A Metrics Framework for Interannual-to-Decadal Predictions Experiments

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US CLIVAR Decadal Predictability Working Group

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Objective 1: *To define a framework to distinguish natural variability from anthropogenically forced variability on decadal time scales for the purpose of assessing predictability of decadal-scale climate variations in coupled climate models.*

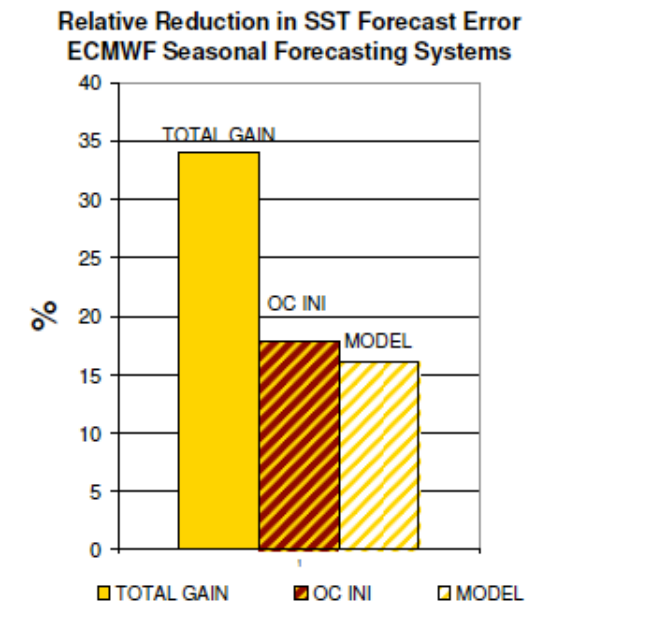
Objective 2: *Work towards better understanding of decadal variability and predictability through metrics that can be used as a strategy to assess and validate decadal climate prediction experiments.*

Outline

- Objective
- Framework
  - Metrics & examples of results
  - Statistical significance
  - Website
- Issues relevant to verification endeavor
  - Bias correction
  - Spatial scale
  - Stationarity/reference period

Motivation: Forecasts need verification

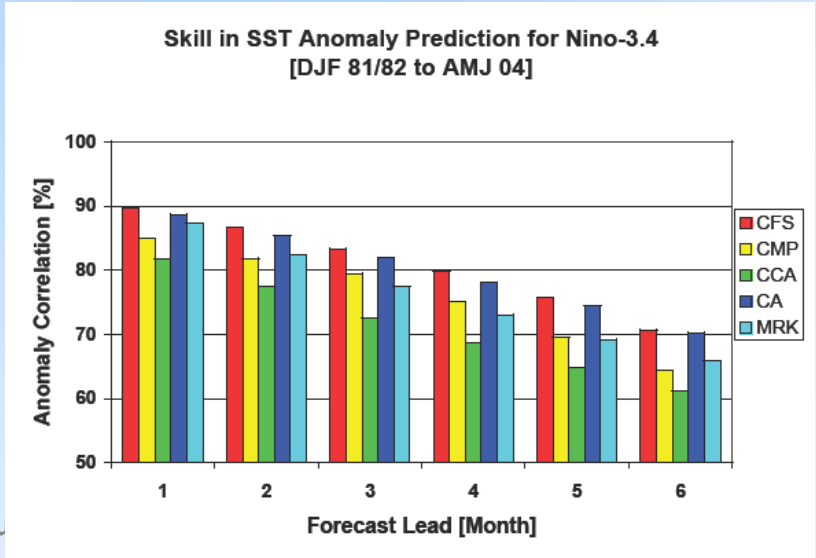
… for tracking improvements in prediction systems



Example from SI:
Recent improvements to ECMWF seasonal forecast system came in almost equal parts from improvements to the model and the ODA

(Balmaseda et al. 2009, OceanObs'09)

… for comparison against other systems and other approaches

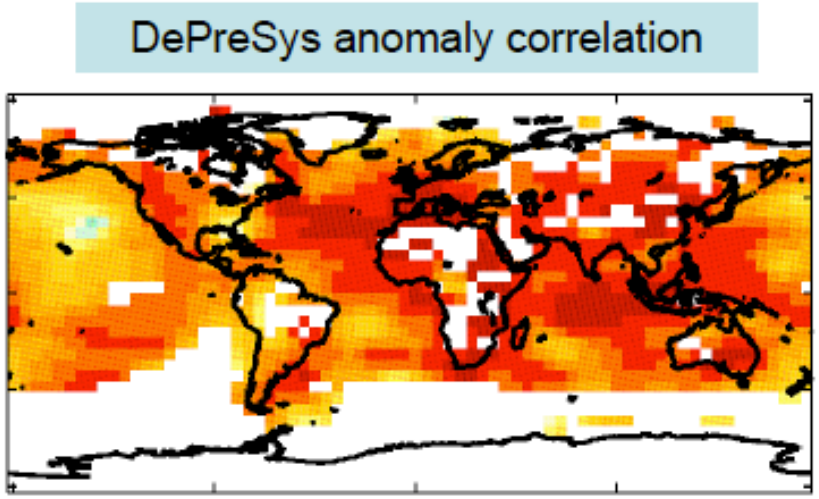


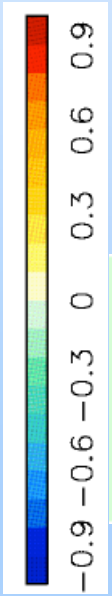
Example from SI:
NCEP-CFS reaches parity with statistical fcsts for ENSO

(Saha et al. 2004, J.Clim)

How "good" are they?: Deterministic Metrics

Regional Average (15°x15°); 5-Year Means:



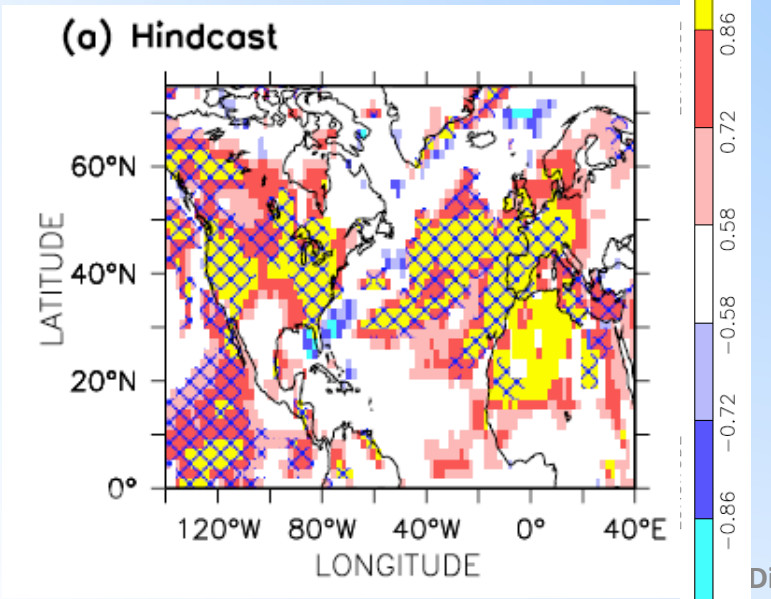


Met Office Hadley Centre

- HadCM3
- 9 member perturbed physics ensemble
- Starting every Nov from 1960 to 2005

(Courtesy: Doug Smith)

Grid Scale; 10-Year Means:



- ECHAM5 + MPI-OM
- 3 member perturbed IC ensemble
- Starting every 5 years Nov from 1955 to 2005

(Keenlyside et al. 2008, Nature)

U.S. CLIVAR Climate Variability & Predictability

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Asking Questions of the Initialized Hindcasts

Question 1: Do the initial conditions in the hindcasts lead to more accurate predictions of the climate?

Question 2: Is the model's ensemble spread an appropriate representation of forecast uncertainty on average?

Time scale: Year 1, Years 2-5, Years 2-9

Spatial scale: Grid scale, spatially-smoothed

Asking Questions of the Initialized Hindcasts

Question 1: Do the initial conditions in the hindcasts lead to more accurate predictions of the climate?

→ Mean Squared Skill Score and its decomposition

$$MSSS = 1 - \frac{MSE_{fcst}}{MSE_{ref}}; \quad \text{if ref} = \text{climatological avg.}$$

$$MSSS(f,\bar{x},x) = r_{fx}^2 - [r_{fx} - \left(s_x / s_f\right)]^2 = Correlation^2 + Cond.Bias^2$$

$$MSSS = 1 - \frac{MSE_{init}}{MSE_{uninit}}; \quad \text{here ref} = \text{uninitialized hindcasts}$$

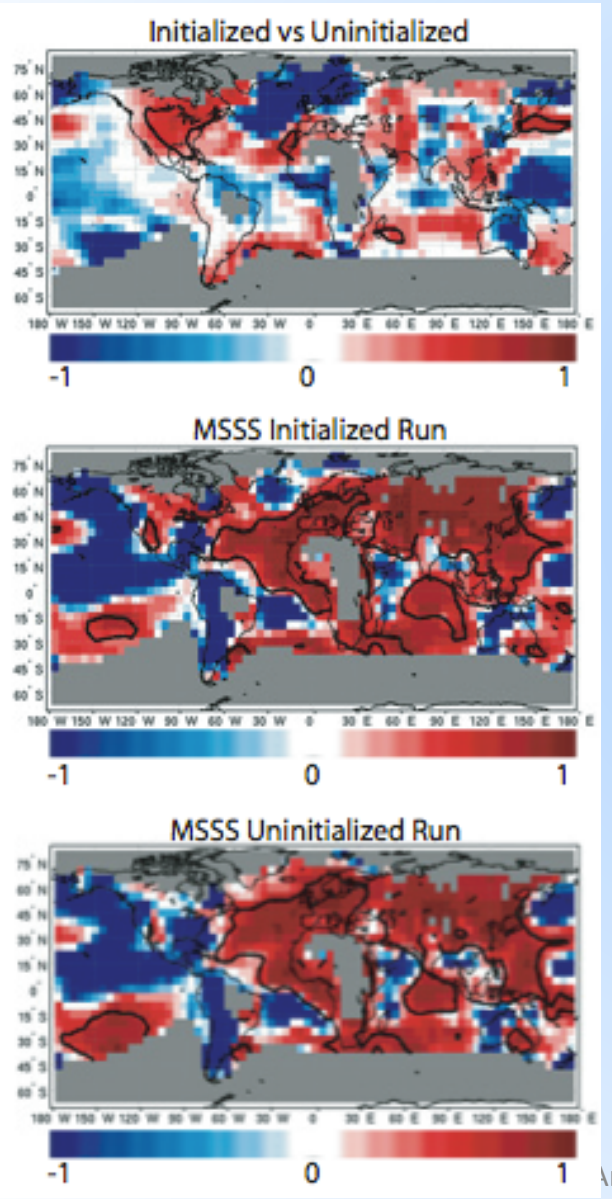
$$MSSS(f,r,x) = \frac{MSSS(f,\bar{x},x) - MSSS(r,\bar{x},x)}{1 - MSSS(r,\bar{x},x)}$$

(from Murphy, Mon Wea Rev, 1988)

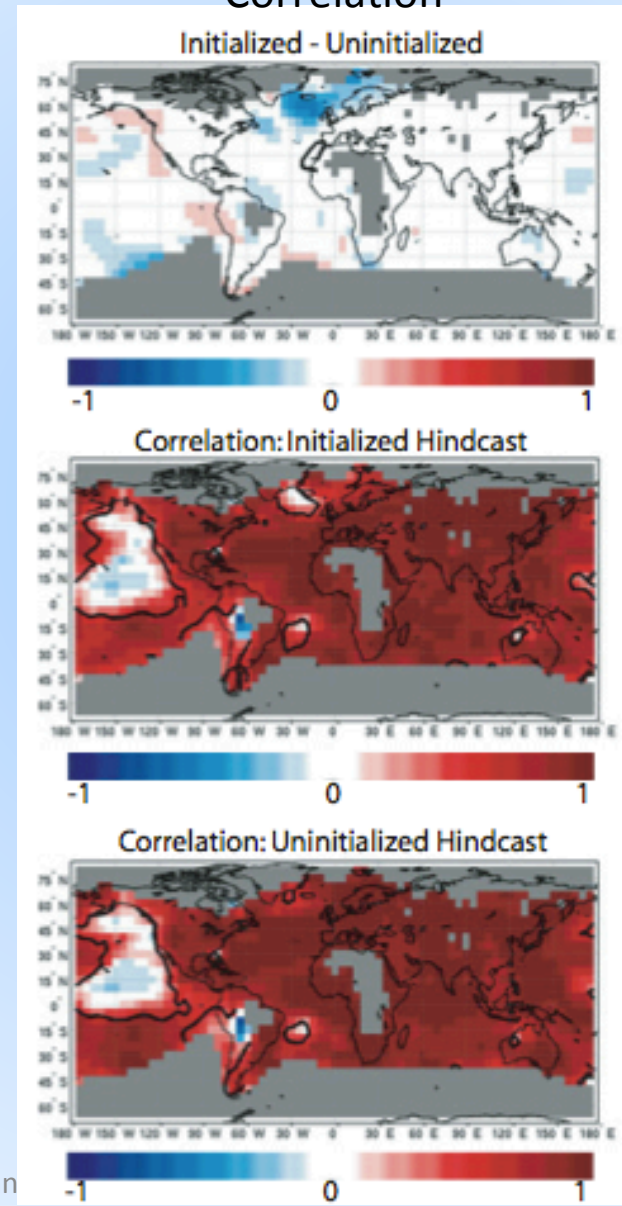
Deterministic Metrics: Mean Squared Skill Score (MSSS)

CanCM4

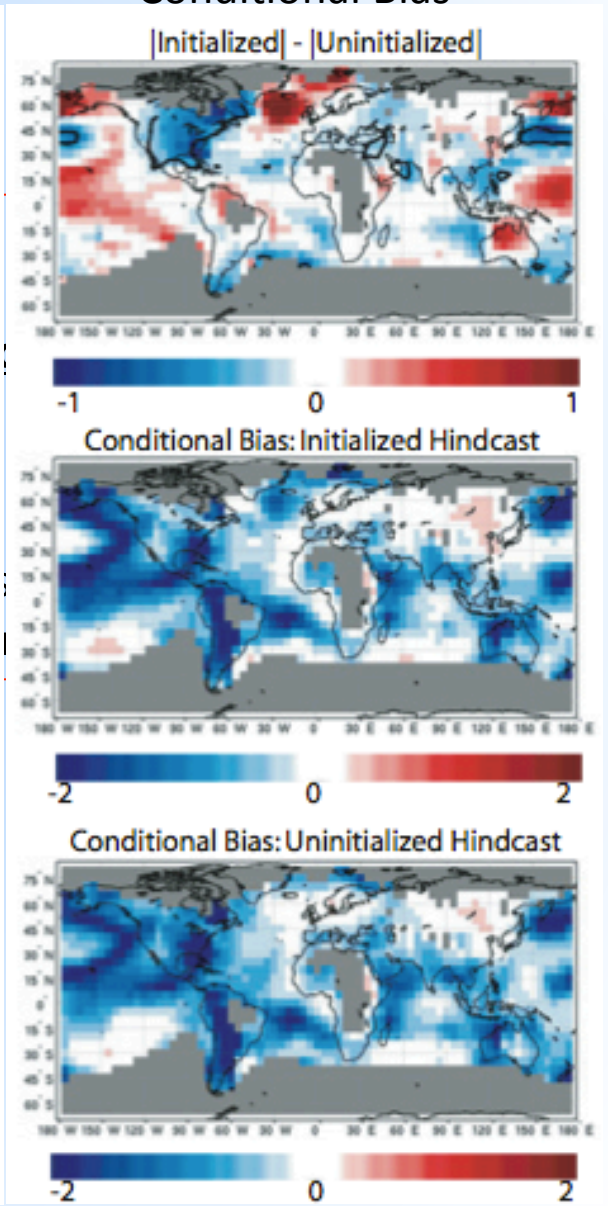
MSSS



Correlation



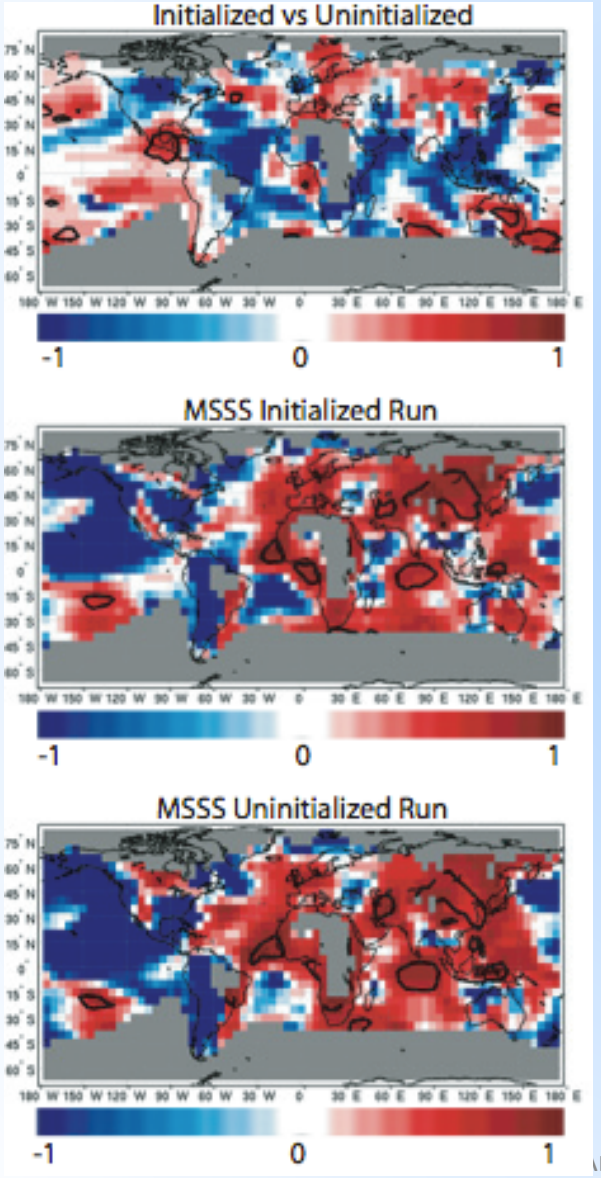
Conditional Bias



Deterministic Metrics: Mean Squared Skill Score (MSSS)

DePreSys

MSSS



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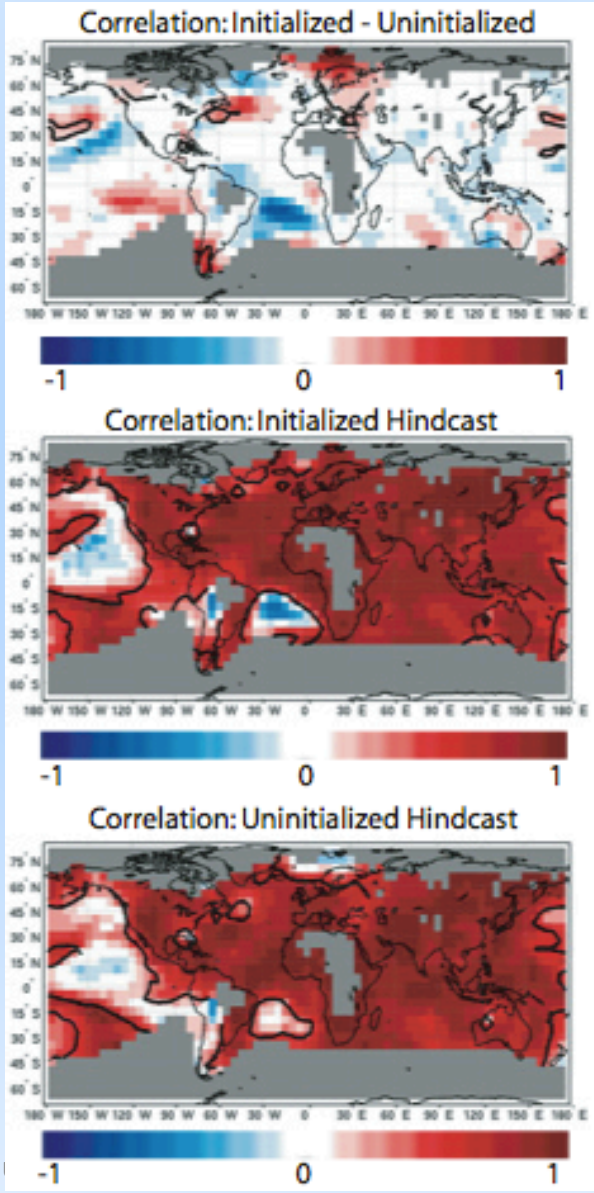

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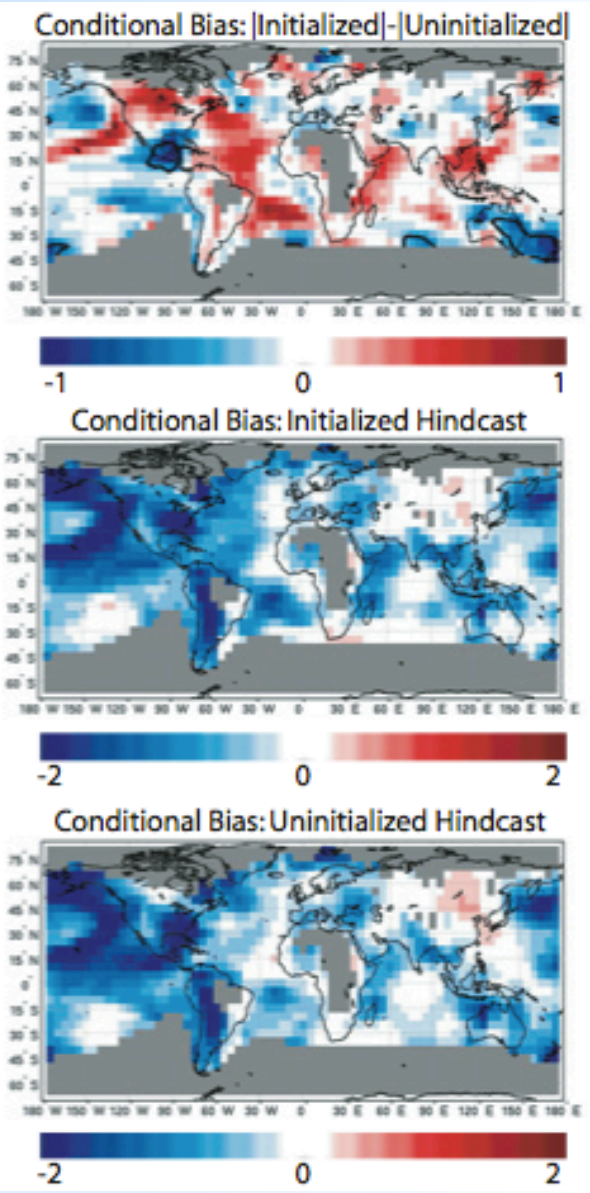

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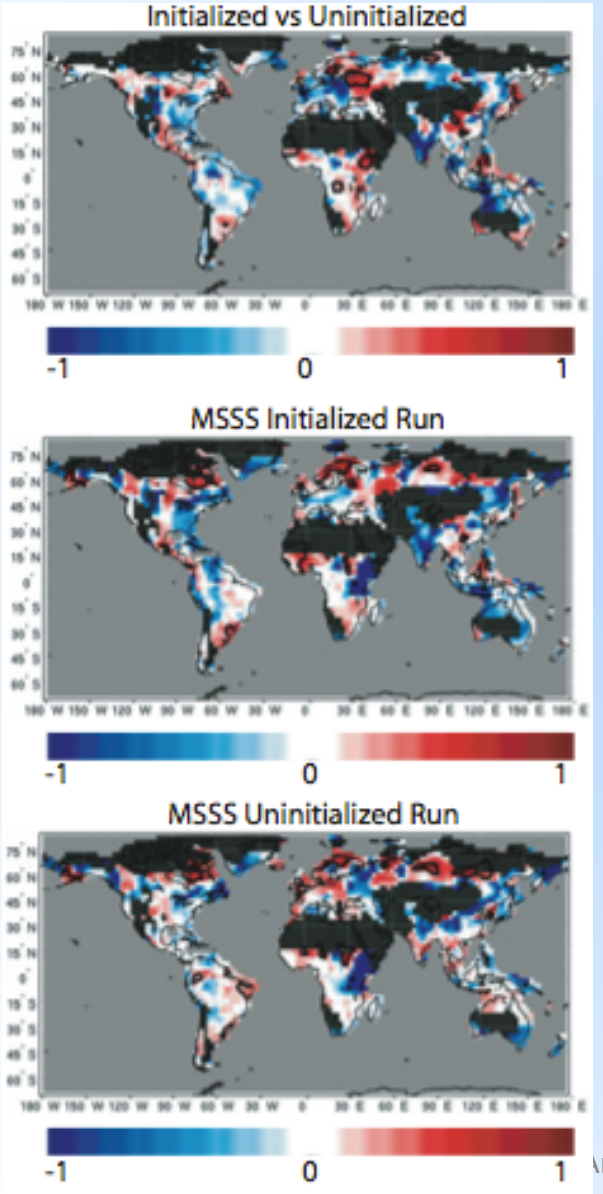

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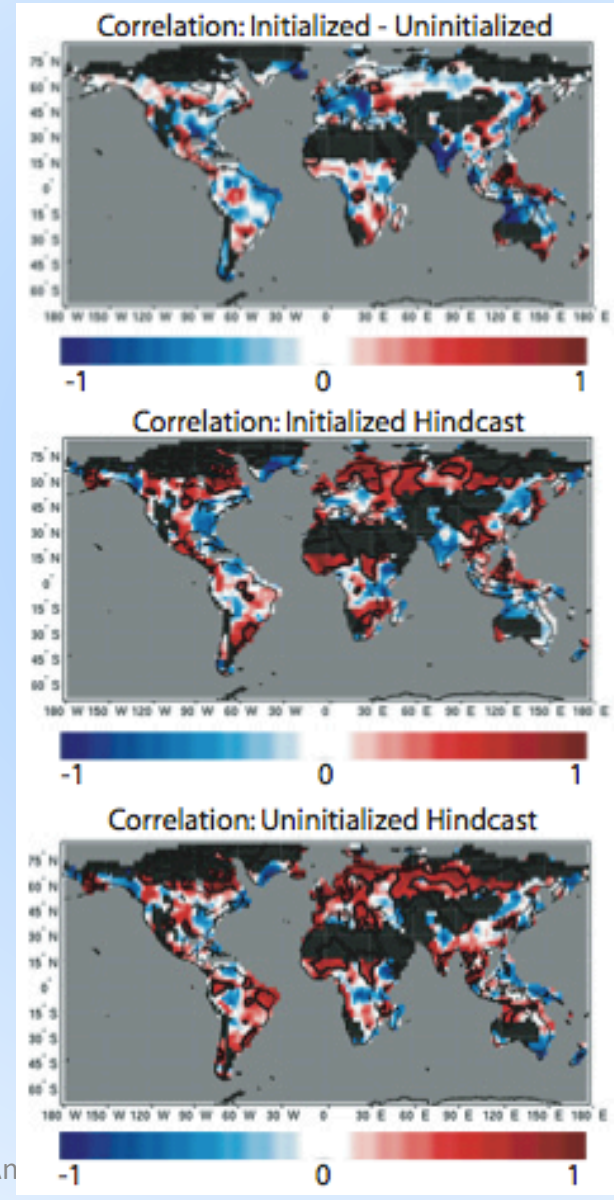

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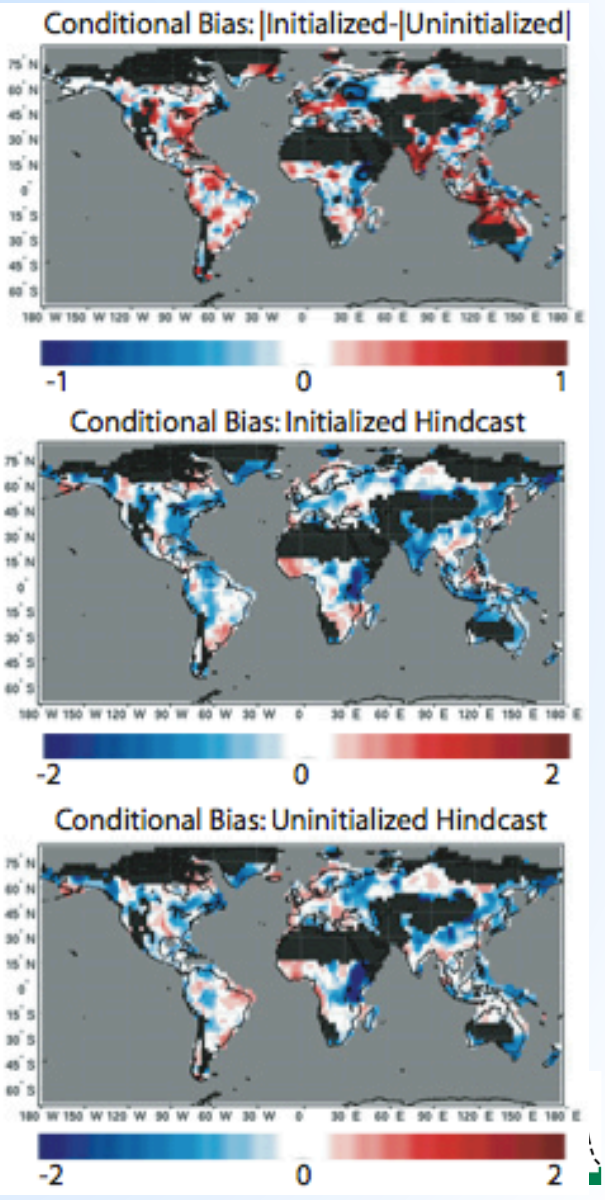

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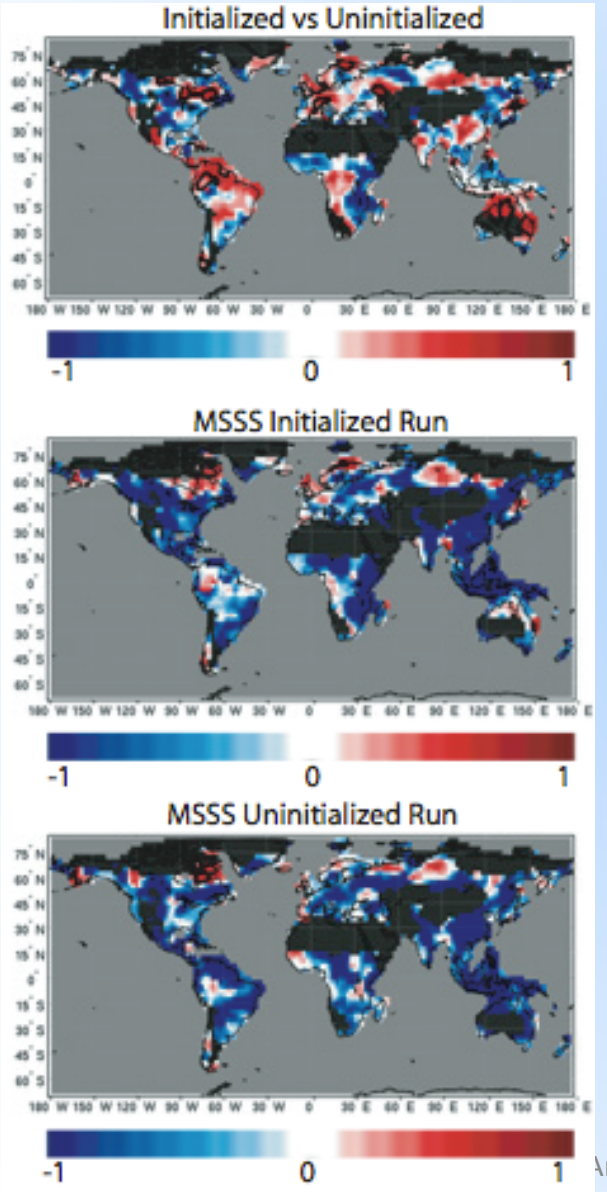

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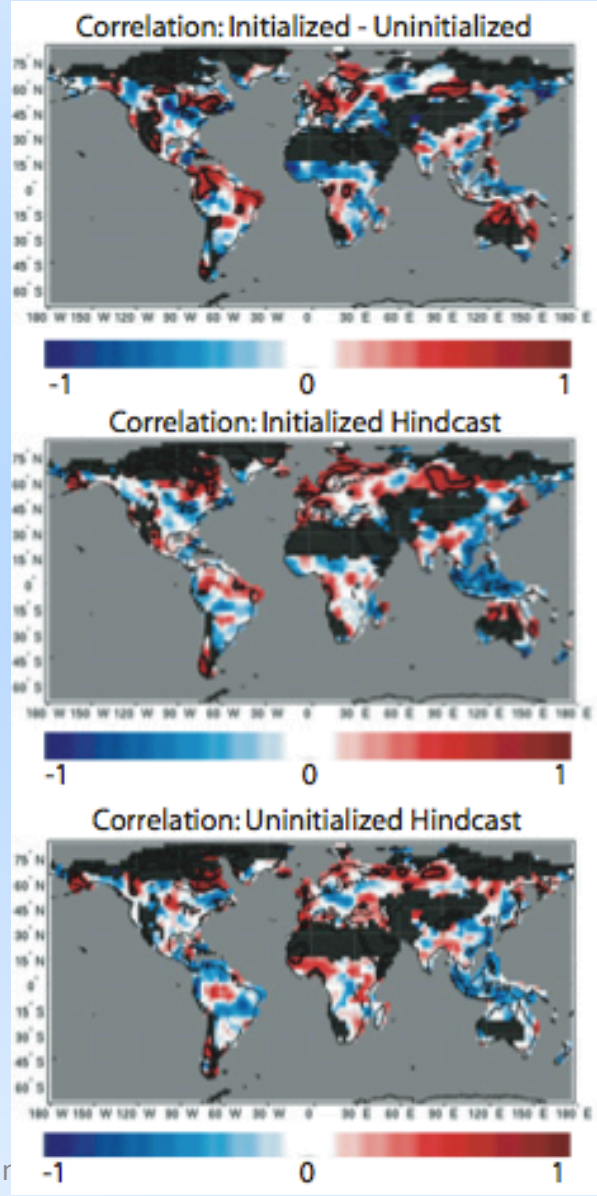

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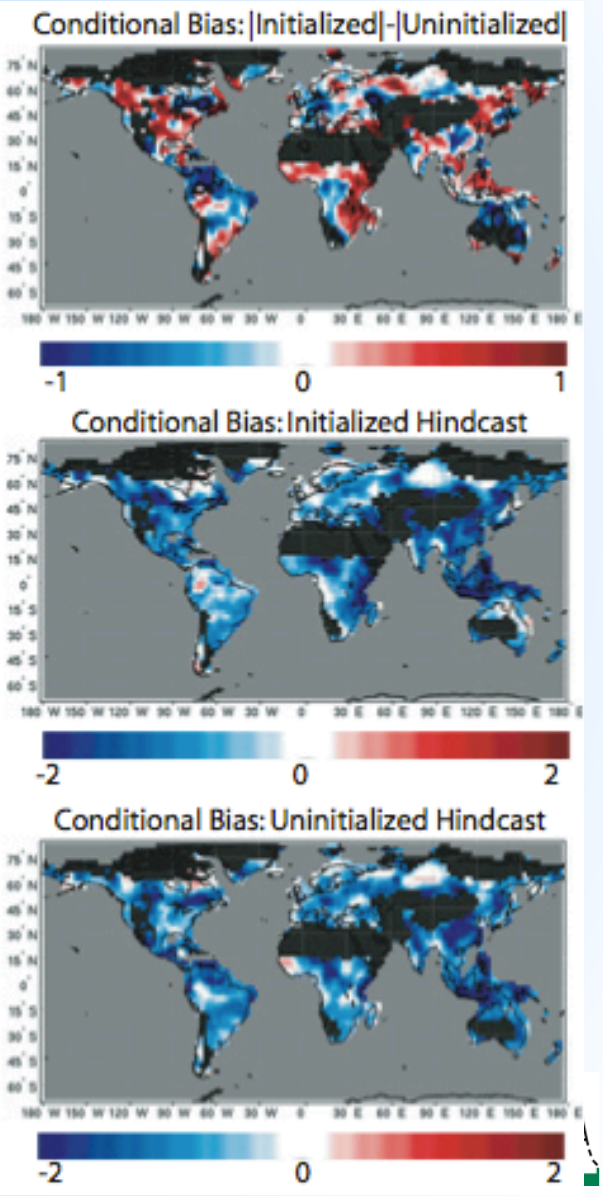


Asking Questions of the Initialized Hindcasts

Question 2: Is the model's ensemble spread an appropriate representation of forecast uncertainty on average?

→ Continuous Ranked Probability Skill Score (CRPSS)

CRPSS = 1 – ($CRPS_{fcst}$/$CRPS_{ref}$)

Q2: **Fcst** uncertainty = average ensemble spread

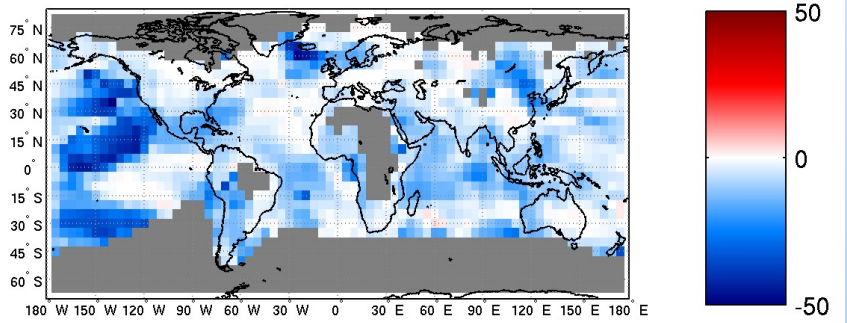
Ref uncertainty = standard error of ensemble mean

$$F = \hat{Y} + \overline{\sigma}_{Ens}; \quad R = \hat{Y} + \sigma_{StdErr}$$

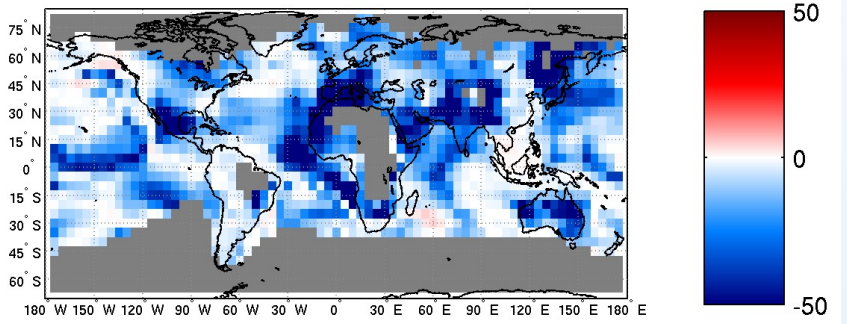
Probabilistic Metrics: CRPSS

$$F = \hat{Y} + \overline{\sigma}_{Ens}; \quad R = \hat{Y} + \sigma_{StdErr}$$

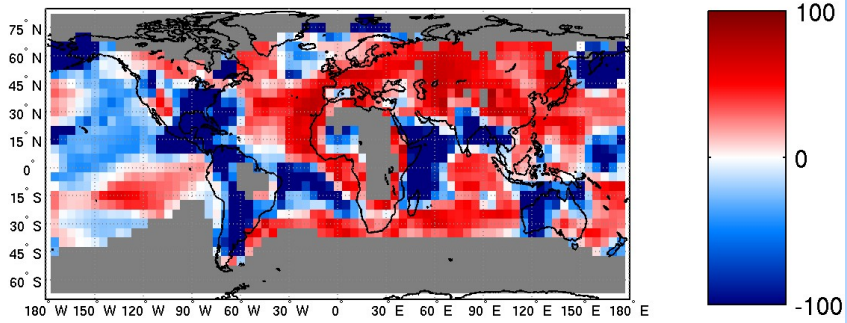
CanCM4 CRPSS (%): Year 2-9 (Obs=HadCRUT3v smooth temp)
Avg Ens Spread vs Standard Error



DePreSys CRPSS (%): Year 2-9 (Obs=HadCRUT3v smooth temp)
Avg Ens Spread vs Standard Error



CRPSS (%):Time-Avg Ens Spread vs Climo



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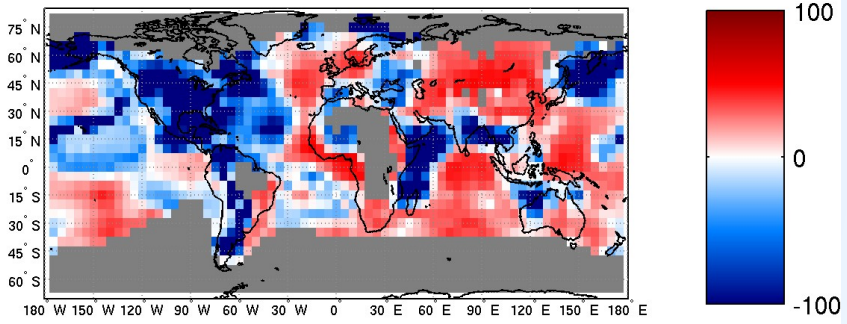
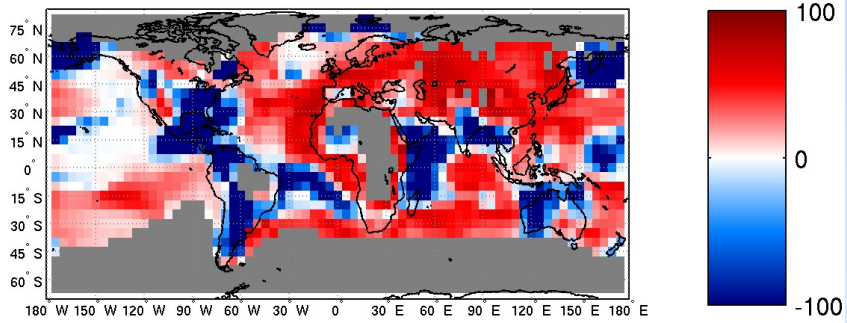


CRPSS (%):Standard Error of Ens Mean vs Climo



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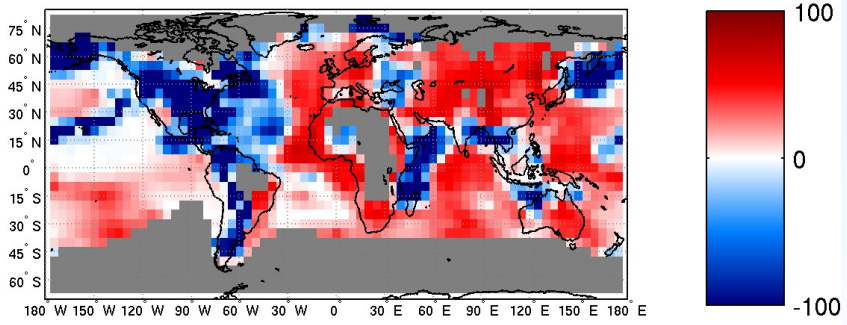
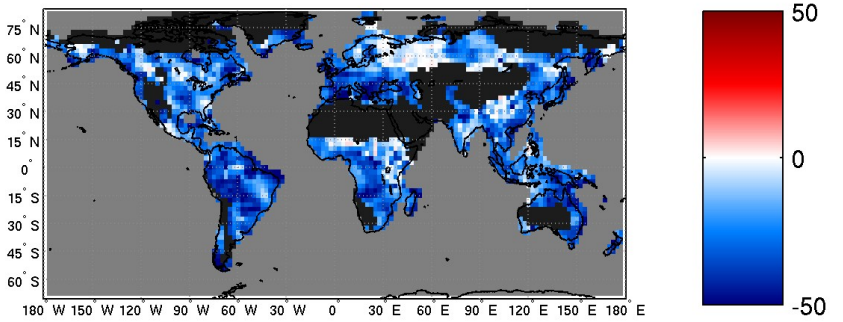


Probabilistic Metrics: CRPSS

$$F = \hat{Y} + \overline{\sigma}_{Ens}; \quad R = \hat{Y} + \sigma_{StdErr}$$

CanCM4 CRPSS (%): Year 2-9 (Obs=GPCC smooth precip)
Avg Ens Spread vs Standard Error



DePreSys CRPSS (%): Year 2-9 (Obs=GPCC smooth precip)
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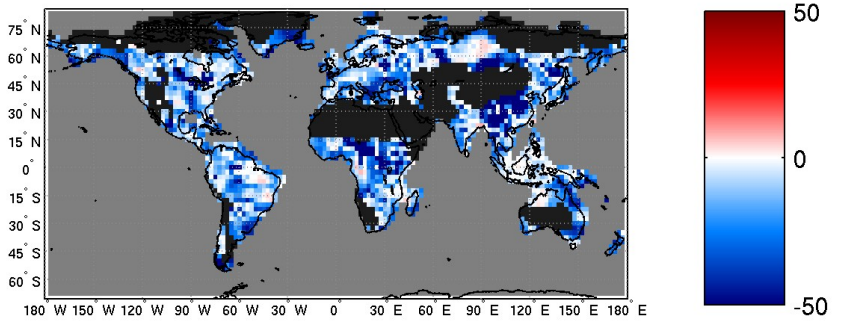
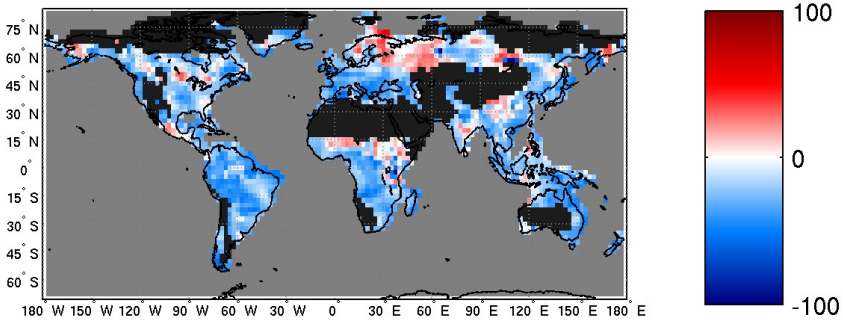


CRPSS (%):Time-Avg Ens Spread vs Climo



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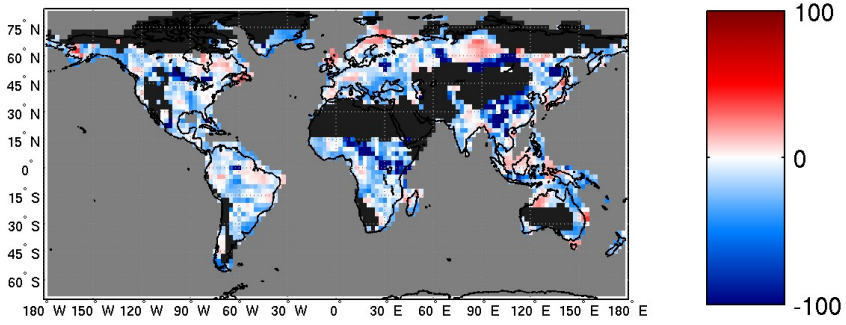

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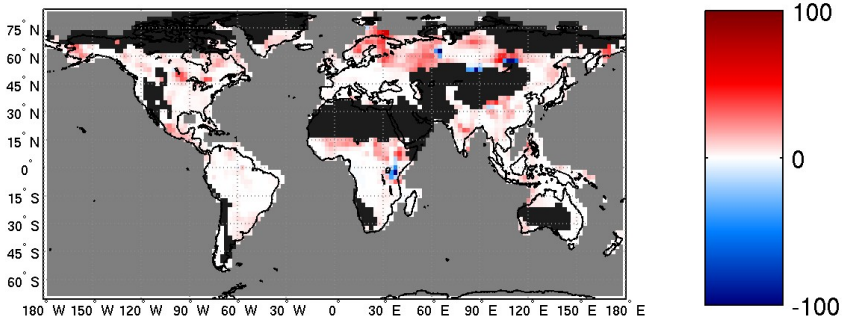

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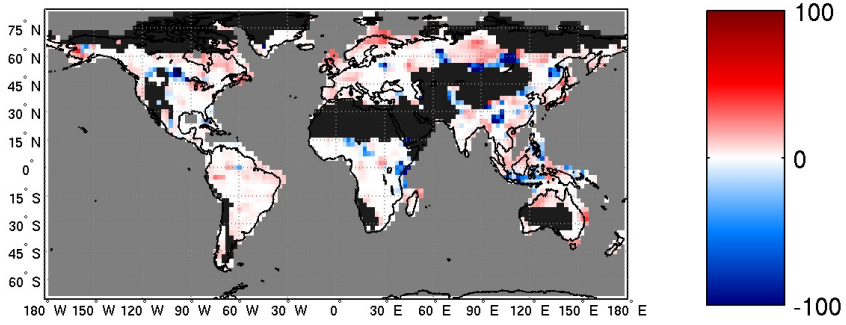


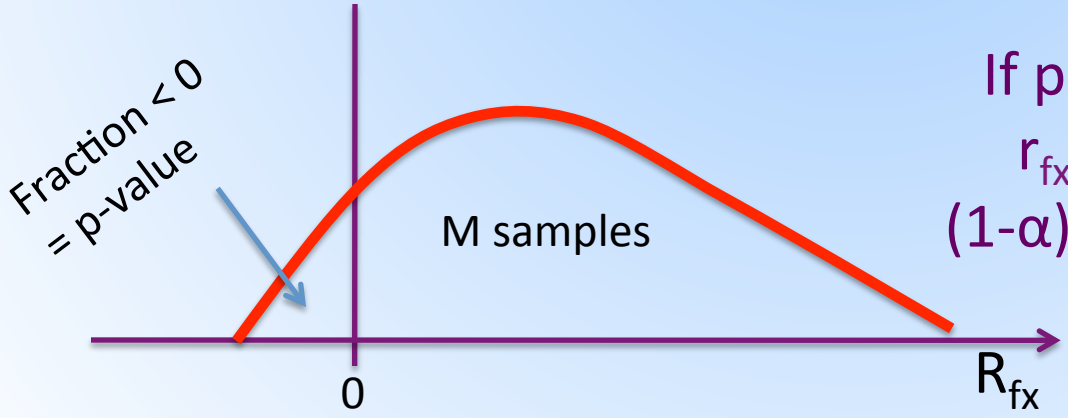
Statistical Significance: Non-parametric bootstrap

Re-sampling, with replacement: k=1,M (~1000) samples

Start out with nominally n=10 start times.
Draw random start times as pairs up to n values.
i.e. 1st draw: i=1 → e.g. I(i,k)=5 (1980), so i=2 → I(i+1,k)=6 (1985), etc.
up to i=10

For each I(i,k), draw N random ensemble members, E, with replacement

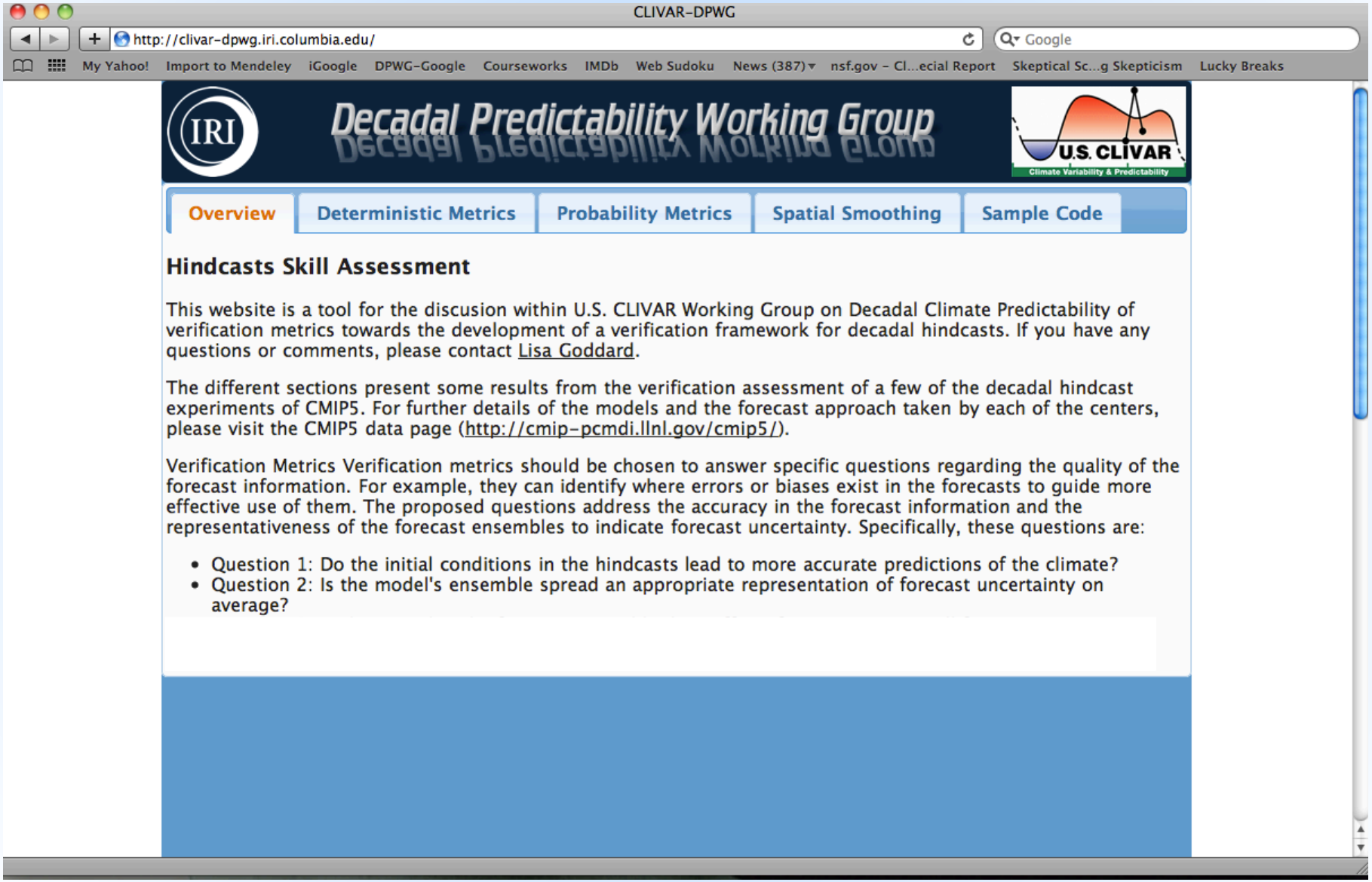
$$\tilde{f}_i^E(k) = f_{I(i,k)}^{E(I)}$$



If p-value <= α, then
r_{fx} is significant at
(1-α)x100% confidence

Proto-type Website: *Work in progress*

http://clivar-dpwg.iri.columbia.edu



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Summary

US CLIVAR Working Group on Decadal Predictability has developed a framework for verification of decadal hindcasts that allows for common observational data, metrics, temporal structure, spatial scale, and presentation

The framework addresses specific questions of the hindcast quality and offers suggestions for how they might be used.

Considerable complementary research has aided this effort in areas of bias and forecast uncertainty, spatial scale of the information, and stationarity impacts on reference period.

Paper to be submitted to Climate Dynamics.

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