Decadal Climate Prediction and Sea Level:
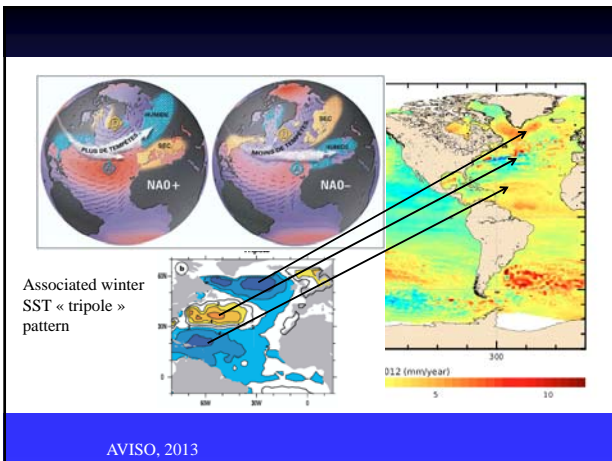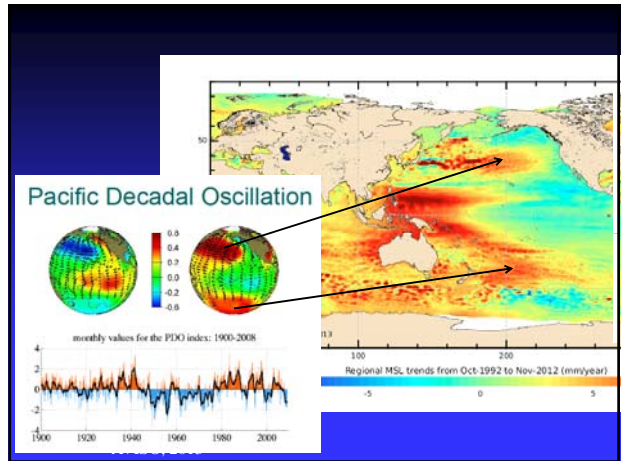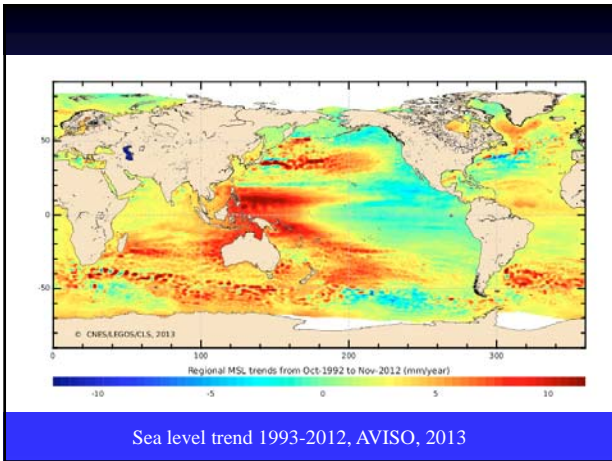State of the Art and Limitations

Philippe Rogel, CERFACS

•Introduction – Decadal Predictability

•Decadal variability mechanisms – North Atlantic

•Decadal Predictions – CMIP5

Colloque au Collège de France, 10 Juin 2013

AVISO, 2013

Sea level trend 1993-2012, AVISO, 2013

Associated winter SST « tripole » pattern

AVISO, 2013

Antarctic Circumpolar wave ? – White and Petersen 1996

AVISO, 2013
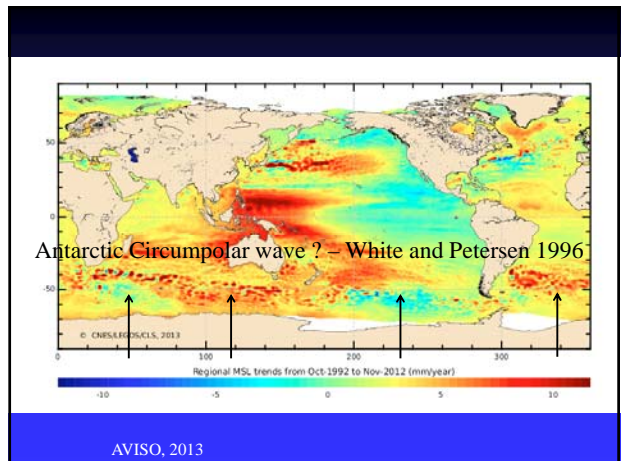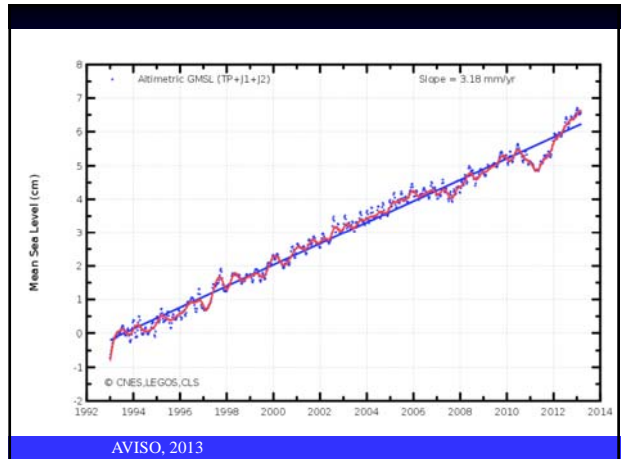
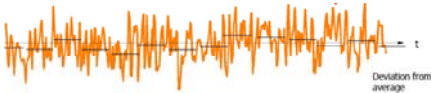Is there some predictability associated with these patterns ?
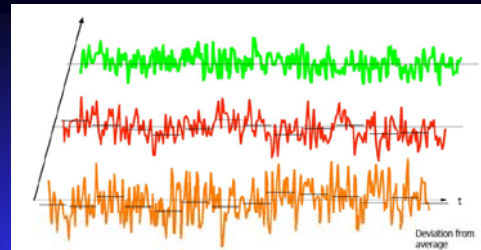
Decadal Predictability

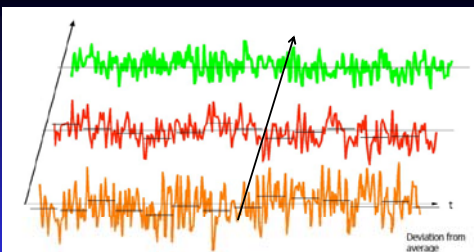…in a model's world…
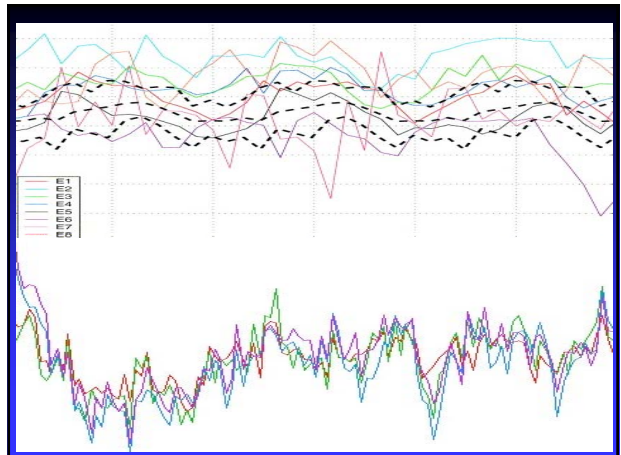
Simulated Climate variable

Boer and Lambert 2008

Ensemble of simulations

Boer and Lambert 2008

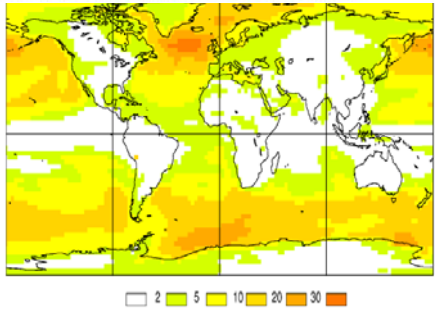Temporal Variance
vs
Inter-ensemble Variance

Boer and Lambert 2008

Temperature: potential predictability of *internally generated* variability $p_\nu = \sigma^2_\nu/\sigma^2$ (%) for *decadal means (CMIP3 multi-model control runs)*

Boer and Lambert 2008

Sources of uncertainty in the IPCC AR4 projections
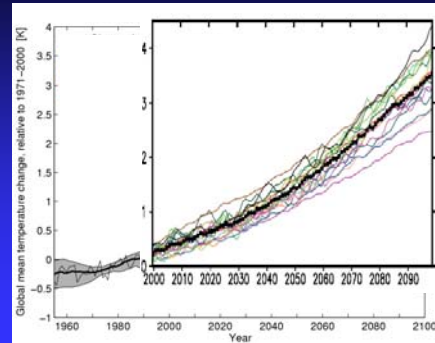
Hawkins and Sutton, 2009

Sources of uncertainty in the IPCC AR4 projections

Hawkins and Sutton, 2009

Sources of uncertainty in the IPCC AR4 projections

Internal variability   Model   Scenario
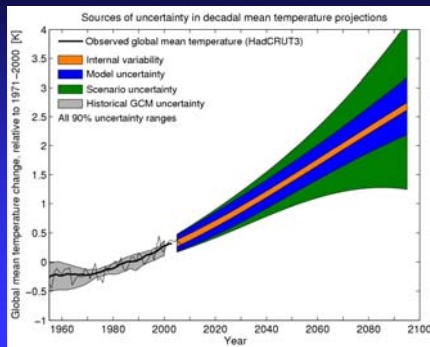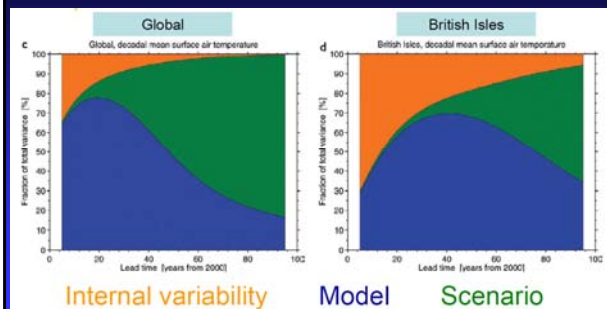
Hawkins and Sutton, 2009

- From models, there is some potential decadal predictability, especially in the North Atlantic Region

- Sources of predictability at regional and decadal scales mix both initial conditions and external forcing

North Atlantic mechanisms

…in a model's world…

North Atlantic mechanisms

Boer and Lambert 2008

North

SL Gradient
40°N-60°N

AMOC

Figure 3. Normalized timeseries of the subpolar gyre index (black) and MOC at 50N (red) from ORAS3. Overplotted are the linear trend estimates. The subpolar gyre index is computed as the sea level differences at 40N and 60N. The decrease in subpolar gyre intensity during the 90's is consistent with *Häkkinen and Rhines* [2004]. The subpolar gyre variability leads the MOC variability at interannual time scales, but the trends are opposite.
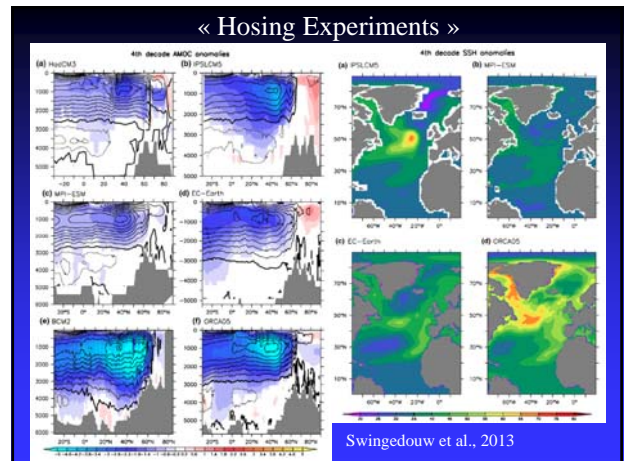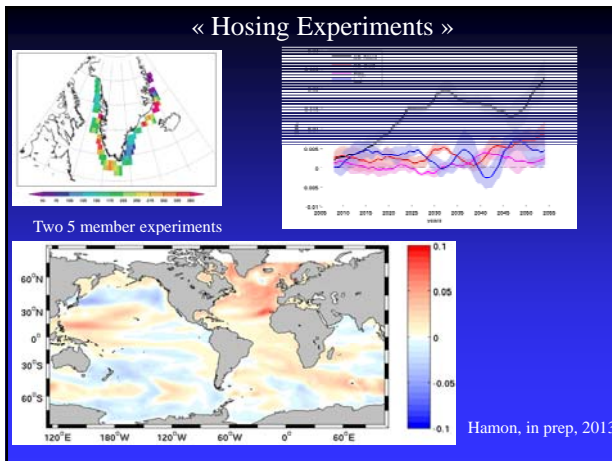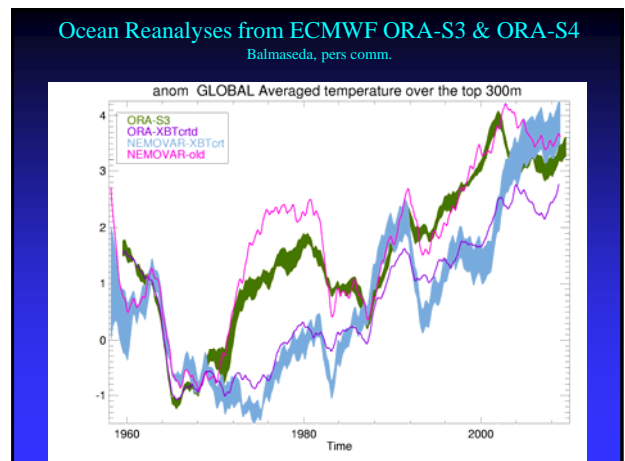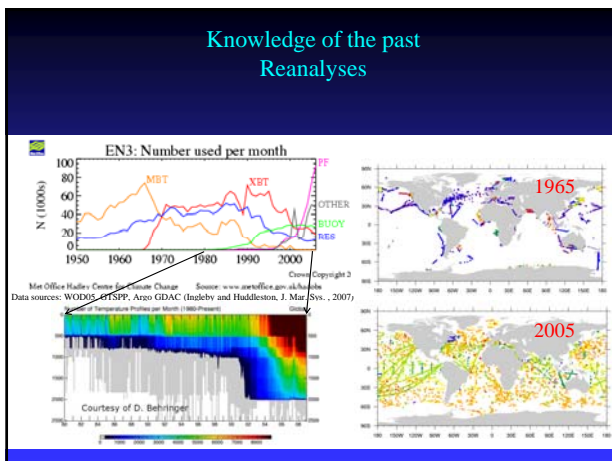
Balmaseda et al., 2007

CNRM-CM5 Coupled model (CMIP5)

Données
Aérosols
GES

METEO FRANCE
Toujours un temps d'avance

CERFACS

Atmosphère
ARPEGE-Climat, T127L, L31

Modèle de surface SURFEX

OASIS

24h   24h

Glace
de mer

Océan
NEMO 1°, L42

24h

Fleuves
TRIP

24h

Long control coupled integration of the CNRM-CM5 model

SL Gradient & Max MOC anomaly

SL Gradient

AMOC

« Hosing Experiments »

« Hosing Experiments »
A benchmark for caracterising the mechanisms at stake in the NorthAtlantic

Fresh water flux
0.025 Sv

Stammer et al, 2011

« Hosing Experiments »

Sea level response in different ocean basins (black: North Atlantic)

Sea level response after 4 decades

Stammer et al, 2011

« Hosing Experiments »

Two 5 member experiments

Hamon, in prep, 2013

« Hosing Experiments »

Swingedouw et al., 2013

- Link between AMOC and Sea level investigated from models: model dependence and potential non-stationarity
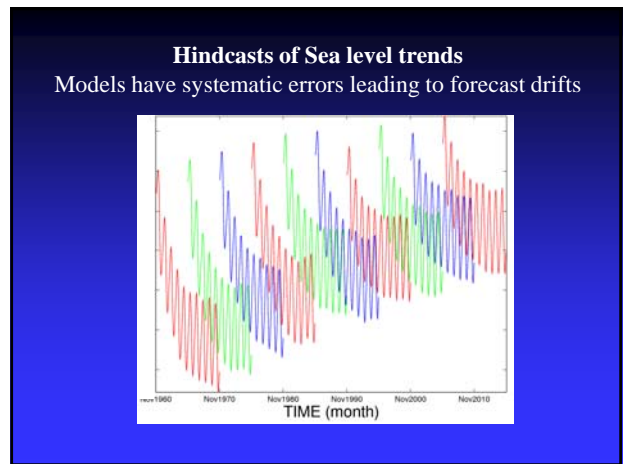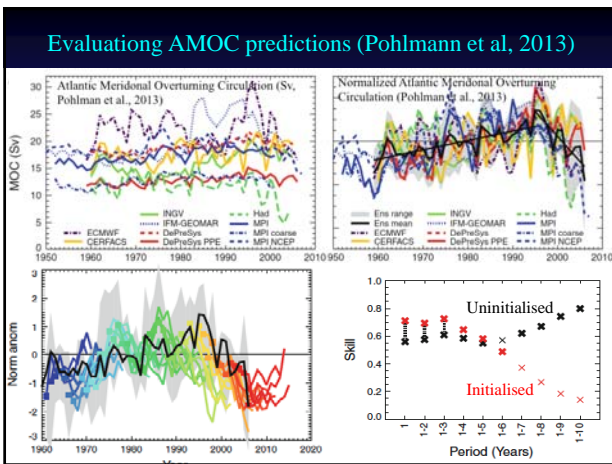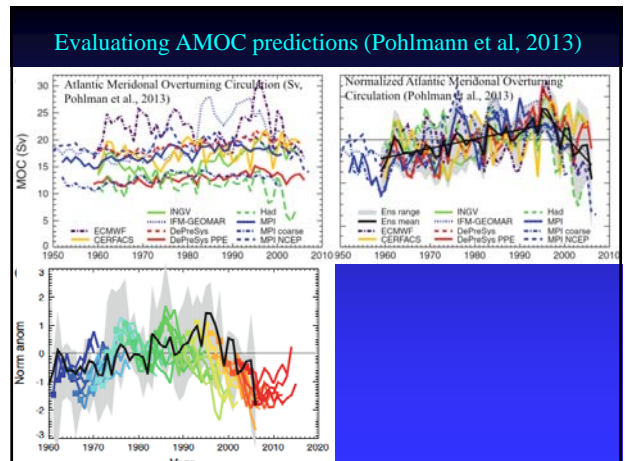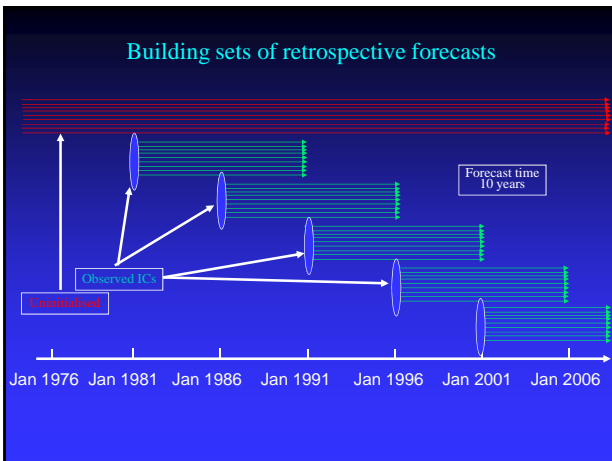
- Hosing experiments constitute a suitable benchmark for characterising mechanisms at stake

Decadal Predictions CMIP5

… models versus real world…

Knowledge of the past
Reanalyses

Ocean Reanalyses from ECMWF ORA-S3 & ORA-S4
Balmaseda, pers comm.

Building sets of retrospective forecasts

Evaluationg AMOC predictions (Pohlmann et al, 2013)

Evaluationg AMOC predictions (Pohlmann et al, 2013)

Hindcasts of Sea level trends
Models have systematic errors leading to forecast drifts

Hindcasts of Sea level trends
Computation of observed and forcasted trends

Hindcasts of Sea level trends
Mean trends computation

Hindcasts of Sea level trends
Trend anomalies computation

TIME (month)
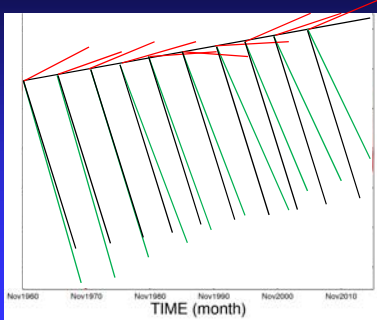
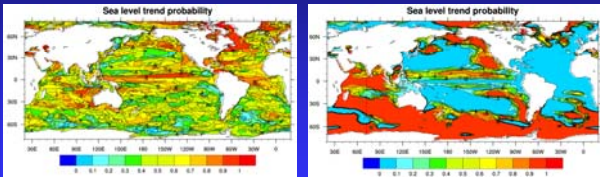
Probabilistic prediction of sea level trends

In the following, we want to assess the predictability of the event E:
« The regional sea level trend will be higher than the long term average global mean sea level trend » (i.e. 1.8 mm/year in observations)

The forecasted probability that E occurs is
$$p = j/P$$

where P is the ensemble size, j is the number of individual members where E occurs

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Probabilistic prediction of sea level trends

Probability that the 2005-2015 sea level trend is higher than the mean 1960-2005 global mean trend

Uninitialised   Decadal hindcasts

Probabilistic prediction of sea level trends

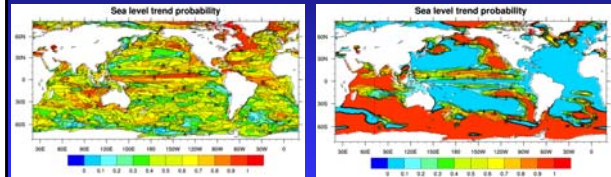**Probability that the 2005-2015 sea level trend is higher than the mean 1960-2005 global mean trend**

Historical   Decadal hindcasts

Q: Is there some reason to believe these maps ? Is one more reliable than the other ?

Reliability Estimates (Brier score)

Observation : $o_i = 0$ or 1

Reliability Estimates (Brier score)

Observation : $o_i = 0$ or 1

Verification dataset needed !
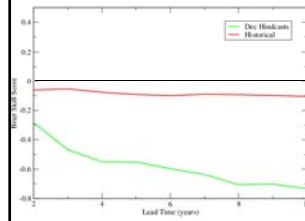Here: Reanalysis

$$BS = \sum_{i=1}^{N} (p_i - o_i)^2$$

Reliability Estimates (Brier score)

$$BS = \sum_{i=1}^{N} (p_i - o_i)^2$$

Skill Score: added value wrt a simple forecast system (here climatological probability forecast)

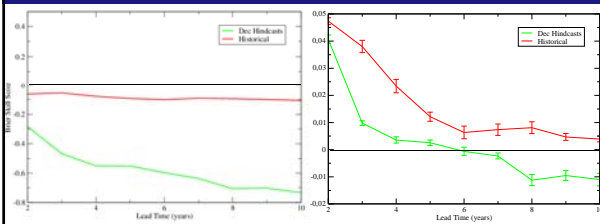$$BSS = 1 - \frac{BS}{BSc}$$

Hindcast performances

Recalibrated hindcast performances

i.e. using knowledge of all hindcasts but the current one

Before Calibration   After Calibration

Final Conclusions

• There is some potential for decadal prediction, especially in the North Atlantic Region

• Realistic prediction experiments show additional skill from ocean initialisation up to year 5 (AMOC, Temperature, Sea Level,…)

• More work needed to investigate mechanisms and model errors
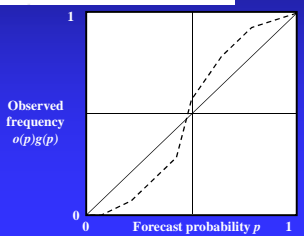
• IPCC AR5 Chapter 11

Merci

Slide 1 (top-left)

Reliability Estimates (Brier score)

$$BS = \sum_{i=1}^{N}(p_i - o_i)^2$$

$$= \int_0^1 [p - o(p)]^2 g(p)dp - \int_0^1 [\bar{o} - o(p)]^2 g(p)dp + \bar{o}[1 - \bar{o}]$$

$$BSS = 1 - \frac{BS}{BSc}$$

$$BSS = BSS_{res} + BSS_{rel}$$

e.g. Palmer, 2002

Observed frequency $o(p)g(p)$

1

0

0   Forecast probability p 1

Slide 2 (top-right)

Reliability Estimates (Brier score)

$$BS = \sum_{i=1}^{N}(p_i - o_i)^2$$

$$= \int_0^1 [p - o(p)]^2 g(p)dp - \int_0^1 [\bar{o} - o(p)]^2 g(p)dp + \bar{o}[1 - \bar{o}]$$

$$BSS = 1 - \frac{BS}{BSc}$$
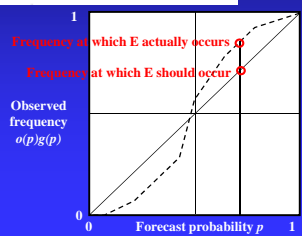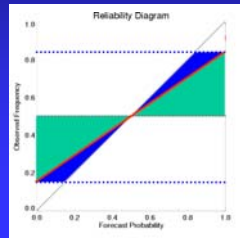
$$BSS = BSS_{res} + BSS_{rel}$$

e.g. Palmer, 2002

Frequency at which E actually occurs o

Frequency at which E should occur o

Observed frequency $o(p)g(p)$

1

0

0   Forecast probability p 1

## Slide 3 (middle-left)

Reliability Estimates (Brier score)

$$BS = \sum_{i=1}^{N}(p_i - o_i)^2$$

$$= \int_0^1 [p - o(p)]^2 g(p)dp - \int_0^1 [\bar{o} - o(p)]^2 g(p)dp + \bar{o}[1 - \bar{o}]$$

$$BSS = 1 - \frac{BS}{BSc}$$

$$BSS = BSS_{res} + BSS_{rel}$$

Reliability Diagram

Slide 4 (middle-right)

Reliability Estimates (Brier score)

$$BS = \sum_{i=1}^{N}(p_i - o_i)^2$$

$$= \int_0^1 [p - o(p)]^2 g(p)dp - \int_0^1 [\bar{o} - o(p)]^2 g(p)dp + \bar{o}[1 - \bar{o}]$$
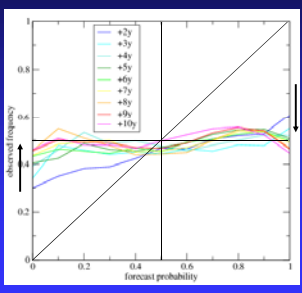
$$BSS = 1 - \frac{BS}{BSc}$$

$$BSS = BSS_{res} + BSS_{rel}$$

Reliability Diagram

Reliability score (the smaller, the better)
Resolution score (the bigger, the better)
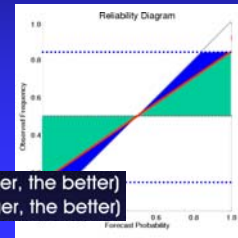
Slide 5 (bottom-left)

Reliability estimates of probabilistic prediction that the sea level trend is higher than the mean 1960-2005 global mean trend

Decadal hindcasts
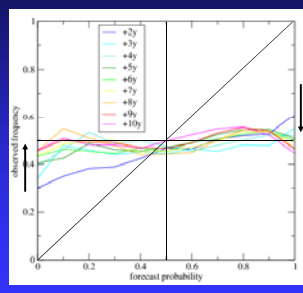
Slide 6 (bottom-right)

Reliability estimates of probabilistic prediction that the sea level trend is higher than the mean 1960-2005 global mean trend
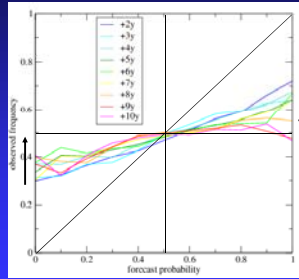
Decadal hindcasts

Reliability diagrams pathological of an « over-confident » prediction system, the ensemble spread is too weak.

Reliability estimates of probabilistic prediction that the sea level trend is higher than the mean 1960-2005 global mean trend
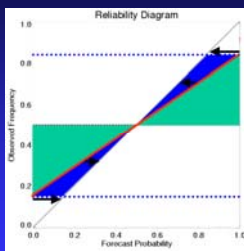
Historicals

Reliability estimates of probabilistic prediction that the sea level trend is higher than the mean 1960-2005 global mean trend
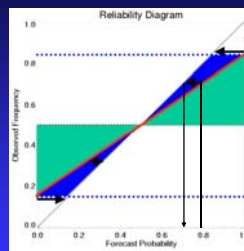
Historicals
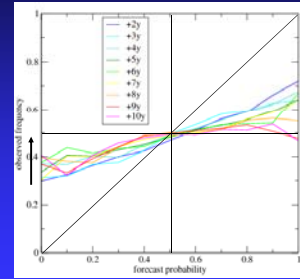
These diagrams lead to negative scores, meaning that no additional information beyond climatology is brought

Reliability diagram or calibration curves

Knowing past (independent) performances of the system allows user to recompute probabilities based on these diagrams.

Reliability diagram or calibration curves
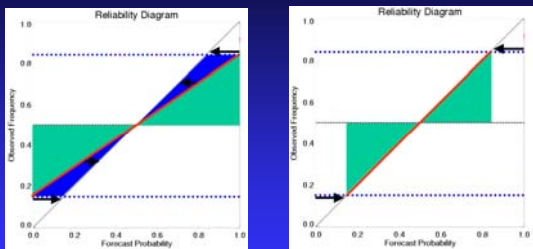

Knowing past (independent) performances of the system allows user to recompute probabilities based on these diagrams.

Reliability diagram or calibration curves

Courtesy of FJ Doblas-Reyes

It leads to more reliable hindcasts, at the cost of a loss of resolution.

It must be made in cross calibration mode, excluding the forecasted year from the calibration phase.