

Design and Framework of Seasonal Prediction Systems

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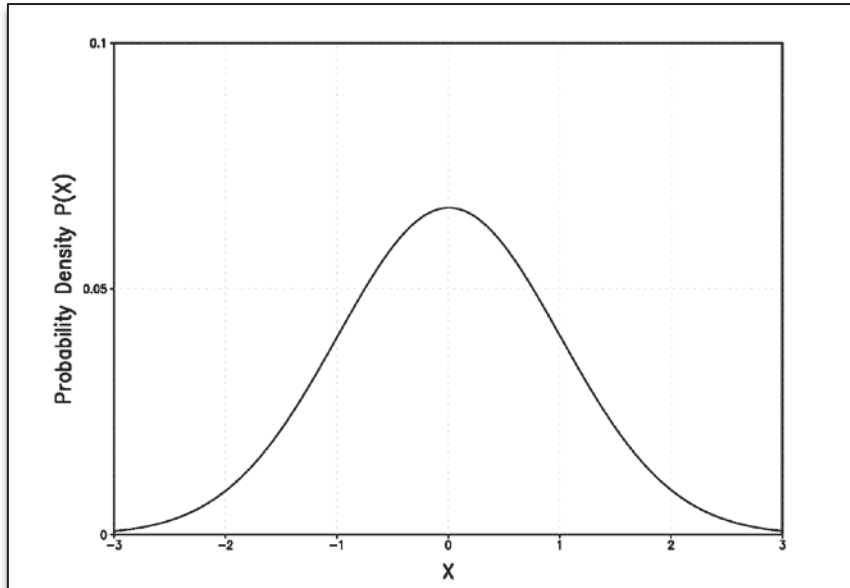
Outline

- What is seasonal prediction and what makes seasonal prediction possible?
- Methods for making seasonal prediction
- An example of seasonal prediction system: NCEP Climate Forecast System version 2 (CFSv2)
- Current status of global seasonal prediction efforts
- Summary

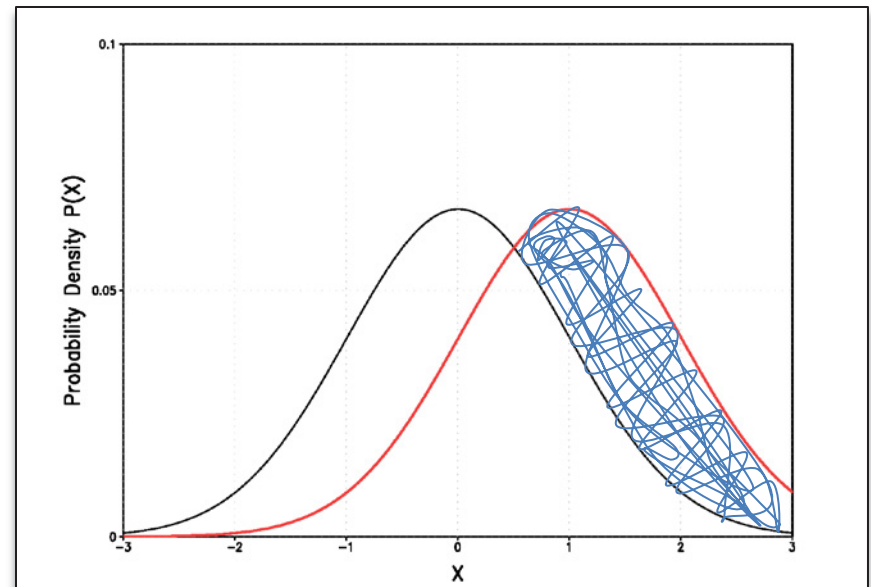
What is Seasonal Prediction?

- Seasonal mean states can be characterized by the probability density function (PDF). This PDF depends on
 - Season
 - Variable
 - Location
- Seasonal prediction depends our ability to differentiate climatological PDF from the PDF for a particular season (for which prediction is to be made)

What is Seasonal Prediction?



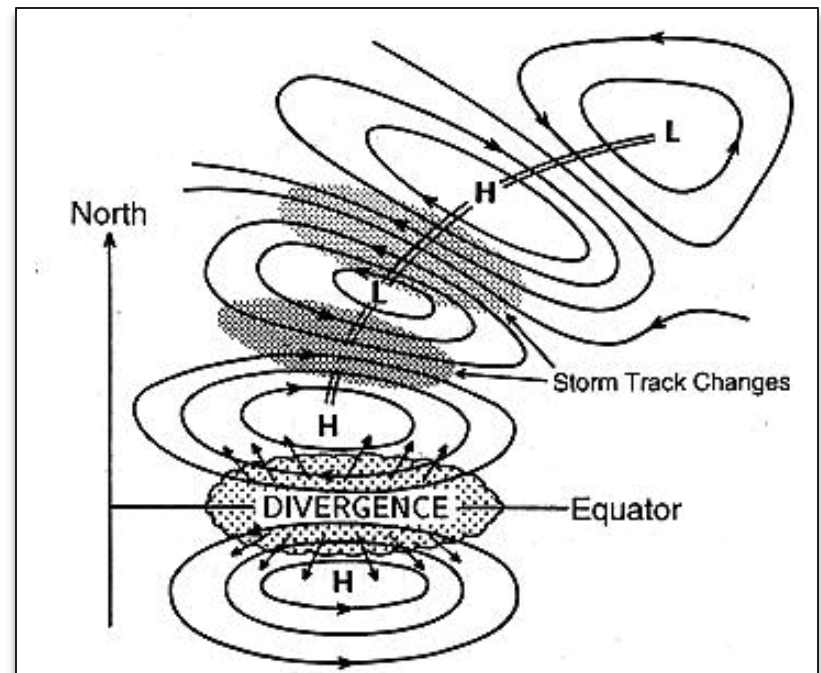
Climatological PDF



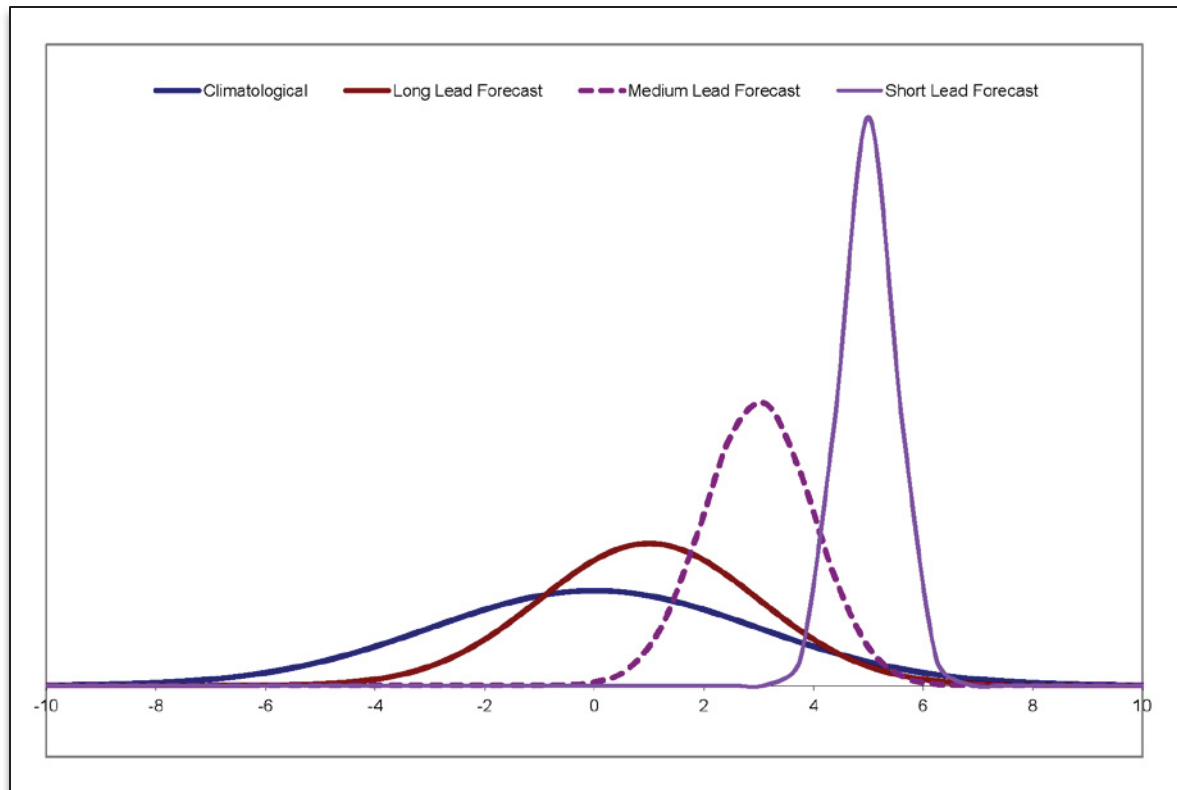
PDF for a Season (Red)

What Lends Predictability in Long-Range Predictions

- Influence of boundary conditions
 - Anomalous SSTs → Influence on atmospheric variability
 - *Tier-2 predictions*
- Initial conditions
 - Weather prediction
 - ENSO prediction
 - *Tier -1 predictions*



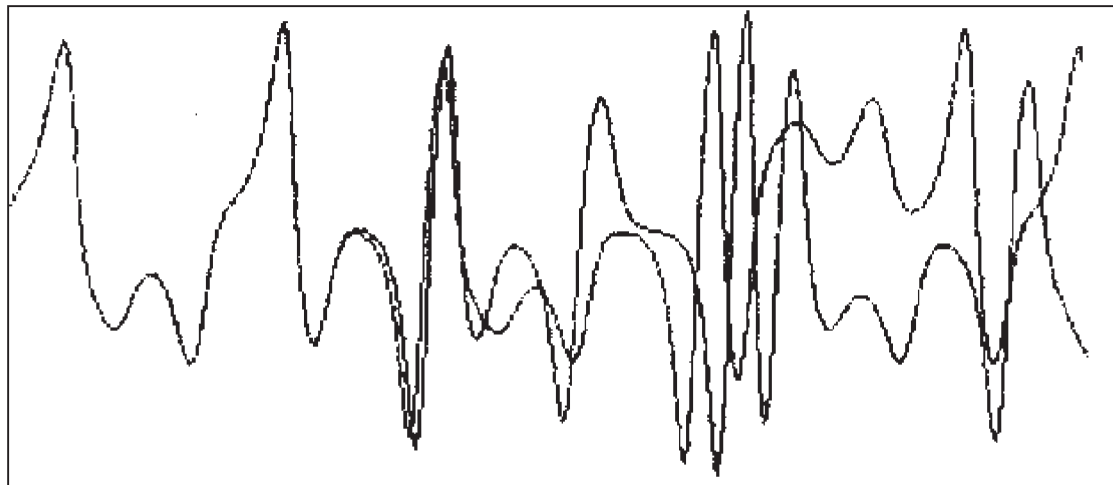
What Lends Predictability in Long-Range Predictions?



- The spread with lead time increases
- PDF shifts towards the climatological PDF

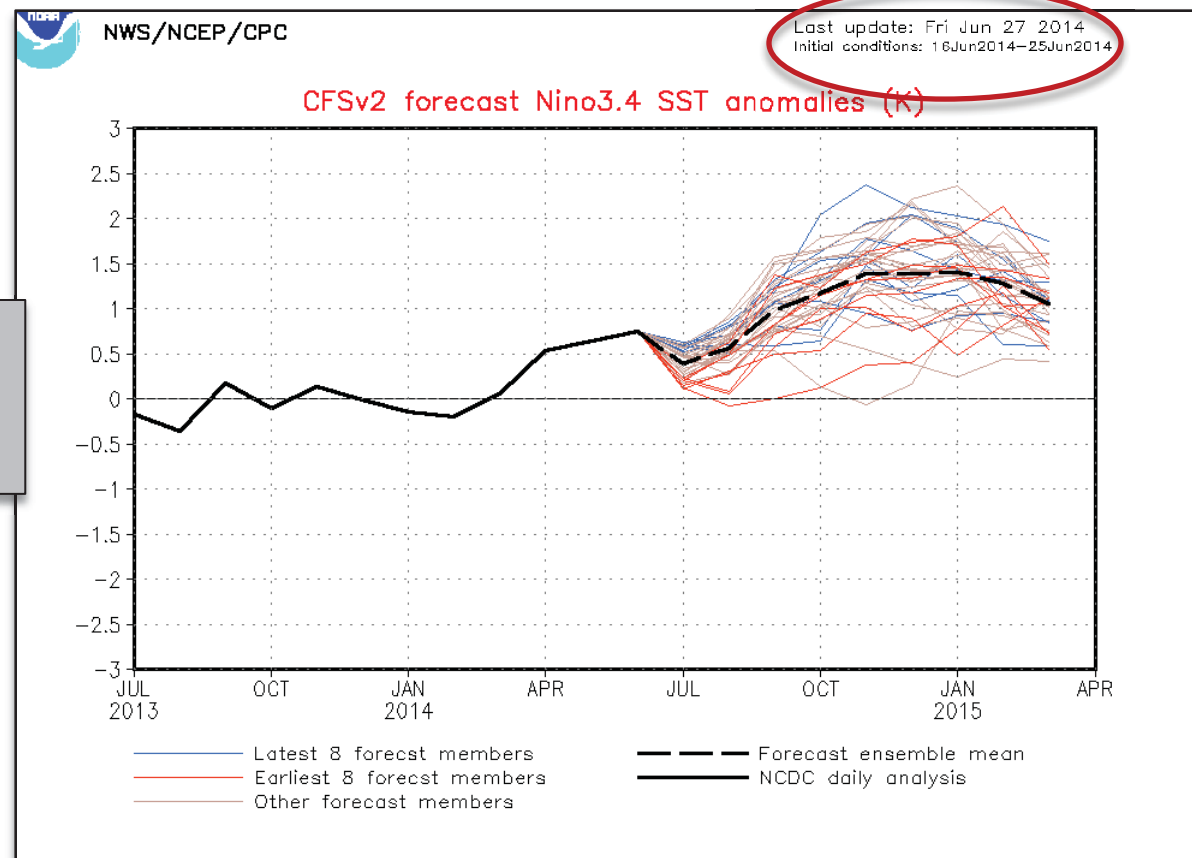
Why there is Spread (Uncertainty) in Forecasts?

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



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

Examples of Spread: ENSO Prediction

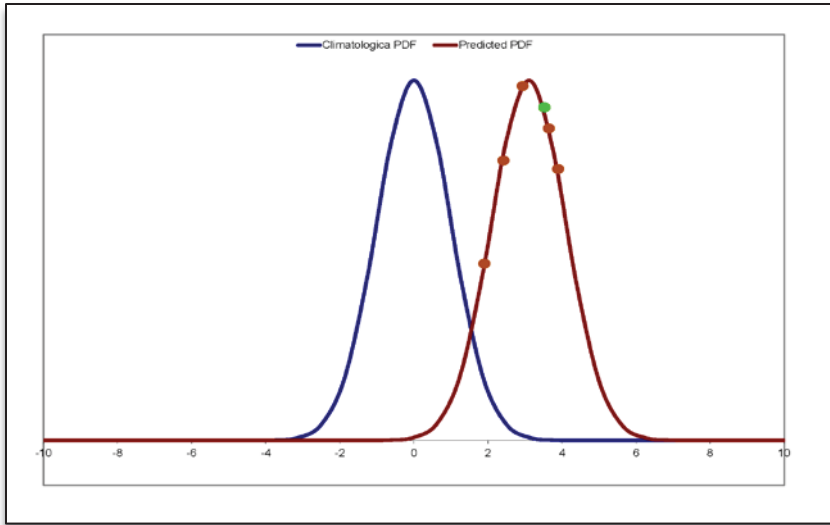


NCEP/CFS
Nino 3.4 SST
Prediction

What Provides Skill in Seasonal Predictions

- It is our ability to distinguish PDF of outcomes for the event to be predicted from the corresponding climatological PDF
- Differences in the PDF can come from differences in various moments of the PDF
 - Mean
 - Spread
 - Skewness

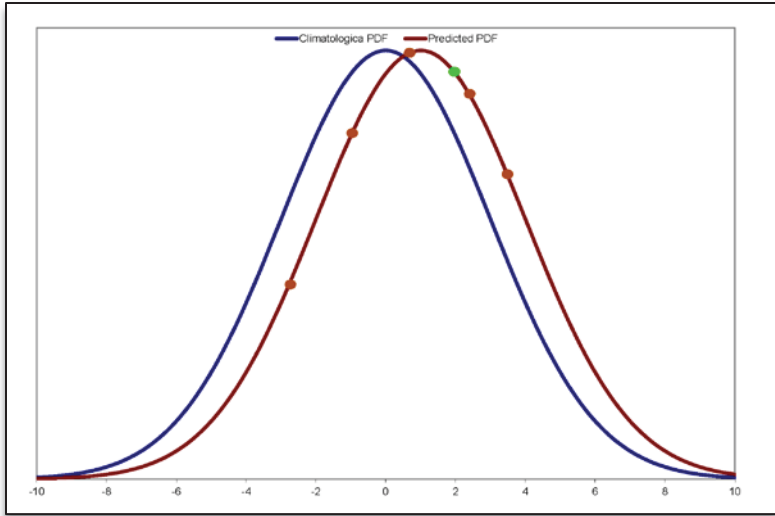
Examples of High/Low Prediction Skill



High
Predictability

Climo PDF
FCST PDF

Low
Predictability



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Seasonal Prediction Methods

- Empirical prediction tools
 - Advantages
 - Trained based on historical observations
 - Unbiased
 - Simple and computationally efficient
 - Disadvantages
 - Limited by observational data
 - Mostly depend on linear relationships
 - Non-stationarity in climate is hard to include
 - Cannot handle unprecedented situations

Seasonal Prediction Methods

- Dynamical Prediction Tools
 - Advantages
 - Linearity and non-stationarity is not an issue
 - Easier to construct PDF of seasonal mean state
 - Easier to handle unprecedented situations
 - Disadvantages
 - Computationally expensive and require a large infrastructure
 - Forecast systems have biases that requires special attention
- Properties of empirical and dynamical prediction tools are complementary in nature, and in general, and generally both are used in the development of final forecast

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Components of a Seasonal Forecast System

- Forecast system components
 - Initialization
 - Hindcasts
 - Real-time forecasts
 - Skill assessment
 - Bias correction and calibration
 - Forecast dissemination

Initialization

- Various components of the forecast system need to be initialized with their observed state
 - Atmosphere (temperature; humidity; winds)
 - Ocean (temperature; salinity; ocean currents)
 - Land (soil moisture; snow)
 - Sea ice (extent; thickness)
- Initialization is done from the Climate Forecast System Reanalysis (CFSR) that provides a consistent 3-dimensional analysis of various components of the Earth System
- After initialization, forecast system is run to nine months into the future

Hindcasts

- What is the purpose of hindcasts?
 - Provides an assessment of the skill of the seasonal forecast system
 - Because of model biases
 - Real-time forecasts have to be bias corrected
 - Hindcasts provide the data set for bias correction
 - Hindcasts are used to develop initial month, and lead-time dependent model climatology
 - Calibration of real-time forecasts

Hindcasts

- Run the forecast system over last thirty years (1981-2010)
- Four nine months forecast every 5th day of the calendar
- 72 forecasts every year

Real-time Forecasts: CFSv2

- Four nine month forecasts every day
- 120 seasonal forecasts in a month
- Real-time forecasts are constructed based on forecasts from latest 10 days of initial conditions, i.e., an ensemble of 40 forecasts is used for developing real-time seasonal predictions
- Lagged ensemble provides an estimate of PDF of seasonal mean states

Real-time Forecasts

- Configuration of real-time forecasts generally differs from their hindcast counterpart
 - More frequent
 - Larger ensembles
- Consistency in the analysis of initial conditions, particularly for slowly varying components of the Earth System (SST, soil moisture) is crucial!

Skill Assessments

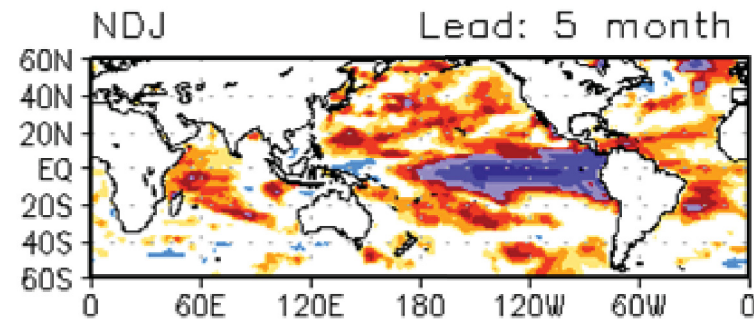
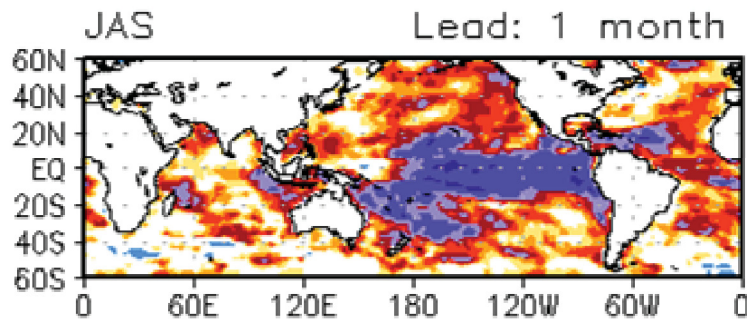
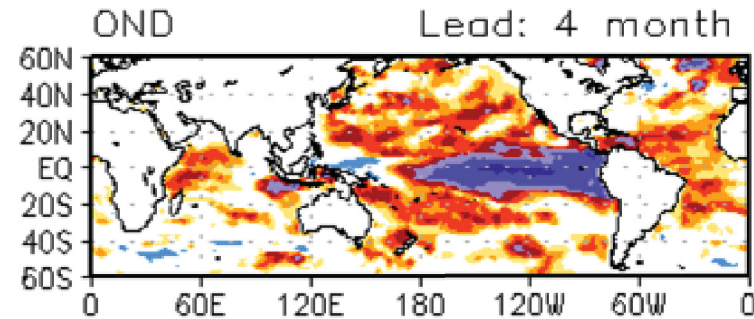
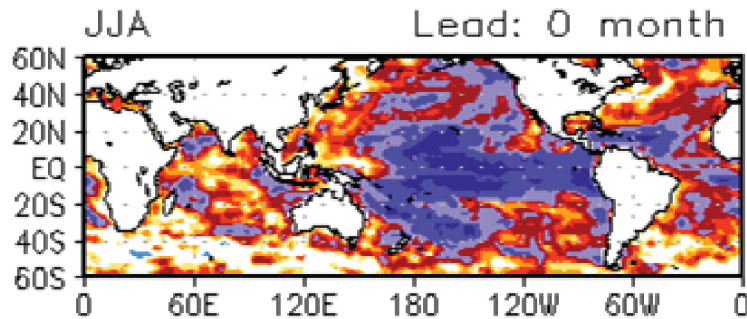
- Based on 30-year hindcast, skill of the CFSv2 can be assessed for
 - Predicting sea surface temperature anomalies
 - Predicting various SST indices that are important for seasonal predictions, e.g., Nino 3.4 SST index
 - Surface quantities over land, e.g., precipitation and surface temperatures
 - Other variables
 - Soil moisture
 - Sea ice

Skill Assessment: SST

Anomaly Correlation

Seasonal correlation: SST

Initial month: May 1981–2006

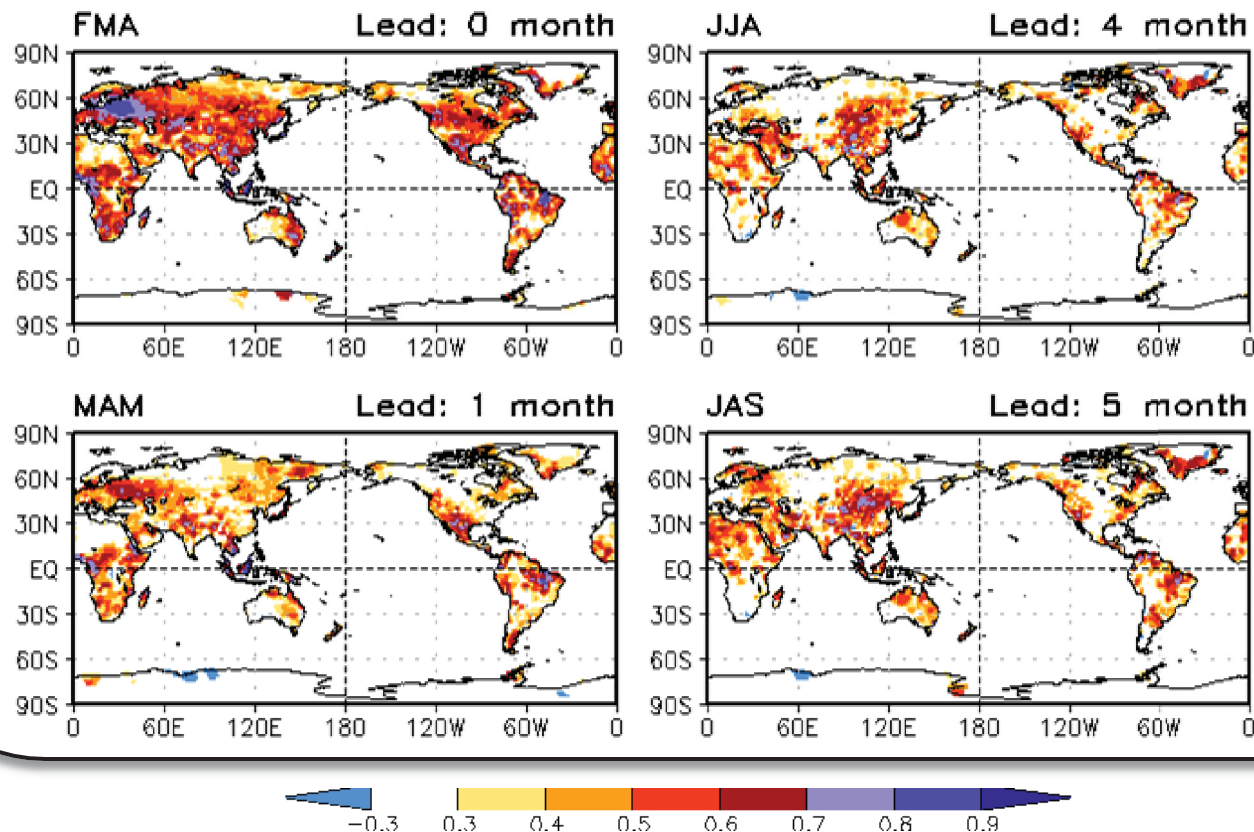


Skill Assessment: Surface Temperature

Anomaly Correlation

CFSv2 Correlation T2m

Initial month: Jan 1982–2009

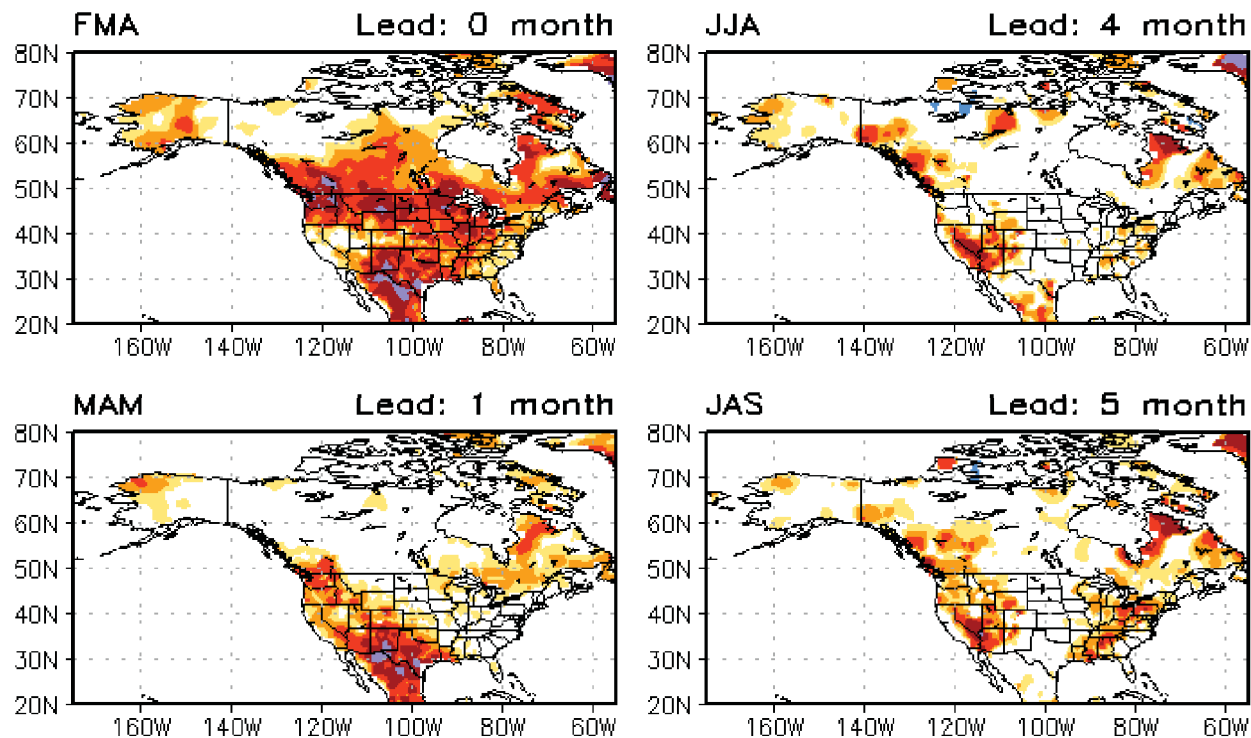


Skill Assessment: Surface Temperature

Anomaly Correlation

CFSv2 Correlation T2m

Initial month: Jan 1982–2009

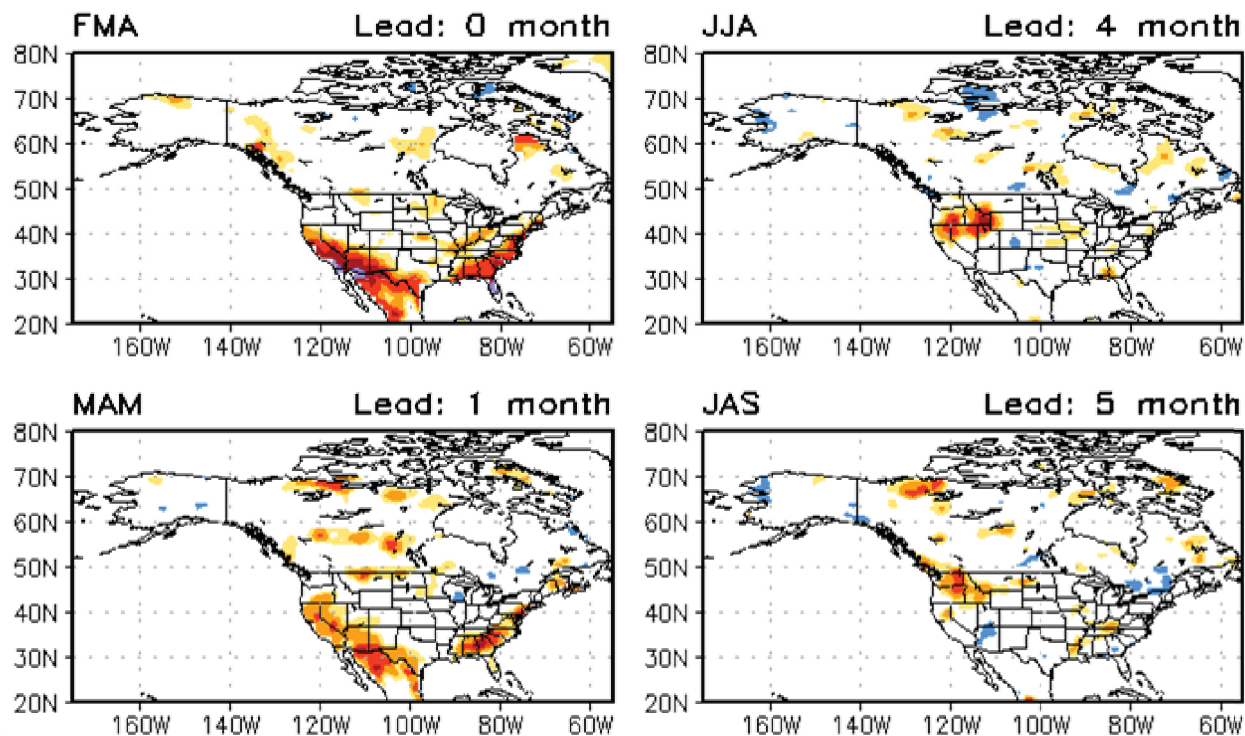


Skill Assessment: Precipitation

Anomaly Correlation

CFSv2 Correlation Precipitation

Initial month: Jan 1982–2009



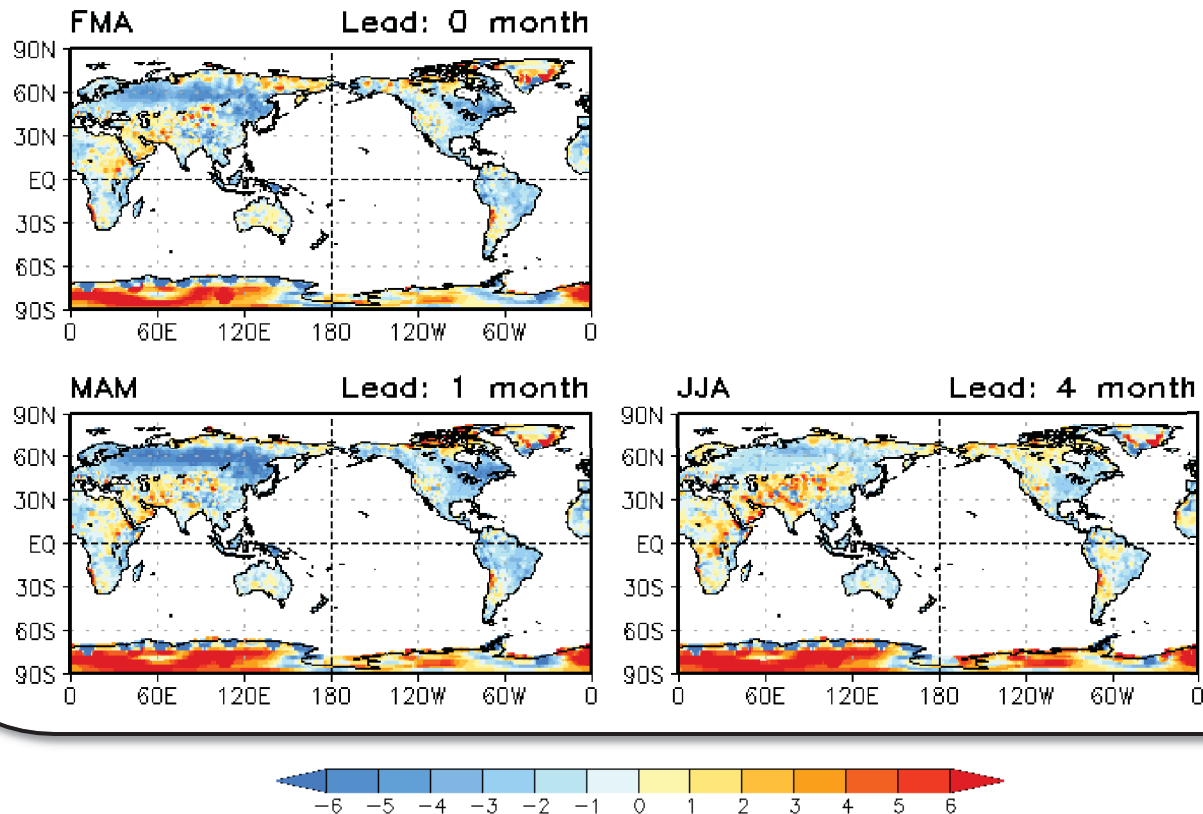
Bias Correction and Calibration

- Bias correction
 - Correct for differences in observed and predicted mean state
 - Adjust if variability between observations and predictions differs
- Calibration
 - Adjust predicted anomaly based on assessment of past skill (e.g., from hindcast data set)
 - If past skill is close to zero, make the forecast PDF same as the climatological PDF

Differences in Mean State

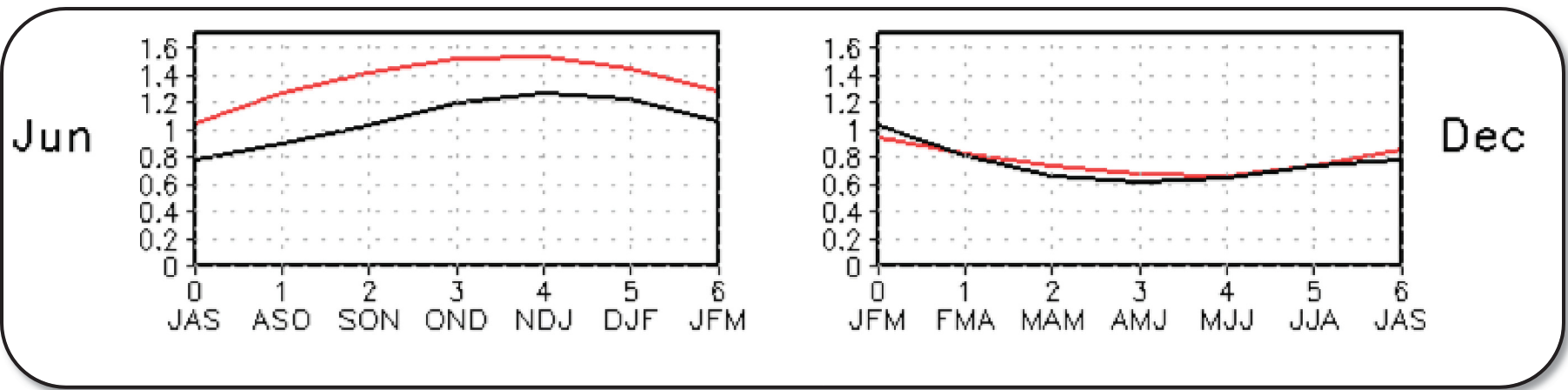
CFSv2 Bias(Fcst-Ghcn) T2m (K)

Initial month: Jan 1982–2009



Differences in Variability

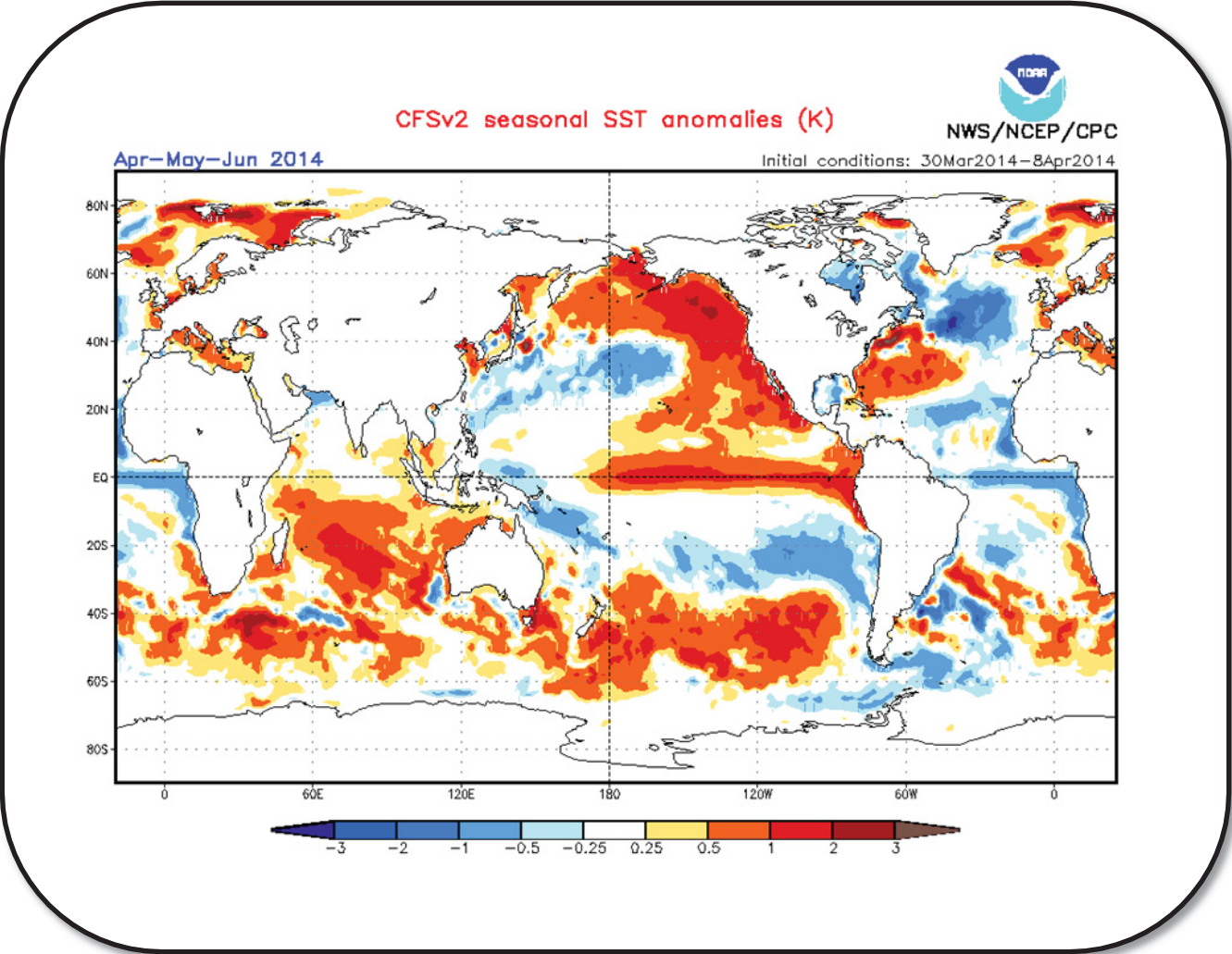
Standard Deviation Nino34 SST(K)



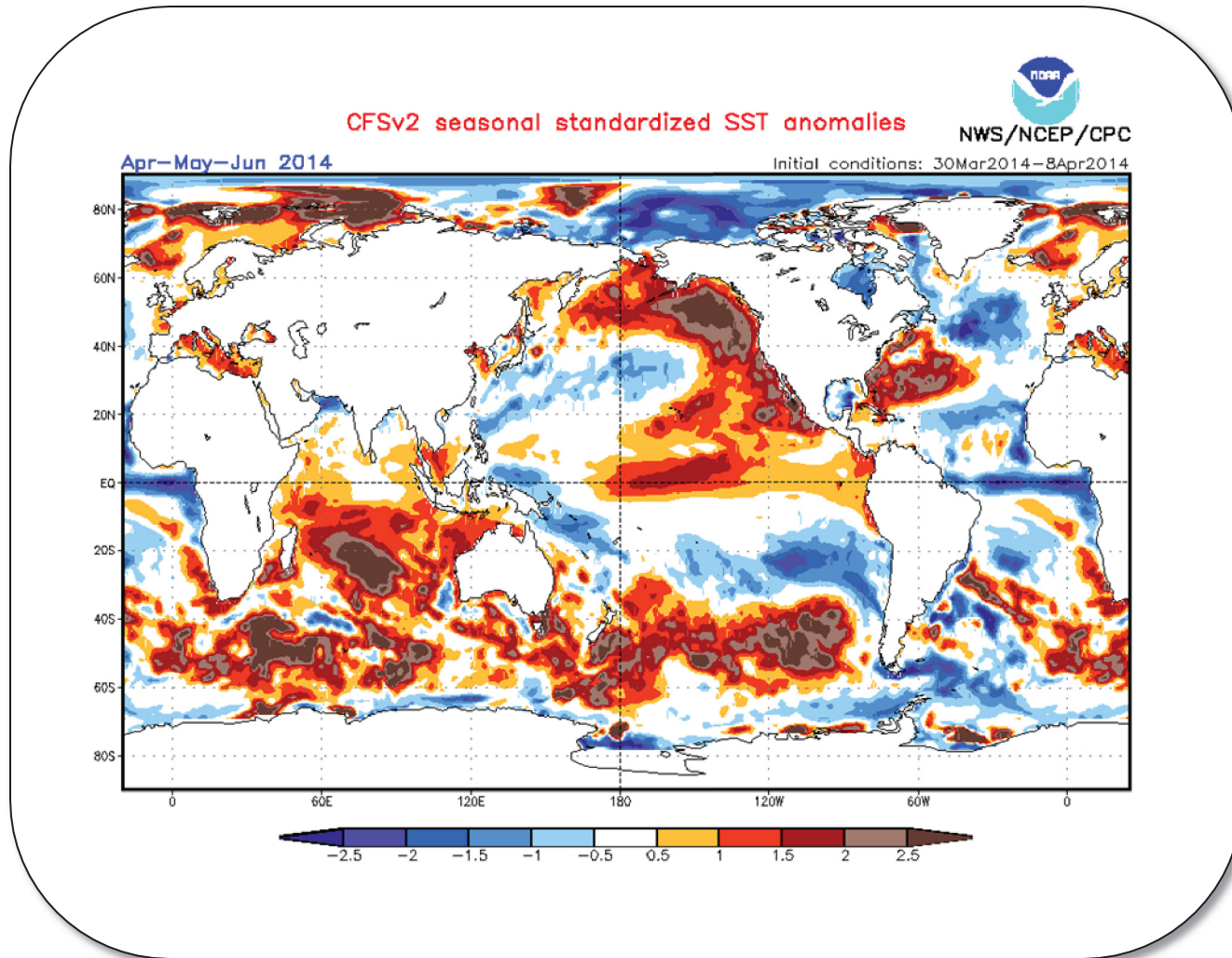
Forecast Dissemination

- Graphical products
 - Bias corrected seasonal mean anomalies
 - Normalized anomalies
 - Bias corrected anomalies with skill mask
- Forecast and hindcast gridded data
 - Real-time forecasts
 - Hindcast data available via several channels
 - Procedures could be developed for statistical downscaling

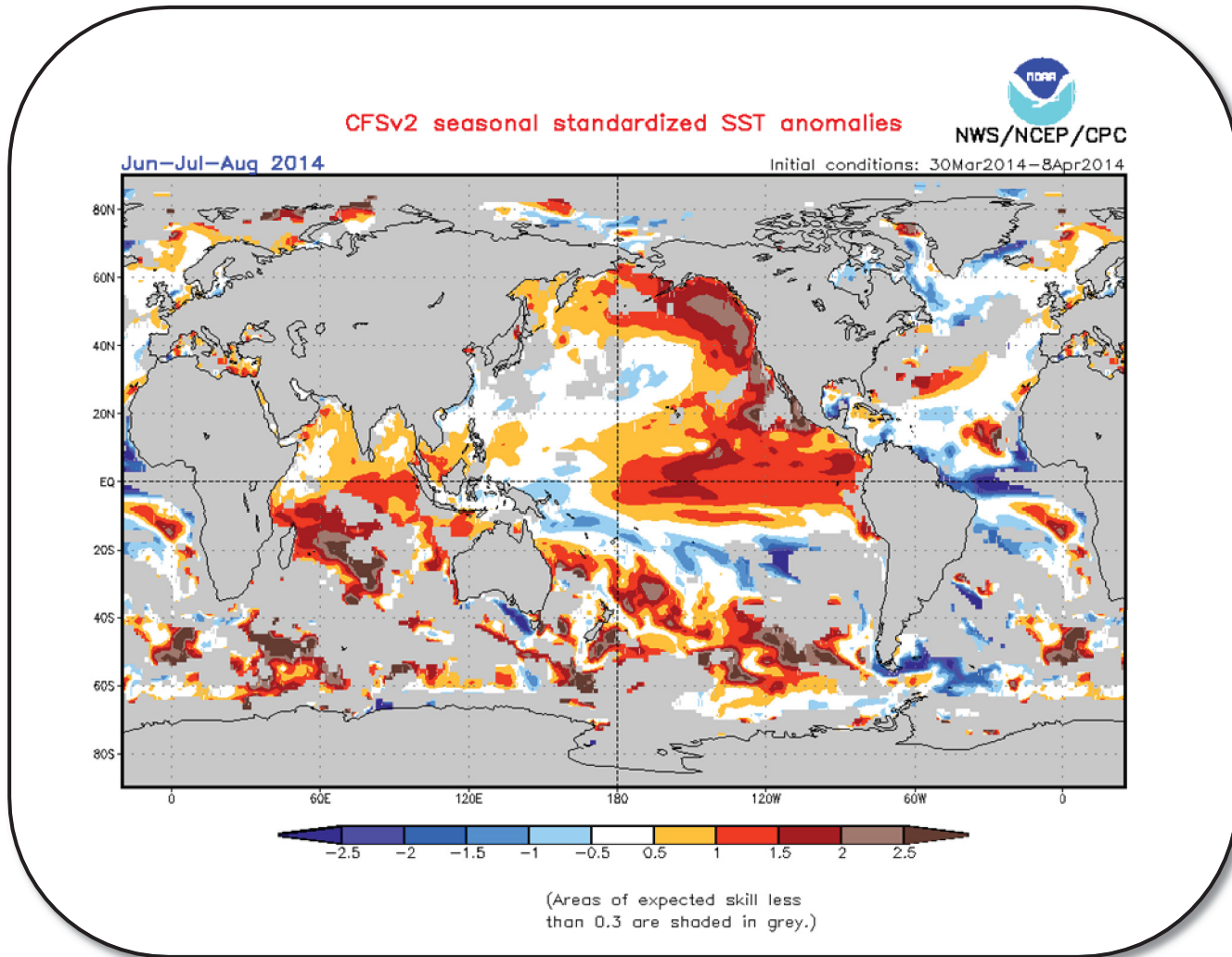
Graphical Products: SST Anomaly



Graphical Products: Standardized SST Anomalies



Graphical Products: SST Anomalies with Skill Mask



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Current Status of Seasonal Prediction Systems

- WMO (World Meteorological Organization) Global Producing Centers (GPCs) for seasonal Predictions
 - 12 in all
 - To be designated as a GPC, a seasonal prediction center has to conform with some designation criterion
 - All GPCs generate seasonal predictions on a monthly basis
 - <https://www.wmolc.org/>

Summary

- Seasonal prediction systems are fairly mature
- Hindcast and real-time forecast data is a huge data base that can be used for various research and analyses purposes
 - Analysis and predictability of extremes
 - Influence of various climatic factors on extremes (attribution and prediction)