Predictability
A Continuing Saga of Controversies

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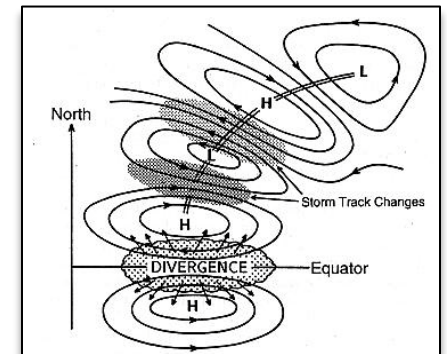# Estimating (limits on) Predictability

- What are the limits of predictability in the observable system – the glass ceiling?

- Is this an open ended or even a well posed question?

- How our efforts in improving models and observing system improving predictability estimates?

Why one cares?

- Managing expectations
  - Users
  - Managers
- Allocating limited resources
  - Challenges in improving models to harvest <u>known</u> predictability
  - Investigations in sources of predictability
  - Optimizing modeling framework (ensemble size; hindcast period; resolution;...) to extract maximum amount of predictability
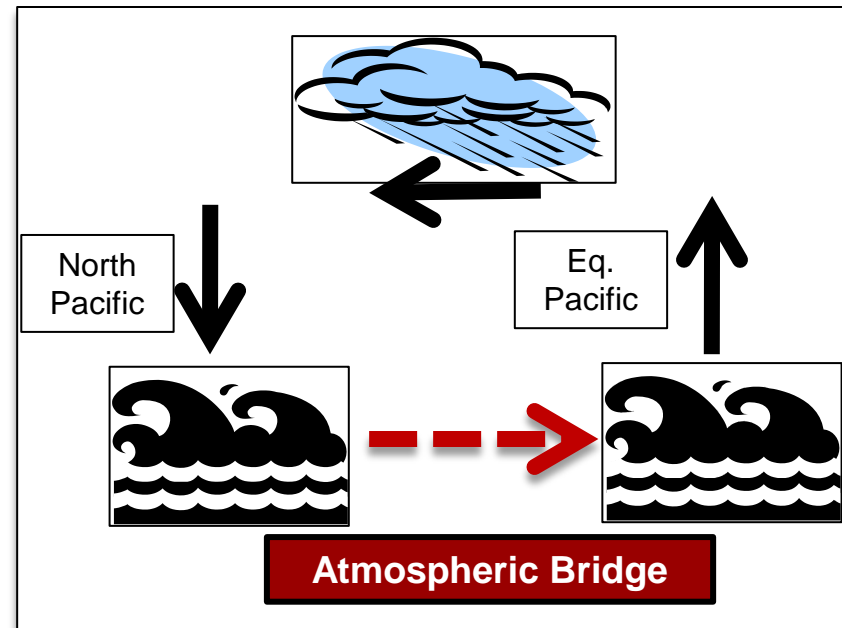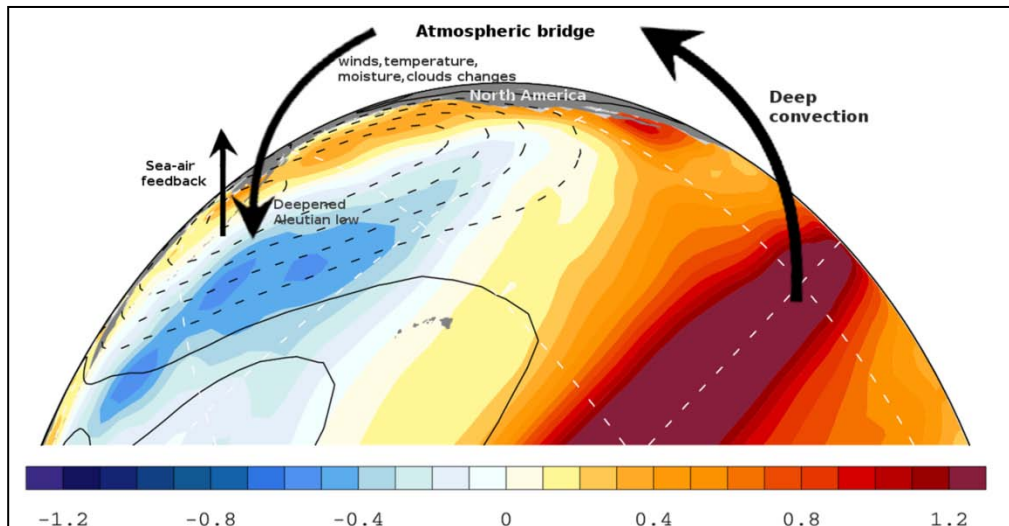
Science Based Limitations on Estimating/Realizing Predictability and Prediction Skill

- <u>Establishing indications of predictability</u> based on known teleconnections to modes of climate variability
  - ENSO SSTs
  - MJO
  - Soil moisture (hot spots)
  - Snow & sea-ice
  - Stratosphere – troposphere connections
- Either the modes of climate variability cannot be well <u>simulated</u>; or well predicted; or issues with replicating <u>teleconnections</u>
- Model development challenge

# Science Based Limitations on Estimating/Realizing Predictability and Prediction Skill

- ## Possible issues
  - Cross-validation in the estimate of prediction skill
  - Differentiating between impact vs. consistency → A false sense of predictability

Noise Based Limitations on Estimating Predictability and Prediction Skill

- Deterministic chaos due to errors in the specification of initial condition

- Uncertainty is a fundamental feature; it can never be removed but could be better quantified

- Highly controversial issue
  - Should this even be tried?
  - Potential predictability assessments leading to widely different estimates

- It is not possible to quantify a true *limit of predictability* for the climate system.
- Quantitative statements can be made regarding the *lower bounds* of predictability, as derived by the performance of existing forecast systems. If a forecast system shows quantitative skill according to some metric, then at least that much predictability must exist in nature.
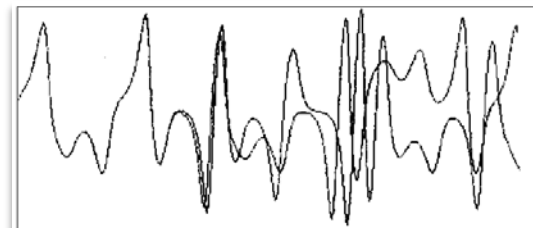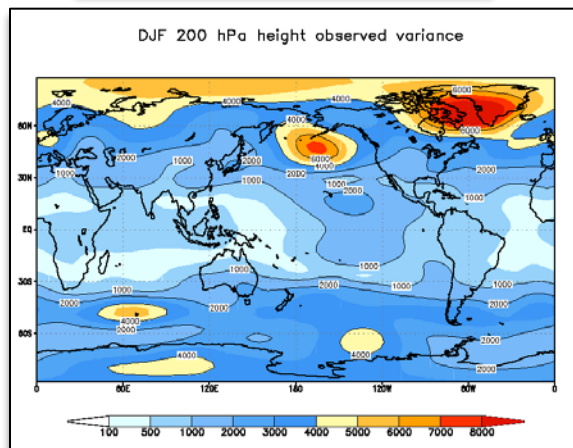
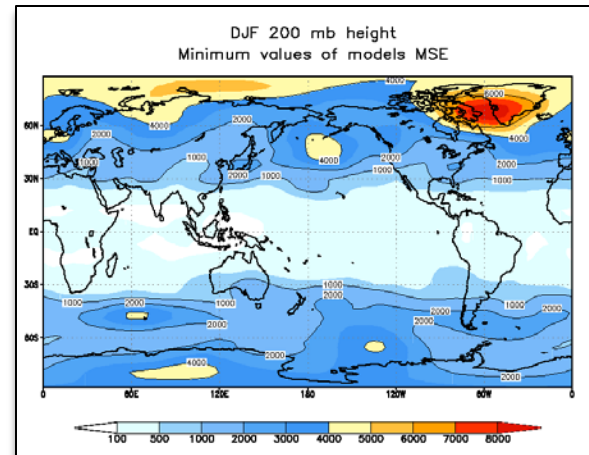# The Basic Question of Estimating Predictability

- Observed variance and its decomposition into predictable and noise component

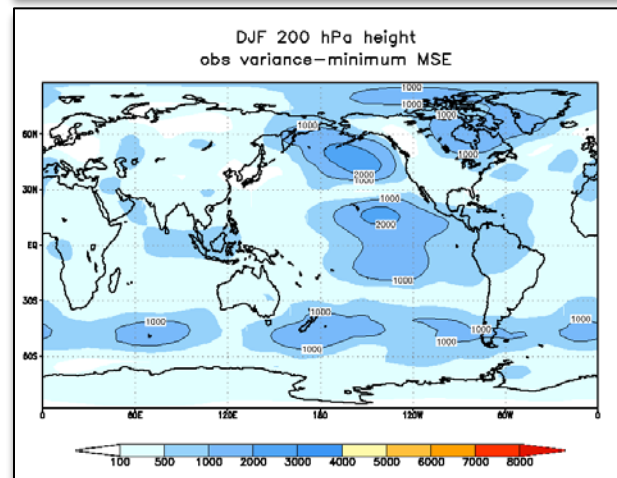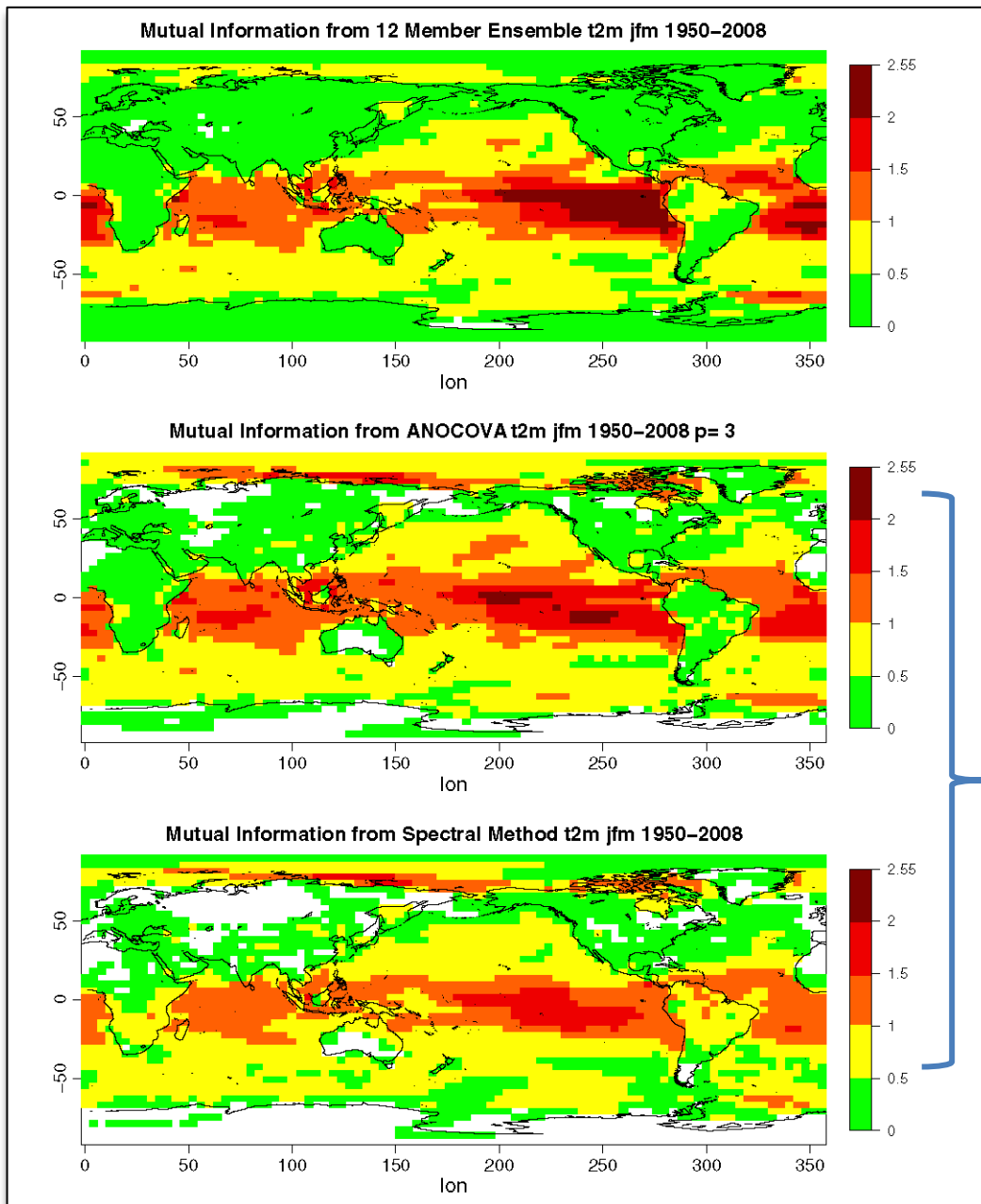# The Basic Question of Estimating Predictability

Total Variability

DJF 200 hPa height observed variance

?

DJF 200 mb height
Minimum values of models MSE

Noise

Related to Ext. Factors

DJF 200 hPa height
obs variance−minimum MSE

Methods for Estimating Predictability: Observational

- Methods based on daily time-series
  - Underlying assumptions (but could be verified)
- Analog approach (limited by data)
- Predictor – Predictand relationships
  - Generally linear approaches
    - Regressions
    - CCA
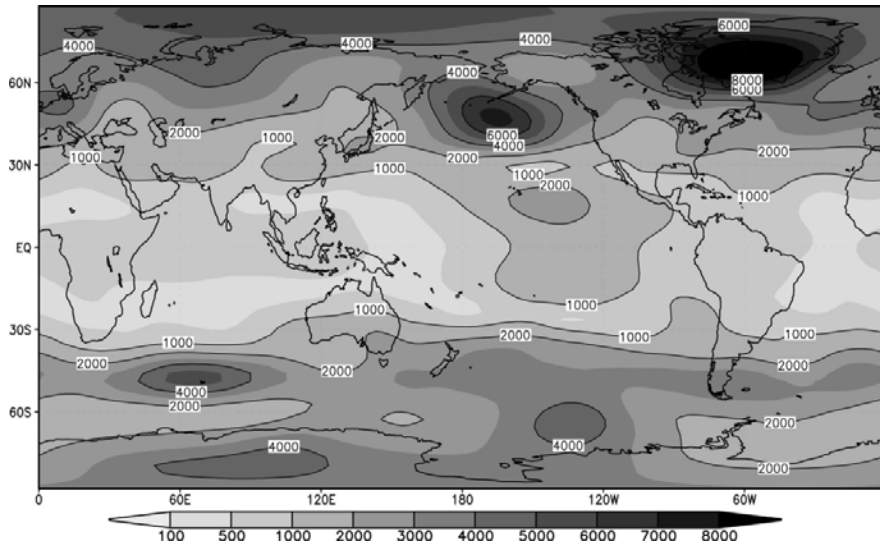- Simple; Unbiased, but non-linearity is hard to incorporate

Mutual Information from 12 Member Ensemble t2m jfm 1950–2008

Mutual Information from ANOCOVA t2m jfm 1950–2008 p= 3

Mutual Information from Spectral Method t2m jfm 1950–2008

Ensemble Based

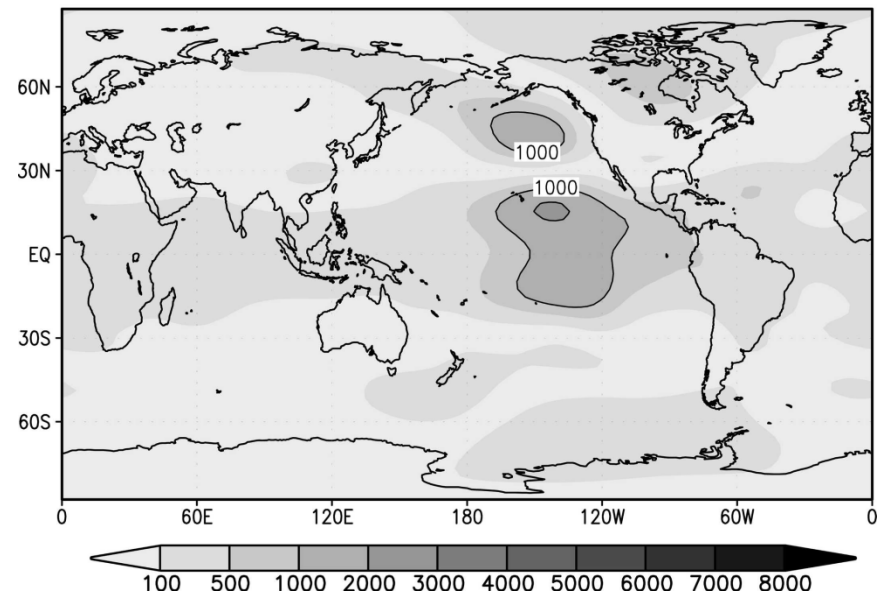Based on Daily Data from Model Simulations

Linear Regression Based Predictability Estimate

Observed 200-mb Z Variance

Variance Accounted by Nino3.4

Methods of Estimating Predictability: Models

- Ensemble can be used to estimate signal and uncertainty (spread)
- Not limited by linear assumptions
- Resource intensive
- Estimates are influenced by model biases
- Simulations from multiple models can used to improve estimates of predictability

CMC2 Forecast for Nino 3.4 IC= 201406

Estimates of Potential
Predictability differ widely

Model 1

Model 2

CMC1 Forecast for Nino 3.4 IC= 201406
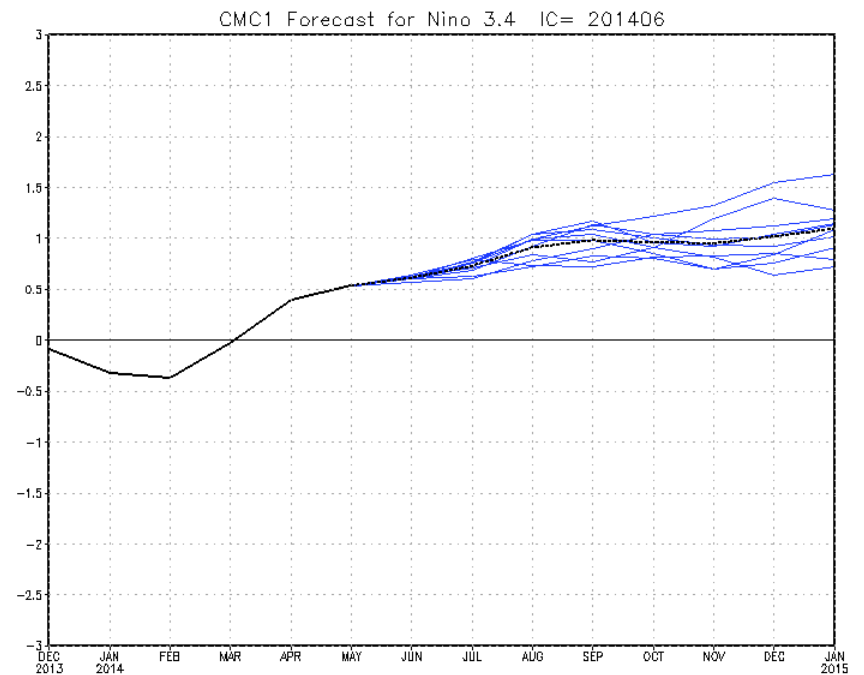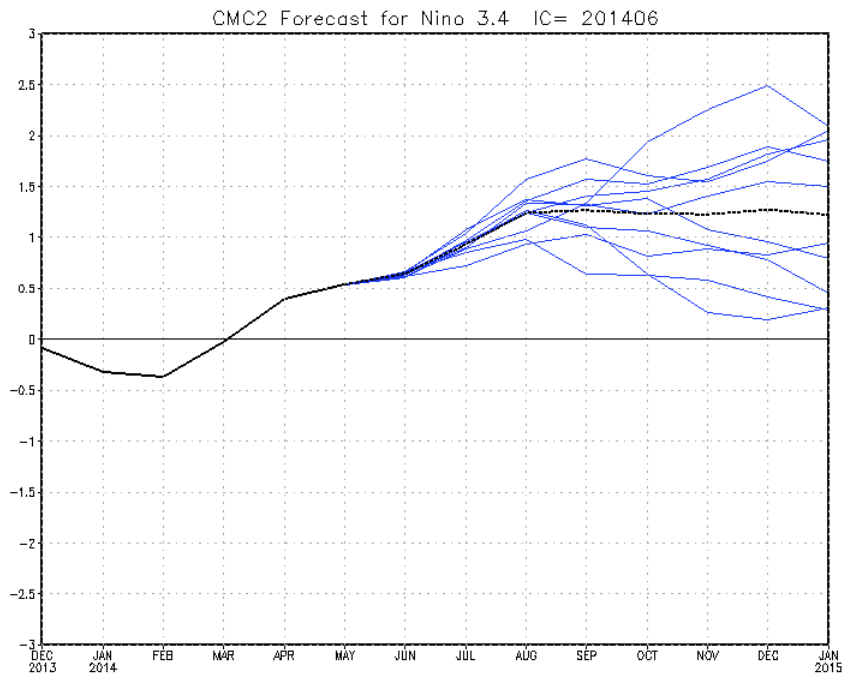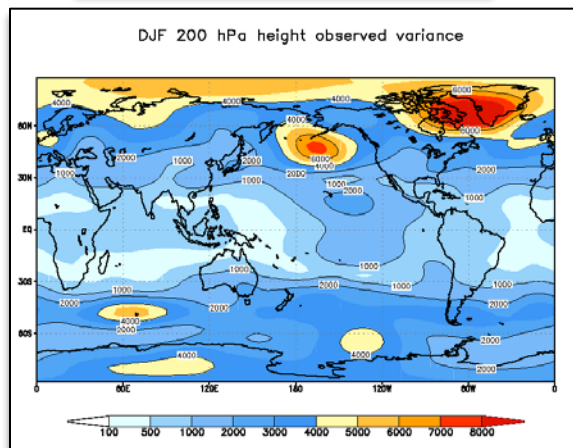
Multi-model Estimate of Predictability

$$RMSE_a = \left\langle \left(F_{ej} - O_j \right)^2 \right\rangle$$

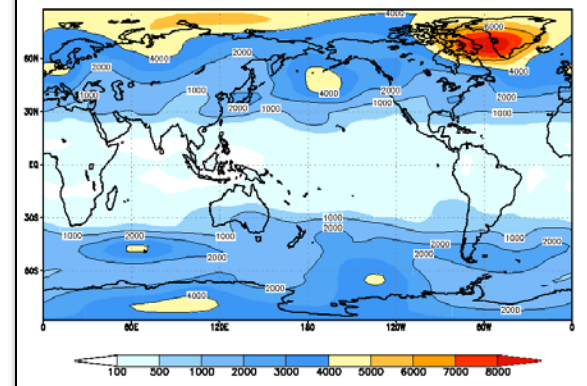$$RMSE_a = \sigma_i^2 + \left\langle \left(\mu_{ej} - \mu_{oj} \right)^2 \right\rangle$$

- Positive definite
- Minimum value is the noise in observations
- Pick up the minimum value from estimates based on different models

→

Multi-model Estimate of Predictability
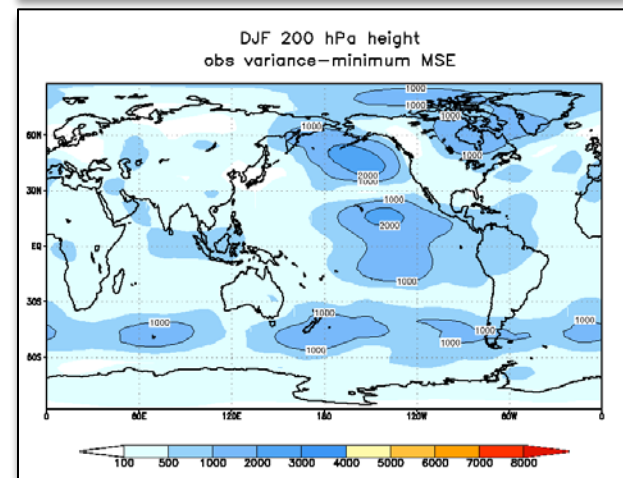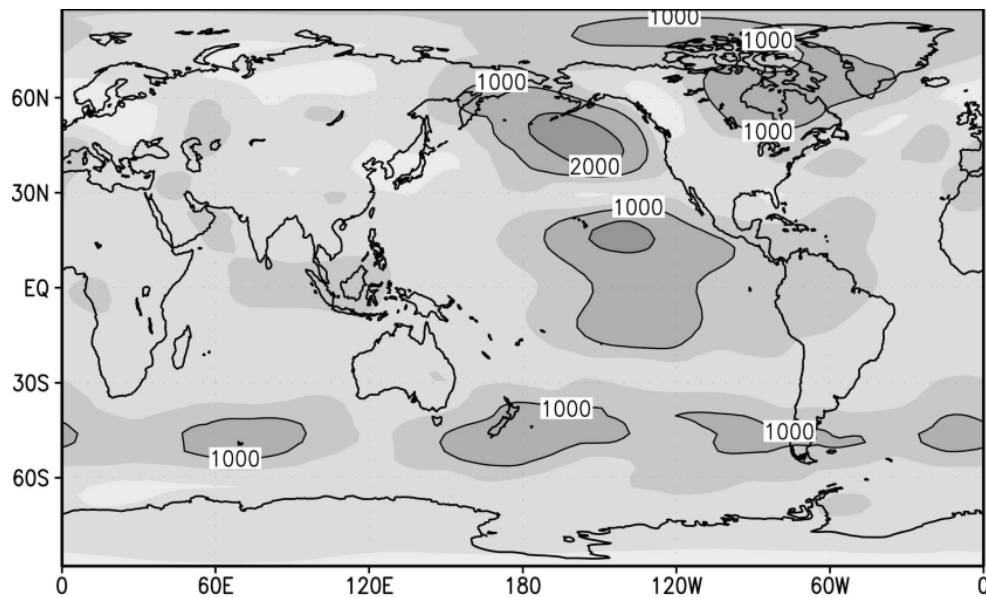
Total Variance

Noise

Related to Ext. Factors

# Can we really not estimate predictability?

- Progression of predictability estimates

  - Linear regression with Nino 3.4 (observations)

  - Estimates based on daily data (observations)

  - Ensemble mean (single model)

  - Ensemble mean (multiple models)

- Various estimates are in same ball park

- Similar to Taylor's expansion…for a convergent series, higher order terms contribute less and less

- What above means is a matter of interpretation

Ensemble Based
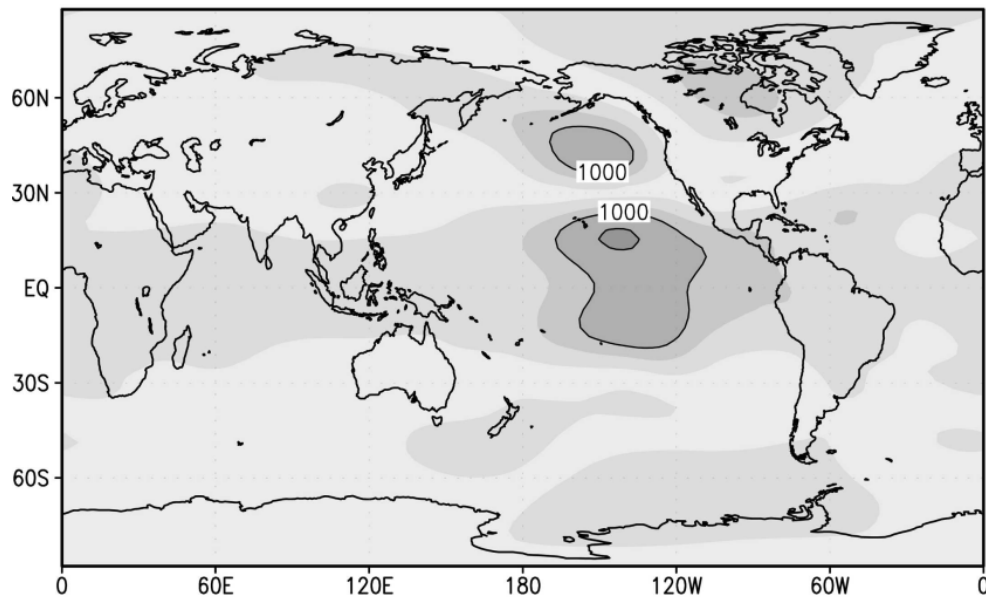
Linear: Variance
Accounted by Nino3.4

100 500 1000 2000 3000 4000 5000 6000 7000 8000
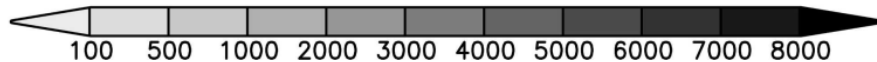
Dangers of Estimating Potential Predictability (PP) Based on Models

- PP estimates differ widely from one model to another
- If model is a perfect rendition of observational variability, then [actual skill = perfect prog skill]
- If model has biases then there are no constraints which what PP AC can go. Perfect prog AC skill can be lower or higher than actual skill

AC SKILL OF DJF SST HCST with Oct IC(1982–2009)
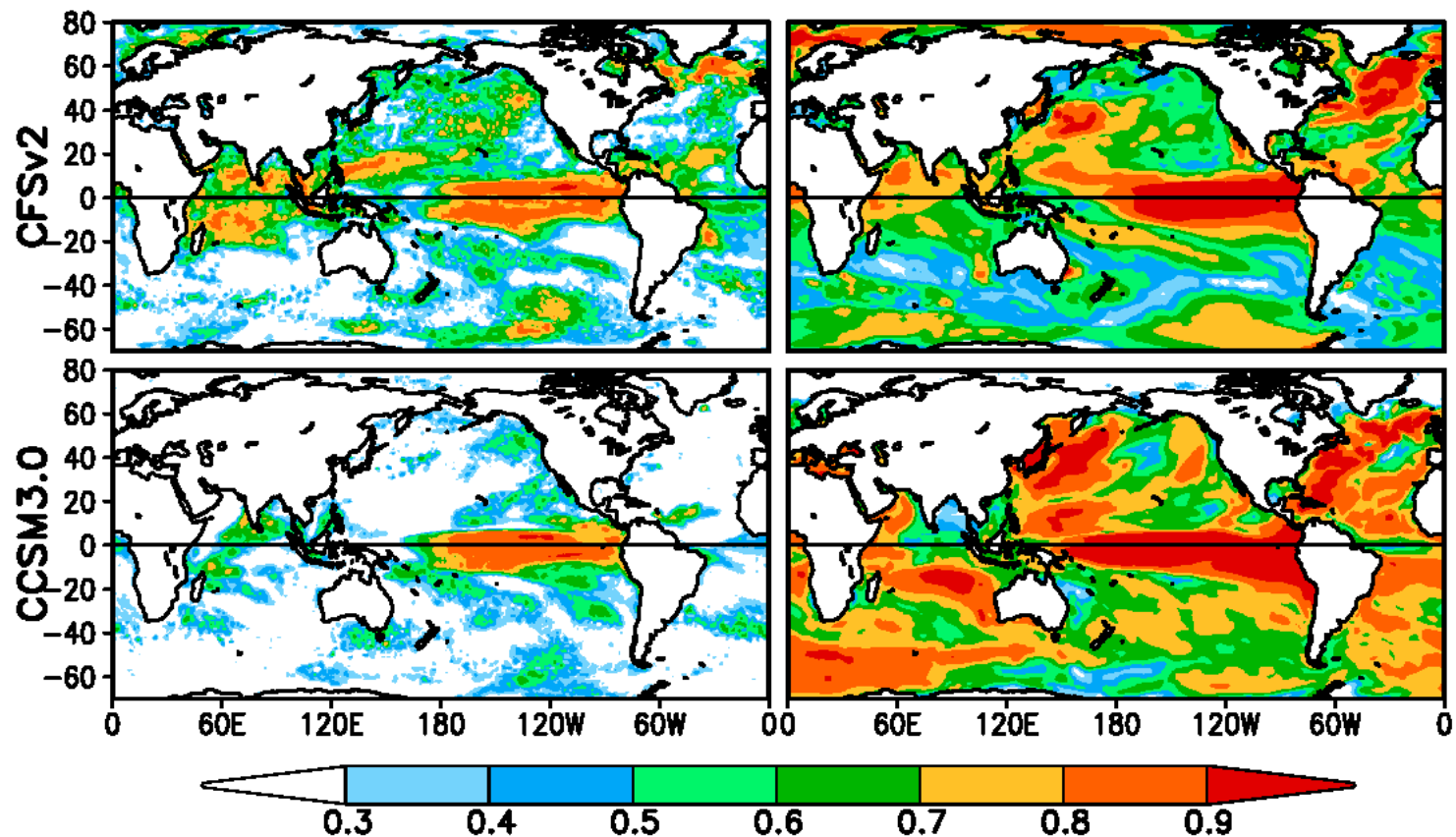
Some Other Comments

- Is the question of estimating predictability even a well posed question?
  - There is an upper limit
  - NRC report statement
- There is a difference between *understanding* and its usefulness for *prediction*...Understanding can as well be about what is not predictable
- Recognizing that there is a considerable low-frequency variability; predictability estimates could easily vary from one epoch to another

Recommendations

- Develop a time history for the estimates of predictability (and prediction skill) to chart progress. Repeat the exercise after every *n* years

- Estimates should follow an open and agreed upon procedures

- US CLIVAR could develop a summary paper of various methodologies for estimating predictability, including their pros and cons