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

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ECMWF (UEF2014) 5th June 2014
So many issues...

ensemble generation

modelling physical processes

initialisation

model resolution

choice of hindcast methodology

model drifts/biases

end user issues

post processing

So little time!
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

Winter 2010-11
strongly negative NAO in Dec

Winter 2013-14
strongly positive NAO in JFM
Seasonal forecasts of Monsoon onset
Active/break cycles
Land falling hurricanes

Aftermath of Haiyan, 2013, Phillipines

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Drivers of predictability: where should we be focussing research effort? (Emphasis on European Winter...)
El Niño – Southern Oscillation Effects

El Niño => easterly winds in UK

Ineson and Scaife, Nat. Geosci., 2009
ENSO mechanisms

• 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

Ineson and Scaife 2008
Quasi-Biennial Oscillation Effects
(After Ebdon 1975)

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 analysis: zonal average at 60N

Case study: January 2013

forecast initialised 22 Dec

Snowfall starts 18th January
Stratosphere effects in winter 2014

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 and the NAO are closely related

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

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

Benedict et al 2004
Wavebreaking: How do models do?

18 Dec

1 day lag

19 Dec

1.5m T

Z200
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

Reduce excessively strong convection over Maritime Continent

Reduce OLR biases

=> Increase in frequency and amplitude of MJO events

Weisheimer et al., 2014
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°**

Small Gulf Stream bias in high res’ Hadley Centre Model

⇒ Good Blocking!

westerly wind anomalies

Atlantic Blocking Frequency

High Res Model

Low Res Model
Eurasian snow cover

Cohen & Entekhabi

DJF mslp composites
outer deciles of October snow cover.
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.
Based on comparison of C20 Reanalysis: Good match with NSIDC database and Historical Soviet Daily Snow Data station records.

Observations:
- How representative is the satellite era?
- Has there been some sort of change in behaviour?
- If so, is it a problem?
Kara Sea
High sea ice anomalies => negative NAO
Yang and Chistensen 2012

Correlations
Autumn Sea Ice
Northern Annular Mode
Li and Wang, J. Clim., 2013

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.
Using models of drivers

NAO – point index (Iceland/Azores), surface fields (mslp)
Why the emphasis on surface fields?

ERAI vs. forecast field

ERAI vs. forecast NAO (modulus)

storminess

1.5m Temp

windspeed
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
perfect forecast system

signal-to-noise \sim \text{correlation}

= \frac{\text{ensemble mean standard deviation}}{\text{ensemble member standard deviation}}

GloSea5

signal-to-noise = 0.2 \quad \text{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