

# Defining a Framework to Verify Initialized Decadal Predictions

Amy Solomon, on behalf of the

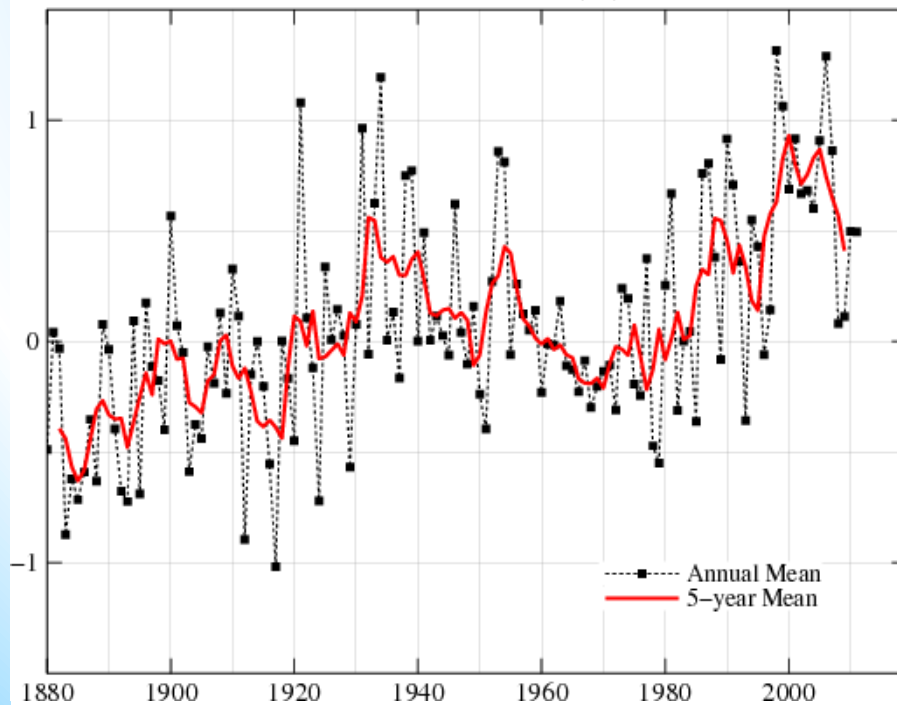
US CLIVAR Decadal Predictability Working Group & Collaborators:

Amy Solomon, Lisa Goddard, Arun Kumar,  
Rob Bergman, George Boer, James Carton, Tom Delworth, Clara Deser,  
Chris Ferro, Tom Fricker, Ichiro Fukumori, Paula Gonzalez, Arthur M. Greene,  
Ed Hawkins, Gabriele Hegerl, Slava Kharin, Ben Kirtman, Yochanan Kushnir,  
Simon Mason, Jerry Meehl, William Merryfield, Rym Msadek, Matthew Newman,  
Doug Smith, David Stephenson, Timothy Stockdale, Rowan Sutton, Dan Vimont

*...Untangling the natural and forced components of the climate is necessary since the response to external forcing may project onto or comingle with natural climate variability.  
(DPWG White Paper, BAMS 2011)*

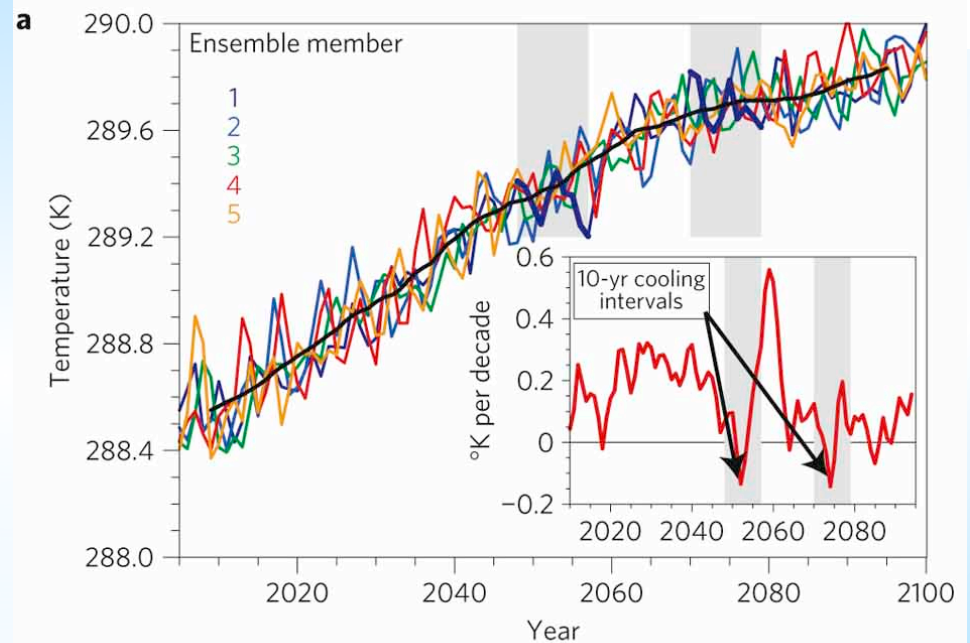
### Annual and 5-year Running Mean U.S. Surface Air Temperature

Continental US annual mean anomalies (°C) vs 1951–1980



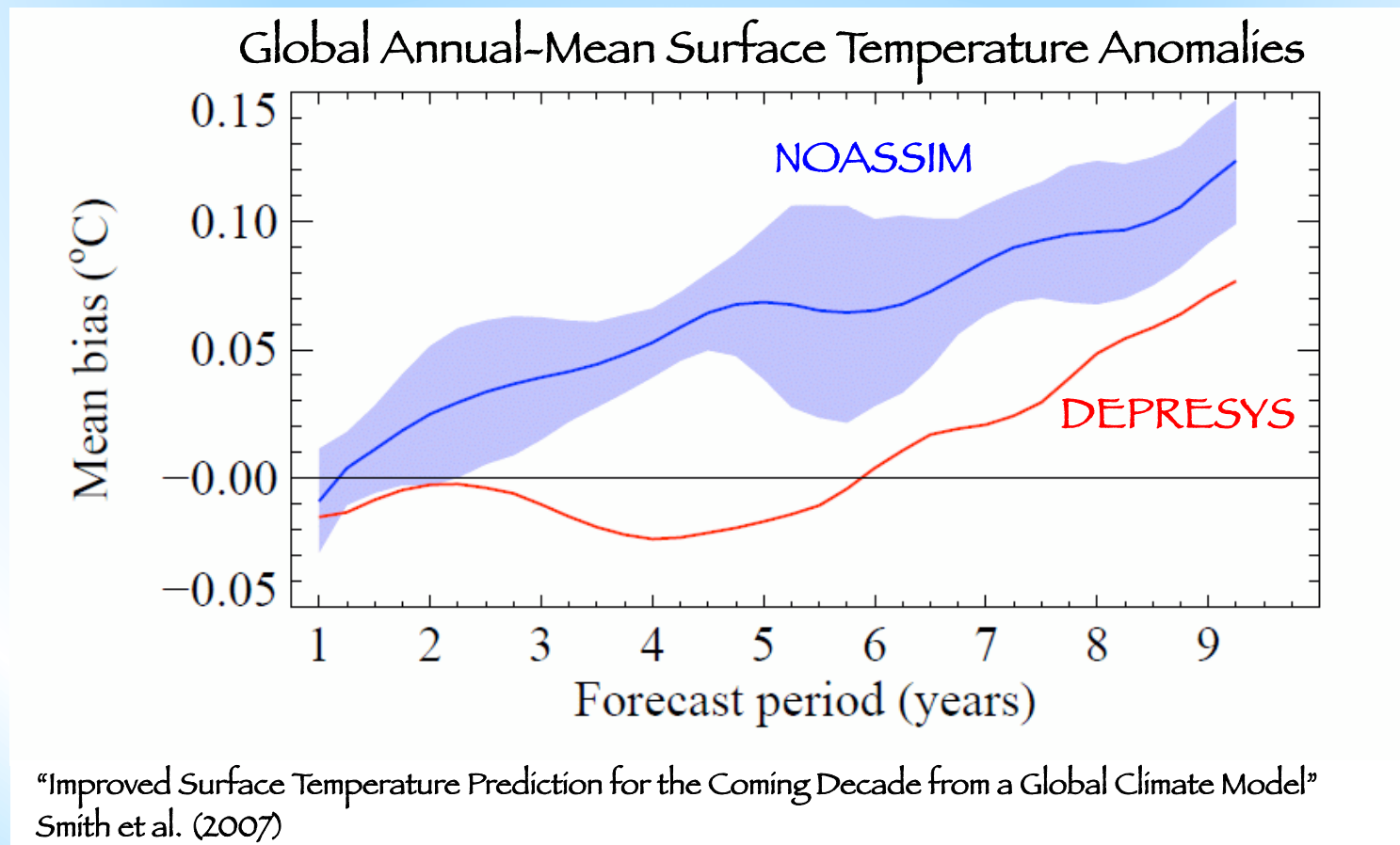
(<http://data.giss.nasa.gov/gistemp>)

### CCSM4 Annual Mean Globally Averaged Surface Temperature

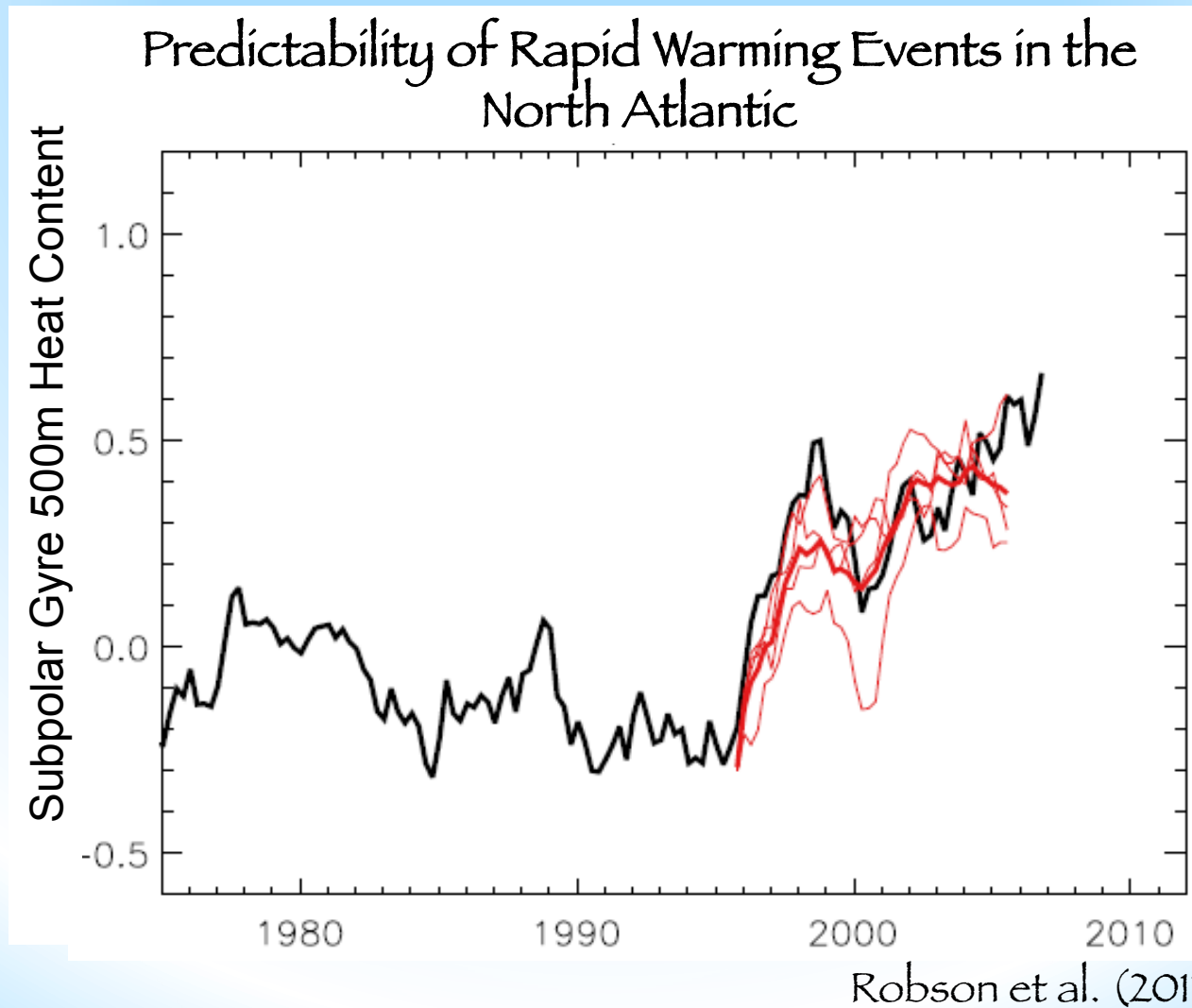


(Meehl et al. 2011)

# Motivation For Initialized DecPred Experiments: Improving Forecast Skill



# Motivation For Initialized DecPred Experiments: Predicting Natural Decadal Variability

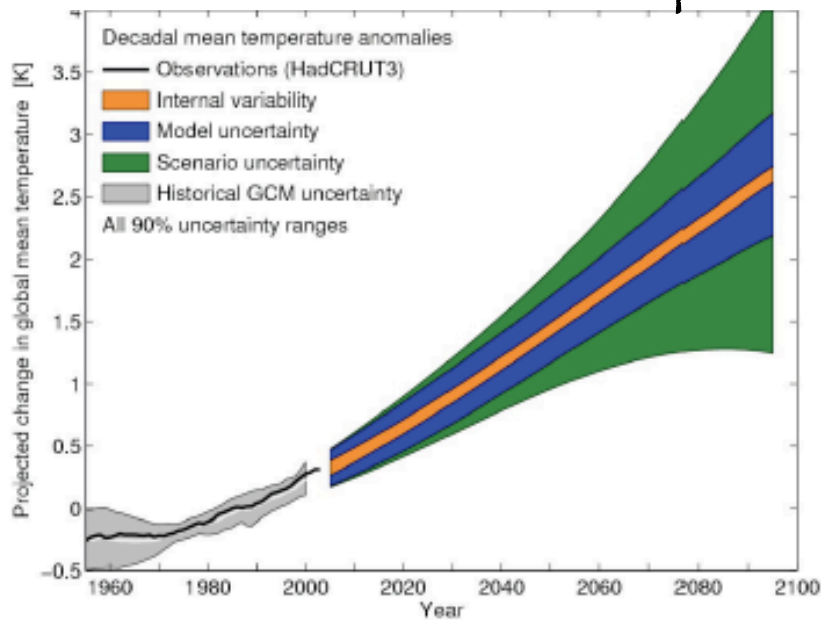




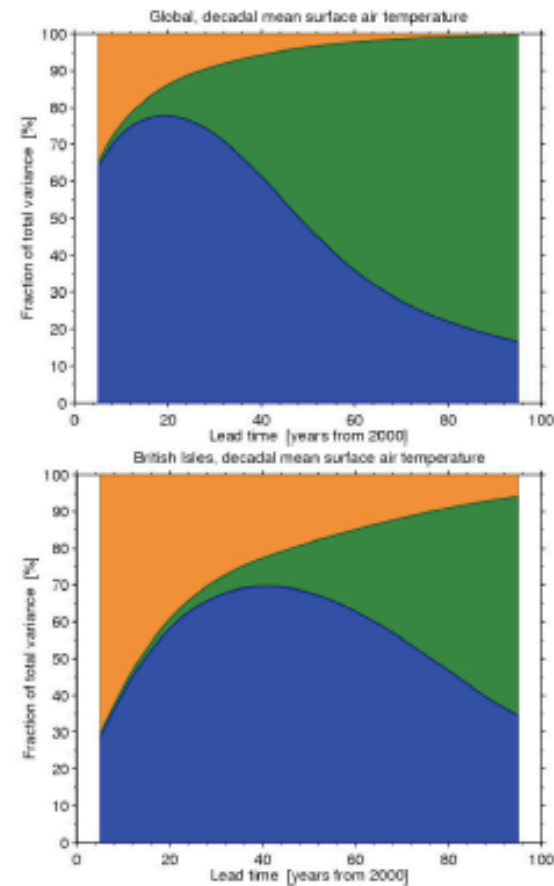
# Motivation For Initialized DecPred Experiments: Understanding Sources of Model Uncertainty

## Estimates of Uncertainty from CMIP3 Ensembles

### Decadal Mean Surface Air Temperature



Hawkins and Sutton (2009,2010)



# Motivation For Initialized DecPred Experiments: Building Trust in Climate Projections

Increasing Trust in Decadal Predictions

## Multi-Model Ensembles

-- Limited role for observations

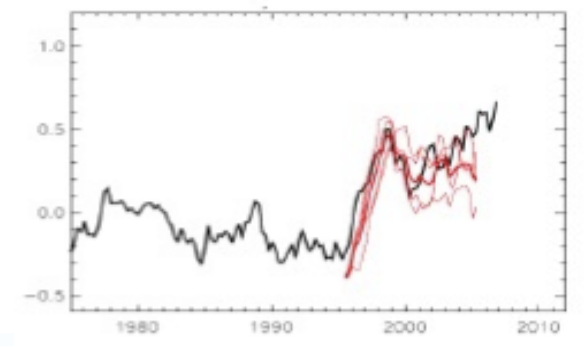
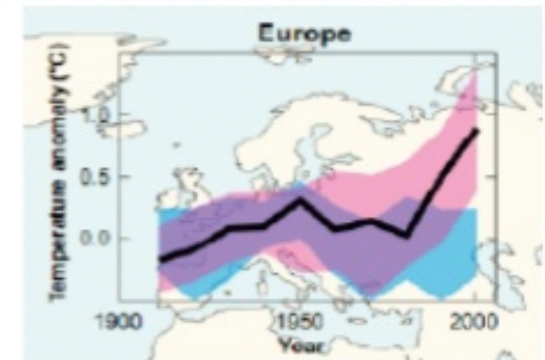
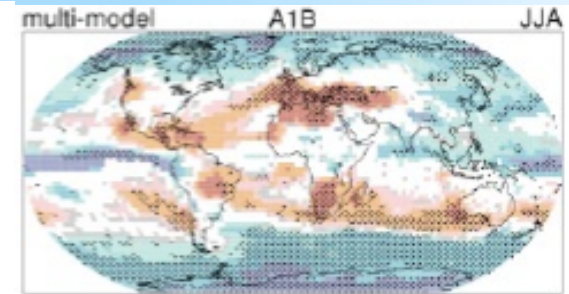
## Detection and Attribution

-- Isolate response to specific forcings

-- Model errors may lead to false attribution

## Initialized Decadal Hindcasts

-- Ability to use observations to test the fidelity of models over different time-scales and to verify simulations of different weather and climate phenomenon



# CMIP5 Initialized Decadal Prediction Experiments

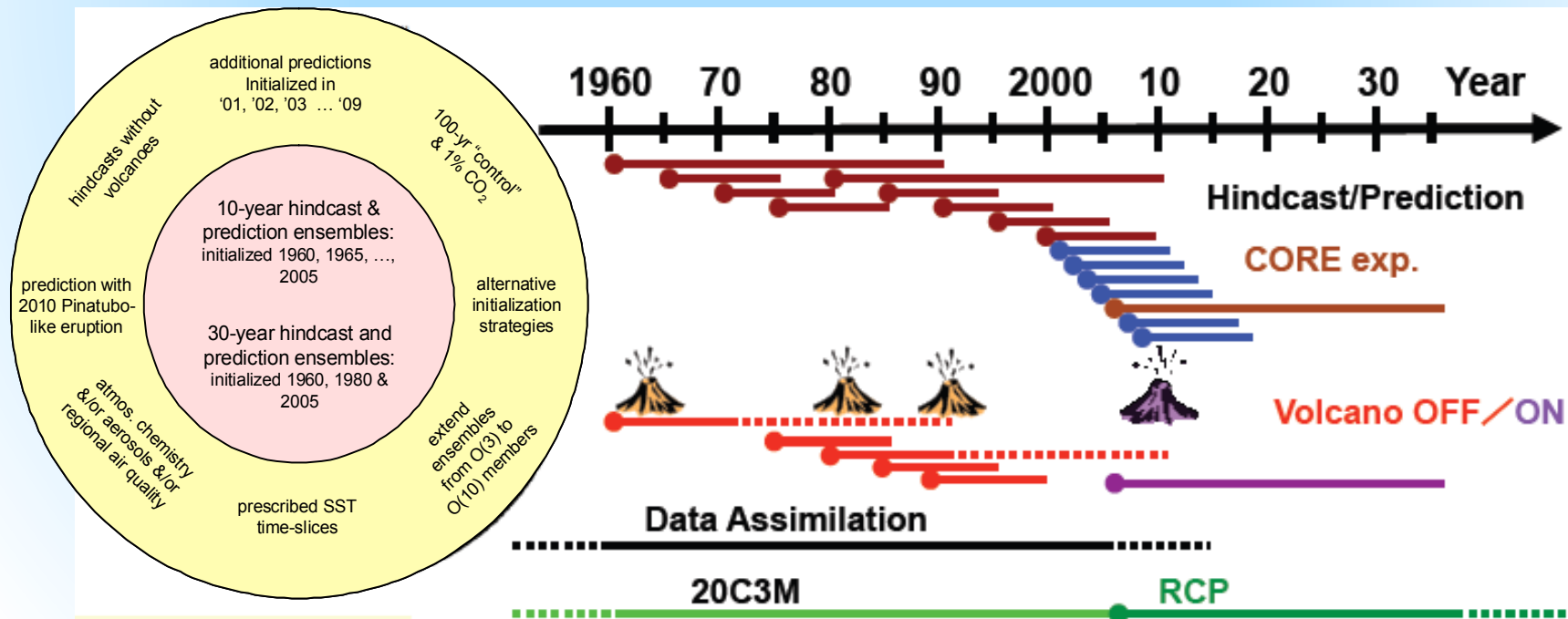


Figure 2. Schematic summary of CMIP5 decadal prediction experiments.

Taylor et al. (2008)

... There will be a new chapter in AR5 on Near-Term Climate Projections

# Challenges: Initialization Strategies

## 1) Full field initialization:

Forecast initial conditions are created by constraining model values to be close to observed values.

...Suffers from model drift and initial shocks

## 2) Anomaly initialization:

Models are initialized with observed anomalies rather than with observed total values (e.g. Pierce *et al.*, 2004, Smith *et al.*, 2007).

Overcomes drifts,

However observed anomalies might not be assimilated at optimal locations relative to features such as the Gulf Stream

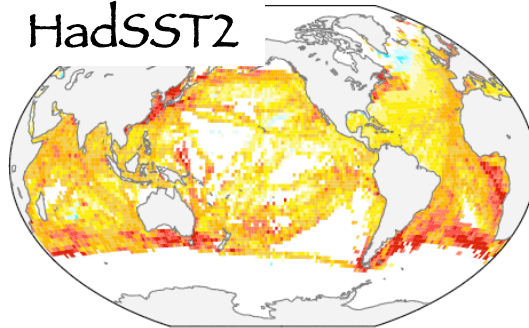
Also, Initialize Full Ocean? Ocean+Atmos? just SSTs?



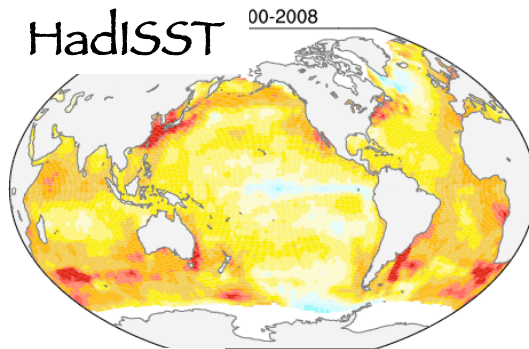
# Challenges: Validating Forced Variability

## Observed 20<sup>th</sup> Century SST Trends

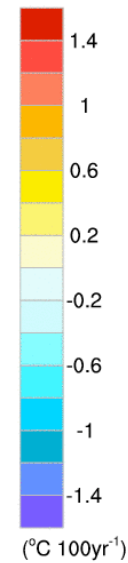
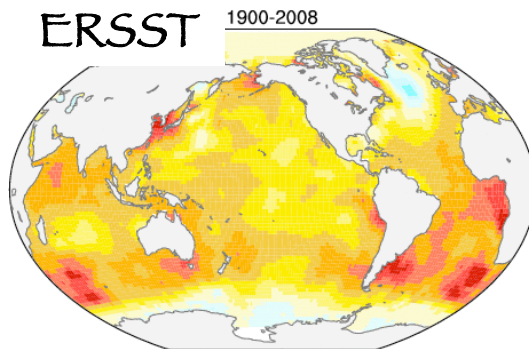
HadSST2



HadISST 00-2008



ERSST 1900-2008

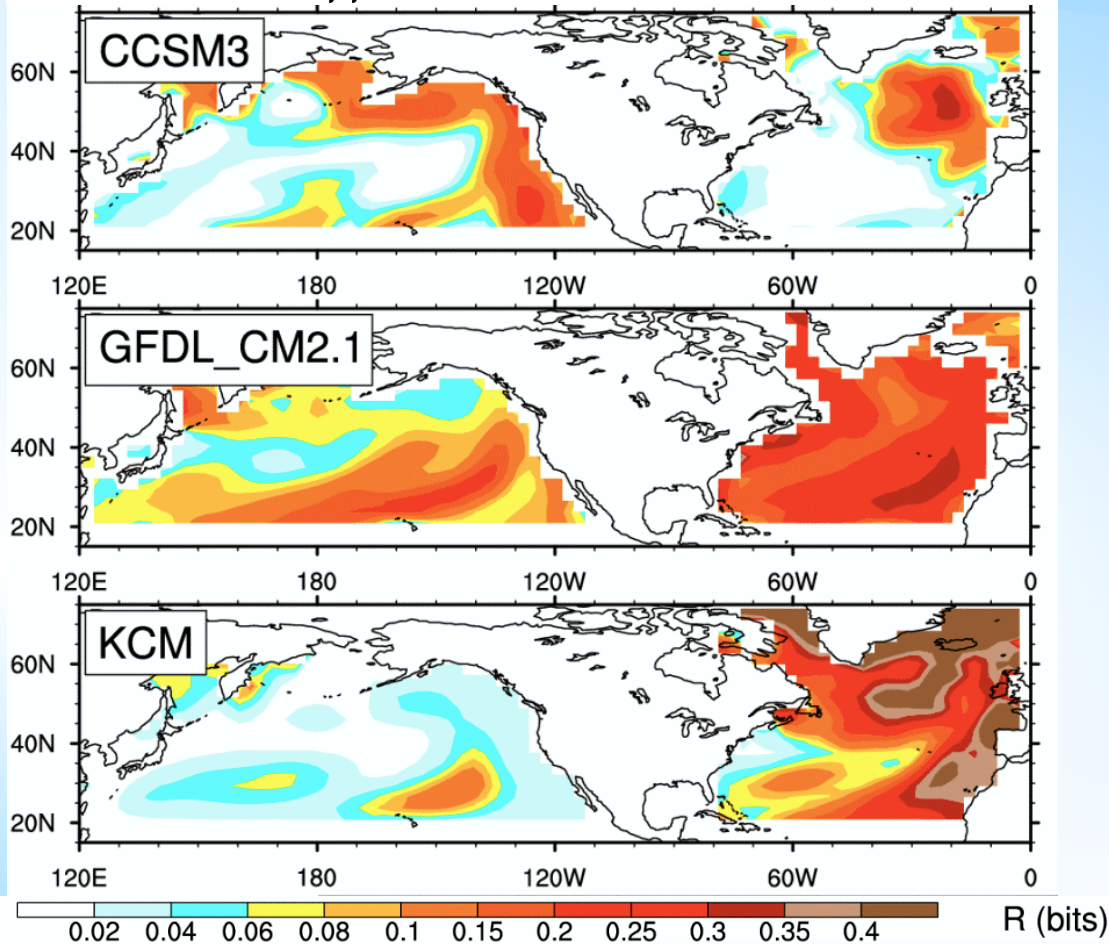


(Deser et al. 2010)

# Challenges: Predictability of Natural Variability

## Model-Dependent Regional Structure

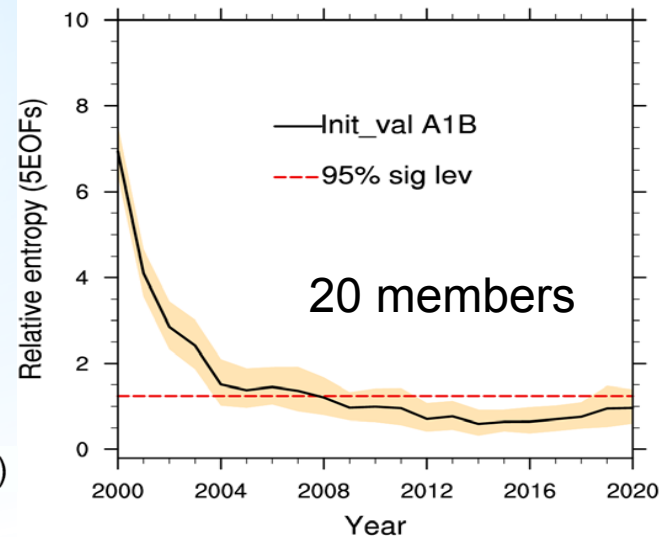
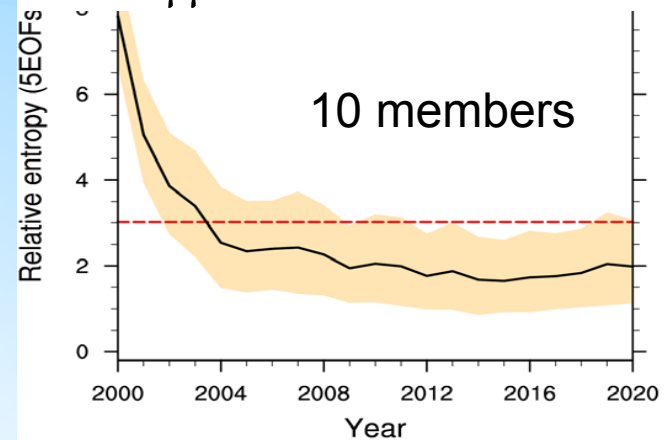
Relative Entropy for years 6-10 of  
Upper Ocean Heat Content



(Branstator et al. 2011)

## Estimating Predictability Requires Large Ensembles

Relative Entropy of  
Upper Ocean Heat Content



(Branstator and Teng 2010)

# Need for Coordinated Verification

In order to:

- 1) Compare forecast *systems* across modeling centers
- 2) Evaluate successive generations of the same forecast system and document improvements over time
- 3) Provide feedback to the modelers regarding model biases
- 4) Manage user expectations in terms of the utility of the forecast information based on hindcast skill

# Need for Coordinated Verification

A verification framework has been developed by the US CLIVAR Decadal Predictability Working Group...

## **A Verification Framework for Interannual-to-Decadal Predictions Experiments**

By L. Goddard<sup>1\*</sup>, A. Kumar<sup>2</sup>, A. Solomon<sup>3</sup>, D. Smith<sup>4</sup>, G. Boer<sup>5</sup>, P. Gonzalez<sup>1</sup>, C. Deser<sup>6</sup>, S. Mason<sup>1</sup>, B. Kirtman<sup>7</sup>, R. Msadek<sup>8</sup>, R. Sutton<sup>9</sup>, E. Hawkins<sup>9</sup>, T. Fricker<sup>10</sup>, S. Kharin<sup>5</sup>, W. Merryfield<sup>5</sup>, G. Hegerl<sup>11</sup>, C. Ferro<sup>10</sup>, D. Stephenson<sup>10</sup>, G.A. Meehl<sup>6</sup>, T. Stockdale<sup>12</sup>, R. Burgman<sup>7</sup>, A. Greene<sup>1</sup>, Y. Kushnir, M. Newman<sup>3</sup>, J. Carton<sup>13</sup>, I. Fukumori<sup>14</sup>, D. Vimont<sup>15</sup>, T. Delworth<sup>8</sup>  
Submitted to Climate Dynamics

The framework will provide information on forecast quality across prediction systems, such that relative comparisons can be made, and provides a baseline against which future improvements can be quantified.



# Asking Questions of the DecPred Experiments

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?

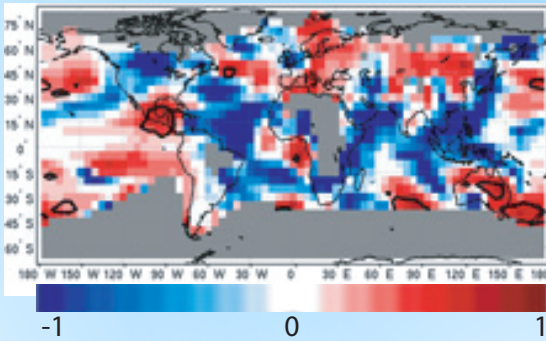
Question 3: In the case that the forecast ensemble does offer information on overall forecast uncertainty, does the forecast-to-forecast variability of the ensemble spread carry meaningful information?

# Deterministic Metrics: Mean Squared Skill Score (MSSS)

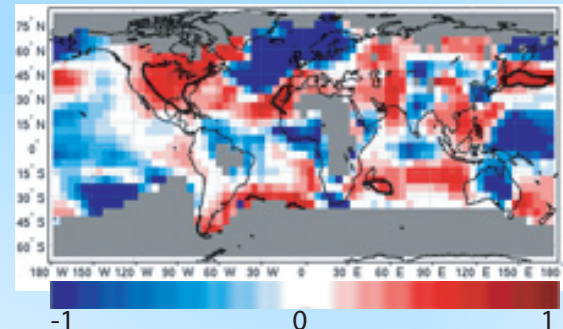
DePreSys: Years 2-9

CanCM4: Years 2-9

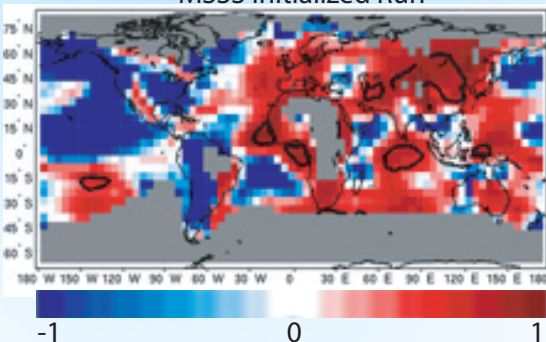
Initialized vs Uninitialized



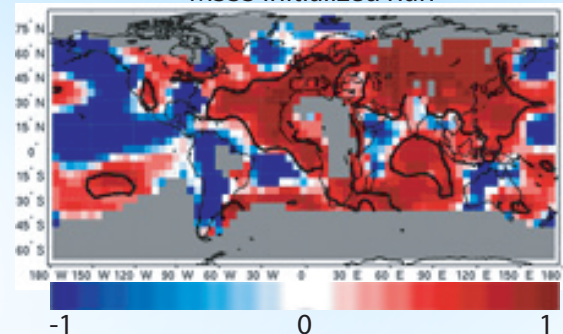
Initialized vs Uninitialized



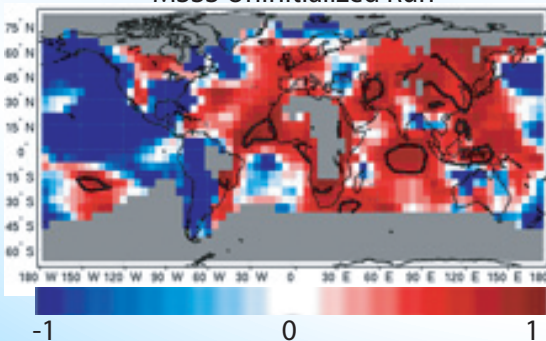
MSSS Initialized Run



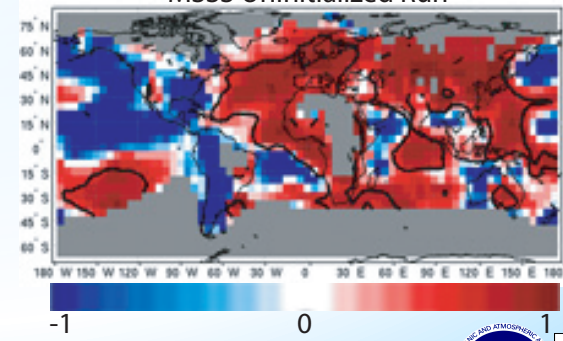
MSSS Initialized Run



MSSS Uninitialized Run



MSSS Uninitialized Run

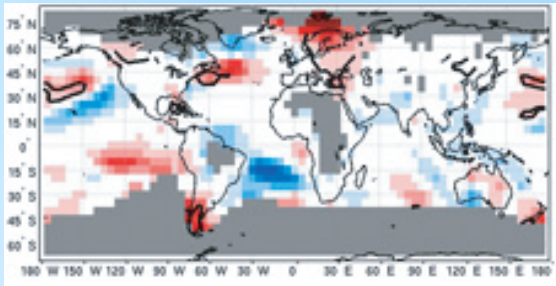




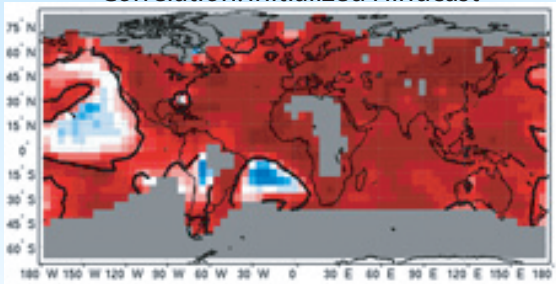
# Deterministic Metrics: Mean Squared Skill Score (MSSS)

Hadley Centre DePreSys Years 2-9

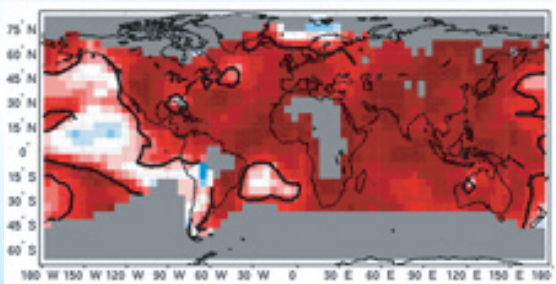
Anomaly Correlation  
Correlation: Initialized - Uninitialized



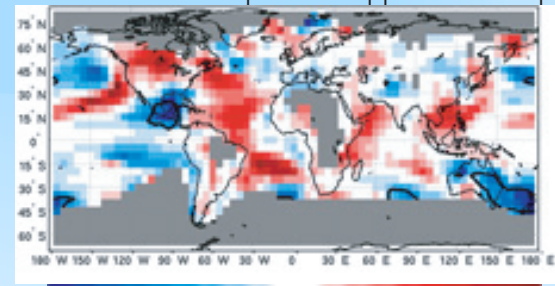
Correlation: Initialized Hindcast



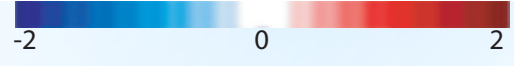
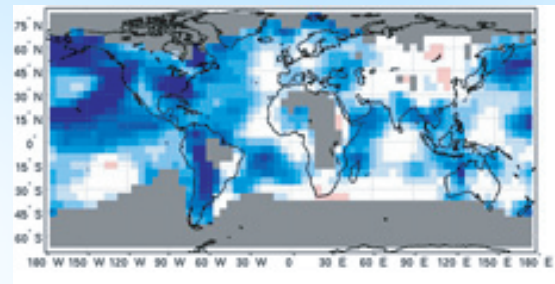
Correlation: Uninitialized Hindcast



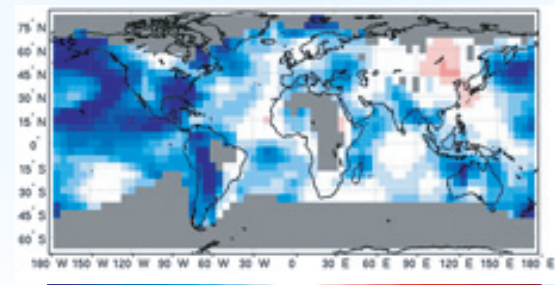
Conditional Bias  
Conditional Bias: |Initialized| - |Uninitialized|



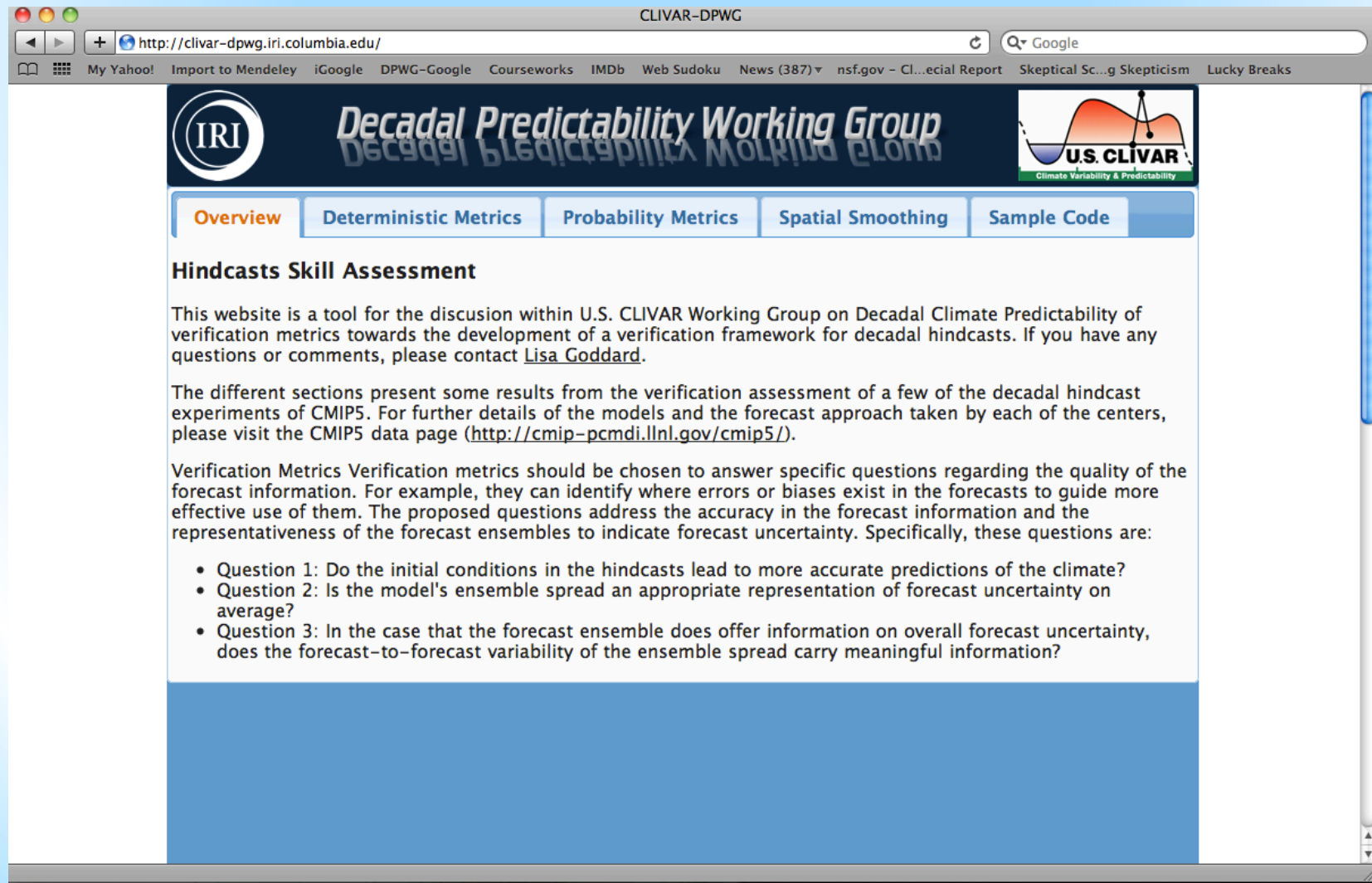
Conditional Bias: Initialized Hindcast



Conditional Bias: Uninitialized Hindcast



# DPWG Metrics Website: <http://clivar-dpwg.iri.columbia.edu>



The screenshot shows a web browser window with the URL <http://clivar-dpwg.iri.columbia.edu/>. The page features the IRI logo and the title "Decadal Predictability Working Group". A navigation menu includes "Overview", "Deterministic Metrics", "Probability Metrics", "Spatial Smoothing", and "Sample Code". The main content area is titled "Hindcasts Skill Assessment" and contains the following text:

This website is a tool for the discussion within U.S. CLIVAR Working Group on Decadal Climate Predictability of verification metrics towards the development of a verification framework for decadal hindcasts. If you have any questions or comments, please contact [Lisa Goddard](#).

The different sections present some results from the verification assessment of a few of the decadal hindcast experiments of CMIP5. For further details of the models and the forecast approach taken by each of the centers, please visit the CMIP5 data page (<http://cmip-pcmdi.llnl.gov/cmip5/>).

Verification Metrics Verification metrics should be chosen to answer specific questions regarding the quality of the forecast information. For example, they can identify where errors or biases exist in the forecasts to guide more effective use of them. The proposed questions address the accuracy in the forecast information and the representativeness of the forecast ensembles to indicate forecast uncertainty. Specifically, these questions are:

- 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?
- Question 3: In the case that the forecast ensemble does offer information on overall forecast uncertainty, does the forecast-to-forecast variability of the ensemble spread carry meaningful information?



## To Modeling Centers and Users of Decadal Forecasts:

Coordinate with the scientific community by

-----Posting results of diagnostic studies on the IRI DecPred website

-----Proposing additional metrics to validate the forecasts