Met Office

Long range forecasting: Drivers of Predictability and how to model them.

Anna Maidens

ECMWF (UEF2014) 5th June 2014

So many issues...

- modelling physical processes
- ensemble generation
- initialisation
- model resolution
- choice of hindcast methodology
- model drifts/ biases
- post processing
- end user issues

So little time!

© Oxfam
© Trocaire.org
© Stefan Penninger
NASA
© Al Jazeera
NASA

Outline

- End user issues
- Modelling the drivers
  - ENSO
  - Stratospheric effects
  - Quasi Biennial Oscillation
  - Blocking and Wave breaking
  - The Madden Julian Oscillation
  - The Atlantic
  - Eurasian snow cover
  - Cryosphere
- How do these feed into improved forecasts?

What is the end user interested in?

Forecasting European winter

© David Moore

Winter 2013-14

strongly positive NAO in JFM

Winter 2010-11

strongly negative NAO in Dec

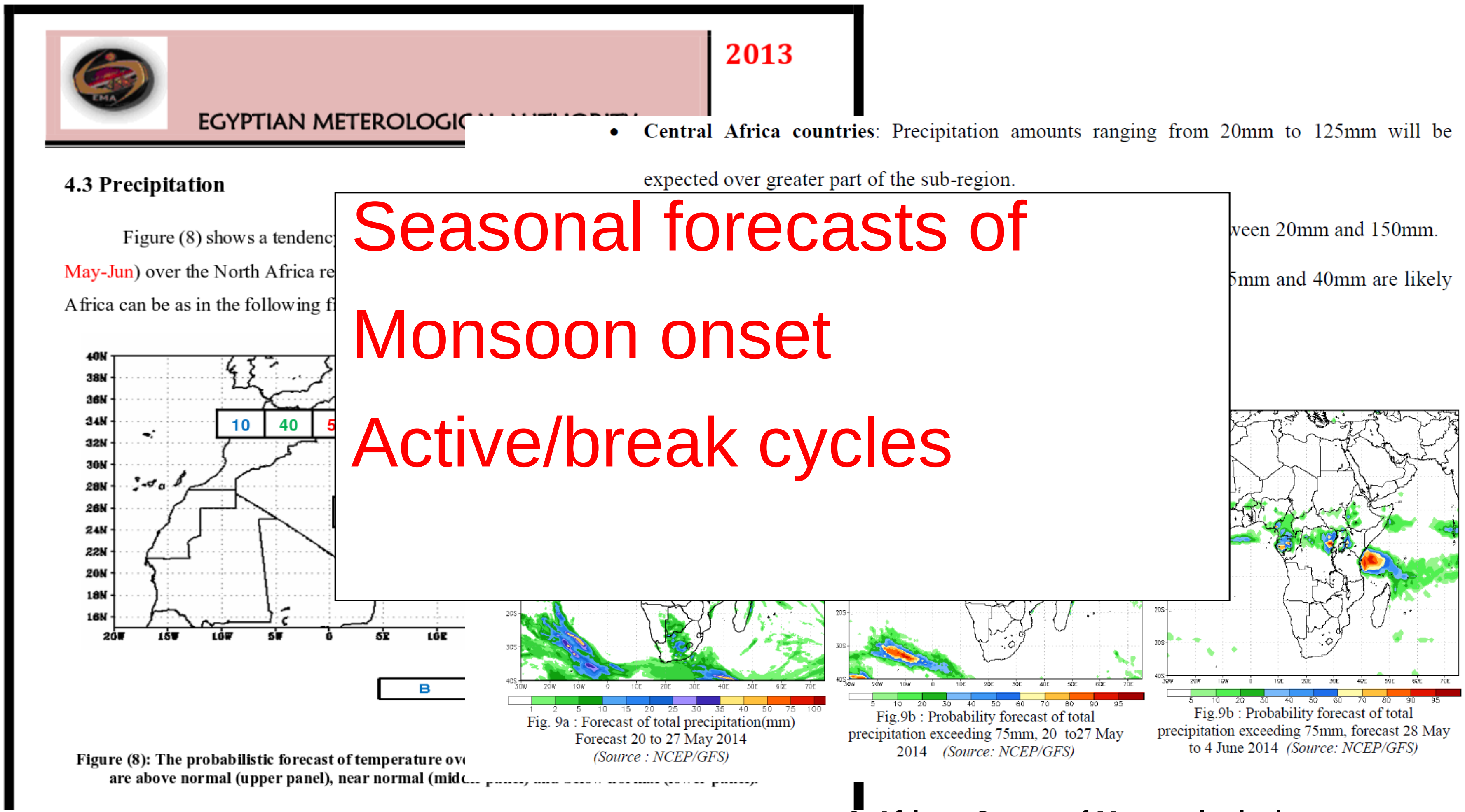
© Oliver Wilton

African Preciptation

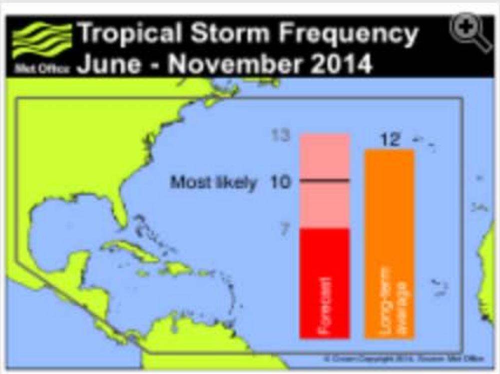
Seasonal forecasts of

Monsoon onset

Active/break cycles



Land falling hurricanes

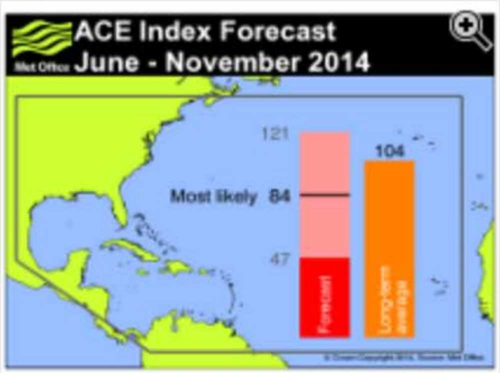


Tropical Storm Frequency Seasonal Prediction 2014

Hurricane Frequenc 2014

Our Climate Services for Reinsurance provide expert advice on seasonal prediction of tropical

consulting@me
customer centr

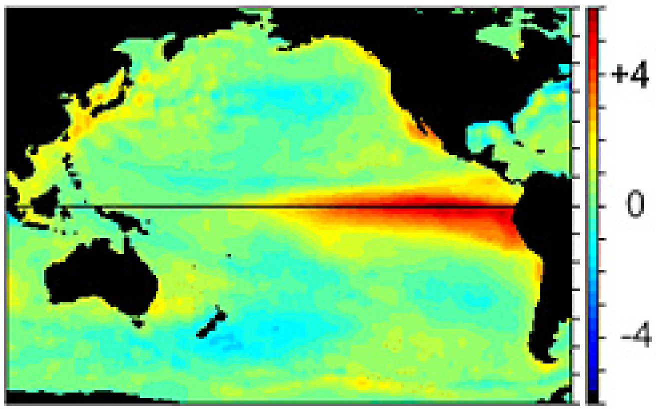


ACE Index Seasonal Prediction 2014

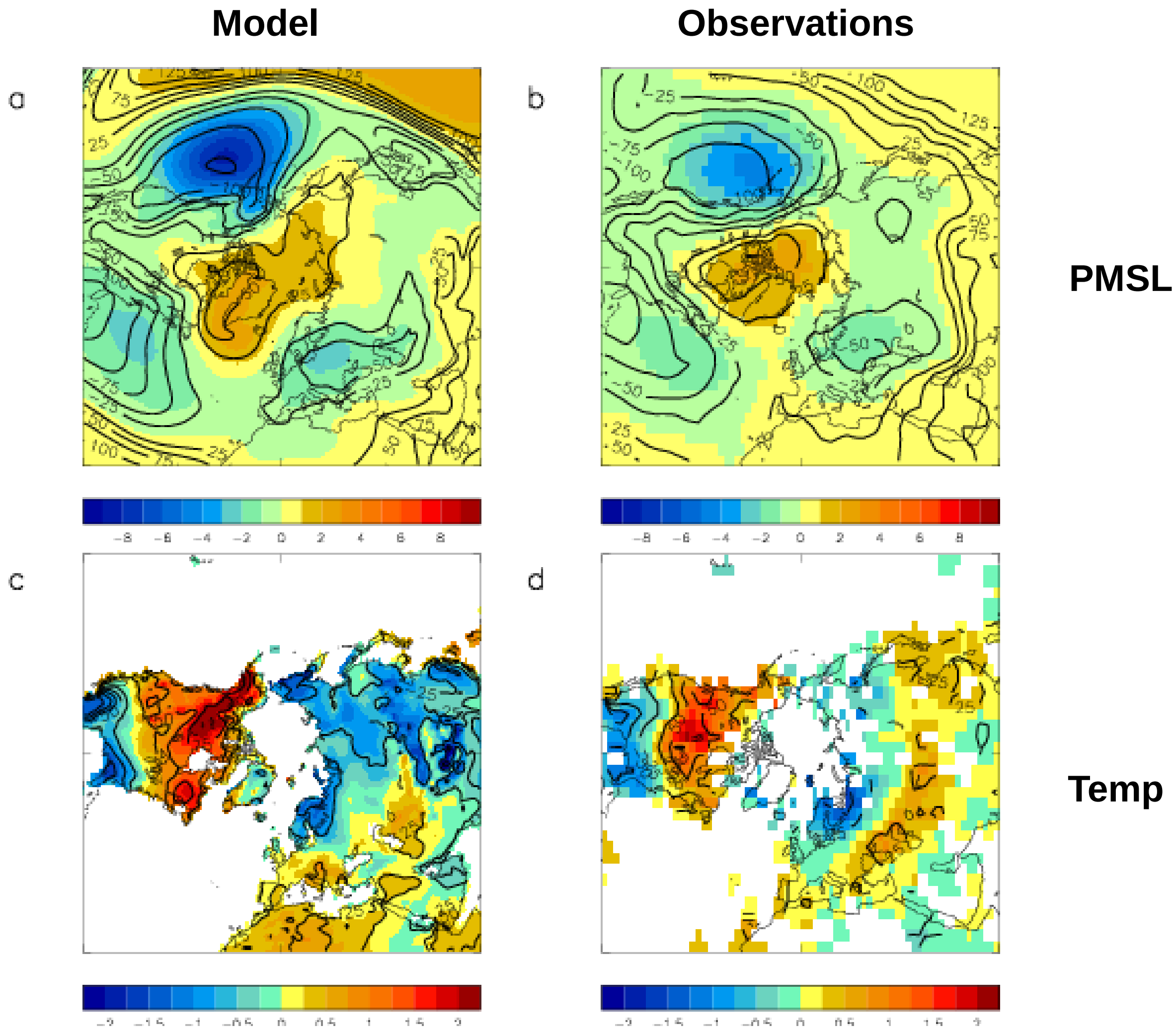
Aftermath of Haiyan, 2013, Phillipines

Drivers of predictability: where should we be focussing research effort? (Emphasis on European Winter...)

El Niño – Southern Oscillation Effects



El Nino => easterly winds in UK



Ineson and Scaife, Nat. Geosci., 2009

ENSO mechanisms

Mean response

- Deepening of Aleutian low
- Enhancement of wave-1 pattern
- Wave activity through depth of troposphere
- Propagates upwards into stratosphere
- Increases chances of sudden stratospheric warming

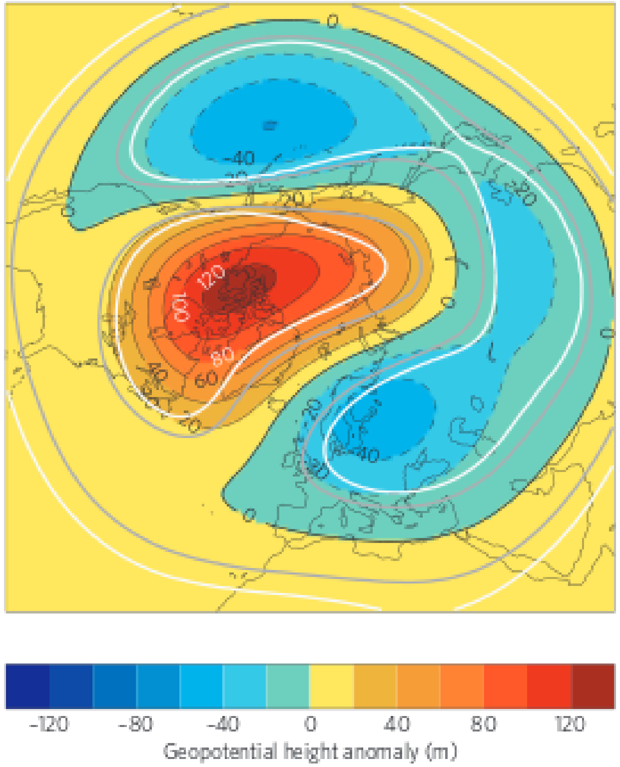


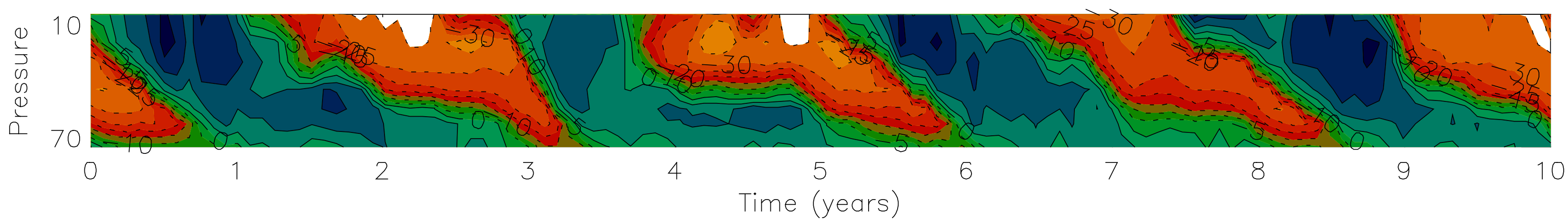
Figure 3 | Modelled lower stratospheric climate response to El Niño. Composite geopotential height anomaly (m) at 46 hPa for December–February. Grey and white contours indicate significance at the 95% and 99% confidence levels.

Ineson and Scaife 2008

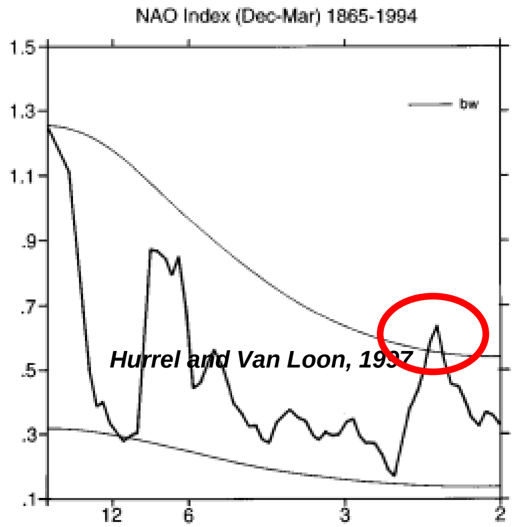
Quasi-Biennial Oscillation Effects

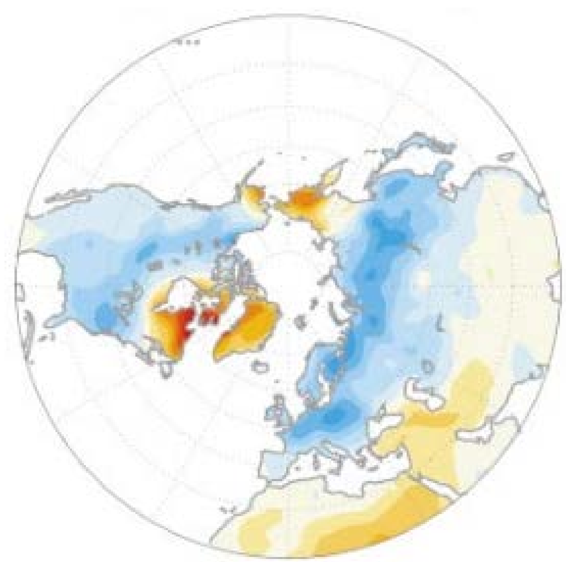
(After Ebdon 1975)

Observed tropical wind oscillations



NAO Power Spectrum





Surface Temperature

QBO easterly – QBO westerly

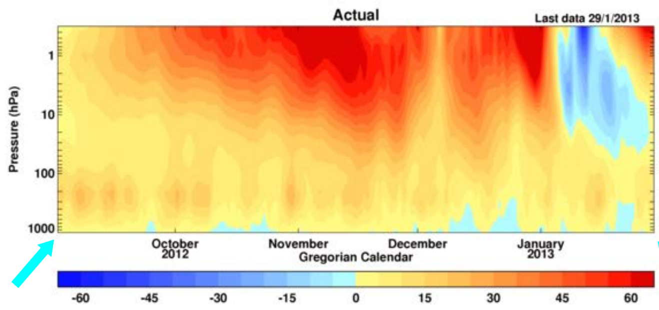
QBO most regular low frequency climate variability after seasonal cycle

Surface signal in observations, potentially important

Stratosphere is one of the main sources of predictability

Case study: January 2013

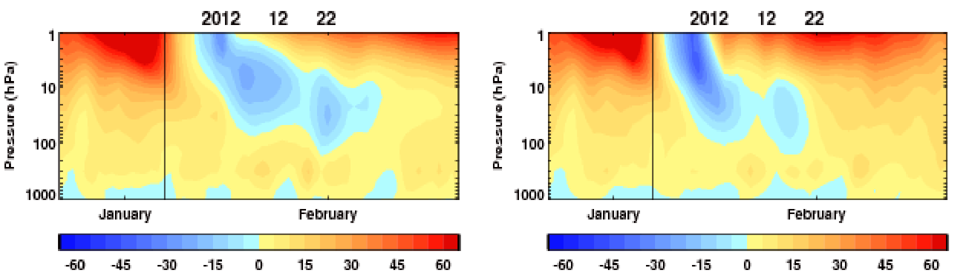
analysis: zonal average at 60N



1 Sep

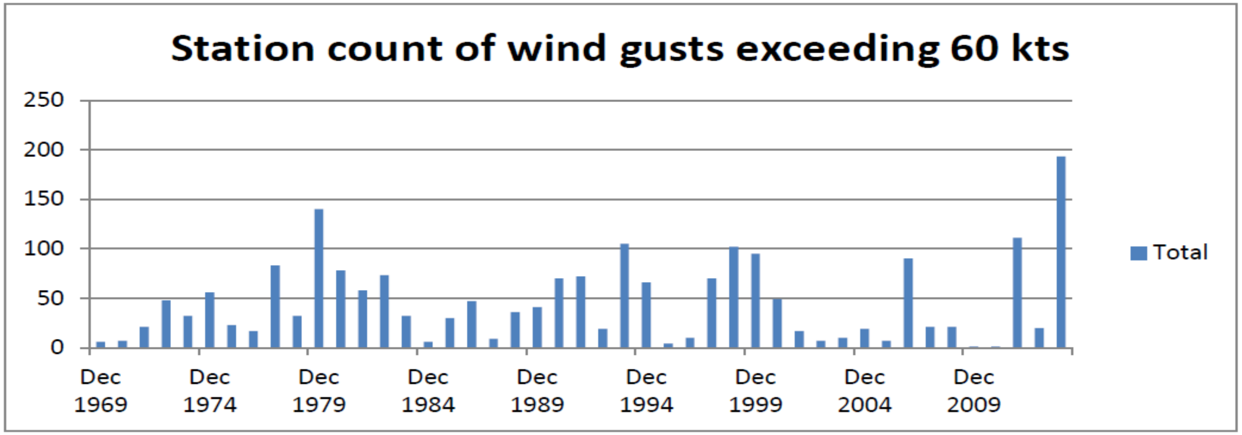
31 Jan

forecast initialised 22 Dec



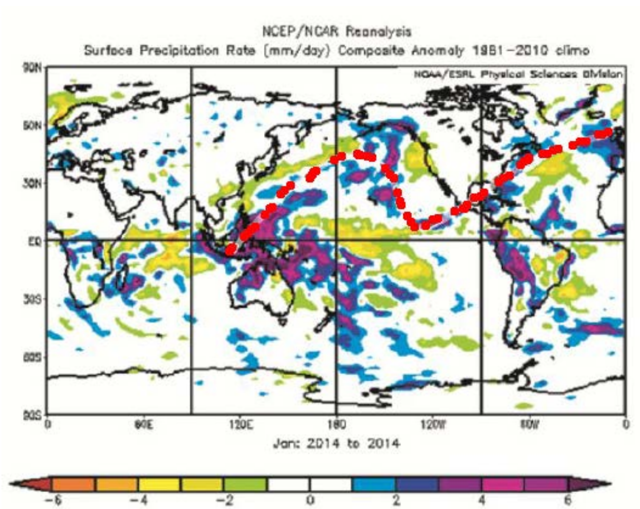
Snowfall starts 18th January

Stratosphere effects in winter 2014



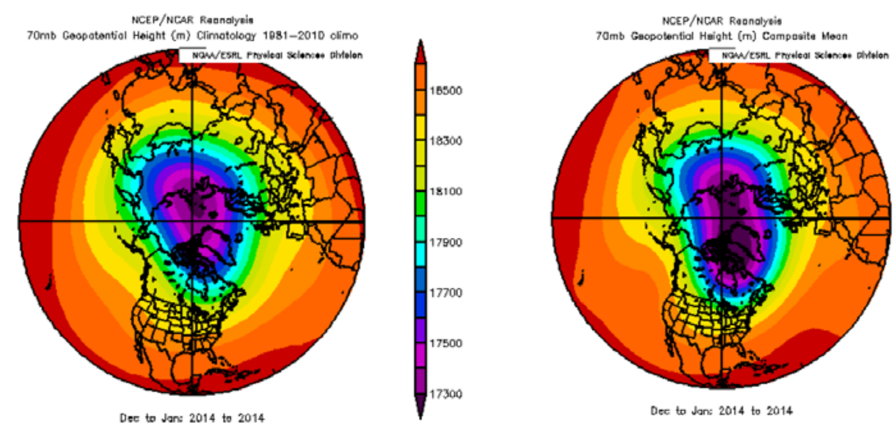
Wettest DJF in England and Wales in 248 year records.

Precipitation anomalies



Jet disturbances

70hPa Geopotential Height

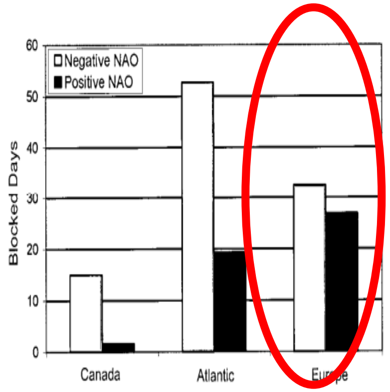


climatology

DJF 2013-14

Slingo et al., 2014, Met Office/CEH briefing document

Blocking, wavebreaking and the NAO

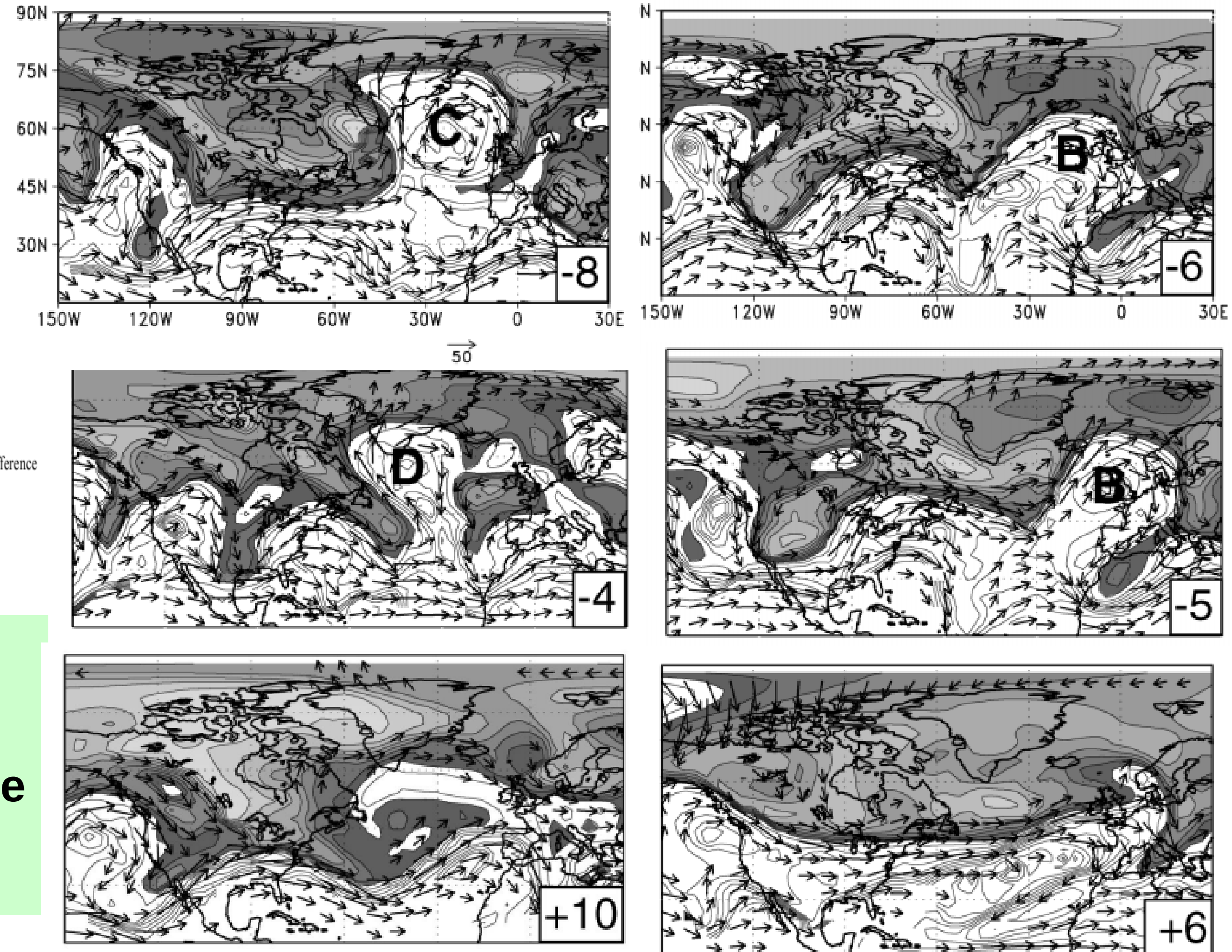


mposite days of regional blocking events for negative NAO (open bars) and positive NAO (solid bars). The difference ween the two phases of the NAO is significant at the 5% level for the Canadian and the Atlantic regions

Blocking and the NAO are closely related

positive (negative) NAO are remnants of anticyclonic (cyclonic) wave breaking

Negative and positive NAO episodes (a pseudotracer view)



Cyclonic wavebreaking: -ve NAO

Anticyclonic wavebreaking: +ve NAO

Benedict et al 2004

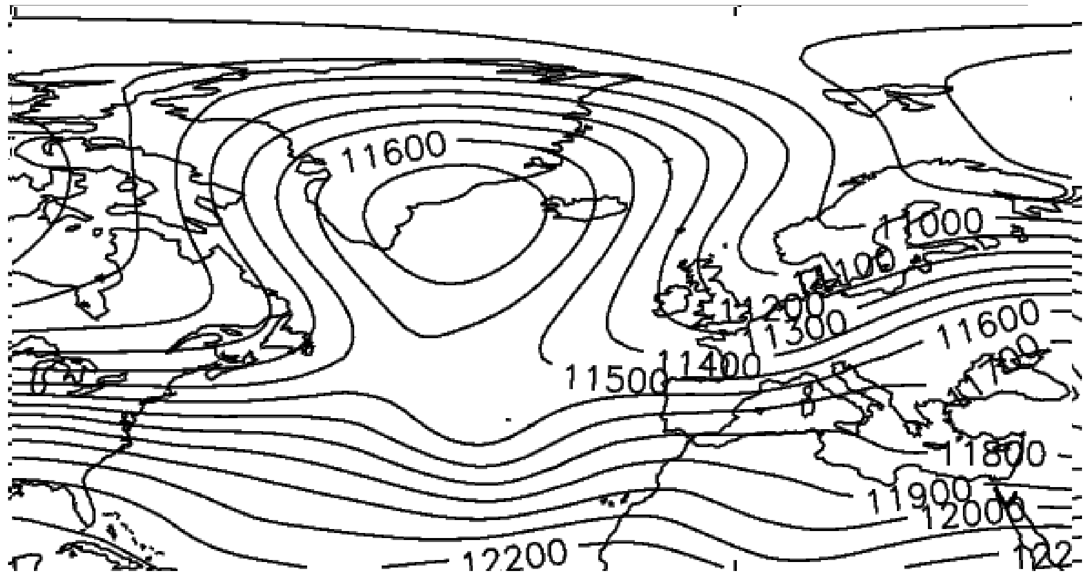
Met Office

Wavebreaking: How do models do?

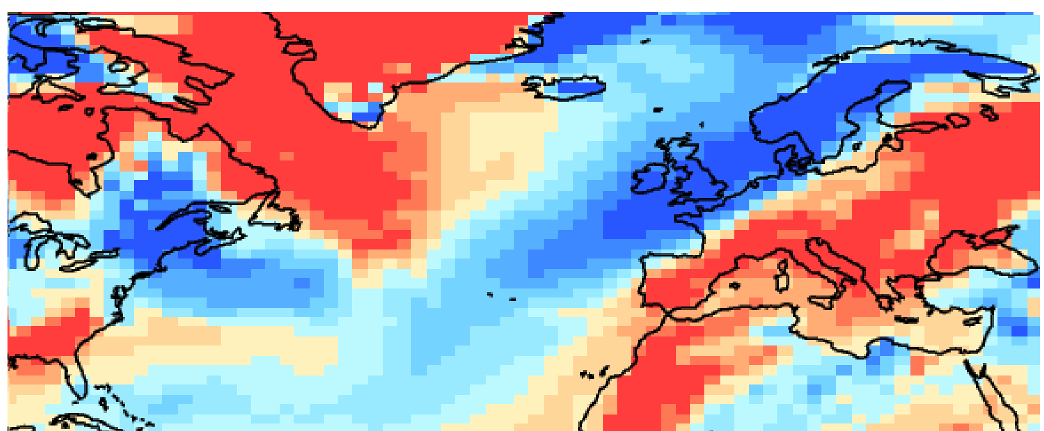
18 Dec

1 day lag

19 Dec



Z200



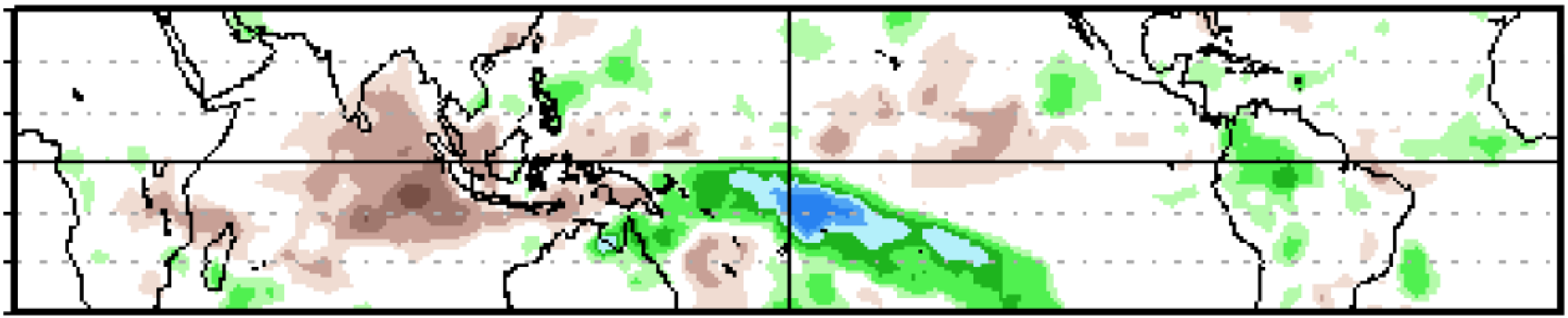
1.5m T

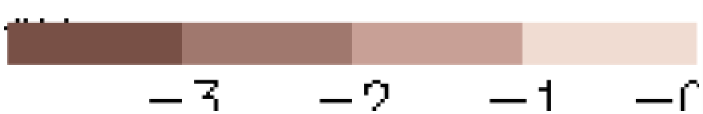
The Madden-Julian Oscillation

Eastward moving convection, period ~ 60 days

importance in tropics – e.g. Indian monsoon breaks

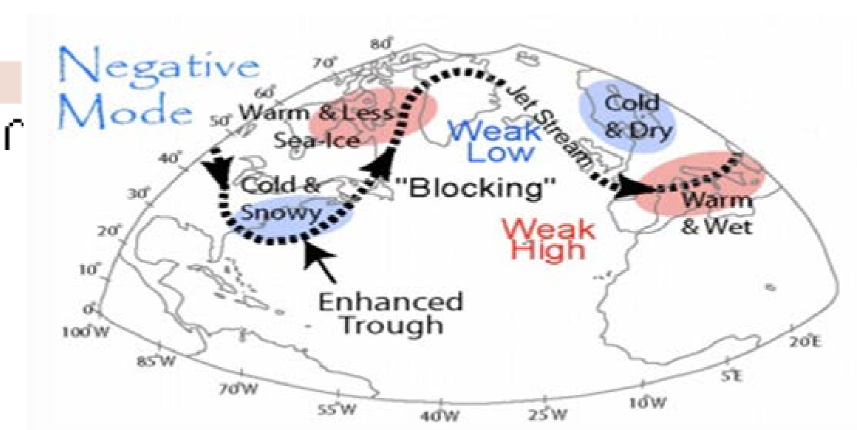
Phase 7





(indications of connection...)

10 days later



Improving the ability to model the MJO

ECMWF system 4

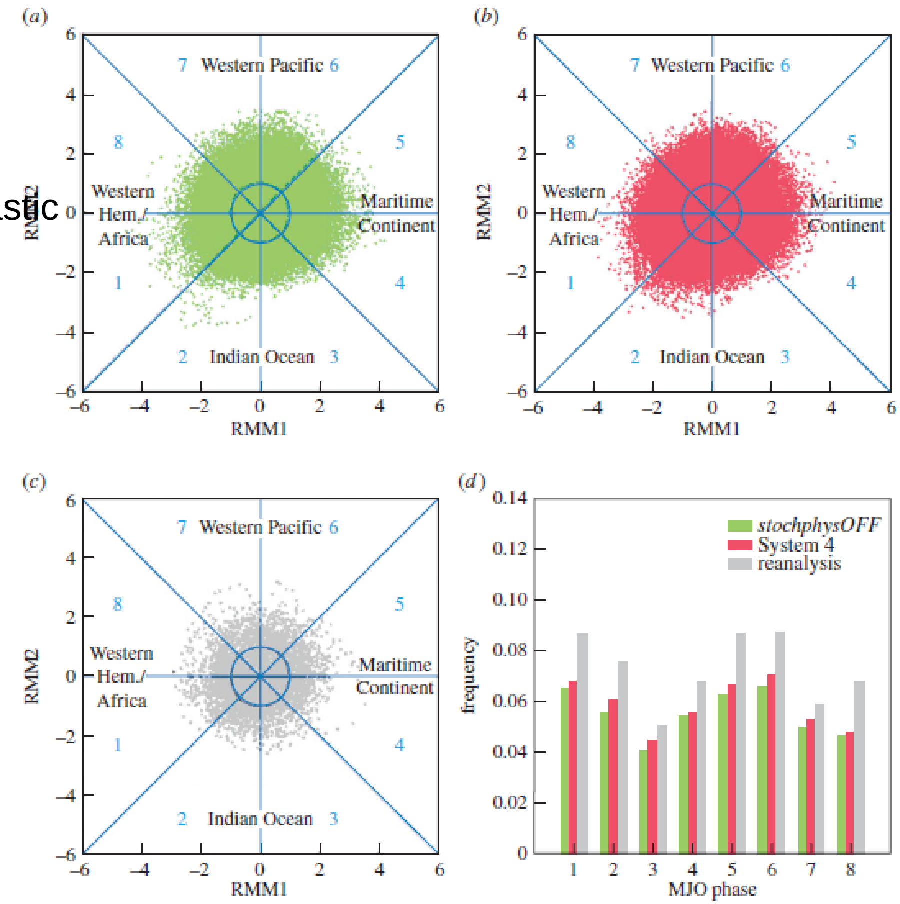
with and without

stochastic physics

no stochastic physics

with stochastic physics

reanalysis



Weisheimer et al., 2014

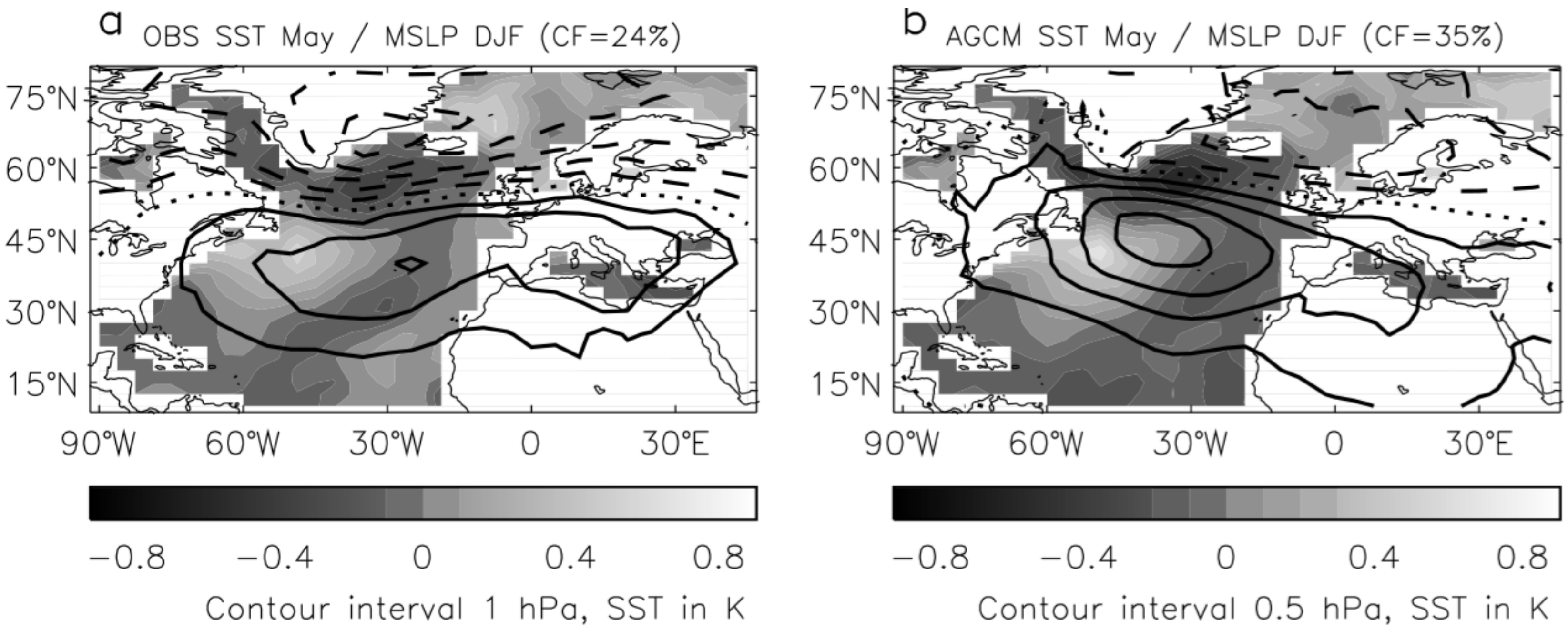
Reduce excessively strong convection over Maritime Continent

Reduce OLR biases

=> Increase in frequency and amplitude of MJO events

Atlantic Sea Surface Temperature and Ocean Heat Content

May SST anomalies, following DJF mslp anomalies.



Rodwell and Folland, *QJ*, 2002.

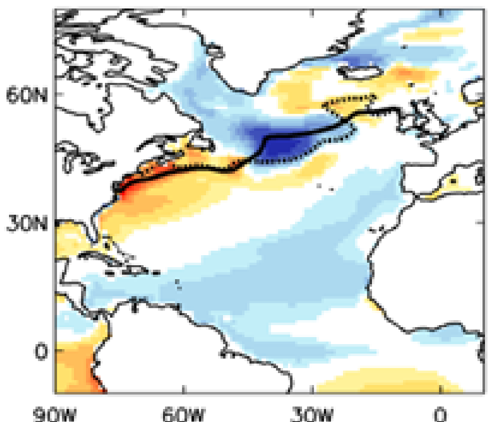
Negative NAO in DJF => SST anomalies in spring => enhanced probability of repeat negative NAO

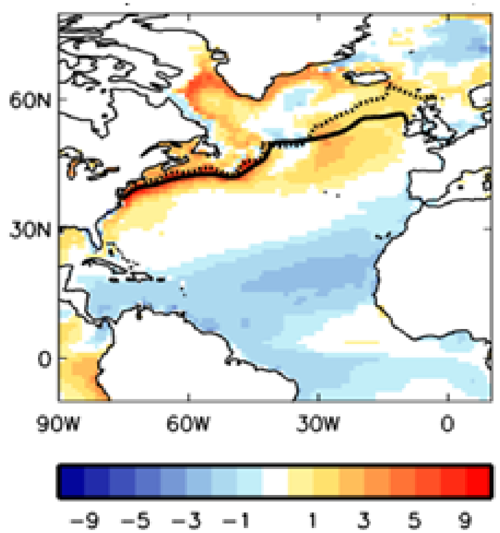
Taws et al. 2010

Atlantic : Ocean modelling and resolution issues

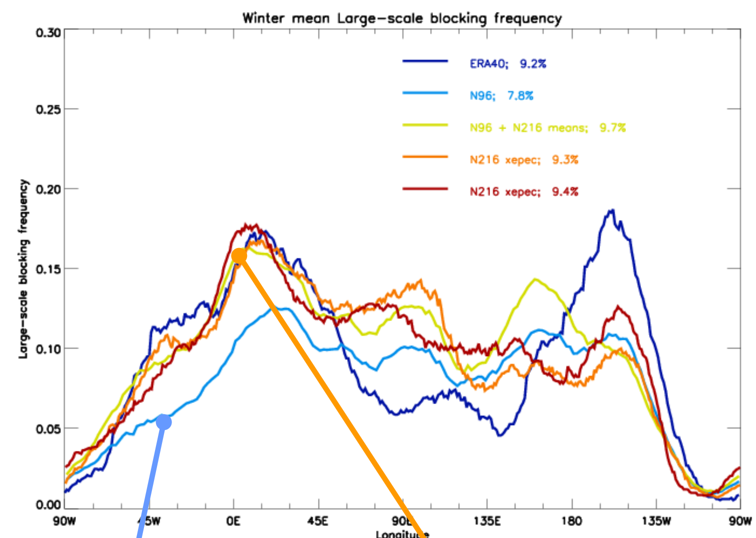
Low Res 1°

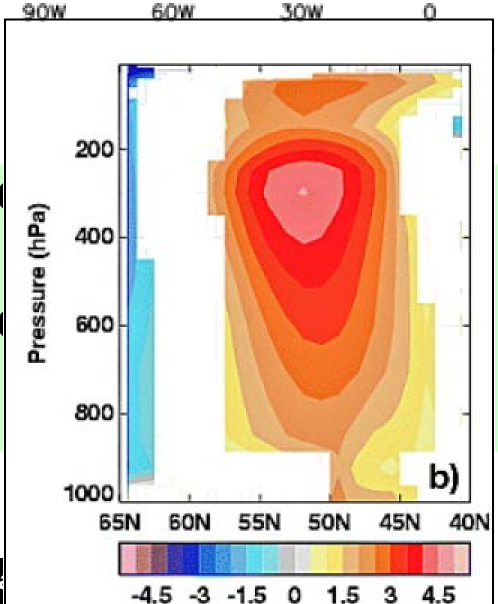
High Res 0.25°





Atlantic Blocking Frequency





Small Gulf Stream bias in high res' Hadley Centre Model

⇒ Good Blocking!

Low Res Model

High Res Model

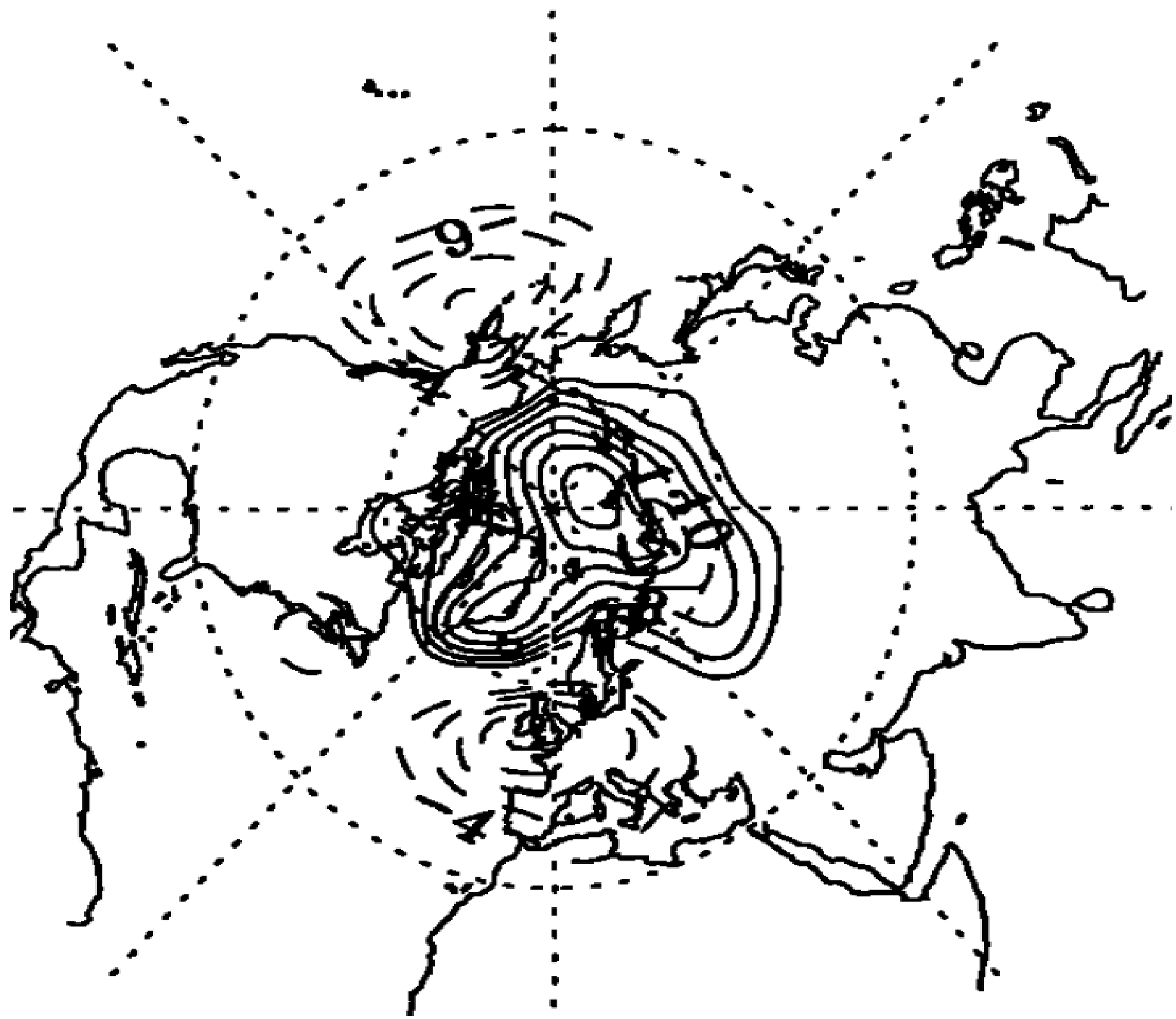
westerly wind anomalies

Eurasian snow cover

DJF mslp
composites

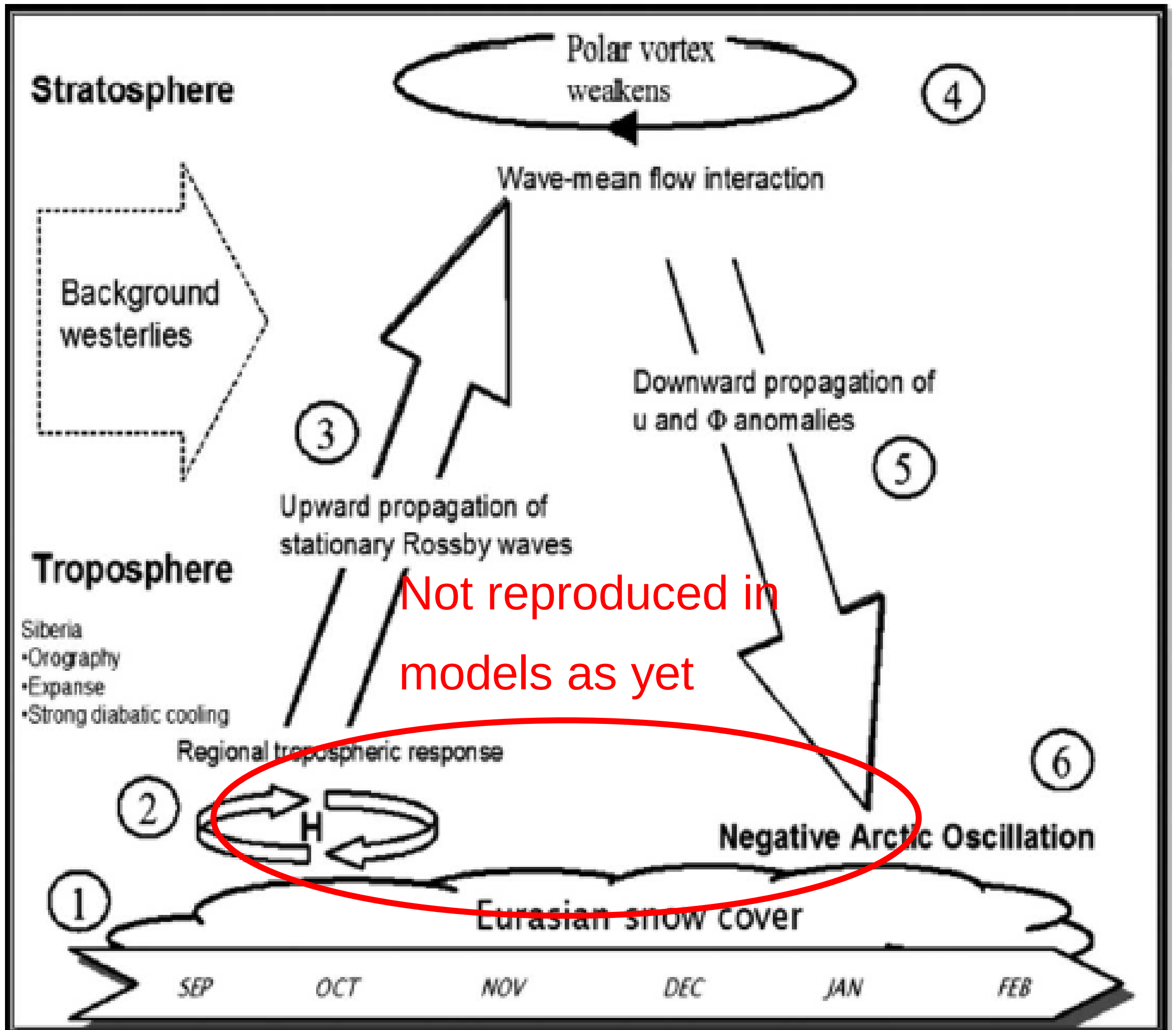
outer deciles of
October snow cover.

Cohen & Entekhabi



Cohen et al's proposed mechanism

1. Diabatic cooling
2. Intensification of W. Siberian High
3. Interaction of high with orography => Rossby Waves
4. Weakened polar vortex
5. Downward propagation of anomalies
6. Negative NAO.



Cohen, Barlow, Kushner and Saito, J Clim, 2007, 5335.

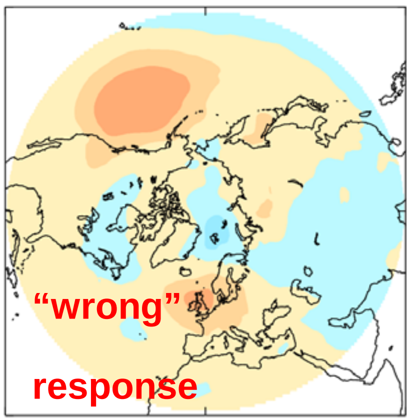
Snow – where next?

Met Office

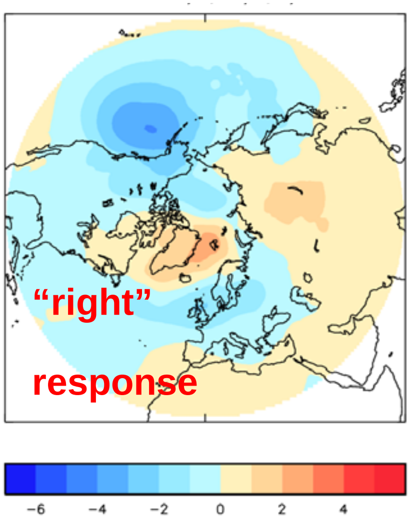
Model behaviour?

DJF mslp composites

Outer quintiles of Oct snow extent



Outer quintiles of Nov minus Oct snow growth

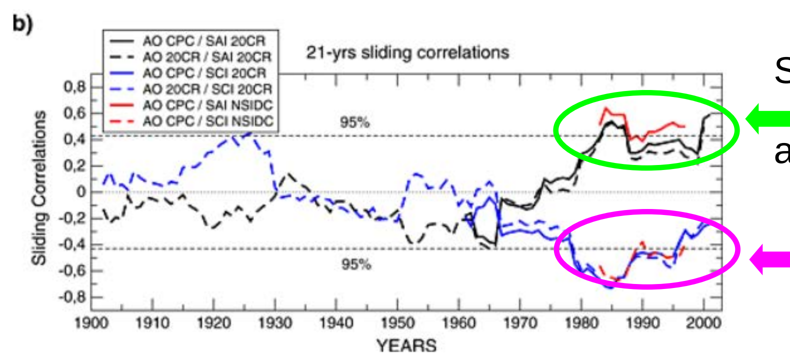


Observations:

How representative is the satellite era?

Has there been some sort of change in behaviour?

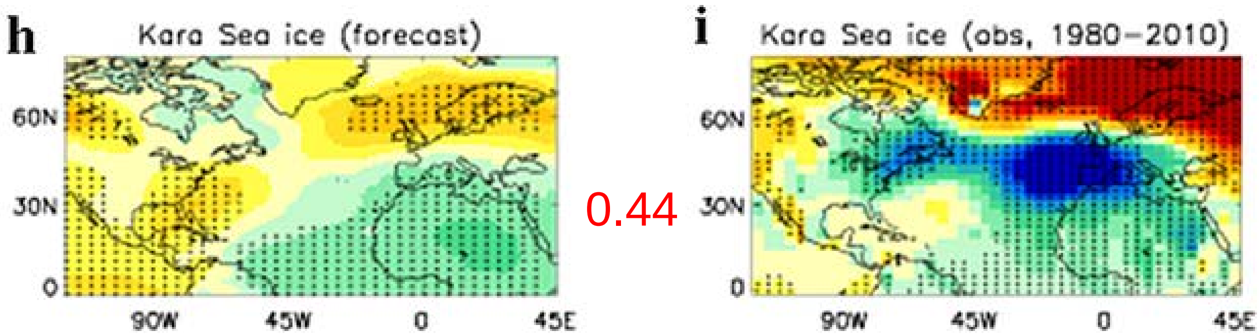
If so, is it a problem?



Peings et al., *GRL*, 2013

Based on comparison of C20 Reanalysis: Good match with NSIDC database and Historical Soviet Daily Snow Data station records.

Cryosphere



0.44

Kara Sea

High sea ice anomalies => negative NAO

Yang and Chistensen 2012

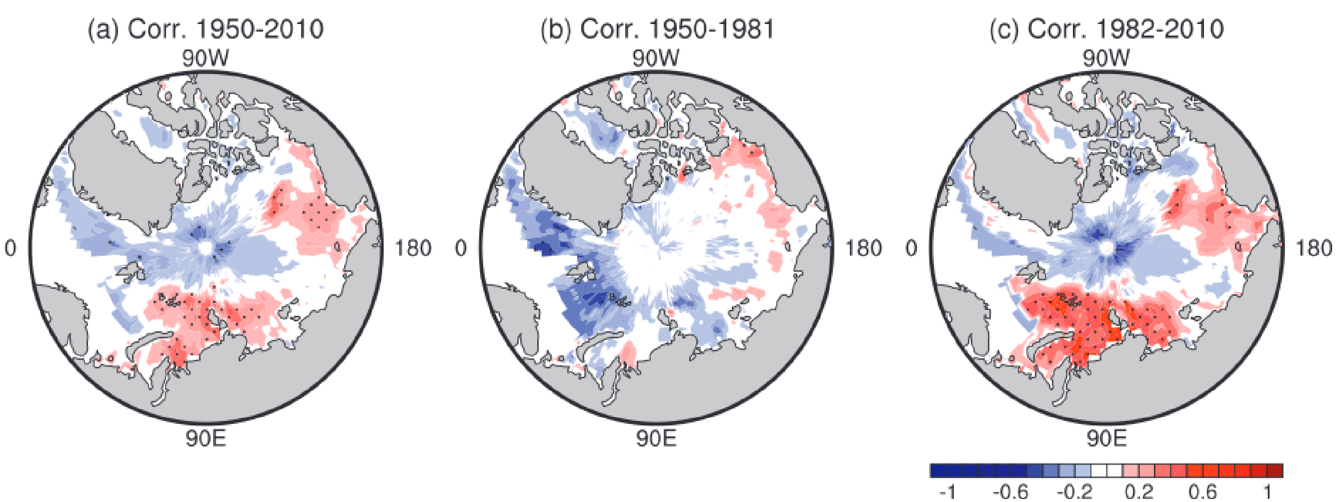


FIG. 1. Correlations of autumn Arctic SIC with winter NAM for the periods (a) 1950–2010, (b) 1950–81, and (c) 1982–2010. The dotted regions have correlations above the 95% confidence level.

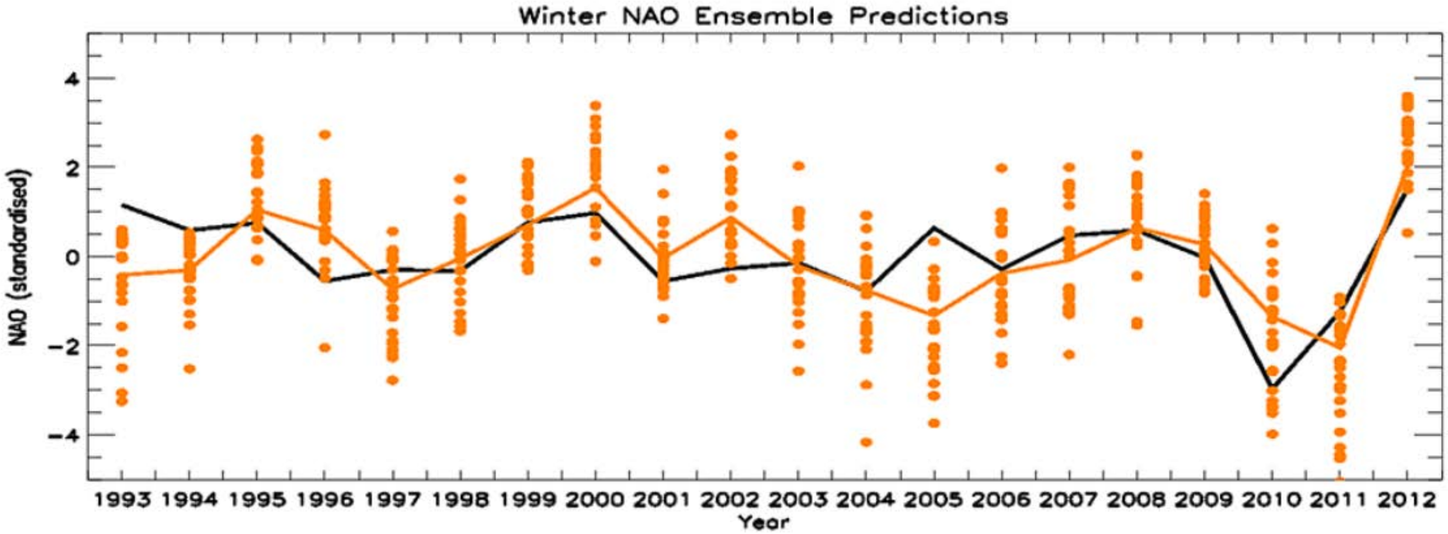
Correlations

Autumn Sea Ice

Northern Annular Mode

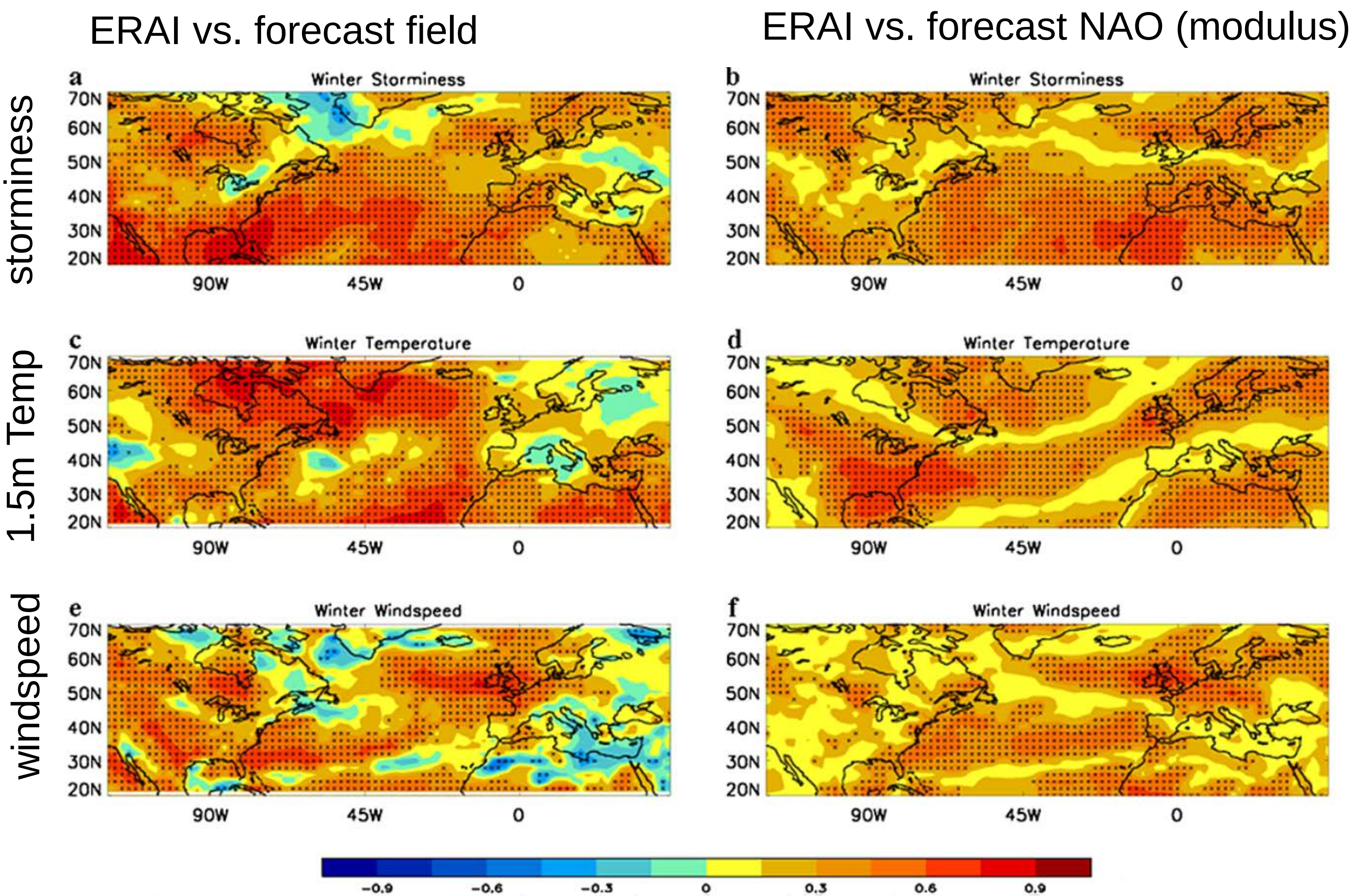
Li and Wang, J. Clim., 2013

Using models of drivers

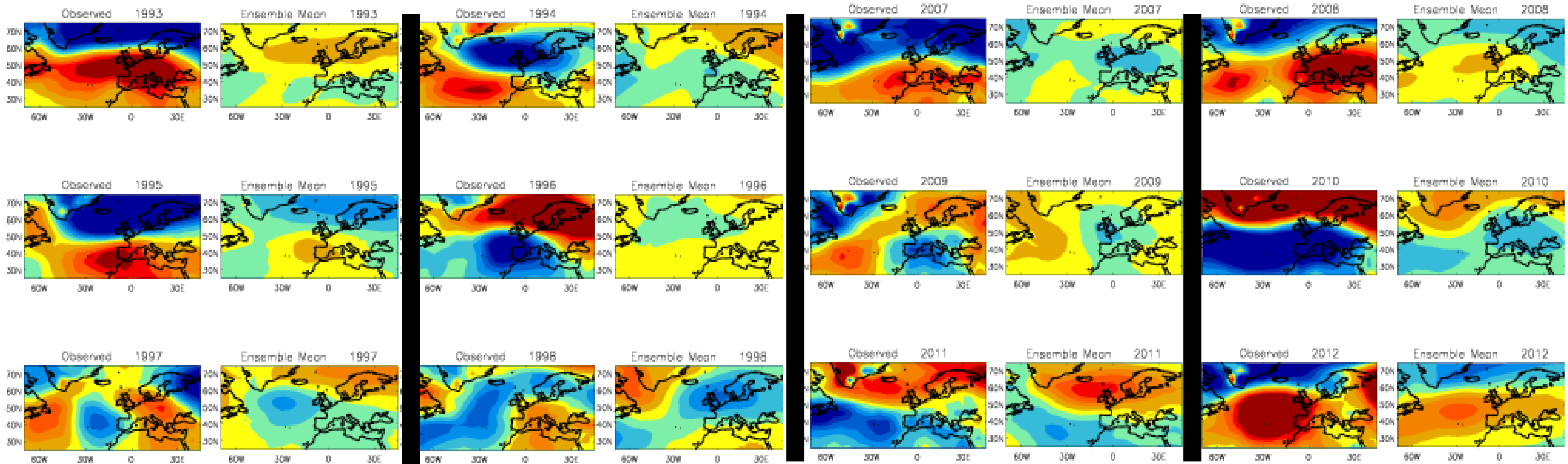


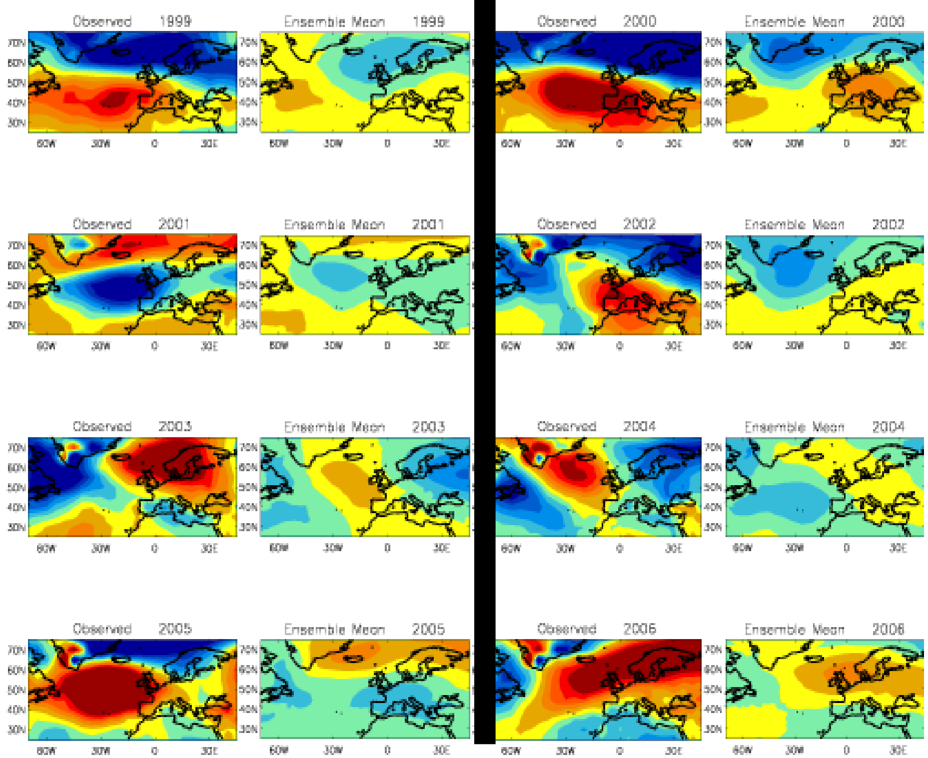
NAO – point index (Iceland/Azores), surface fields (mslp)

Why the emphasis on surface fields?



Individual winters





Good agreement between pressure patterns in many individual years

Especially later ones

Strength always underestimated

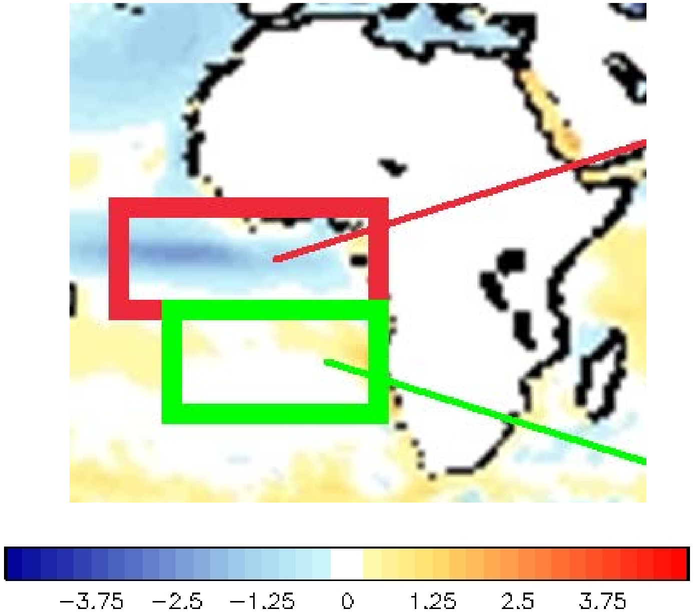
Isn't that to be expected?

Other Seasons/regions: some examples

European Summer

"Real world..."

How intrinsically predictable is the summer NAO? Keeley et al. 2011 – indistinguishable from red noise



African Monsoon

Model

We know SSTs in the Gulf of Guinea are a key driver

But the Met Office model has biases there...

Conclusions

Conclusions

Drivers

We know what some of these are – ENSO, QBO, MJO, Atlantic ocean, land surface...

But we still need work on some of the observational relationships – issues of stationarity and statistical robustness.

Mechanisms

Some of the mechanisms look fairly robust (role of stratosphere, wave breaking), some are badly understood.

Modelling

Where we do understand mechanisms, sometimes we model them well, sometimes badly, sometimes not at all.

Priority areas – ocean-atmosphere coupling, land surface

Questions?

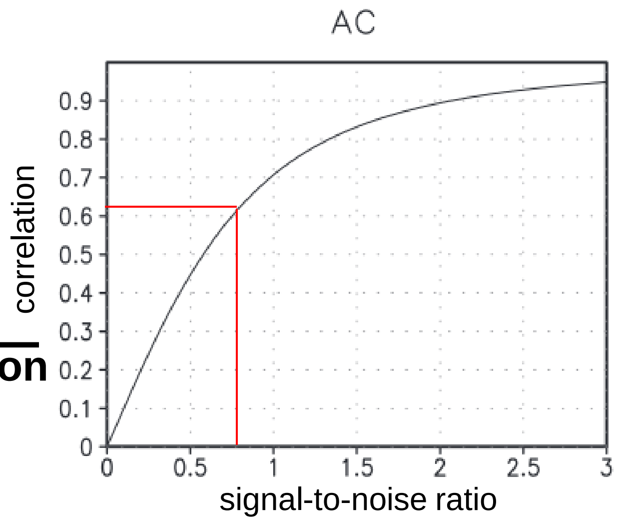
Additional slides

Additional slide – signal-to-noise

perfect forecast system

signal-to-noise ~ correlation

$$= \frac{\textbf{ensemble mean standard deviation}}{\textbf{ensemble member standard deviation}}$$



Kumar 2009

GloSea5

signal-to-noise = 0.2 **Very much lower than expected!**

But variability of NAO from individual forecast members is OK (~8hPa)

seems to be ensemble mean signal which is too small

Individual forecast members contain weaker predictable signals than observations.

Hindcast length

Finite computational resources...

resolution? hc length? ensemble size?

Long versus short hindcasts...

warming signal? May just get skill from trend

ocean data – recent improvements

so initial states for older hc may not be as good