Sensitivity to initial conditions and external forcing in climate predictions.

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30 Years of Ensemble Forecasting and Symposium for Prof. Tim Palmer

ECMWF

Reading 5th of December 2022

ISAC Consiglio Nazionale delle Ricerche
Istituto di Scienze dell'Atmosfera e del Clima

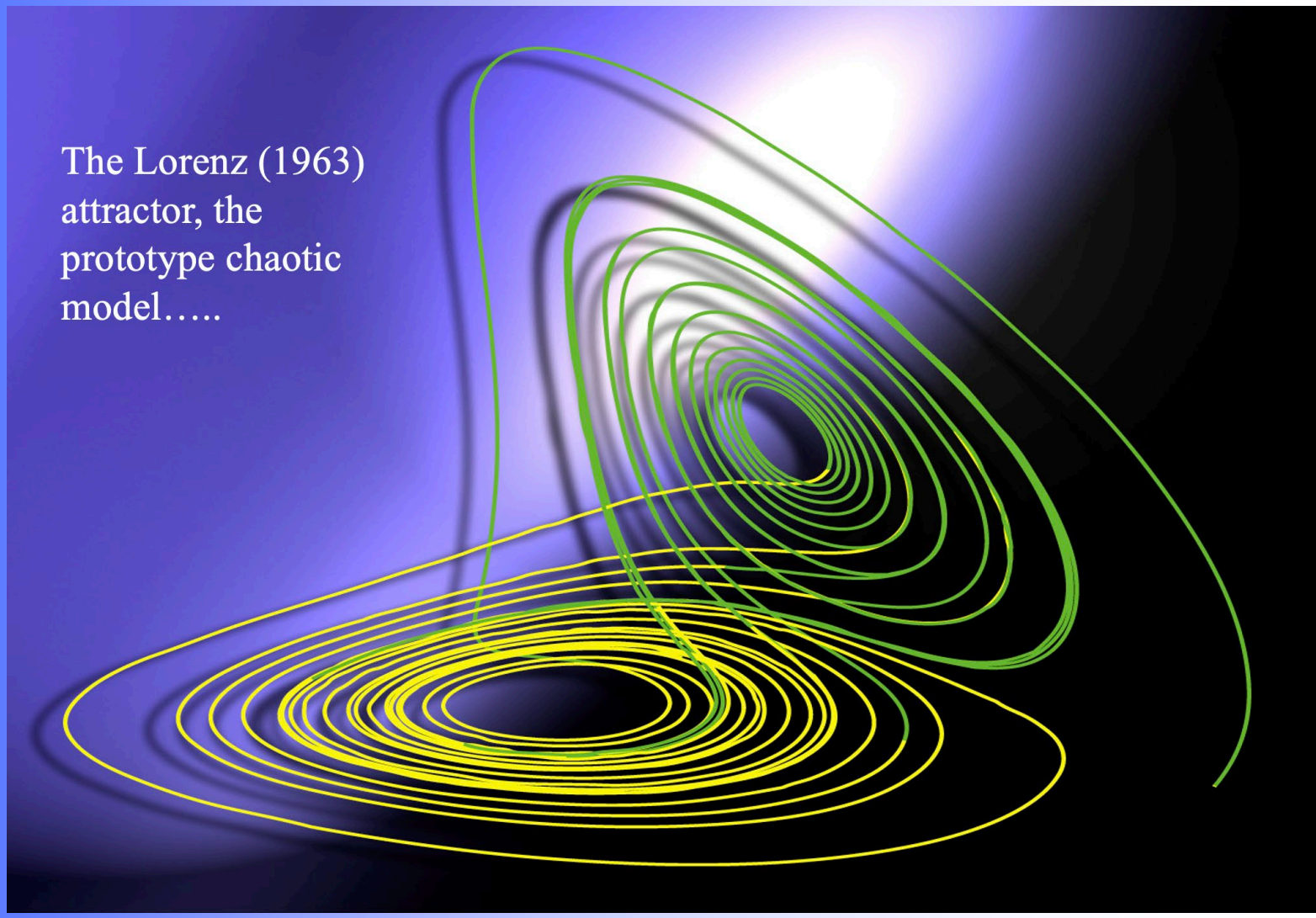
About 30 years ago… May 1992
ECMWF Training course on Predictability…

Introduction to Chaos

by

Tim Palmer

About 30 years ago… May 1992…
ECMWF Training course on Predictability…



Flow dependent predictability (forecasting forecast skill)

Predictability arising from changes in the boundary conditions and/or external forcing

Hybrid problems at the edge between predictions of the first and the second kind

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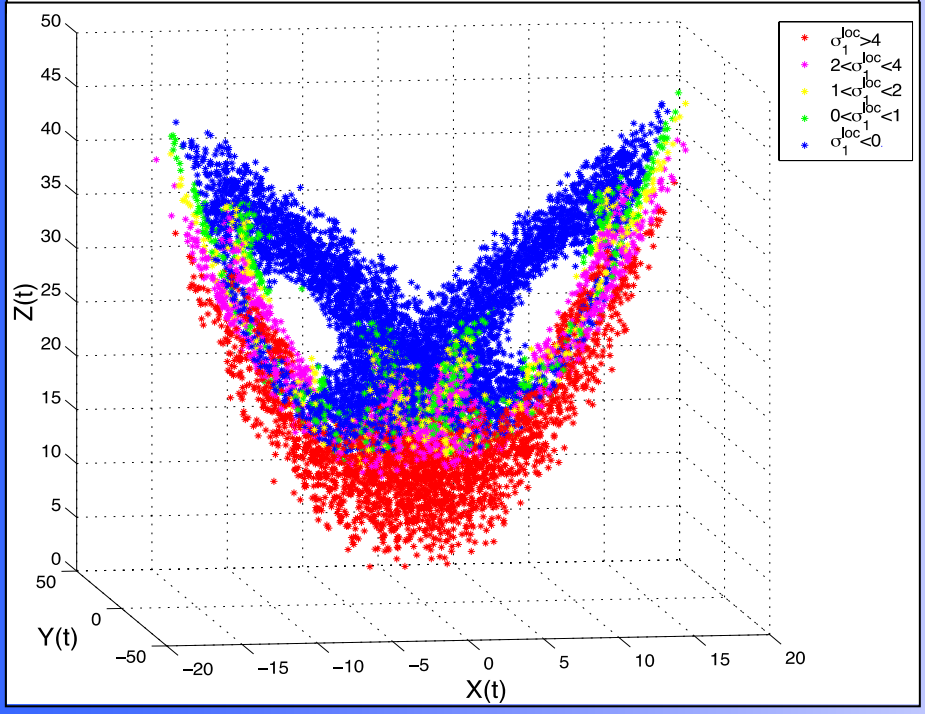
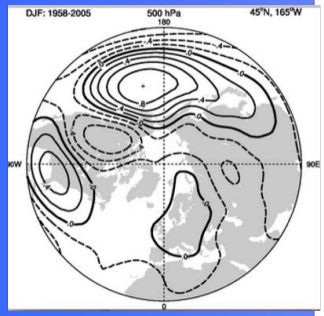
Error growth in Lorenz63

Error growth in Lorenz63:

blue: decay; green: moderate; yellow/purple: medium; red: high.

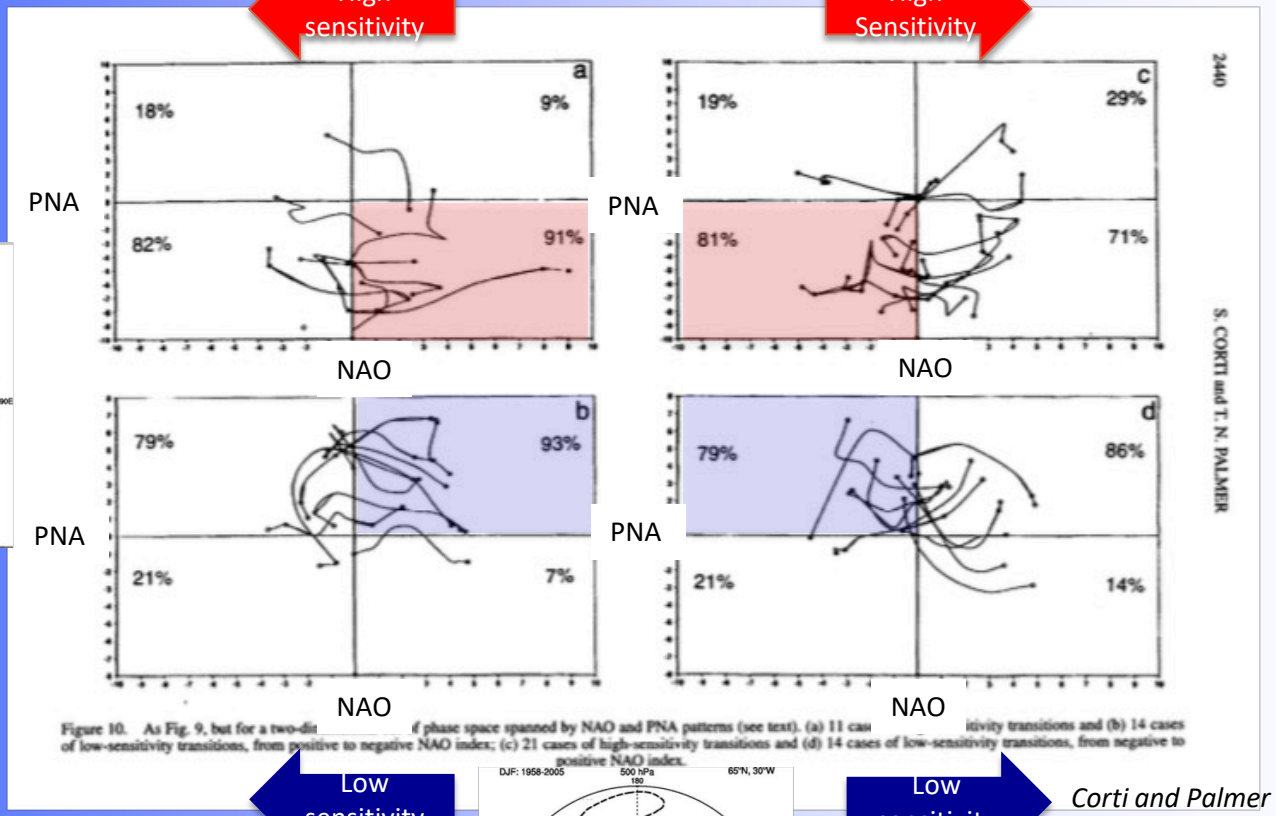


Predictable and unpredictable NAO transitions in a QG model

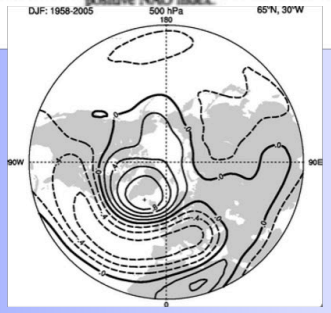


High sensitivity

High Sensitivity



Low sensitivity



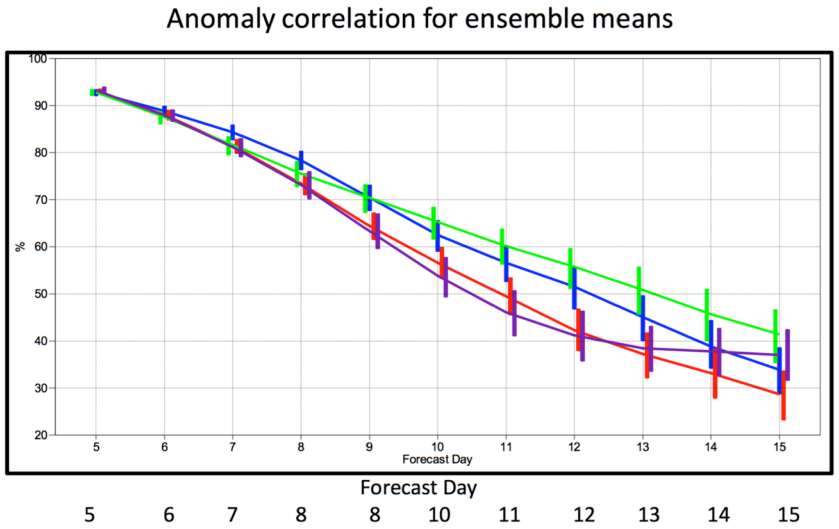
Low sensitivity

Corti and Palmer QJ 1997

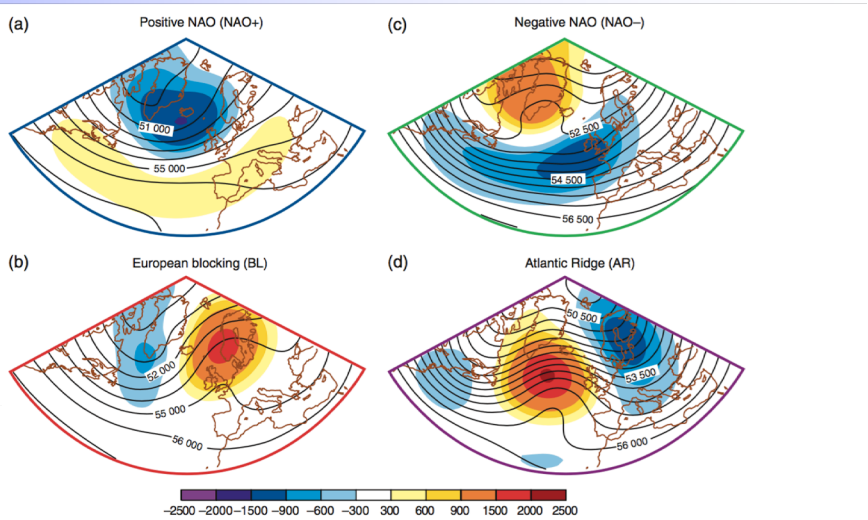
Sensitivity=||L*NAO||/||NAO||

Flow dependent Euro-Atlantic regime predictions in the ECMWF model

ECMWF Operational forecast 2007-2012 (Oct-Apr).



Anomaly correlation of the ensemble means for the four forecast categories as a function of forecast range. The bars, based on 1000 subsamples generated with the bootstrap method, indicate the 95% confidence intervals.



(a–d) Geographical patterns of the four Euro-Atlantic climatological regimes (both anomalies and full fields) for the October to April cold season. The ial anomalies (colour shading) and geopotential (contours) at 500 hPa are shown.

 Q. J. R. Meteorol. Soc. (2014)

Ferranti, Corti and Janousek QJ 2015

Flow dependent predictability (forecasting forecast skill)

Predictability arising from changes in the boundary conditions and/or external forcing

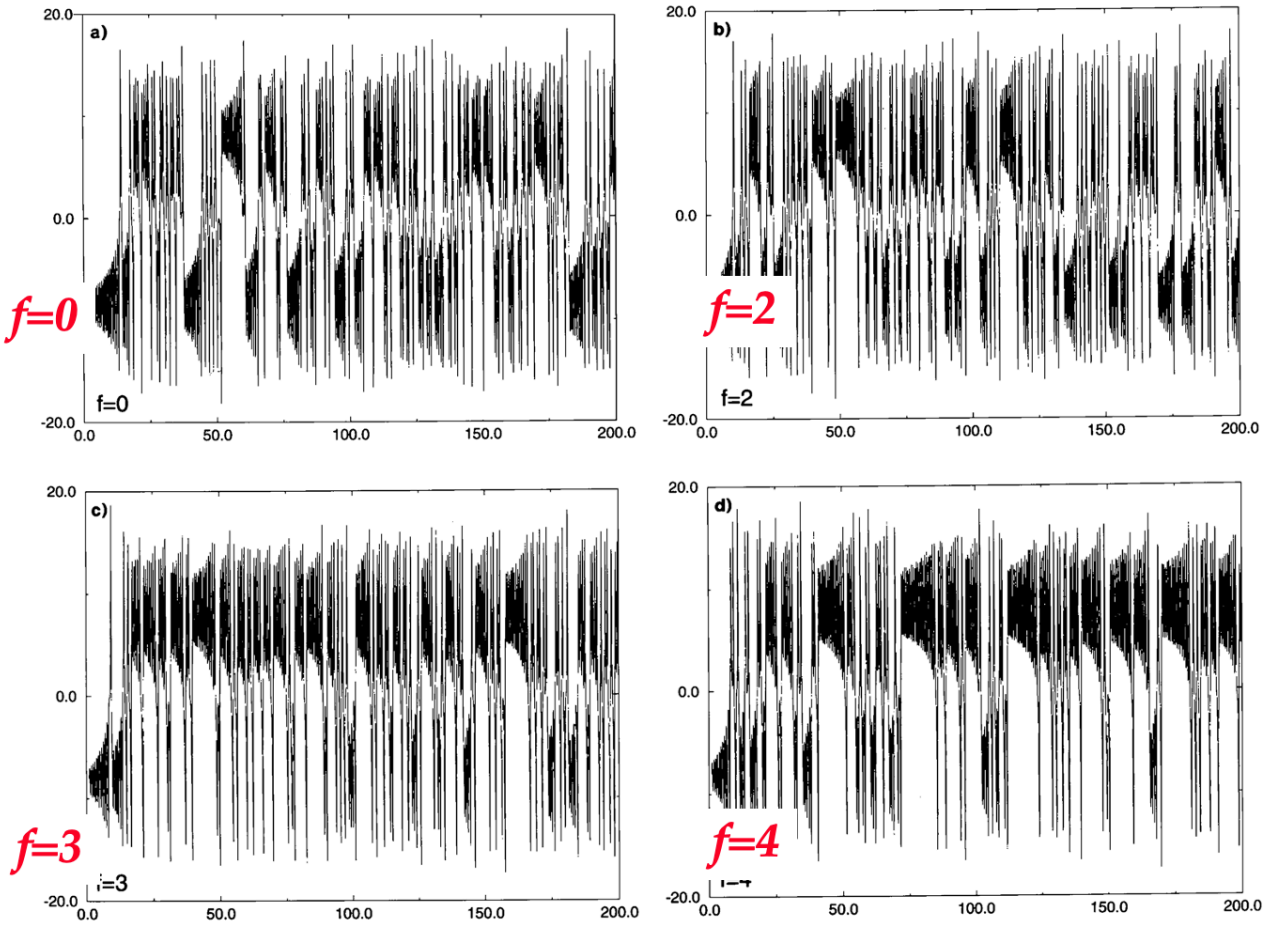
Hybrid problems at the edge between predictions of the first and the second kind

Introduction to chaos for:

Seasonal climate prediction

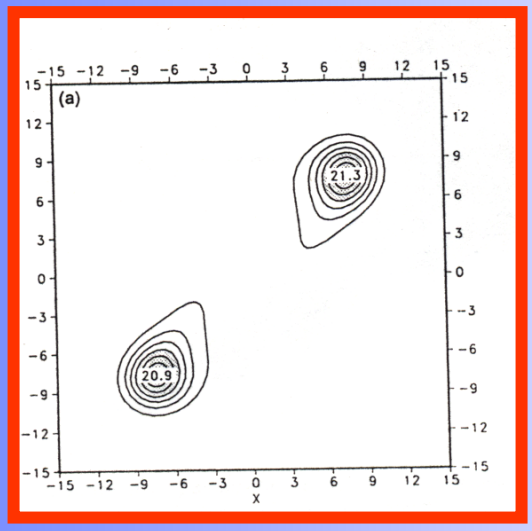
Atmospheric predictability
arises from slow variations
in lower-boundary forcing

Add external steady forcing f to the Lorenz (1963) equations

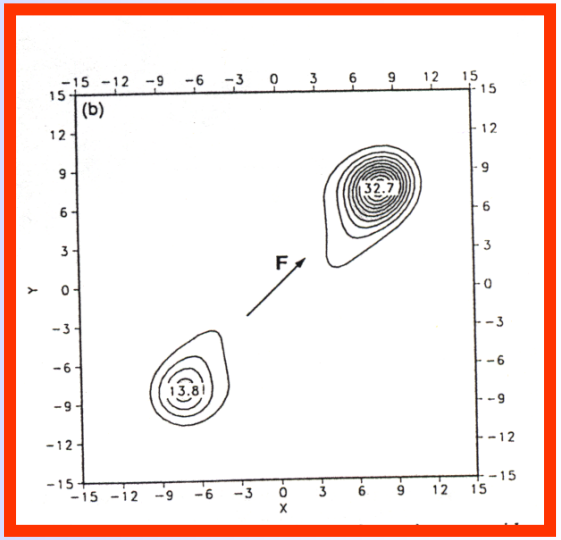


The influence of f on the state vector probability function is itself predictable.

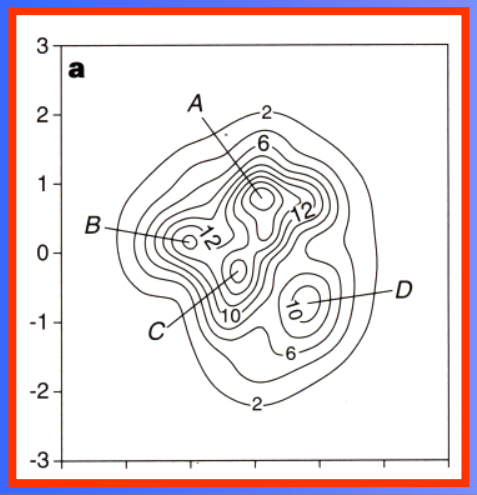
Predictability arising from changes in the boundary conditions and/or external forcing



LORENZ63 PDF

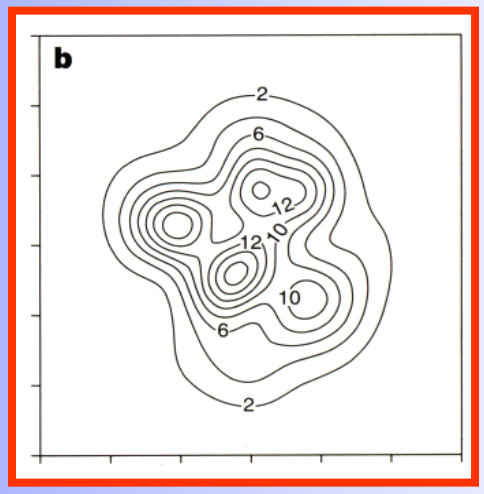


Forced LORENZ63 PDF



(a) Weather regimes PDF

Climate 1949-1994

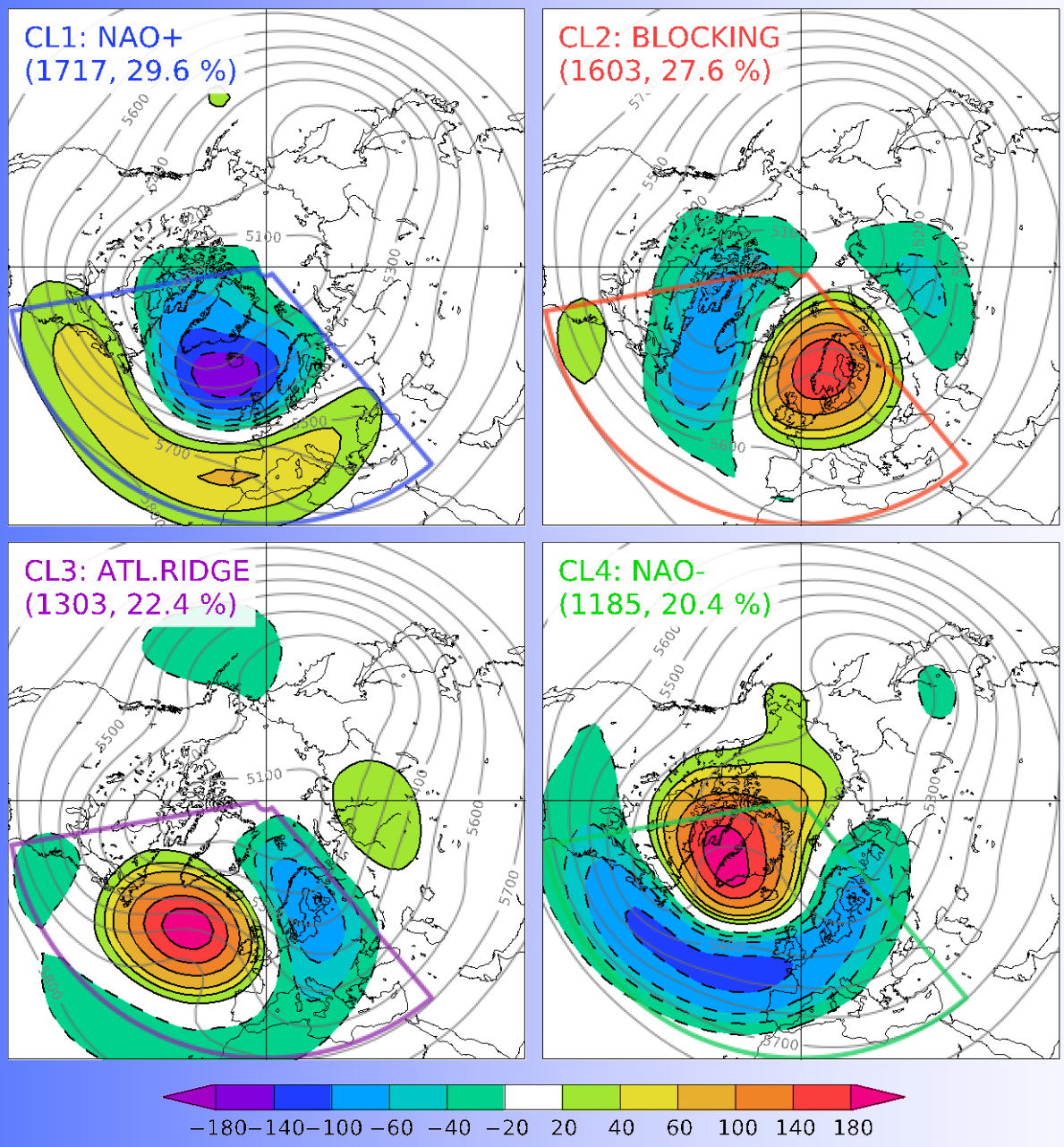


(b) As in (a), but taking out 13 El Nino and 7 La Nina winters

Corti, Molteni and Palmer Nature 1999

Euro-Atlantic Weather Regimes

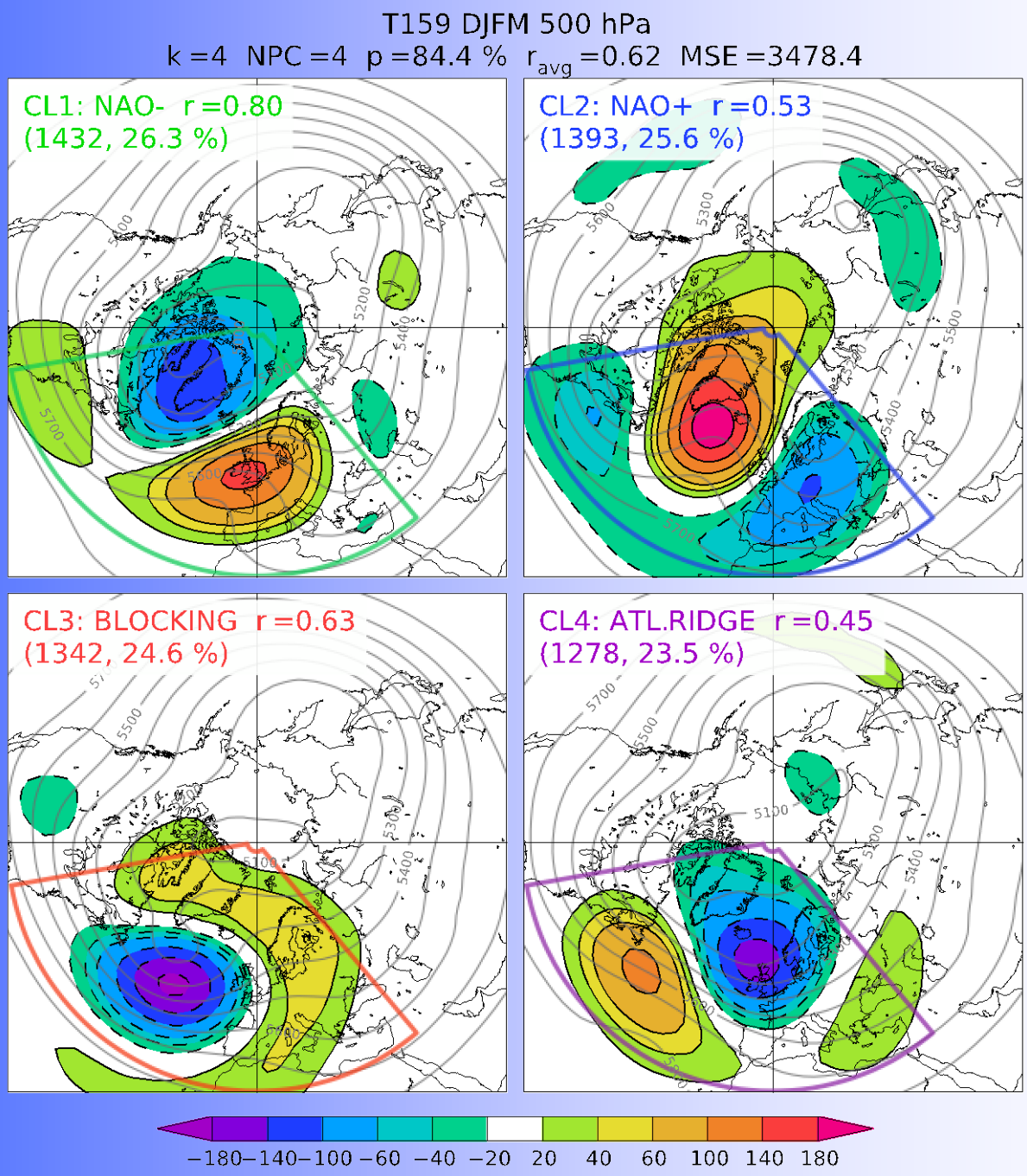
Reanalysis



Dawson, Palmer and Corti GRL 2012

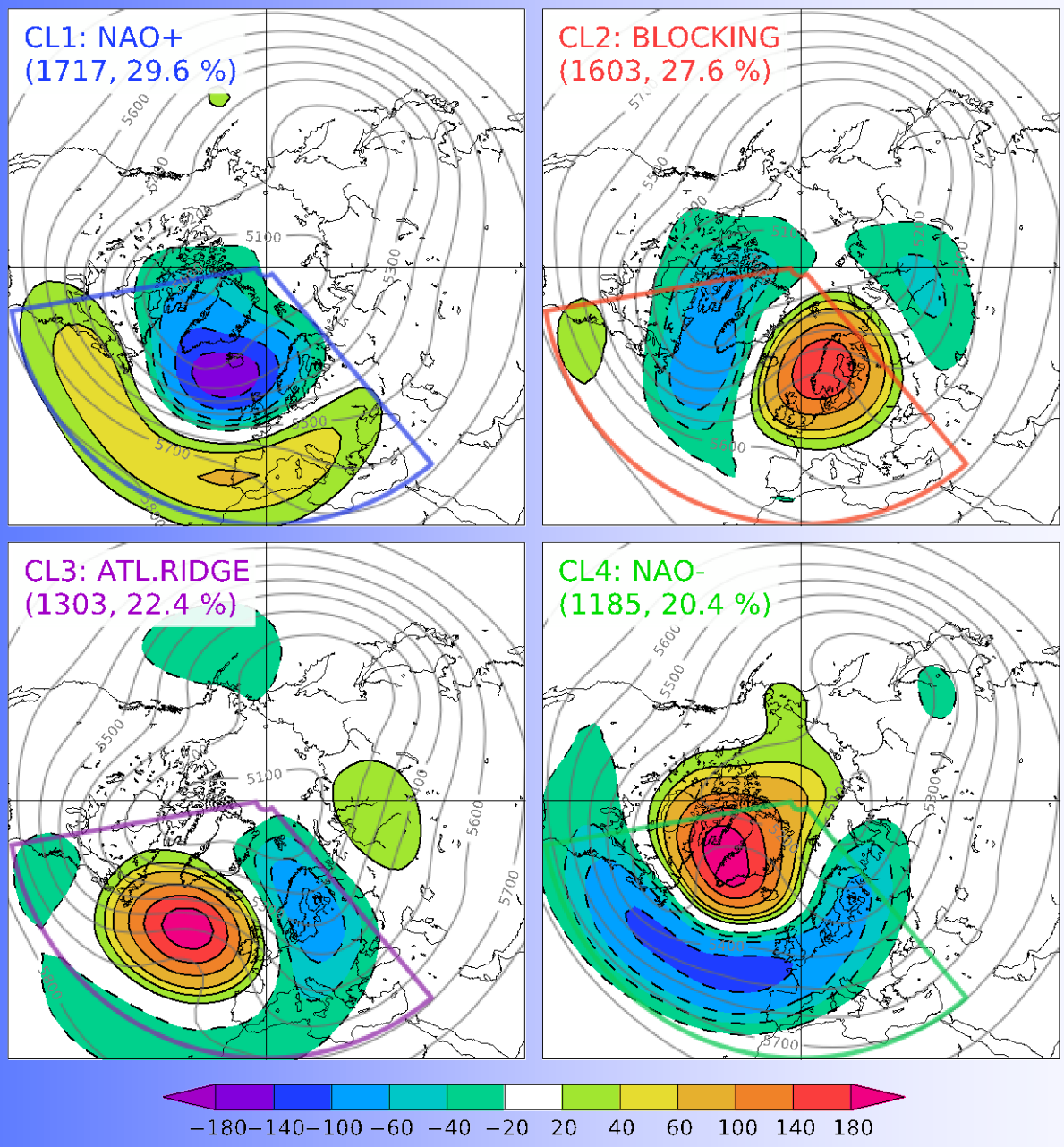
Euro-Atlantic
Weather Regimes

ECMWF model
T159



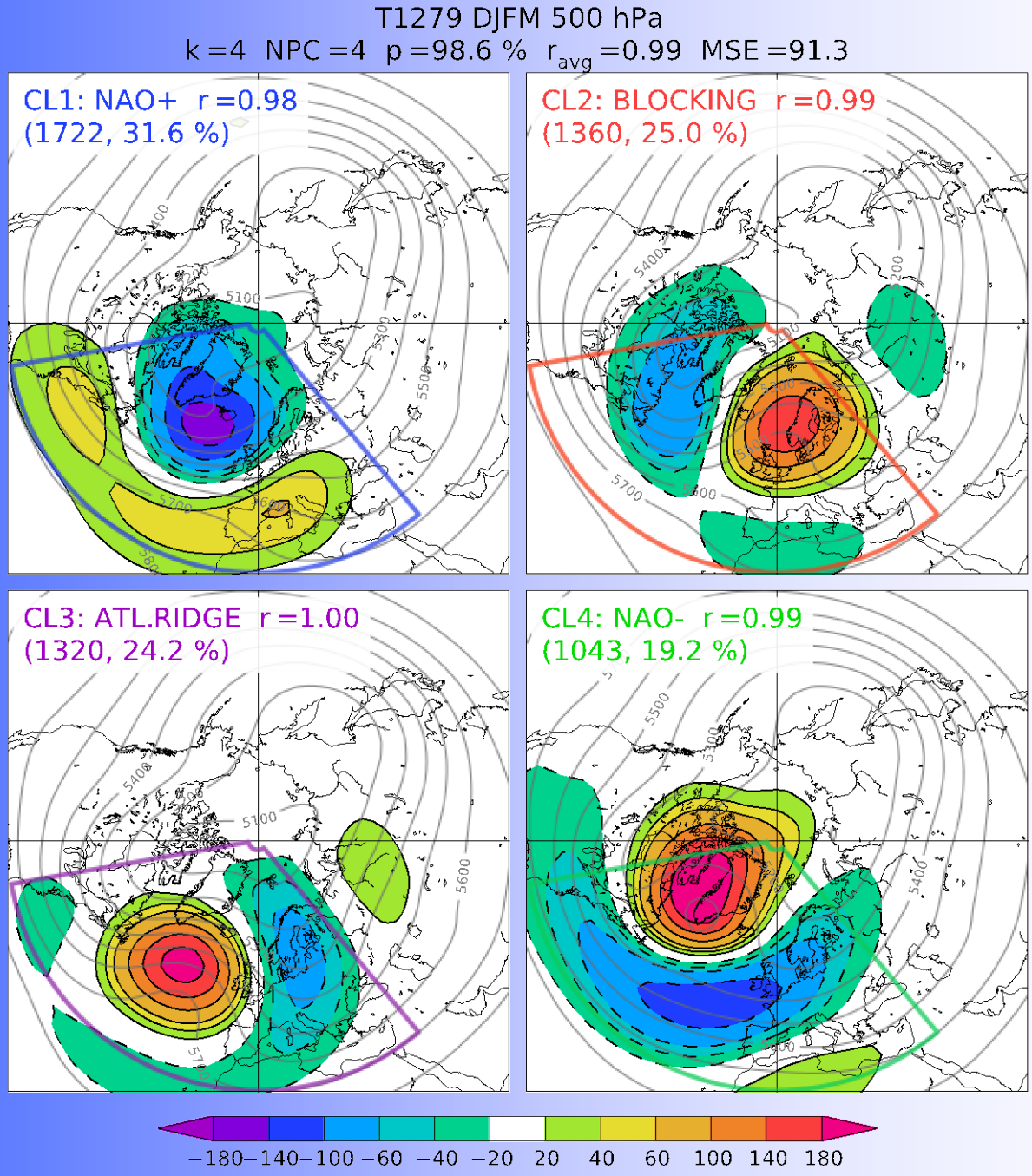
Euro-Atlantic Weather Regimes

Reanalysis



Euro-Atlantic
Weather Regimes

ECMWF model
T1279



Simulation of Weaher regimes:
State of the Art CMIP5 (lower res) vs. CMIP6 (high res)

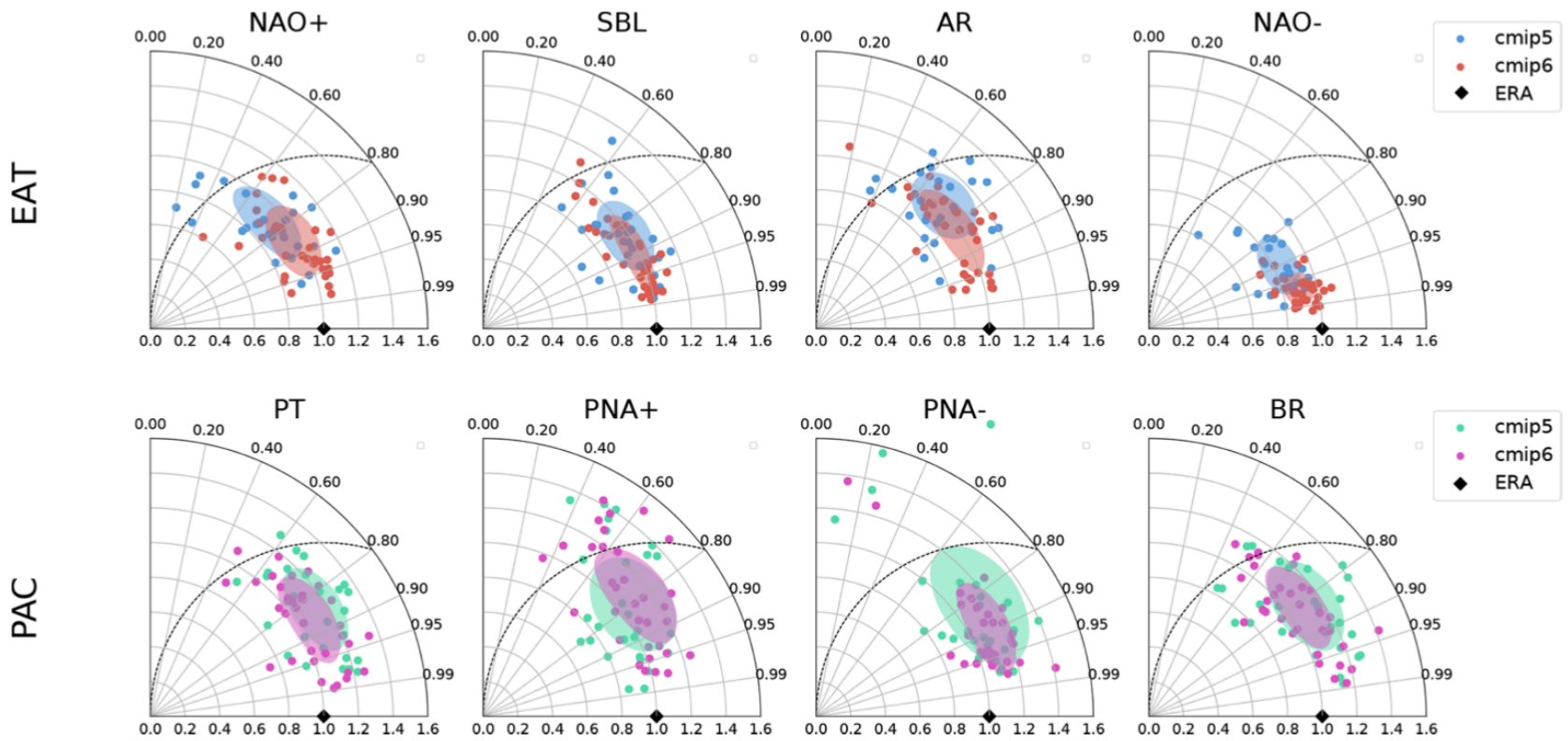


Figure 2. Taylor diagrams showing the agreement between simulated and observed regime patterns for CMIP5 (blue and green) and CMIP6 (red and pink) models. The shaded ellipses are used to indicate the overall ensemble performance; they are centred on the ensemble mean and have semi-axes equal to the ensemble standard error. The simulated patterns are those obtained from the computed regimes of the historical simulations in the common period 1964–2005. The observed patterns are those computed from the reanalysis.

Fabiano, Meccia, Davini, Ghinassi, and Corti WCD 2021

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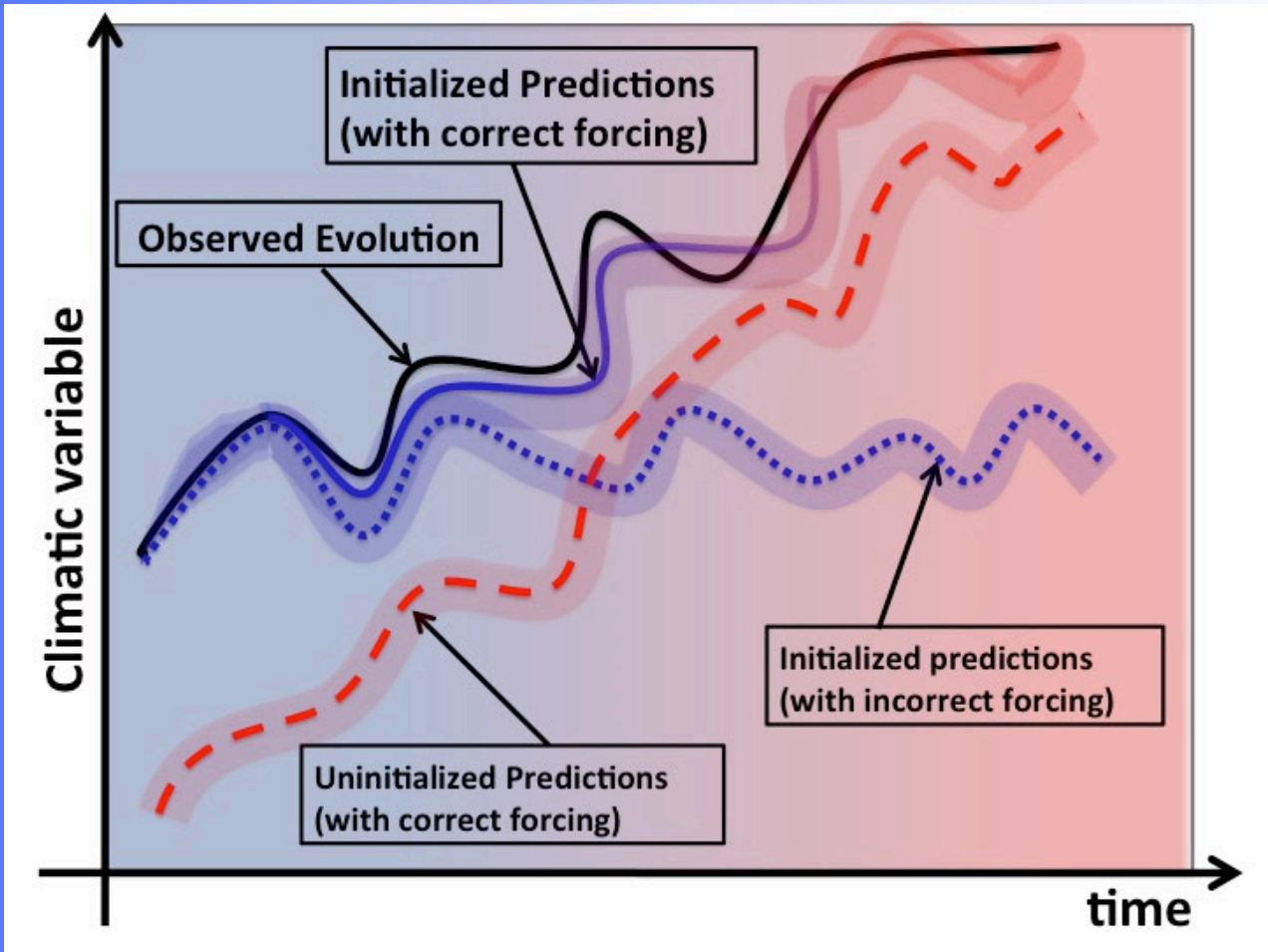
Initialized and uninitialized predictions

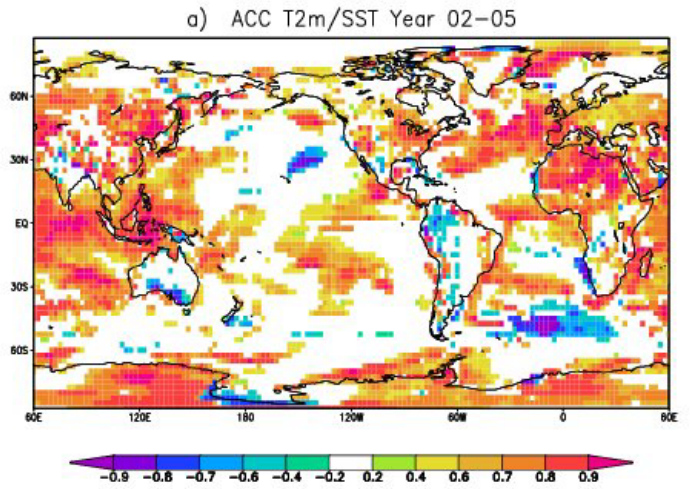


Cartoon from Corti, Palmer, Weisheimer, Balmaseda et al. 2015 – Journal of Climate

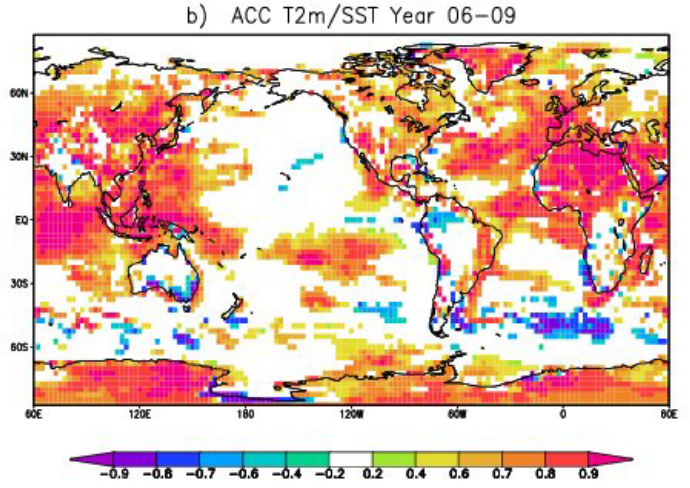
Grand Ensemble of all experiments - 54 Ensemble members

T2m &SST Anomaly Correlation Coefficient (95% level confidence)

YR 2-5



YR 6-9



Corti, Weishmeier, Palmer, Doblas-Reyes and Magnusson 2012 GRL

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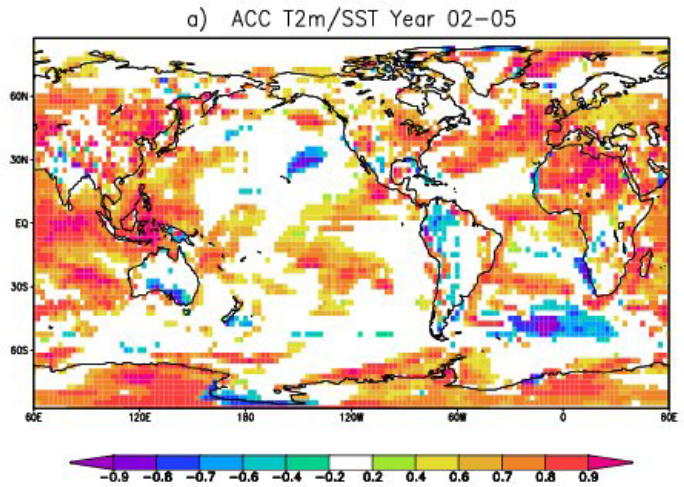
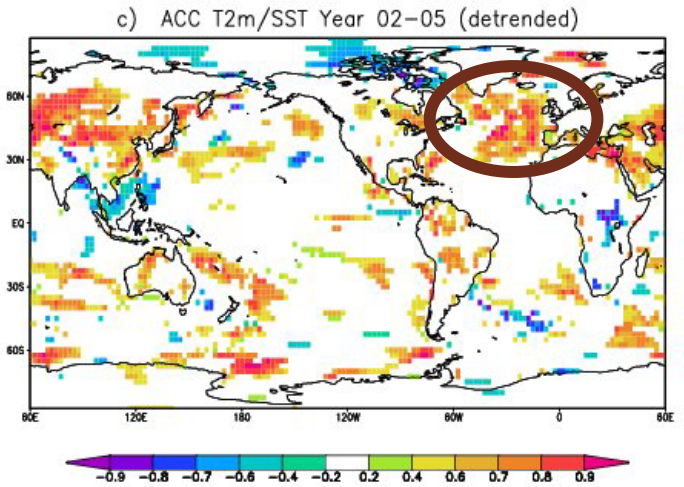
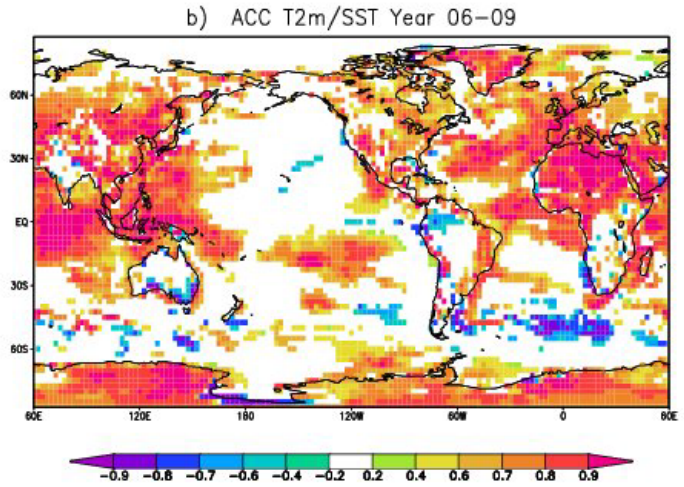


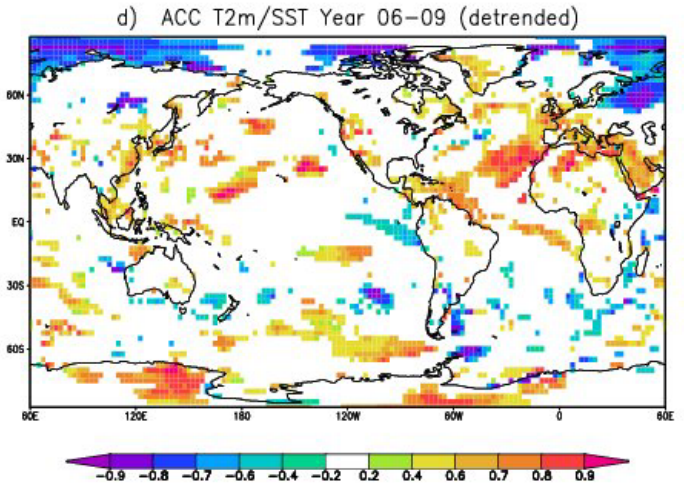
YR 2-5 – climate trend out



YR 6-9

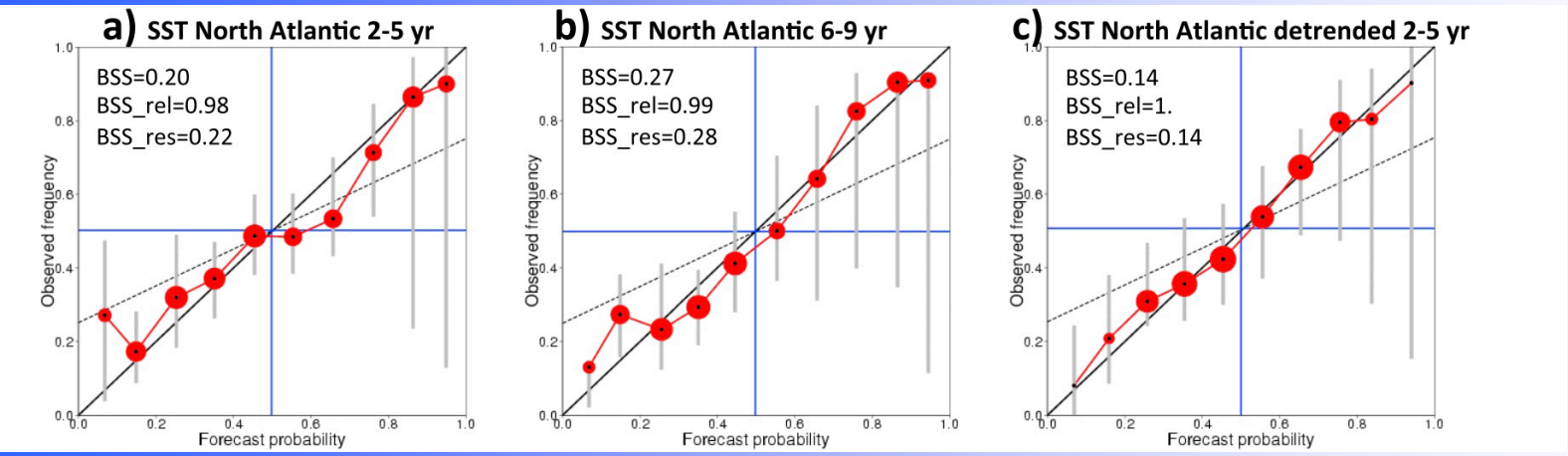


YR 6-9 – climate trend out

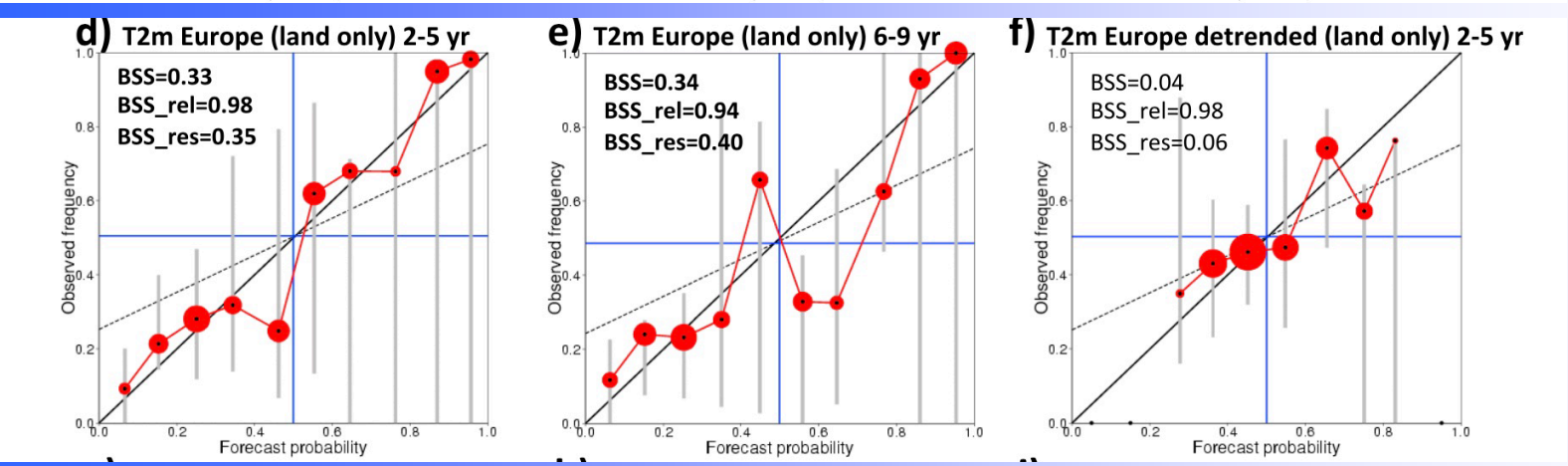


Corti, Weishmeier, Palmer, Doblas-Reyes and Magnusson 2012 GRL

Decadal time scale: First look at and near "the source region"



North Atlantic SST



Europe (land) T2m

2-5 yr

6-9 yr

2-5 yr detended

Not too bad!!

CMIP5 – 63 Ensemble members – Event: T2m below the lower tercile -2-5 year

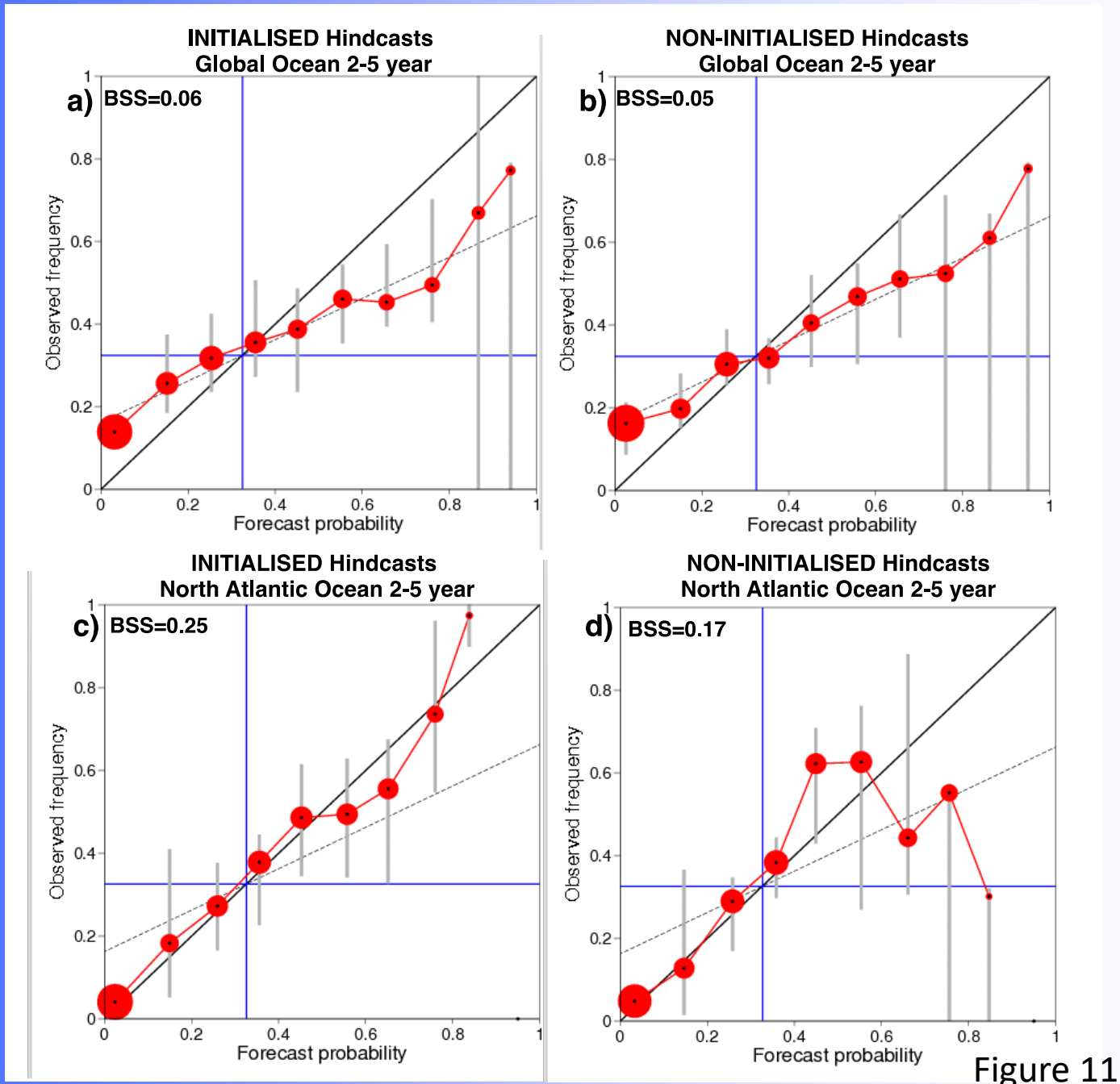
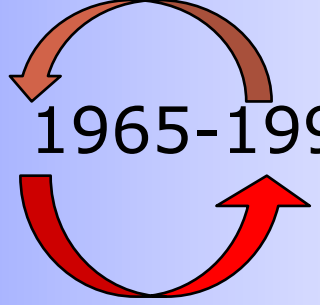


Figure 11.5 IPCC 2013

SWAP Experiment - 1965-1995



10-year integrations from:

A 1965 initial conditions, observed forcing (GHG & aerosols) from 1965 (control1)

B 1995 initial conditions, observed forcing (GHG & aerosols) from 1995 (control2)

C 1965 initial conditions, observed forcing from 1995

D 1995 initial conditions, observed forcing from 1965

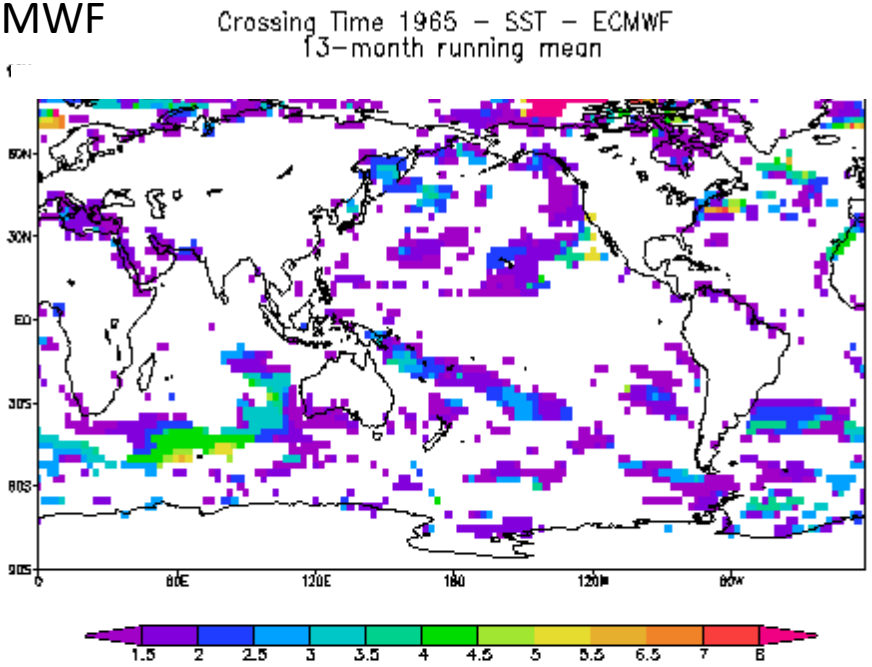
By comparing A with D, and B with C, we have two estimates of decadal predictability (arising from having different initial conditions and the same GHG forcing).

By comparing A with C, and B with D, we have two estimates of the impact of GHG forcings (since initial conditions are the same).

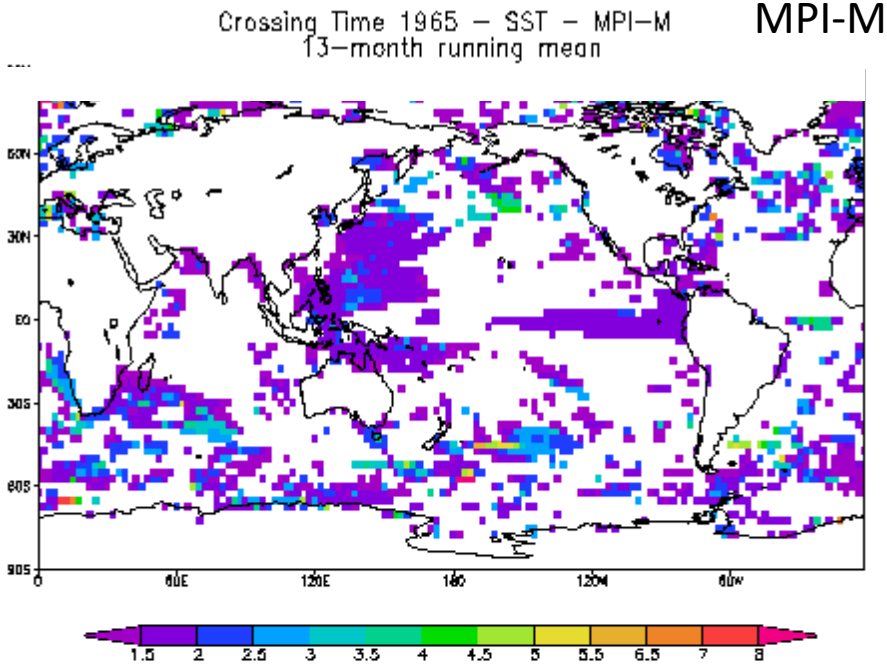
Corti, Palmer, Balmaseda, Weisheimer et (plures) al. JCLim 2015

Crossing times for SST- ensemble means

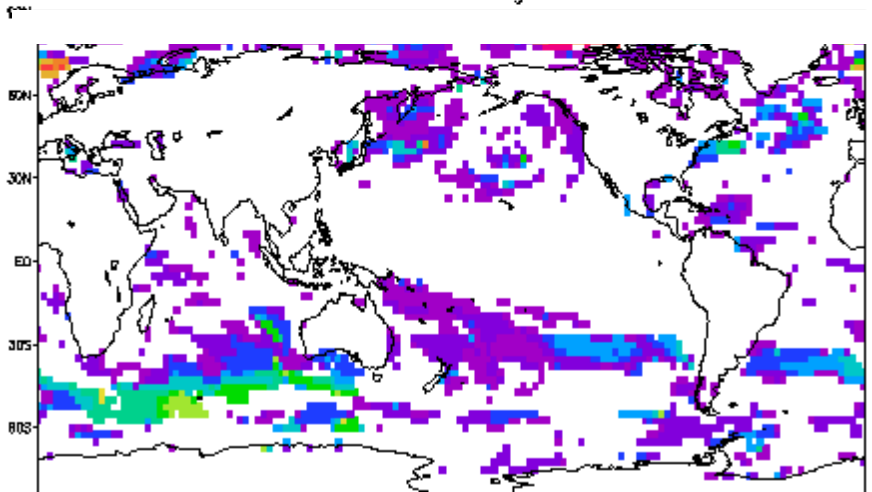
ECMWF



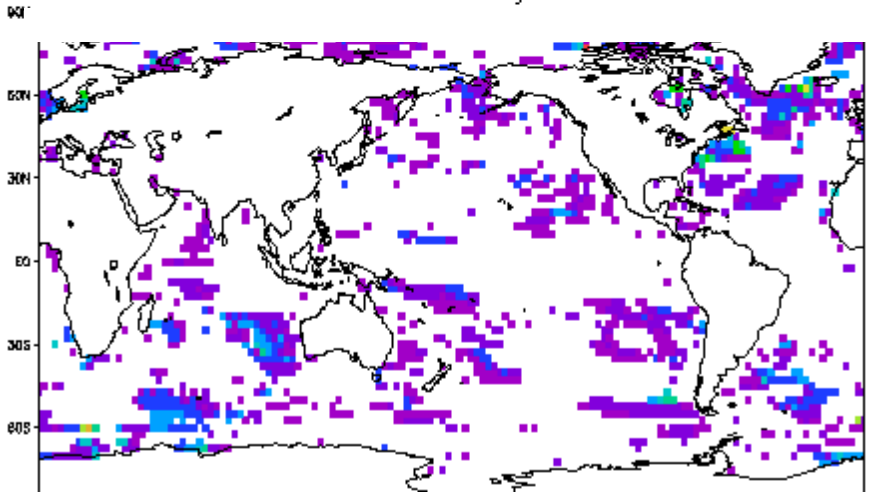
MPI-M



KNMI

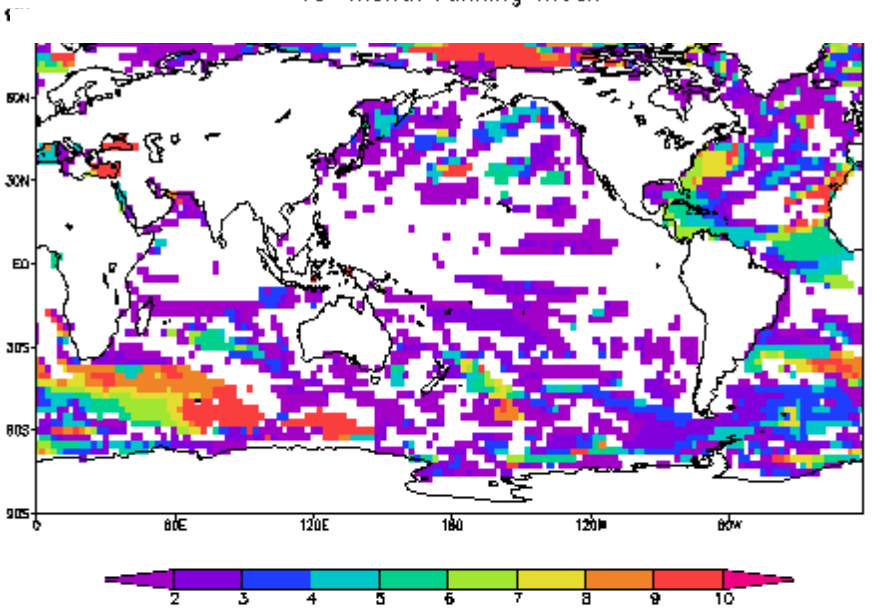


HadCM3

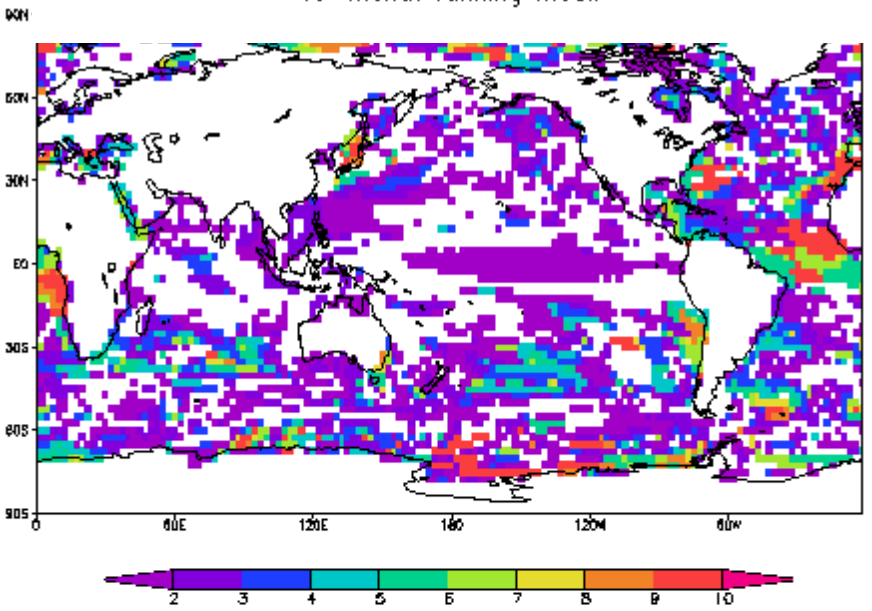


Crossing times for Heat Content 0-700m – ensemble means

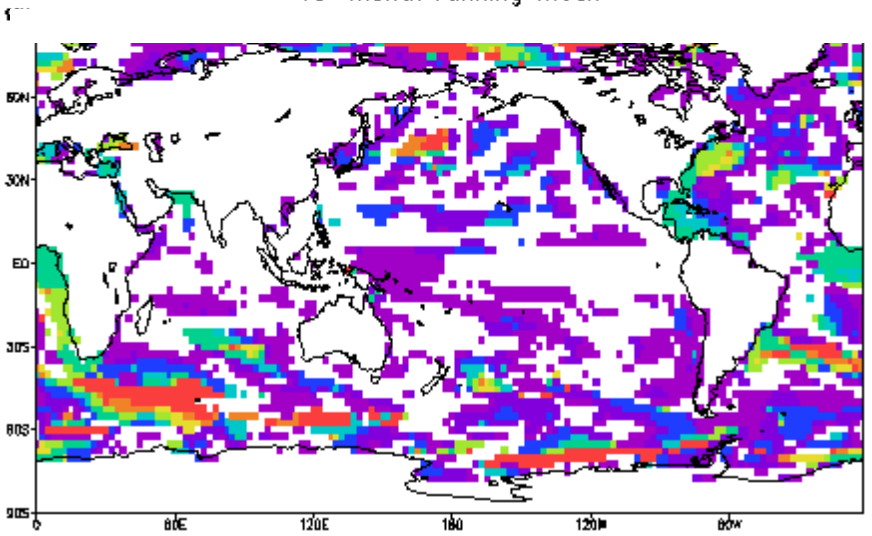
ECMWF



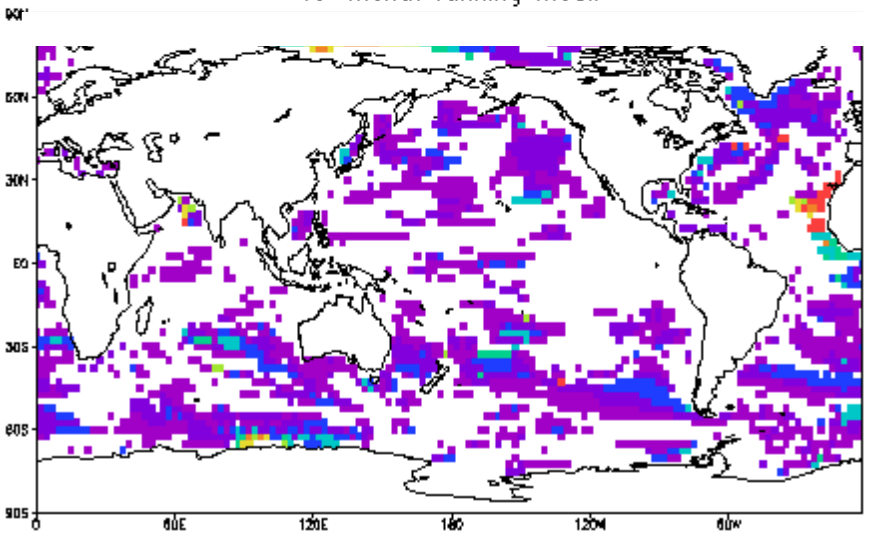
MPI-M



KNMI



HadCM3



Summary

- **We studied** flow dependent predictability in a QG model and we identified fairly distinct paths in phase space associated with predictable and unpredictable transitions, qualitatively similar to that found in the Lorenz63 model.
- **We investigated** how predictability arising from changes in the boundary conditions and external forcing might be intimately linked to the (correct) simulations of natural circulation regimes and their associated variability.
- **We showed** that the simulation of such regimes improves considerably when increasing model resolution.
- **We assessed** (for the first time) the reliability of multi-year predictions using probabilistic Attributes Diagrams for near-surface air temperature and sea surface temperature. It was found that over the North Atlantic the hindcasts are both sharp and reliable, even after detrending, confirming the importance of initialisation in that region.
- **We found** that the correct initialization has a multi-year impact on SST predictability over specific regions such as the North Atlantic, the north-western Pacific, and the Southern Ocean. The impact of initialization is even longer and extends to wider regions when below-surface ocean variables are considered