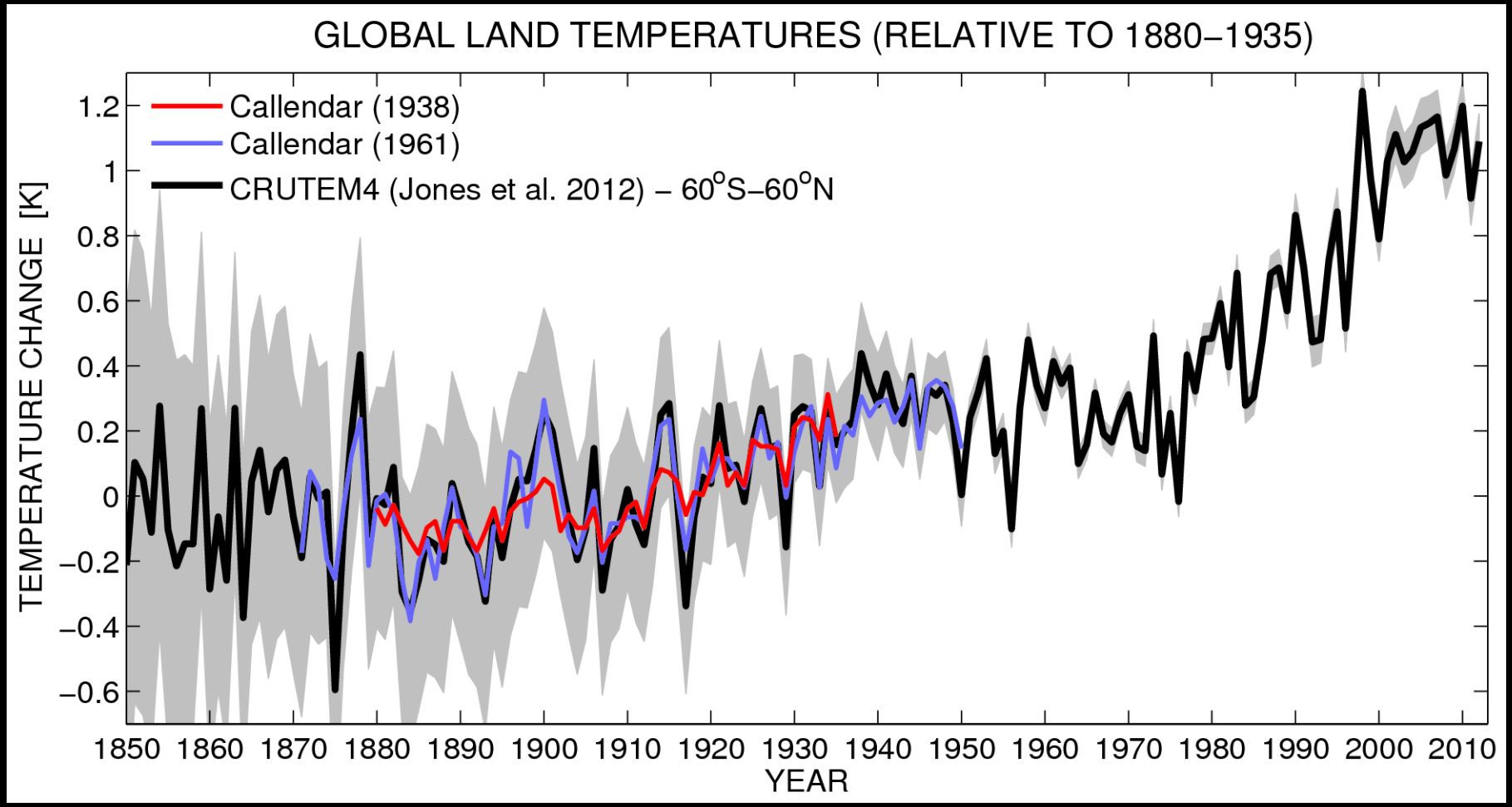
The grandfather of decadal variability?

Guy Stewart Callendar
(1898 – 1964)

Callendar (1938) first to show increase in global temperatures and related this to CO_2

Published (almost) exactly 75 years ago!

Exactly 75 years ago: Callendar (1938, QJRMS)



Hawkins & Jones, 2013, in press at QJRMS

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Variation in the reliability of ensemble SST predictions from seasonal to decadal timescales

Chun Kit Ho, **Ed Hawkins**, Len Shaffrey, Jochen Bröcker

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Submitted to GRL

SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Evaluating Smith et al. 2007

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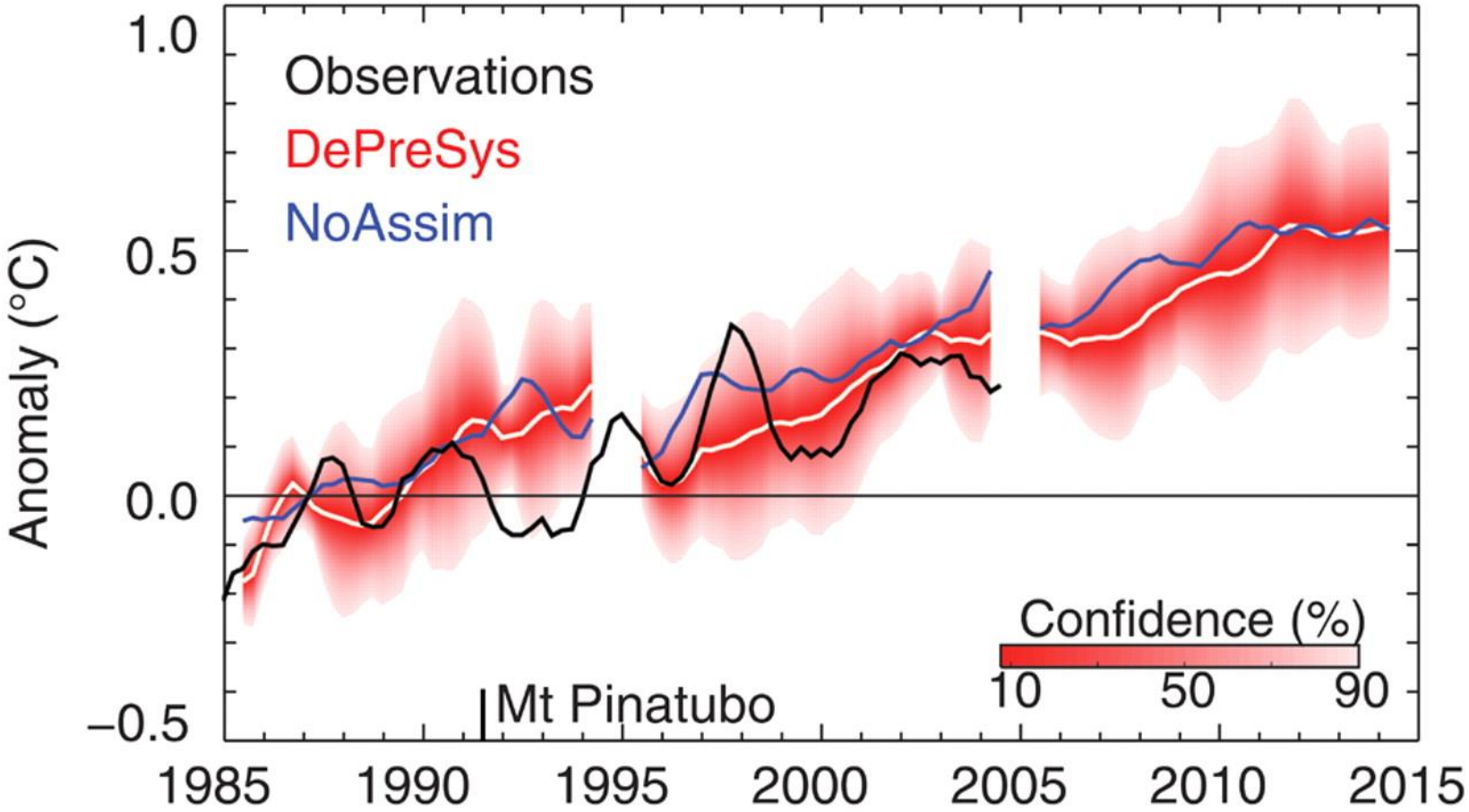
Prediction is very difficult, especially about the future

-- Niels Bohr



Smith et al. 2007

Evaluating Smith et al. 2007

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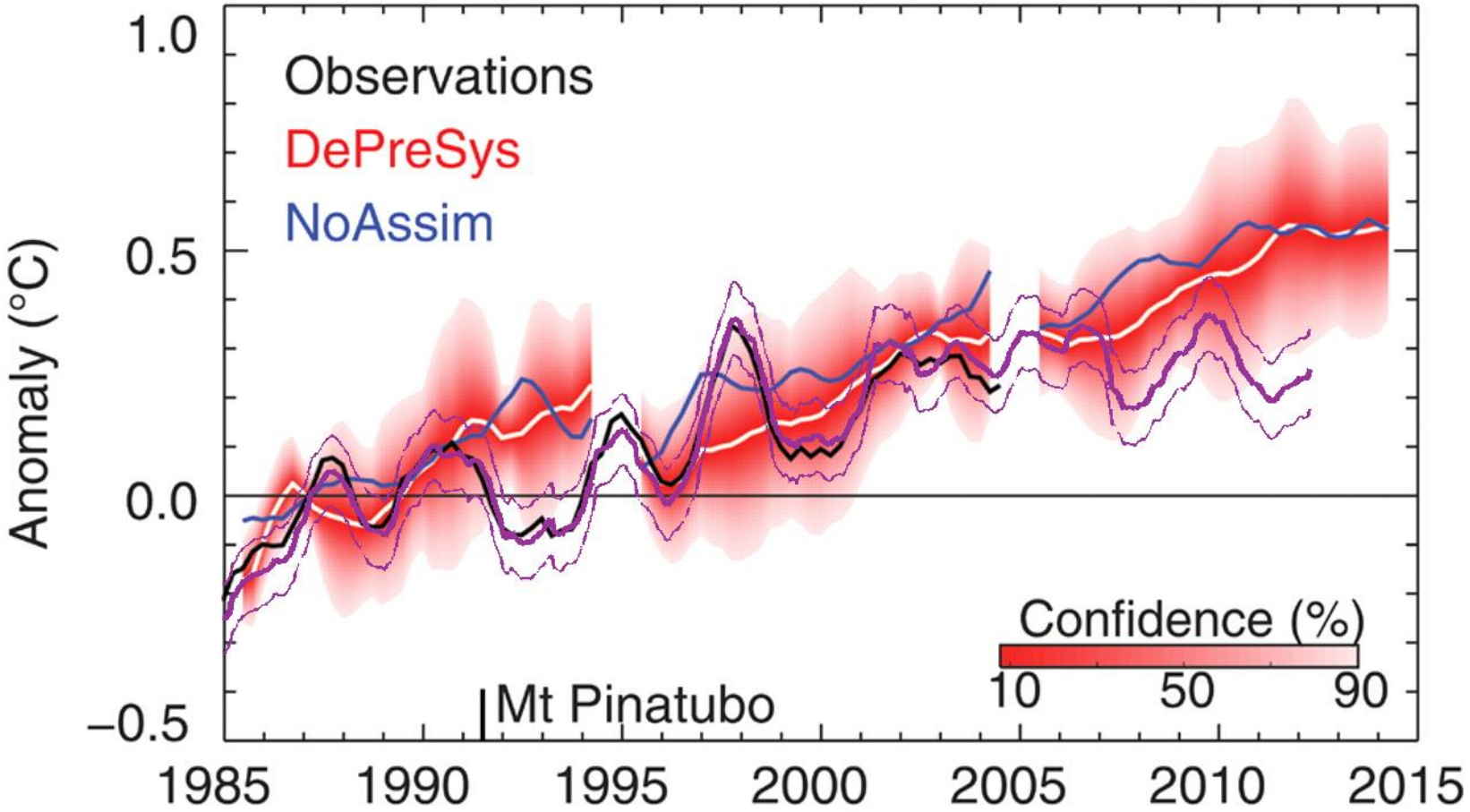

Smith et al. 2007

Reliability of seasonal to decadal predictions

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- Can seasonal to decadal prediction systems support production of reliable **probabilistic** forecasts?

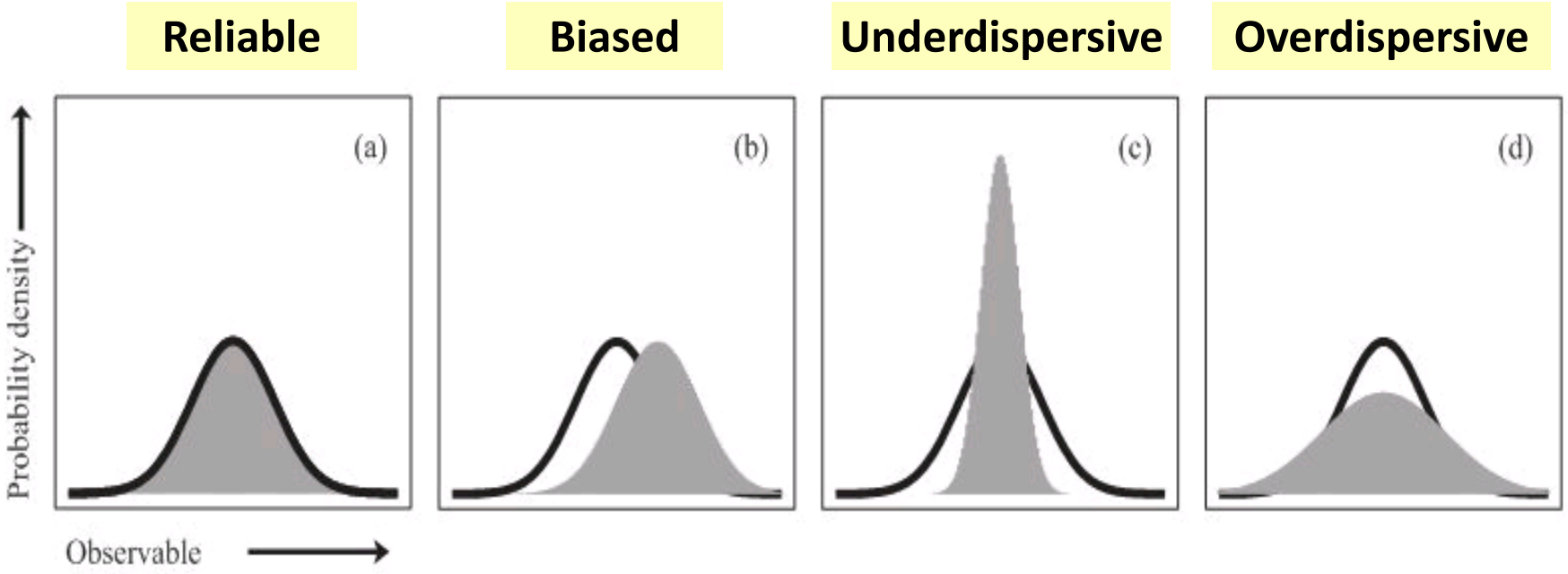

Fig. 8.1 from Weigel (2012)

Reliability and dispersion

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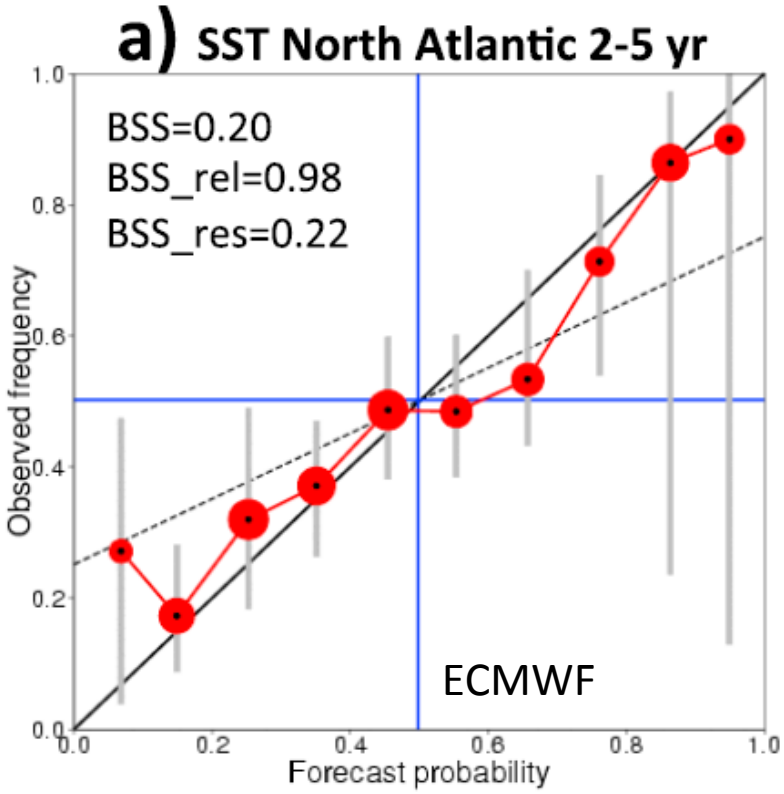
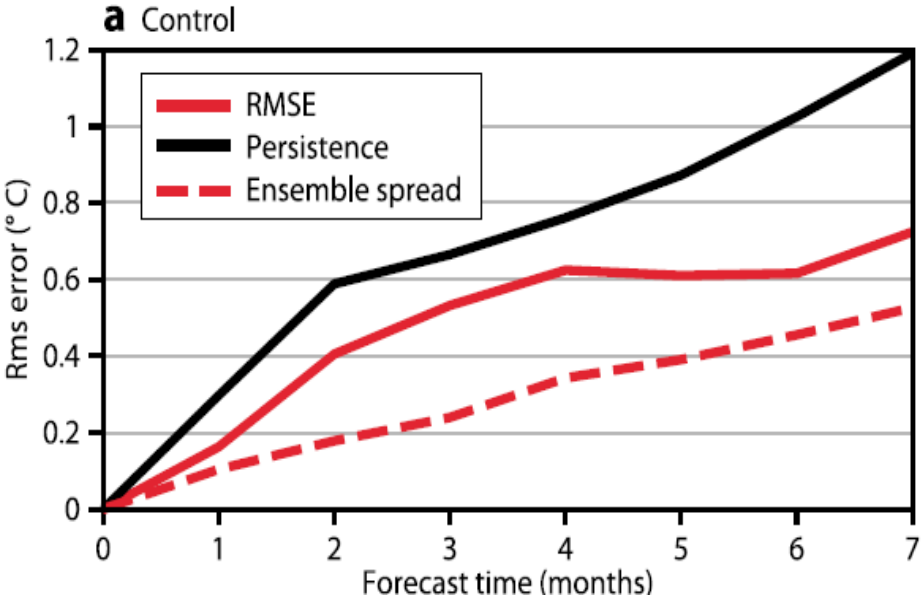


RMSE in Nino 3.4 predictions from ECMWF



Reliability: forecast probabilities should match observed relative frequency

Dispersion: ensemble spread should be the same as RMSE – necessary for reliability

Corti et al. 2012 **& see poster**

Weisheimer et al. 2011

Parallel DePreSys ensemble experiments

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- We consider the **spread-error ratio** for different lead times:

$$\sqrt{\frac{m+1}{m}}\frac{\sigma_e(\tau)}{\mathrm{RMSE}(\tau)}$$

  - Ratio > 1: **overdispersion** (underconfident)
  - Ratio < 1: **underdispersion** (overconfident)

m = number of ensemble members

ENSEMBLE DESIGN – 3 parallel ensembles with HadCM3:

DePreSys ICE **DePreSys PPE** **NoAssim PPE**

- All have 46 hindcasts (1960-2005), 9 ensemble members
- Both DePreSys ensembles are anomaly initialised from obs.
- Initial condition ensemble (ICE) uses standard HadCM3
- Perturbed Physics Ensembles (PPE) use 9 spun-up versions of HadCM3 with perturbations to 29 atmospheric parameters
- This analysis compares hindcast SSTs with HadISST
- Bias correction as in Kharin et al. 2012

Spread-error ratio - first season (DJF)

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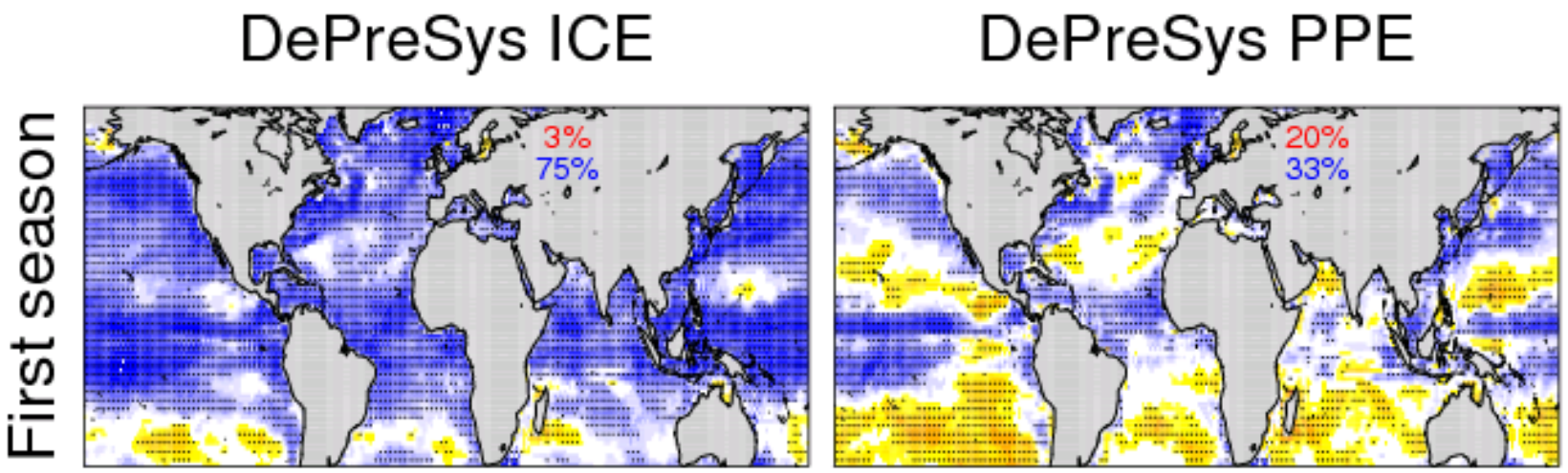
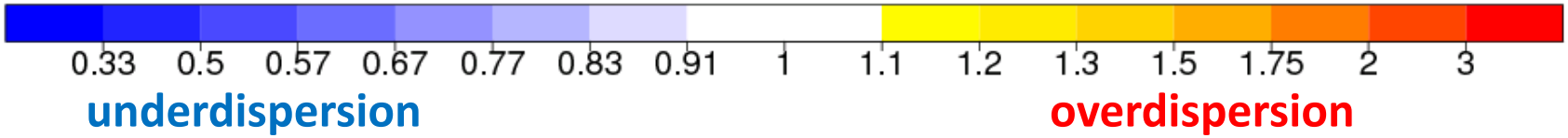


- Underdispersion consistent with many other seasonal prediction systems
- Perturbed physics ensemble has improved reliability



Spread-error ratio – first year

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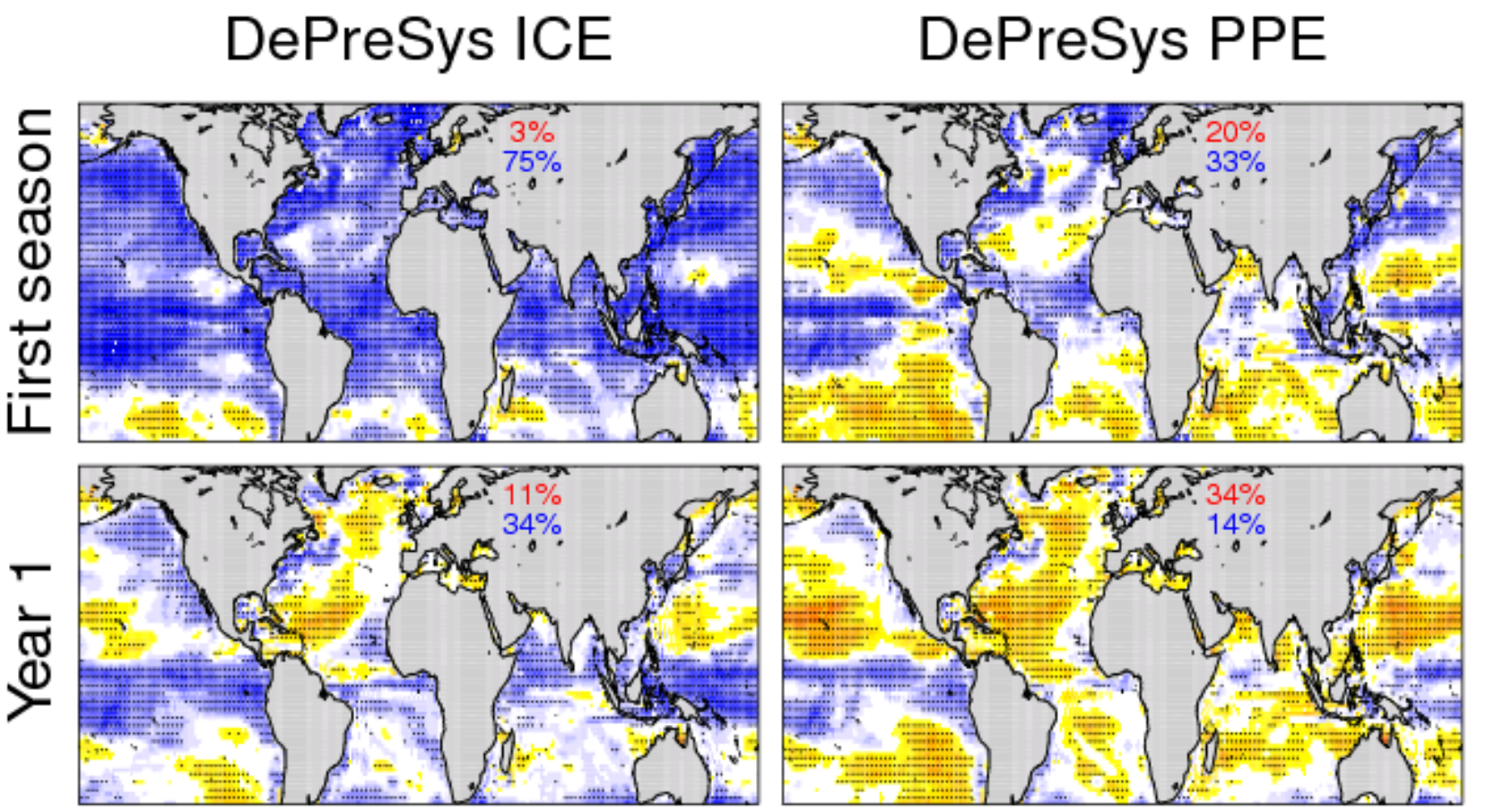
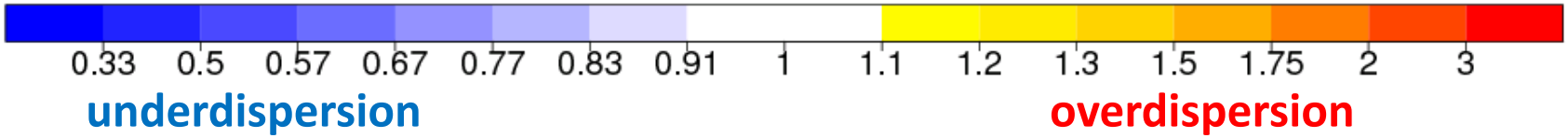


- Dispersion increases when considering year 1



Spread-error ratio – first three years

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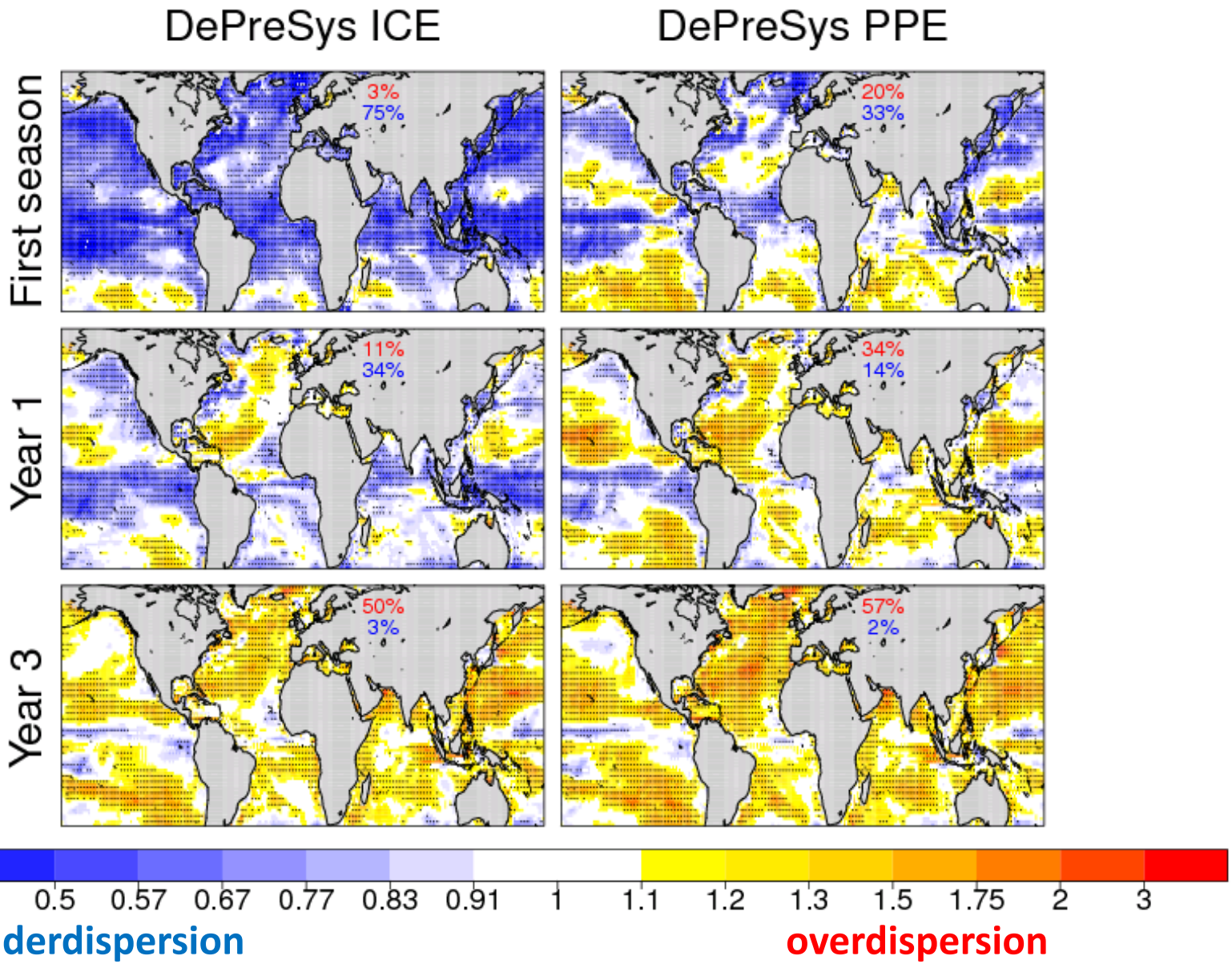

Spread-error ratio – first nine years

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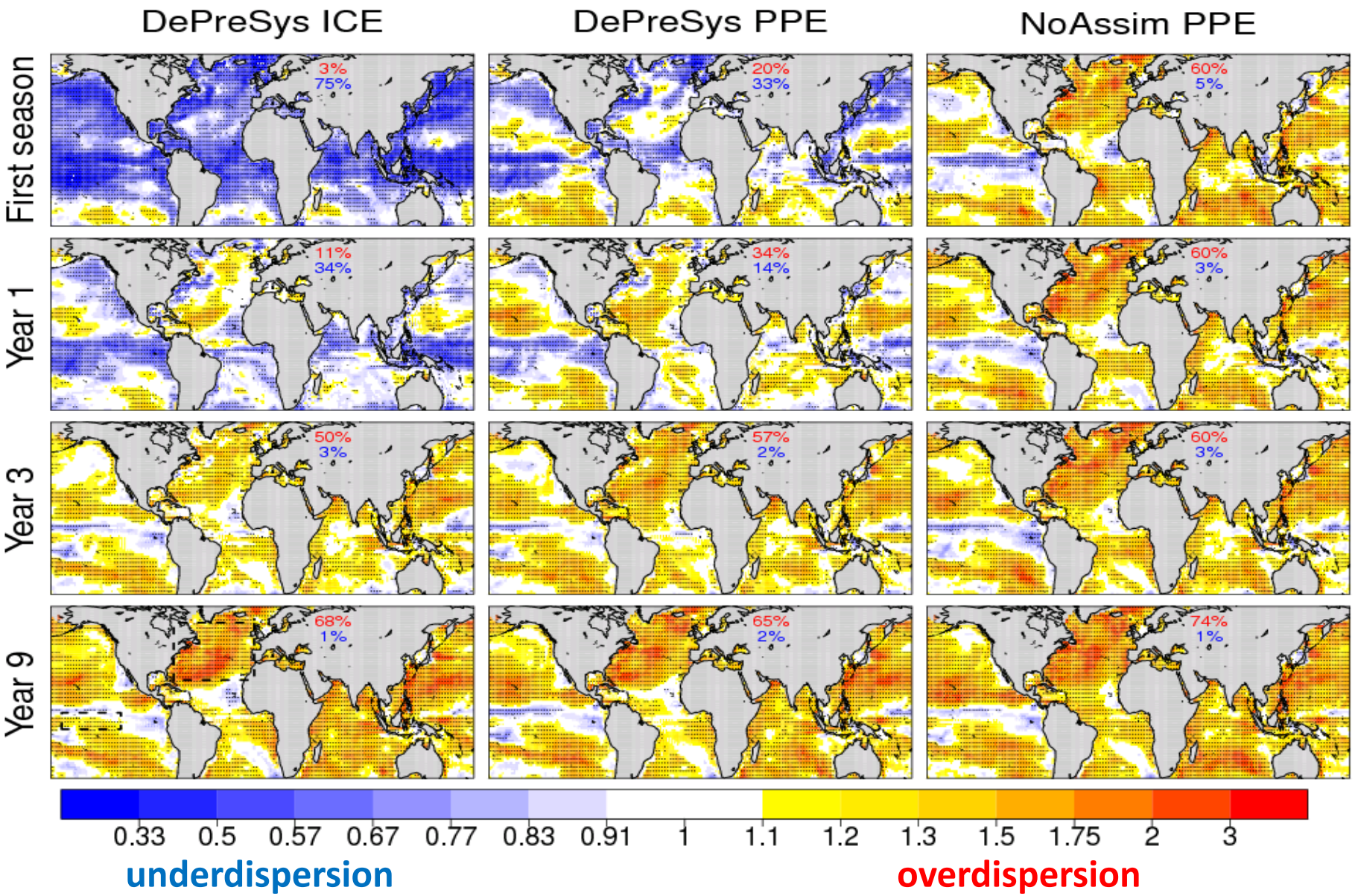

What causes the overdispersion?

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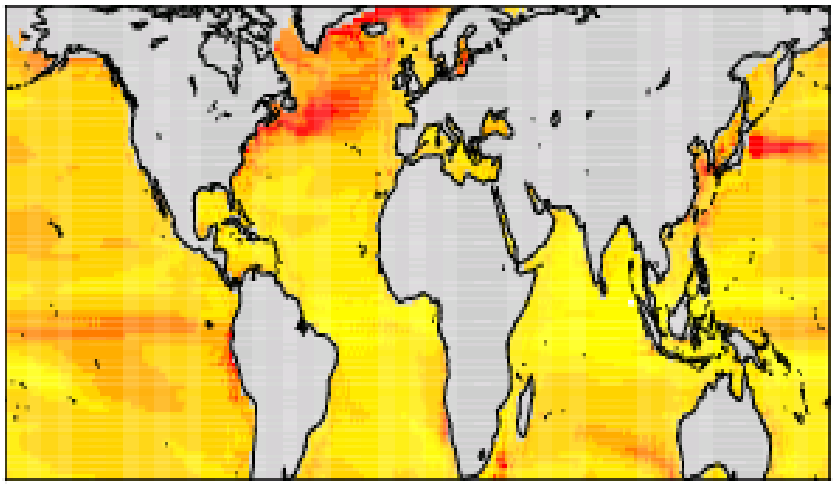
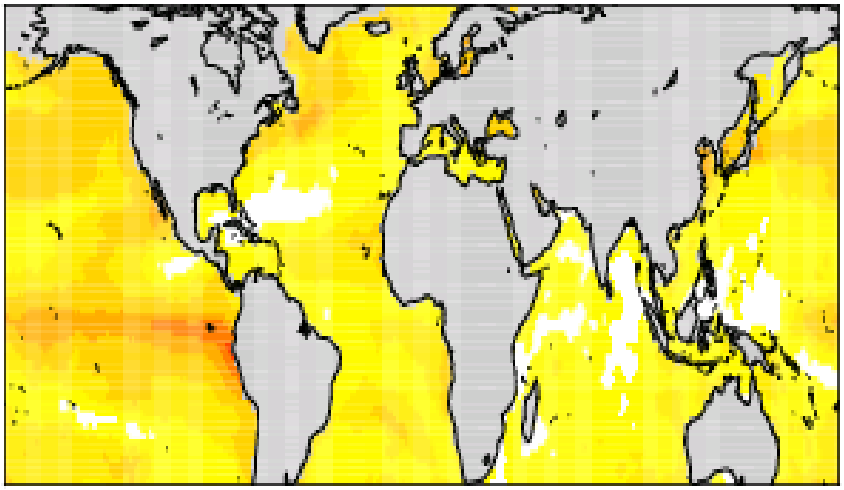
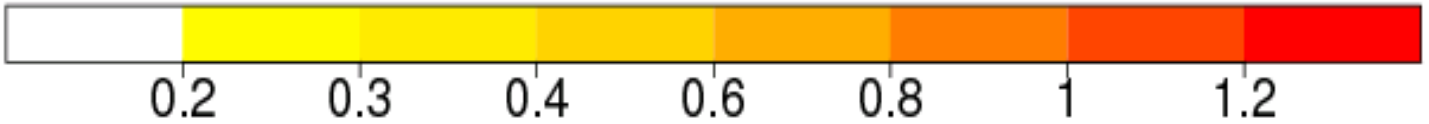
- For a reliable system, observations & ensemble forecasts need to have same climatological variance

HadCM3 control SSTs



HadISST (detrended)





Standard deviation (K)

What causes the overdispersion?

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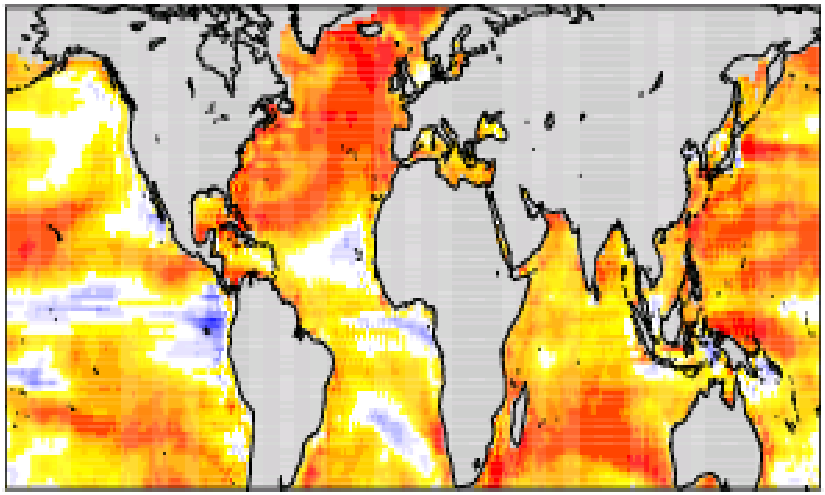
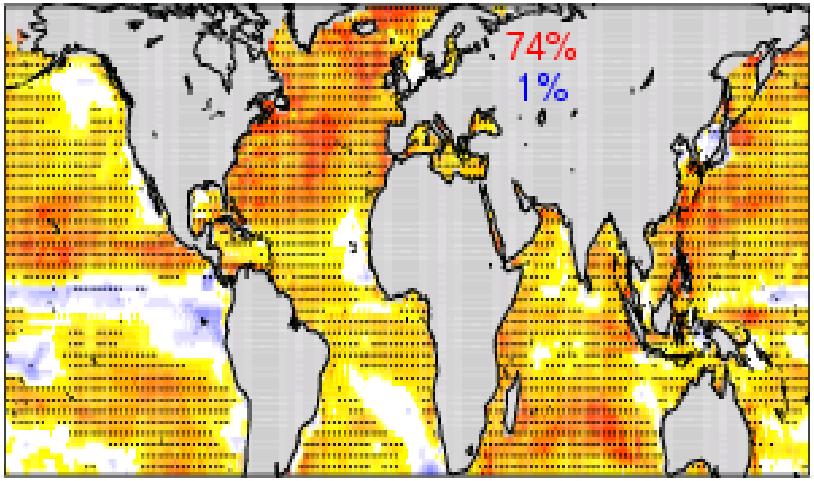
- For a reliable system, observations & ensemble forecasts need to have same climatological variance

Ratio of model to observed variability



Year 9 dispersion ratio in NoAssim PPE



Summary

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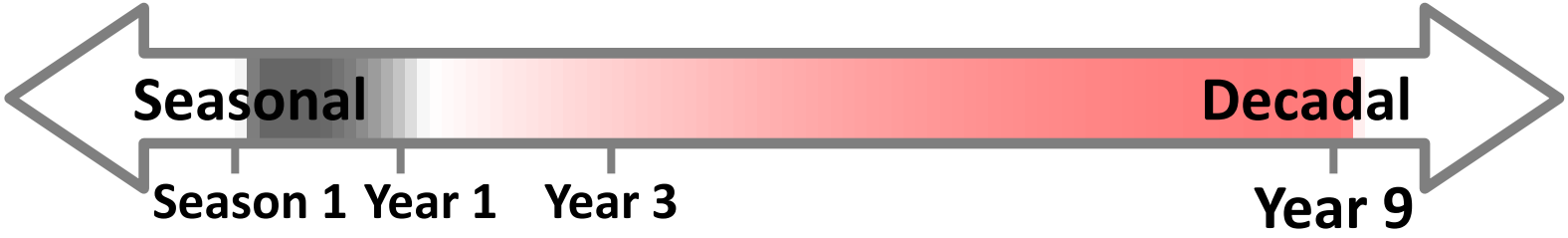
Factors affecting dispersion in DePreSys SST forecasts



Excessive **model internal variability**

Model initialisation reduces spread

Parameter perturbations produce larger spread than initial condition perturbations

overdispersion

underdispersion

Spatial variation of reliability

- North Atlantic most overdispersed
- Underdispersion in Tropical Pacific for all lead times

Implications

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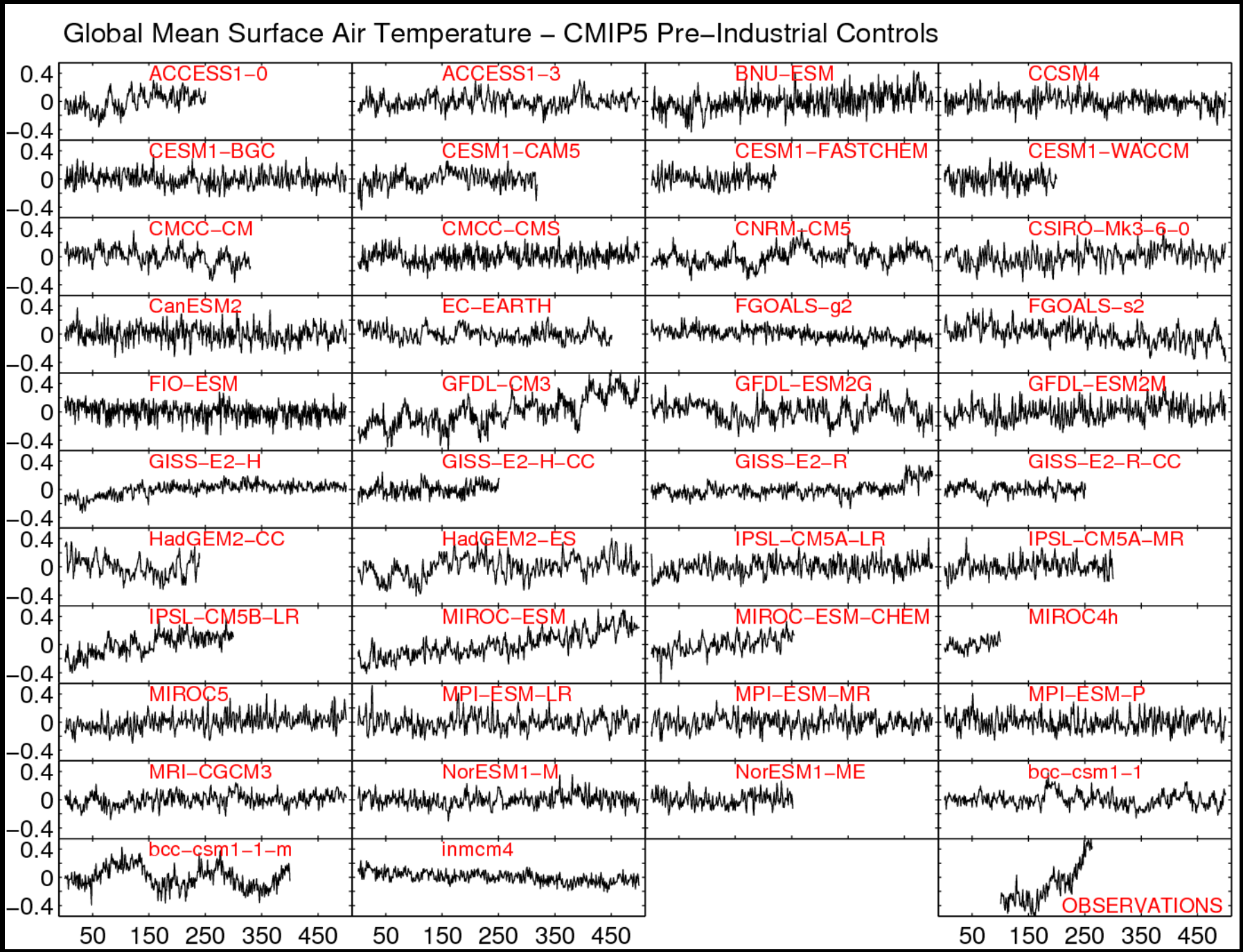
- **Ensemble prediction system design**
  - Climate model variability is at least as important as any perturbation scheme
  - Simulated variability should be assessed in forecast system design
  - Both skill *and* reliability should be assessed when analysing hindcasts
  - Dispersion estimates are robust to considering fewer start dates (not shown)


Global Mean Surface Air Temperature – CMIP5 Pre–Industrial Controls
ACCESS1–0
ACCESS1–3
BNU–ESM
CCSM4
CESM1–BGC
CESM1–CAM5
CESM1–FASTCHEM
CESM1–WACCM
CMCC–CM
CMCC–CMS
CNRM–CM5
CSIRO–Mk3–6–0
CanESM2
EC–EARTH
FGOALS–g2
FGOALS–s2
FIO–ESM
GFDL–CM3
GFDL–ESM2G
GFDL–ESM2M
GISS–E2–H
GISS–E2–H–CC
GISS–E2–R
GISS–E2–R–CC
HadGEM2–CC
HadGEM2–ES
IPSL–CM5A–LR
IPSL–CM5A–MR
IPSL–CM5B–LR
MIROC–ESM
MIROC–ESM–CHEM
MIROC4h
MIROC5
MPI–ESM–LR
MPI–ESM–MR
MPI–ESM–P
MRI–CGCM3
NorESM1–M
NorESM1–ME
bcc–csm1–1
bcc–csm1–1–m
inmcm4
OBSERVATIONS
0.4
0
−0.4
50
150
250
350
450