Variability and Predictability in Long-Range Predictions

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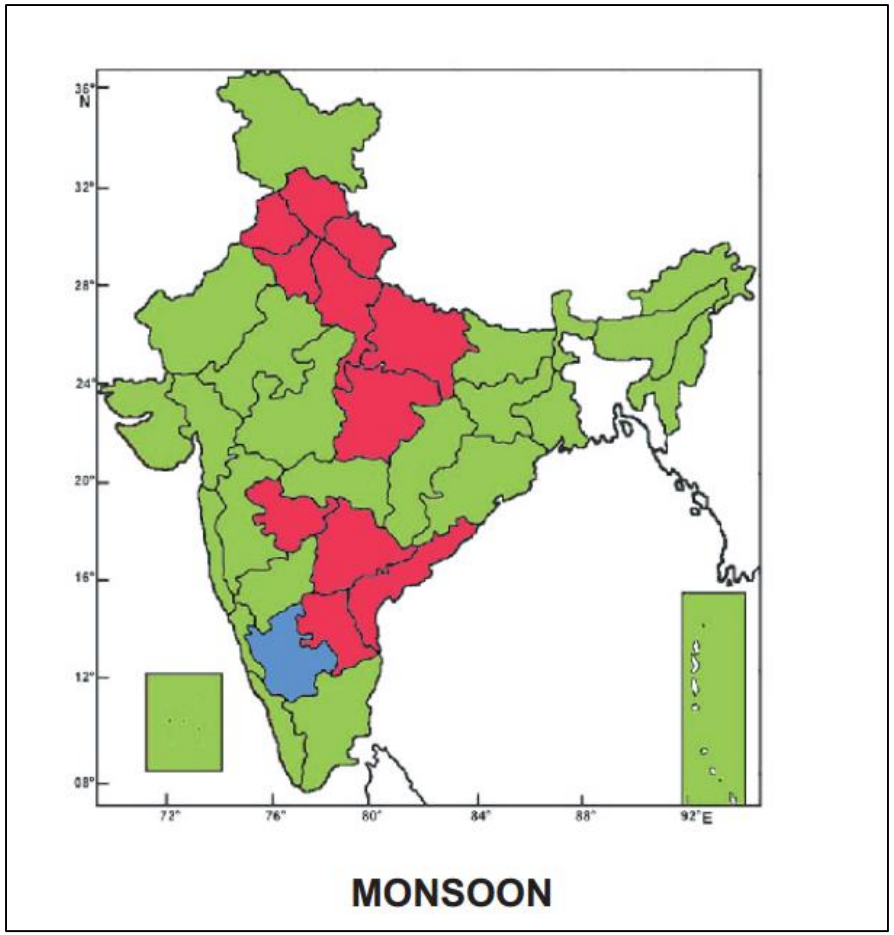
Outline

- What is weather and climate variability?
- What is predictability?
- How is predictability quantified?
- Sources of predictability
- Estimating predictability
- Realizing predictability (or prediction skill)

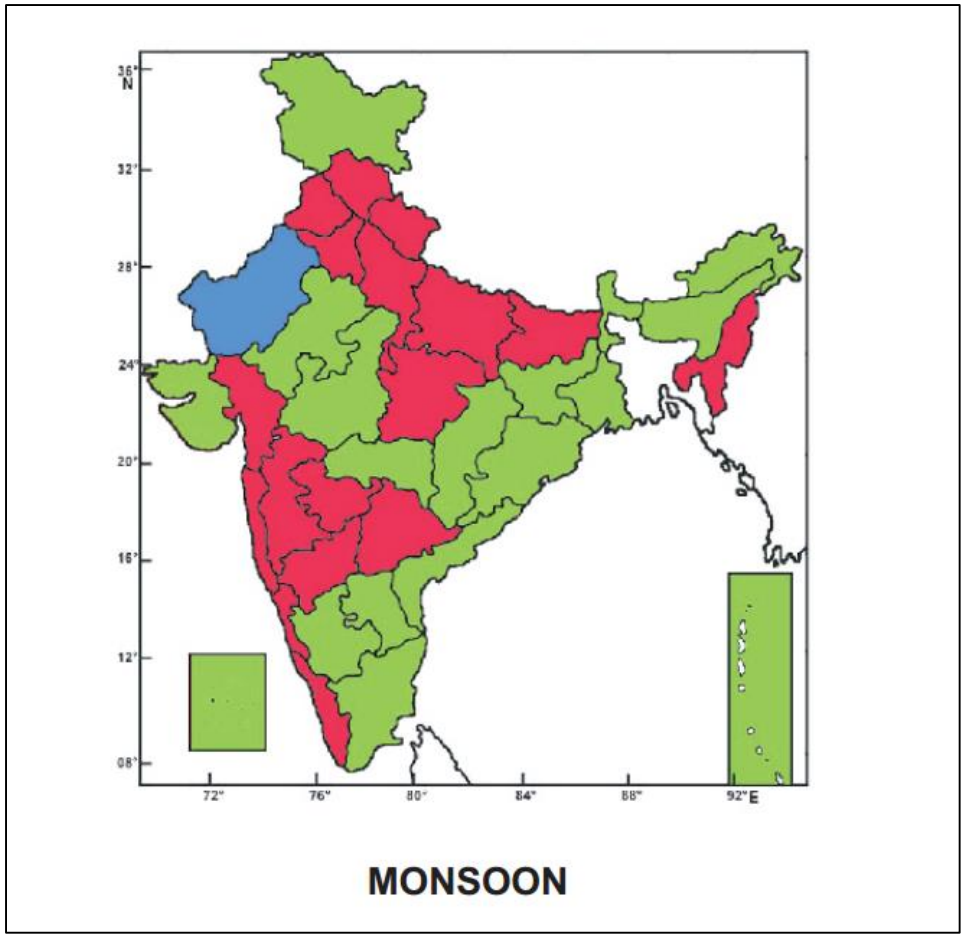
Weather and Climate Variability

- Temperature tomorrow is not the same as today
- Monthly (seasonal) mean precipitation for June-July-August seasonal average over India is not the same in 2014 as in 2015
- Average precipitation over India for a 10-year average changes from one decade to another

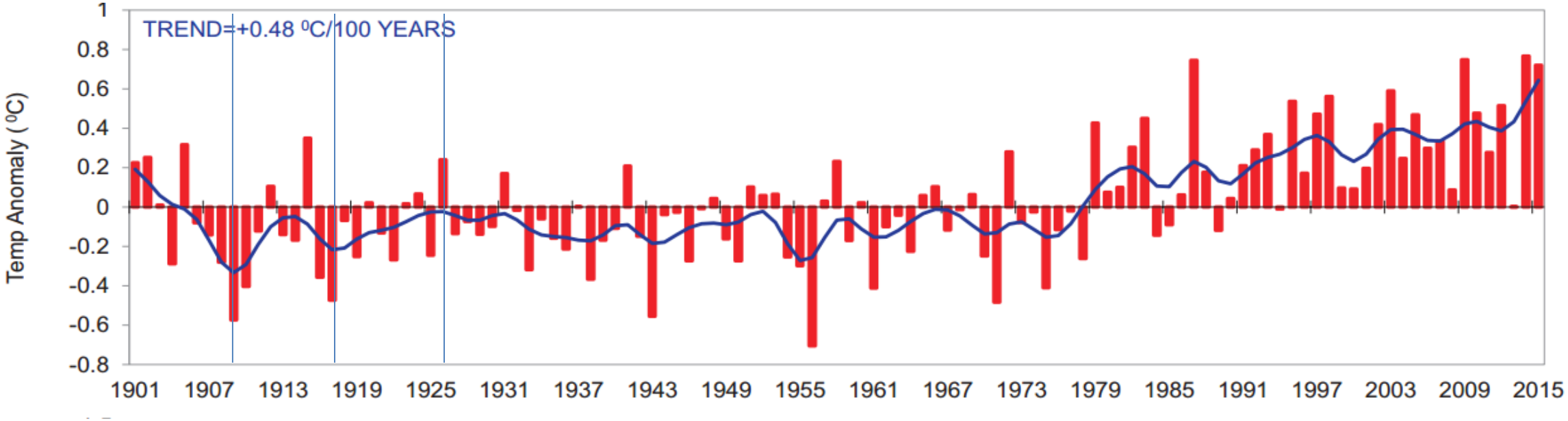
2014



2015

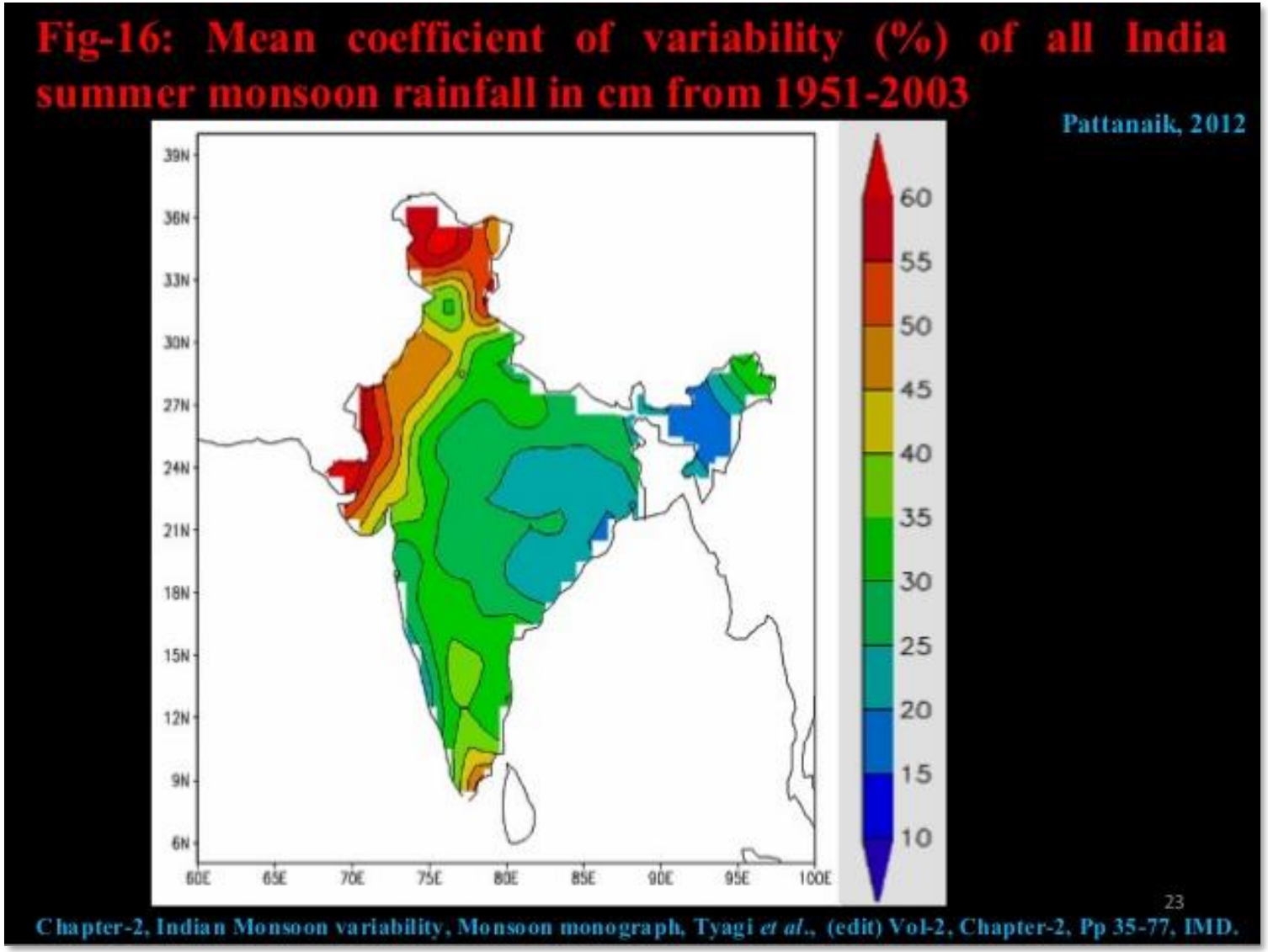


EXCESS +20% OR MORE | NORMAL +19% TO -19% | DEFICIENT - 20 % TO - 59 % | SCANTY - 60 % TO -99 % | NO RAIN -100 %

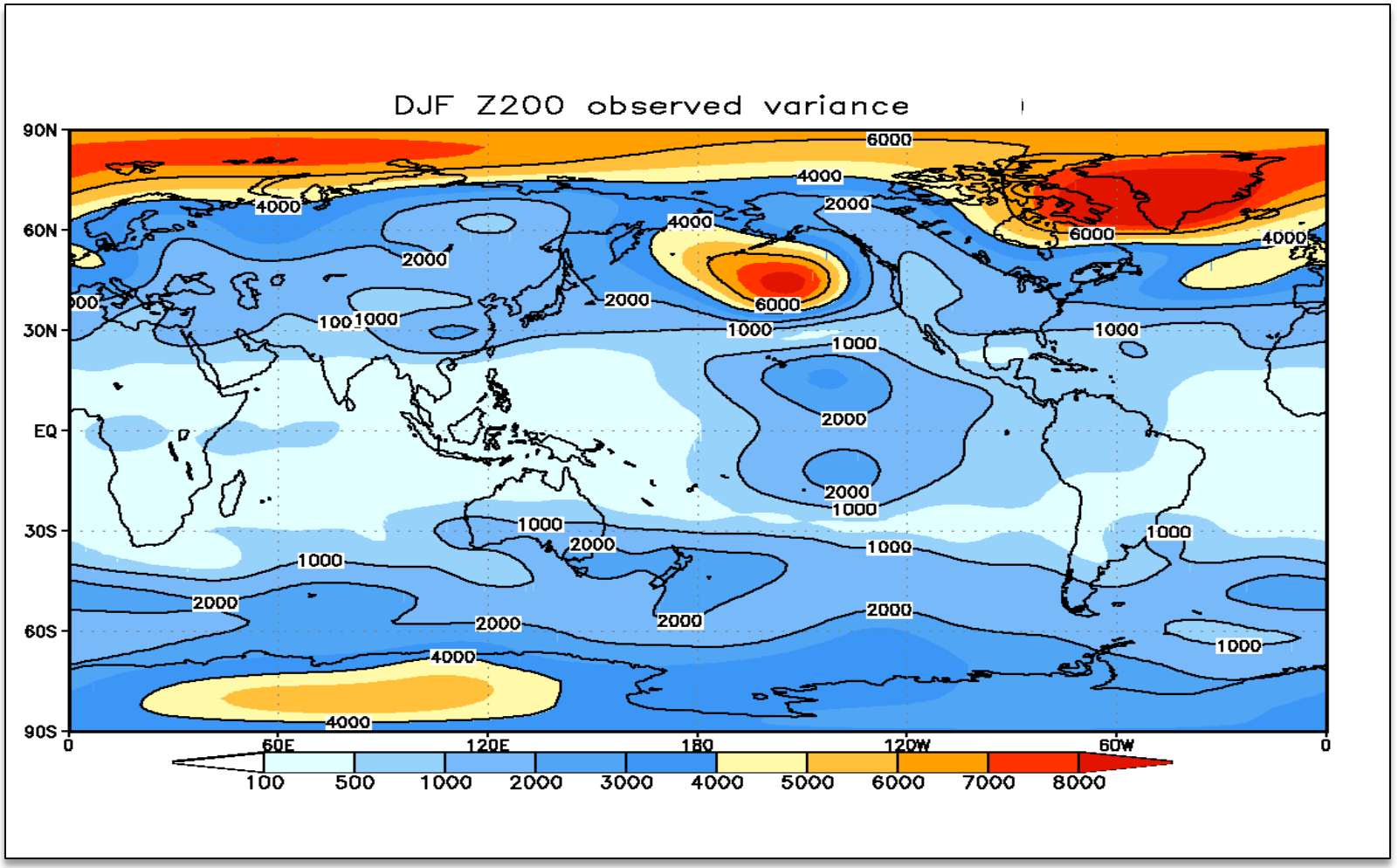


Annual Mean All India Temperature Anomaly

Quantifying Variability



Variance of 200-mb DJF Seasonal Mean Height



Predictability

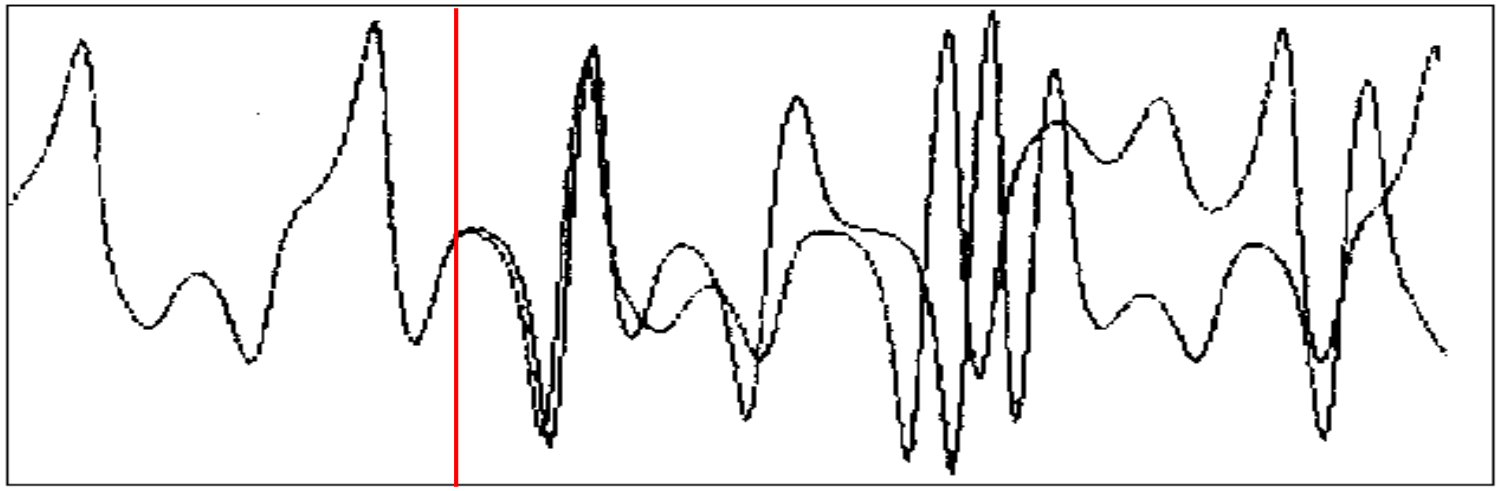
- Predictability: From the knowledge of the current state of the ocean, our ability to anticipate its future evolution

- Prediction for a particular time-scale, what fraction of variability can be anticipated?
  - Predictability varies between 0-100% of variability

Why all the variability is not predictable?

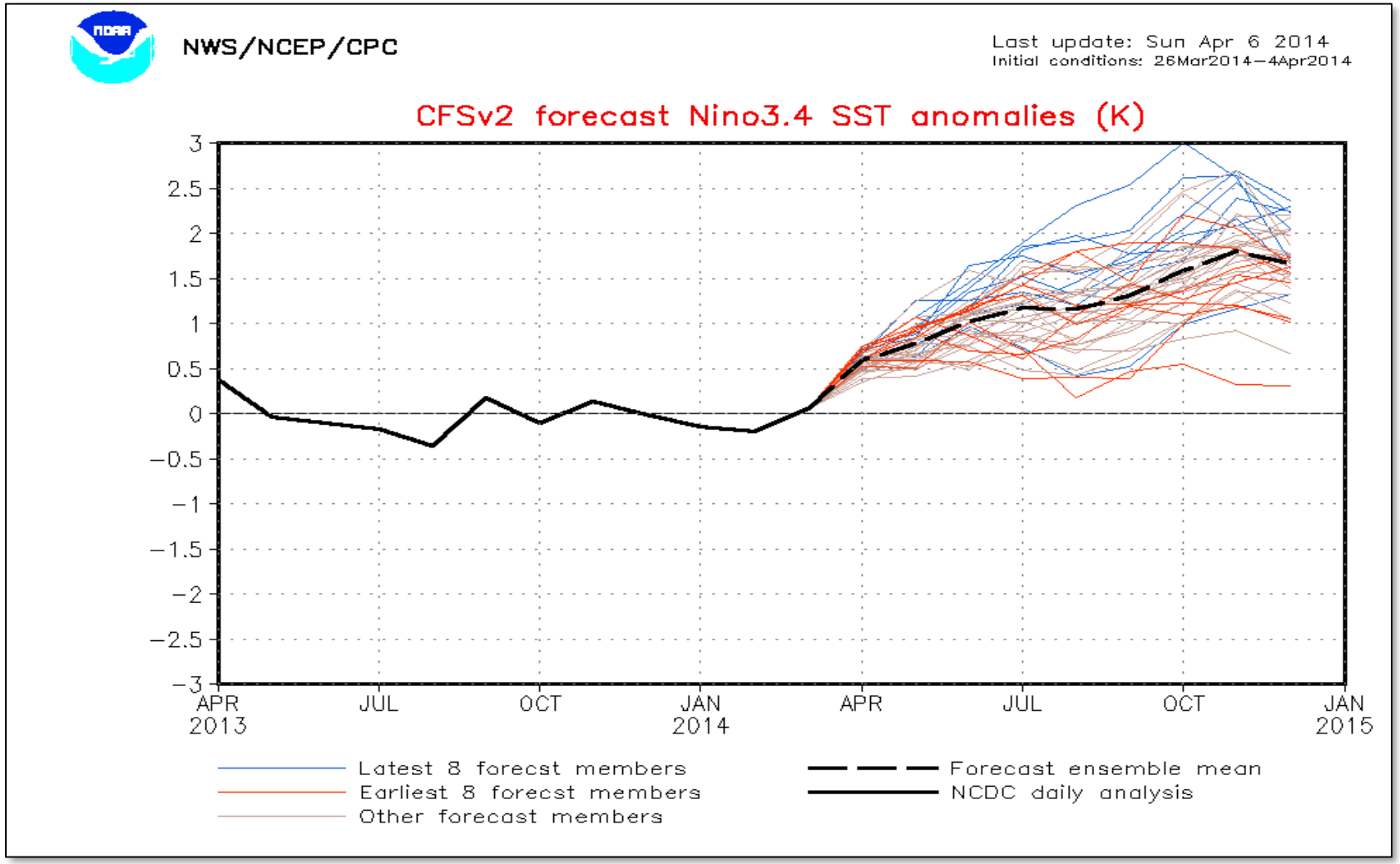
There is always a spread (uncertainty) in forecasts!

- Non-linear dynamical systems sensitivity to specification of initial conditions
- Deterministic chaos
- Uncertainty could be better quantified, but can never be removed

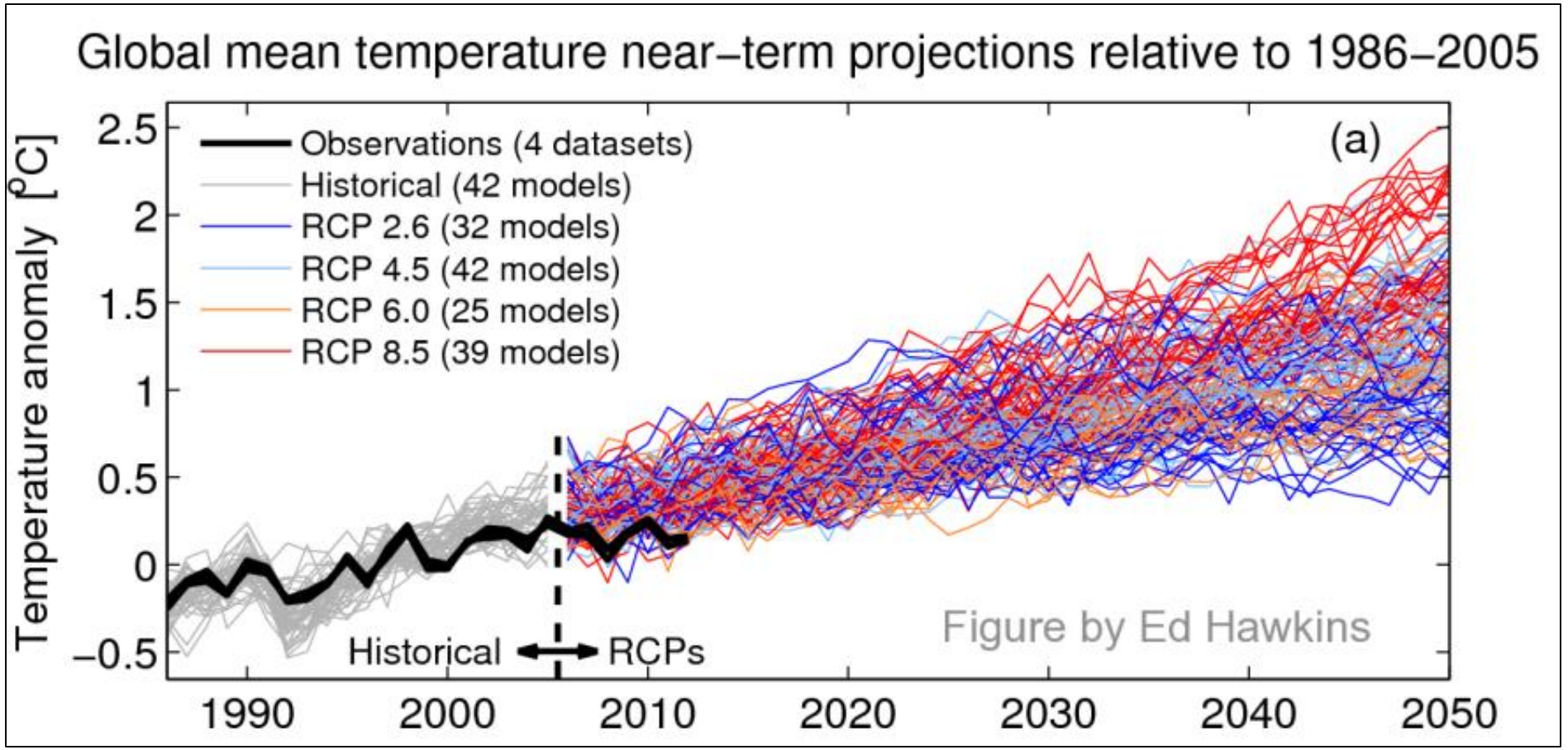


- $dx/dt = \sigma (y - x)$
- $dy/dt = x (\rho - z) - y$
- $dz/dt = xy - \beta z$

Example of Seasonal Prediction



Example of Climate Projection

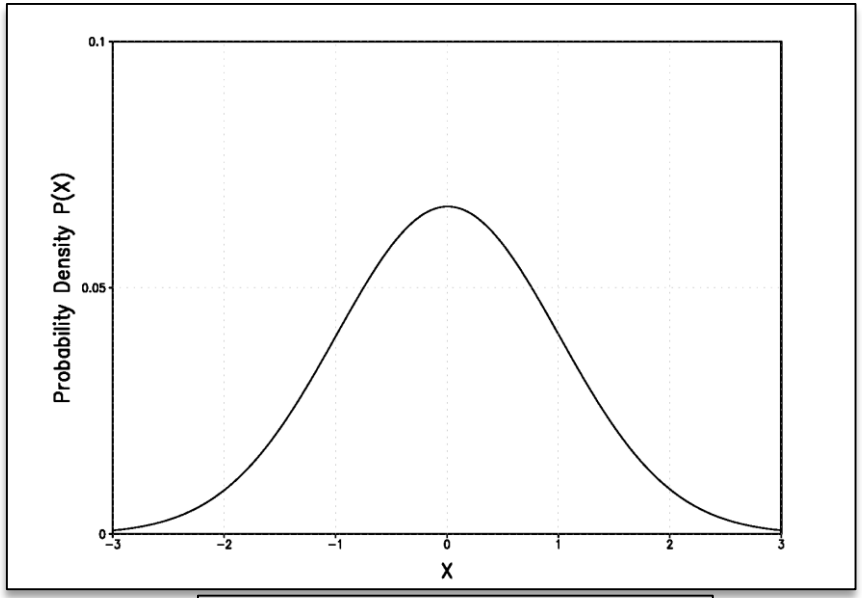


- The forecast spread (uncertainty) can be quantified using ensemble prediction approach where a collection of forecasts is initiated from small perturbations in the initial conditions
- In a nutshell
  - The reason for a limit on predictability stems from limits on the accuracy of predictions on shorter time-scales
  - One cannot *always* predict the state of the atmosphere Δt from now with 100% accuracy no matter how small Δt is.

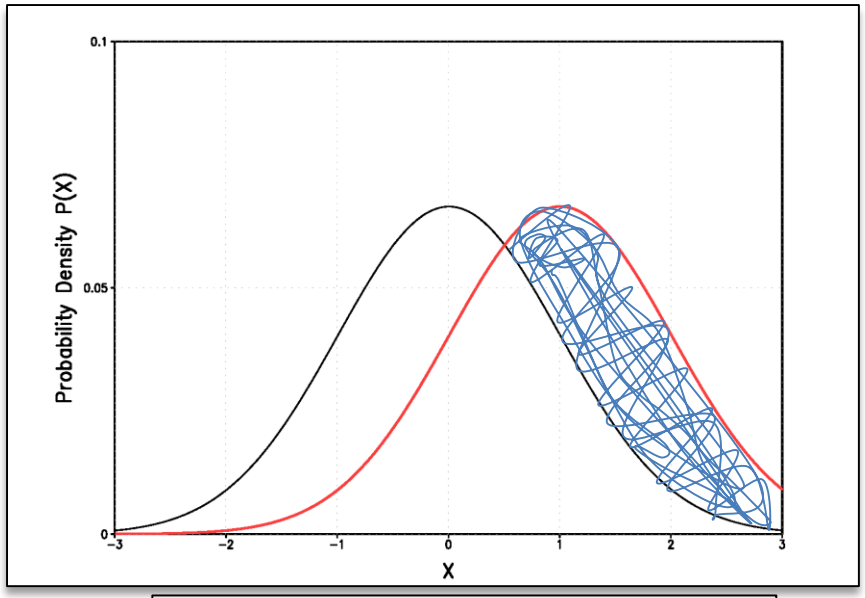
How is Predictability Quantified?

- Spread in forecast outcomes from different initial conditions can be quantified as probability density function (PDF)
- It is our ability to distinguish PDF of outcomes for the event to be predicted from the climatological PDF
- Differences in the PDF can come from differences in various moments of the PDF
  - Mean
  - Spread
  - Skewness

How is Predictability Quantified?

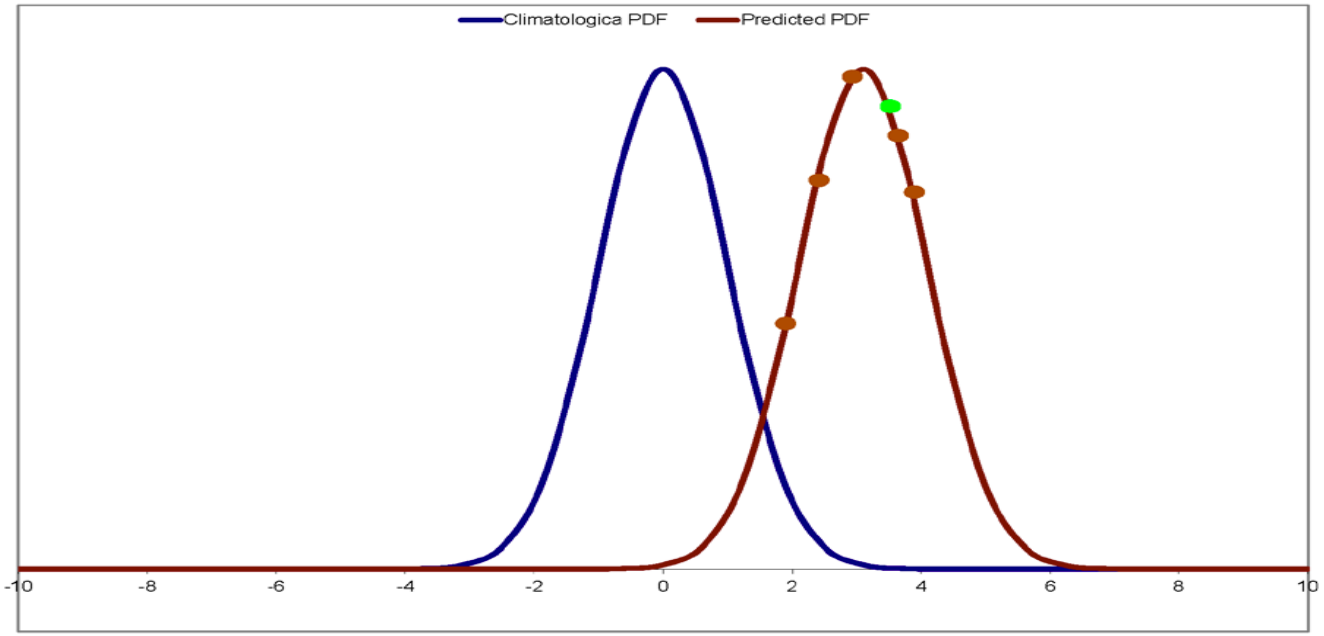


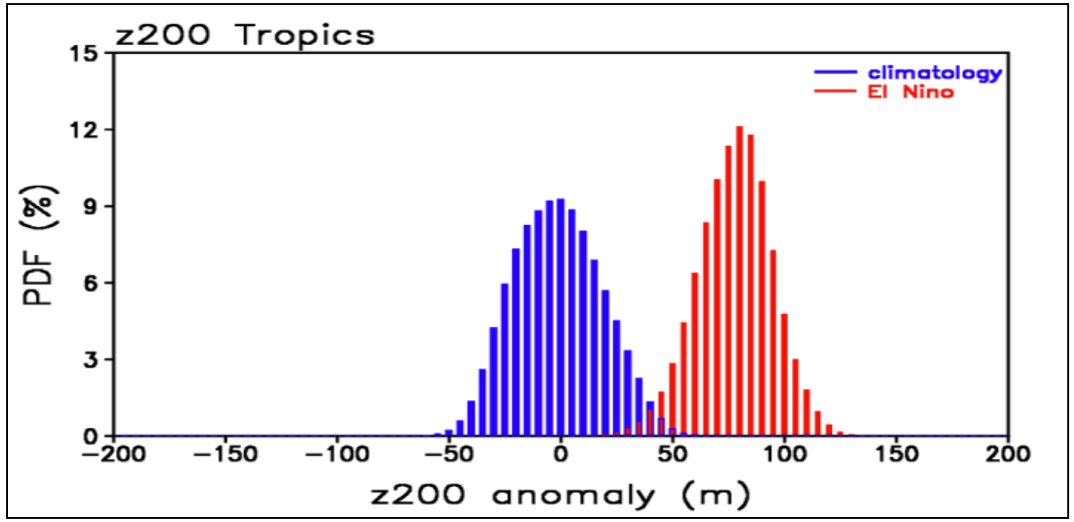
Climatological PDF



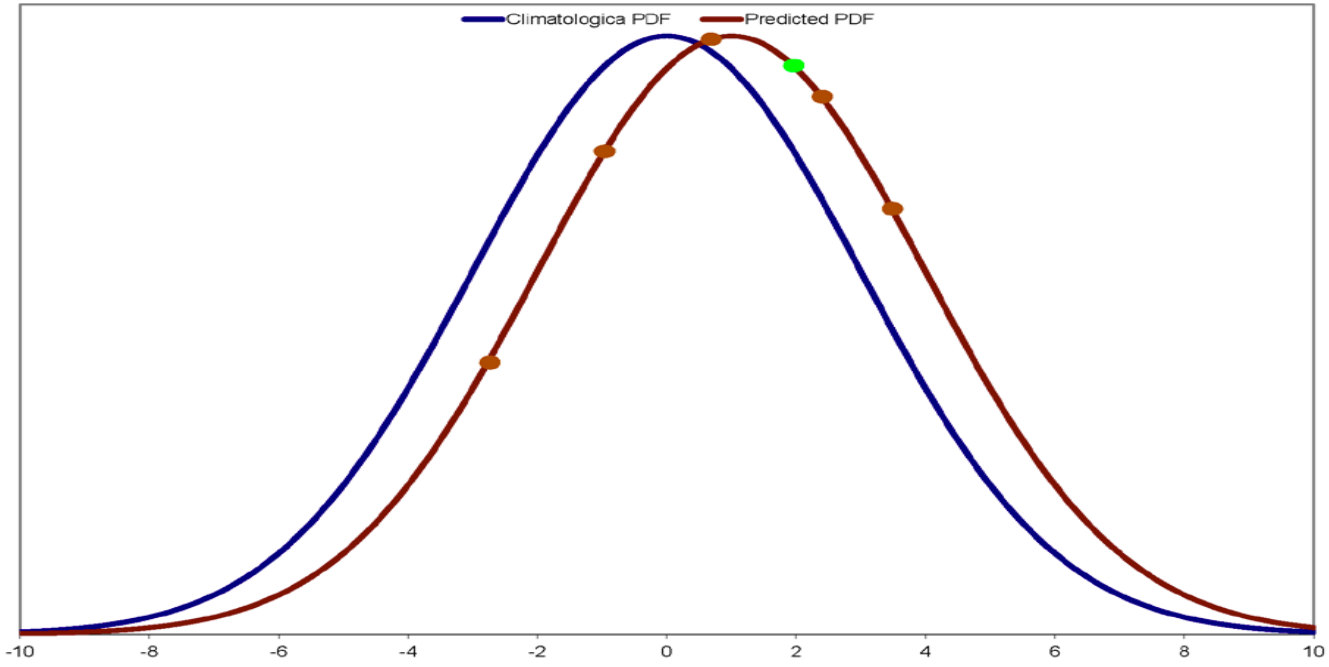
PDF for a Season (Red)

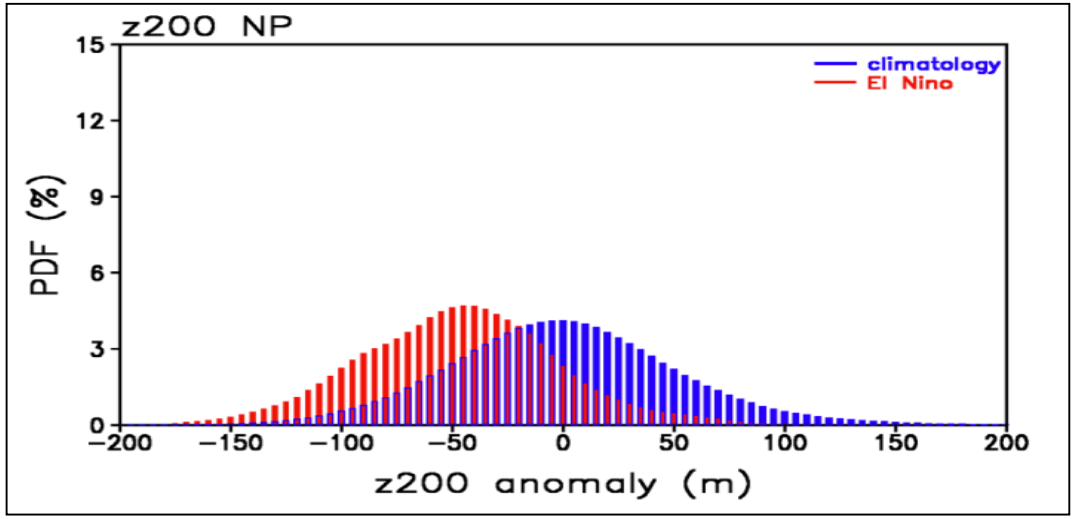
High predictability





Low predictability





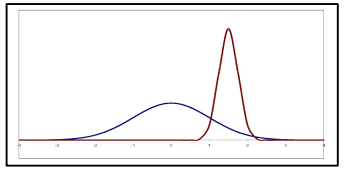
Why it is Important to Understand and Quantify Predictability?

- Helps gauge limits of prediction skill and manage expectations
- Helps pinpoint sources of predictability, e.g., SST → for atmospheric variability
- How do climate models simulate processes, physics and interactions to better predict "sources" of predictability?
- Provides one way to focus model improvements
- Where to place limited resources (ensemble size, model resolution, analysis, perturbations,…)

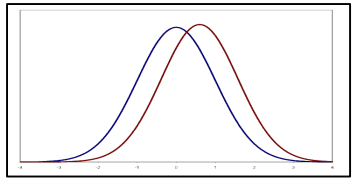
Sources of Predictability

Sources of Predictability

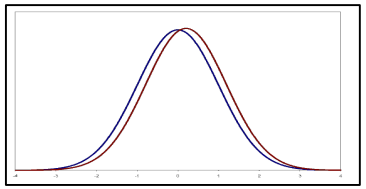
- Weather – Atmospheric initial conditions



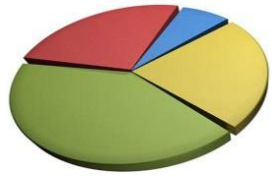
- Seasonal – Boundary conditions (upper oceans, soil moisture, snow, sea-ice…)



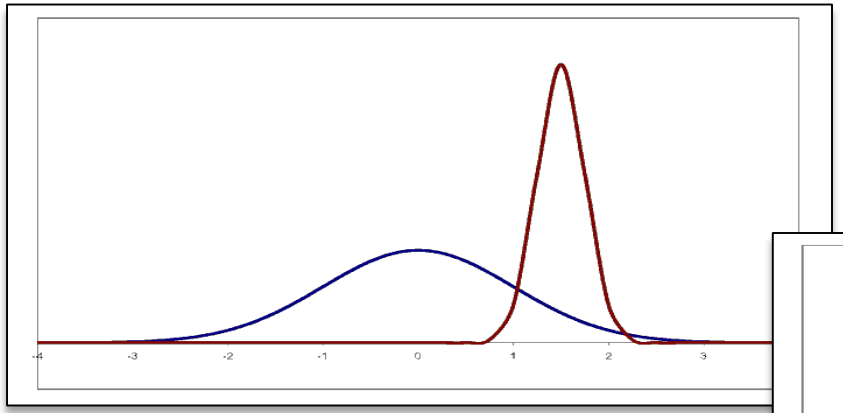
- Decadal – deeper oceans,…
- Climate projections – CO_2,…



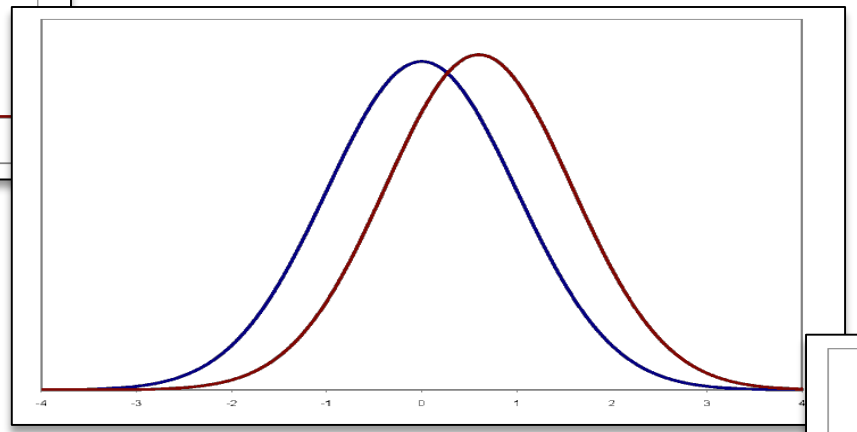
- For different lead time, the relative contribution from sources of predictability differs



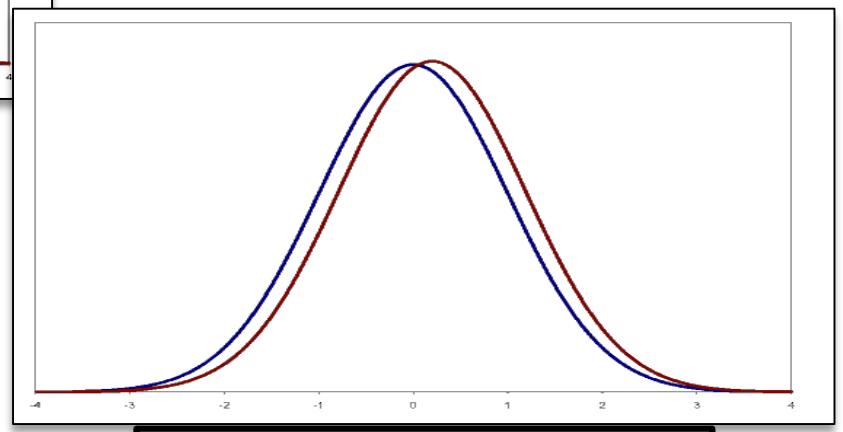
Influence of Various Factors on the PDF



...initial conditions

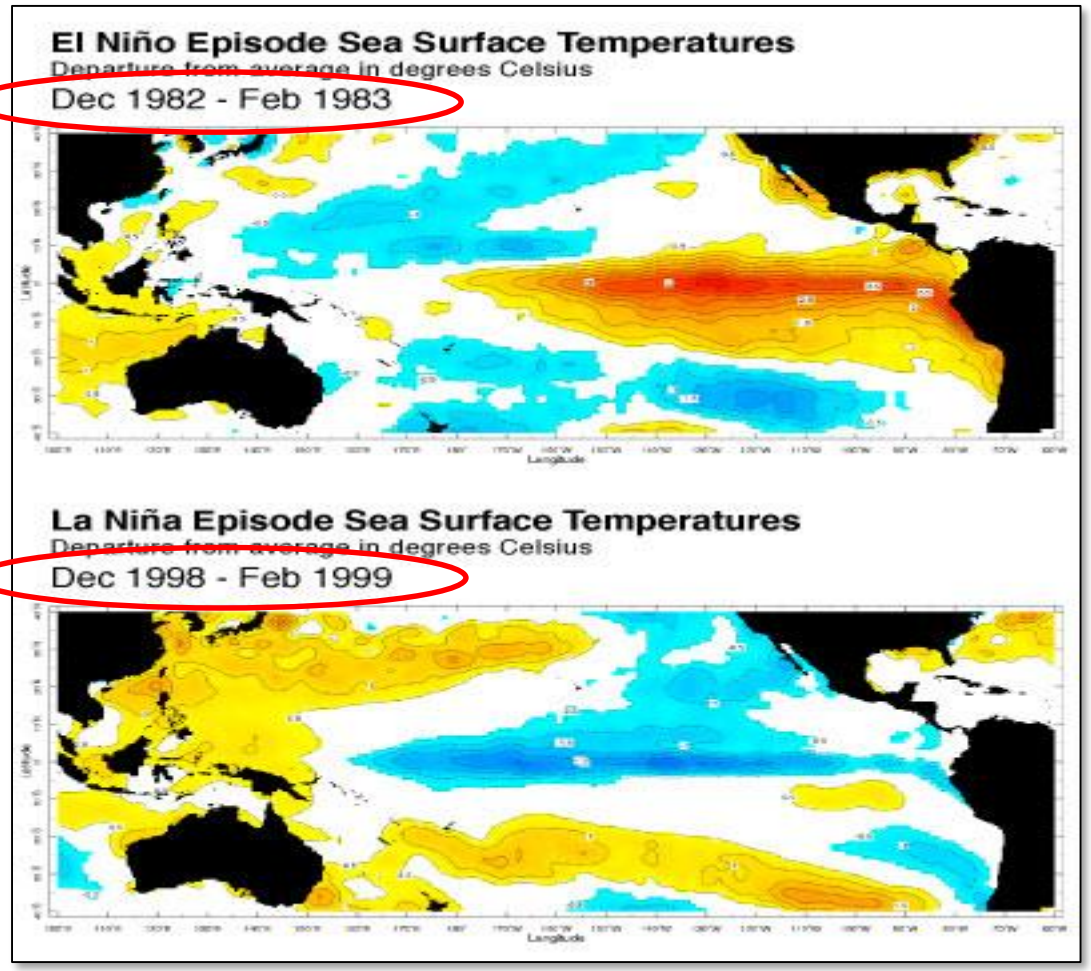


...boundary conditions

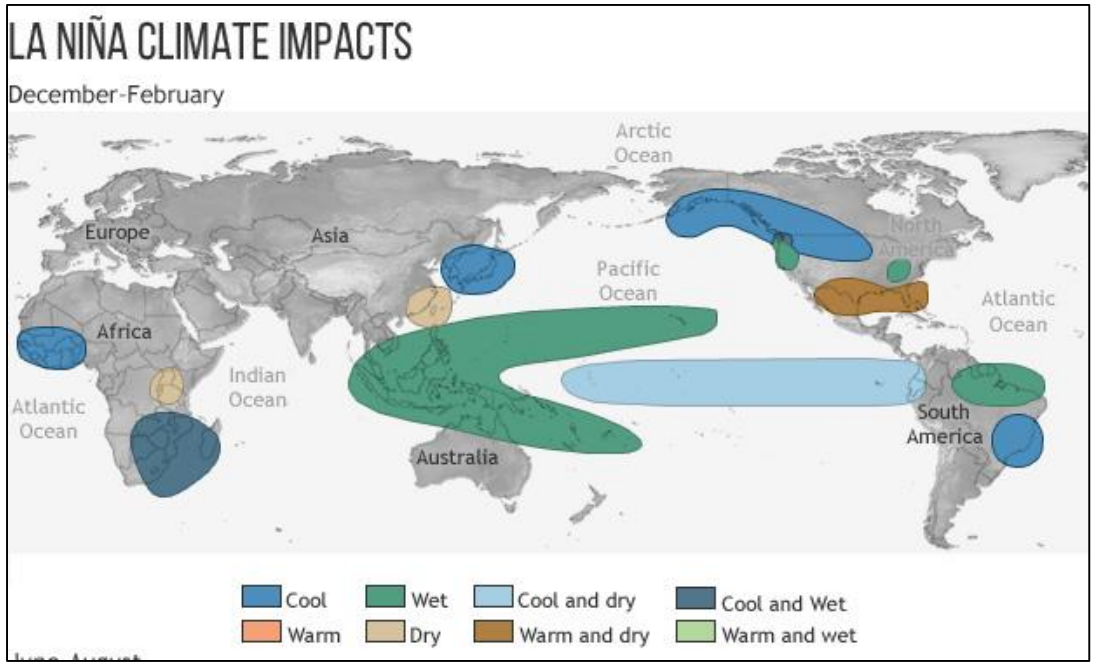


...external conditions

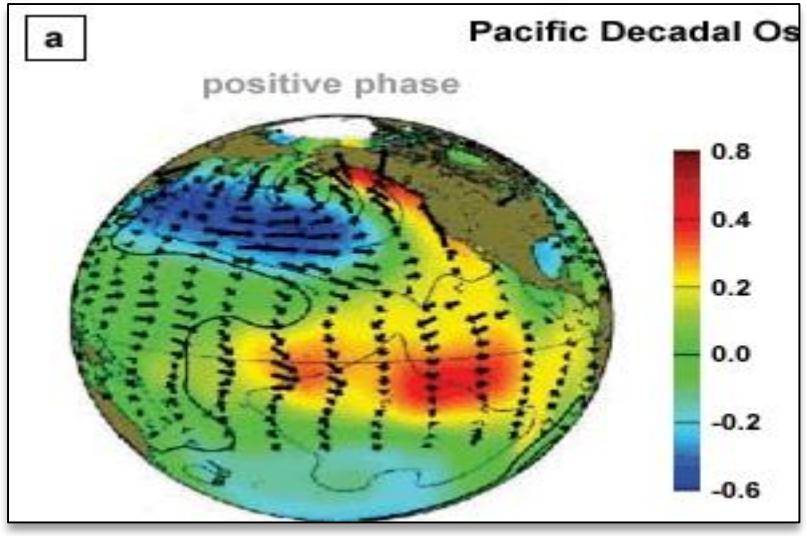
Seasonal-to-Interannual - ENSO



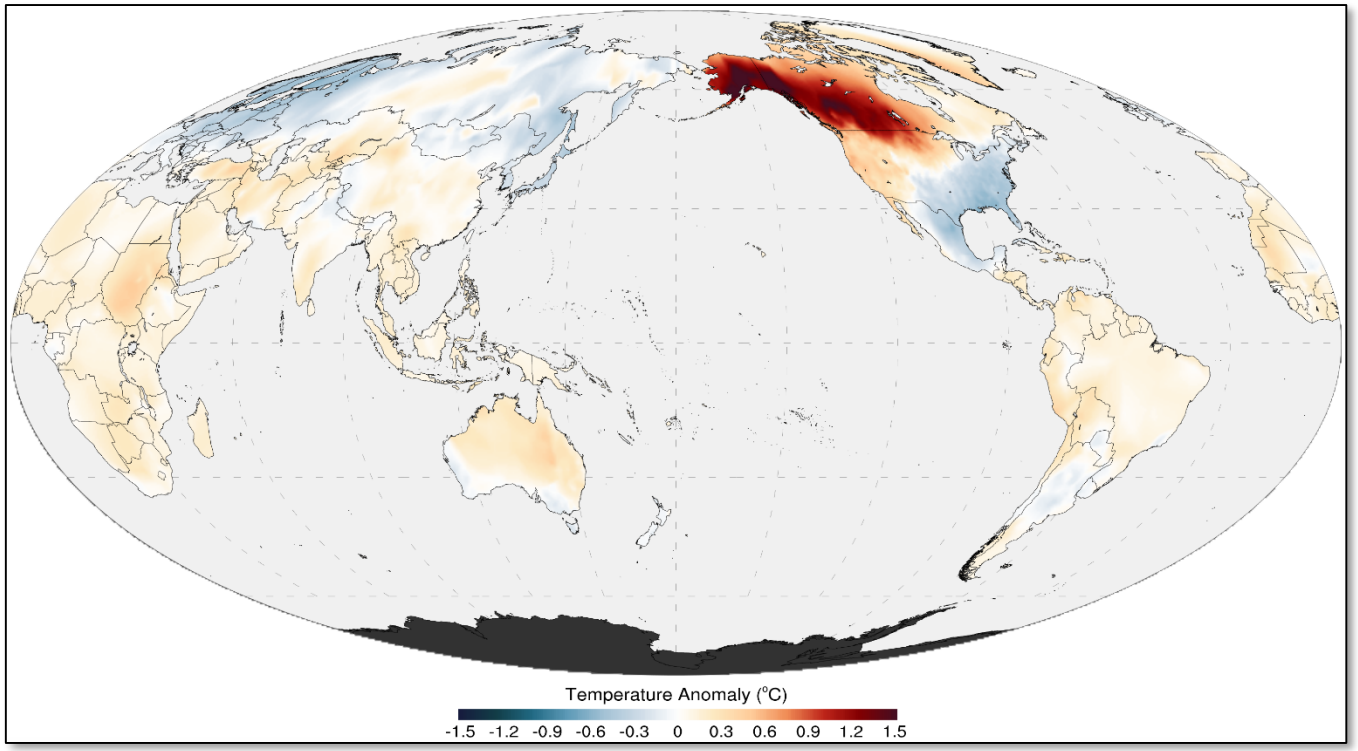
Sea Surface Temperature Anomaly



Decadal - PDO



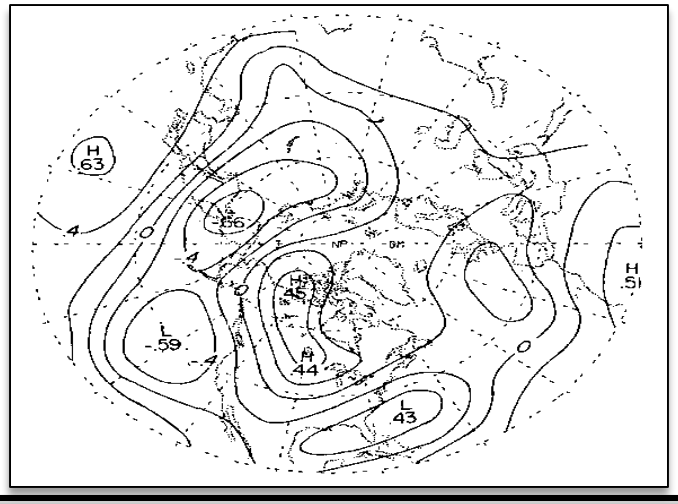
Sea Surface Temperature Anomaly (shading)



Estimating Predictability

Methods for Estimating Predictability

- Observational data Daily time-series
  - Predictor – Predictand relationships
  - Analogs
  - Daily time-series



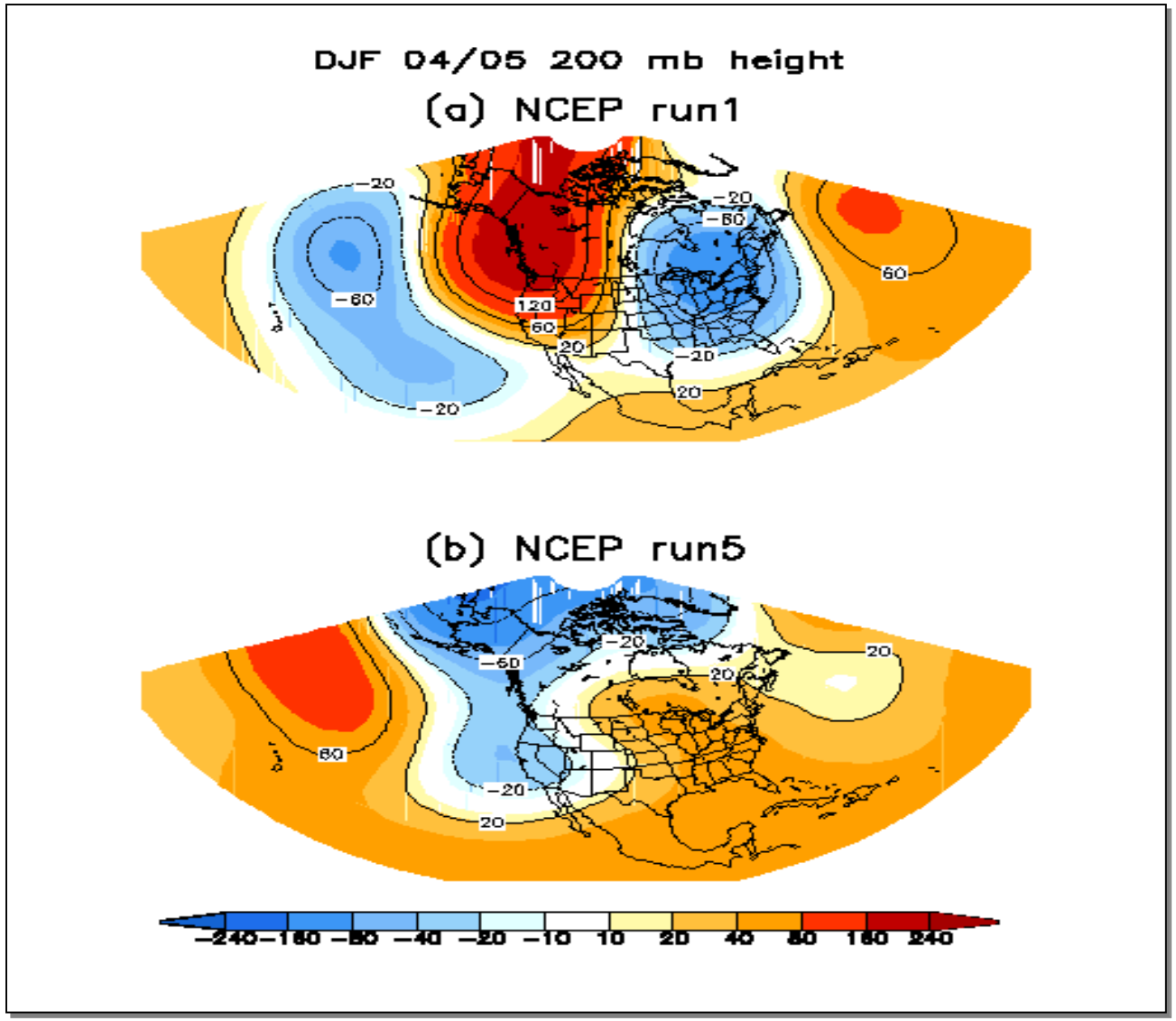
DJF Z700 Correlation with SST index

- Simple; unbiased, but non-linearity is hard to incorporate

Methods for estimating predictability

- Models
  - Ensemble of integrations
    - Spread among the ensemble members is the unpredictable component
    - Ensemble mean (the common part) is the predictable component

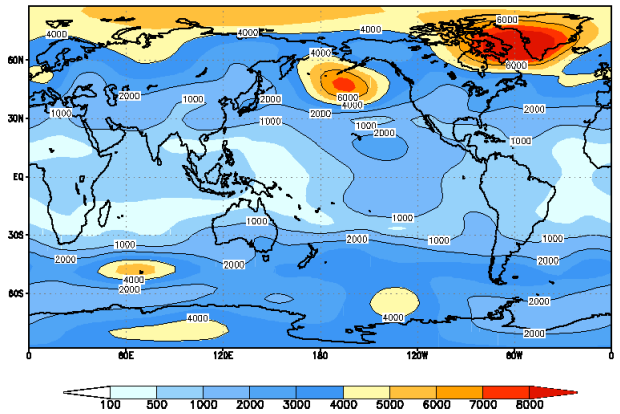
Model Simulations



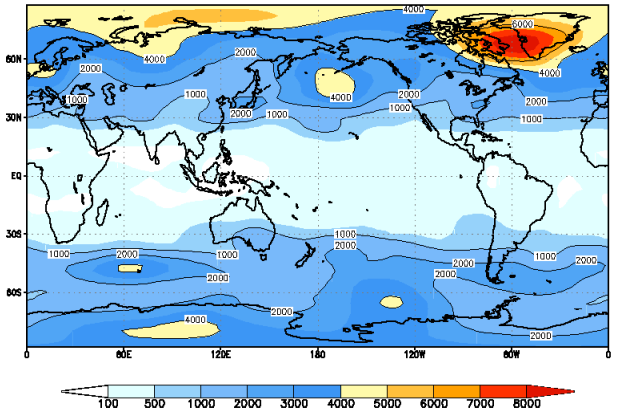
Decomposing Total Variability

DJF 200-mb Z

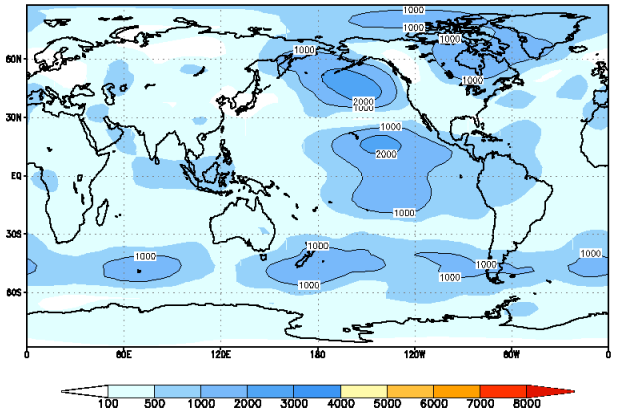
Total Variability



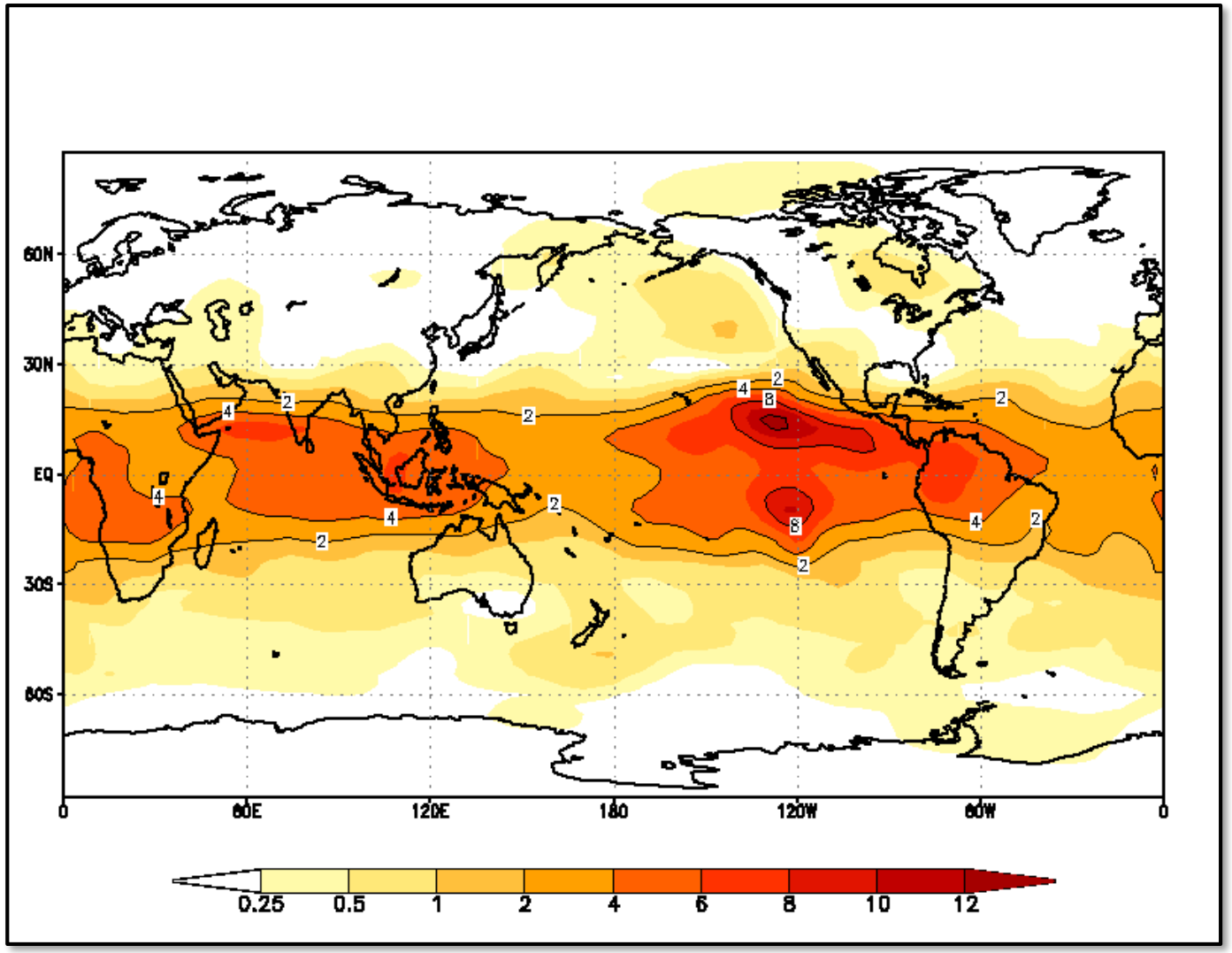
Unpredictable Component



Predictable Component



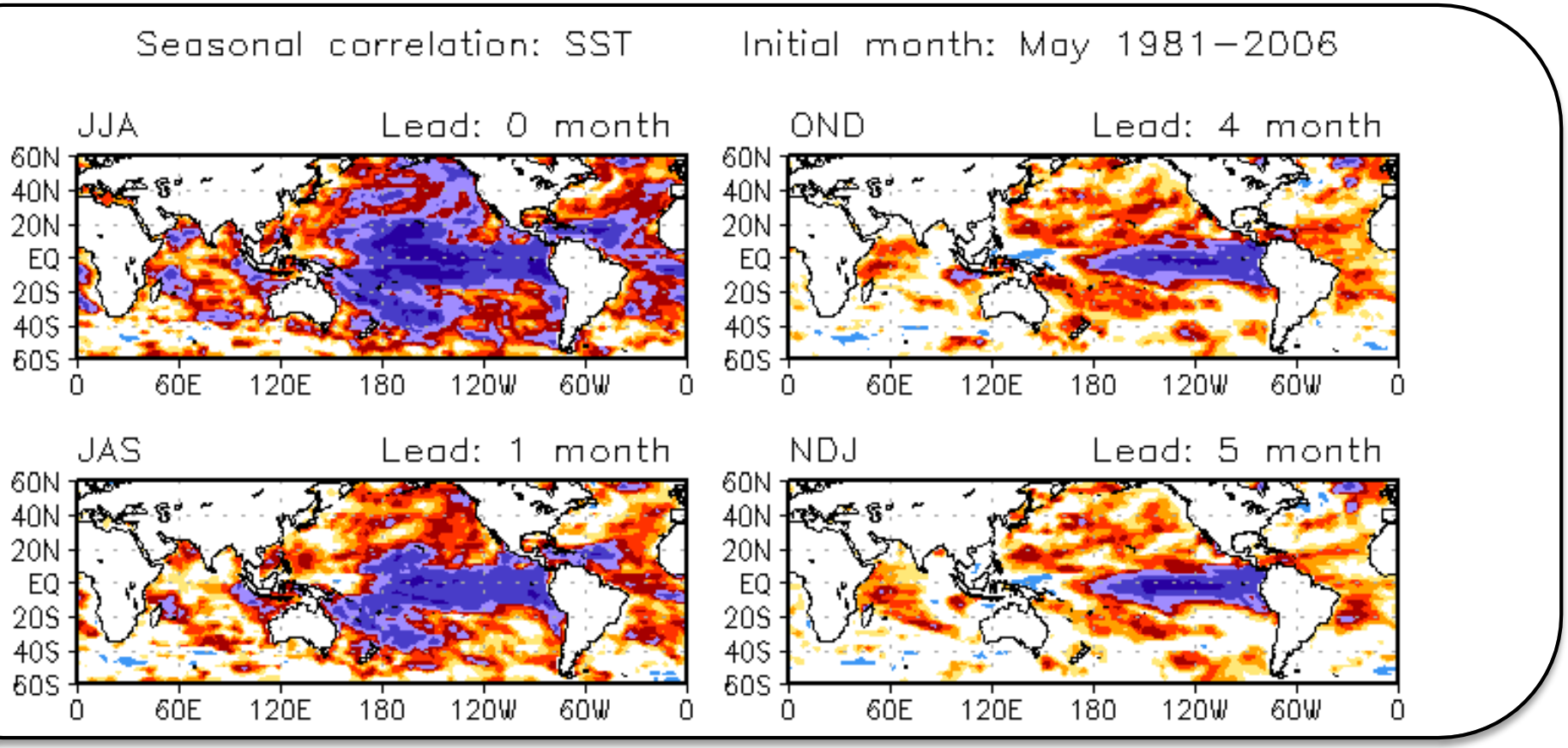
Ratio of Predictable and Unpredictable Component 200mb Z



Realizing Predictability

- Predictability → Prediction skill
- Requires a real-time forecast system
- To realize predictability that exists, forecast systems need to have certain attributes
- → Design and framework of long-range prediction systems (Thursday)

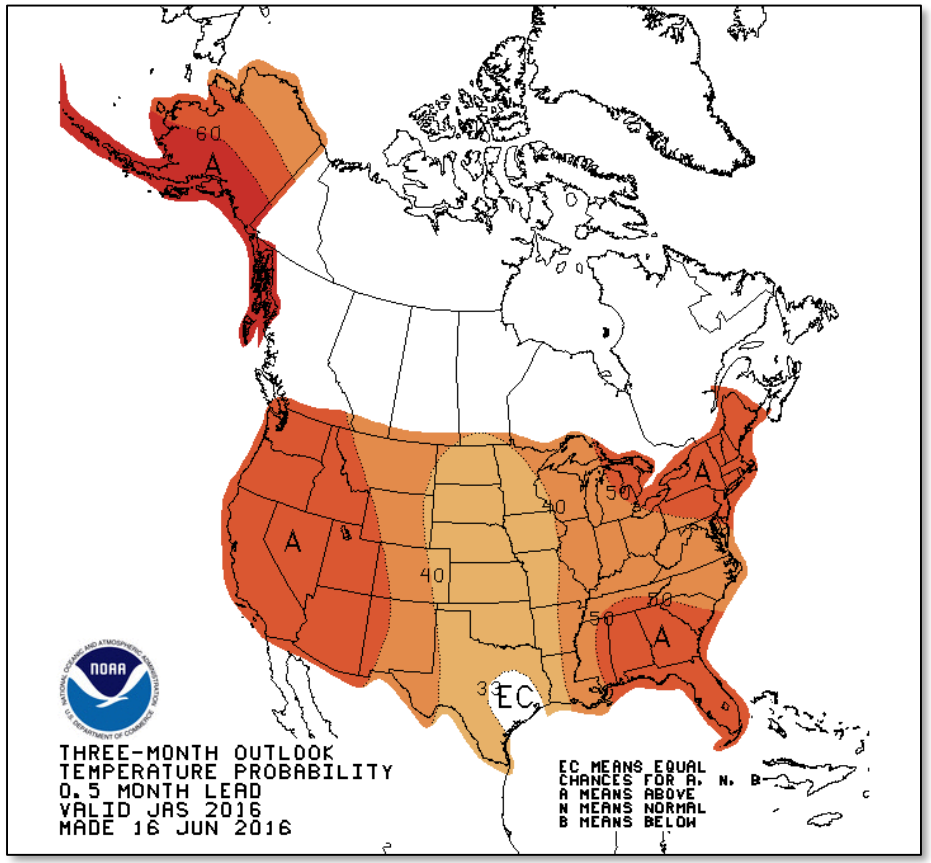
Realizing Predictability



Implication of Limited Predictability

- Since future outcomes are not certain, forecasts have to be probabilistic

- Decision making under probabilistic information context is hard



Summary

- There is variability associated with all time-scales
- All variability cannot be anticipated in advance – Predictability
- There are physical reasons that allow us to anticipate variability – sources of predictability
- Predictability can be estimated either from observational data or model simulations
- Forecast systems allow to realize predictability as prediction skill