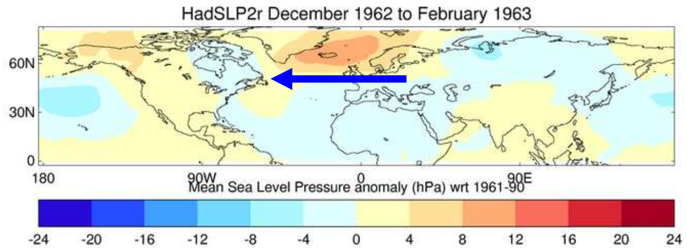
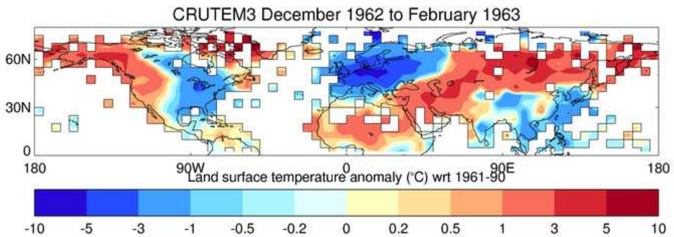
Seasonal to decadal prediction of the Arctic Oscillation

D. Smith, A. Scaife, A. Arribas, E. Blockley, A. Brookshaw, R.T. Clark, N. Dunstone, R. Eade, D. Fereday, C.K. Folland, M. Gordon, L. Hermanson, J.R. Knight, D.J. Lea, C. MacLachlan, A. Maidens, M. Martin, A.K. Peterson, M. Vellinga, E. Wallace, J. Waters and A. Williams.

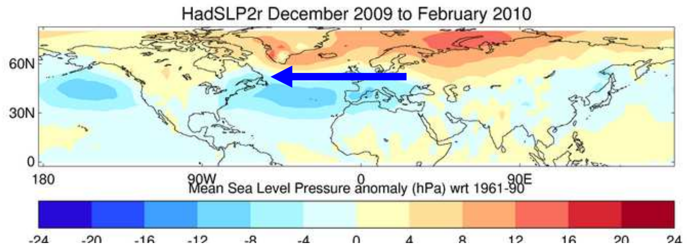
Northern Europe in Winter depends largely on which way the wind blows (AO/NAO):

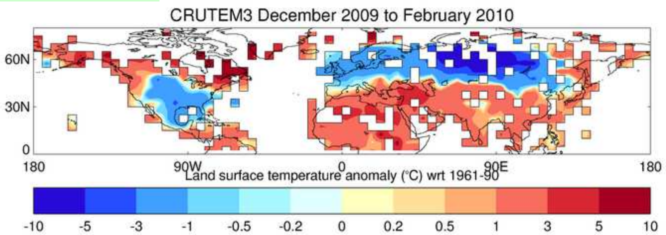
Winter 1962/63





Winter 2009/10



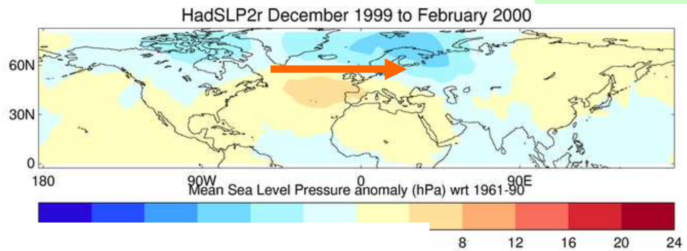


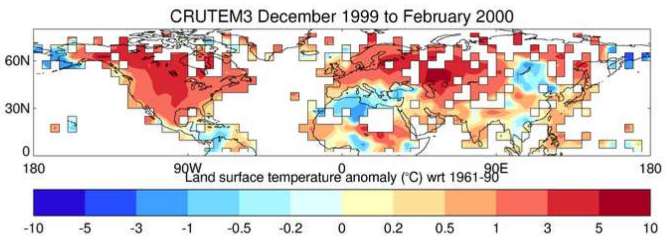
Weakened Pressure Gradient

Cold advection into Europe

Cold, calm and dry

Winter 1999/00





Strengthened Pressure Gradient

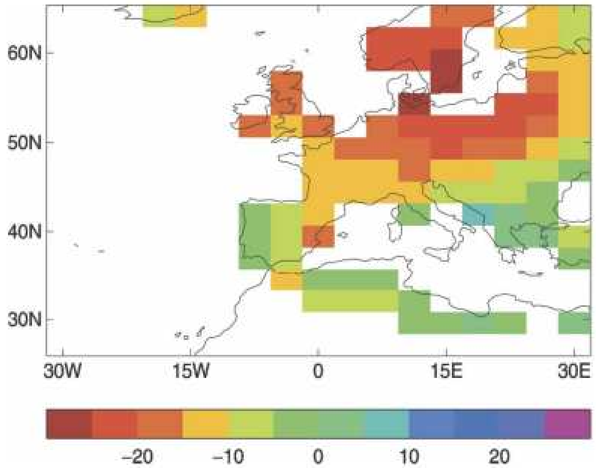
Warm Europe

Mild, stormy and wet

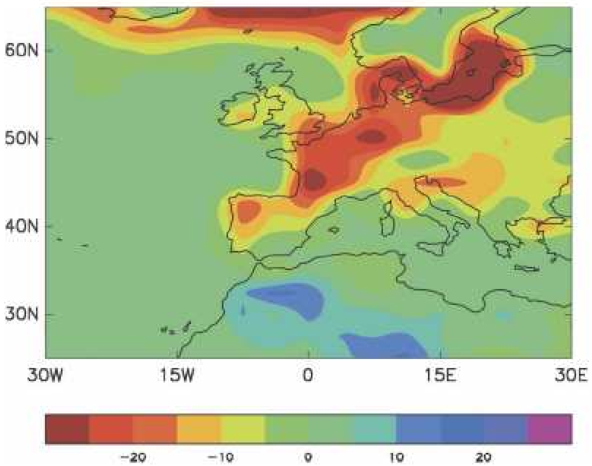
Decadal changes depend on the NAO…

Met Office
Hadley Centre

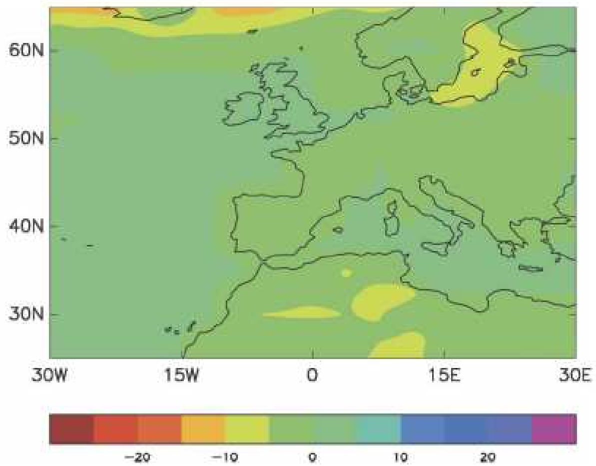
Observed Decrease in Frosts



Modelled decrease in Frosts



Without NAO change



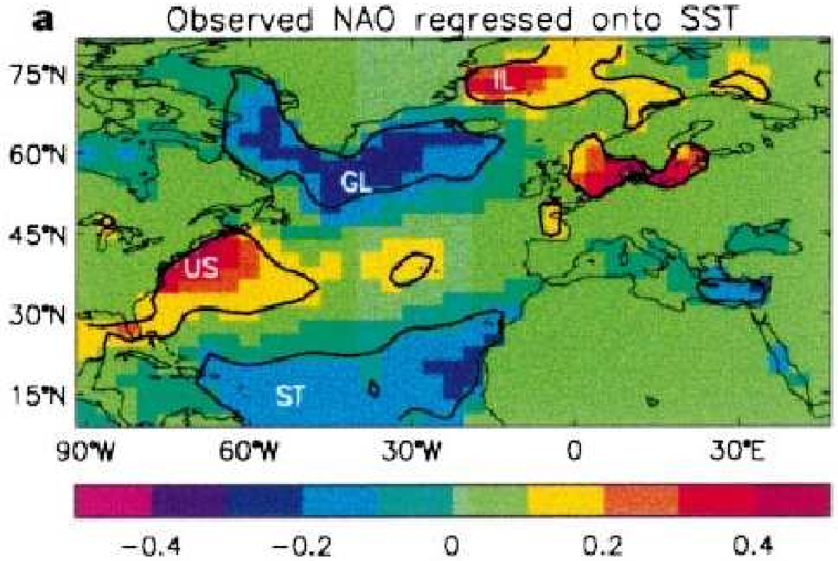
1960s to 1990s changes

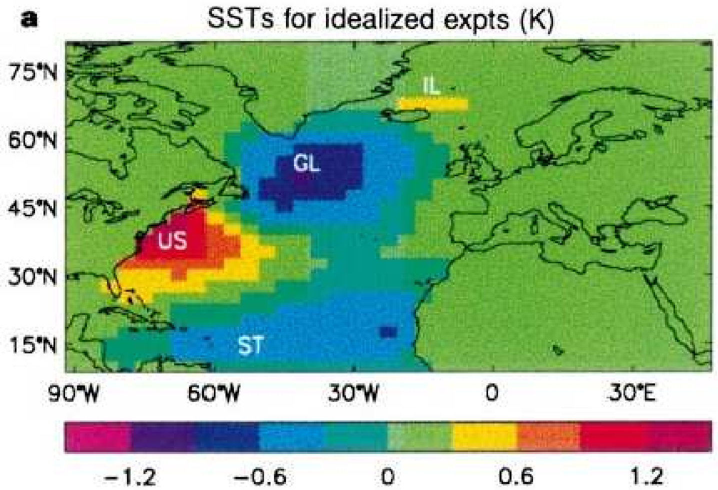
Scaife et al, 2005, 2008

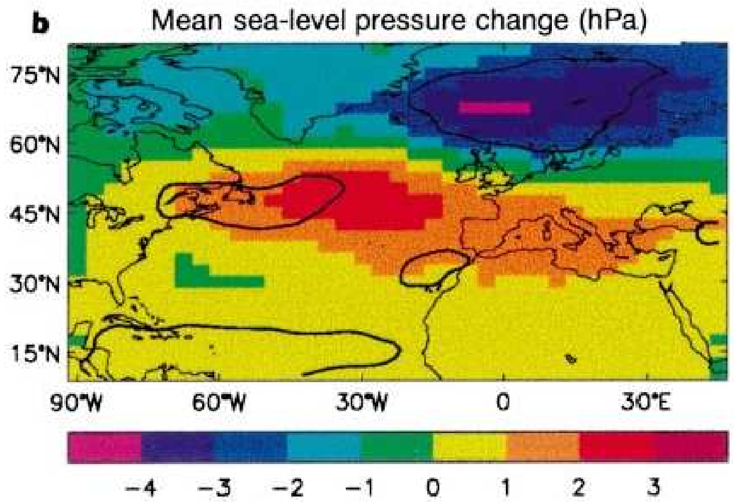
Contents

- Potential sources of skill
- Model results
- Future research

Potential sources of AO (NAO) predictability





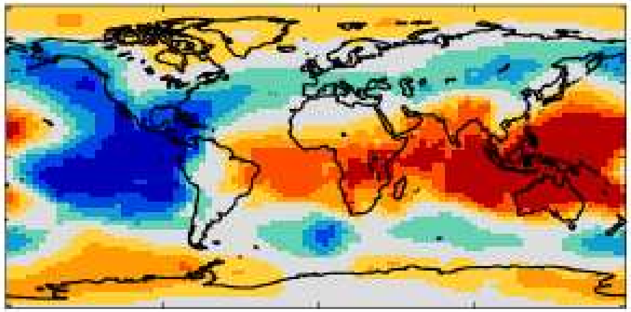


Rodwell *et al*, 1999

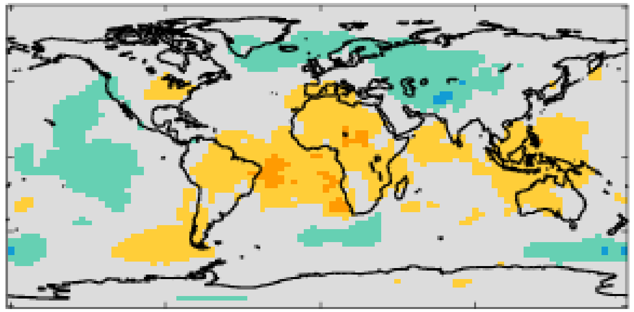
Potential sources of AO (NAO) predictability

Met Office
Hadley Centre

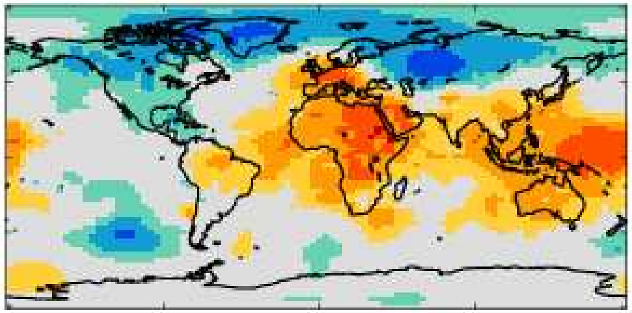
ENSO



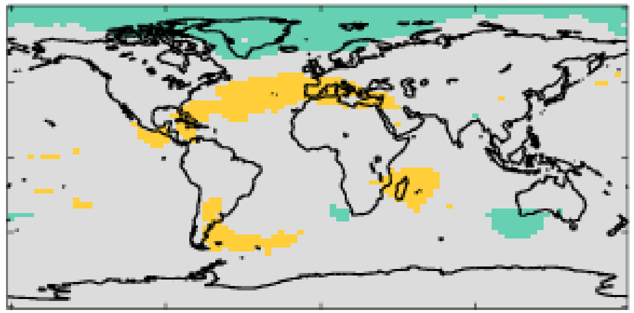
Solar (11 year cycle)

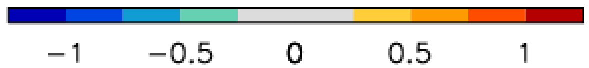


Volcanoes



QBO



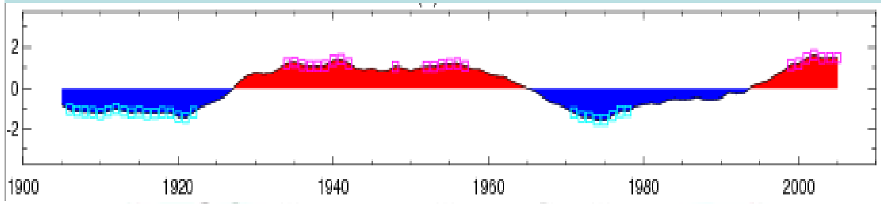


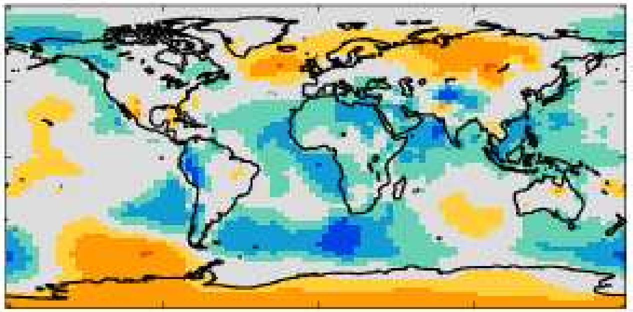
- Observed DJF mslp composites
- Units are standard deviations

Smith *et al*, 2011

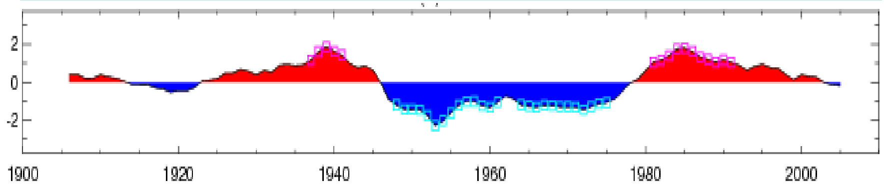
Potential sources of predictability: decadal

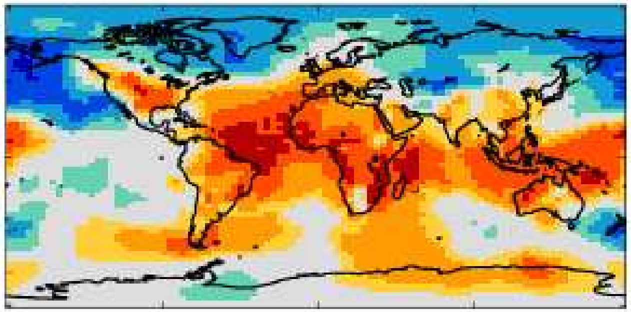
Atlantic multi-decadal variability (AMO)



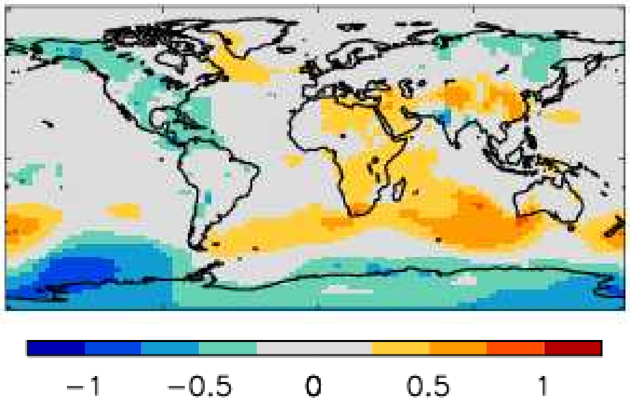


Pacific decadal variability (PDO/IPO)





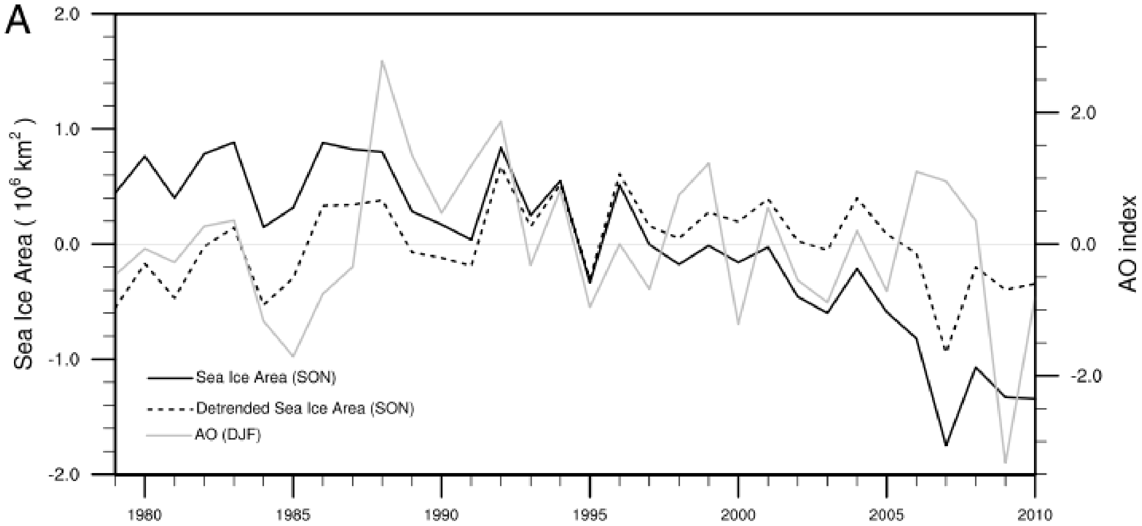
Long term trend

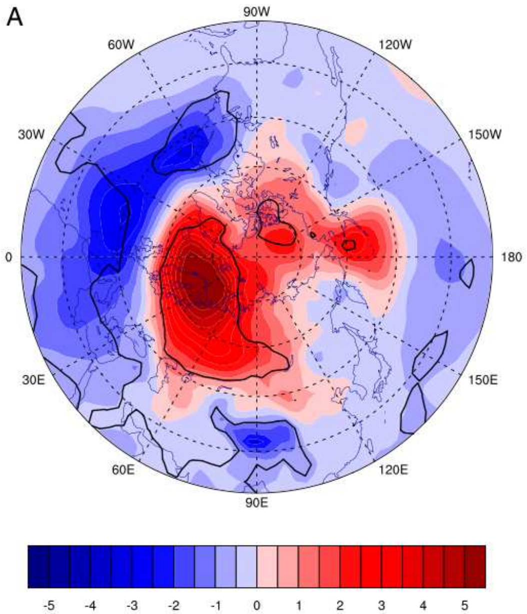


- Observed DJF mslp composites
- Units are decadal standard deviations

Smith *et al*, 2011

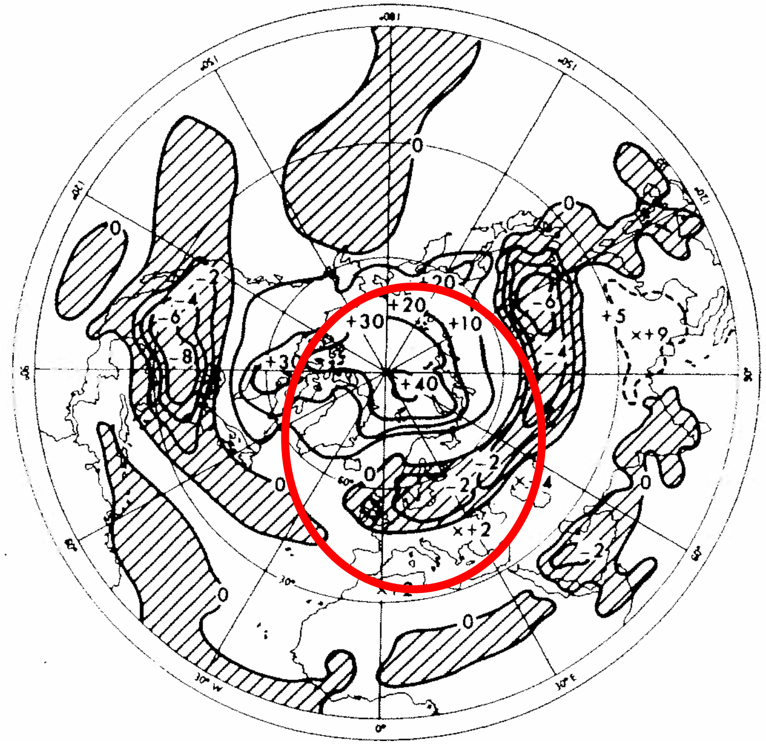
Potential sources of AO (NAO) predictability: Arctic sea ice





Regression of Arctic sea ice and mslp

Liu *et al*, 2012



Newson, R.L., 1973. Response of a general circulation model of the atmosphere to removal of the Arctic ice-cap. Nature, 241, 39-40.

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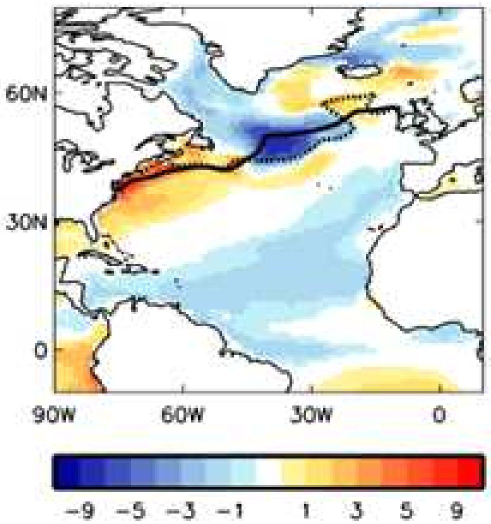
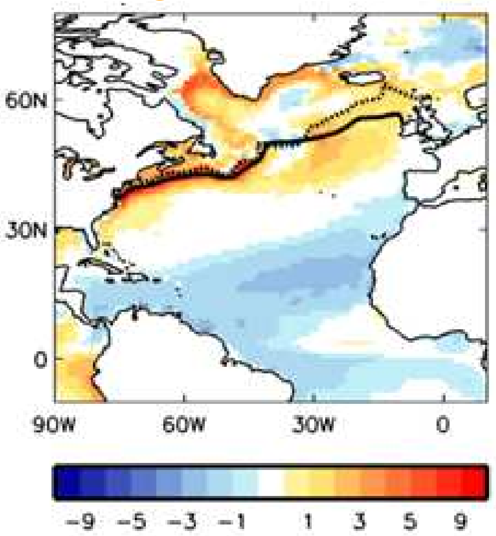
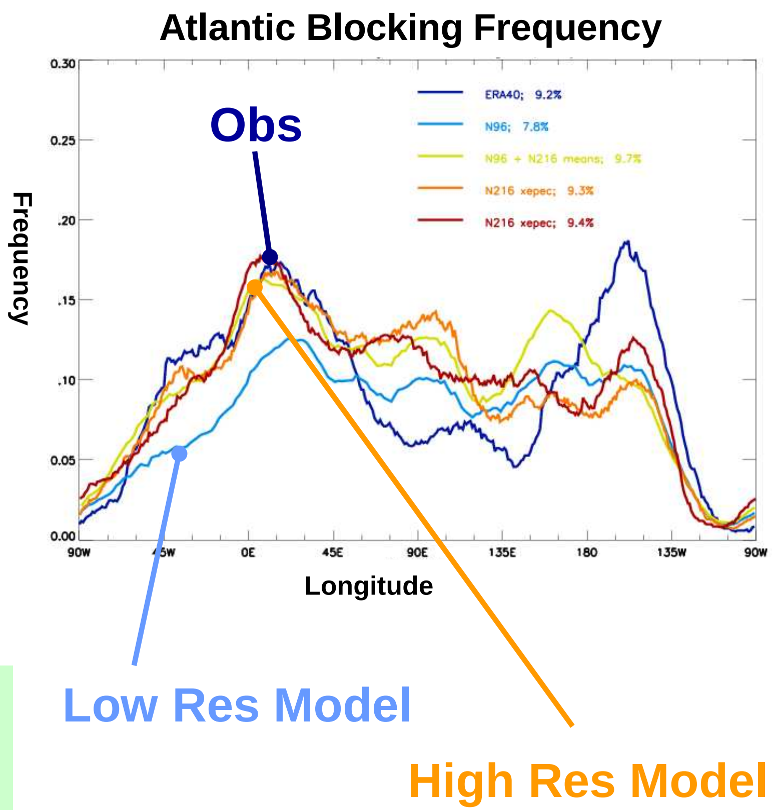
Atlantic Ocean: blocking

Low Res 1°



High Res 0.25°





Cold winter bias (°C) in Gulf Stream

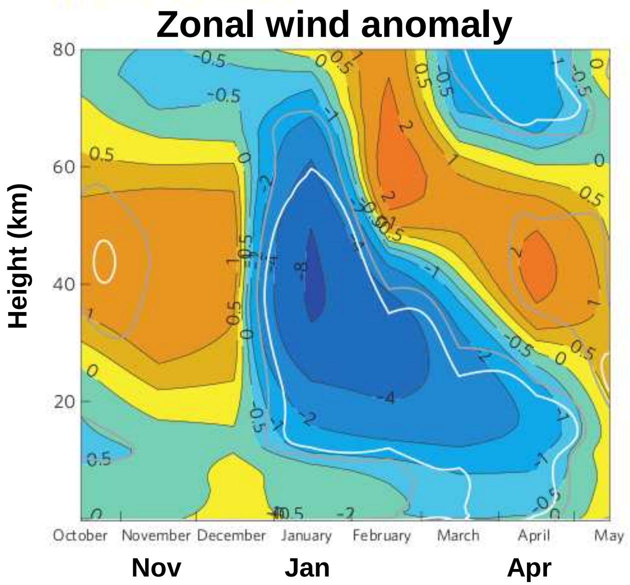
Occurs in standard seasonal forecast models

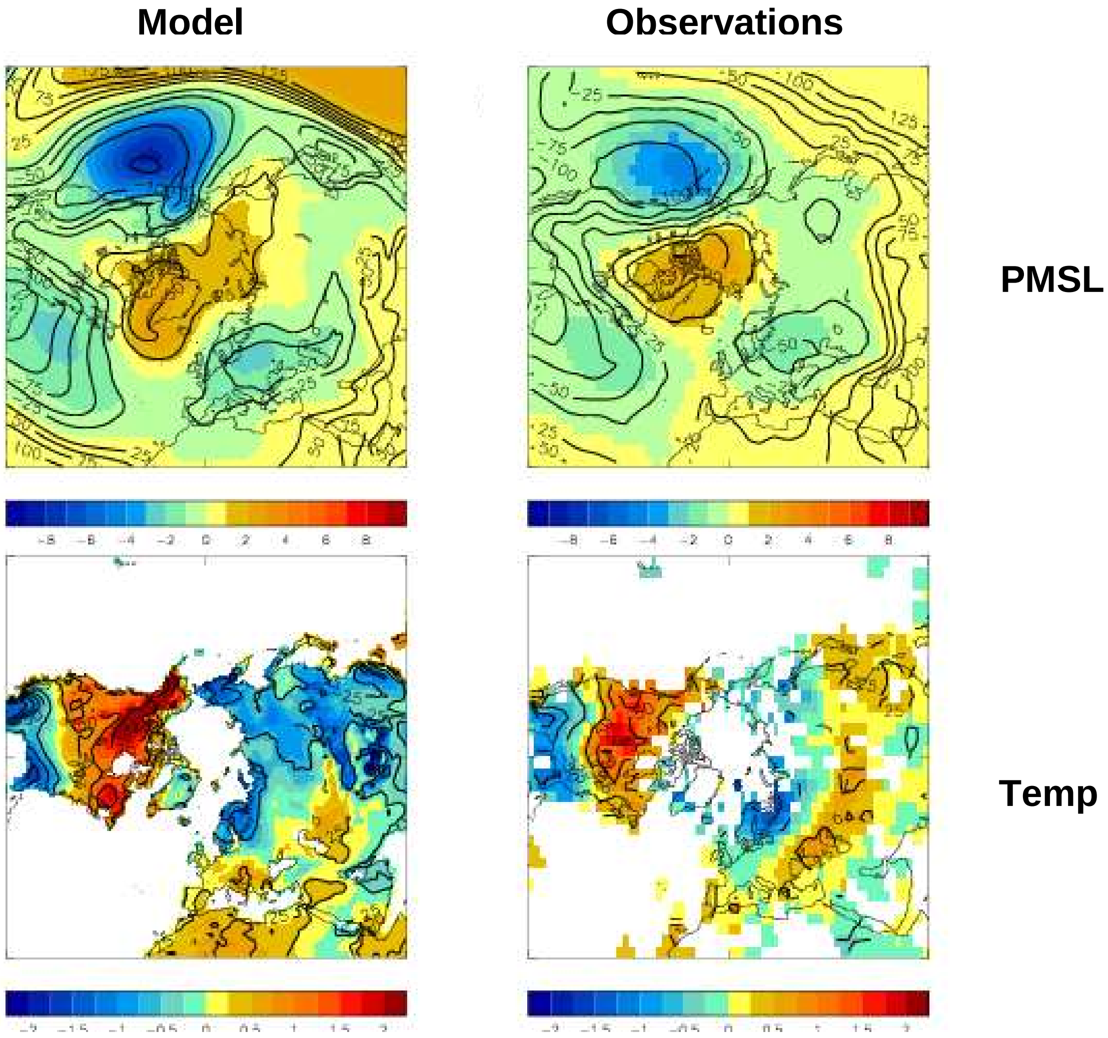
Small Gulf Stream bias in high res' Hadley Centre Model

⇒ Good Blocking!

Scaife et al., GRL, 2011

Modelled El Niño – Southern Oscillation



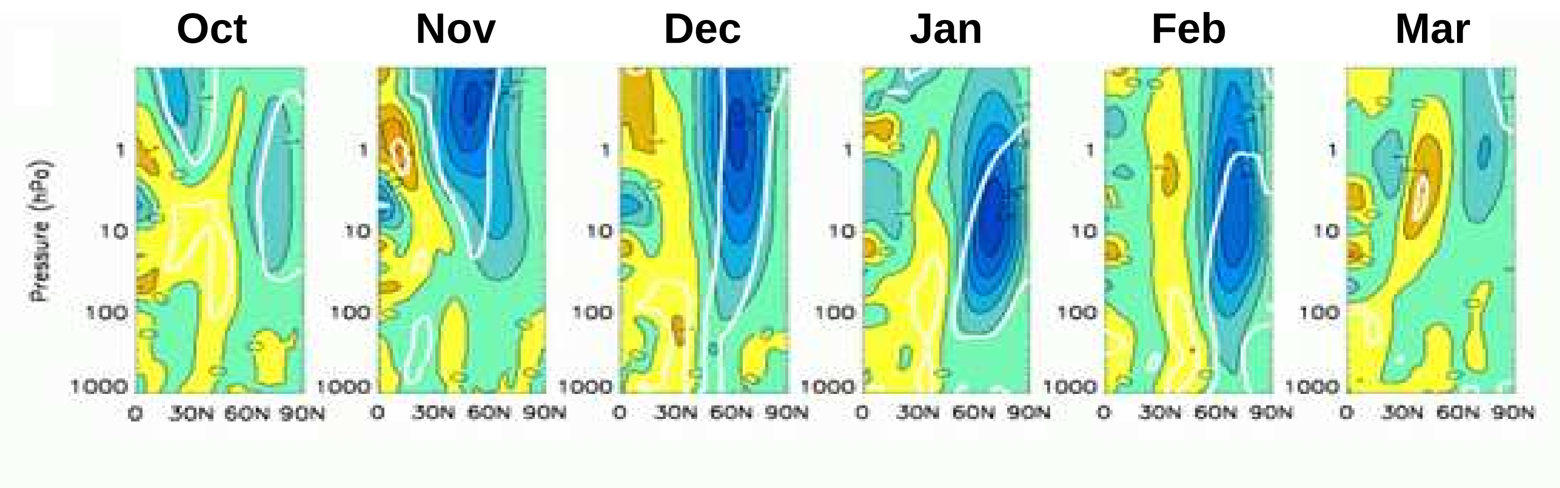


El Nino => easterly winds in UK (-ve AO) in late winter

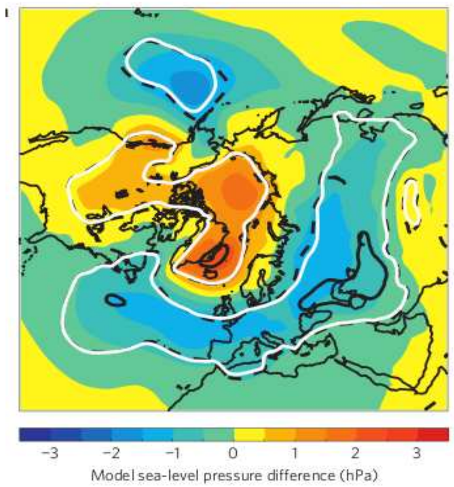
Occurred in 2009/10

Ineson and Scaife, Nat. Geosci., 2009

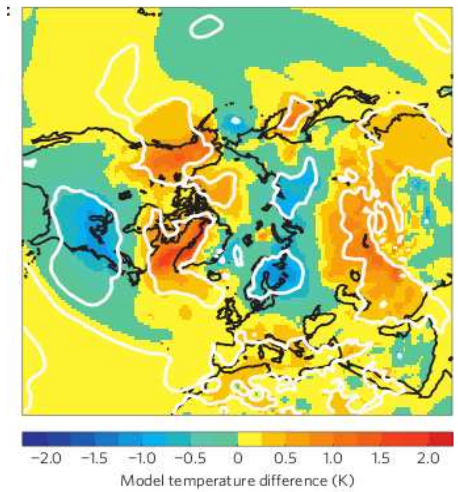
Solar min minus max simulated by model

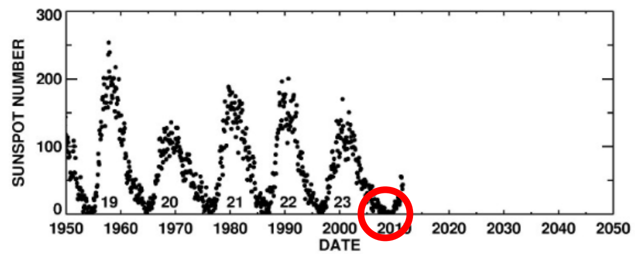


Sea Level Pressure



2m Temperature

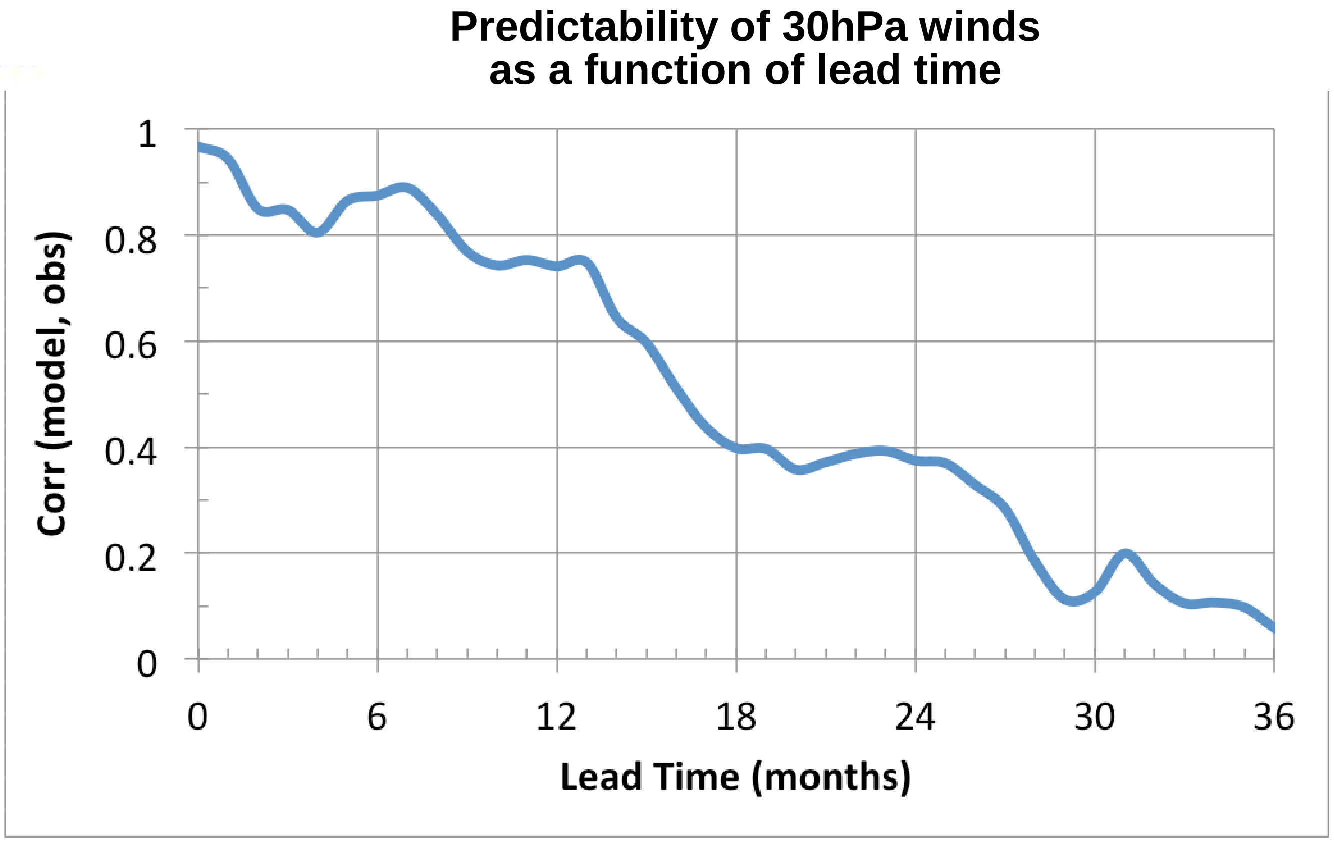




-ve Arctic Oscillation / NAO

Ineson et al, 2011.

QBO predictability



High levels of predictability for *following* winter

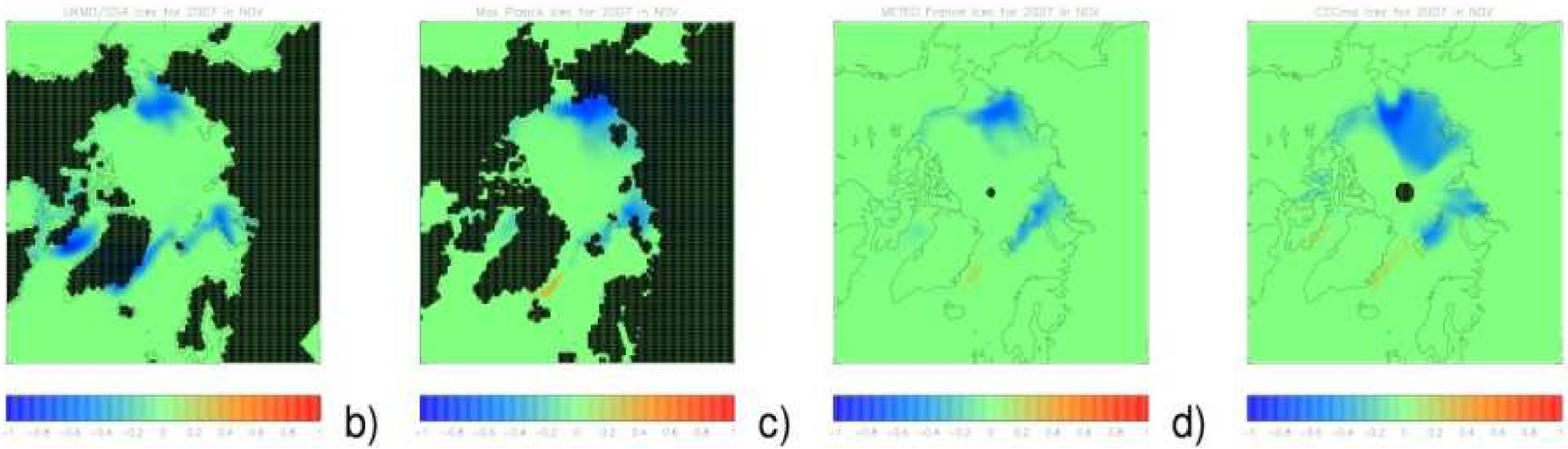
At least as high as ENSO

Probably the longest range predictable signal internal to the atmosphere

Maria Athanassiadou

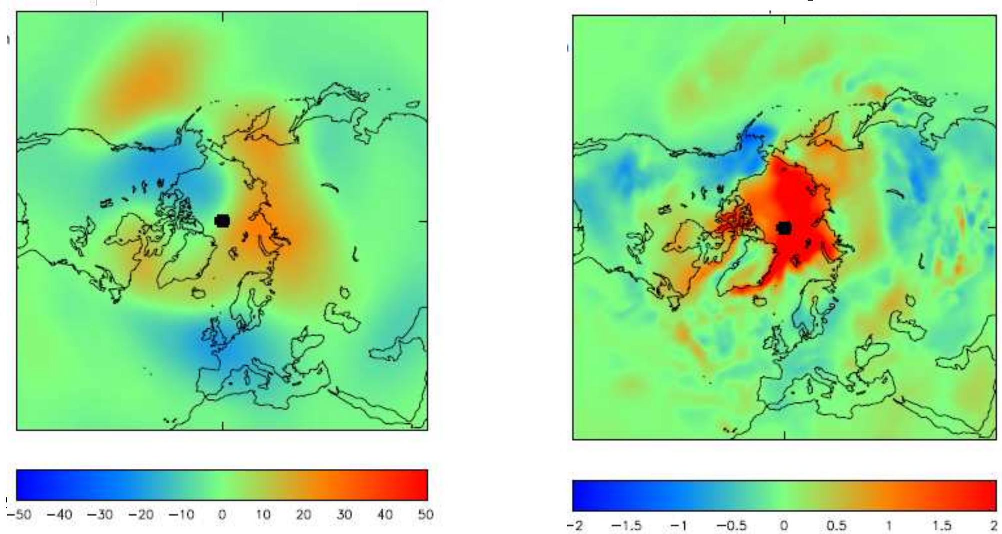
Effect of Sea Ice depletion on seasonal forecasts (a WGSIP expt)

UKMO **MPI** **MeteoFr** **CCCma**



Nov

500hPa GPH **2m Temperature**

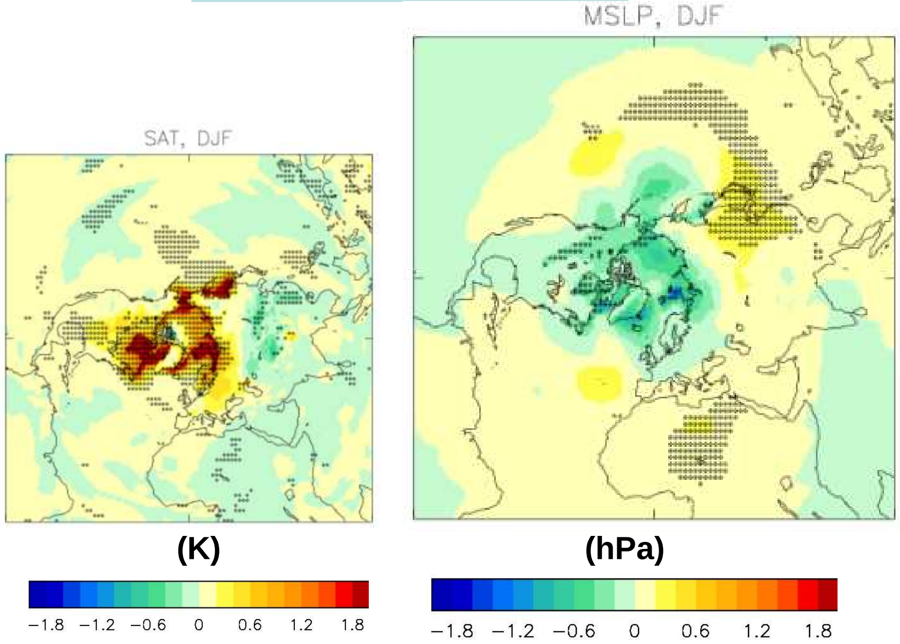


DJF

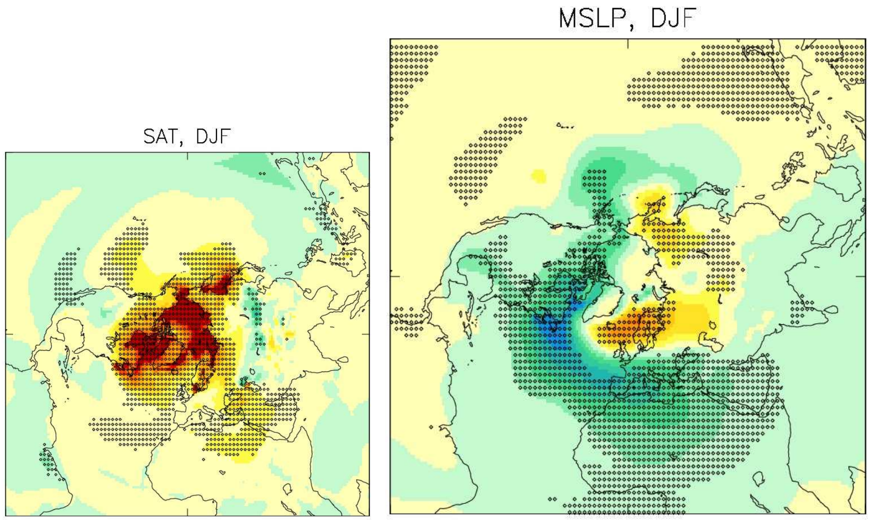
Drew Peterson

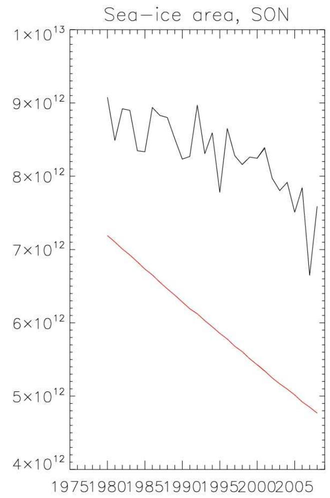
Effect of sea ice depletion in winter

Atmospheric model



Coupled O-A model





Extrapolate sea ice trend out for next 30 years

Ocean mixed layer free to respond in coupled experiments

Arctic warming in both experiments but stronger in coupled model

Weak – barely significant circulation response in atmosphere only model

Coupling is important for this response

Smith et al, in prep

Met Office GloSea5

Global Seasonal Forecast System 5

Model: **HadGEM3H N216L85O(0.25)**

Initialisation: **NWP state + NEMOVAR + Sea Ice**

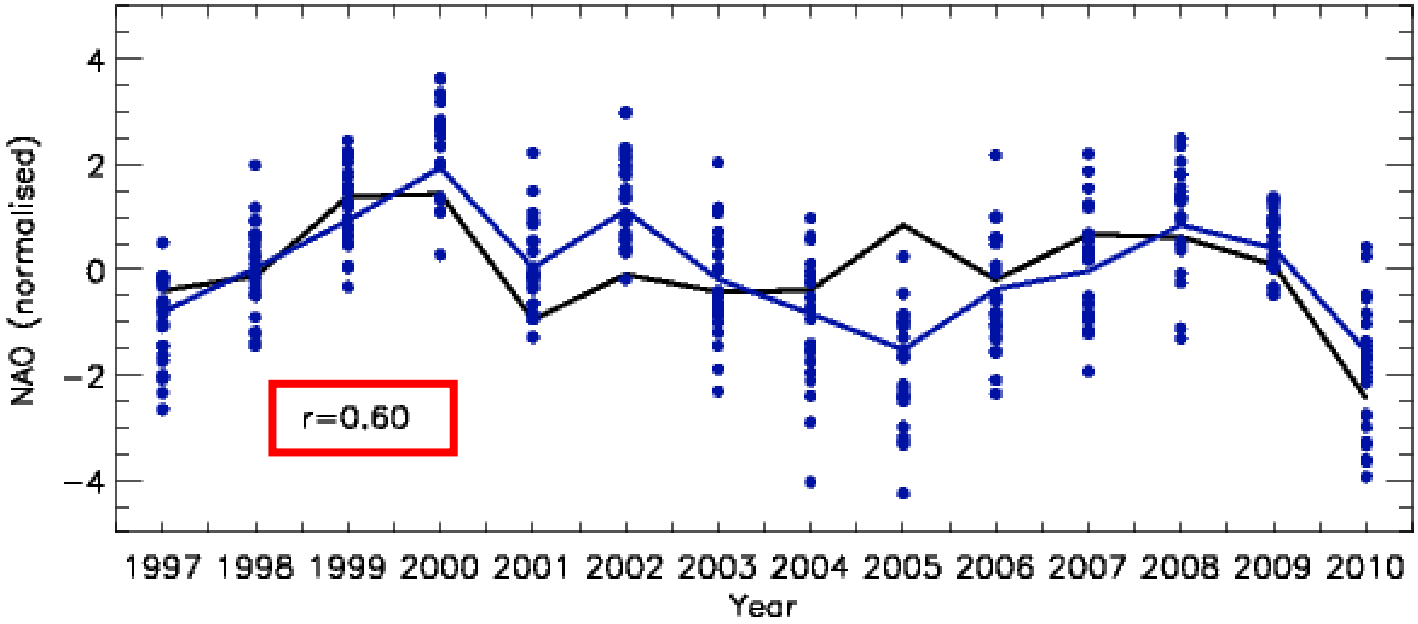
Winter Hindcasts: **24 members starting around 1 November**

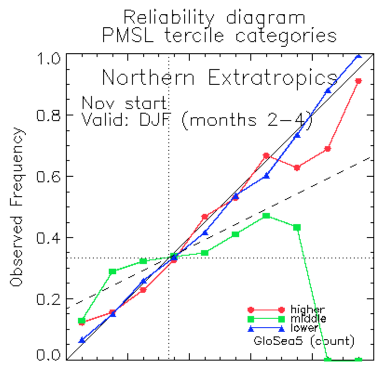
Designed for the job…

Predictability of the NAO!

(and pretty reliable PMSL predictions)

Retrospective winter forecasts

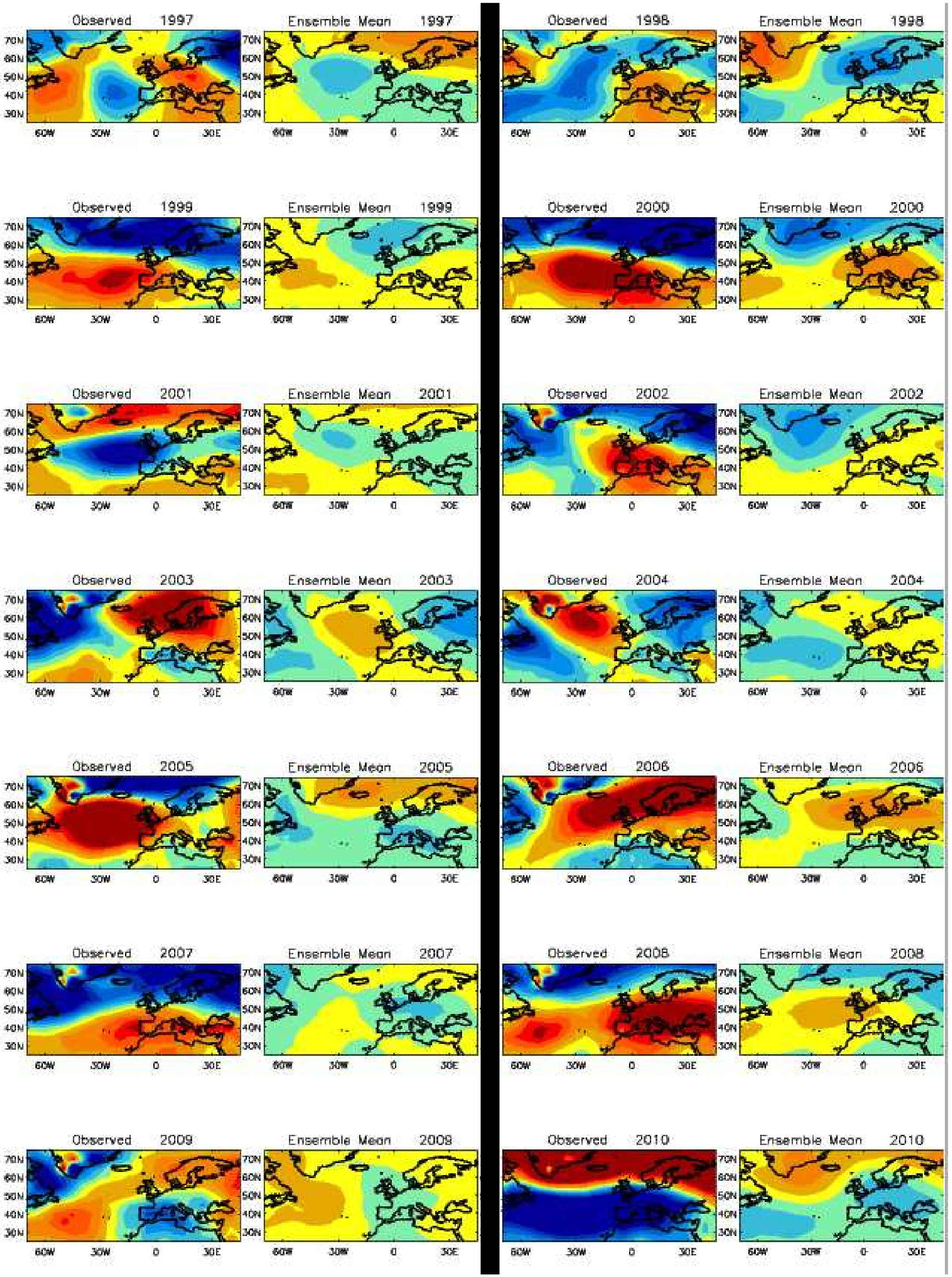




NAO skill **r~0.6** **(c.f. ECMWF 0.16, NCEP 0.25: not stat. sig.)**

Significant at the 98% level

(Scaife et al. submitted)

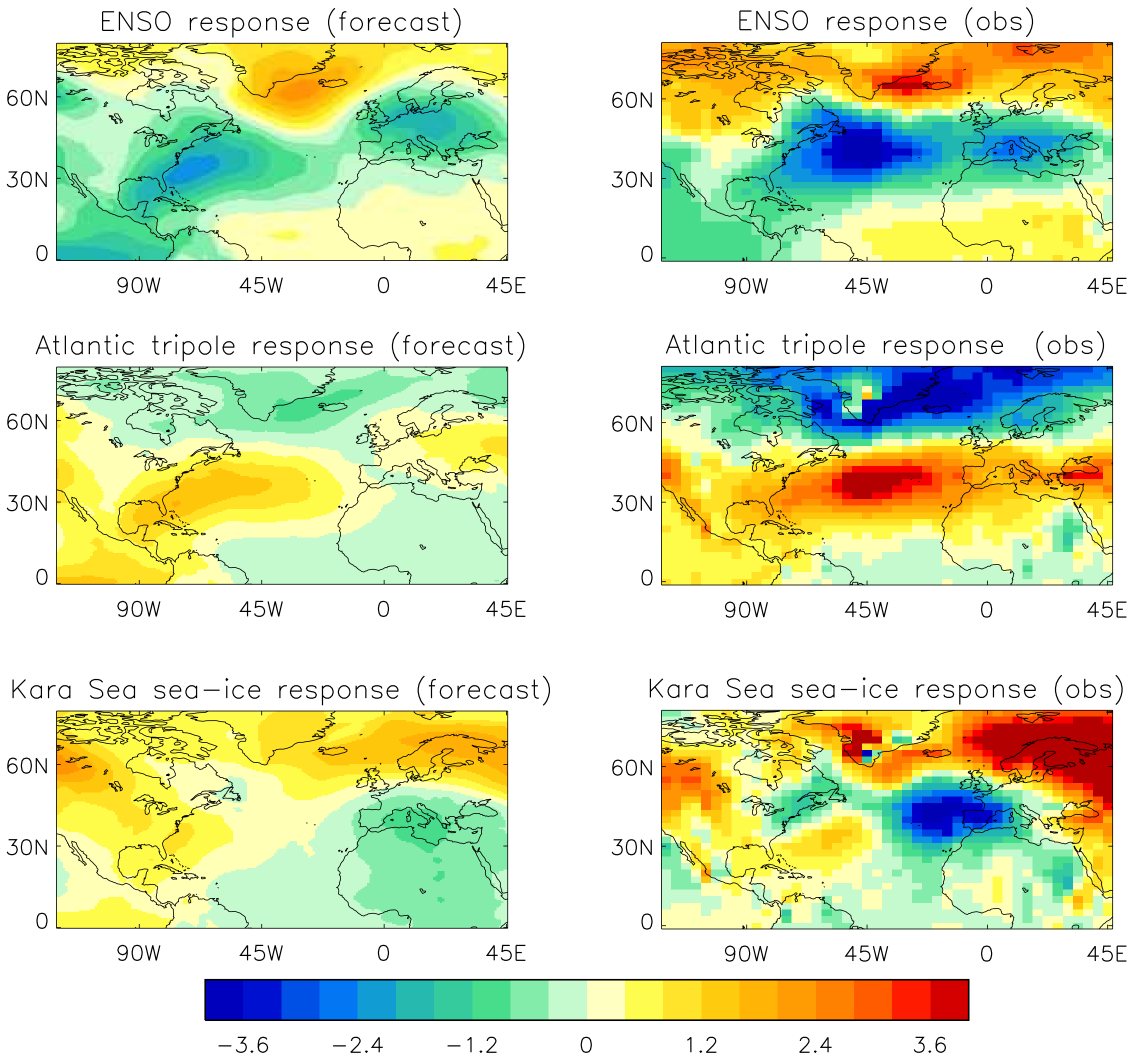


Individual winters

Very good agreement between pressure patterns in many individual years

Strength always underestimated

Sources of predictability…



Strongest minus weakest cases for November predictors:

ENSO Niño3.4

Atlantic Tripole

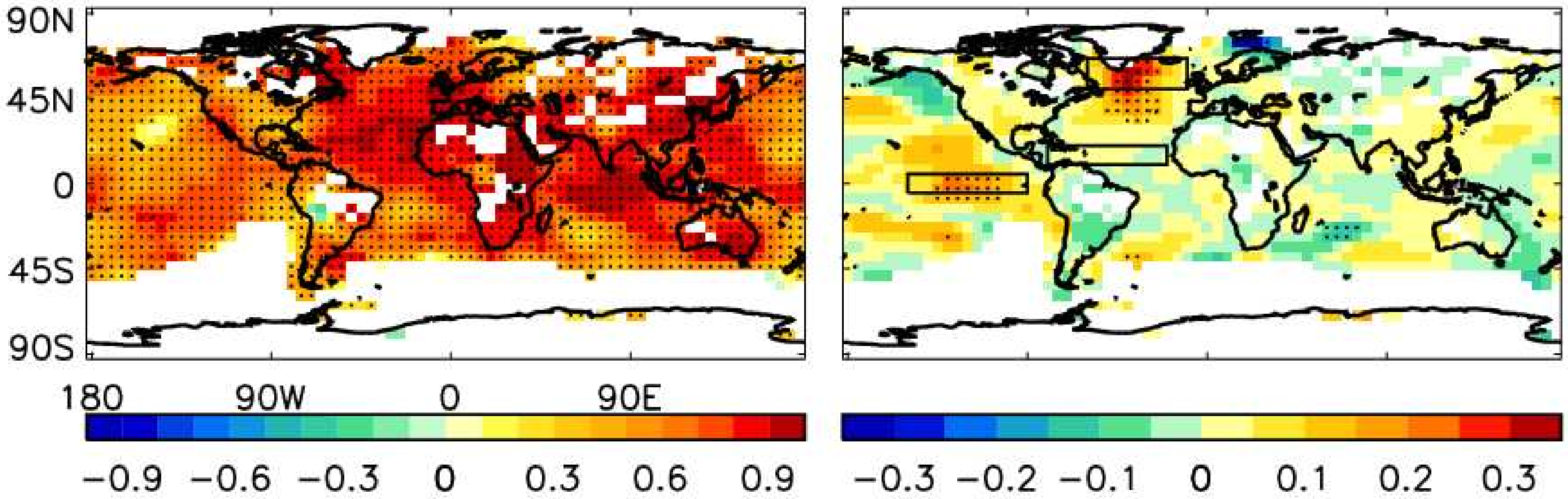
Kara sea-ice

Response is weaker in model than obs

Nick Dunstone

Surface temperature predictions (five year means)

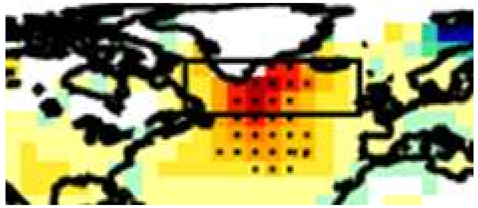
Skill of initialised predictions | Initialised - Uninitialised

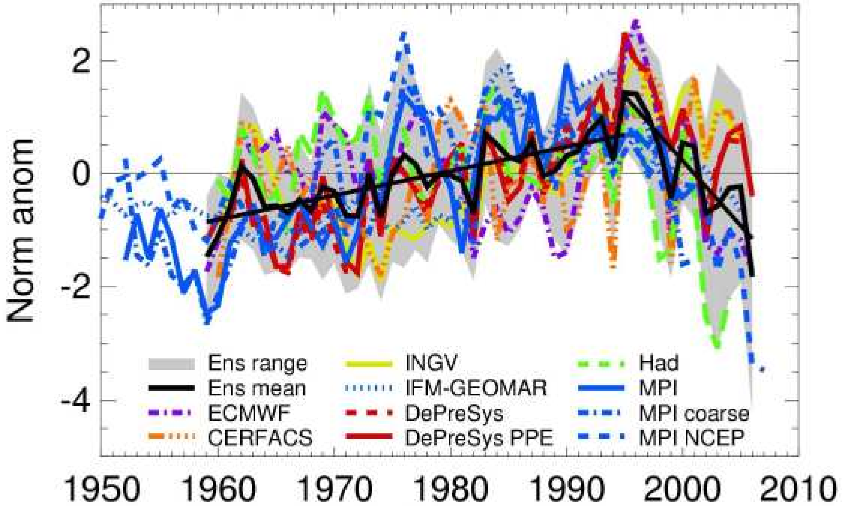


- Skilful almost everywhere (positive correlations)
- Mostly due to external forcing
- Initialisation gives improved skill mainly in North Atlantic and tropical Pacific

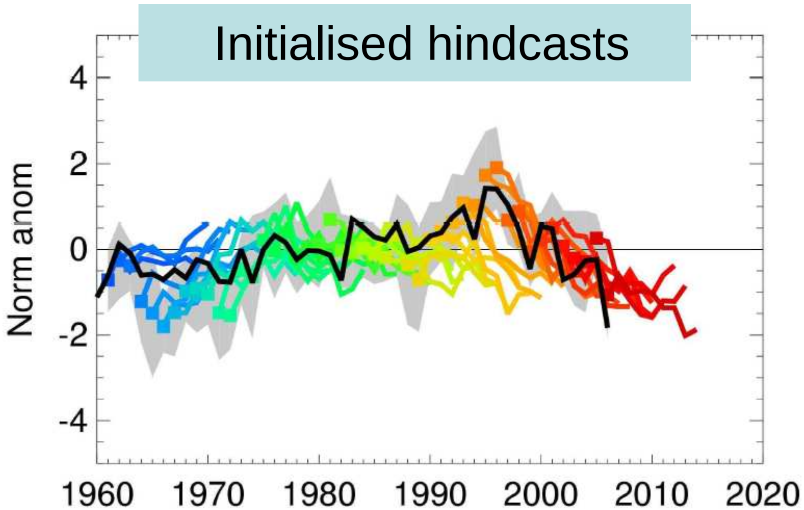
(Smith et al. 2010)

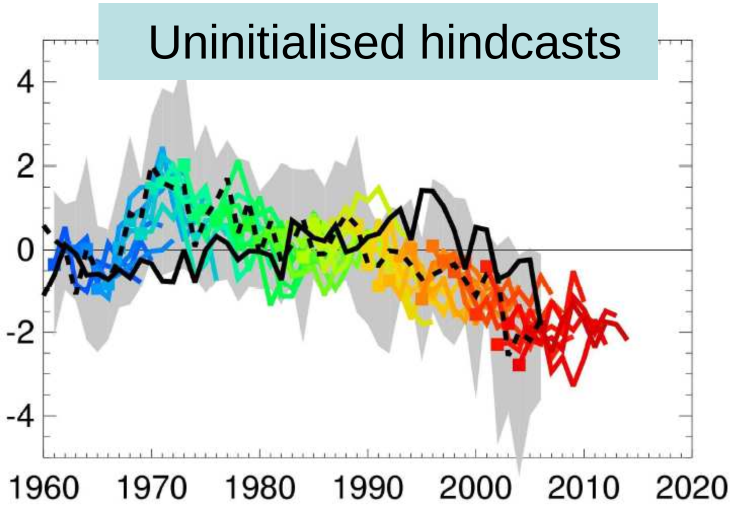
Physical basis for improved skill





- Atlantic overturning: no historical observations – must rely on models
- Consistent signal: increase from 1960 to 1995, decrease thereafter
- Agrees with related observations
- Some skill in initialised predictions, but not in uninitialised predictions





(Pohlmann et al. 2013)

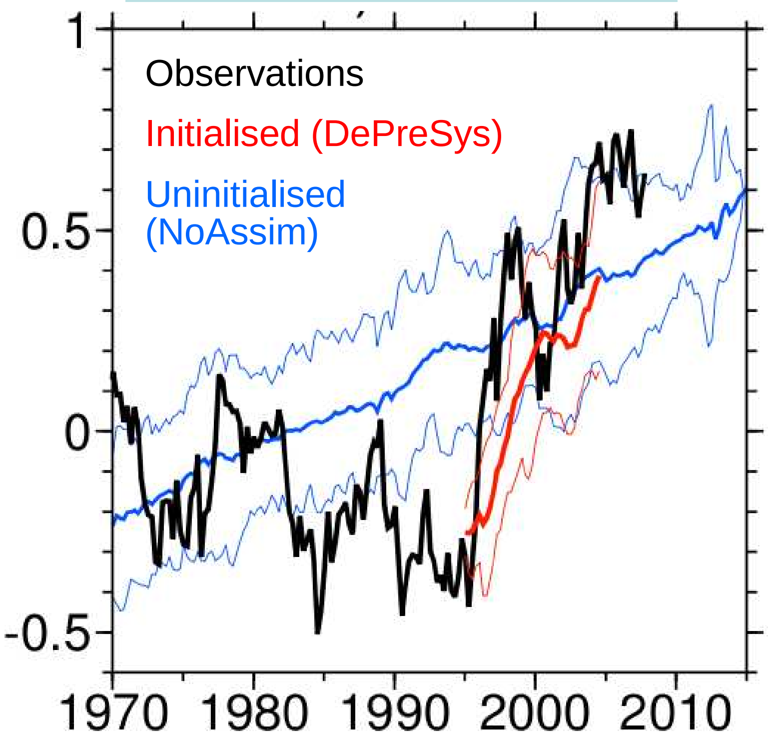
Met Office
Hadley Centre

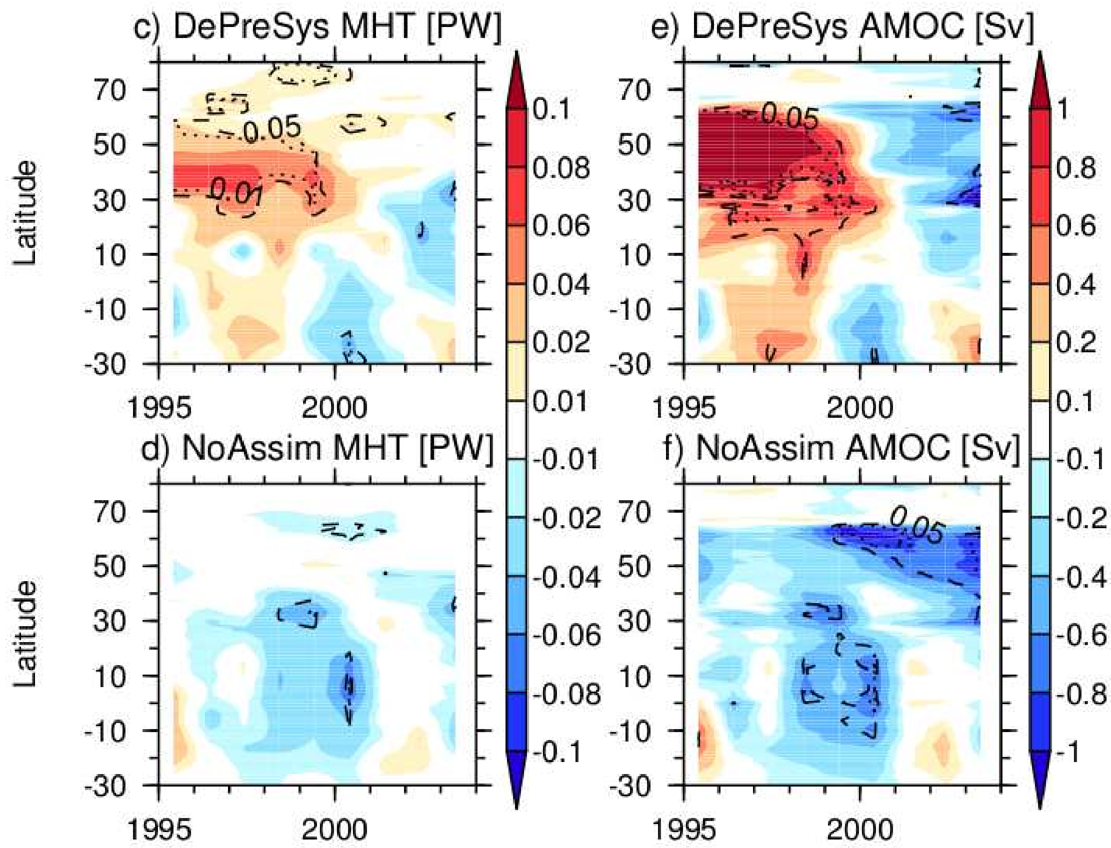
North Atlantic sub-polar gyre (SPG)

Meridional heat transport

Overturning circulation

SPG 500m temp





- Improved skill for 1995 rapid warming results from initialisation of increased Atlantic overturning circulation and meridional heat transport

(Robson et al. 2012, also Yeager et al. 2012)

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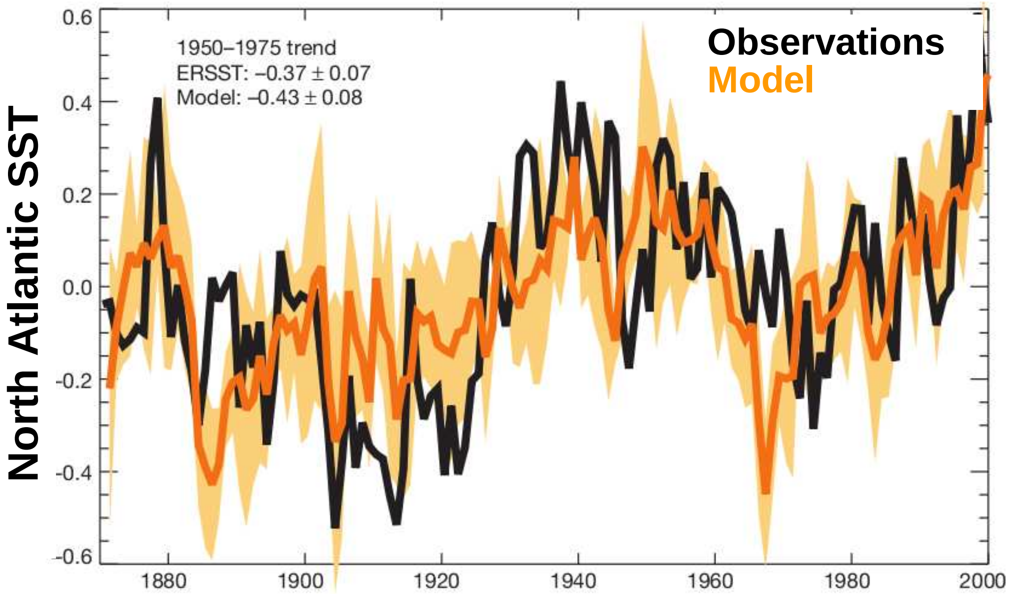
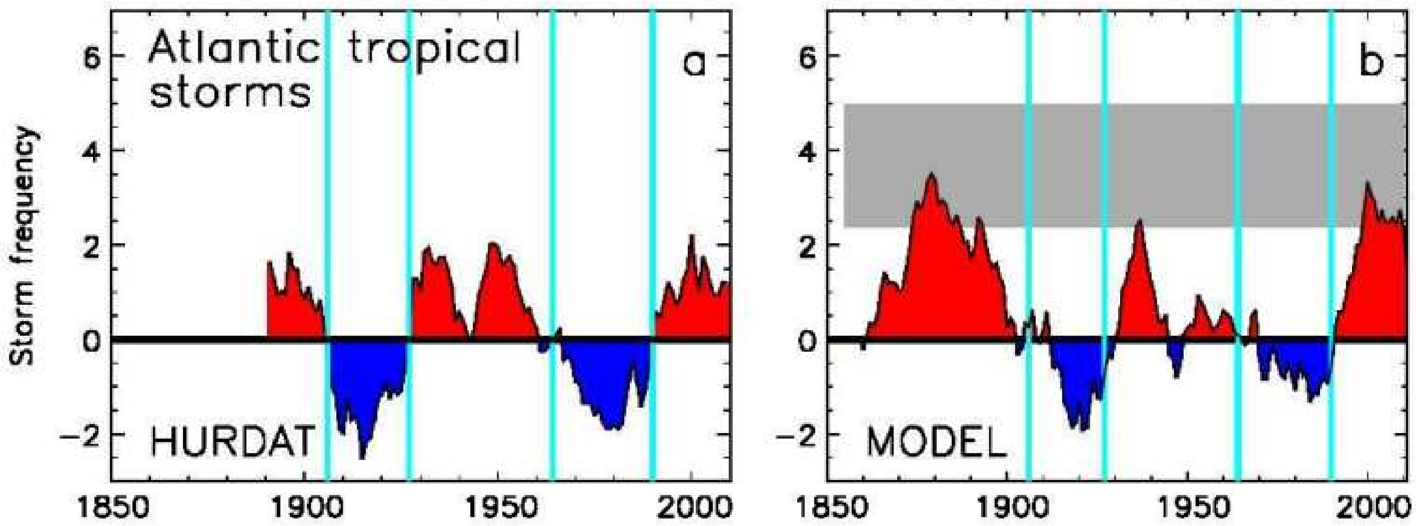
Potential role of aerosols…

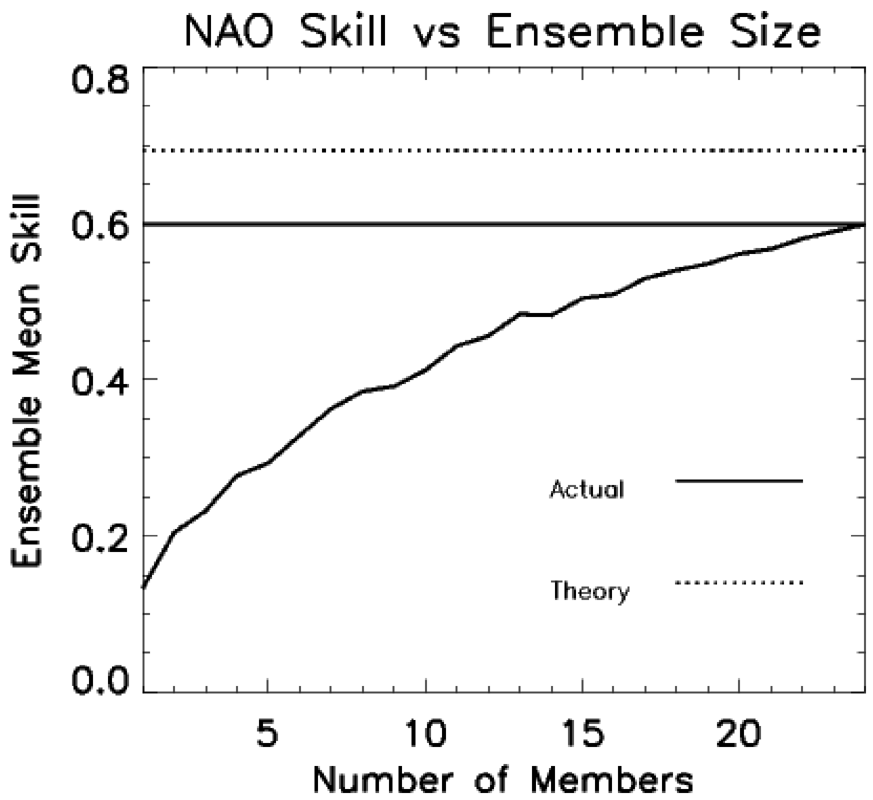


Booth et al., 2012



Dunstone et al., 2013

Effect of ensemble size on NAO skill

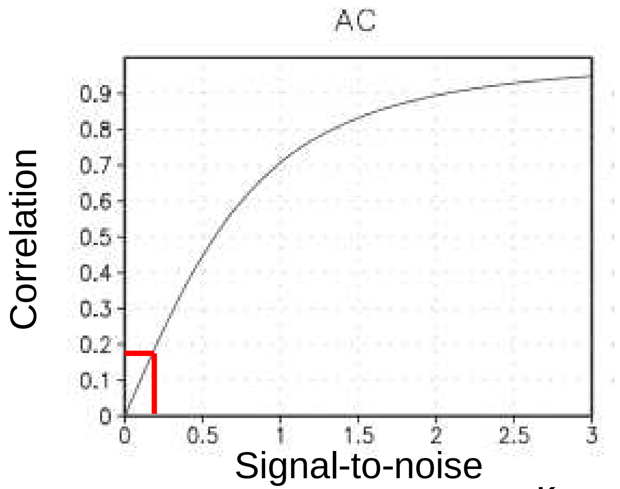


Increasing ensemble size increases correlation

Signal to noise is small ~0.2

Mismatch between correlation and signal-to-noise ratio

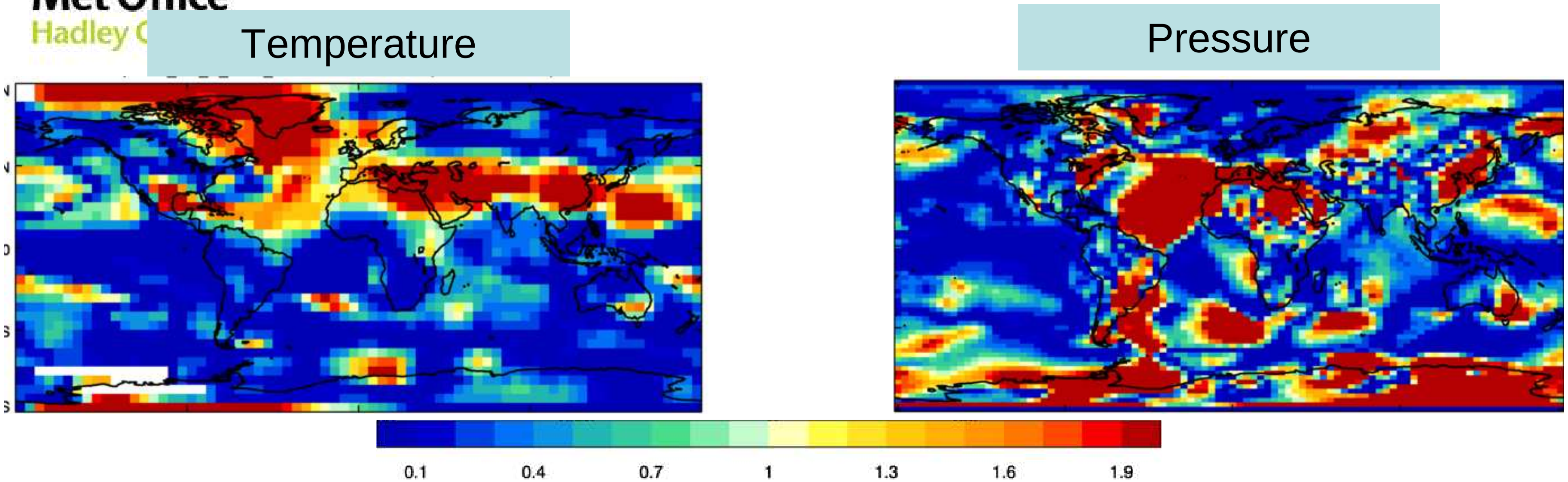
Approaching theoretical asymptote (Murphy, 1990) : 0.7 for GloSea5



Kumar 2009

Signal to noise and correlation:

Years 2-5



- Is predictable component of obs and model the same?
- predictable component of obs P(obs) = r^2
- predictable component of model

  P(model) = var(ensemble mean)/var(ensemble member)

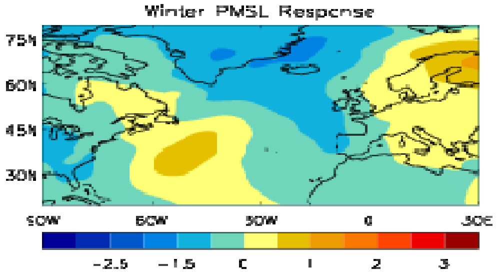
- Plot ratio P(obs)/P(model)
- Each member not necessarily a potential realisation of reality

  Need large ensemble, and to adjust variance

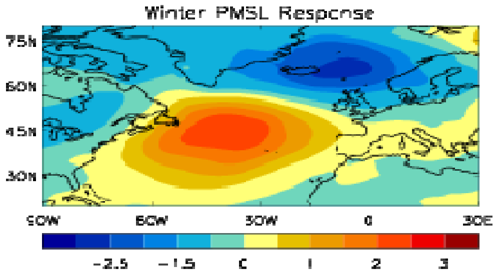
(Eade et al. In prep)

Lagged response to solar forcing

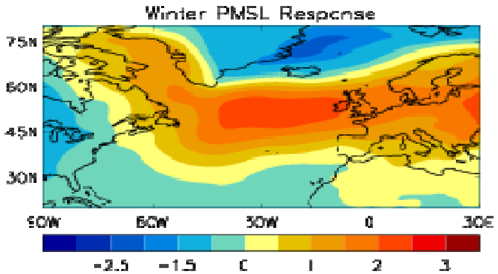
Year 1



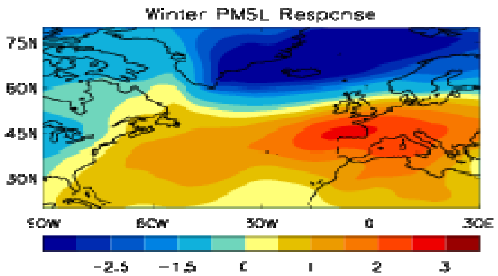
Year 2



Year 3



Year 4



Sea level pressure response to a solar constant forcing

Builds up year on year…

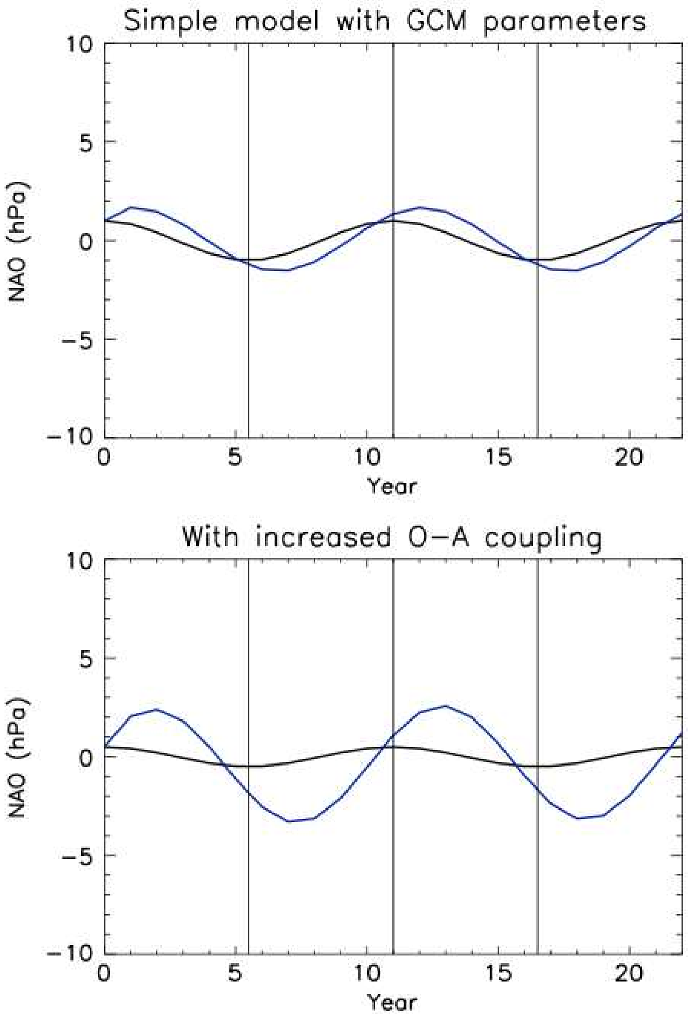
Scaife et al, GRL, 2013

Is ocean-atmosphere interaction too weak?

Simple model

$$\mathrm{SST}(y) = \alpha \cdot \mathrm{NAO}(y) + \beta \cdot \mathrm{SST}(y-1)$$

$$\mathrm{NAO}(y) = F \cdot S(y) + \gamma \cdot \mathrm{SST}(y)$$



Simple model with GCM coefficients => no lag

Requires increased O-A coupling

Scaife et al, 2013

Summary

Met Office
Hadley Centre

- Skilful seasonal predictions of NAO

  correlation > 0.6

- Several sources of skill including

  Sea Ice, Atlantic, ENSO – these 3 alone explain 50% of variance

  Implies need for interactive sea ice, good Atlantic and stratosphere

- Skilful decadal predictions of Atlantic SST, but limited NAO response

- Response to SST may be too weak in models

- Possible importance of anthropogenic aerosols for driving decadal variability of Atlantic SST