctic sea ice?



- **30 year period 1979 to 2009**
- **Control: use observed Arctic sea ice**
- **Perturbed: use reduced Arctic sea ice, obtained by projecting the 30 year trend**
- **10 ensemble members (300 simulated years)**
- **AMIP: atmosphere model forced by observed SST (set to 0°C where sea ice removed)**
- **COUPLED: fully coupled model, constrained by observed temperature and salinity below 200m – SST can respond to sea ice**

(Smith et al. in prep)

DJF

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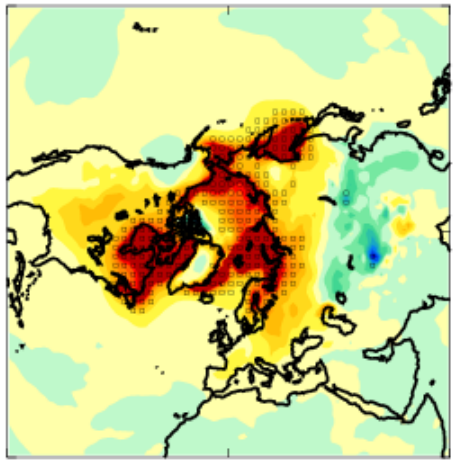
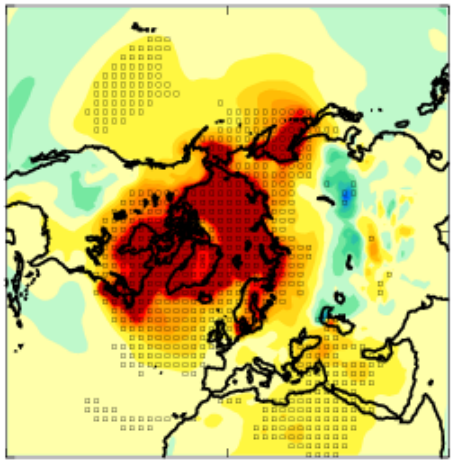
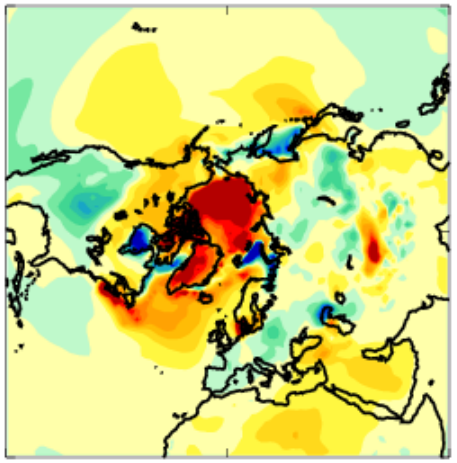
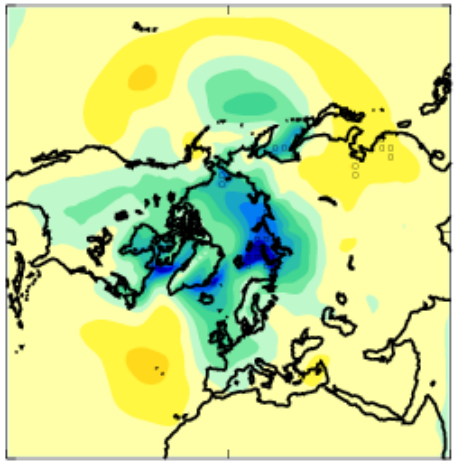
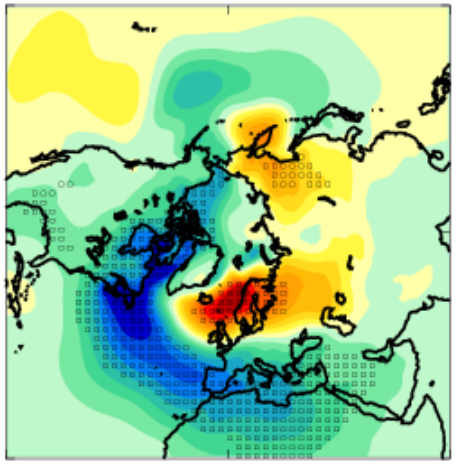
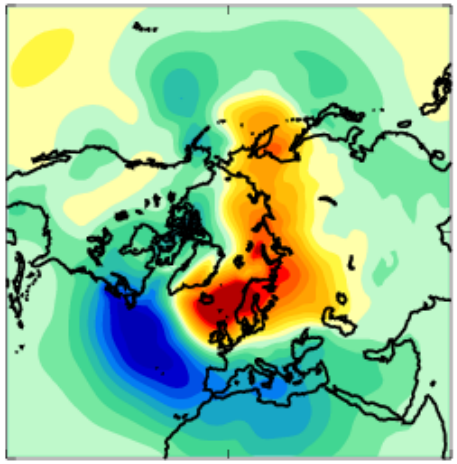
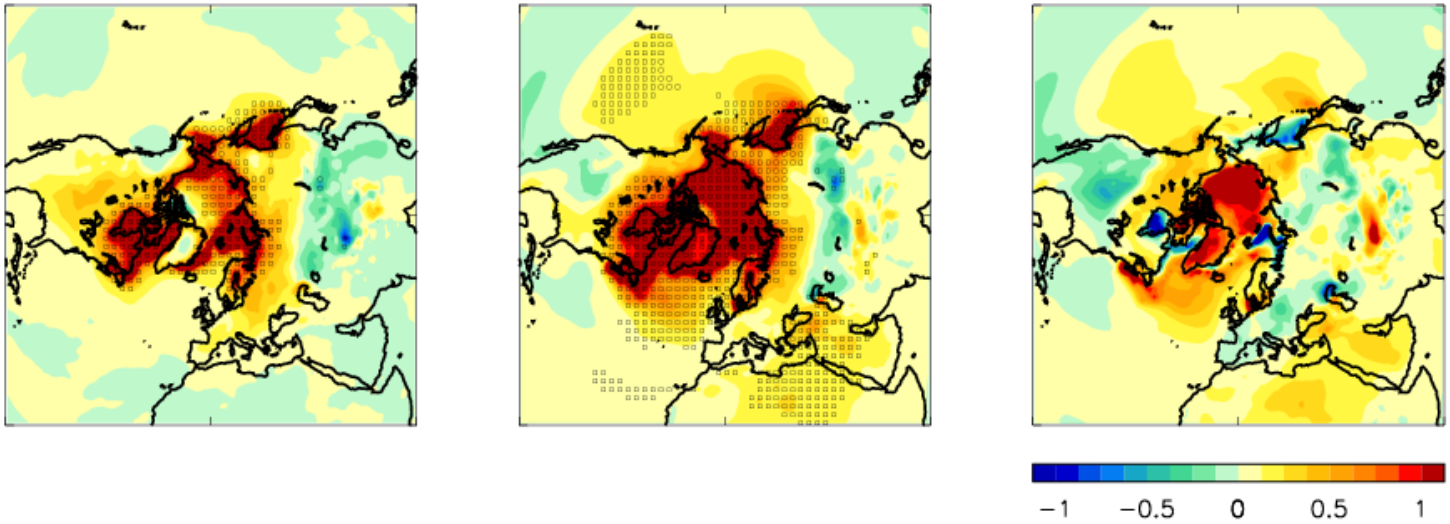
	AMIP	Coupled	Difference
Temperature			
Pressure			

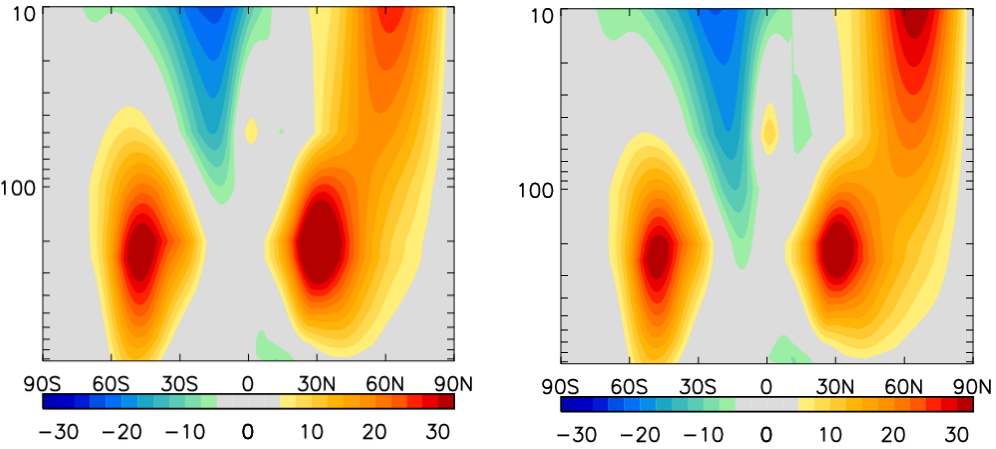
Why is the DJF response different in AMIP and Coupled?

Met Office Hadley Centre

AMIP | **Coupled** | **Coupled - AMIP**

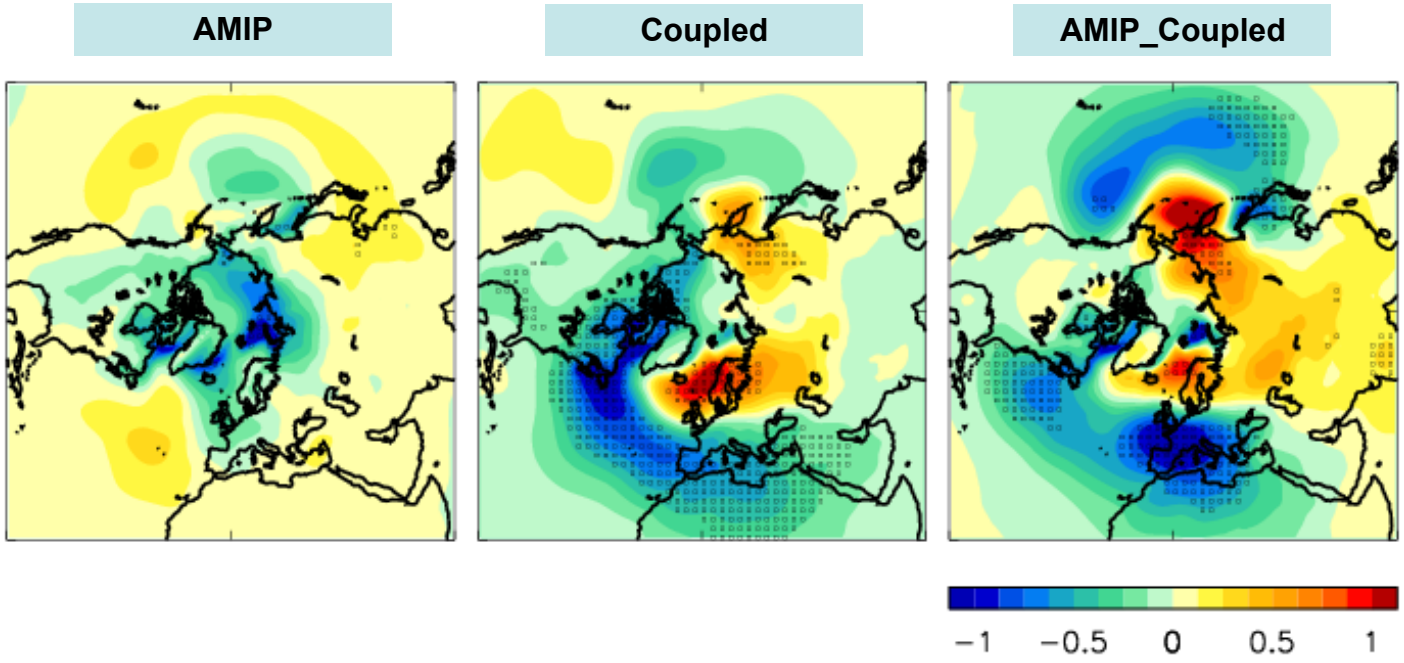


Differences in temperatures: coupled model allows surrounding regions to warm



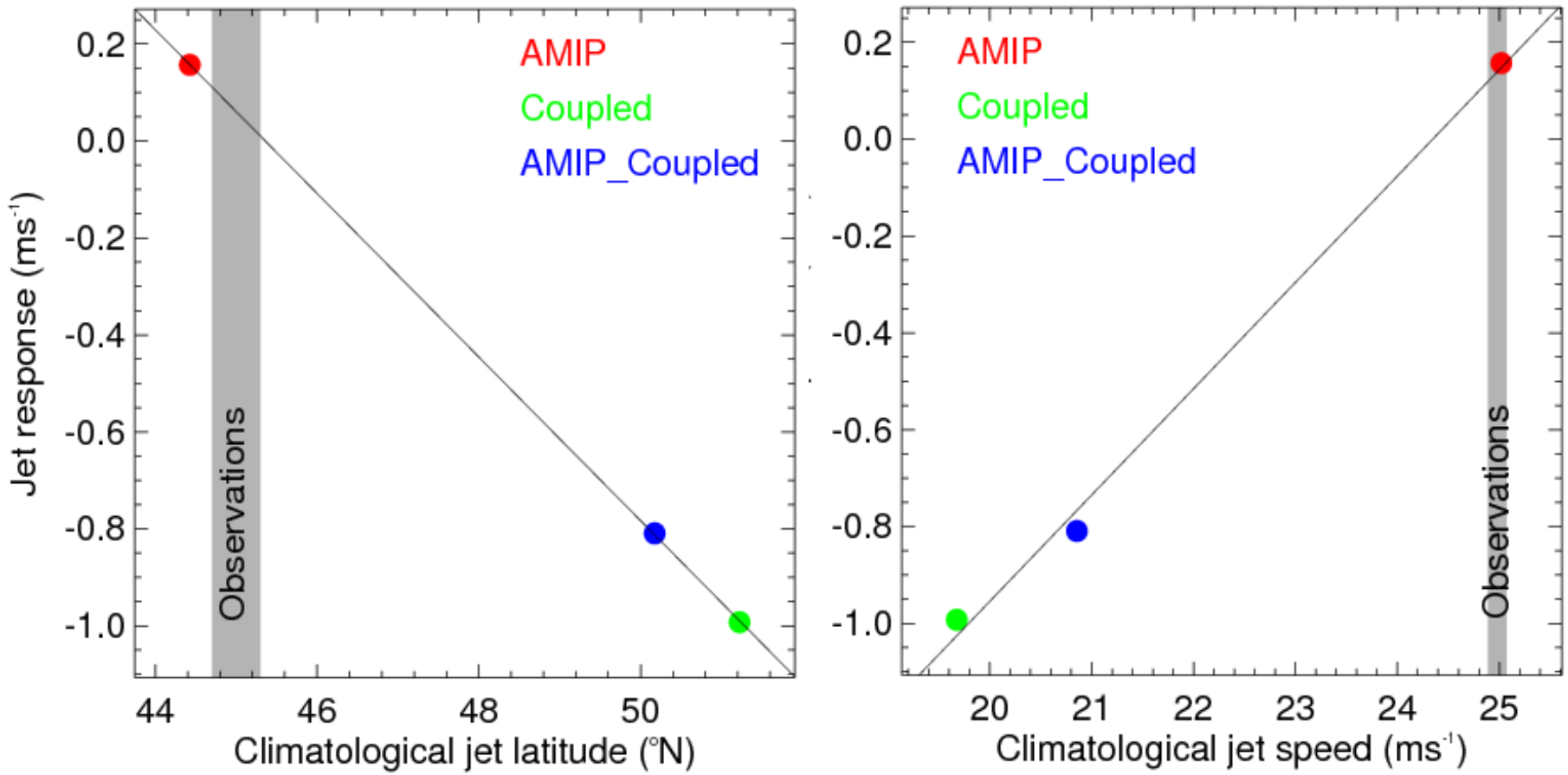
Model biases: zonal winds are weaker and shifted northwards in the coupled model

DJF sea level pressure



- **AMIP_Coupled: as AMIP but with coupled model SST biases**
- **AMIP_Coupled reproduces the Coupled model response**
- **Response depends on model climatology**

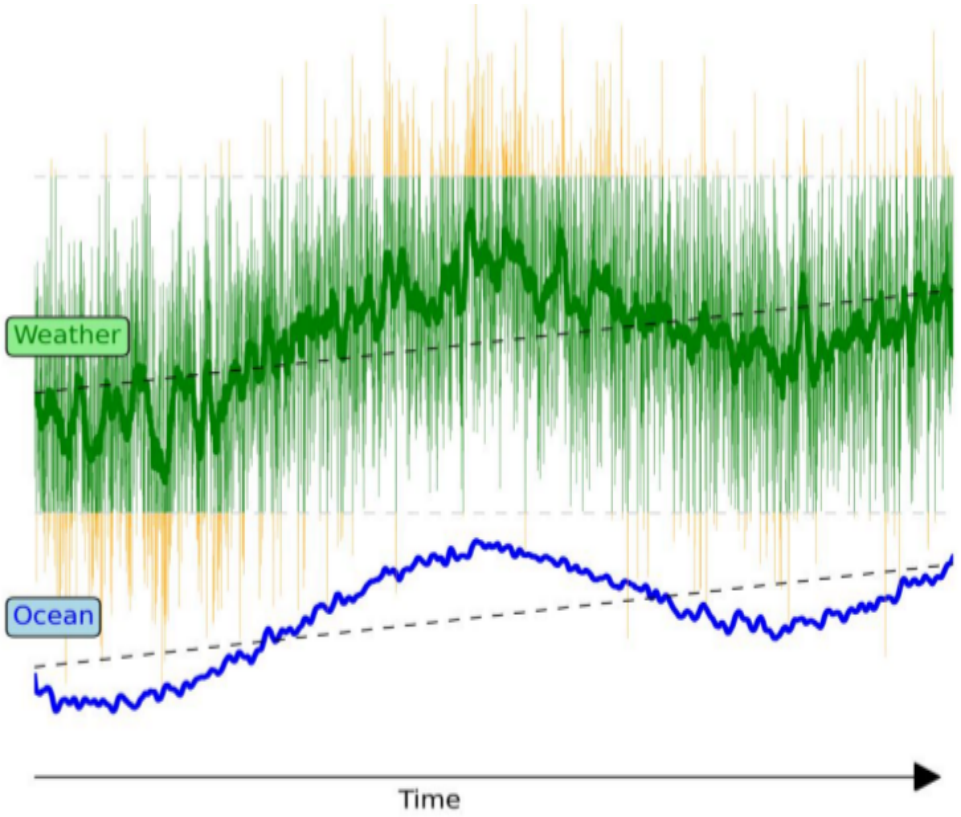
Jet response vs climatology



- **Response depends on the climatological latitude and/or speed of jet**
- **WHY??**

Also Kidston et al, 2011 for Antarctic sea ice

Predictable component



Total variance of a time series can be split into

- Predictable component (*signal*): fraction of variance that is predictable
- Unpredictable component (*noise*)
- Predictable component arises from e.g. ocean influence on atmosphere, external forcings ...
- Modulates probability of extreme events

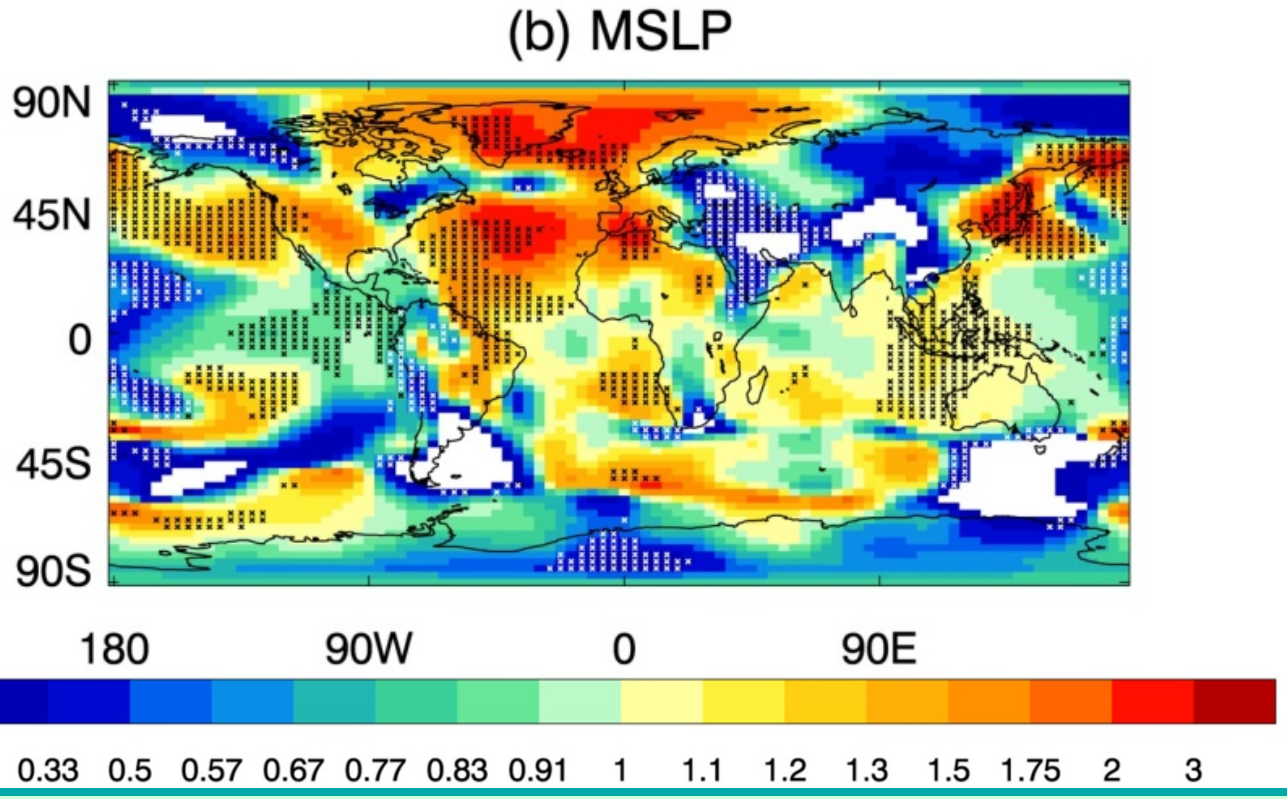
Ratio of predictable components (RPC)

$$RPC = \frac{PC_{obs}}{PC_{\mathrm{mod}}} \geq \frac{r}{\sqrt{\sigma^2_{\mathrm{ens\_mean}} / \sigma^2_{\mathrm{ens\_members}}}}$$

- Ignore negative r
- Investigate seasonal in GloSea5; DJF from ~Nov 1st
  - 24 members; 20 start dates (~1st Nov 1992-2011)
- Also decadal (years 2-5), Met Office + CMIP5
  - 70 members; 46 start dates (1st Nov 1960-2005)

(Eade et al. 2014)

RPC in seasonal DJF hindcasts



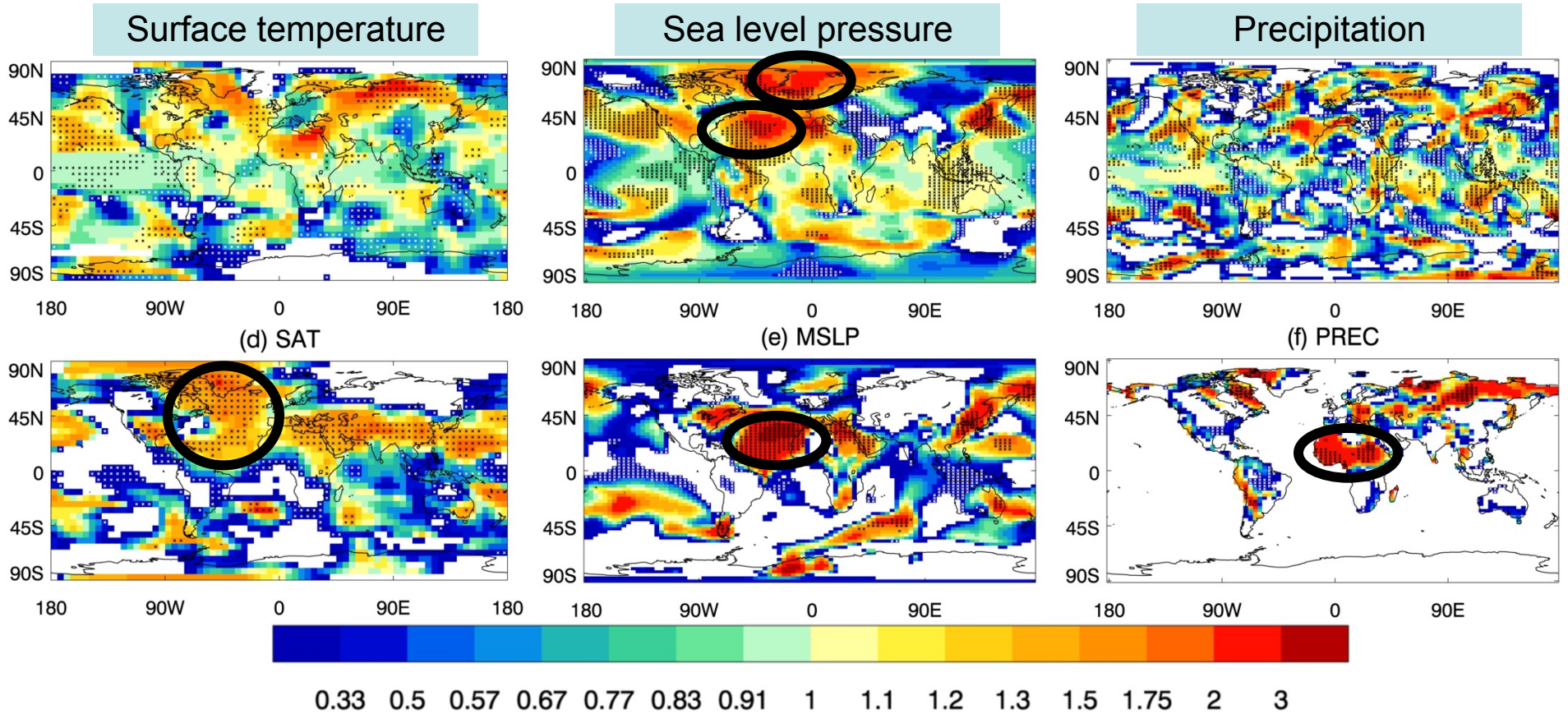
Perfect forecast system: RPC = 1

RPC << 1: over-confidence, ensemble members agree well with one another but not with observations (noted in previous studies)

RPC >> 1: under-confidence, ensemble mean agrees well with observations but members agree less well with each other (unexpected!)

(Eade et al. 2014)

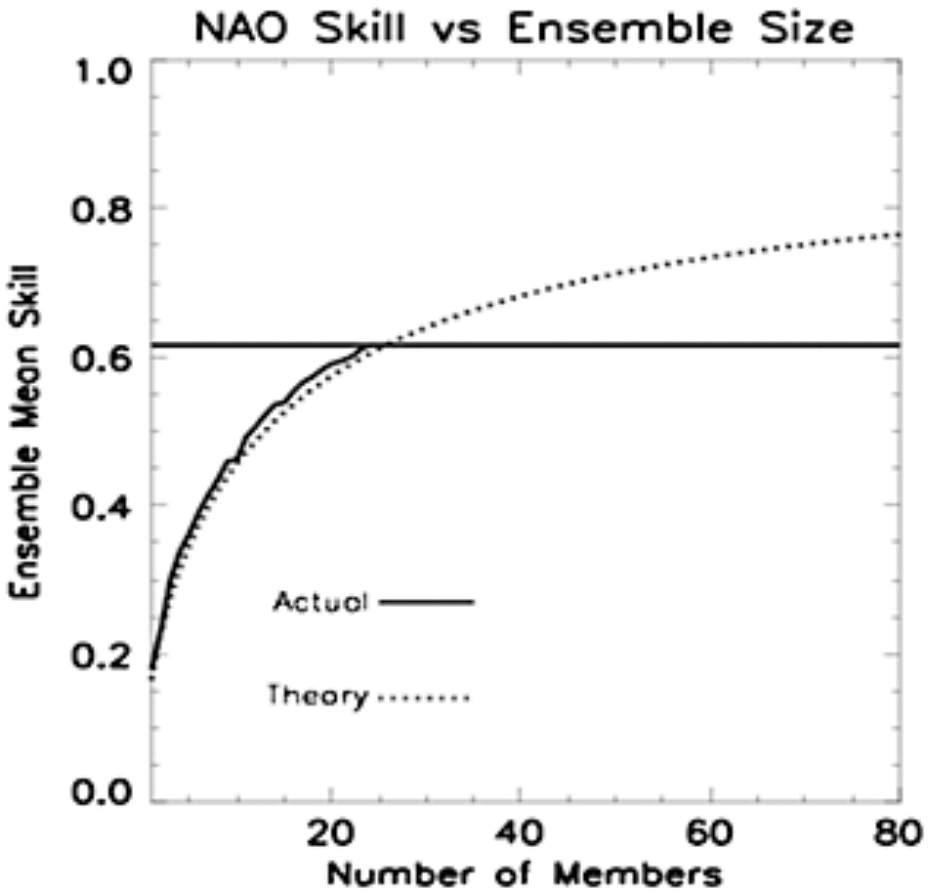
RPC in seasonal (DJF, top) & decadal (Yrs 2-5, bottom) hindcasts



RPC >> 1: Known regions of **physical variability**

NAO; North Atlantic decadal variability: MDR, SPG, Sahel

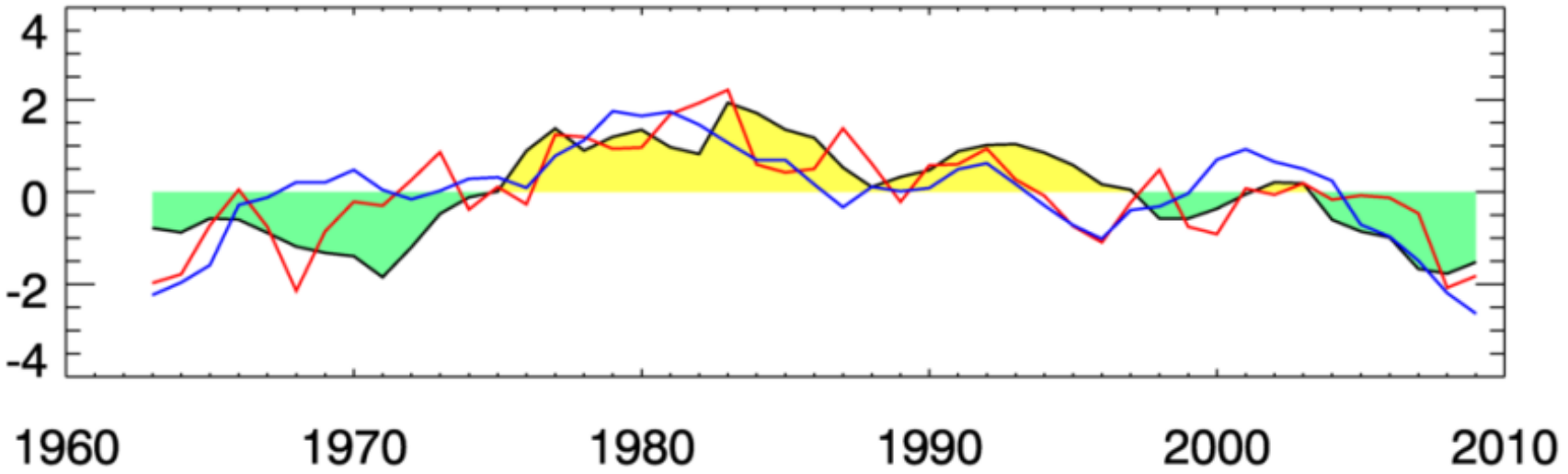
Effect of ensemble size on North Atlantic Oscillation skill



Scaife et al., 2014, GRL.

- Can now make skilful forecasts of NAO
- Correlation = 0.6
- But need large enough ensemble to get rid of noise
- Potentially even higher correlations with more members
- RPC = 2.3 >> 1, i.e. under-confident (correlation not matched to signal-to-noise ratio)
- Need to correct variances to make RPC = 1

Can we predict the PDO?



- Detrended 5-year running mean PDO
- CMIP5 decadal hindcasts (red) r = 0.7
  - yearly start dates (HadCM3, CanCM4, MPI, GFDL, MIROC5)
  - include 2 lagged start dates → 174 ensemble members
- equivalent uninitialized simulations (blue) r = 0.6
- **PDO potentially predictable but externally forced?**

(Eade et al. In prep)

Can we predict the PDO?

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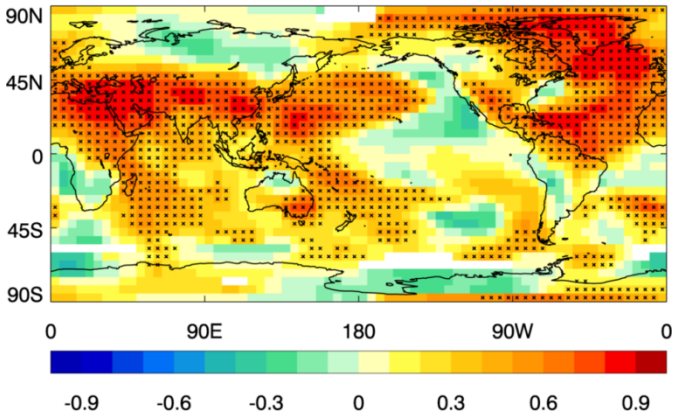
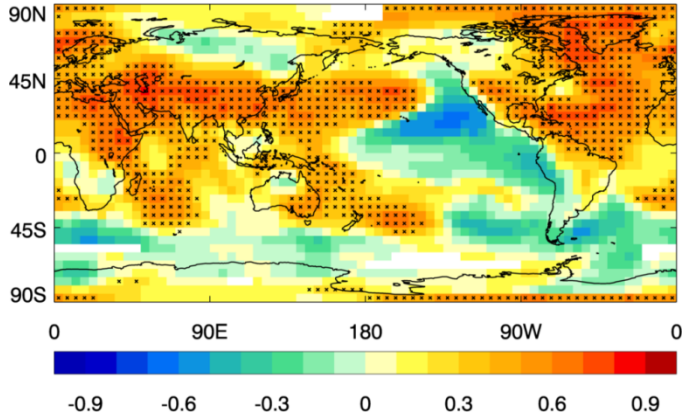
Correlation of detrended T 1960-2010

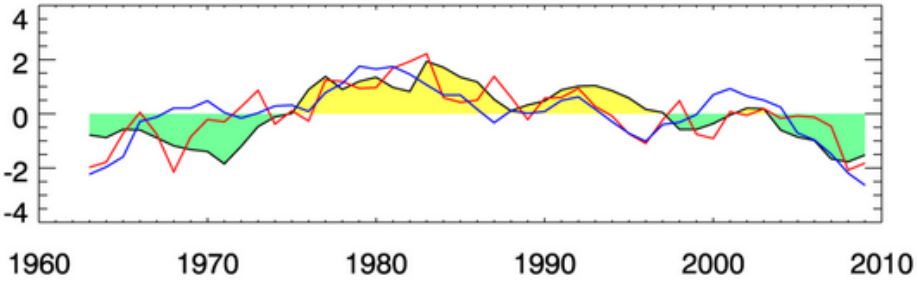
Initialized



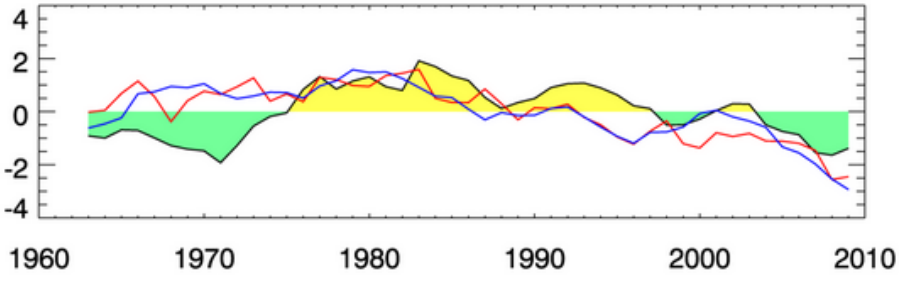
Uninitialized



Detrended PDO, r=0.7



Detrended PDO, r=0.4

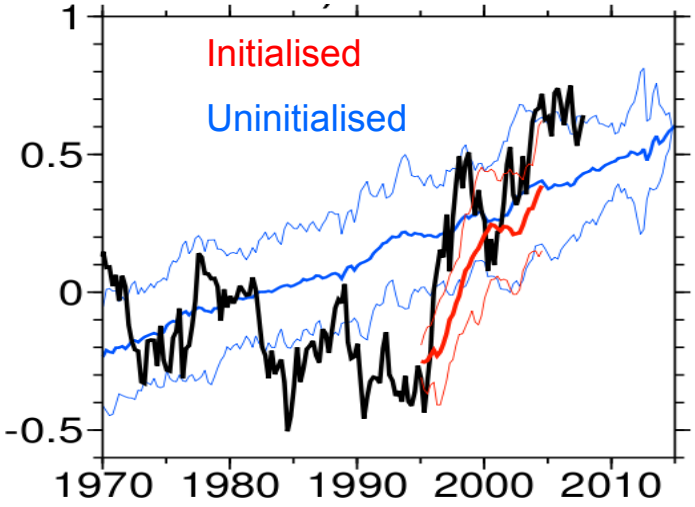


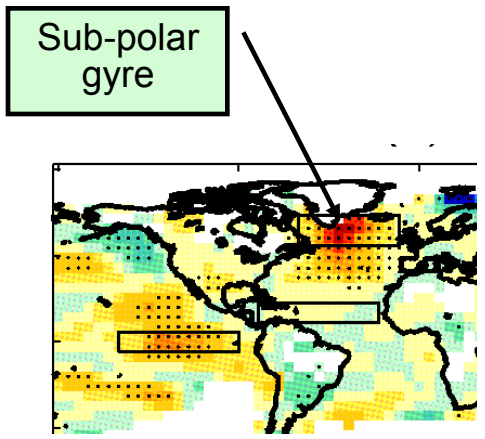
- **No skill in eastern tropical Pacific (key region for the hiatus)**
- **Over longer period from 1880 uninitialized skill drops to r = 0.3**
- **Apparent skill since 1960 not robust? And not eastern tropical Pacific**
- **Care needed when interpreting detrended skill!**

(Eade et al. In prep)

Decadal skill: sub-polar gyre

Predictions of sub-polar 1990s gyre warming

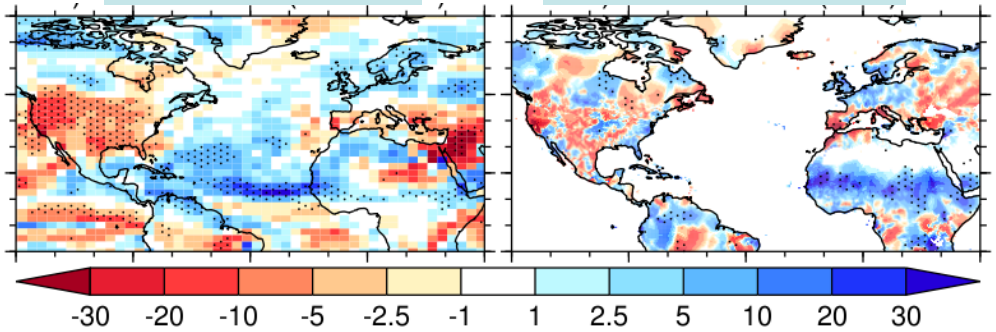




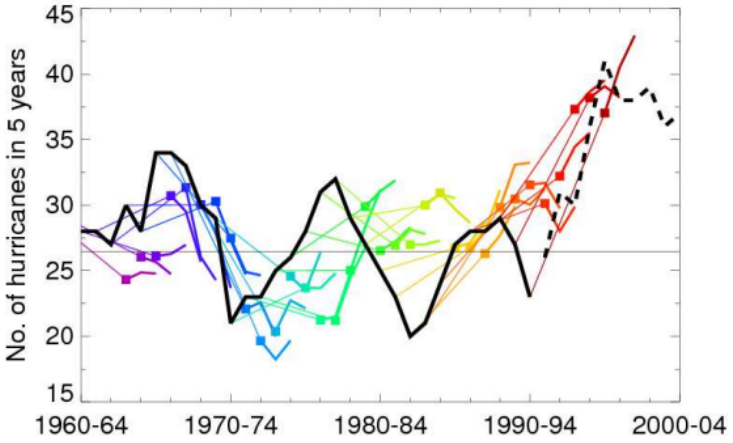
Impacts: rainfall

Model

Observations

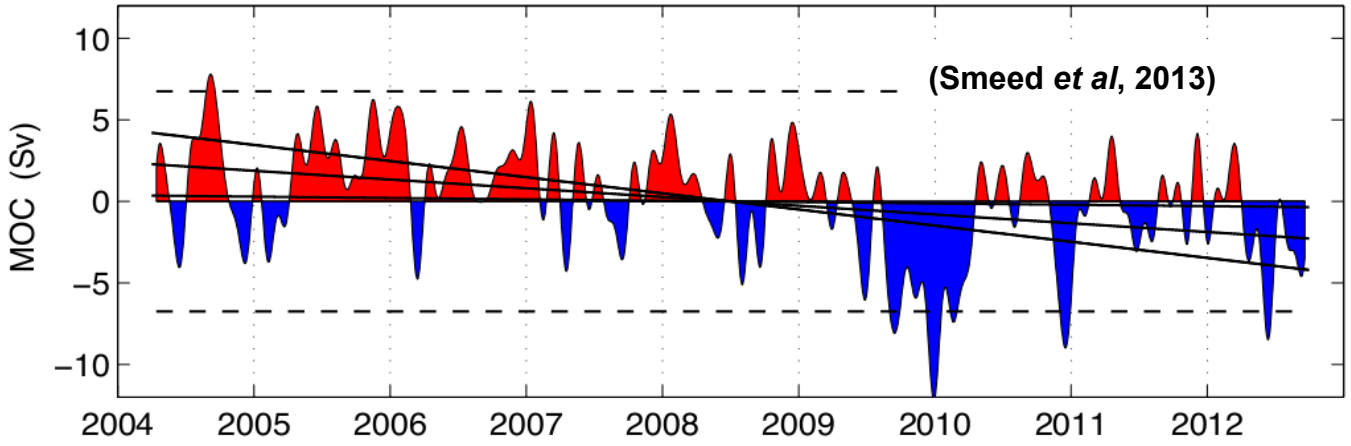


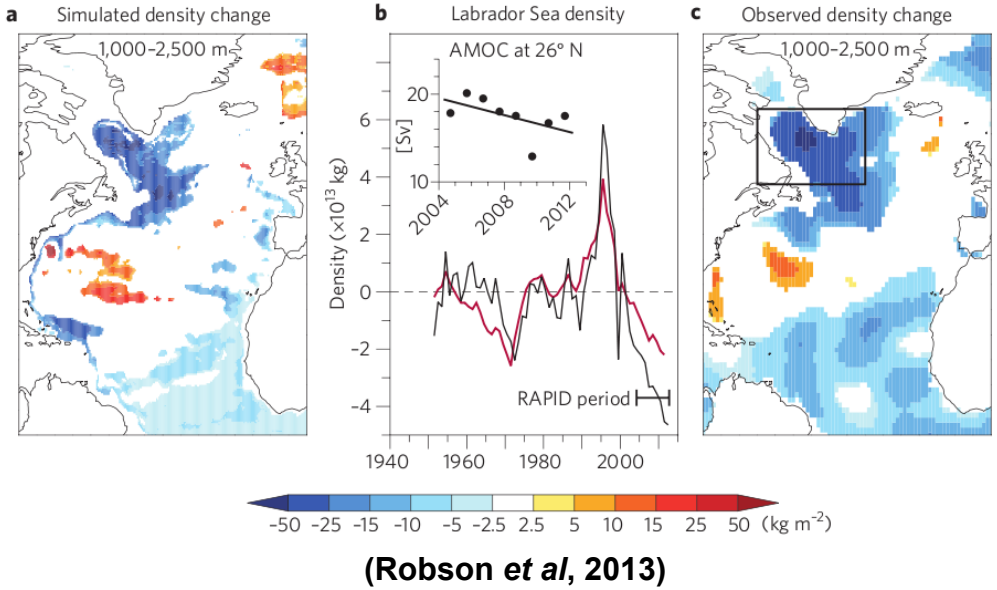
Impacts: hurricanes



(Robson et al. 2012, 2013, 2014: Smith et al 2010, 2013)

Observed weakening of Atlantic overturning circulation



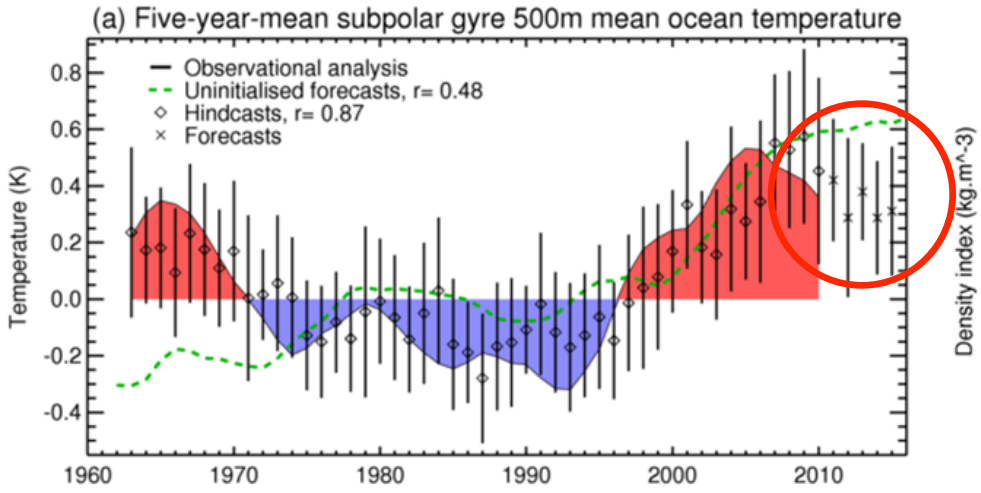


(Robson *et al*, 2013)

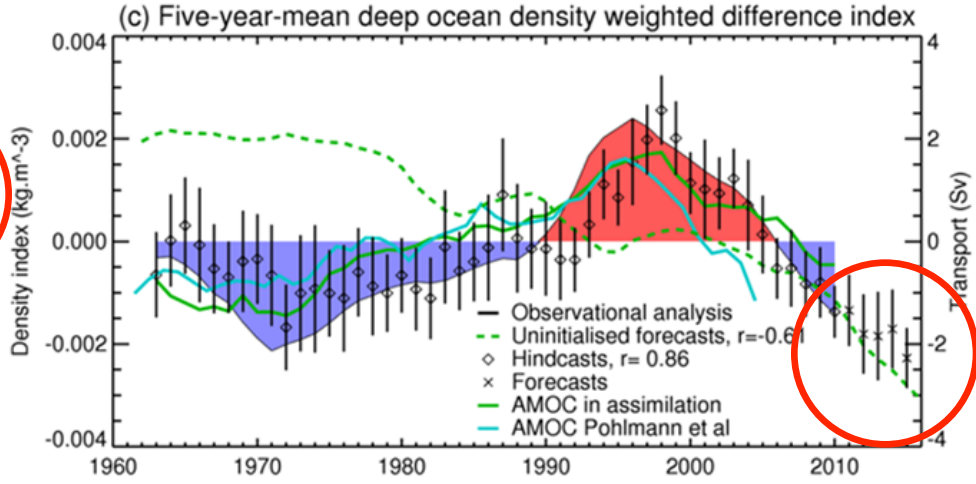
- Weakening of AMOC in direct observations (RAPID)
- and inferred from deep densities
- **0.5 Sv per year**
- **30% decrease in 10 years!**

Predicted cooling of North Atlantic

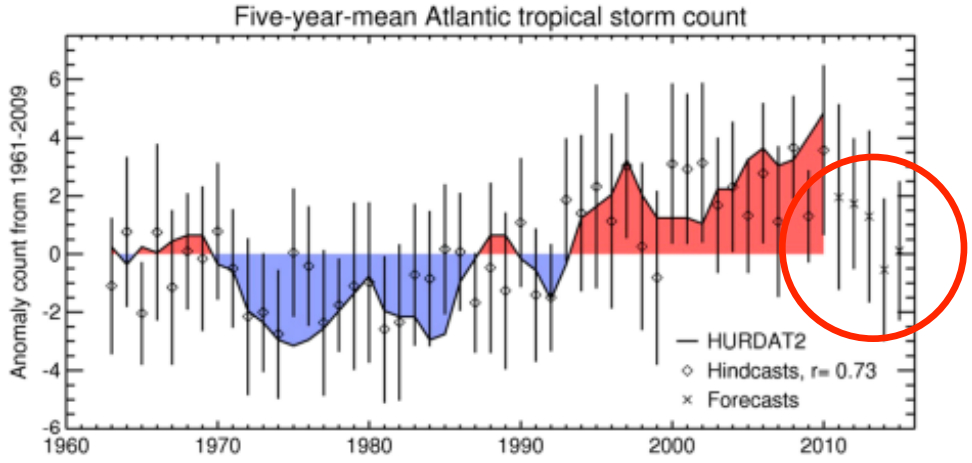
Temperature



Ocean circulation



Atlantic tropical storms



(Hermanson *et al*, 2014)

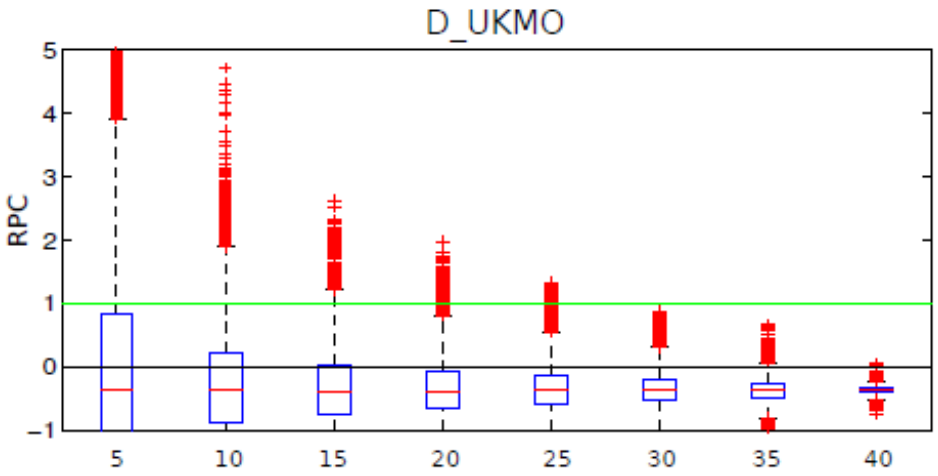
- Atlantic predicted to cool in response to weakening of ocean overturning
- Likely to cause climate impacts around the Atlantic basin
- Not a reversal, but impacts associated with warm Atlantic less likely:
  - ➢ cold winters and wet summers in Europe less likely
  - ➢ fewer hurricanes than recent peaks
  - ➢ reduced Sahel rainfall
  - ➢ reduced risk of drought in SW USA

Summary

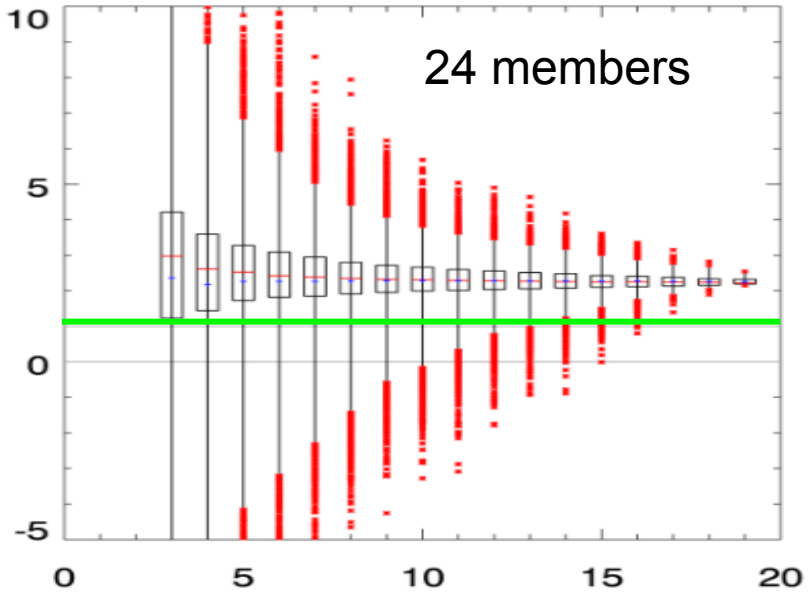
- Observed reduction in incoming energy at onset of hiatus
  - what is the role of ocean heat uptake?
- Response to Arctic sea ice is uncertain
- Models underestimate the predictability of the real world
  - need large ensemble and to adjust variance
  - some measures may underestimate skill
  - perfect model experiments not an upper limit!
- No skill for eastern tropical Pacific
- Potentially important changes in the Atlantic occurring now
  - Need to understand climate impacts
  - Multi-model forecasts → DCPP component B !

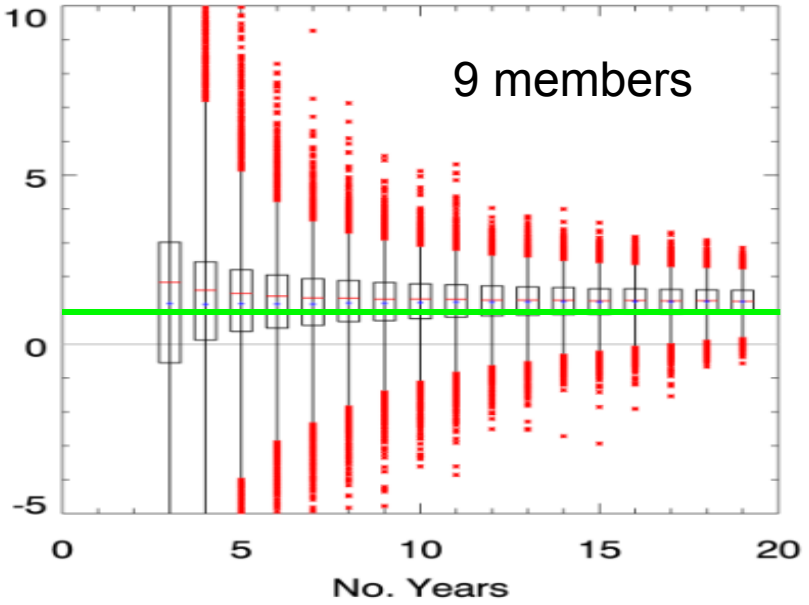
RPC sensitivity

GloSea3



GloSea5





(Shi *et al*, 2015)

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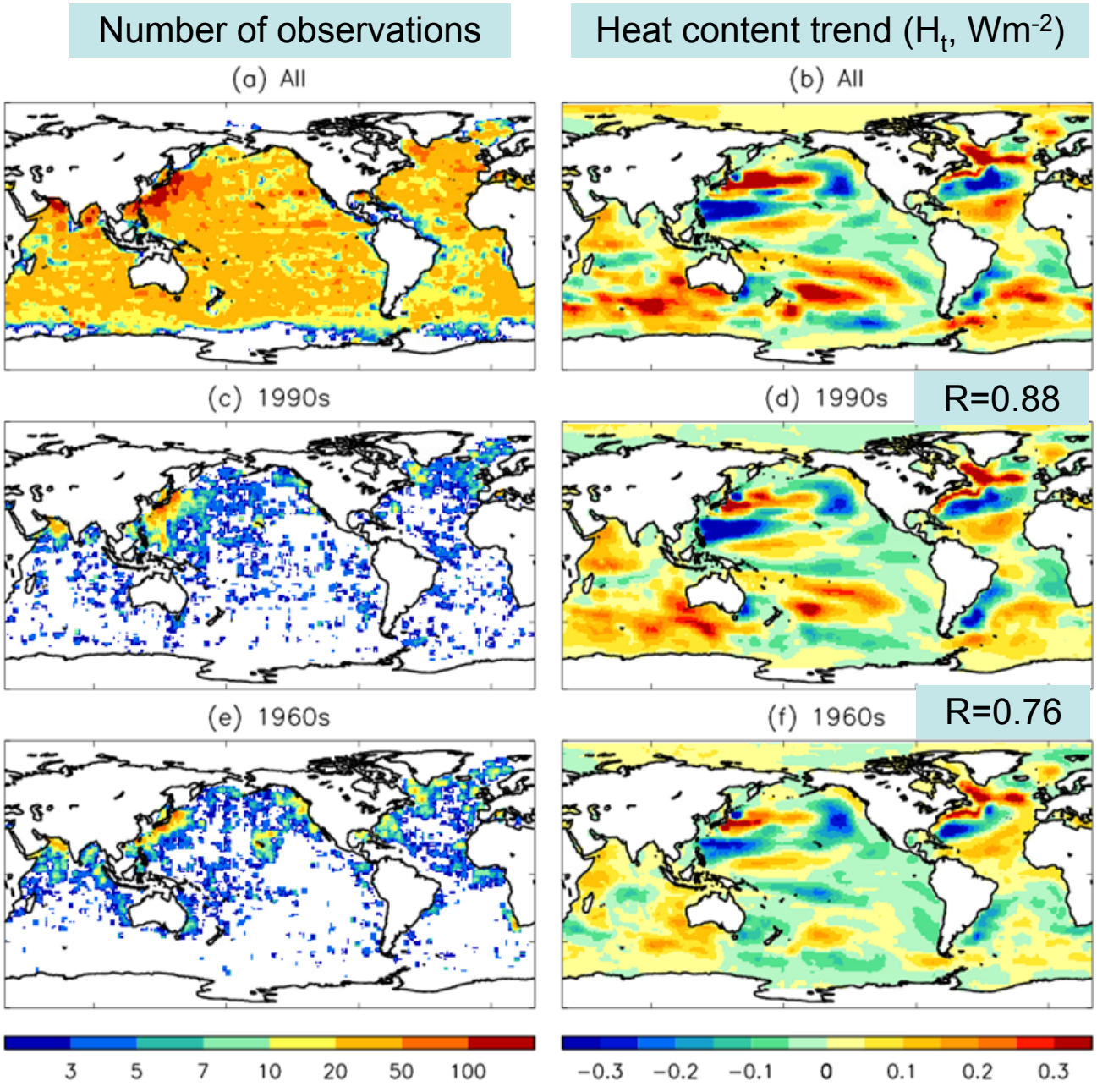
Assessment of Met Office ocean analysis



Data withholding experiments

- **Reconstruct Argo period 2008-12 using sub-sampled observations typical of historical periods**
- **Uncertainties in annual mean global ocean heat content range from 28 ZJ using 1950-56 obs to 8 ZJ using 2005-11 obs**
- **Uncertainties in global H_t range from 0.7 Wm^{-2} using 1950-56 obs to 0.2 Wm^{-2} using 2005-11 obs**
- **Possible instrument errors and regions not adequately sampled are not included**

(Smith et al. 2015)

Can we predict the PDO?

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1970s shift

2000s shift

Observations

Initialized

Climatology