UK Model Development and Evaluation

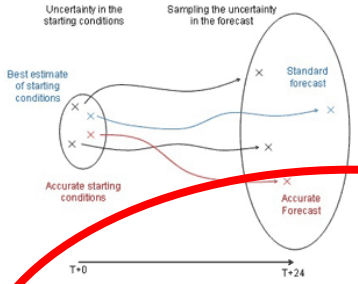
Dan Copsey

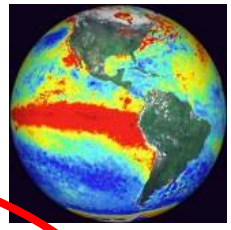
31st July 2013 – ESPC & NUOPC Workshop – SCRIPPS, La Jolla, San Diego

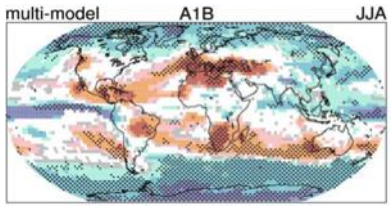
Global Modelling

Unified Prediction across Timescales

Hours Days Weeks Months Seasons Decades Centuries







Deterministic NWP
Atmosphere
25km 70L

MOGREPS EPS
Atmosphere
MOGREPS-G 35km
MOGREPS-15 60km
Ocean/Sea ice
0.25deg 75L

GLOSEA5 EPS
Seasonal forecasts
60km Atmosphere
0.25deg Ocean/Sea ice

DePreSys EPS
Decadal forecasts
140km Atmosphere
1deg Ocean/Sea ice

HadGEM3
Climate prediction
60km Atmosphere
0.25deg Ocean/Sea ice

This presentation

The future

Waves
Wavewatch III

Coupled Model
GC1.0

Aerosols
UKCA-Mode

Ocean
NEMO
GO5.0

Atmos
UM
GA5.0

Land
JULES
GL5.0

Sea-Ice
CICE
GSI5.0

Aerosols
CLASSIC

Met Office current 15 day ensemble prediction system MOGREPS-15

MOGREPS – the Met Office Global and Regional Ensemble Prediction System

MOGREPS-15 = 15 day global ensemble.

- Currently atmosphere only but moving to couple to NEMO ocean and CICE sea ice.
- Atmosphere model = Met Office Unified Model
- Resolution = ~60 km & 70 levels.
- Number of ensemble members = 24 (run twice a day)
- ETKF for initial condition perturbations
- SKEB2 Stochastic physics
- Run at ECMWF

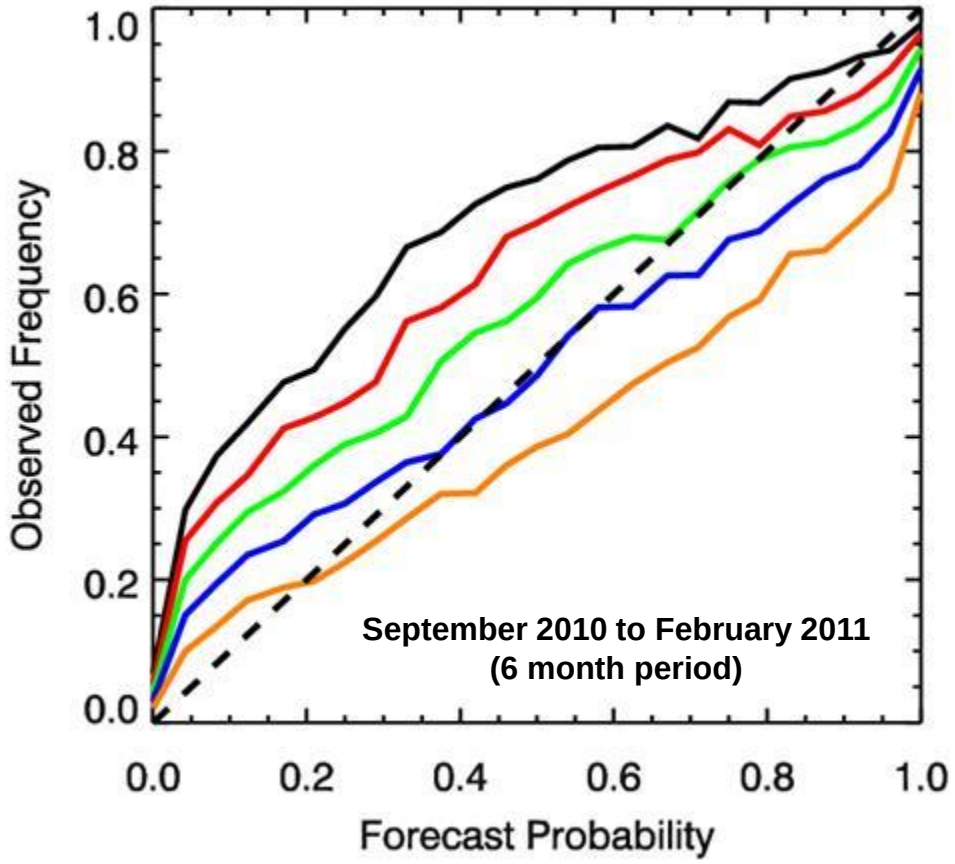
MOGREPS-15 - Current verification methods

- Root mean square (RMS) errors
- Brier skill scores (BSS)
- Ranked probability skill score (RPSS)
- ROC curves
- Reliability diagrams

Verification for 40mph winds (event anywhere within county)

Reliability Diagram

(T+33h to T+42h forecasts)



Forecast Thresholds

Threshold	Colour
≥ 42mph	
≥ 40mph	
≥ 38mph	
≥ 36mph	
≥ 34mph	

All forecast thresholds are verified as if they are forecasting 40mph events

Under-forecasting → ~36mph forecasts might be best at forecasting 40mph events

Jonathan Flowerdew

Testing moving our 15 day forecasts to a coupled atmosphere-ocean-sea ice system.

Tim Johns, Ann Shelly, José Rodríguez, Dan Copsey, Catherine Guiavarc’h, Jennie Waters, Peter Sykes, Dan Lea

Description of new 15 day coupled forecasting system

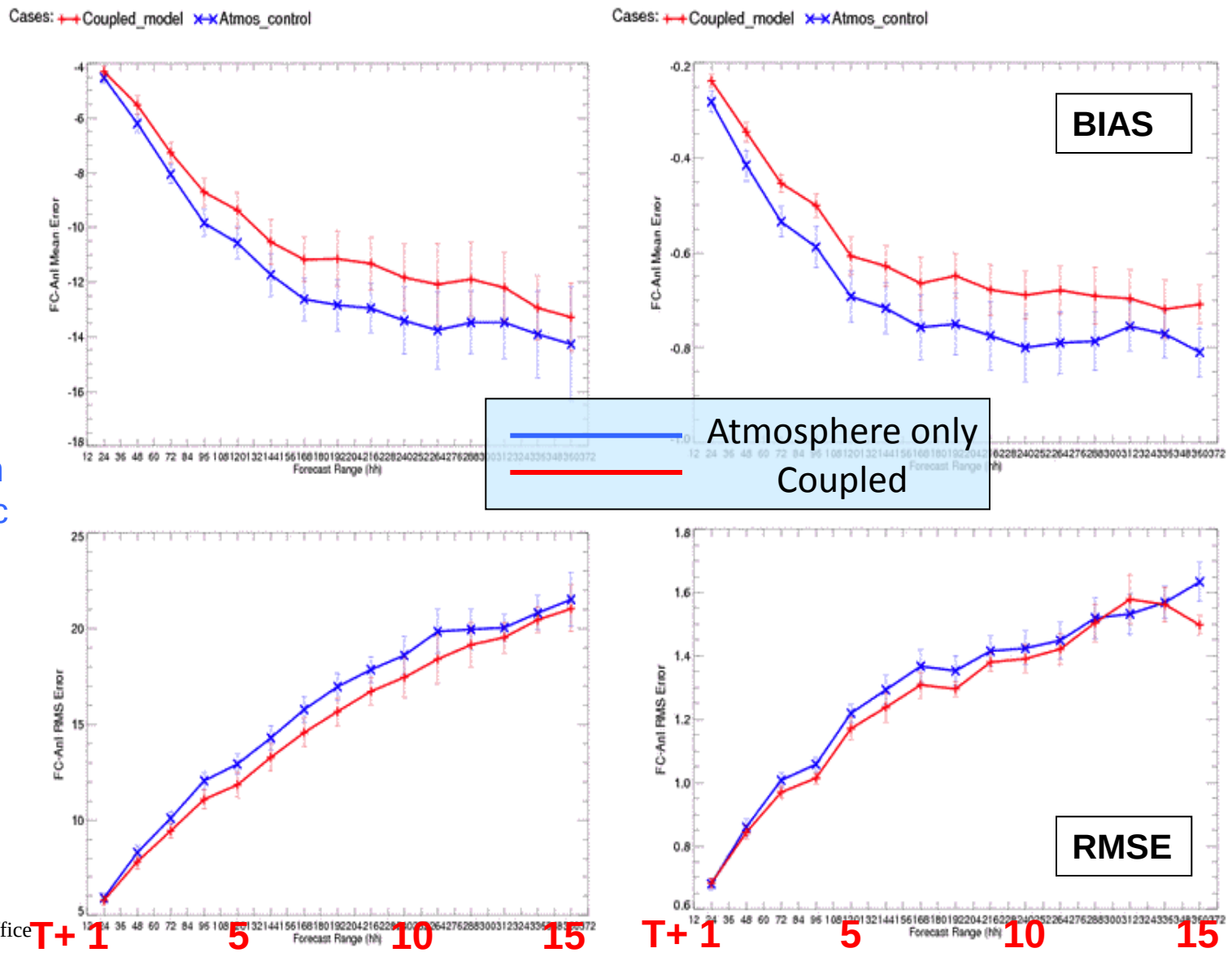
- Atmosphere model = Unified Model, GA3.0 (Walters et al. 2011 GMD), N216L85 (~60km in mid latitudes)
- Land model = JULES, GL3.0, N216, 4 layers
- Ocean model = NEMO3.2 ORCA0.25L75 (~28km in mid latitudes)
- Sea ice model = CICE4.1 ORCA0.25
- Run length = 15 days
- Atmosphere initialised from operational NWP analysis
- Ocean and sea ice initialised from FOAM NEMOVAR analysis system
- Parallel atmosphere only and ocean only control runs were made to assess the improvements made in having a coupled system.

Tropics

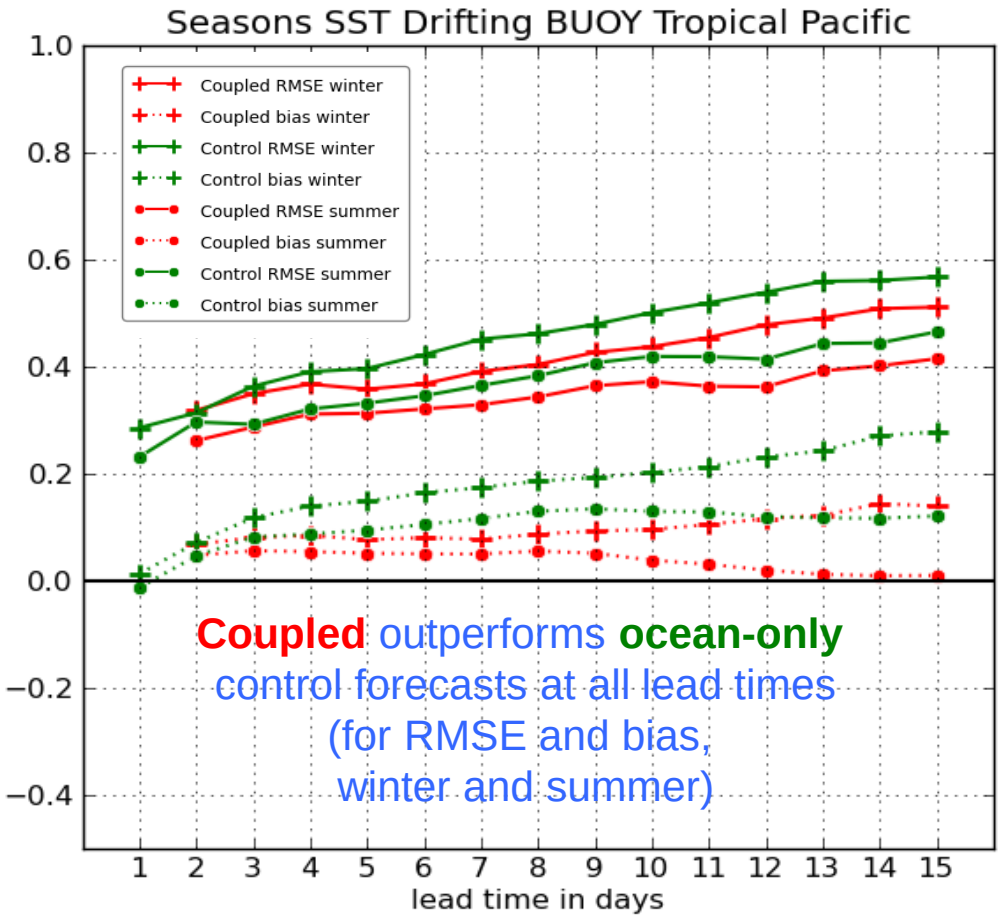
500hPa Height DJF

925hPa T JJA

- Two examples of good coupled skill relative to atmosphere-only control forecasts
- Tropics is the main area of atmospheric performance difference
- Performance mostly comparable in the extra-tropics

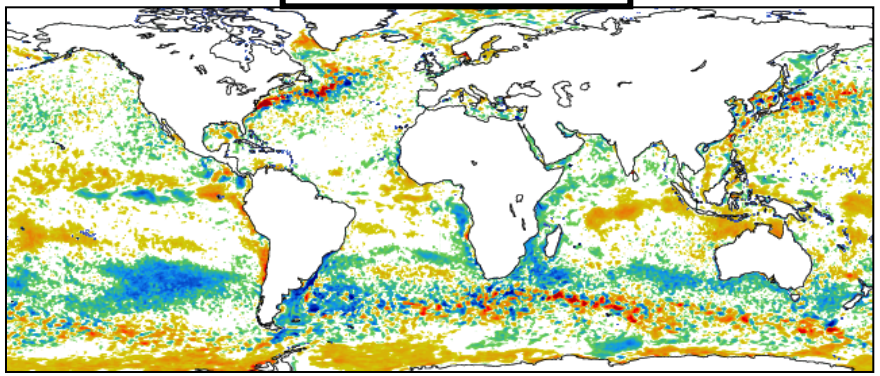


Ocean Verification (SST): Coupled versus ocean-only control forecasts

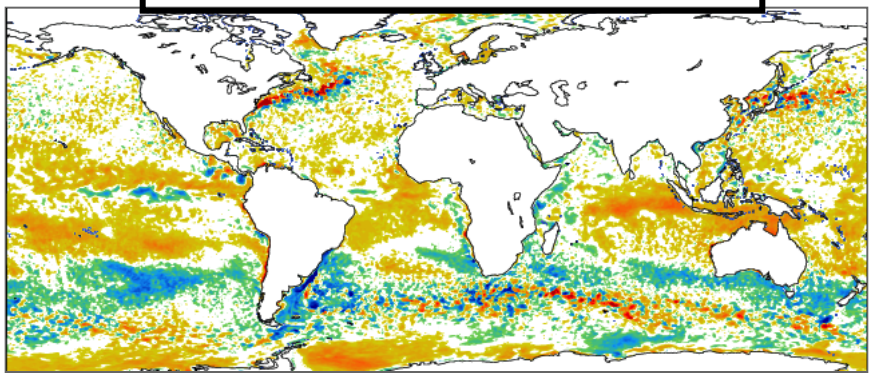


DJF Bias at Day 15

Coupled

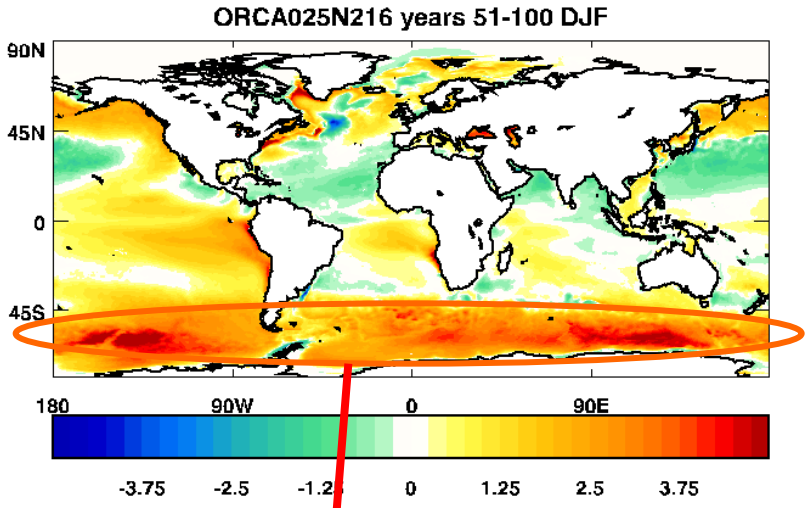


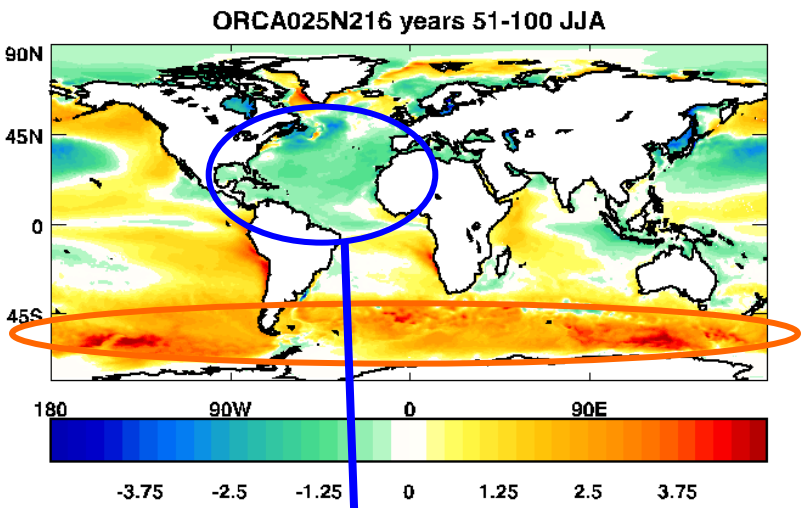
Ocean Only Control



SST biases: Climate vs. Coupled NWP

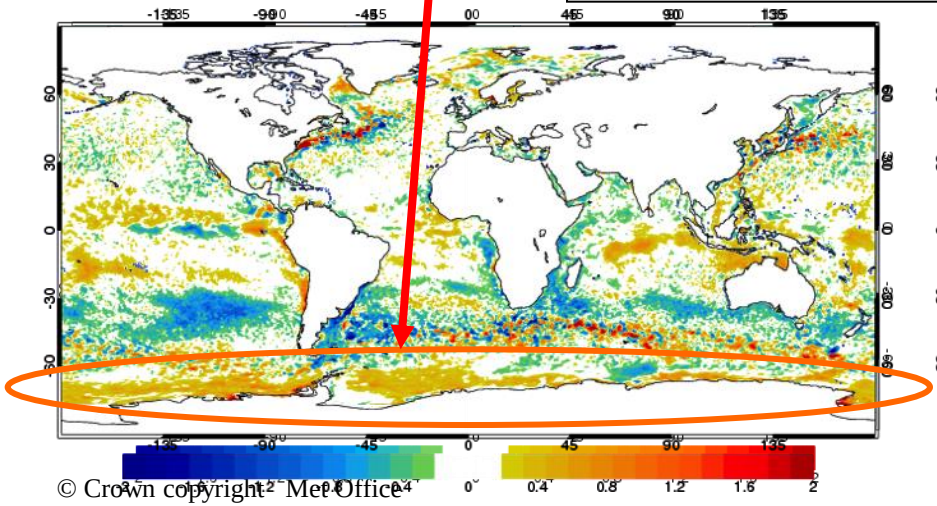
Climate:50-yr mean

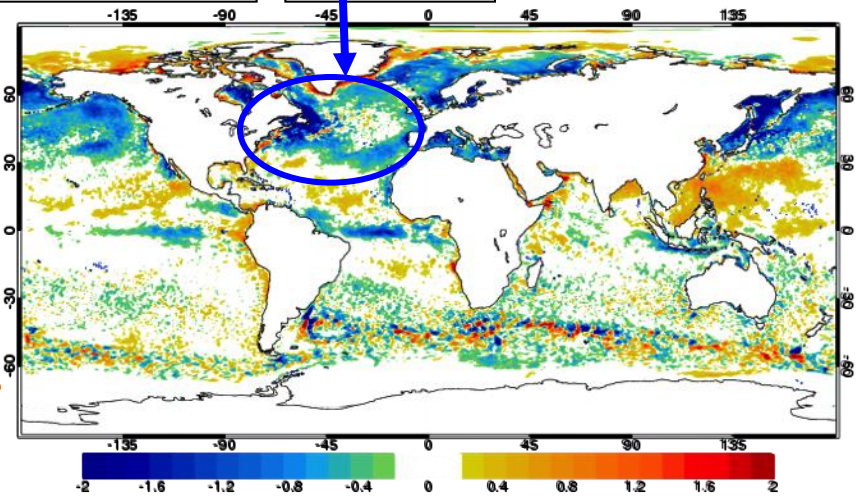




Coupled NWP: 10 cases

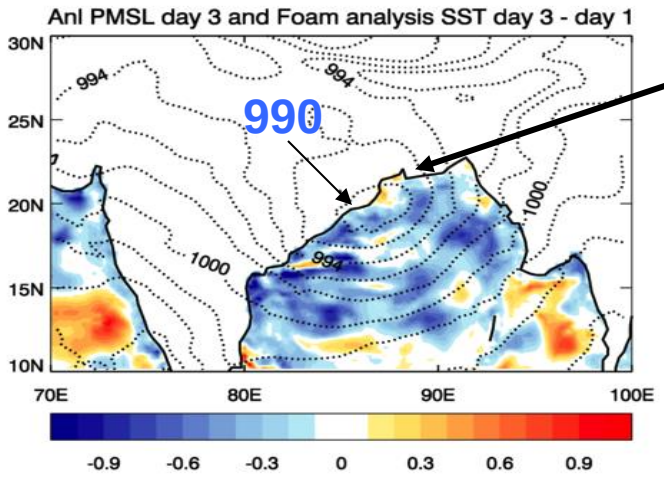
Day 14





Synoptic Case Study:
Bay Of Bengal Tropical Monsoon depression
August 2008 – Day 3 Forecasts

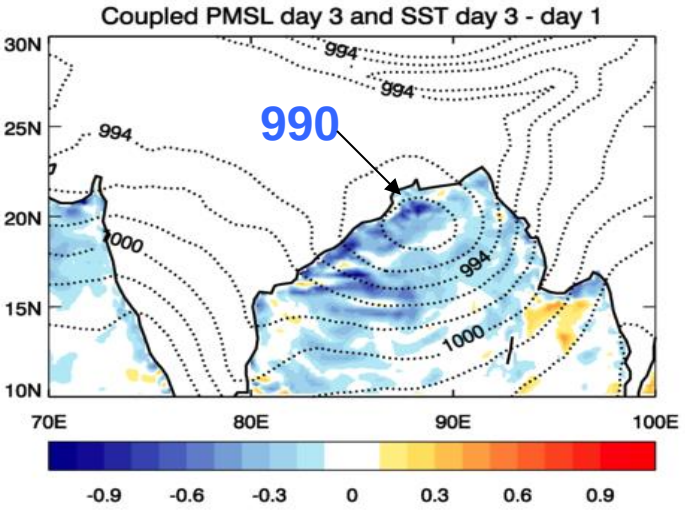
Analysis

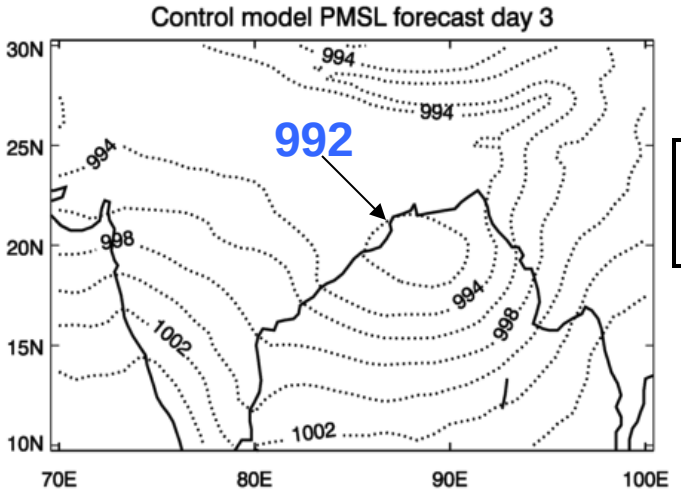


Central pressure (<990hPa) captured by day 3 in coupled model forecast but atmosphere control has shallower depression.

Additional skill comes from interactive ocean – see cooling in BoB in evolution of the SST (day 3-day 1: colour shading)

Coupled Model

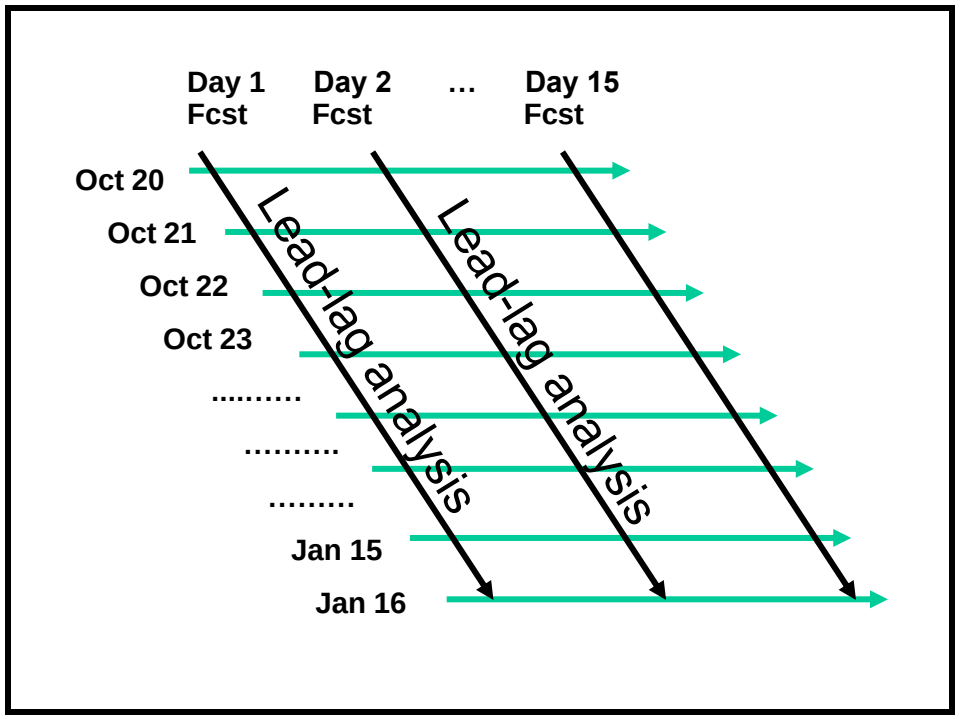




Atmos Control

MJO in Coupled O-A for NWP

YOTC MJO-E and MJO-F



HadGEM3-AO N216L85 (GA3.0) +

ORCA025L75 (NEMO3.2) +

CICE (4.1) + **OASIS** coupler

2 strong MJO events between Oct 2009 to Jan 2010, in YOTC period

Coupled case studies for each start date: Oct 20th 2009 to Jan 16th 2010

OLR as proxy for convection

OLR/SST anomalies calculated for each date (wrt. climatologies from NOAA OLR/OSTIA reanalyses)

5 day running mean applied to each forecast to smooth high frequency variability

Lead-lag correlation analysis between SST and OLR for consecutive day 1, day 2 … forecasts (for observed state, coupled model and atmos control)

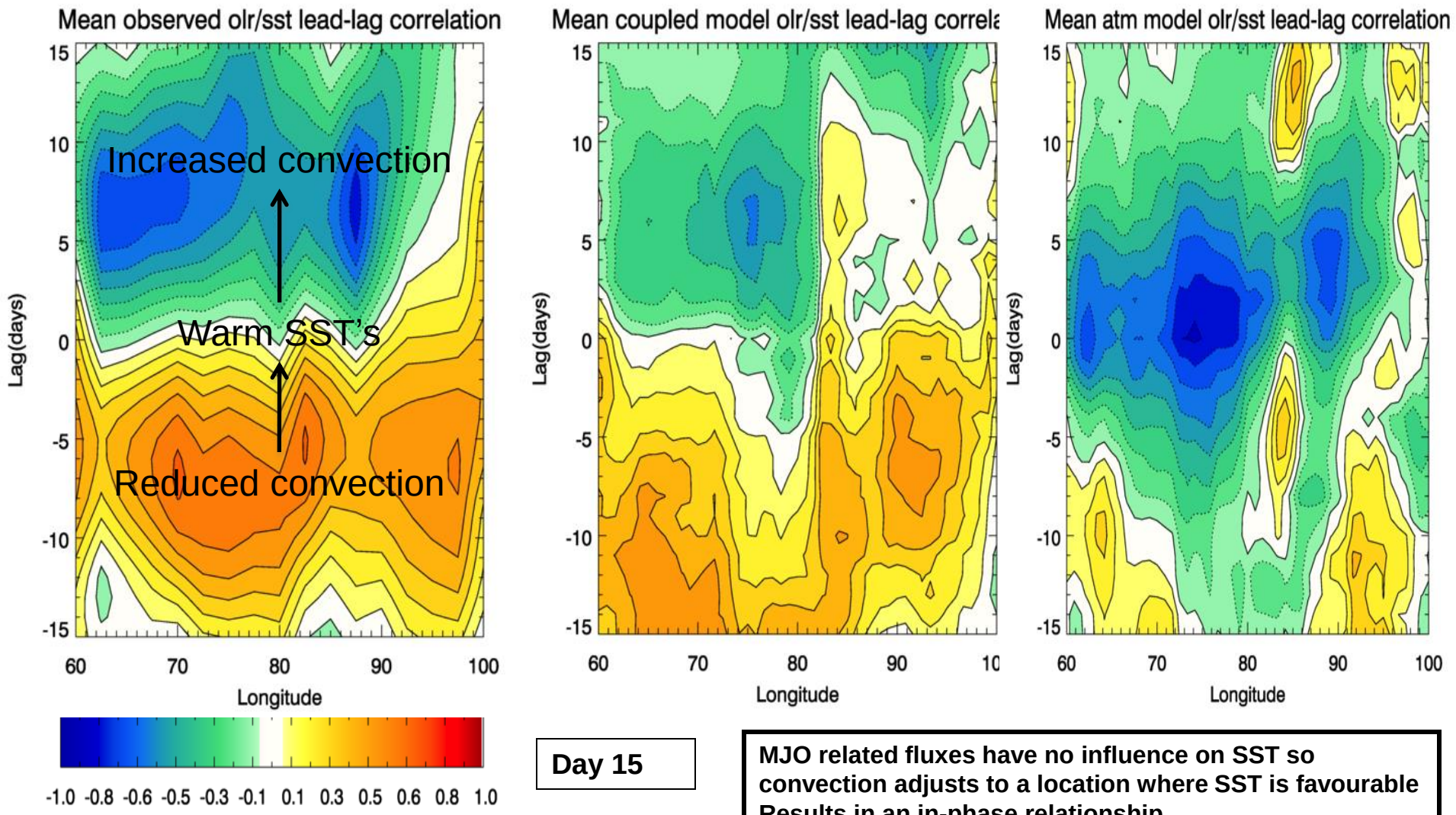
Ann Shelly

OLR/SST phase relationship : Indian Ocean

Observed state

Coupled model

Atmosphere control



Warm SST's lead enhanced convection by ~5-10days

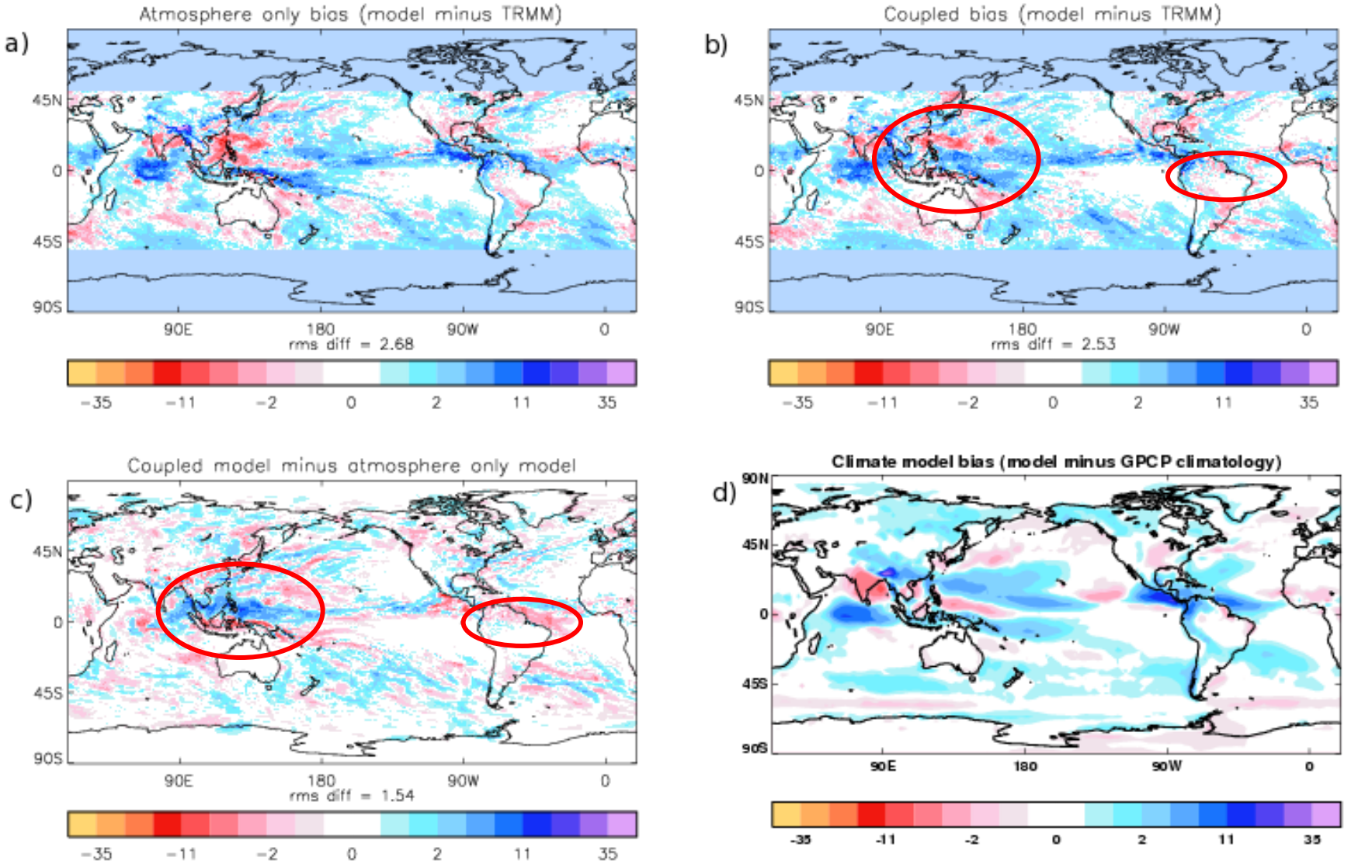
Day 15

MJO related fluxes have no influence on SST so convection adjusts to a location where SST is favourable Results in an in-phase relationship

Coupled model maintains phase lagged relationship

JJA mean precipitation biases

Day 11-15 - average over 10 cases



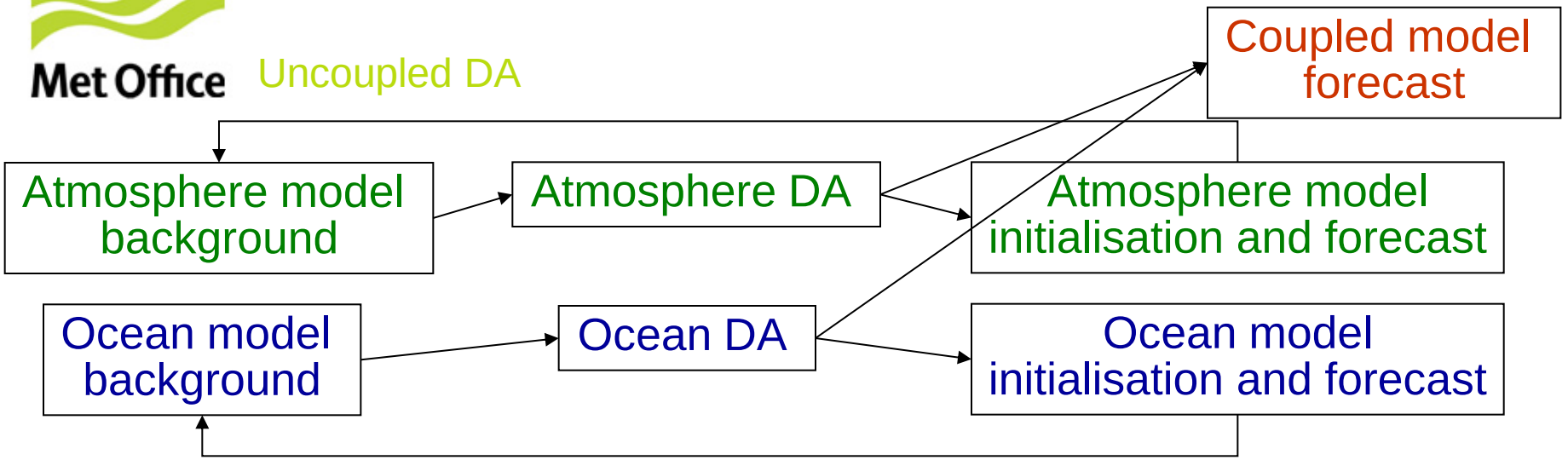
Improved precipitation over the Maritime continent with an interactive ocean

Because of coupled feedbacks.

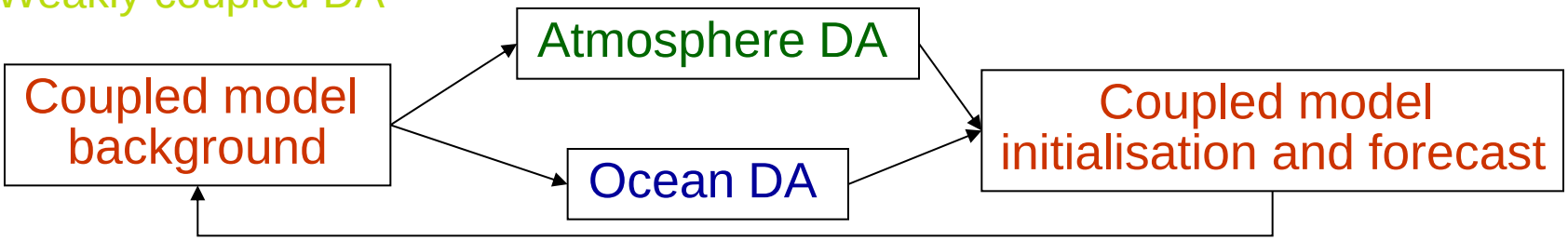
Coupled data assimilation

Met Office

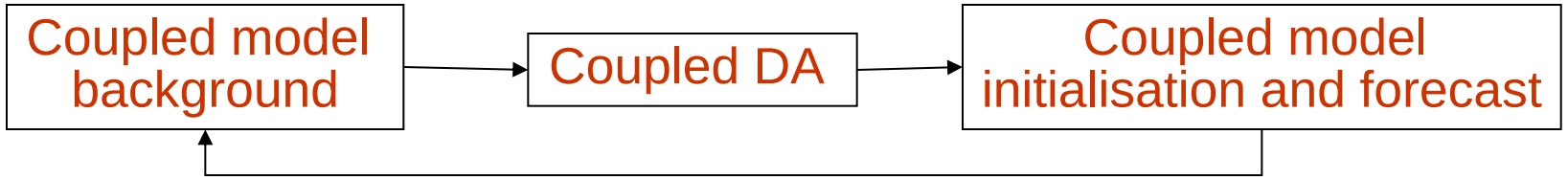
Uncoupled DA



Weakly coupled DA

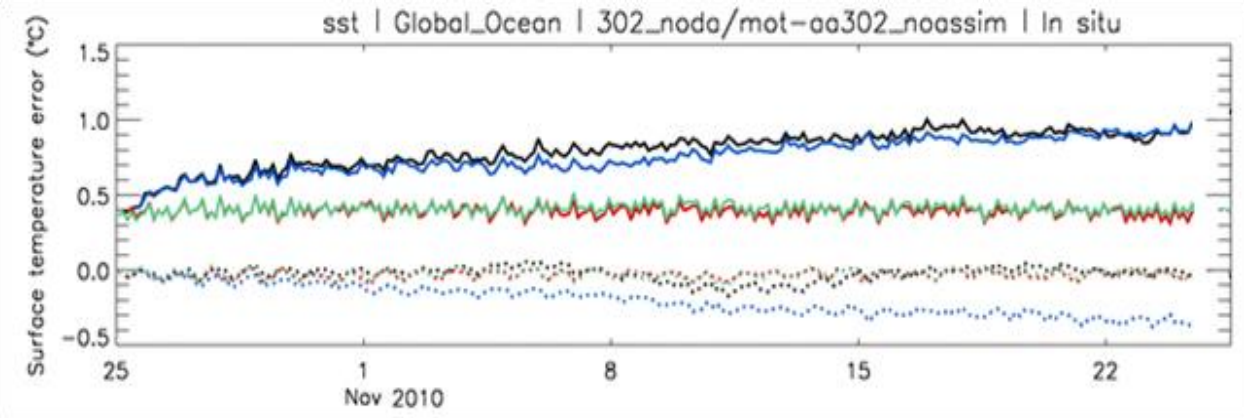


Fully coupled DA

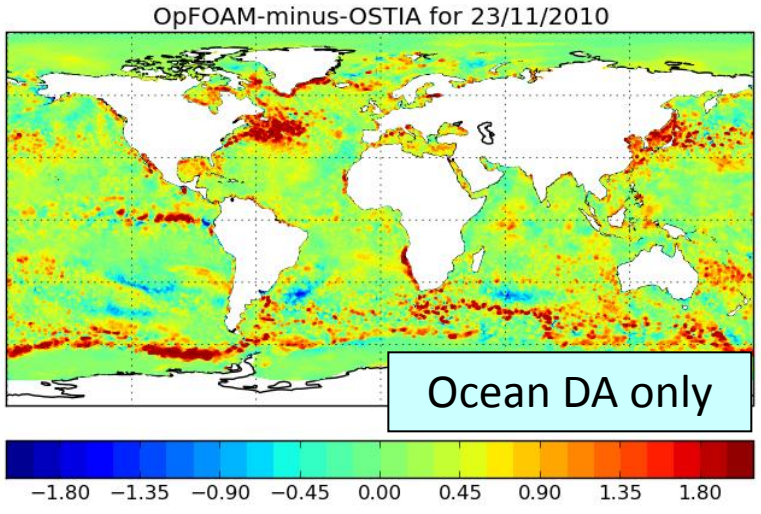


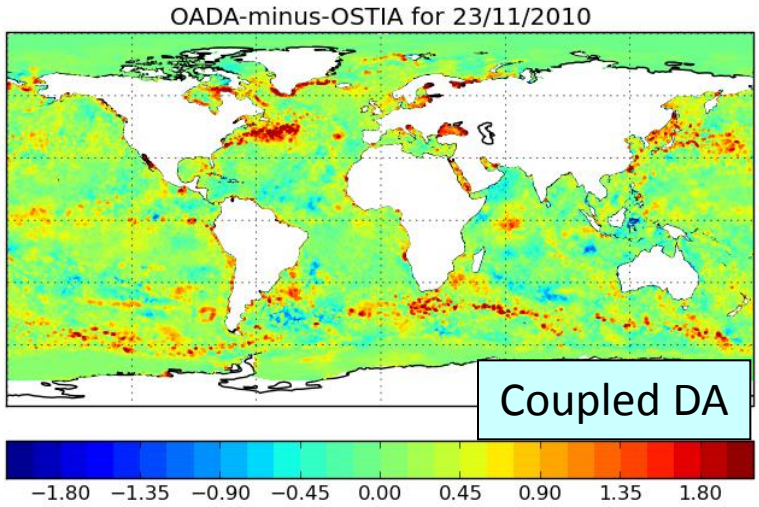
Coupled DA: Impact on SST

RMS (solid) and mean (dotted) error for SST background state minus in situ observations



Daily average SST difference from OSTIA for 23/11/2010.





Met Office global seasonal ensemble prediction system: GloSea5

Alberto Arribas and the rest of the GloSea team

GloSea5 – the Met Office Global Seasonal Ensemble Prediction System

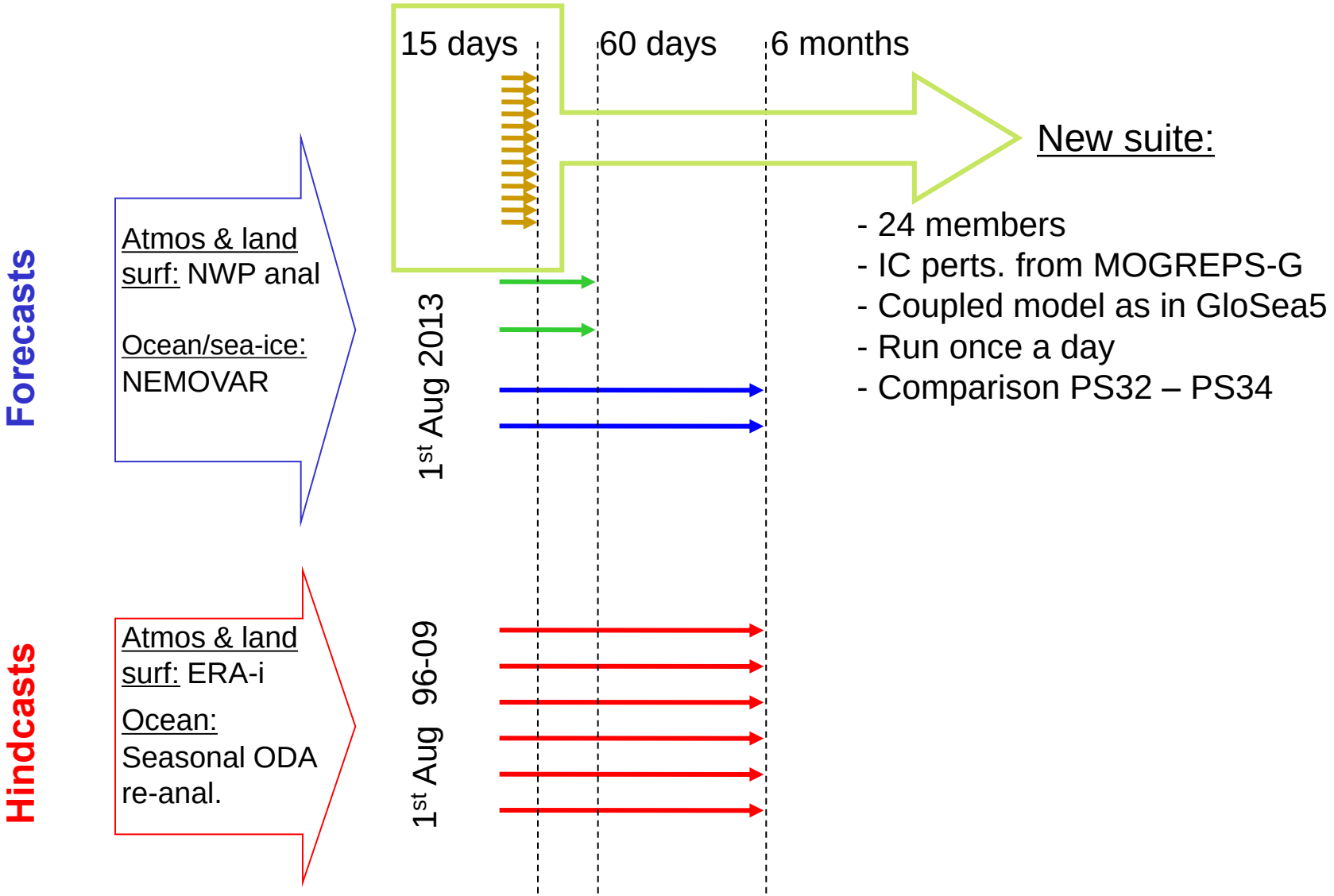
- Atmosphere model = Unified Model, GA3.0, N216L85 (~60km in mid latitudes)
- Land model = JULES, GL3.0, N216, 4 layers
- Ocean model = NEMO3.2 ORCA0.25L75 (~28km in mid latitudes)
- Sea ice model = CICE4.1 ORCA0.25
- Run length = 6 months
- Number of ensemble members = 2 per day. 3 weeks worth goes into the forecast for the season ahead (total = 42 members).
- Bias correction applied by subtracting off known biases from hindcasts which are run operationally once per week to represent similar dates over the past 14 years.

Met Office strategy

	Hindcast length	Frequency of system upgrades	Centre's priorities
JMA	~ 30 yr	?	?
NCEP	~ 40 yr	8 yr	Link to re-analysis
ECWMF	~ 25 yr	5 yr	Med-range
UK Met Office *	14 yr	1 yr	Link to model development

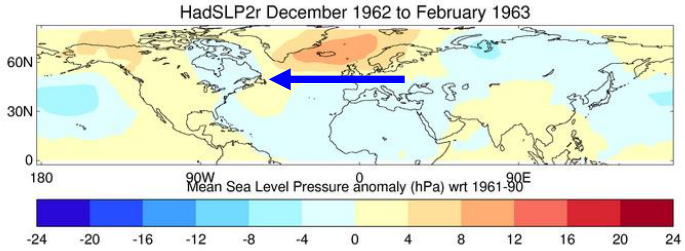
* Arribas et al., 2011: GloSea4 ensemble prediction system for seasonal forecasting. MWR. 139, 1891-1910

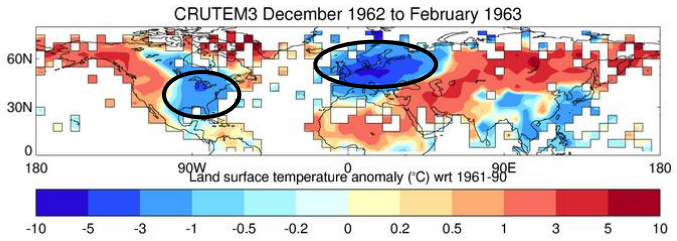
Daily runs available from operational forecasting systems for long-range



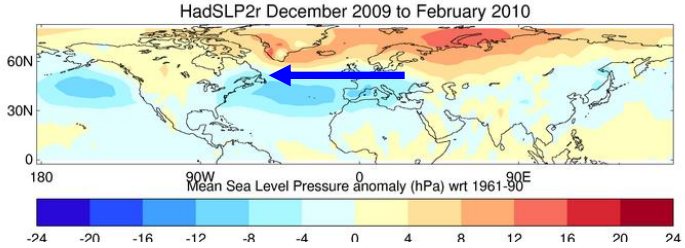
Introducing the North Atlantic Oscillation (NAO)

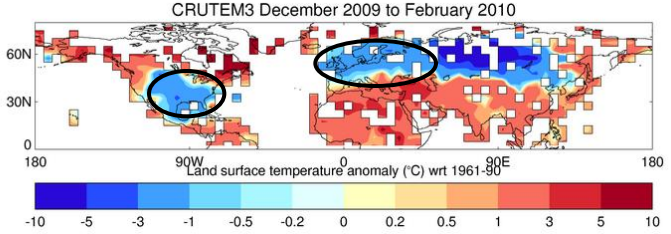
Winter 1962/63 (negative NAO)



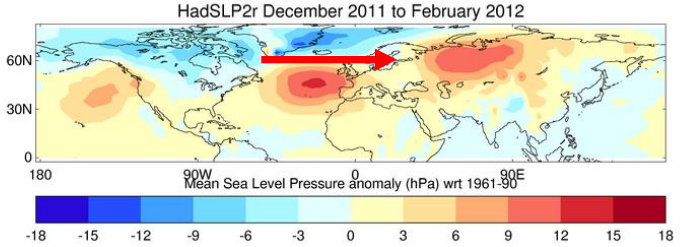


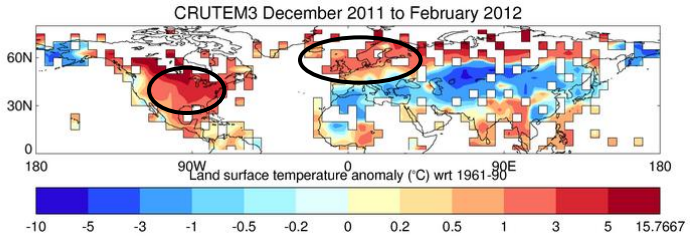
Winter 2009/10 (negative NAO)





Winter 2011/12 (positive NAO)





Negative NAO gives:

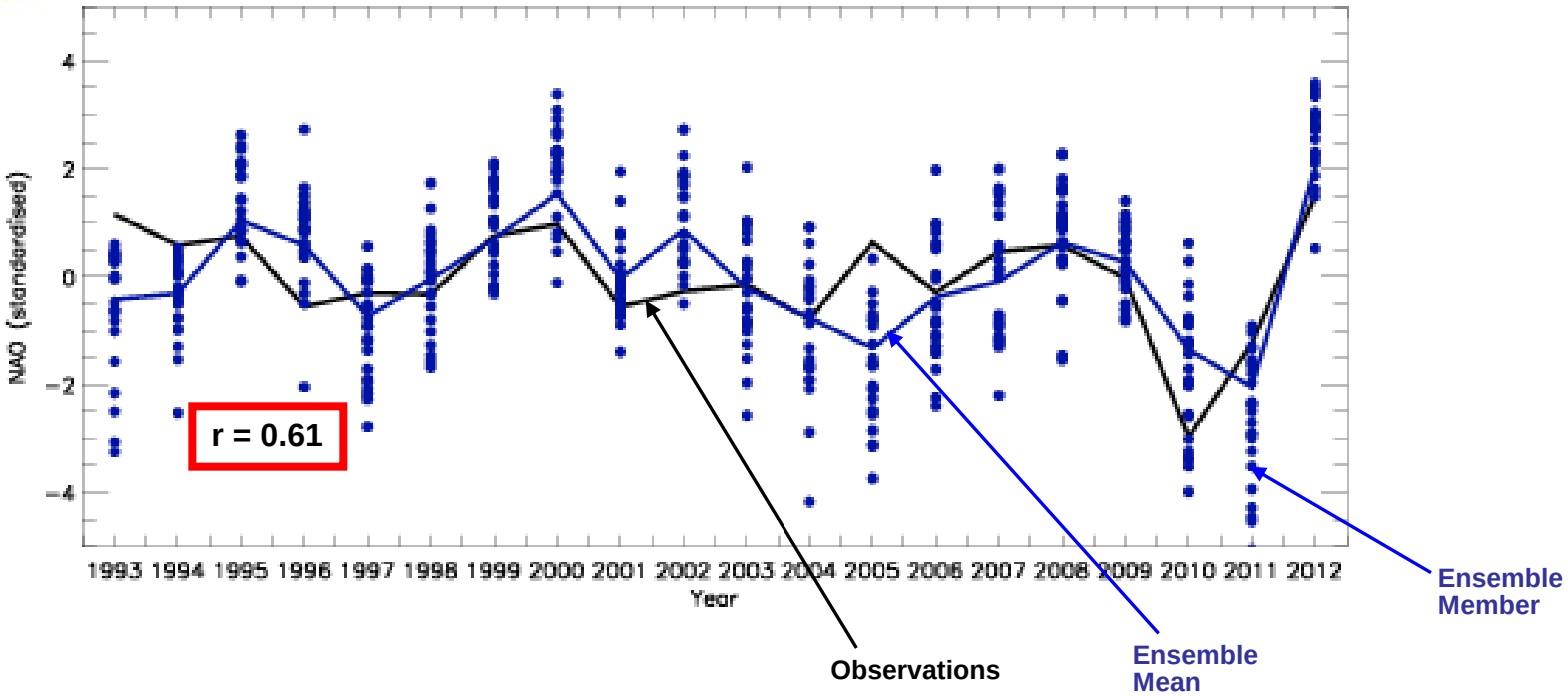
Weak P Gradient

Cold advection into Europe

Cold, calm and dry

Predictability of the NAO

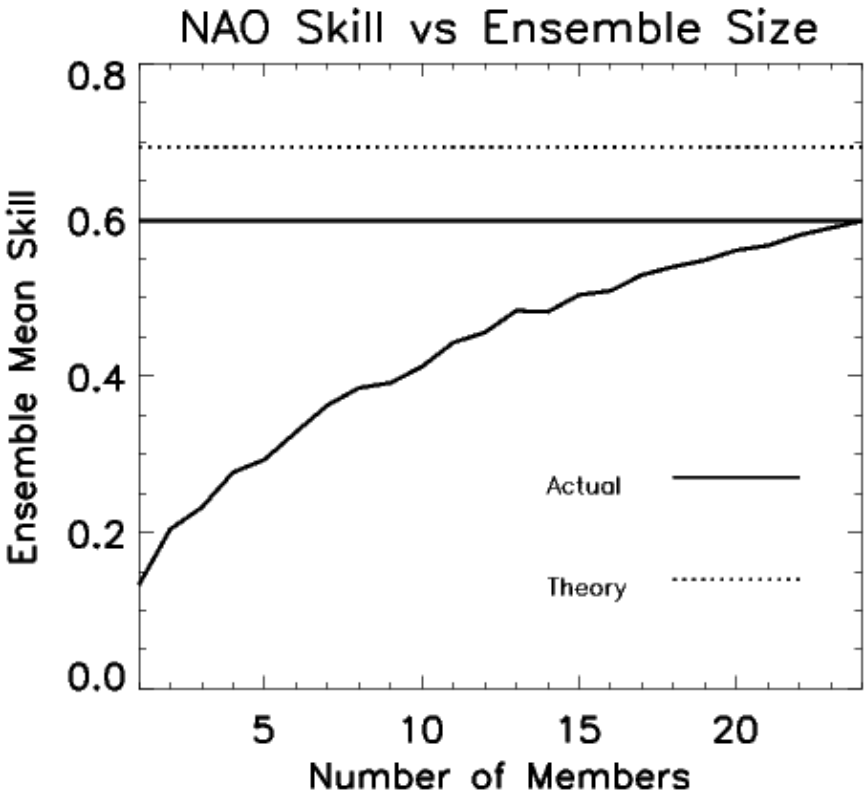
Retrospective winter forecasts from early November



NAO skill: correlation=0.61 (c.f. ECMWF 0.16, NCEP 0.25: not significant)

Significant at the 98% level

Effect of ensemble size on skill



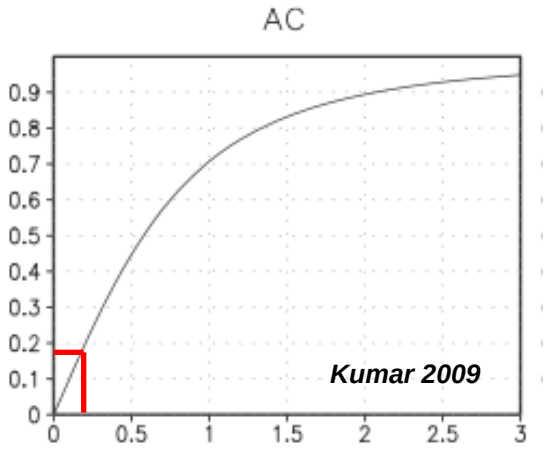
Resample for different ensemble sizes

(do this without replacement)

Approaching theoretical asymptote (Murphy, 1990)

0.7 is possible with this system!

BUT signal to noise is small ~0.2 ??

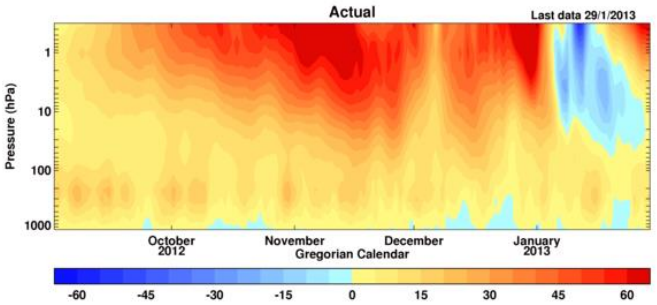


Signal to noise

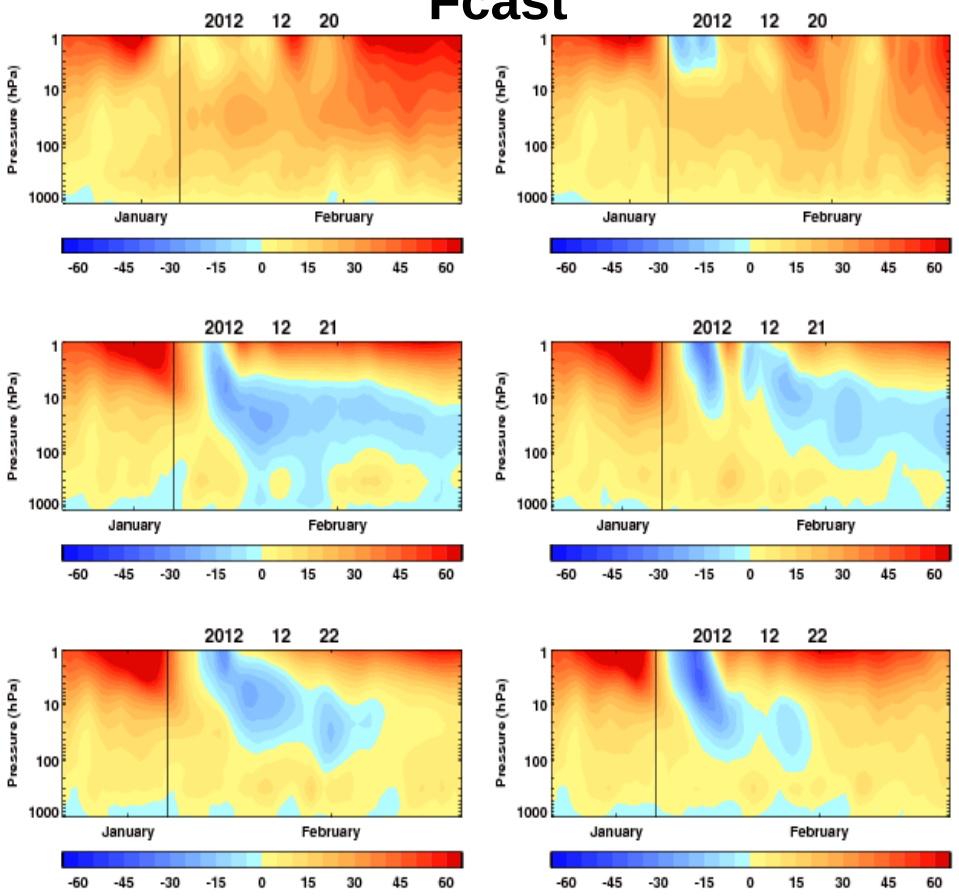
Why does the stratosphere matter?
Sudden Stratospheric Warming Jan 2013

Zonal mean zonal winds at 60° N

Obs



Fcast

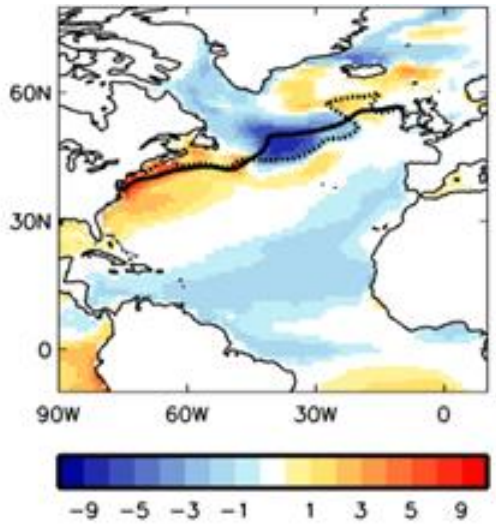


Jan 2013 – SSW appearing in forecasts from 21st Dec
Operational forecasts from late Dec => increased risk of easterlies etc…
DfT warned from 4th January onwards

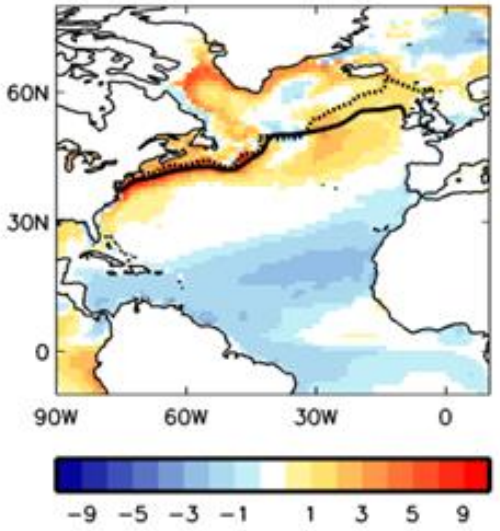
Why does ocean resolution matter?

(Atlantic Blocking: an 'old chestnut' of climate modelling issues)

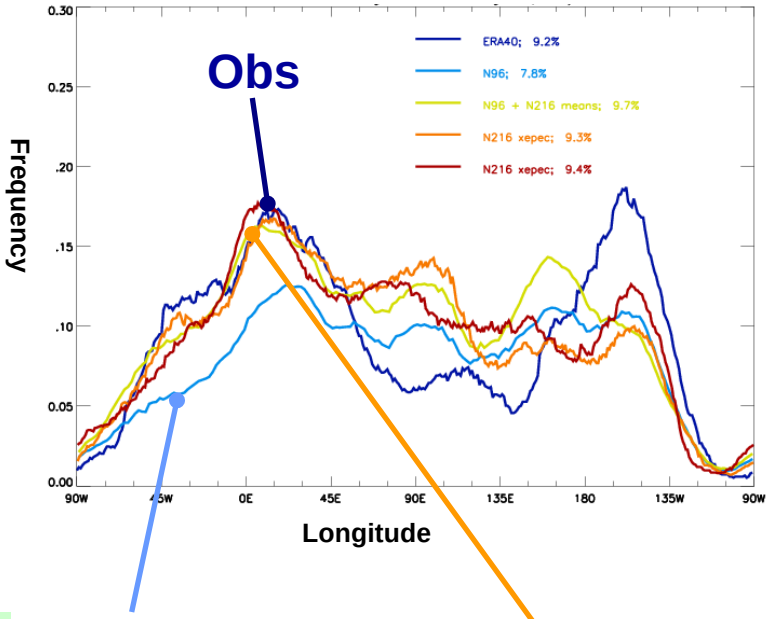
Low Res 1°



High Res 0.25°



Atlantic Blocking Frequency



Low Res Model

High Res Model

Cold winter bias (°C) in Gulf Stream

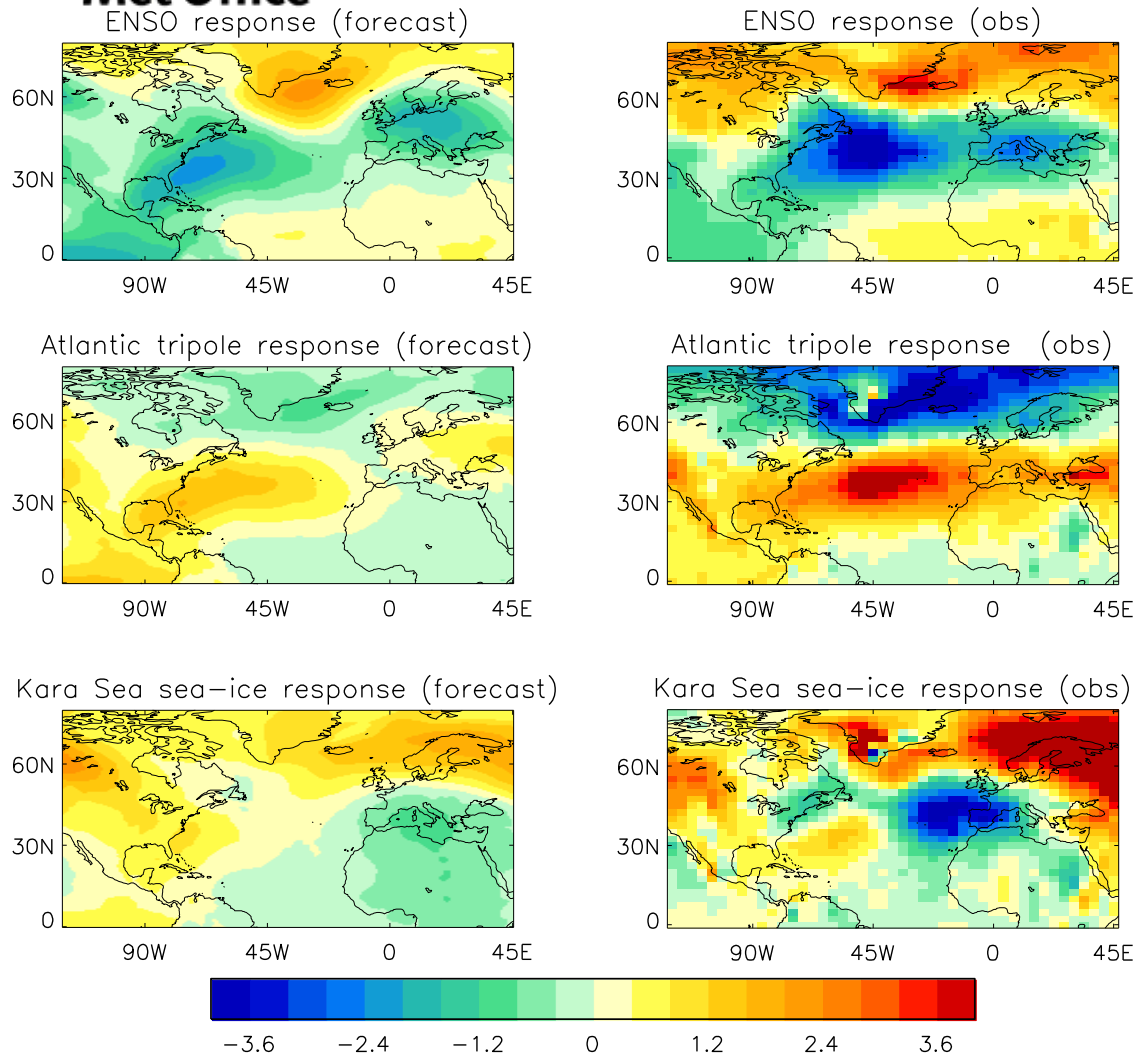
Occurs in standard seasonal forecast models

Small Gulf Stream bias in high res' Hadley Centre Model

⇒ Good Blocking!

Scaife et al., GRL, 2011

Sources of predictability…



Strongest minus weakest cases for mid-November predictors:

1. ENSO Niño3.4
2. Atlantic Tripole
3. Kara sea-ice (45-75E, 67-80N)

Model reproduces main mechanisms but response is weaker than in obs.

Summary

Summary

- Some off line bias correction can be done for ensemble forecasts (e.g. wind thresholds).
- Coupled models outperform atmosphere only and ocean only forecasts in the following areas:
  - Improved forecasts of atmospheric air temperatures in the tropics.
  - Improved forecasts of SSTs.
  - Improved forecasts of tropical depressions.
  - Correct lead-lag relationship between SSTs and atmospheric convection, improving the MJO and tropical precipitation near the Maritime Continent.
- Coupled data assimilation shows potential for improving forecasts by removing inialization shock.
- The UK Met Office seasonal forecasting system (GloSea5) has been upgraded recently with improved physics, horizonal and vertical resolution. These have improved:
  - Predictability of the NAO, due to reduced mean state biases (no cold SST bias in the North Atlantic) and improved teleconnections (e.g. ENSO via sudden stratospheric warmings).

Questions and answers