Background And Framework for Establishing a Seasonal Precipitation Forecast Improvement Project (SPFIP)

Outline

- Vision
- Motivation for establishing the program
- Definitions
- Foundational documents
- State of seasonal forecasting skill including gaps
- Science goals
- Framework for a SPFIP

Vision

Vision: Development of a holistic program to improve seasonal forecast skill through improved understanding of known sources of predictability, exploration of new sources, and improvement of the representation of these processes in our models.

Realizing this vision will require a substantial and sustained commitment of resources and need to leverage all members of the short-term climate prediction community including operational centers, federal labs, and academic partners!

Motivation for Improving Seasonal Precipitation Forecasts

The National Climatic Data Center has recorded droughts in the United States having severe economic impacts (more than $1 billion in damages) during 16 of the 21 years from 1980 to 2011, with an estimated annual average direct drought loss of $9.5 billion (adjusted to 2011 dollars; Smith and Katz, 2013)).

Definitions

For purpose of this discussion:

1. Seasonal forecast refers to first 3 month season and includes the first month's forecast.
2. Although focus is on precipitation it should be recognized that work to be undertaken will also benefit seasonal temperature forecasts.
3. Predictability is used qualitatively to describe the extent to which the representation of a physical process contribute to prediction skill. Estimates of the lower-bound on predictability are obtained from the skill of current forecasts.

Foundational Documents

Assessment of Intraseasonal to Interannual Climate Prediction and Predictability (NRC, 2010).

Sub-Seasonal to Seasonal Prediction Research Implementation Plan (WMO, 2014)

California Drought Service Assessment (Werner et al., 2015)

Prospects for advancing drought understanding, monitoring, and prediction. (Wood et al., 2015)

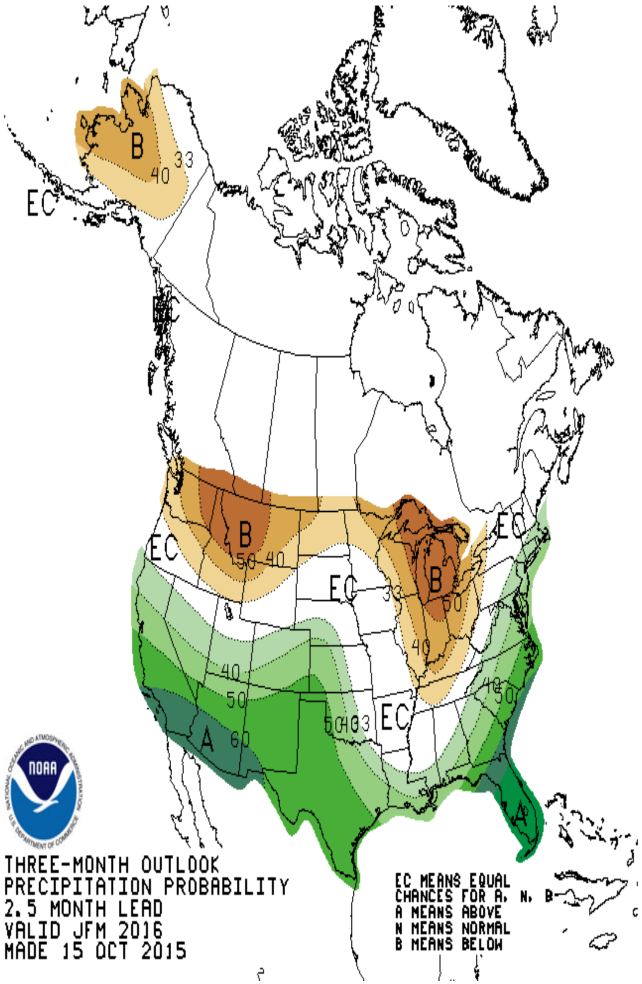
Causes and Predictability of the 2011-2014 California Drought. (Seager et al., 2014).

State of Seasonal Climate Forecasting

- CPC Seasonal Outlooks
- Skill level of current seasonal forecast tools
- Footnote on ENSO and its role in Seasonal Forecasts for the US
- Examples of where our most skillful tools don't perform well indicating gaps in our knowledge or limited predictability or both
  - 1 Month JFM 2015 NMME forecast
  - Greatly reduced skill of NMME in predicting SST variability outside of central and eastern Tropical Pacific

Human Forecasters Use Various Tools To Develop Seasonal Predictions:

- Dynamical Models
- Statistical Models
- Historical Analogs
- Historical Composites



Goal is to leverage complementary skill between the tools.

Ultimately, skill of seasonal forecast depends on skill of tools made available to the forecaster.

Multi-Model Ensembles and the North-American Multi-Model Ensemble (NMME) Project

Why do use multi-model ensembles (MME) for forecasts?:

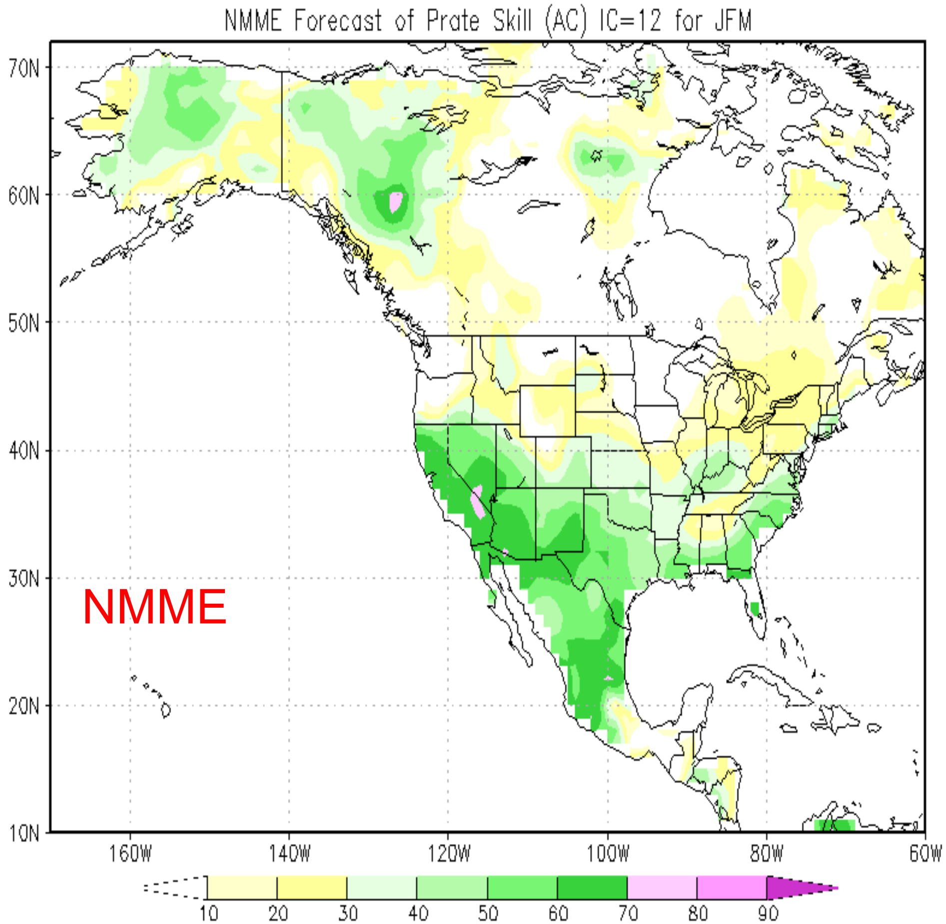
- Allows representation of model uncertainty.
- Possibility of complementary skill between models.
- Skill of MME is frequently higher than that from the most skillful member in the ensemble (though if one model is dominantly better this is not always true).

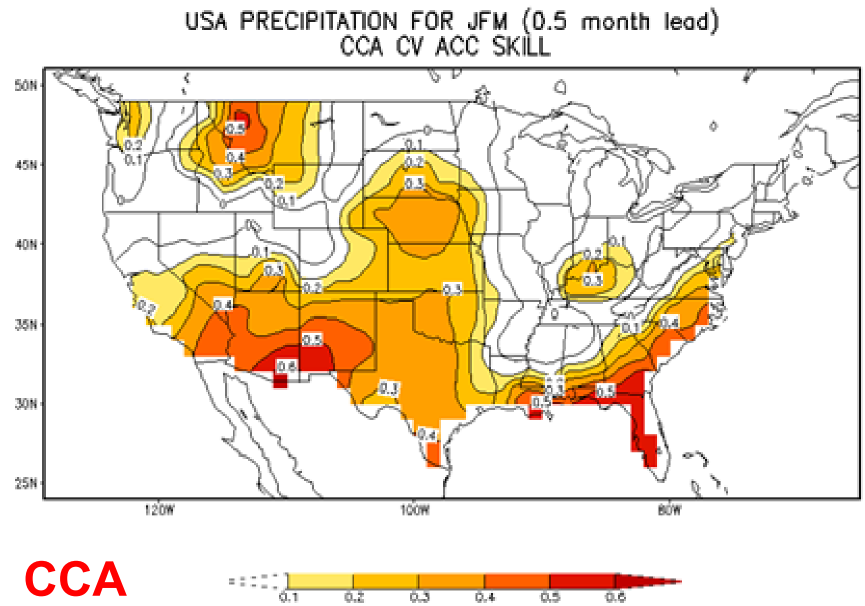
NMME is frequently our most skillful tool but there is still room for improvement.

Models/Groups Participating in NMME

Organizations	Models
NOAA/NCEP	CFSv2
NOAA/GFDL	CM2.1 FLOR (March 2014)
NASA/GMAO	GEOS5
Environment Canada	CMC1-CanCM3 CMC2-CanCM4
NCAR	CCSM3.0 CCSM4.0 (July 2014)
NCAR	CESM1.0 (Mar. 2015)

Lead 1 Precipitation Forecast Skill for JFM from Two State of the Art Forecasting Tools: NMME and CCA





Users perspective on the skill level of these forecast tools and hence their utility will vary.

Footnote on ENSO and Seasonal Prediction Over the US

ENSO isn’t the only factor controlling the seasonal distribution of precipitation over the US.

However, it is commonly accepted that accurate forecasts of ENSO and its associated teleconnections are a necessary but not sufficient condition for accurate seasonal precipitation forecasts.

Lead 1 NMME SST Forecast for January 2015

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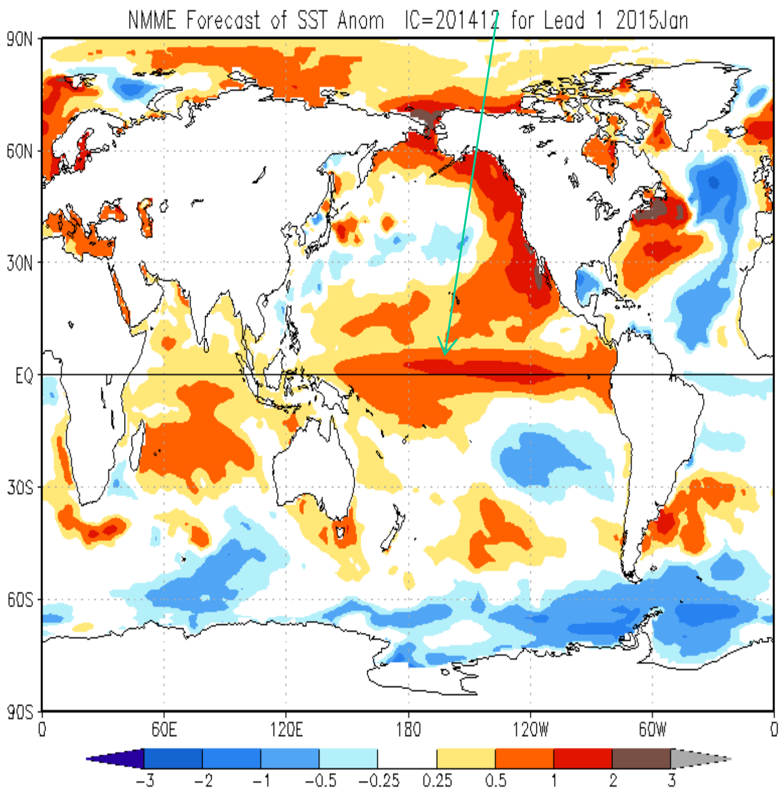
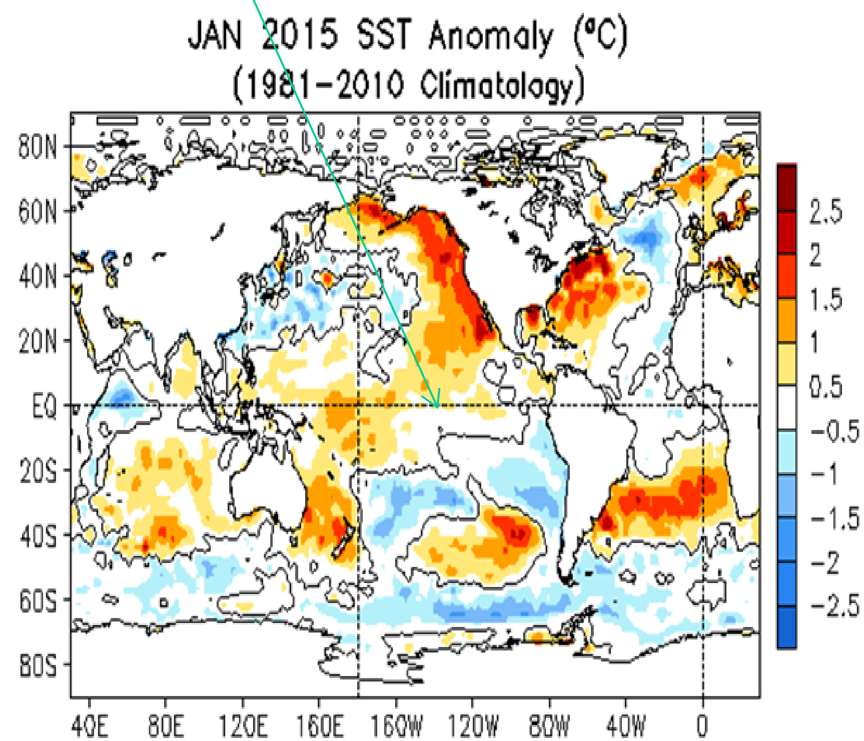
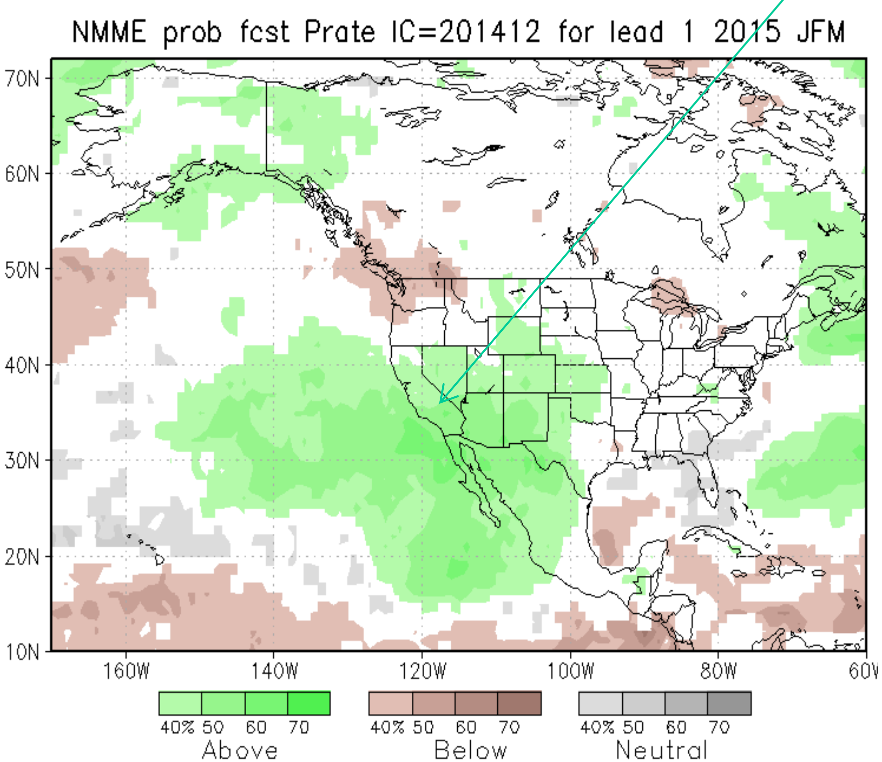
1 month lead NMME forecast calls for moderate cannonical El-Nino while observed anomalies were confined to western Pacific

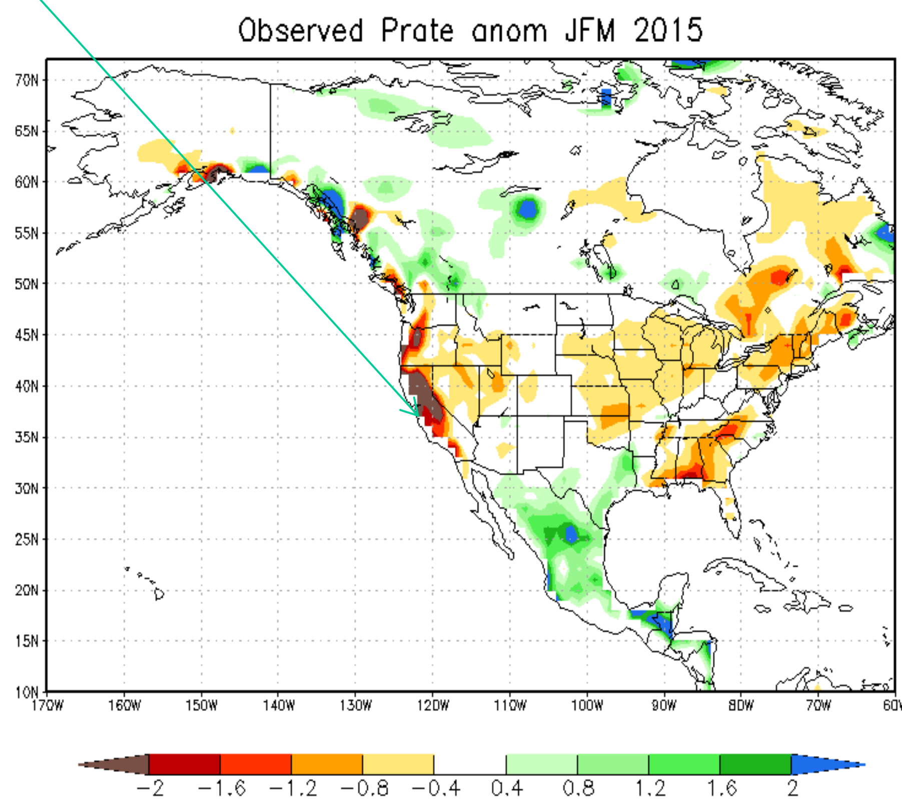




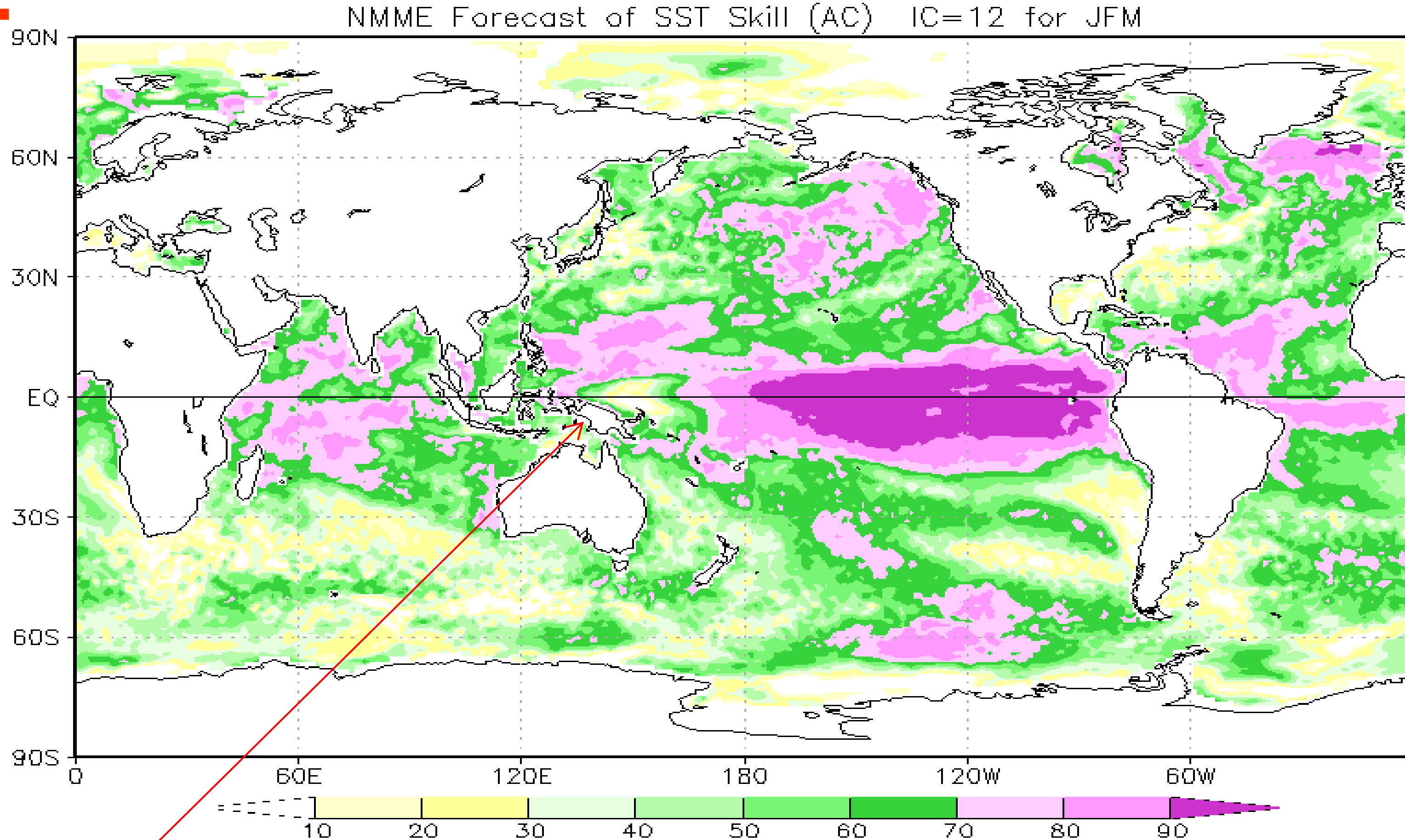
Lead 1 NMME Precipitation Forecast for JFM 2015

Associated precipitation forecast calls for modest probability of above normal precipitation, while record breaking drought was observed.





Retrospective Forecast Skill of Lead 1 NMME SST Forecast for JFM from NMME



State of the Art MME Dynamical Forecast System has Low Skill in Predicting Near-Equatorial Western Pacific SST. If SST in this region drove the large-scale pattern past two years there is an issue.

Key Science Issues that Need to Be Addressed to Improve Seasonal Forecast Skill

Borrowing heavily from the collective recommendations made in the foundational documents especially the NRC Report on Intraseasonal to Interannual Prediction and Predictability

National Academy Assessment of State of Interaseasonal to Interannual Climate Prediction and Predictability (2010)

Main Conclusions:

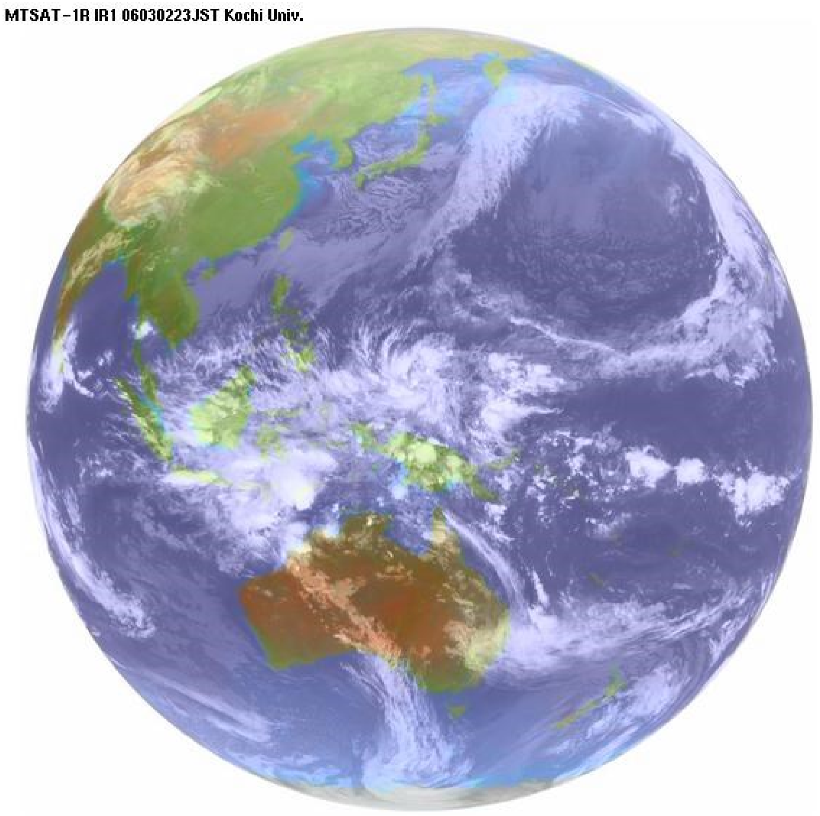
- There are no "silver bullets;" there is no single action that will lead to a revolutionary leap forward in ISI predictions.
- Incremental increases in ISI forecasting quality are to be expected as the building blocks of ISI forecasts are improved and we increase knowledge of sources of predictability.

Challenge 1: Understanding Processes Controlling Organization of Tropical Convection

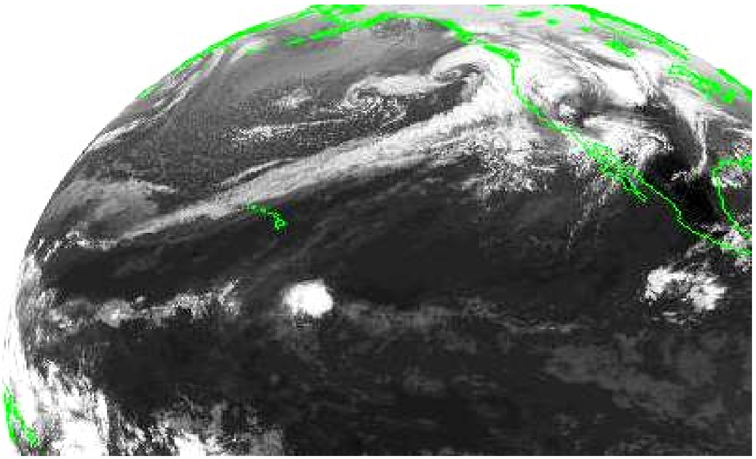
- A pervasive weakness of weather and climate models.

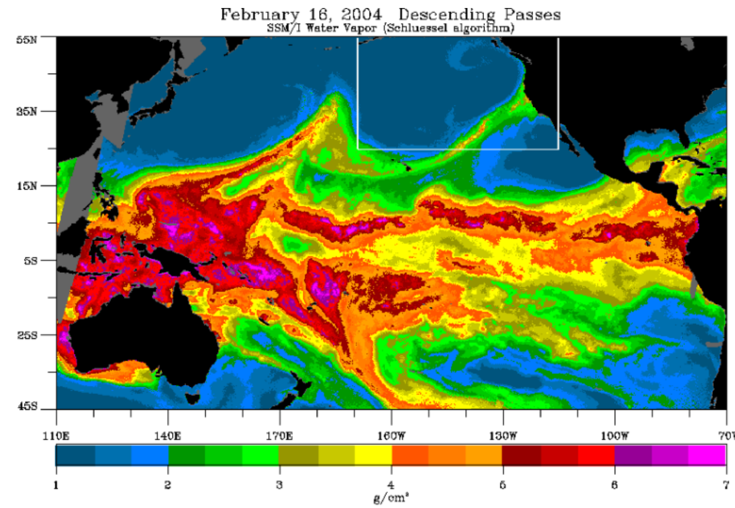
- Studies suggest that beyond 10 days, variations in tropical heating are a (the) major source of predictability, including weather events.

- Tropical climate biases often appear very early in model integrations.



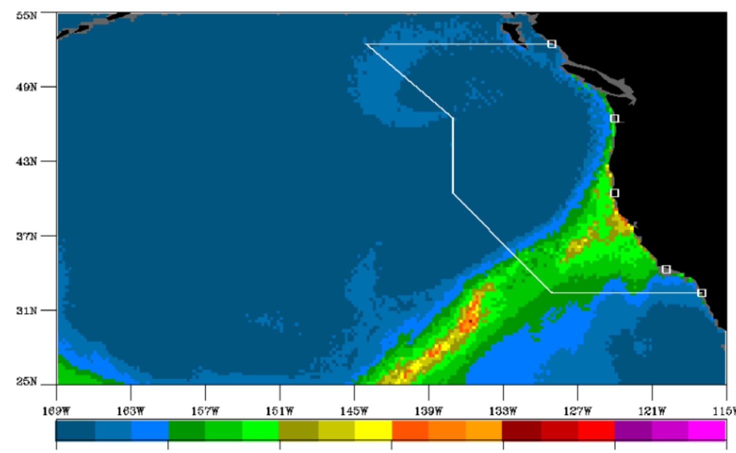
Challenge 2:
Improve Understanding and Prediction Tropical – Extratropical Interactions





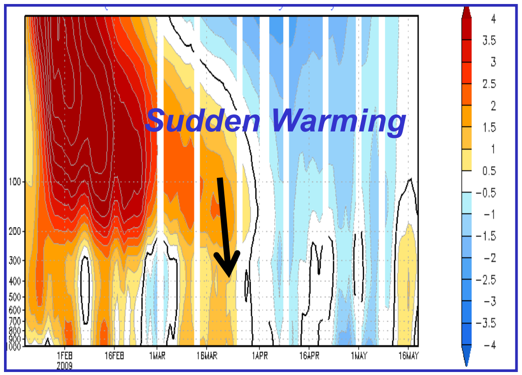
Improve understanding and prediction of:

- Madden-Julian Oscillation
- "Atmospheric Rivers"
- "Pineapple Express" events
- Blocking and Storm Tracks
- Impacts: West Coast floods



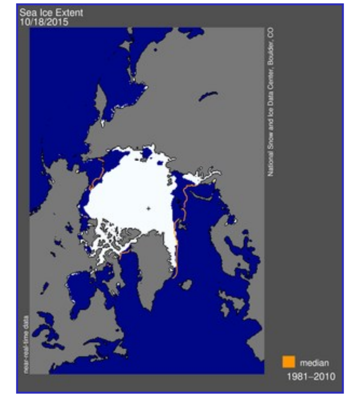
California floods & "Atmospheric Rivers" (Bao et al 06)

Challenge 3:
Increase Understanding and Exploit Sources of Predictability

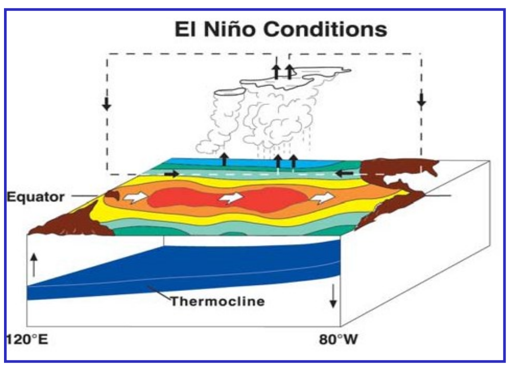


Stratosphere – Troposphere Interactions

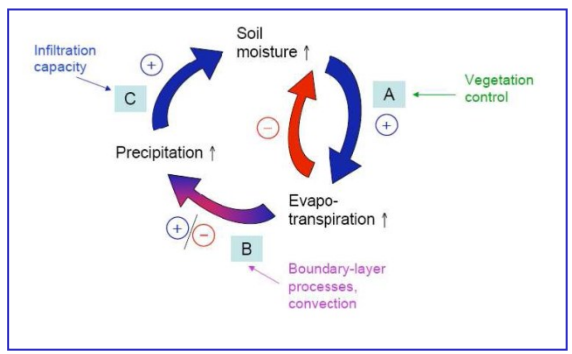
Key sources that link climate to weather:



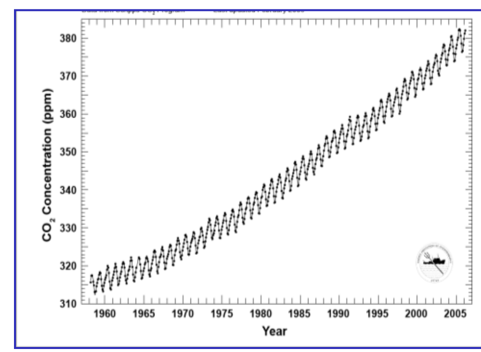
Arctic Sea ice



Ocean-Atmosphere Interactions; Role of sea-surface temperature



Land -Atmosphere Interactions; Role of soil moisture & land processes

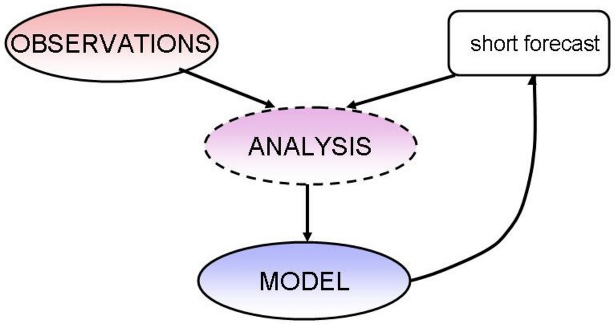


Long-term Trends and Climate Variability

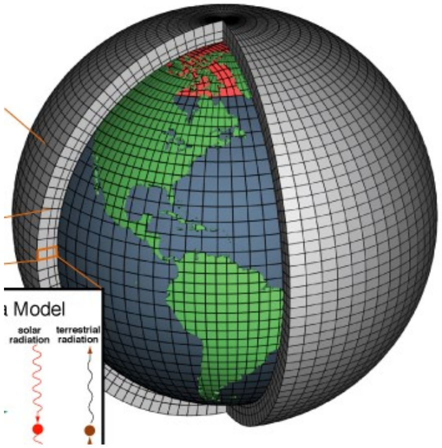
THE NATIONAL ACADEMIES:
http://www.nap.edu/catalog/12878.html

Challenge 4:
Improve the "Building Blocks"

Upgrade Data Assimilation Systems



Identify / correct model errors



Enhance Observational Networks

Improvements in models, observational networks, and data assimilation systems lead to improved understanding and more realistic prediction over time.

SPFIP Science Goal 1: Improved Understanding and Modeling Sources of Seasonal Predictability

- Madden-Julian Oscillation
- Stratosphere-Troposphere Interactions
- Ocean-atmosphere coupling (including ENSO)
- North Atlantic Oscillation (NAO)/Arctic Oscillation (AO)
- Land-atmosphere feedback
- Polar Sea-Ice
- Atmospheric Rivers
- Pacific Decadal Oscillation
- Role of SST forcing versus internal variability?

SPFIP Science Goal 2: Improved Seasonal Prediction Tools

Identify cause reduce systematic errors in coupled atmosphere-ocean general circulation models (CGCMS):

- Double intertropical convergence zone
- Excessively strong equatorial cold tongue
- Weak or incoherent intraseasonal variability and associated teleconnection
- Failure to represent multi-scale organization of tropical convection
- Poorly represented cloud processes, especially low-level clouds

Increase model resolution to better resolve physical processes and orographic variations

SPFIP Science Goal 2: Improved Seasonal Prediction Tools

Improved Representation of physical process in CGCMS:

- Deep and shallow convection
- Planetary boundary layer in the atmosphere and the ocean
- Sea ice
- Soil moisture
- Snow cover

Exploration of new statistical techniques and hybrid dynamical-statistical techniques

- Need to ensure rigorous cross-validation to estimate true forecast skill

SPFIP Science Goal 3: Improved Forecast Products to Meet User Needs

To be discussed at workshop:

Framework for an SPFIP

1. Need to recognize the difficulty of the problem and ensure adequate resources are obtained.
2. Essential components (funding amounts are per year and assume a 10-year program):
   - Grants program supporting mission-driven research on understanding sources of predictability
   - Support to modeling centers for model improvements
   - Grants program on tailoring products for end users
   - Support infrastructure for testing new tools and transitioning to operations
   - High-performance computing augmentation
3. Key partners:
   - Academic community
   - Within NOAA: NWS (NCEP, NWC), OAR (GFDL, ESRL, CPO); NESDIS (NCEI)
   - Other willing federal agencies

How to Measure Success for SPFIP

1. (Somewhat) arbitrarily chosen metric of 20% improvement over year 1 baseline at 5 years and 40% improvement over year 1 baseline at 10 years.

   This engenders two very distinct replies:

   a. You are nuts: We can't achieve that.

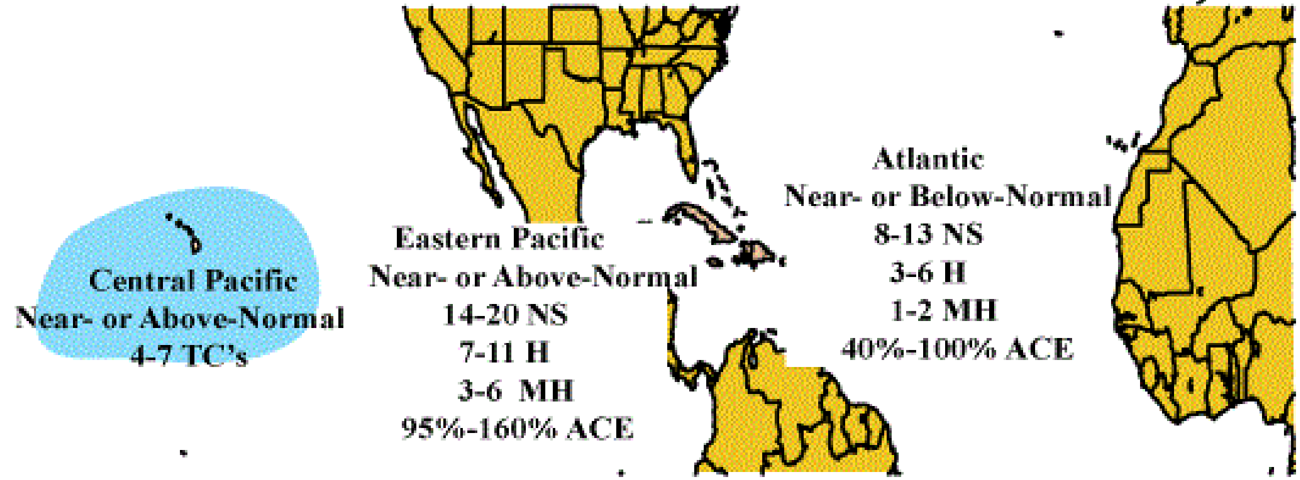
   b. That doesn't seem very ambitious

2. As part of the white paper we need to define some baseline metric(s) and set goals for improving on those metrics.

   Given that the motivation for this project is to inform water resource decisions the best approach may be to let water resources experts propose some initial metrics and then iterate with climate scientists to refine these.

Extra Slides

NOAA's 2014 Hurricane Season Outlooks Issued in May



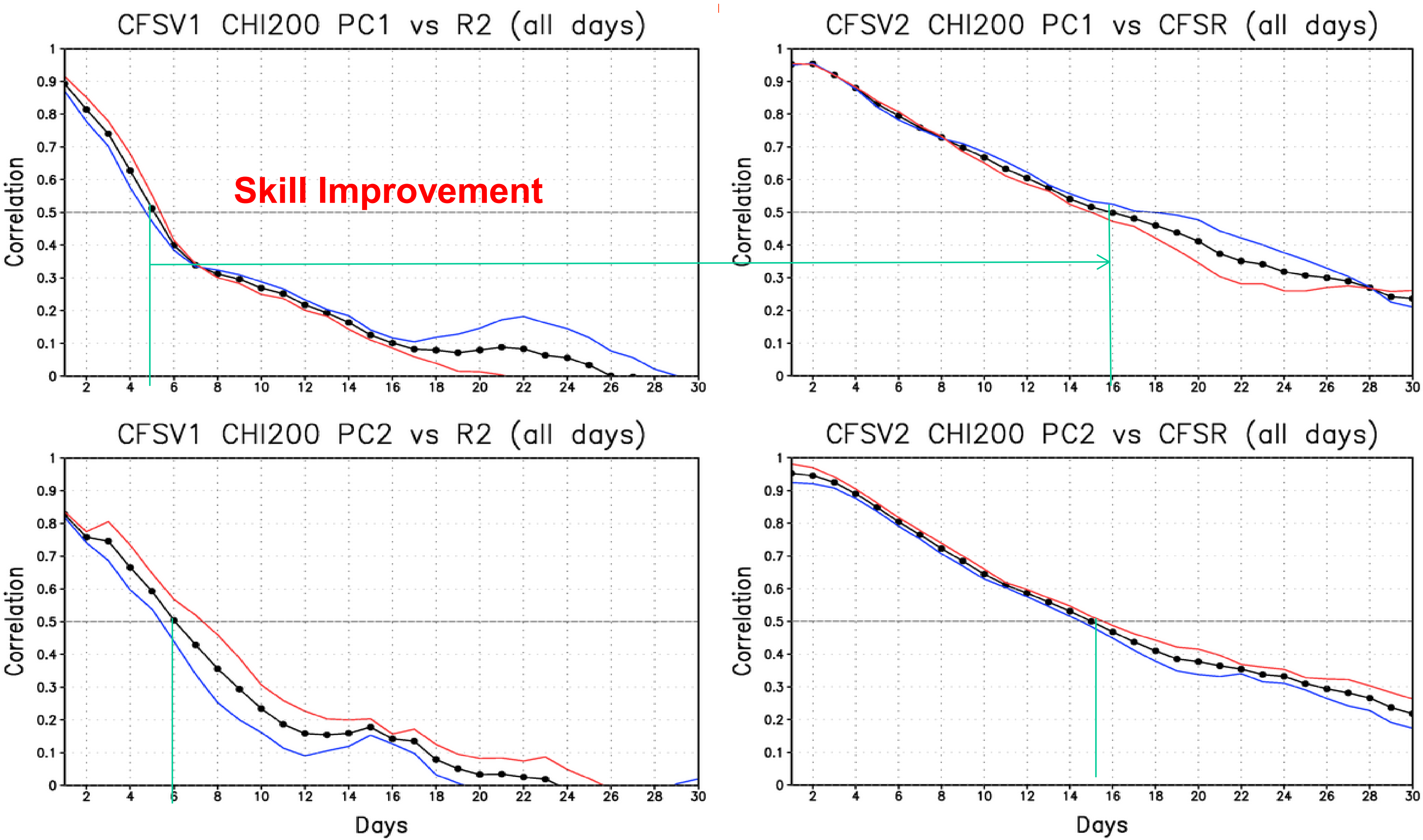
NOAA's 2014 Atlantic and Eastern Pacific hurricane season outlooks indicate the likely ranges (each with a70% chance) of Named Storms (NS), Hurricanes (H), Major Hurricanes (MH), and percentage of the median Acccumulated Cyclone Energy (ACE).

NOAA's 2014 Central Pacific hurricane season outlook indicates the likely number of tropical cyclones (TC), which include tropical depressions, tropical storms and hurricanes.

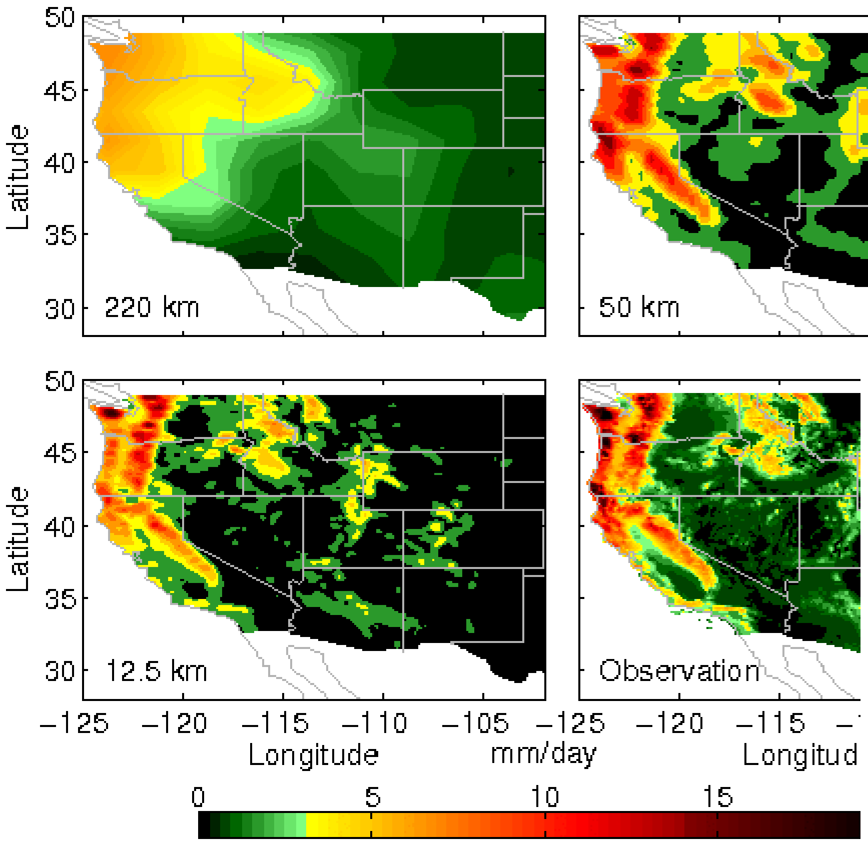
For 2014 the probabilities of each season type are:

	Atlantic	Eastern Pacific	Central Pacific
Above Normal	10%	50%	40%
Near Normal	40%	40%	40%
Below Normal	50%	10%	20%

Improvement in Forecast Skill of MJO from CFSV1 to CFSV2



DJF precipitation: GFDL HiRAM vs. Observation



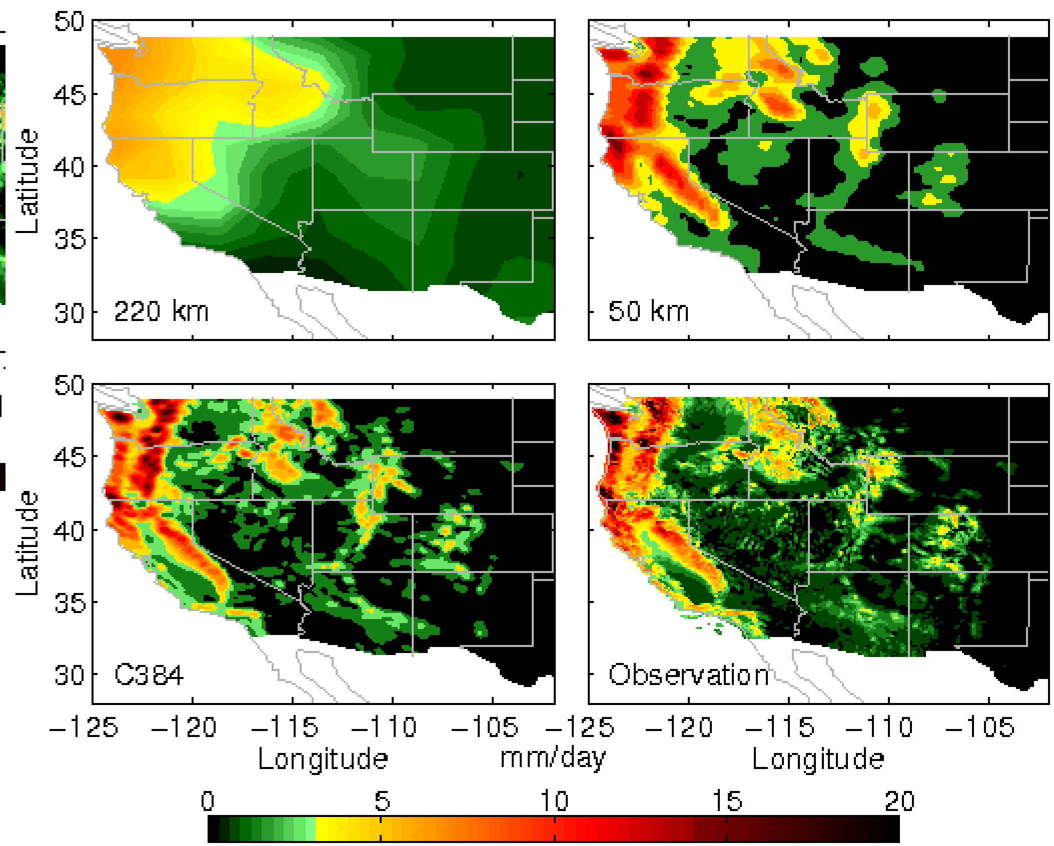
Need hi-res to provide regional details. But global uniform resolution is still too expensive

→

Make hi-res affordable with variable-res approach

C384 stretched

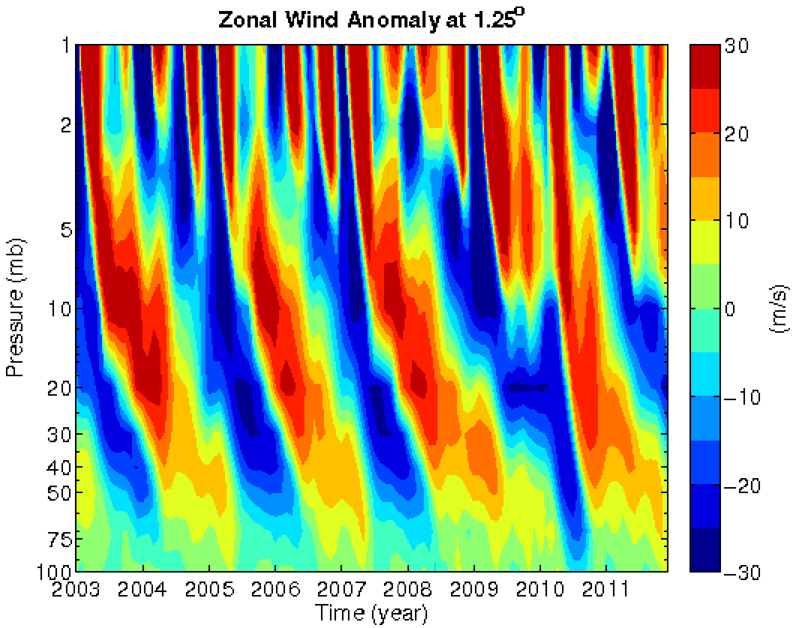
(~10 km over CONUS)



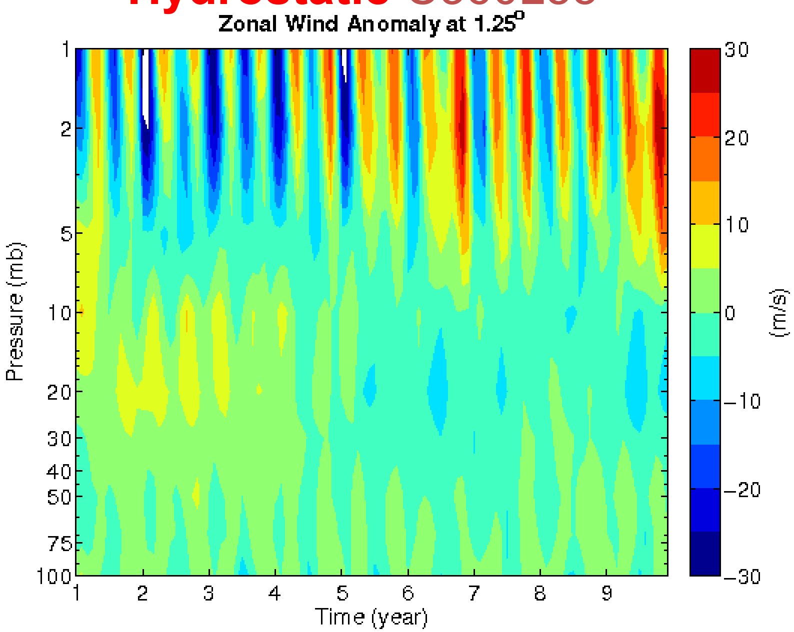
QBOs:

- QBOs are difficult to simulate in GCMs
- Believed to have impacts to monsoon precipitation, stratospheric ozone, hurricanes, and the stratospheric sudden warming

NASA Merra Data (analysis)



Hydrostatic C360L55



Non-hydrostatic C360L55