Met Office

Skilful Long Range Forecasts for Europe

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Most extreme December for a century:

December 2010

London



Image courtesy of Channel 4

December 2010

Stockholm



...and then this just 5 years later

December 2015

London



Image courtesy of The Telegraph Newspaper

December 2015

Stockholm

Swedes bask in record winter temperatures



The sun shining in Stockholm over the weekend. Photo: Anders Wiklund/TT

European and eastern U.S. winters depend on large scale Atlantic pressure anomalies



High pressure over Iceland Weak jet stream Cold, calm and dry

December 2010 ΔT



December 2015 ΔT





Low pressure over Iceland Strong jet stream Mild, stormy and wet

Lots of things trigger the winter North Atlantic Oscillation



All show the same NAO-like response

Kidston et al, Nat. Geosci., 2015.

Full Implementation of Seamless Prediction: From Hours to Decades

Global coupled modelling on all timescales

	Past climate	Now	Hours	Days	1-week	Seasonal	Decadal	Climate	Confidence
									boundary
	Analysis of past weather observations to manage climate risks			Predicting hazardous conditions	g routine and s weather s.	Monthly predictio of droug	Monthly to decadal predictions - probability of drought, cold,		Global and regional climate predictions.
	Eg. Agriculture: informs crop choice, planting to yield optimisation and minimise crop failure risk. Public, emerge response, inter Disaster Risk Reduction			nergency international Risk n	hurricanes Contingency planners, national and international humanitarian response, government and private infrastructure investment		s, cho onal wa se, stro te infi ent	licy and adaptatio oices. Impacts on ter resources, hea ess, crops, rastructure.	
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Forecast lead-time

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Fully coupled model (Atmosphere-Land-Ocean-Sea Ice) World leading ocean resol'n + high atmosphere resol'n Coupled sea ice and well resolved stratosphere Used across timescales: monthly->seasonal->decadal

MacLachlan et al QJRMS 2015, Dunstone et al Nat Geosci 2016

Benefit of increased ocean resolution



Winter prediction skill comes mainly from the NAO



K-means clusters

Skill of cluster frequencies

Nicky Stringer

2000

2010

Winter prediction skill for the NAO



Now extended to show significant interannual skill

So far so good with real time forecasts

Surface weather skill



Skill for predicting seasonal storms, temperatures, winds Higher skill over Europe if inferred from forecast NAO



Where does the skill originate?

Sources of seasonal predictability

Tropical rainfall skill

455

90S

Rossby Wave Source Anomalies



Tropical rainfall shows good prediction skill Able to predict year to year changes Encouraging skill in all basins **Preferred source regions**

Fluctuate with forcing from other regions

Sources located at edge of jets where vorticity gradient is large

Sources of seasonal predictability



Rays intersect main centres *from a few common sources* Wave 2, 3 mainly responsible as wave 4 rarely propagates Tropical rainfall explains a fair proportion of forecast variations

Scaife et al, QJRMS, 2017



A case study – winter 2015/16



Winter 2015/16: a joint record El Niño



2015/16 Forecast



1997/8



2015/16





Very clear signals for a near record event

Remote but not irrelevant

Similar to 1982/3

Other El Niño winters





Winter 2015/16





December Temperature



December Rainfall



Very clear signals for a westerly winter Good agreement with subsequent observations Early warning of December flooding





Climate Services

Growing Climate Services



Impacts are skilfully predicted, suggesting potential climate services

but

we have to infer them from the NAO....

Predicting Baltic Sea Ice extent



Palin et al, J. App. Met. Clim., 2015



Forecast Mild normal Severe Mild 4 (4) 1 (1) 0 (0) Near normal 2 (2) 7 (5) 2 (3) Severe 0 (0) 2 (2) 2 (3)

Winter river flow forecasting from NAO and flow persistence



Hgure 2. Sources of predictability of winterriver flows as reflected by the coefficients for a regression model of winter river flow on othere to hold two predictors: long range forecast of atmospheric circulation over the Sonth Altarici as characterized by the NAO index (a), and observed monthly mean river flow for November (b). The aquifer sources paress (light blue shading) show where groundwater makes an important contribution to river flows.

Svensson et al, Env. Res. Lett., 2015

Karpechko et al, Env. Res. Lett., 2015



An outstanding paradox

A Signal to Noise Paradox



Skill rises slowly with ensemble size Real world more predictable than model! Undermines basis of ensemble prediction Members NOT alternate realisations of obs Not a simple problem of incorrect spread spread in model NAO ~ variability in obs NAO Highly significant (98%)

Scaife et al GRL 2014, Eade et al GRL 2014, Siegert et al 2015, Dunstone et al 2016, Scaife and Smith 2018

Ratio of predictable components

 $RPC = r_{mo} / (\sigma_{em} / \sigma_{tot}) = r_{mo} / r_{mm}$

Eade et al, GRL, 2014

RPC should be 1 but is actually > 1

Model can predict real world better than itself!

Correlation	r = 0.6	
Ensemble <i>mean</i> variability	σ_{em} = 2.3hPa	
Ensemble <i>member</i> variability	$\sigma_{tot} = 8hPa$	$\sigma_{\rm obs}$ ~ 8hPa

RPC = 2.2

Model has high skill but small predictable signal: "Signal to Noise Paradox"



Siegert et al, 2015

The signal to noise paradox may be widespread



It has been around a long time

It is present in atmosphere only experiments and other models

It also appears to be present in the response to forcings

Atmospheric resolution?

1994-2016 Winter NAO Index correlation skill vs HadSLP2 mean and 90% confidence interval 1.0 0.9 0.8 0.50 0.6 Correlatio 0.4 0.3 0.2 GloSea N512 GloSea N216 0.1 N512 (theoretical) N216 (theoretical) 0.0 2 12 14 28 32 0 4 6 8 10 16 18 20 22 24 26 30 34 36 38 40 Number of Members per Year

More than doubling atmospheric model resolution to ~25km has no impact on skill or spread

Ruth Comer

Atmospheric resolution?



More than doubling atmospheric model resolution to ~25km bas no impact on skill or spread

Ruth Comer

Ocean resolution?



Our seasonal hindcasts are 0.25 deg and are only ocean eddy permitting Would eddy resolving models at 1/12° give better O-A coupling?

Craig MacLachlan

Ocean resolution?



ORCA 1/12

ORCA 0.25



Our seasonal hindcasts are 0.25 deg and are only ocean eddy permitting

Would eddy resolving models at 1/12° give better OA coupling?

Craig MacLachlan

Conclusions

- Seasonal predictability of the North Atlantic Oscillation and hence
 European winters has been demonstrated and is running operationally
- Predictability emanates from the tropics
- Seasonal climate prediction services for Europe are feasible
- Signals are anomalously small and lead to a "Signal to Noise Paradox" which is resistive to increasing model resolution
- Ensemble mean regressions are needed to extract forecast signals, large ensembles are needed and probabilistic measures underestimate skill



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