Belgian Geography Days
Université de Liège
November 17, 2017

Climate Prediction

Where are we?

François Massonnet

@FMassonnet

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

UCL Université catholique de Louvain

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'Hot and dry' UK summer forecast

The UK is "odds on for a barbecue summer", with no repeat of the washouts of the last two years, according to Met Office forecasters.

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Sun worshippers may get more joy on UK beaches than last year

However, they warn that heavy downpours cannot be ruled out.

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As millions of Britons holiday at home after that promise of a 'barbecue summer', how did the Met Office get it so wrong?

When's it going to stop, Dad? Misery on the Devon coast

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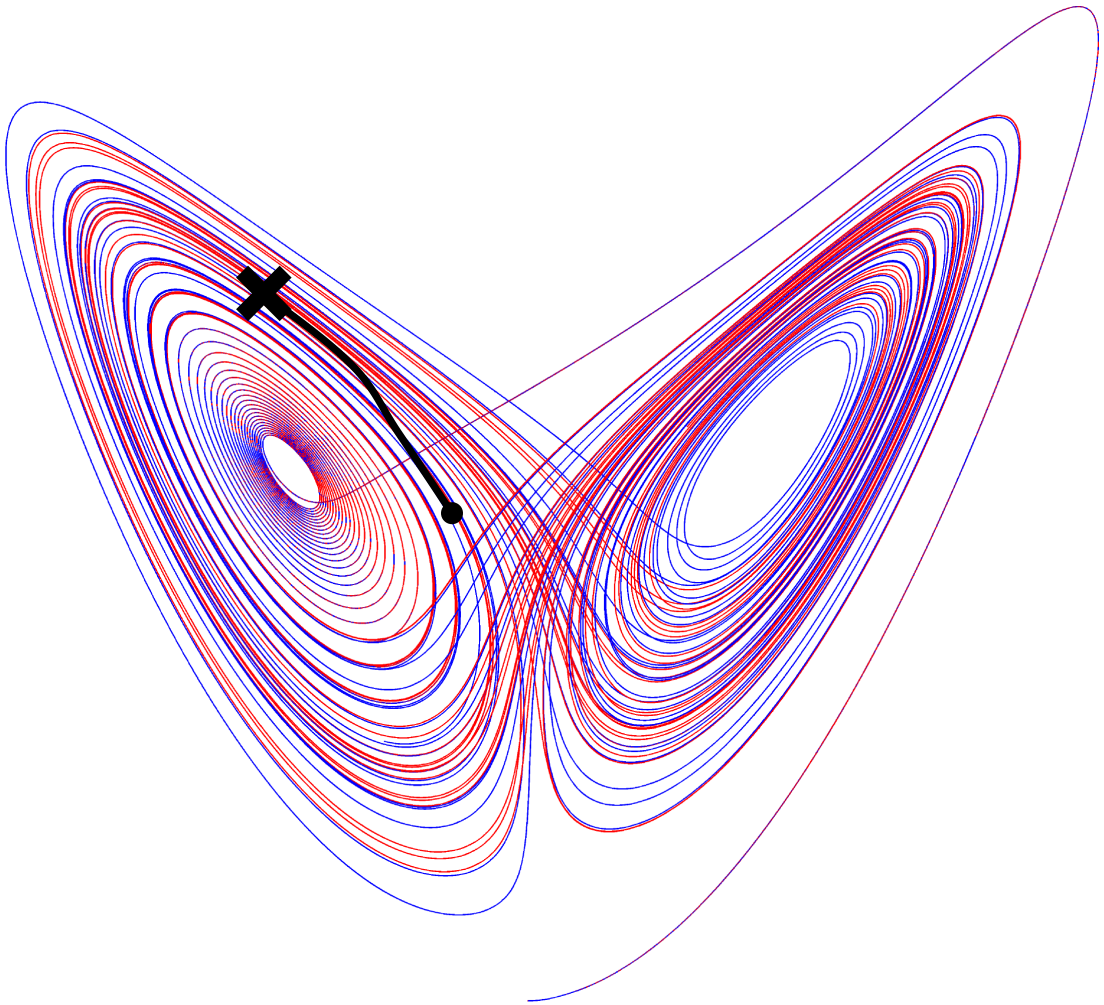
Prediction: the time scale defines the question



Initial-value problem

Numerical weather prediction

1 day

1 week

1 month

1 season

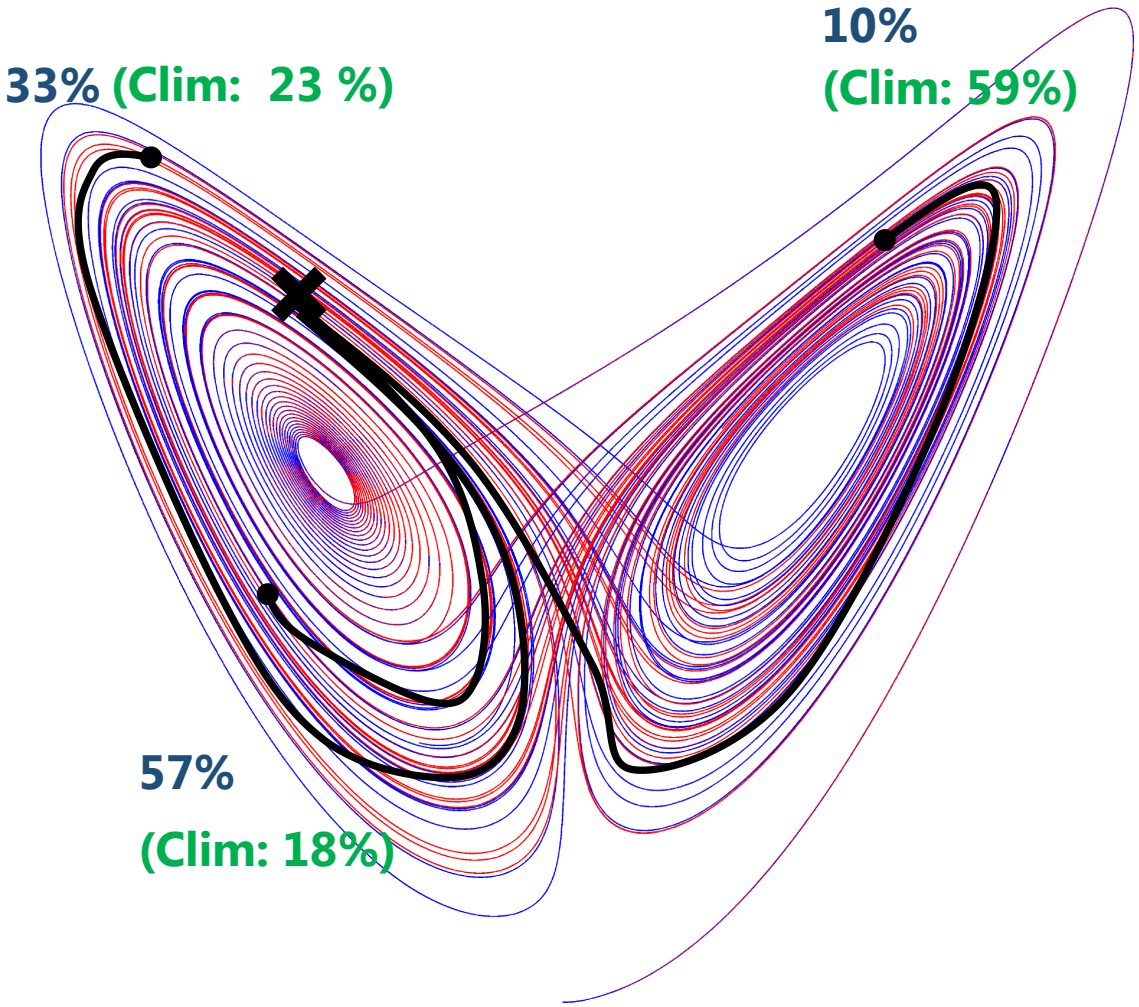
1 year

1 decade

1 century

Boundary-value problem

Prediction: the time scale defines the question



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Numerical weather prediction

Medium-range, sub-seasonal, seasonal prediction

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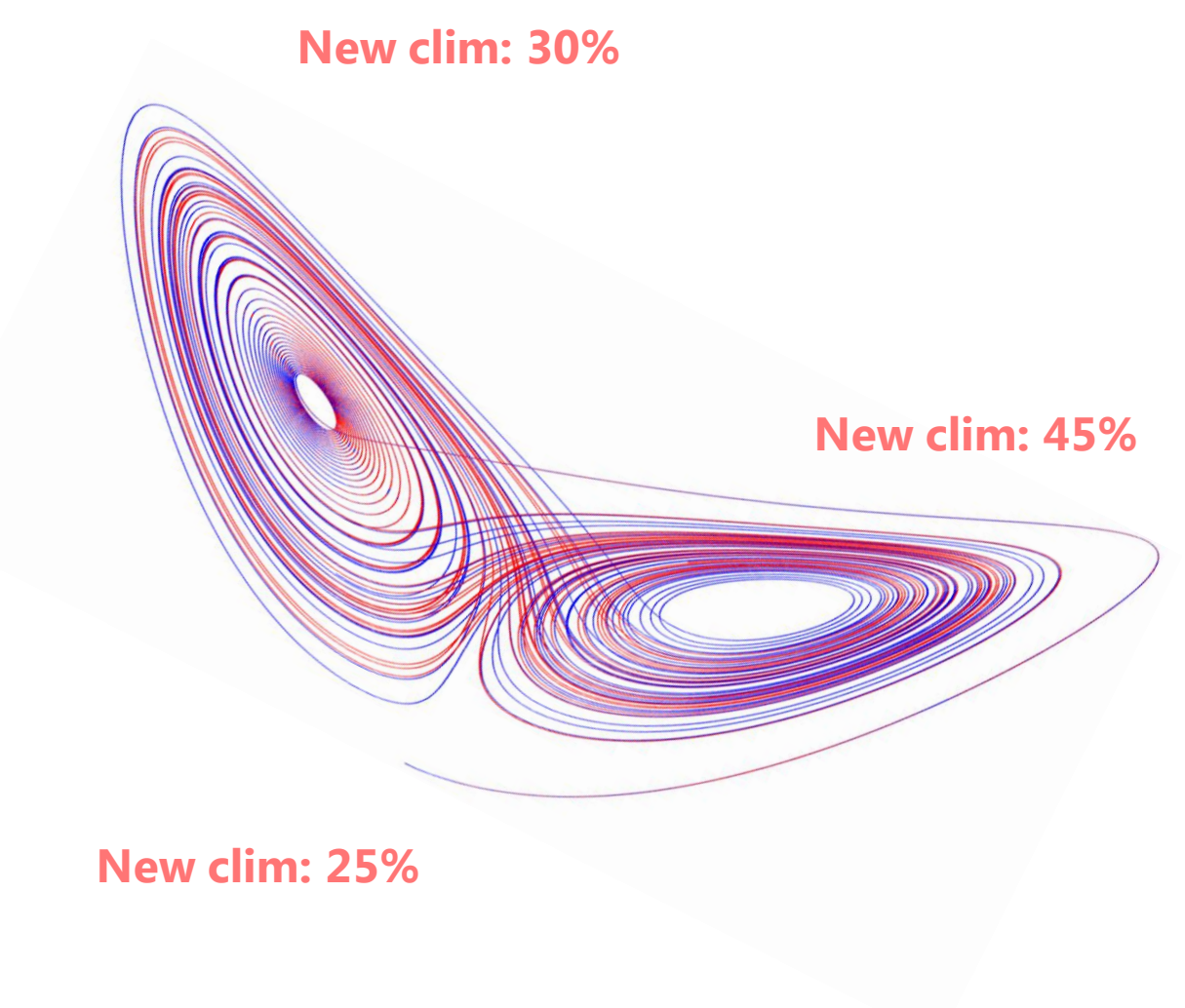

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Climate change, projections

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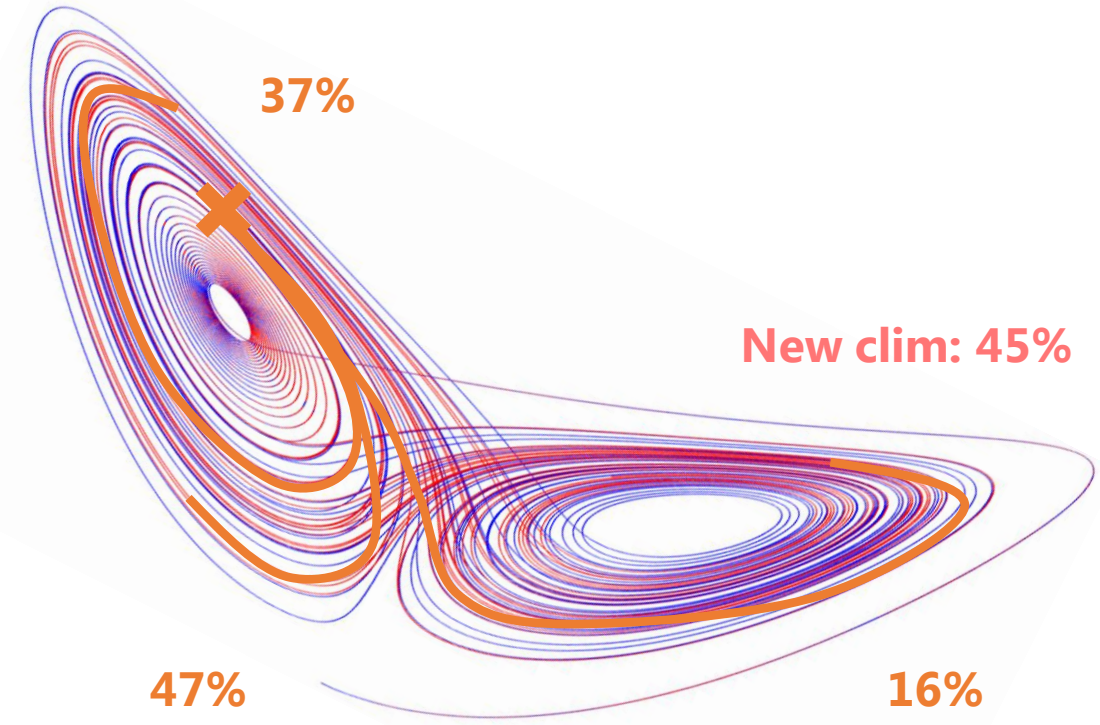

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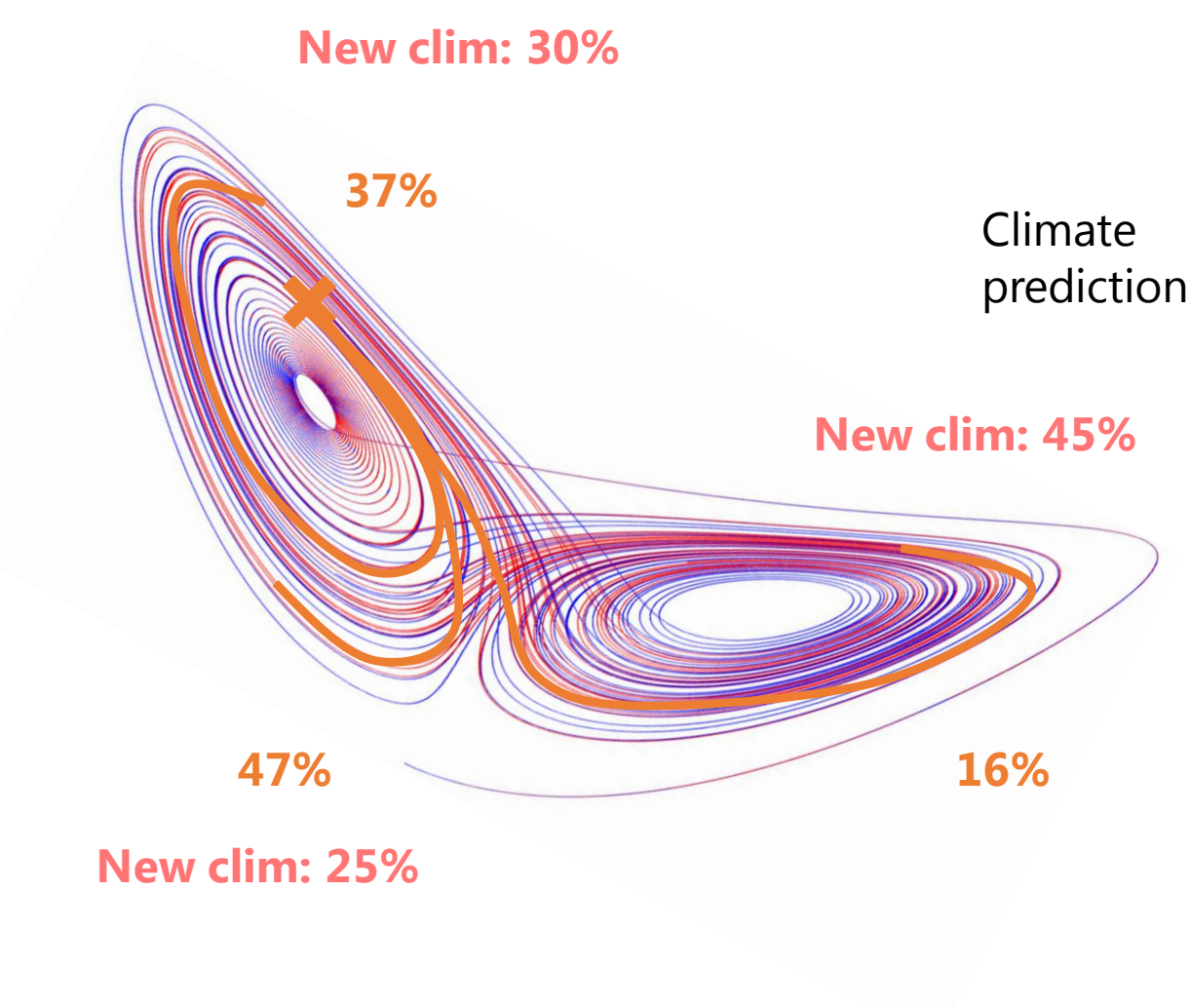

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Boundary-value problem

Outline

1. What is a climate prediction system?

2. What is a good climate prediction?

3. Are today's climate predictions good?

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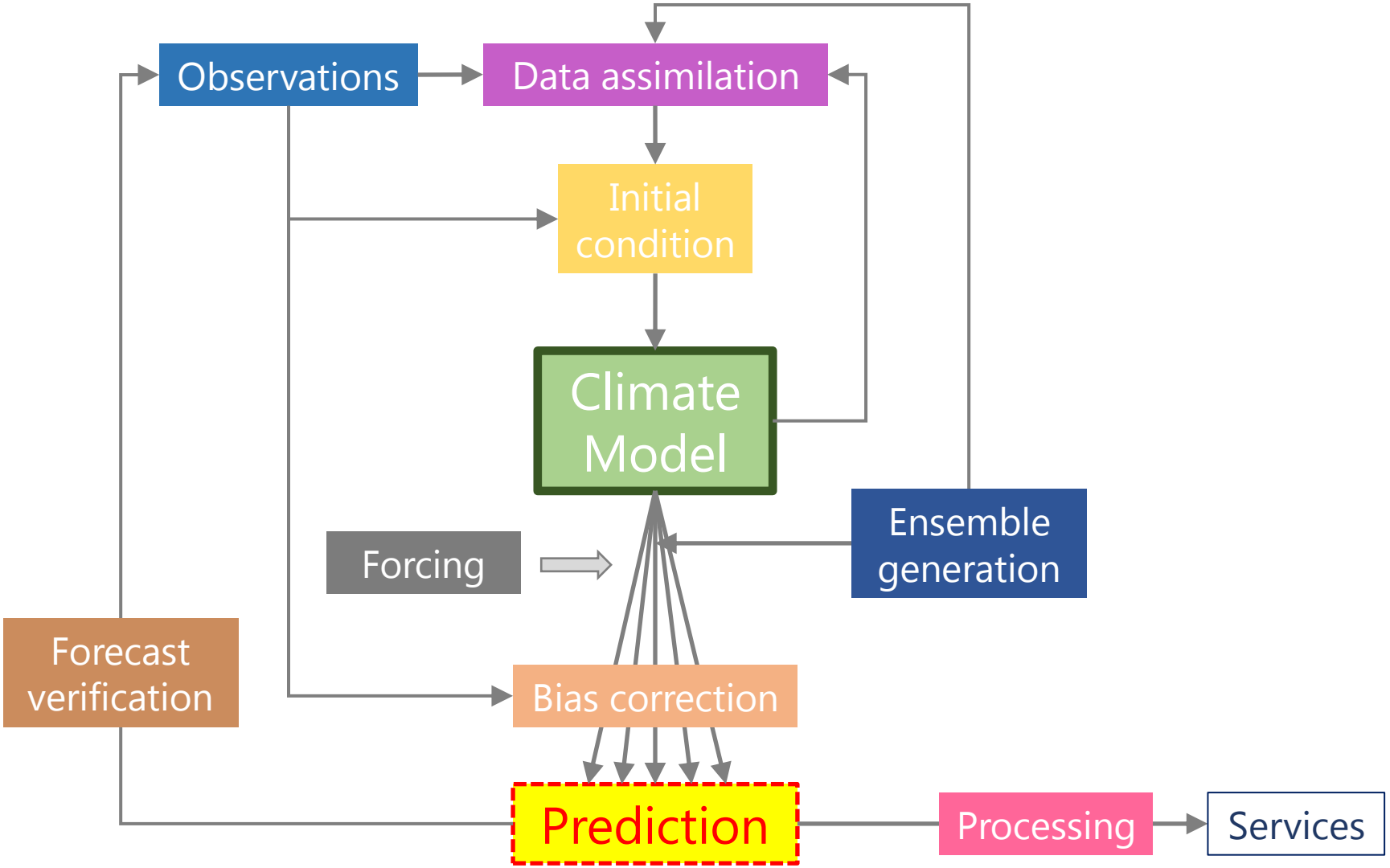
Climate prediction system: much more than a model



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What Is a Good Forecast?
An Essay on the Nature of Goodness in Weather Forecasting

ALLAN H. MURPHY

College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon

(Manuscript received 11 August 1992, in final form 20 January 1993)

Murphy, *Wea. Forecasting*, 1993

Consistency 1) The forecast corresponds to the best judgment based on **a priori knowledge**

Quality 2) The forecast corresponds to **observed conditions** during the forecast period

Value 3) The forecast results in **incremental** economic and/or other **benefits**

Verifying a weather forecast is quite straightfoward

	7 Nov	8 Nov	9 Nov	10 Nov	11 Nov	12 Nov	13 Nov	14 Nov	15 Nov	16 Nov
Will it rain tomorrow?	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	No
Did it actually rain?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Score	1	0	1	1	1	1	1	1	0	1

Score= 8 / 10 = 0.8

(This example is purely fictitious)

Verifying a climate forecast is a long and painful process

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Will it snow for Christmas?	30%	70%	40%	70%	80%	70%	30%	90%	70%	20%

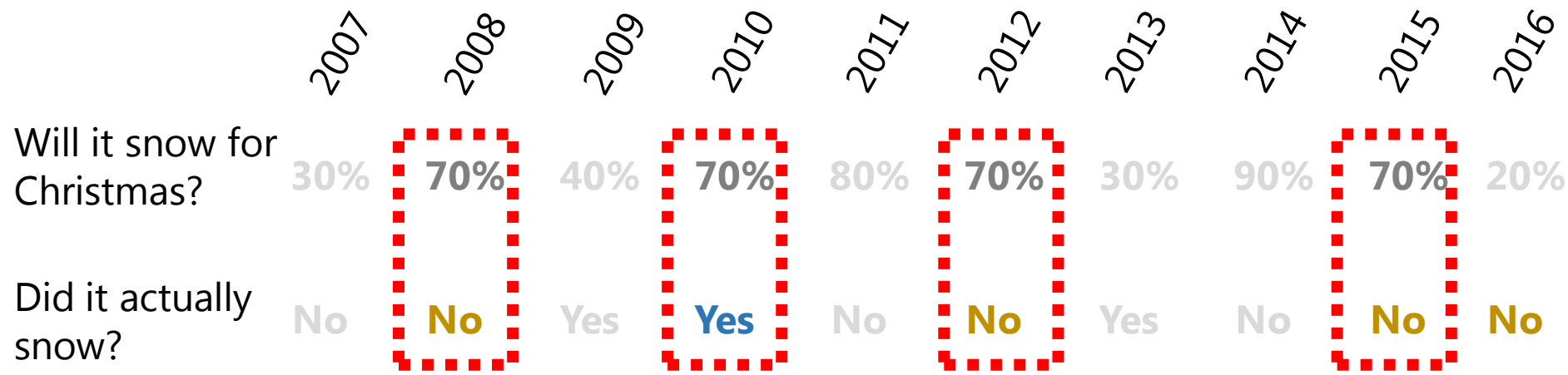
(This example is purely fictitious)

Verifying a climate forecast is a long and painful process

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Will it snow for Christmas?	30%	70%	40%	70%	80%	70%	30%	90%	70%	20%
Did it actually snow?	No	No	Yes	Yes	No	No	Yes	No	No	No

(This example is purely fictitious)

Verifying a climate forecast is a long and painful process



From all the times that the forecast system predicted a 70% chance of snow, if actually snowed 25 %

(This example is purely fictitious)

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1. What is a climate prediction system?
   Much more than a model

2. What is a good climate prediction?
   One that has consistency, skill and value

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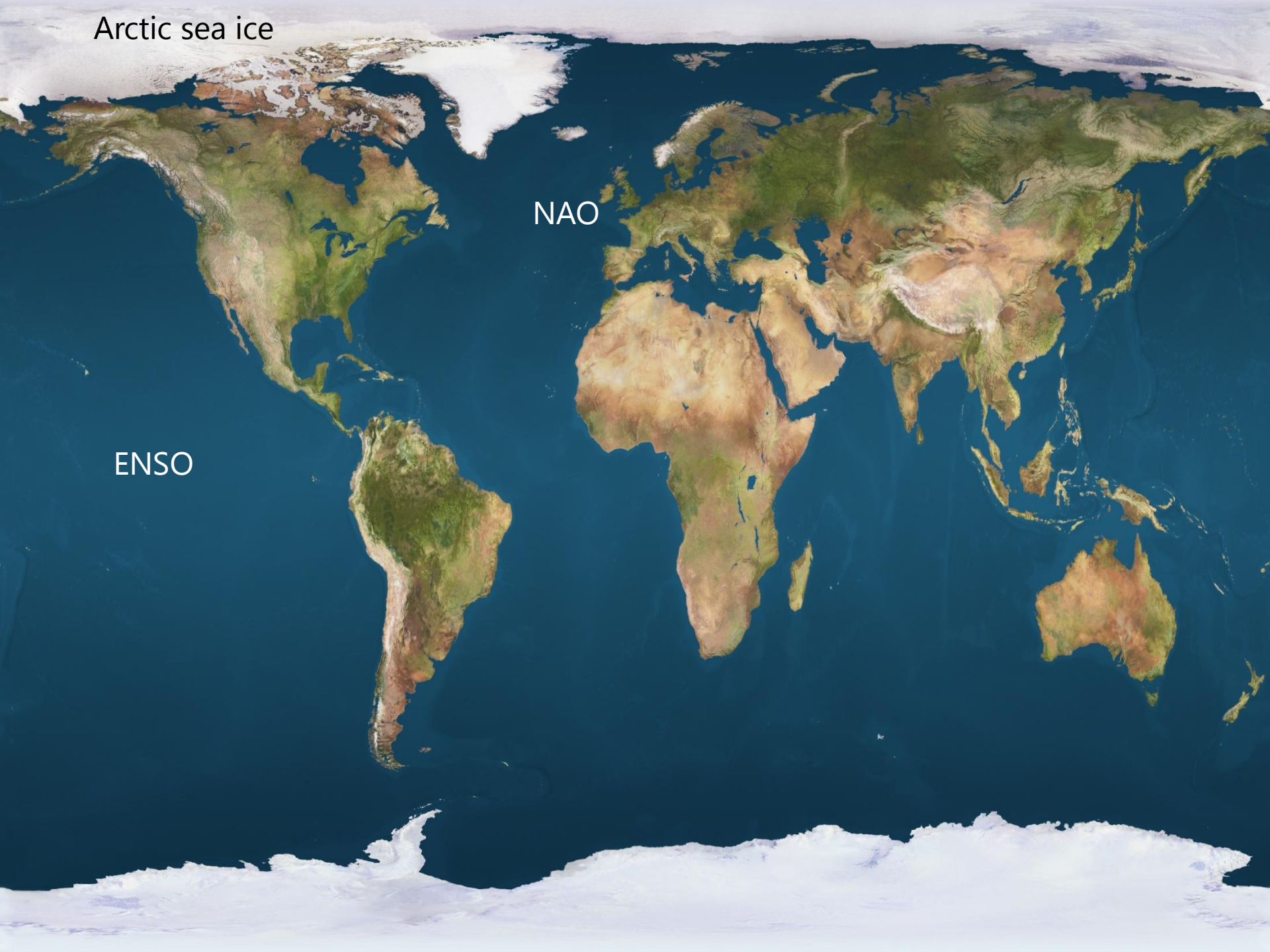

Arctic sea ice
NAO
ENSO

North Atlantic Oscillation forecasts from months to a year

nature geoscience

LETT

PUBLISHED ONLINE: 17 OCTOBER 2016 | DOI: 10.1038/

Skilful predictions of the winter North Atlar Oscillation one year ahead

Nick Dunstone*, Doug Smith, Adam Scaife, Leon Hermanson, Rosie Eade, Niall Robins Martin Andrews and Jeff Knight

LETTER

Skilful seasonal predictions for the European energy industry

Robin T Clark[1], Philip E Bett, Hazel E Thornton and Adam A Scaife

Met Office Hadley Centre, Exeter, United Kingdom

[1] Author to whom any correspondence should be addressed.

E-mail: robin.clark@metoffice.gov.uk

Keywords: seasonal prediction, nao, energy, predictability

Geophysical Research Letters

RESEARCH LETTER

10.1002/2014GL059637

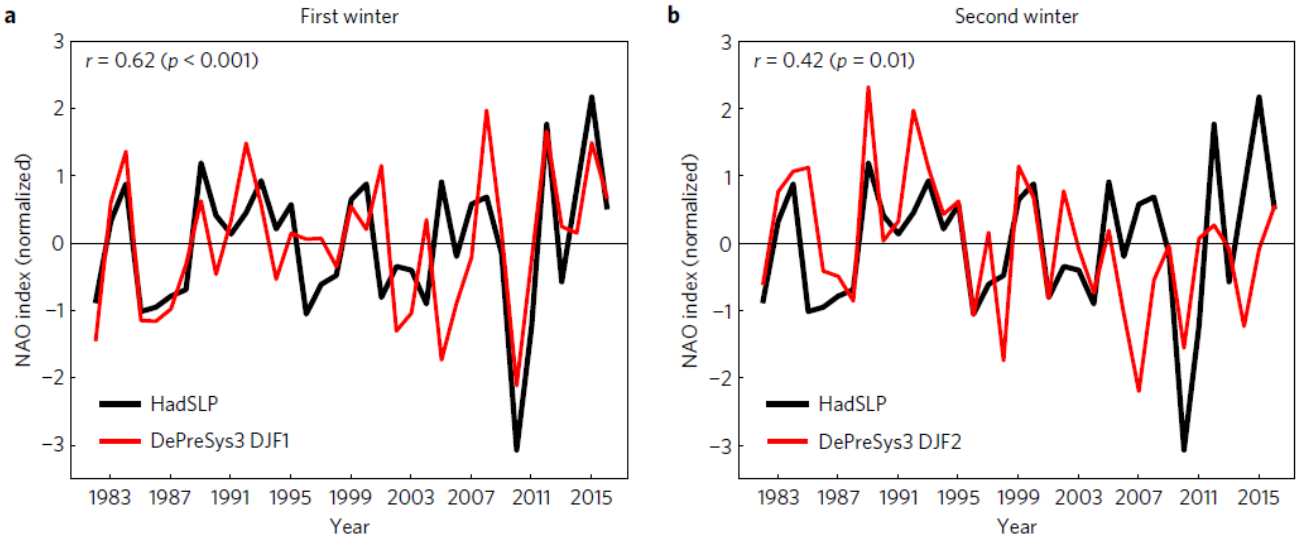
Skillful long-range prediction of European and North American winters

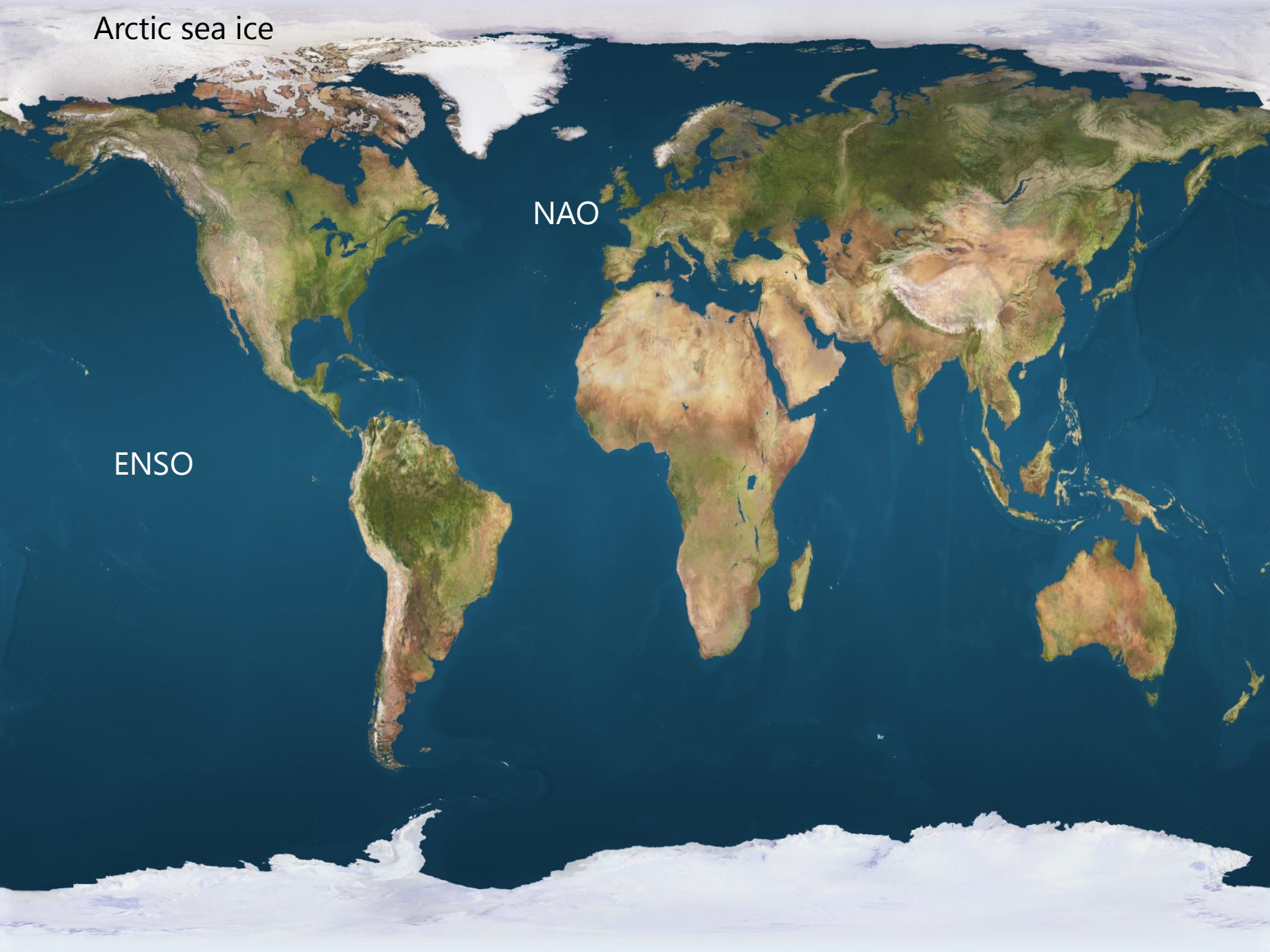
Key Points:
- The winter NAO can be skilfully predicted months ahead
- The signal-to-noise ratio of the predictable signal is anomalously low
- Predictions of the risk of regional winter extremes are possible

A. A. Scaife[1], A. Arribas[1], E. Blockley[1], A. Brookshaw[1], R. T. Clark[1], N. Dunstone[1], R. Eade[1], D. Fereday[1], C. K. Folland[1,2], M. Gordon[1], L. Hermanson[1,3], J. R. Knight[1], D. J. Lea[1], C. MacLachlan[1], A. Maidens[1], M. Martin[1], A. K. Peterson[1], D. Smith[1], M. Vellinga[1], E. Wallace[1], J. Waters[1], and A. Williams[1]

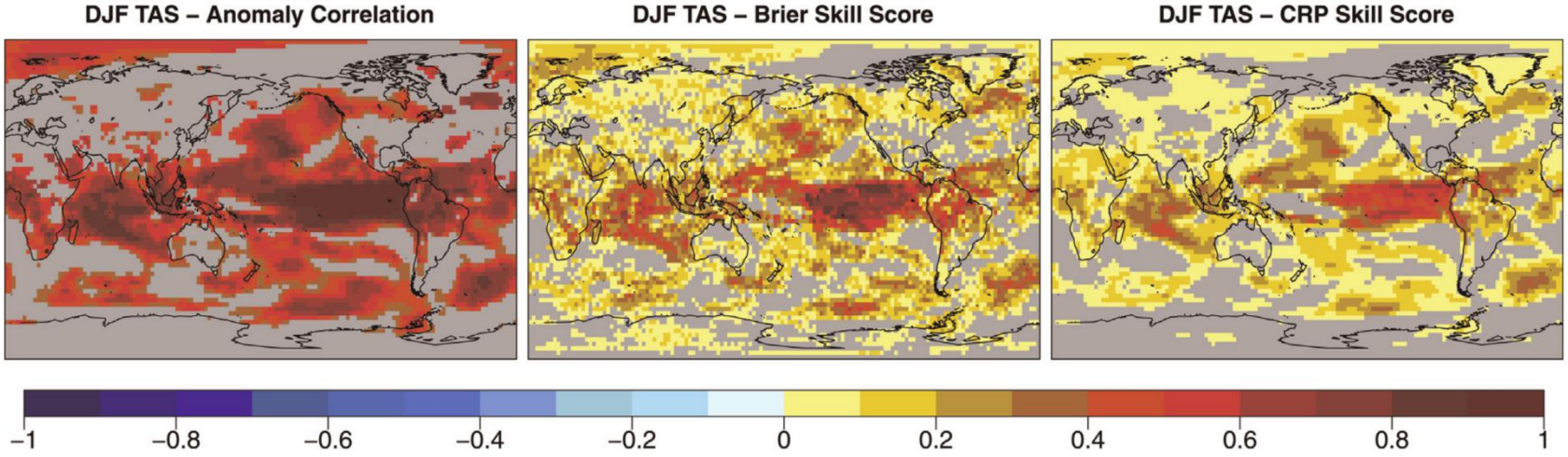
[1]Met Office Hadley Centre, Exeter, UK, [2]Department of Earth Sciences, University of Gothenburg, Gothenburg, Sweden, [3]Willis Research Network

NAO forecasts with the UK MetOffice system




Arctic sea ice
NAO
ENSO

ENSO is (by far) the most predictable phenomenon at the seasonal time scale



[Pepler et al., Weath. and Clim. Extr., 2015]

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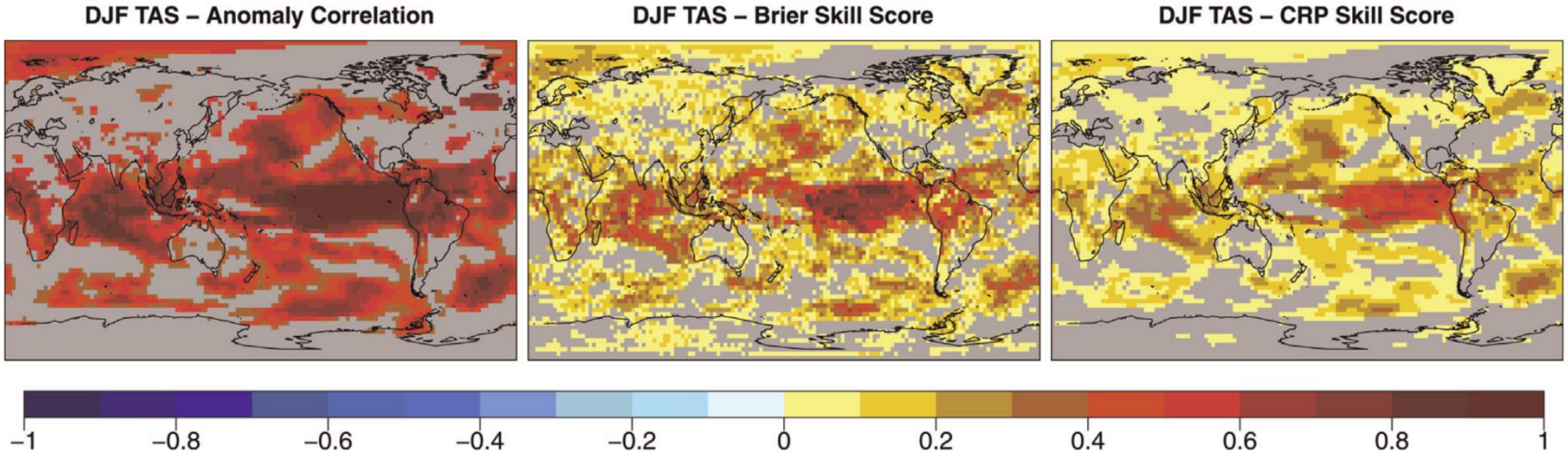
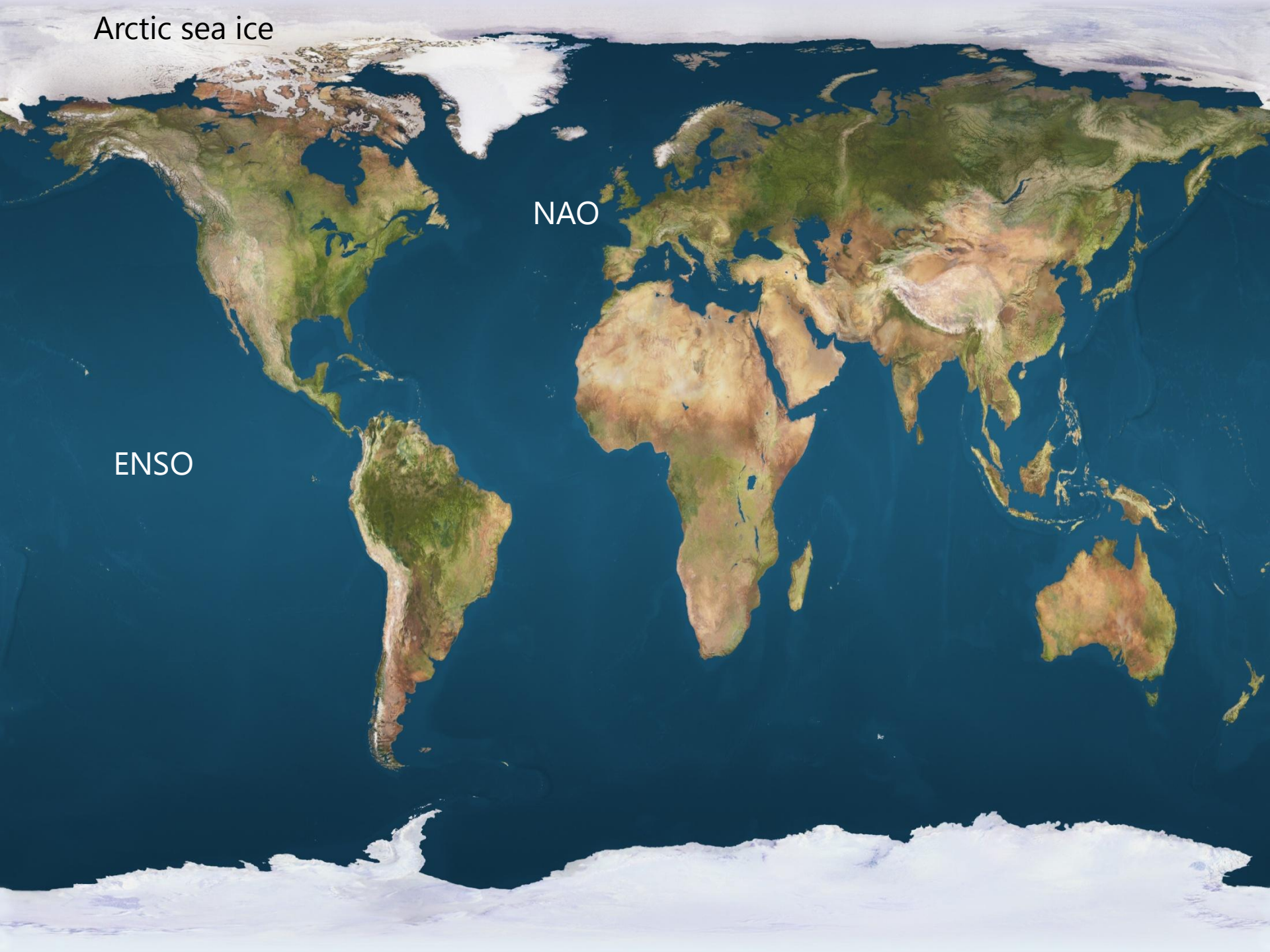


[Pepler et al., Weath. and Clim. Extr., 2015]


Arctic sea ice
NAO
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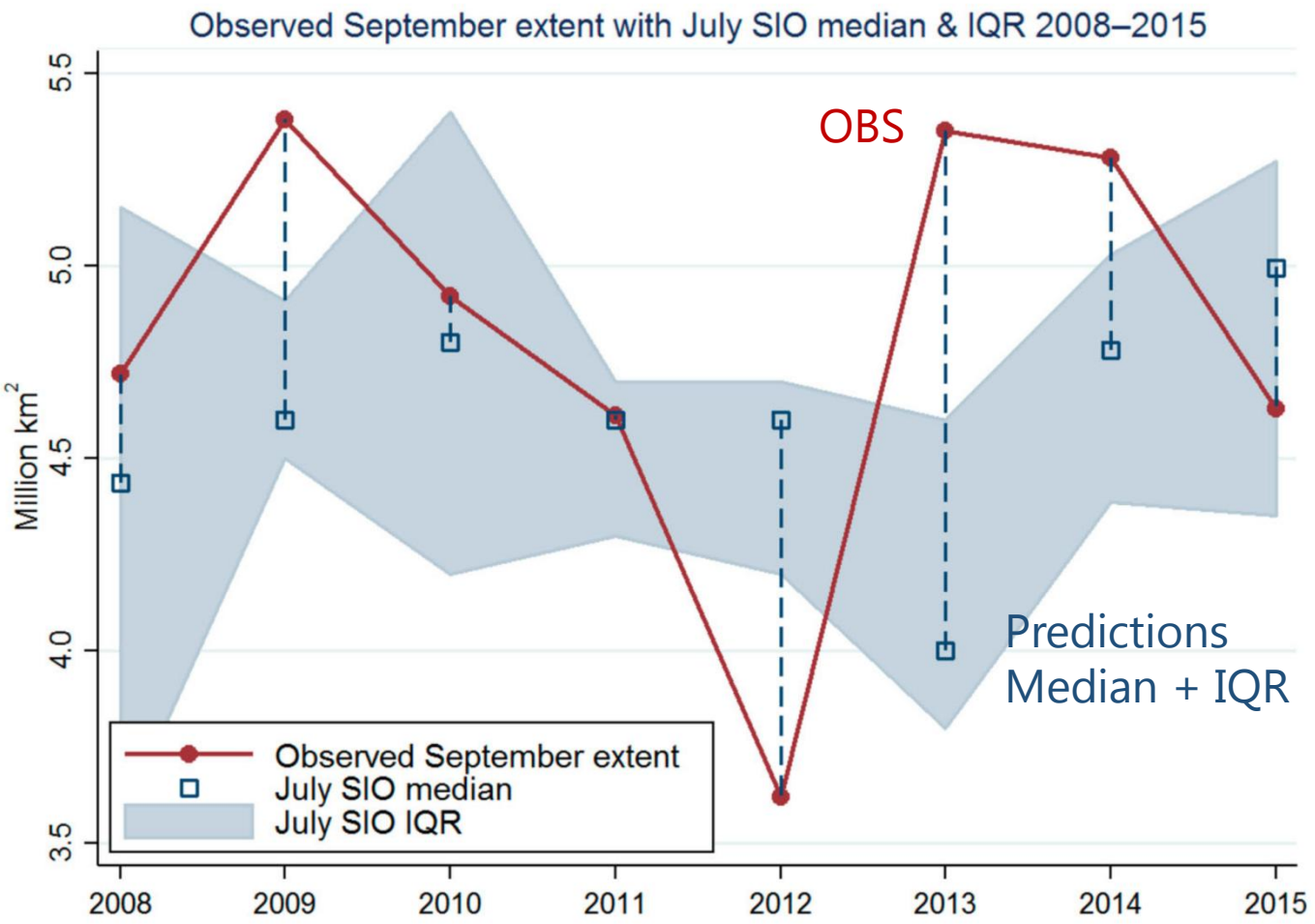
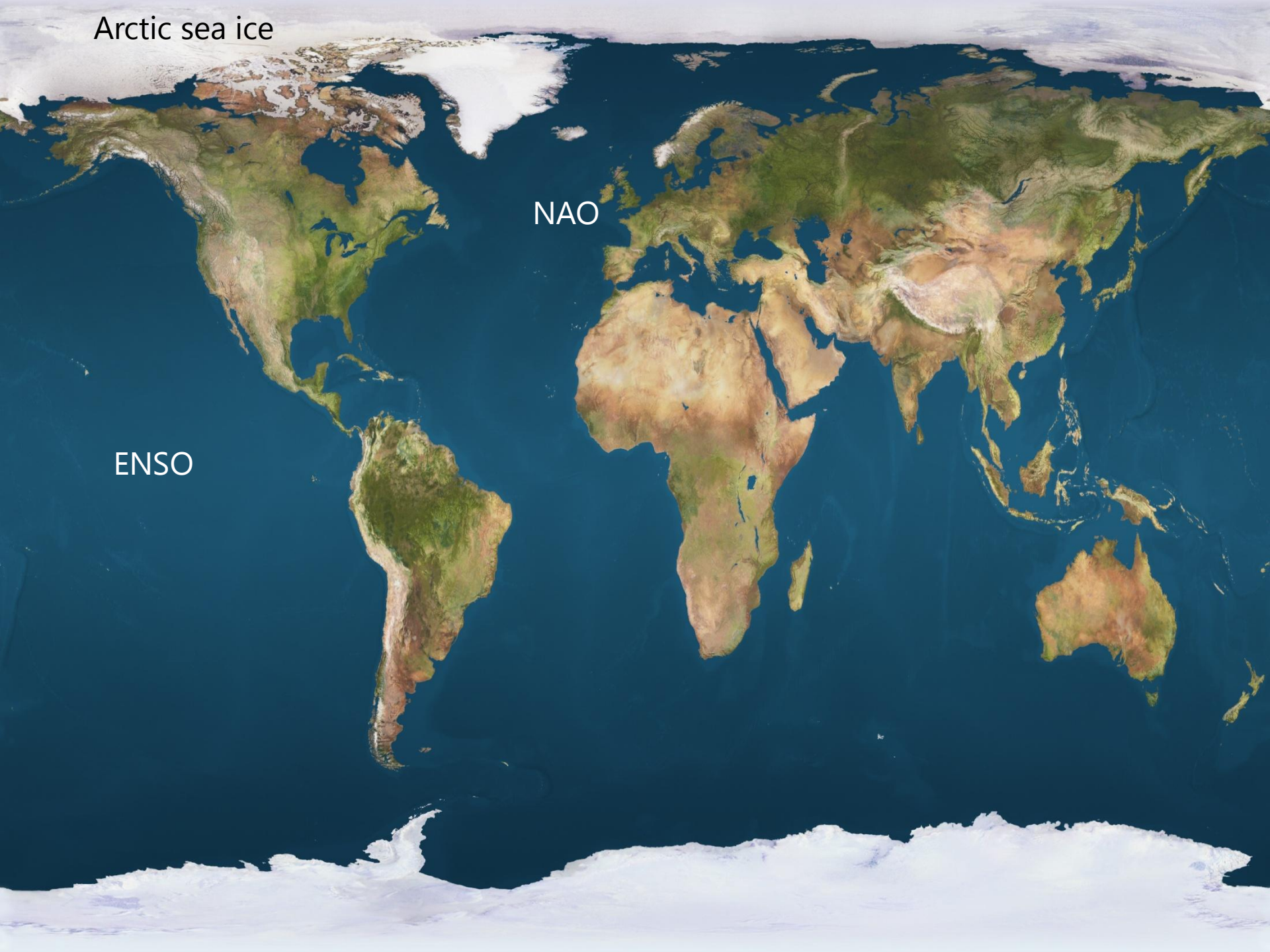
Arctic sea ice: no good predictions beyond the trend



[Hamilton and Stroeve, Polar Geog., 2016]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   One for which the climate prediction system is well designed

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   In some cases, there is skill. The emerging field of « climate services » attempts to find value in the forecasts.

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Sun worshippers may get more joy on UK beaches than last year

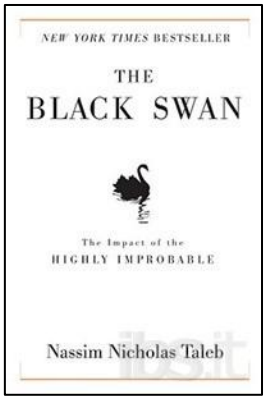
However, they warn that heavy downpours cannot be ruled out.

Climate prediction: where are we?

1. Climate Prediction is a science in-the-making
   The field was literaly « born » 10 years ago with the advent of high-performance computing

2. It's a field with high expectations
   Potential benefits for society are enormous

3. Hindcasting is not forecasting
   « Everything is obvious once it has happened »



Thanks!

francois.massonnet@uclouvain.be

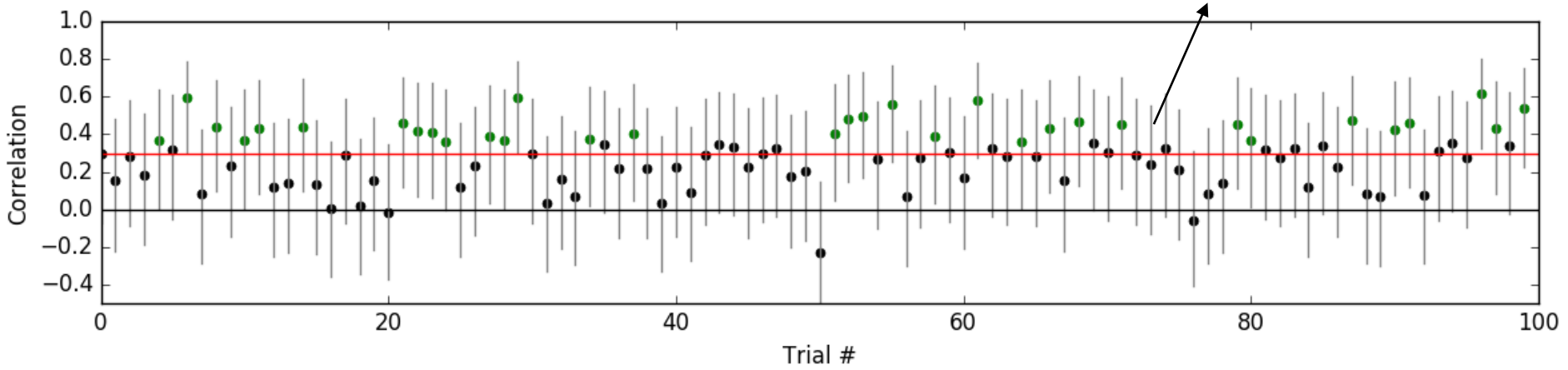
@FMassonnet

Importance to better design experimental protocols and report negative results

Sample correlation and confidence interval

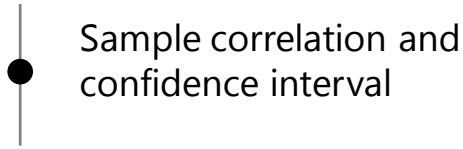
True correlation = 0.3 (effect)

False negative (type-II error)



Low power → If negative results are not published, reported correlations overestimate true correlation

Importance to better design experimental protocols and report negative results



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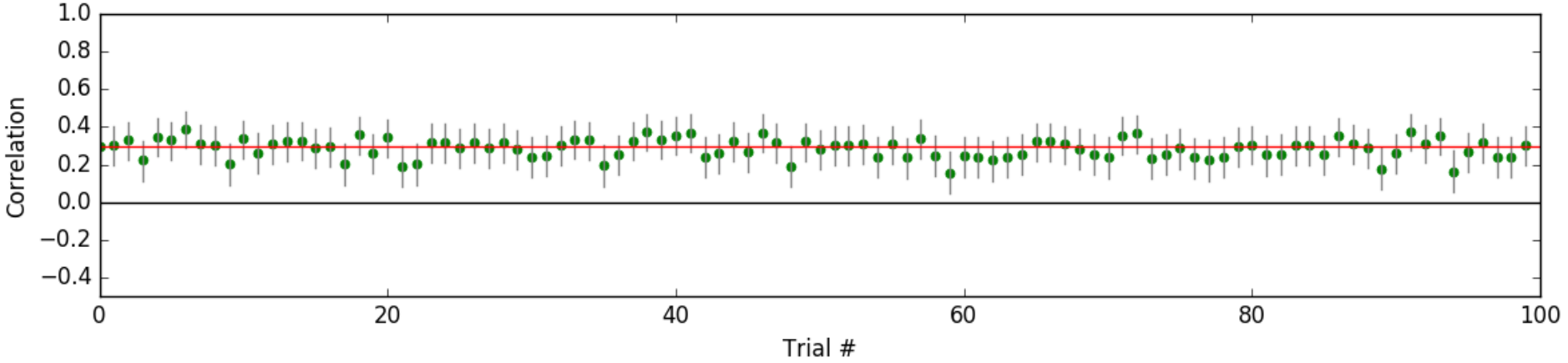
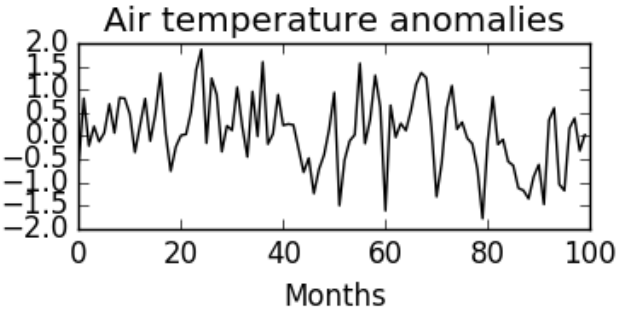
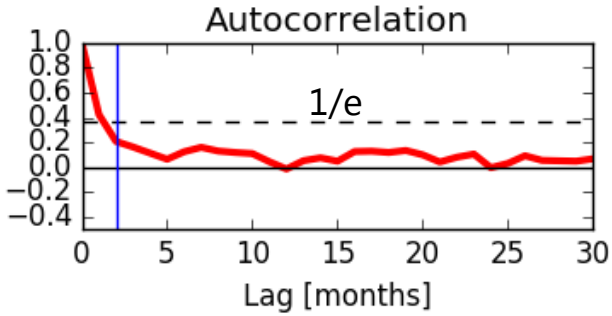


High power → Reported correlations reflect true correlation

Predictability beyond weather time scales: importance of couplings

C





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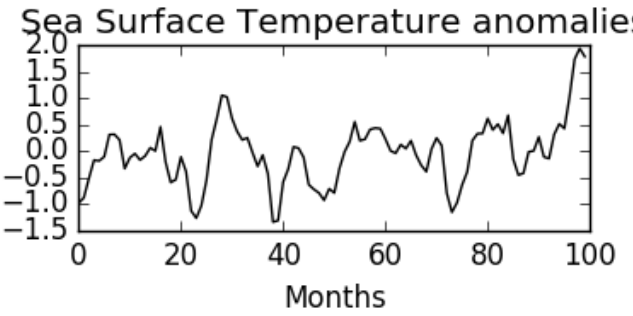

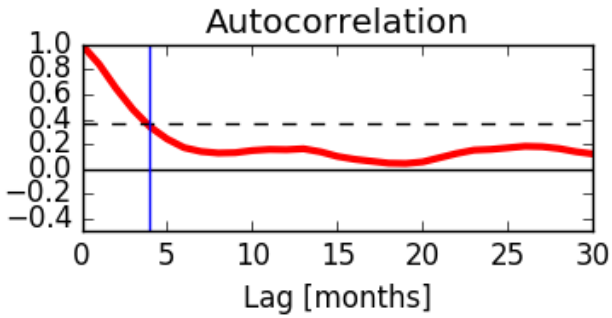

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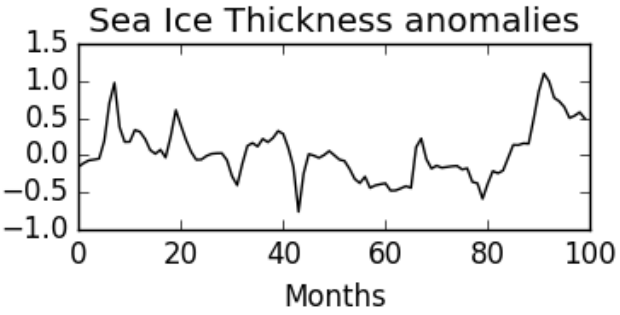
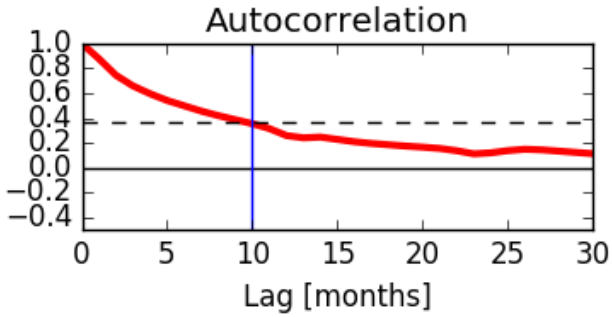
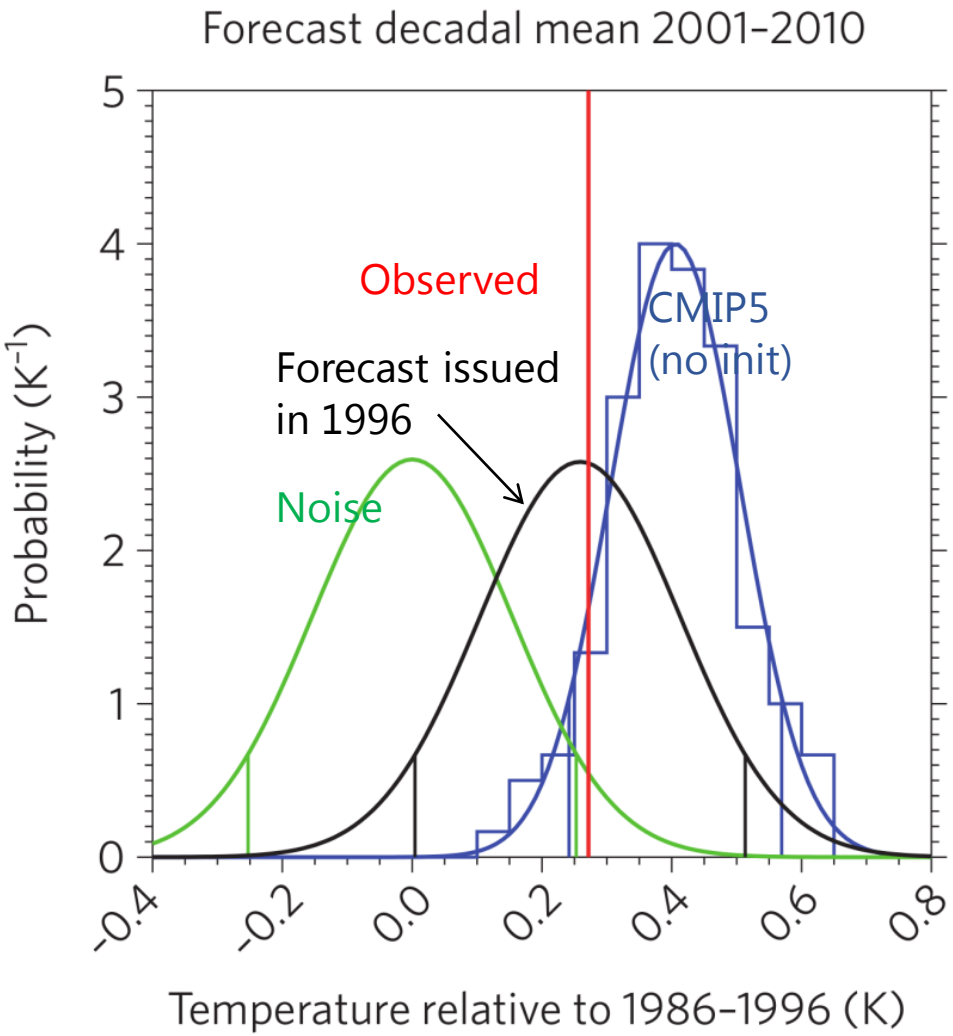




http://www.climate.be:3000/TECLIM/ClimateData.git

One of the very first decadal forecasts

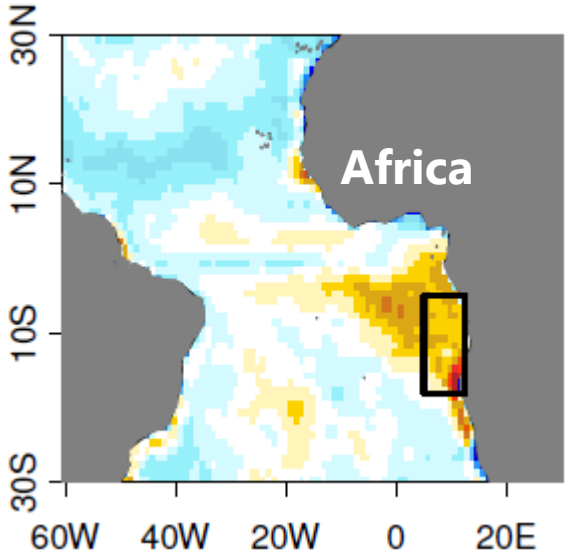


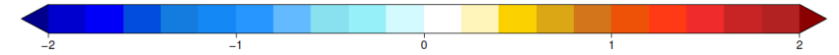
[Allen et al., Nature Geosci., 2013]

Identifying and explaining the origin of climate prediction drift

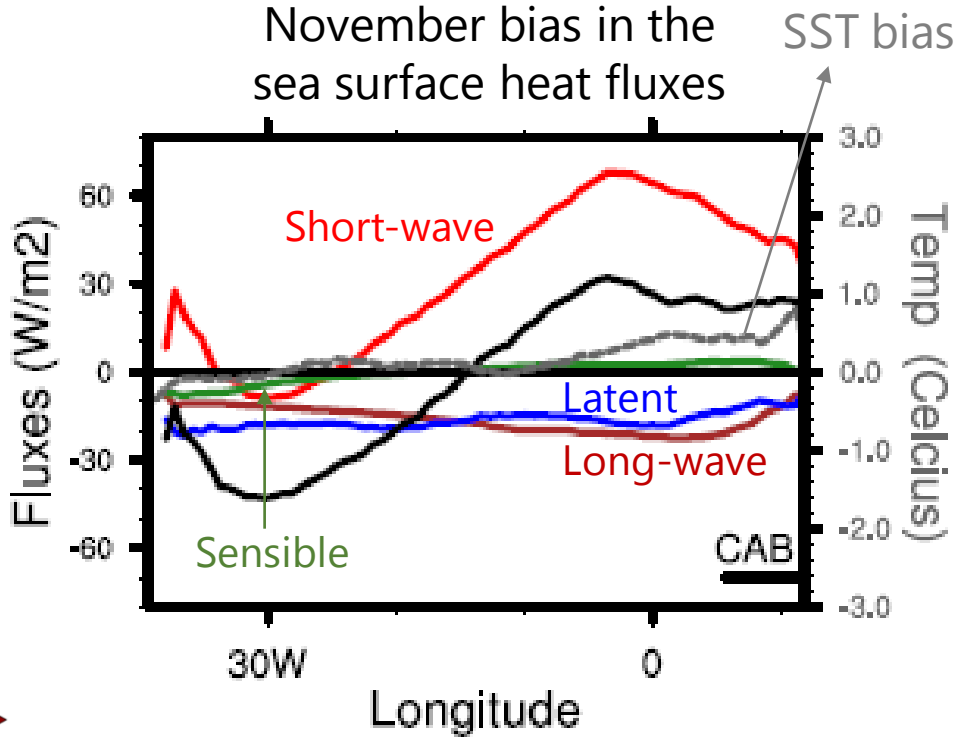
Seasonal predictions of EC-Earth

SST November bias



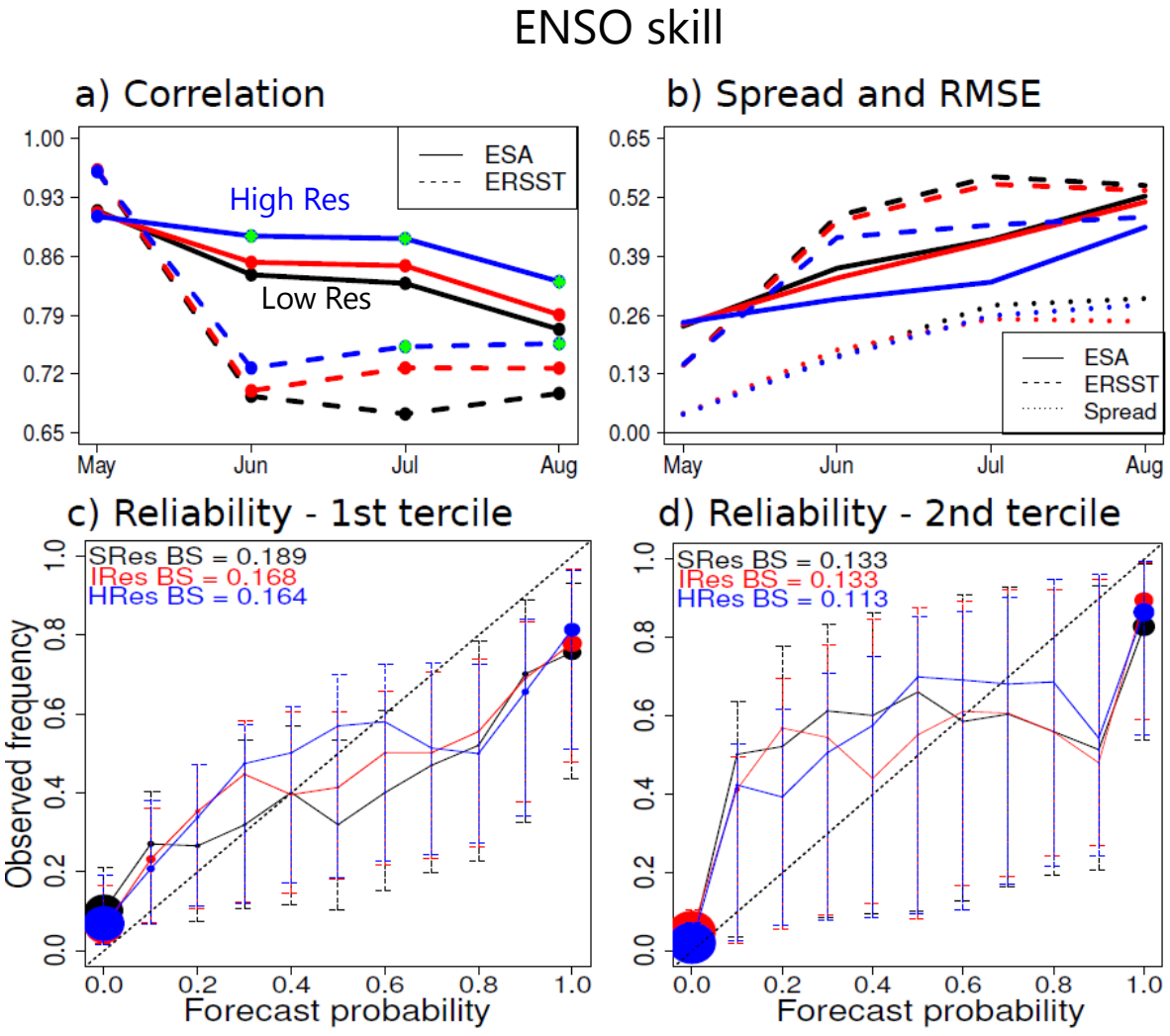


November bias in the sea surface heat fluxes



Exarchou et al., 2017 (in revision)

Higher horizontal resolution increases ENSO skill



Prodhomme et al., J. Clim., 2016

The quality of a prediction does not only depend on the model used

Observational reference

Model prediction

Skill score (e.g. correlation)

correlation between forecast and observational reference

0 1

Irreducible (inherent) error

Model, forcing, initial condition errors

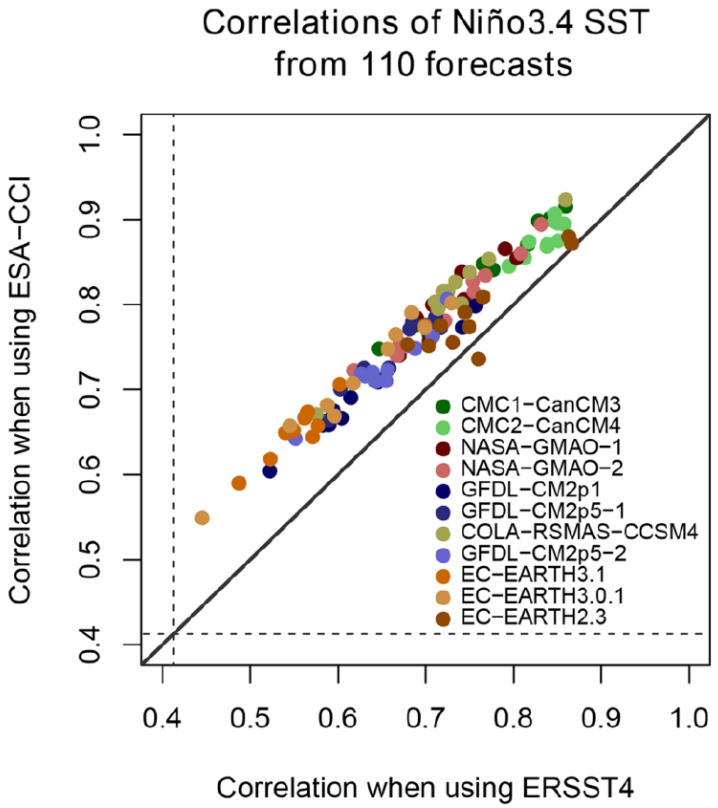
Observational error

Limited sampling

Lorenz, *J. Atm. Sci.*, 1963; Orrell et al., *Nonlin. Proc. Geoph.*, 2001; Okuro et al., *Int. J. Rem. Sens.*, 2014; Scaife et al., *GRL*, 2014.

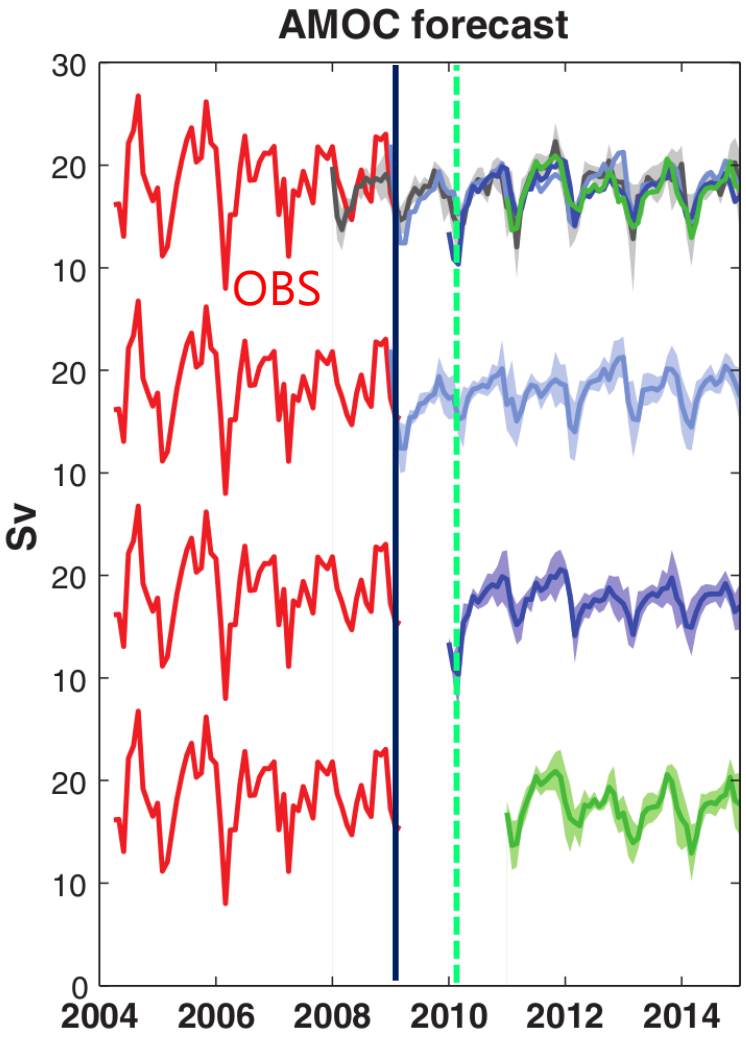
The emerging role of observational uncertainty in forecast verification

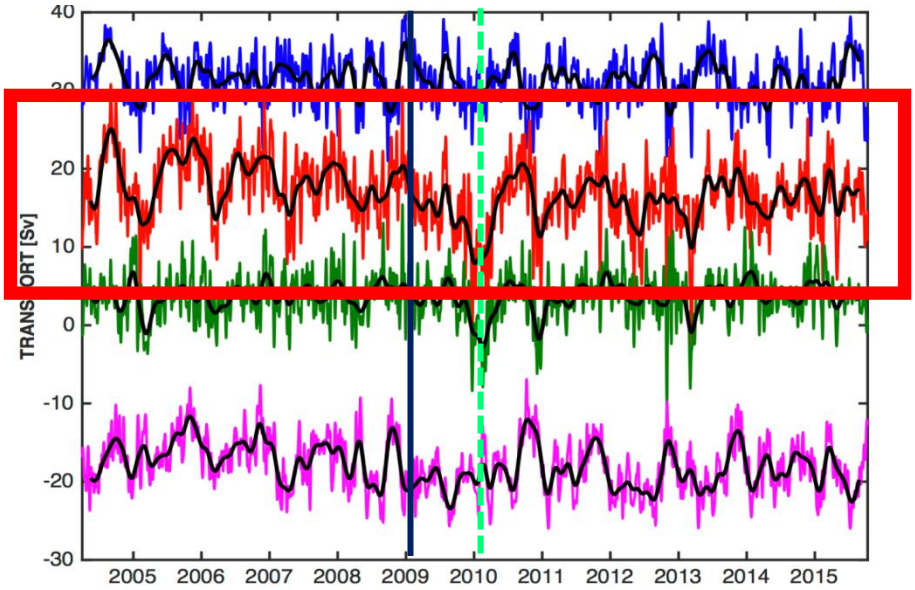
- Verification products are uncertain, too!
- Observations and predictions can be viewed as two noisy instances of the same, unknown truth
- Forecast verification scores must account for uncertainty in observations



Massonnet et al., Science (2016); Mudryk et al., Geophys. Res. Lett. (2017); Sospedra-Alfonso et al., J. Clim. (2016), Gómez-Navarro et al., Geophys. Res. Lett. (2012); Candille and Talagrand, Quat. J. Roy. Met. Soc. (2008); Bowler, Meteorol. Appl. (2008).

Atlantic Meridional Overturning Circulation: skill (?)



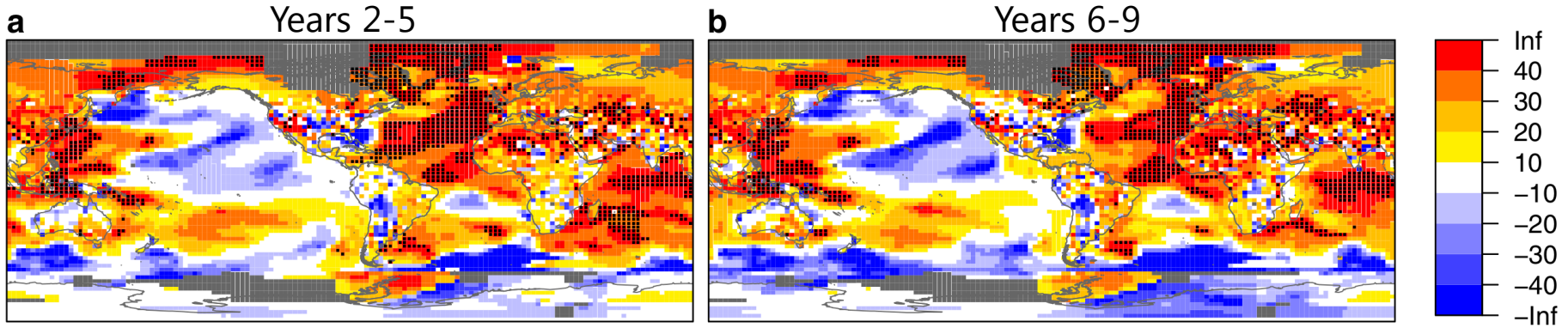


http://www.rapid.ac.uk/rapidmoc/rapid_data/transports.php

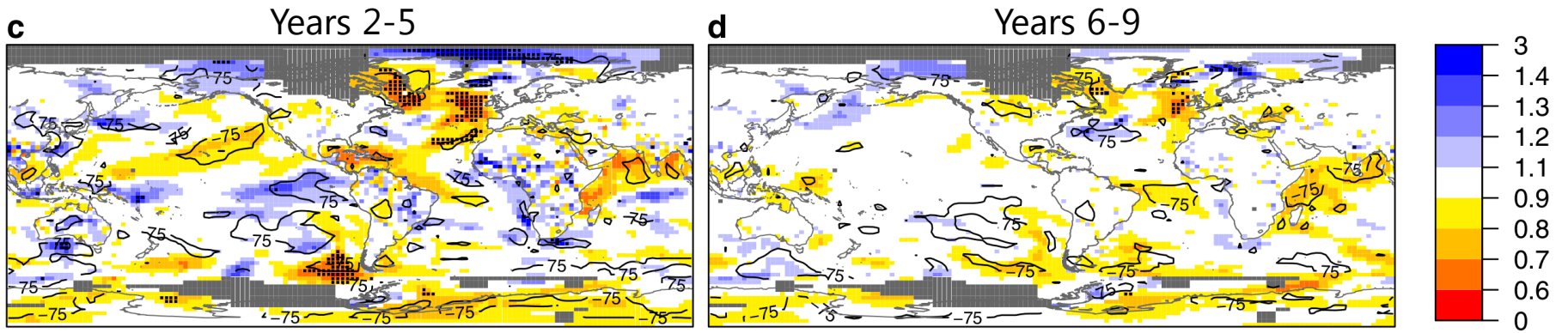
[Matei et al., Science, 2012]

Decadal prediction: skill essentially stems from forced component

CMIP5 decadal forecasts of near-surface air temperature skill (RMSSS)



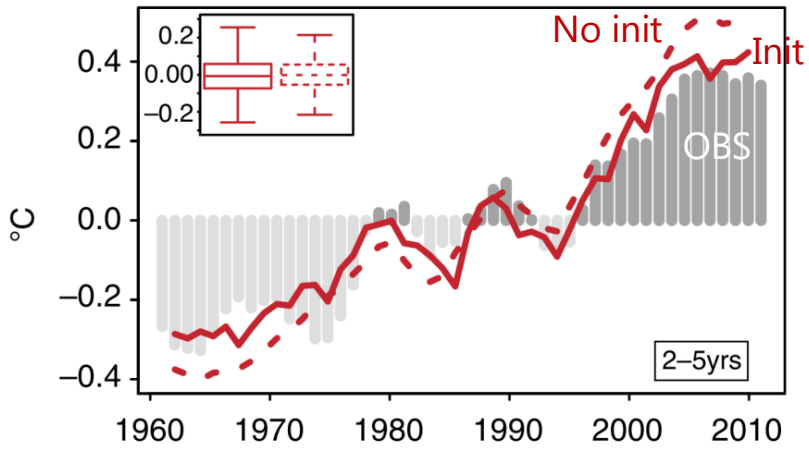
Marginal skill due to ocean initialization (ratio RMSSS)



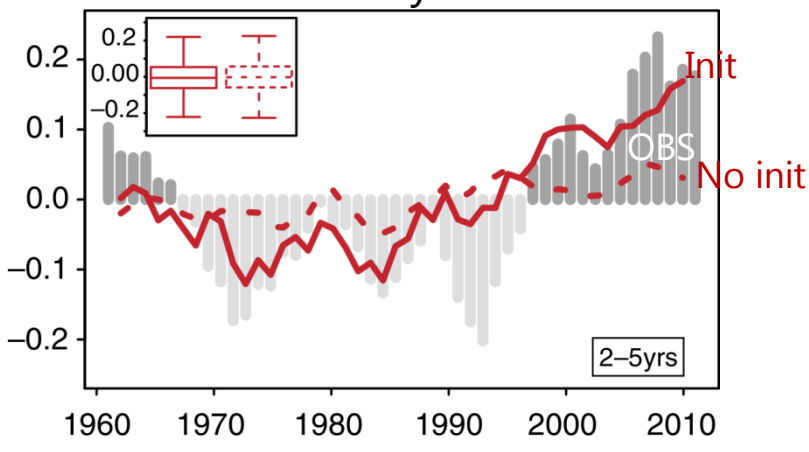
[Doblas-Reyes et al., Nature Comm., 2013]

… but initialisation matters!

Global-mean temperature



Atlantic Multidecadal variability index



[Doblas-Reyes et al., Nature Comm., 2013]