Forecasting Precipitation for Winters of 2016 and 2017 and Associated Science Challenges

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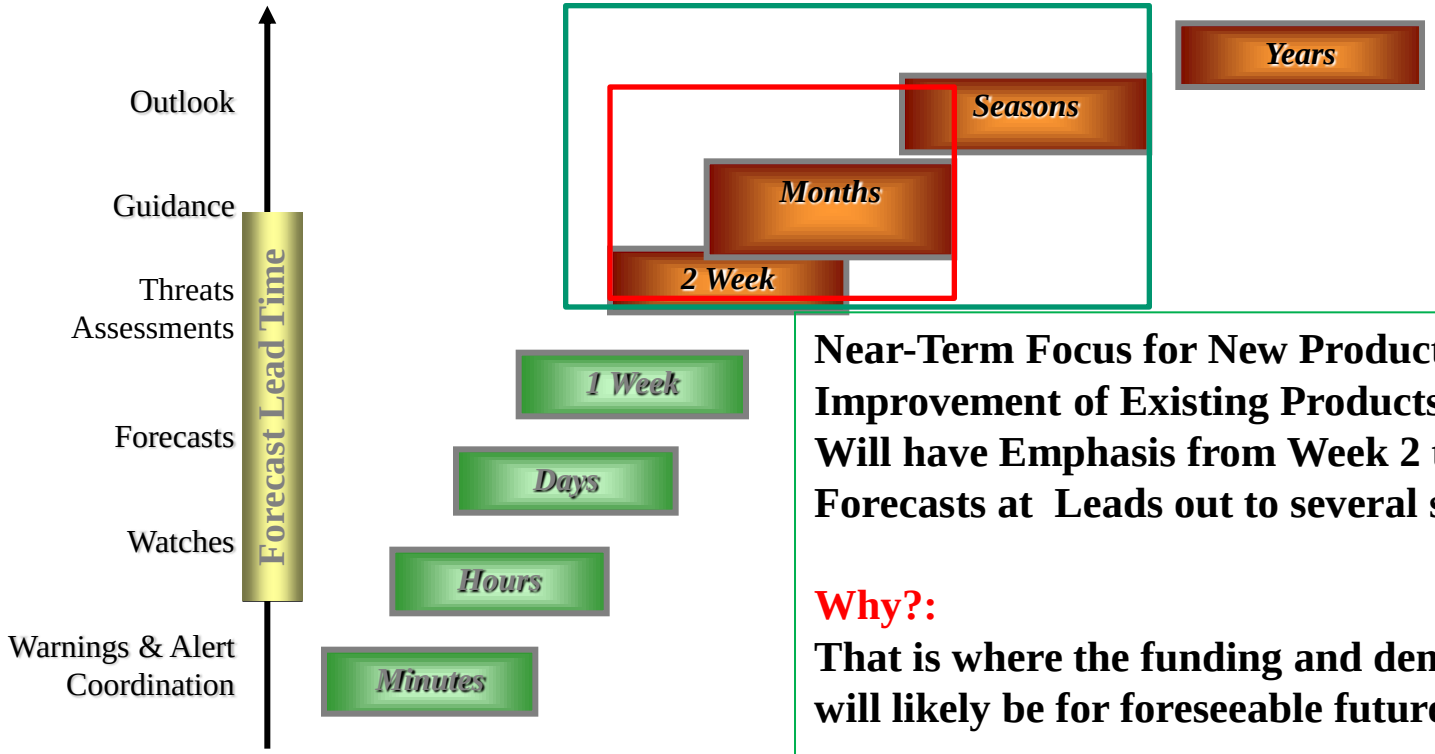
Director, Climate Prediction Center

Outline

- CPC Suite of Products
- CPC Forecast Process
- FY2016-2017 Precipitation Outlooks
  - Week 2
  - Monthly
  - Seasonal
- Science Challenges for Forecasting Precipitation on Subseasonal to Seasonal Timescale
- GFDL Results for FY2017 Winter

CPC Near-Term Focus within NOAA Seamless Suite of Forecast Products



Near-Term Focus for New Products and Improvement of Existing Products
Will have Emphasis from Week 2 to Seasonal Forecasts at Leads out to several seasons.

Why?:
That is where the funding and demand are and will likely be for foreseeable future.

Longer timescale is important but is handled by other parts of NOAA.

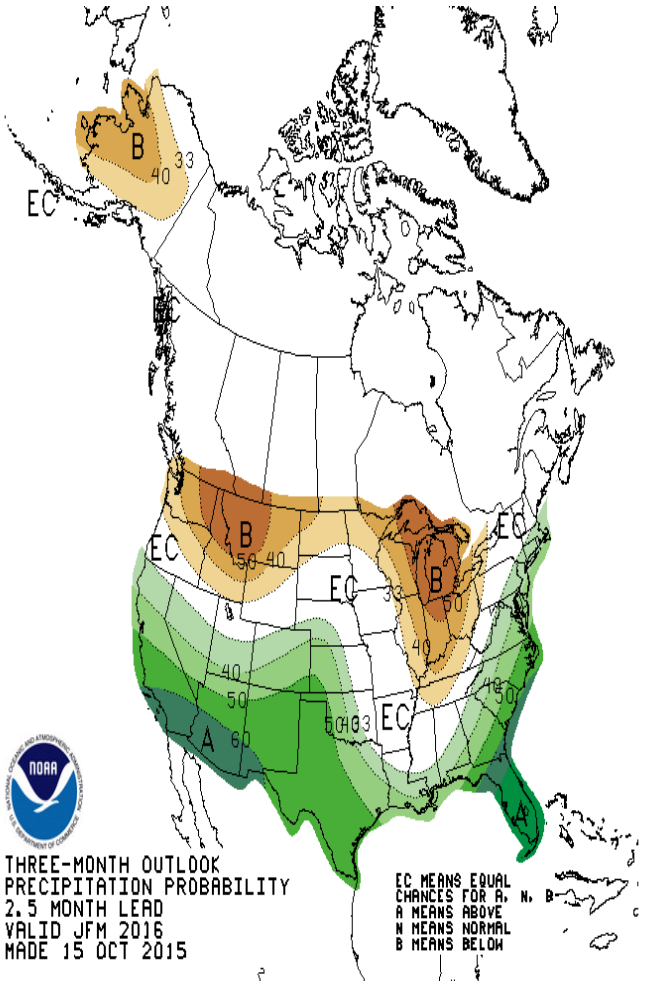
Generation of CPC Precipitation Outlooks

Human Forecasters Use Various Tools To Develop Seasonal Predictions:

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

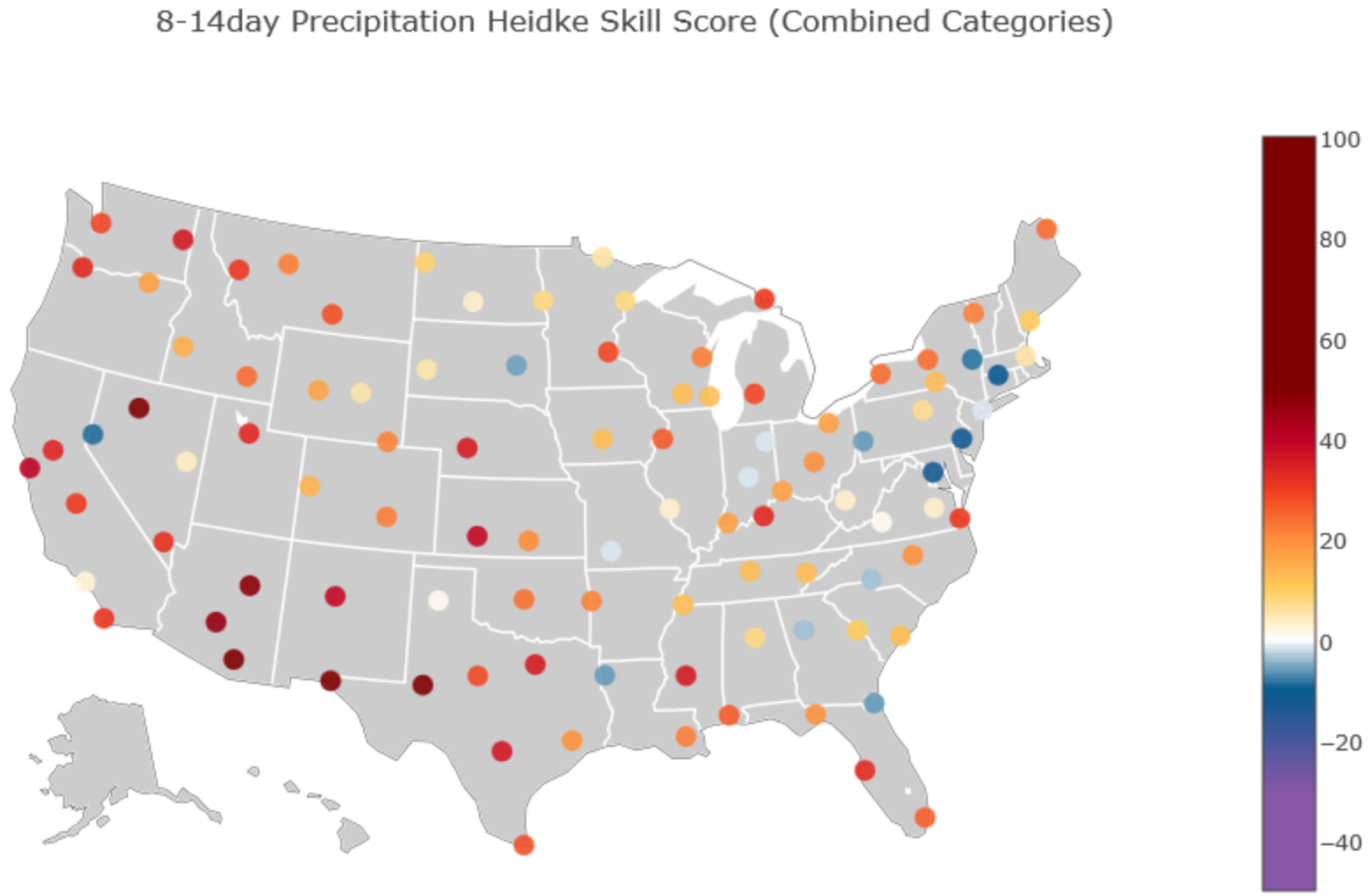
Goal is to leverage complementary skill between the tools.

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

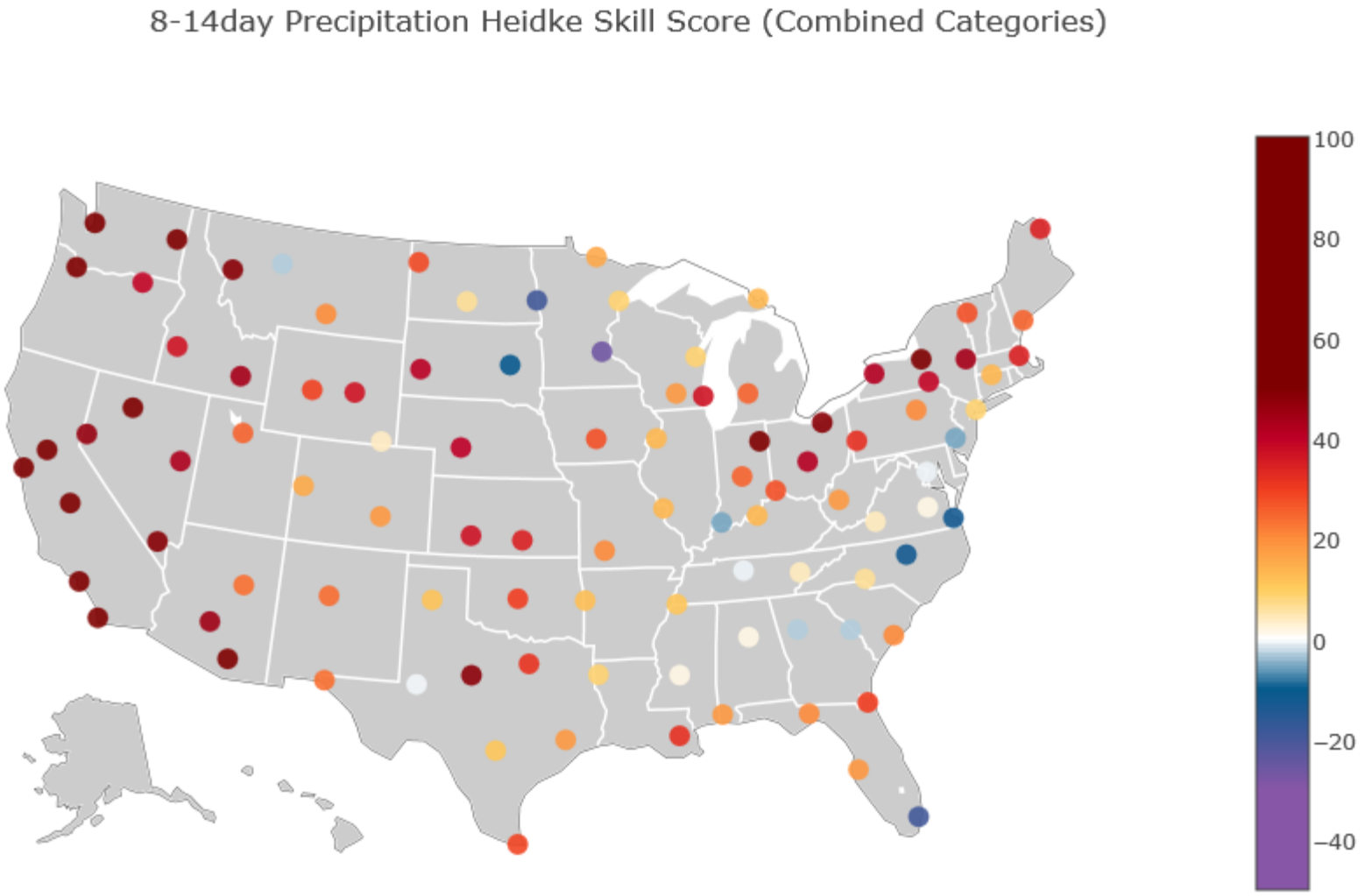


Week 2 Forecasts

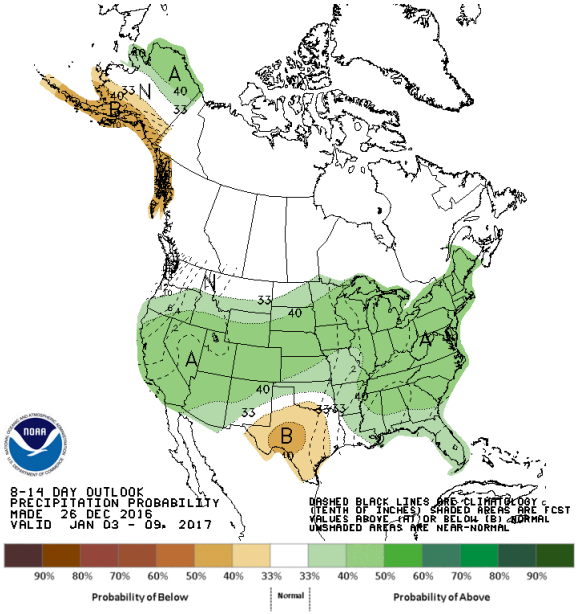
CPC Week-2 Precipitation Forecast Verification for JFM 2016



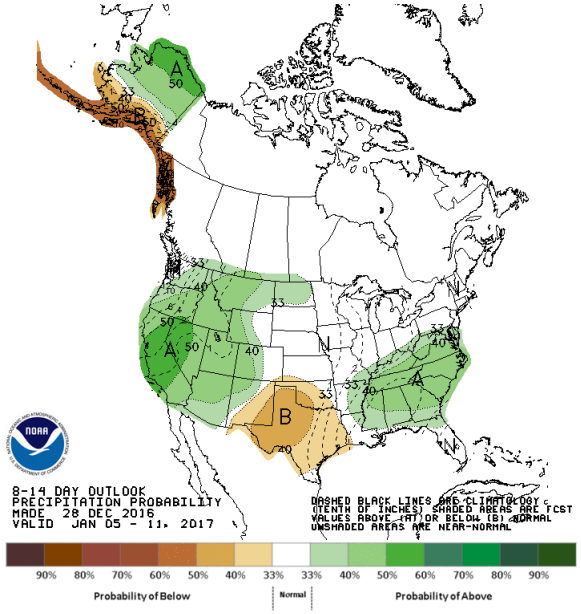
CPC Week-2 Precipitation Forecast Verification for JFM 2017



CPC 8-14 Day Precipitation Forecasts



Valid January 3-9



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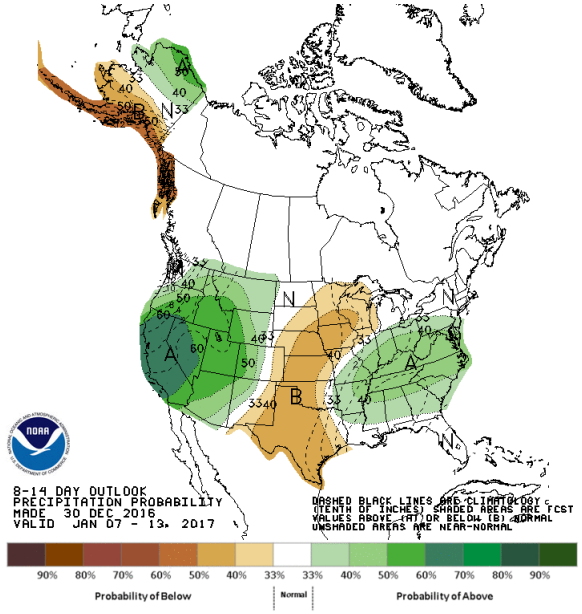
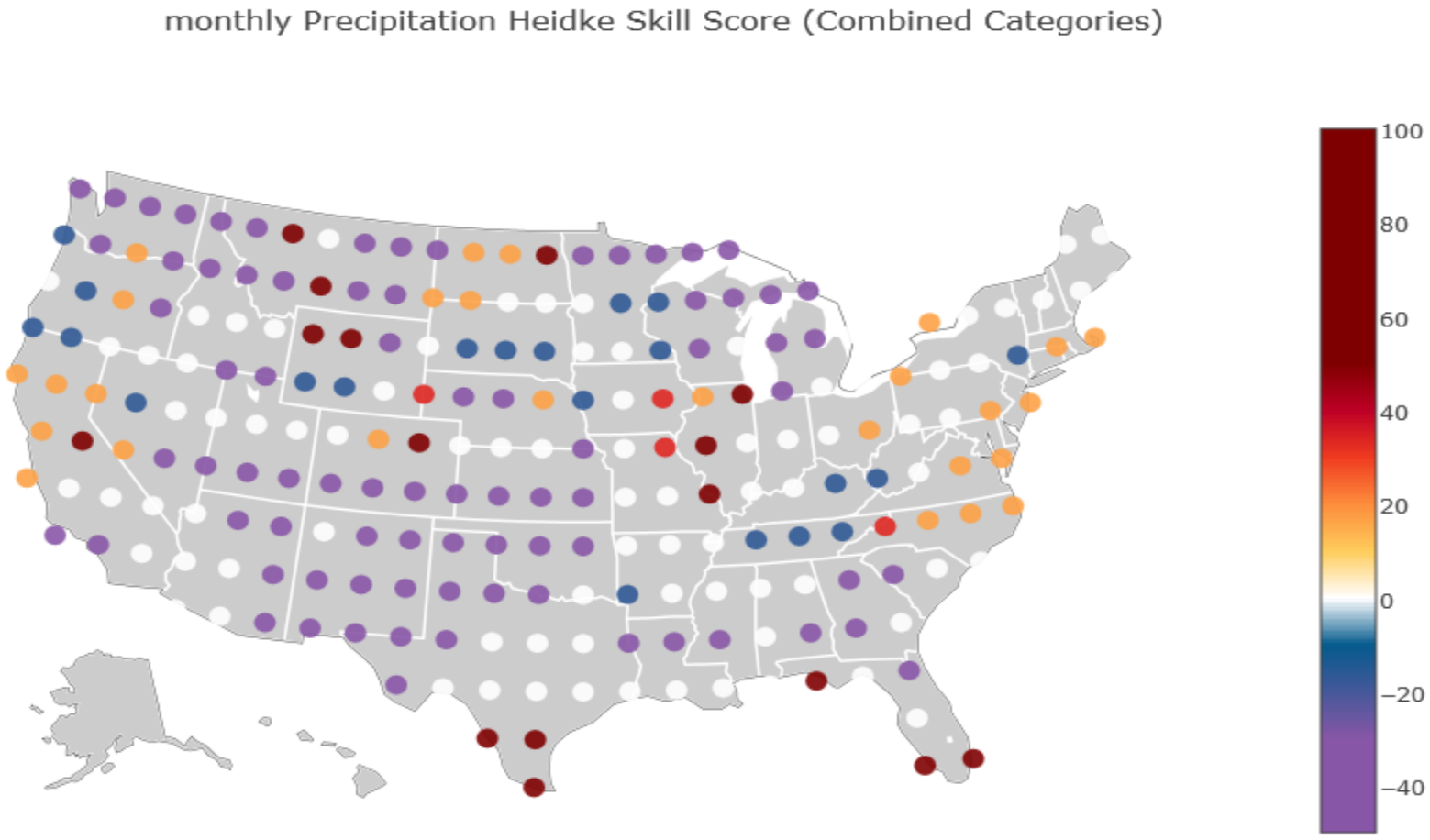


Valid January 7-13

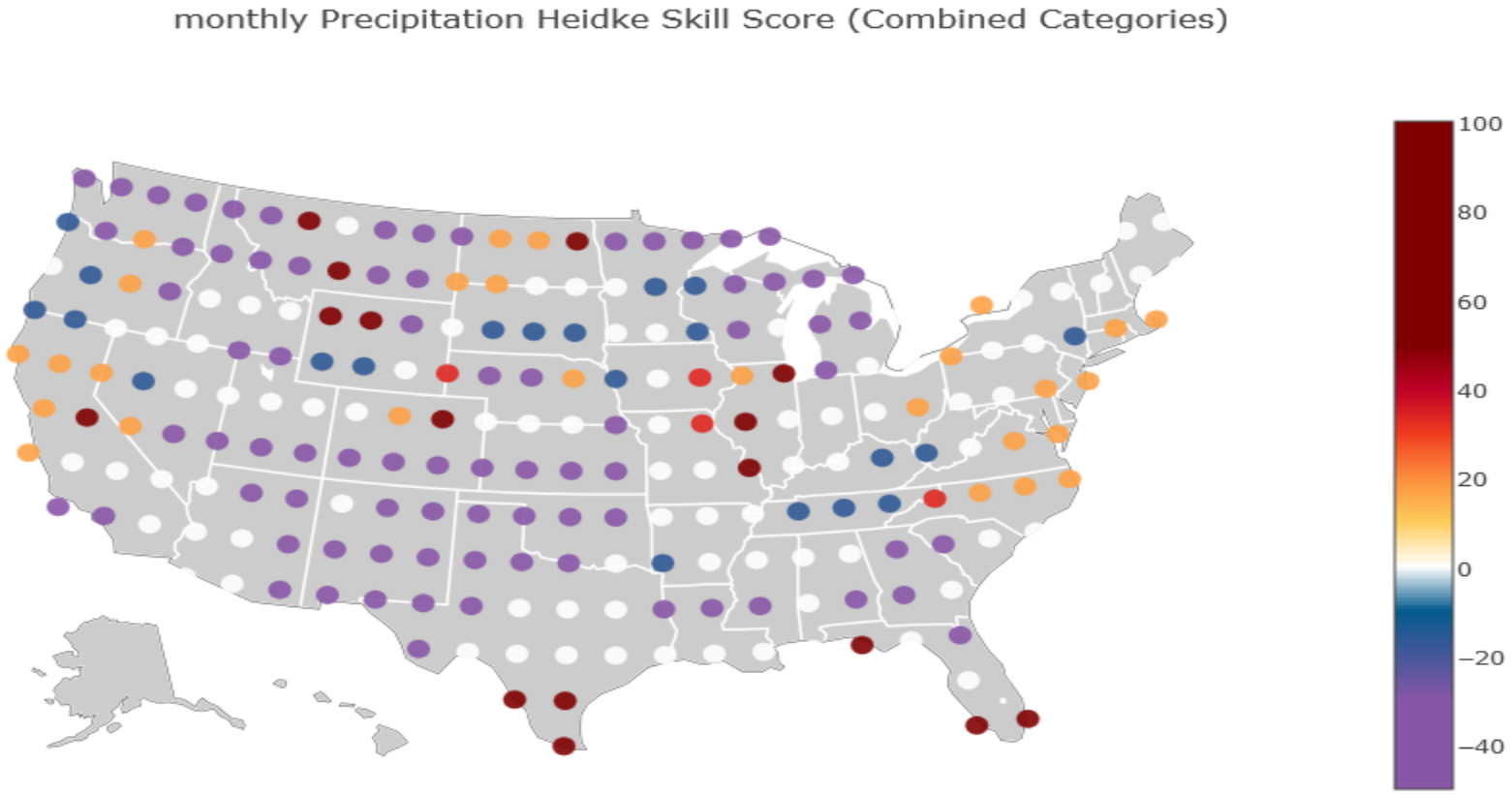
CPC Week Two Forecasters Call for Enhanced Probability of Above Normal Precipitation for Early January 2017

Monthly Forecasts

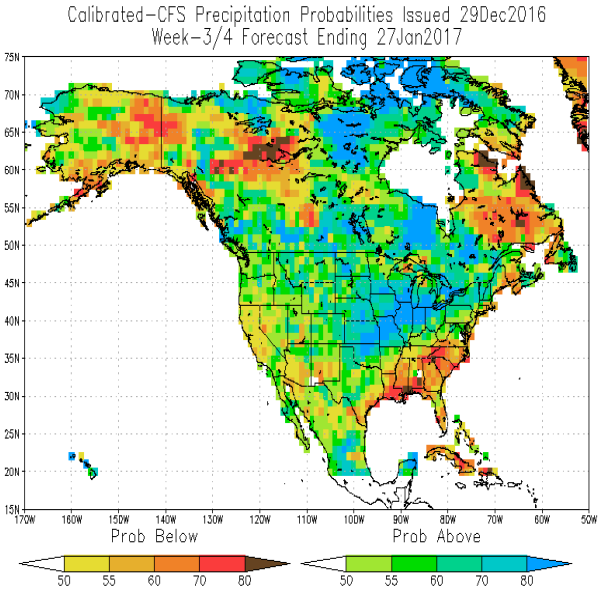
CPC Monthly Precipitation Forecast Verification for JFM 2016

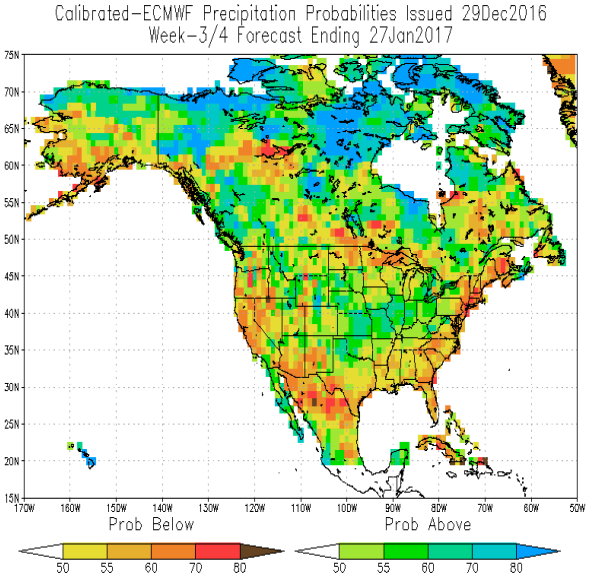


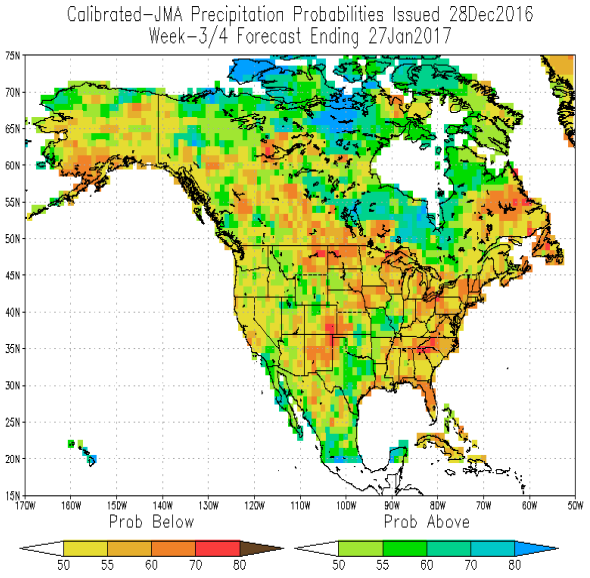
CPC Monthly Precipitation Forecast Verification for JFM 2017



Week 3-4 Numerical Guidance Precipitation Forecasts Valid January 14-27, 2017:



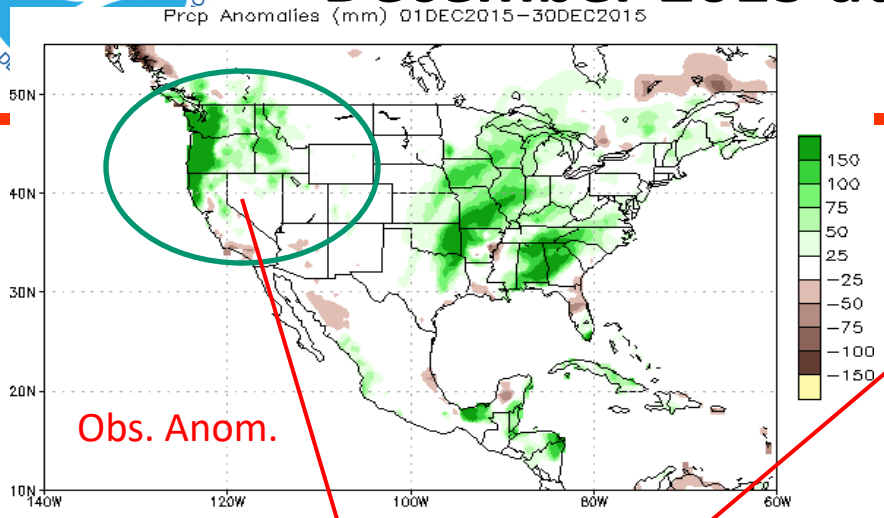


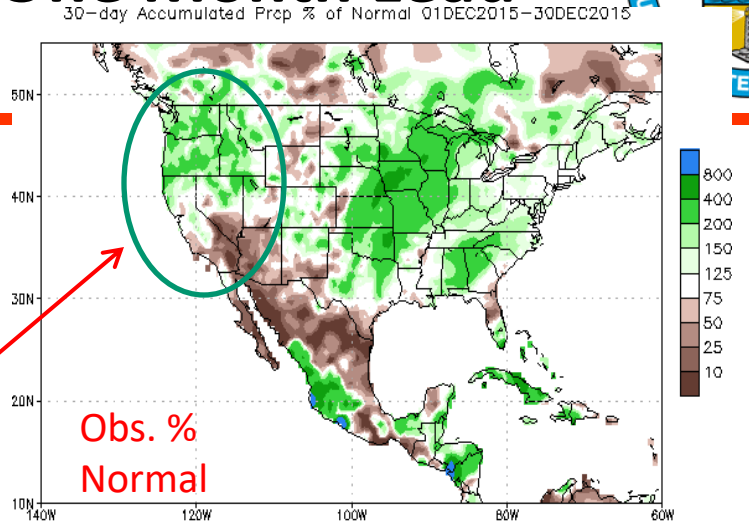


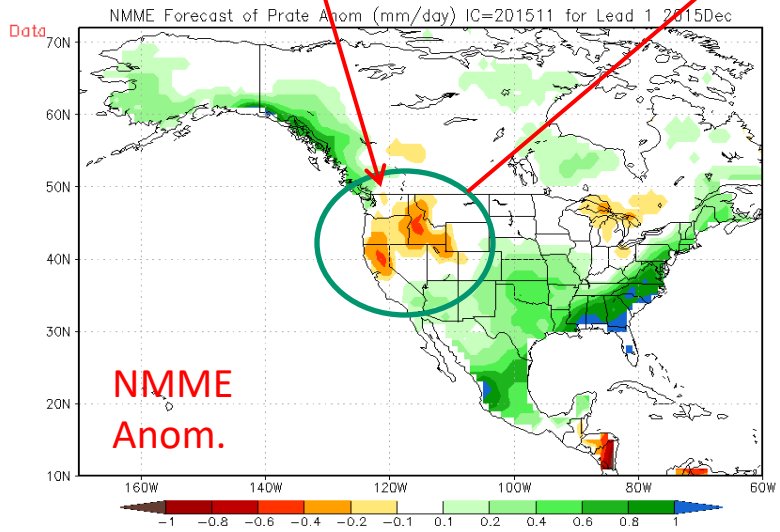
CFS **ECMWF** **JMA**

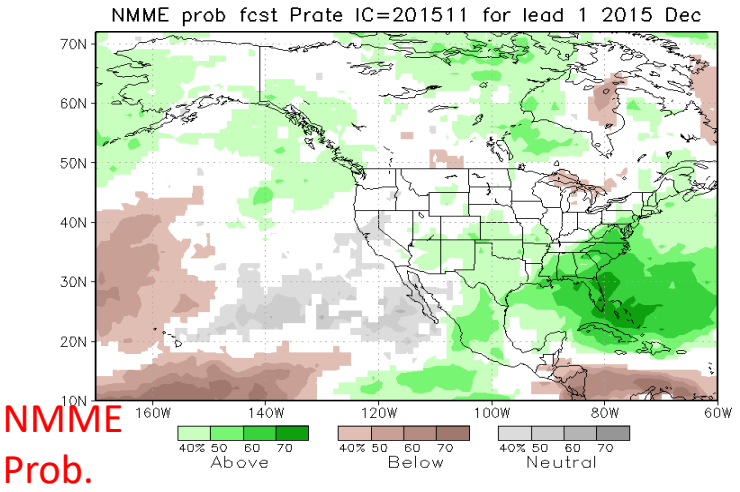
State of the Art Week 3-4 Guidance is Unanimous on Enhanced Probability of Below Normal Precipitation for California for Last Two Weeks of January 2017

NMME Precipitation Forecast
December 2015 at One Month Lead



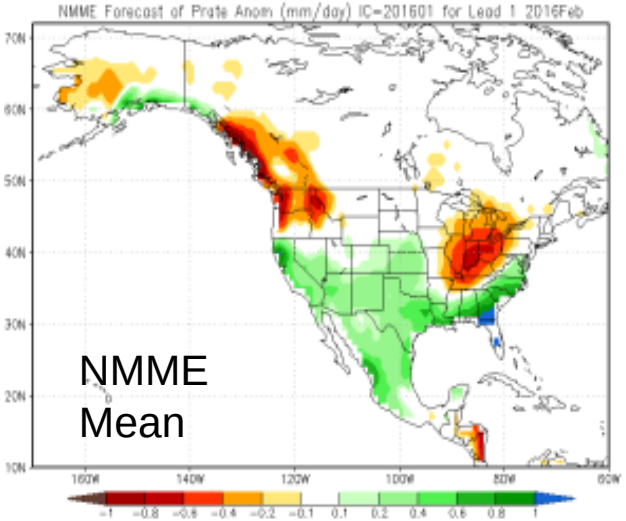


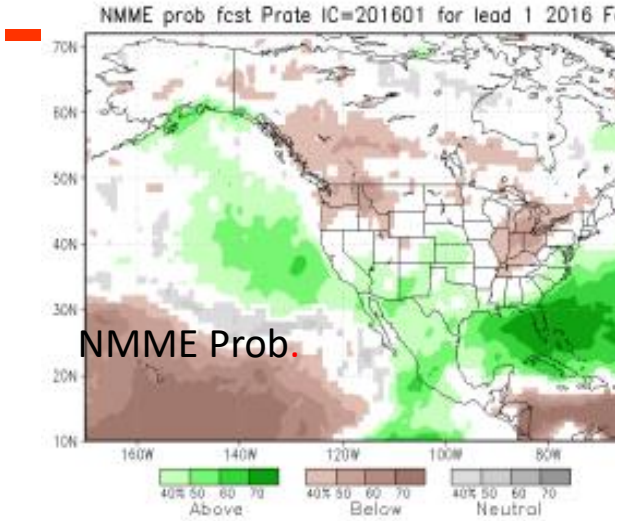


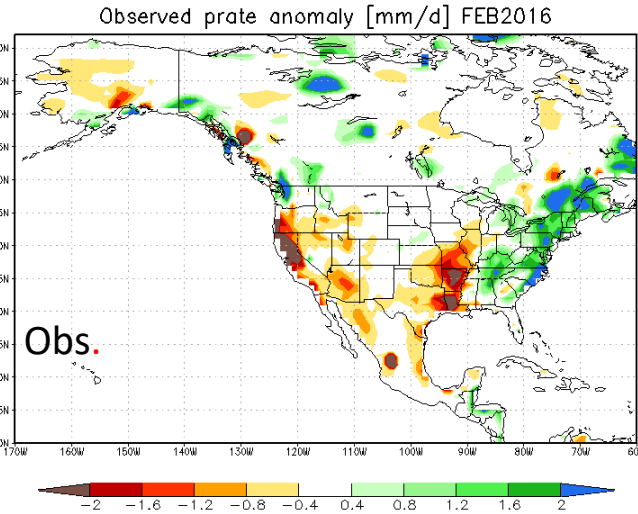


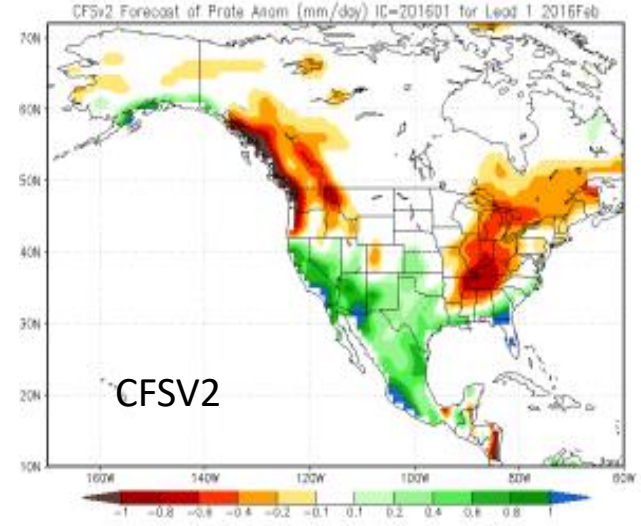
State of the art NMME misses major precipitation anomalies in Western US.

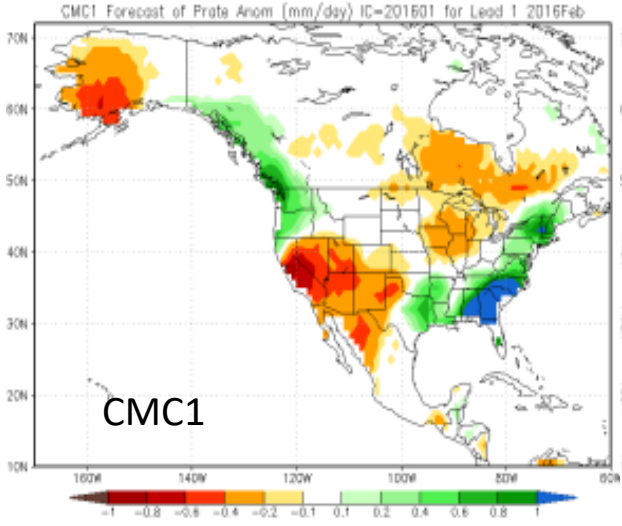
NMME Precipitation Forecast
One Month Lead for February 2016

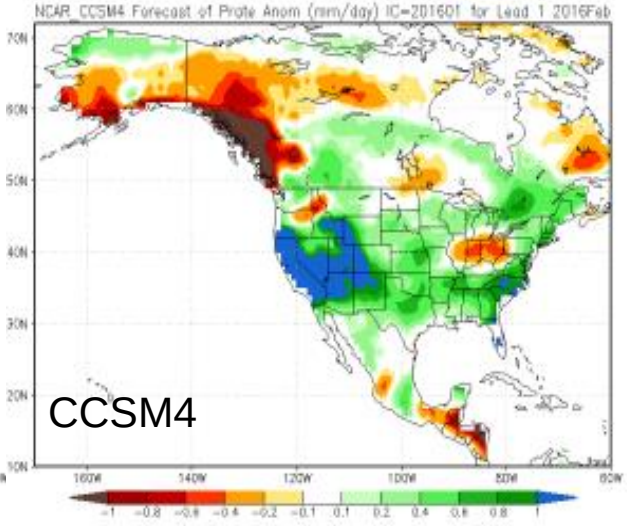




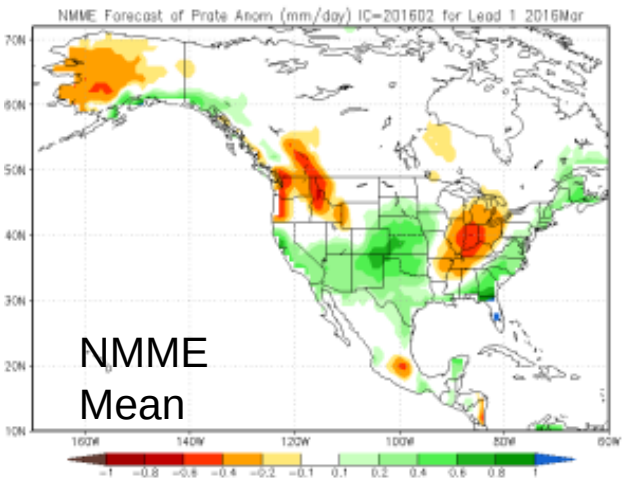


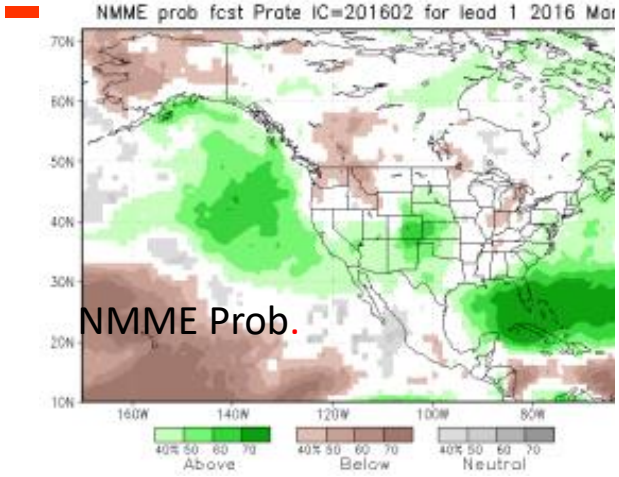


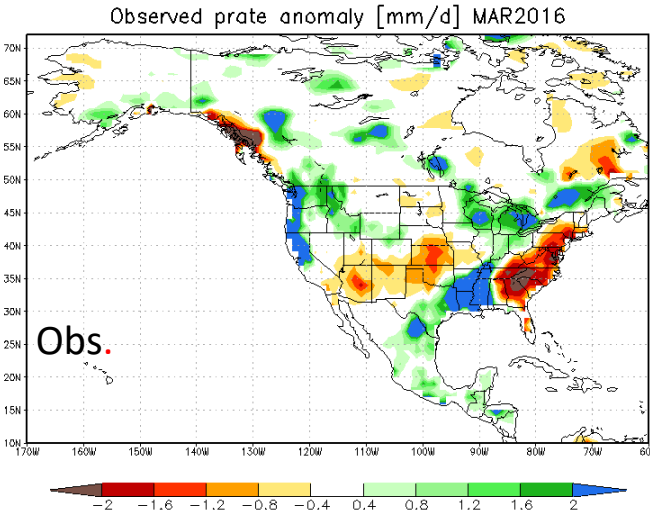


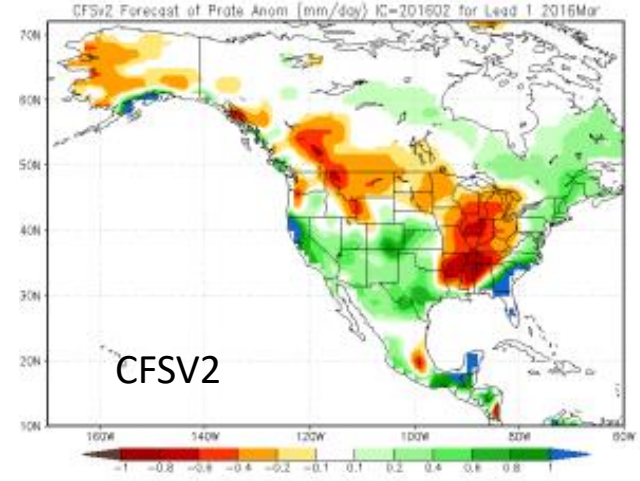


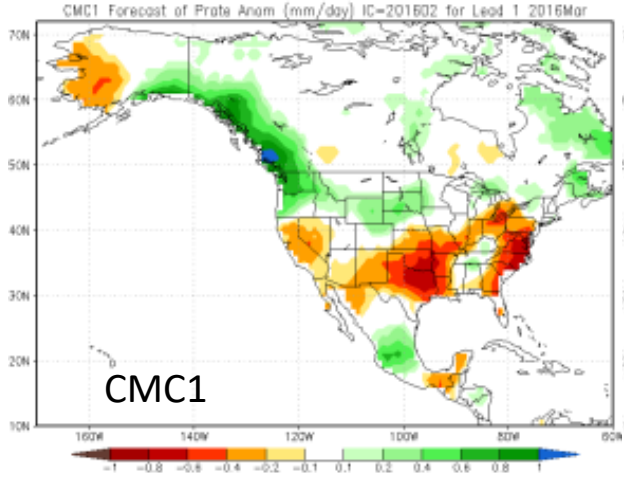
NMME Precipitation Forecast
One Month Lead for March 2016

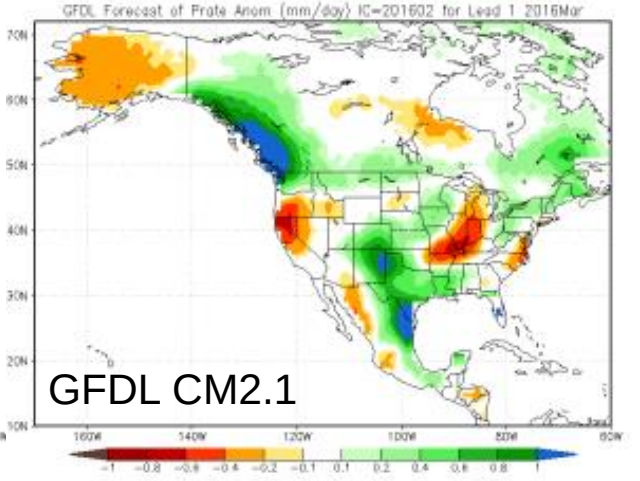




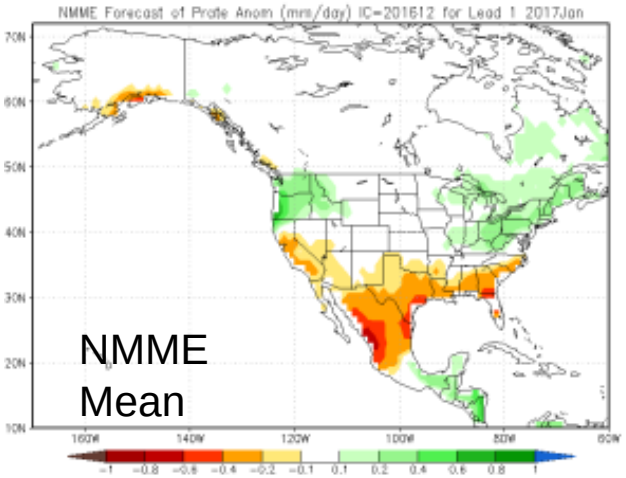


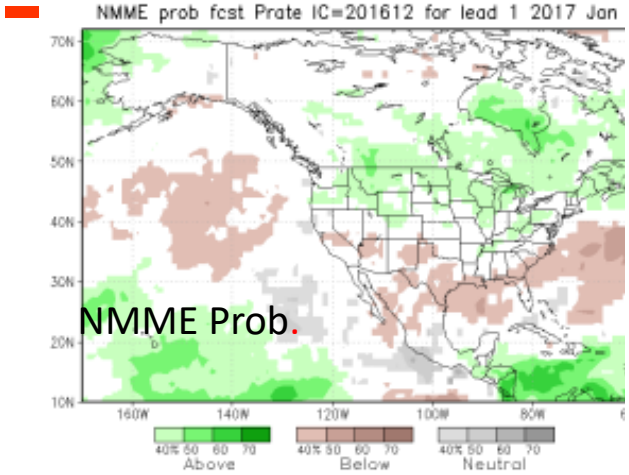


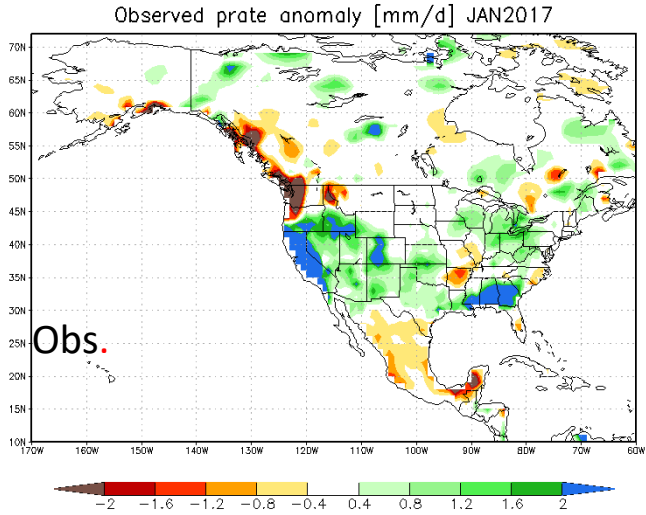


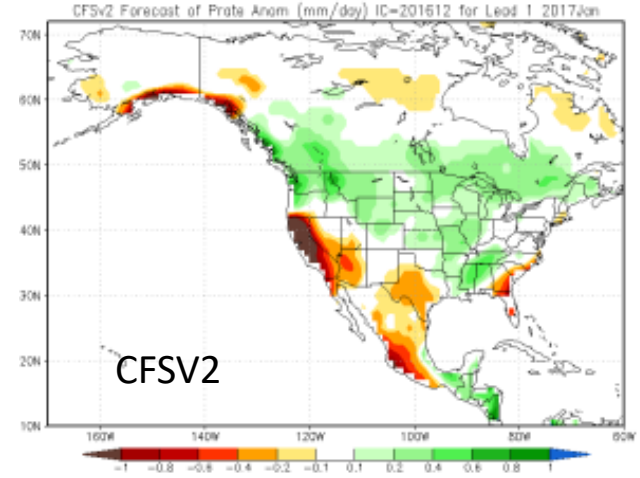


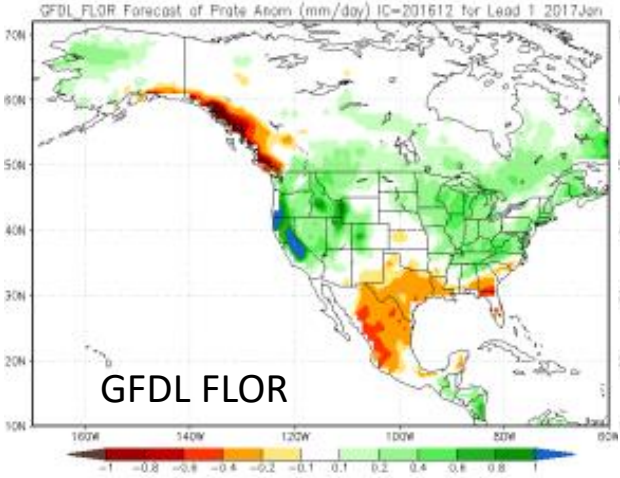
NMME Precipitation Forecast
One Month Lead for January 2017

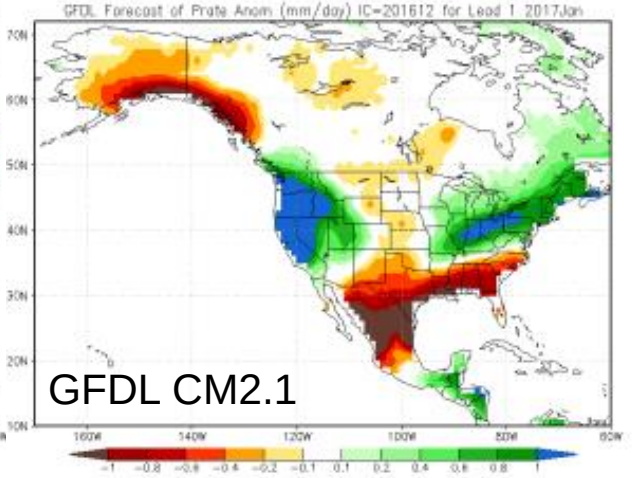






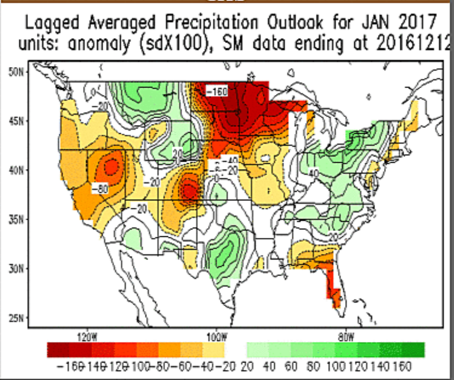






JAN 2017 [Precipitation]

CAS



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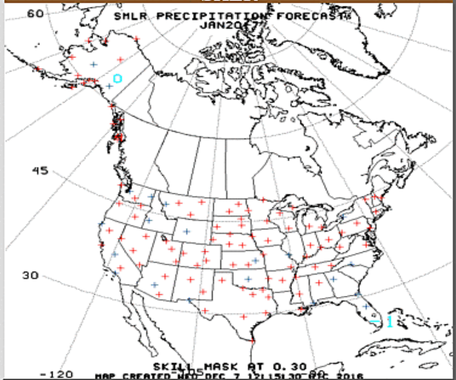

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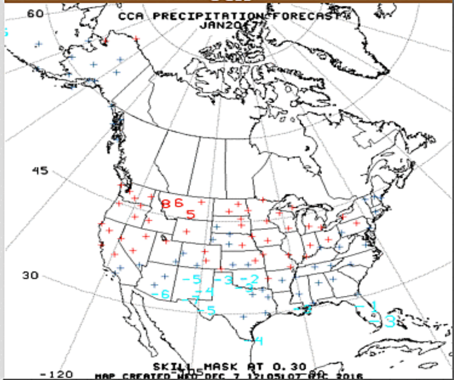

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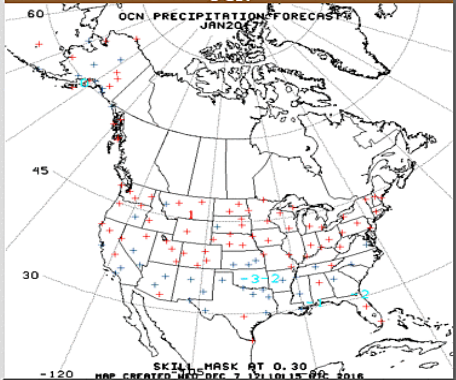
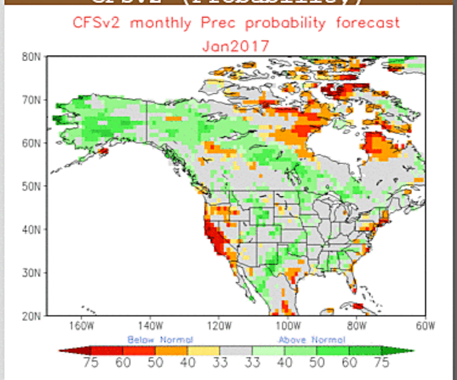
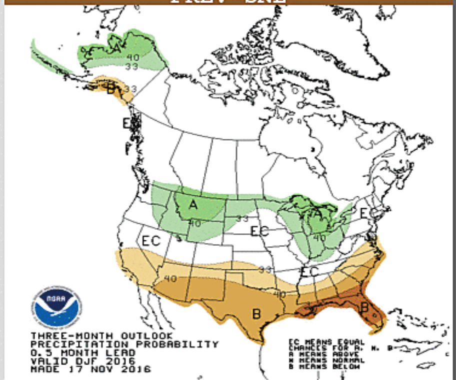


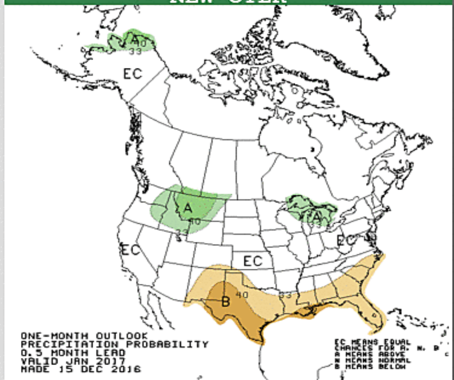
CFSv2 (Probability)



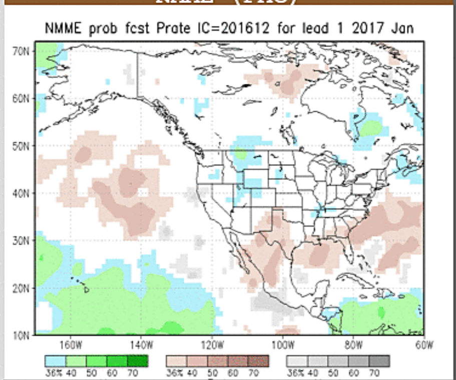
PREV-SNL



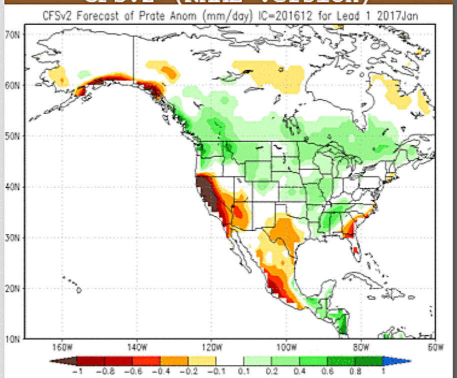
** NEW-OTLK **



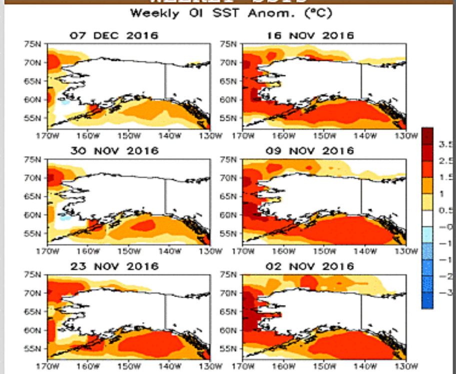
NMME (PAC)



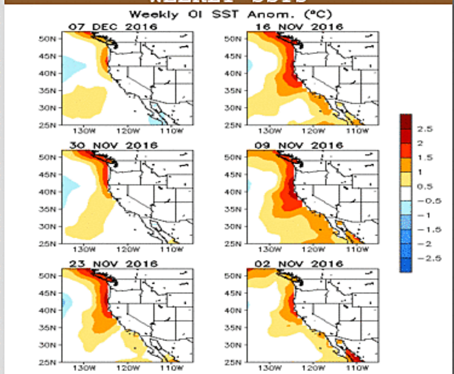
CFSv2 (NMME version)



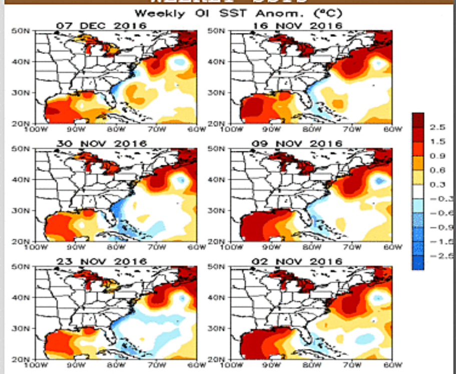
WEEKLY SSTs



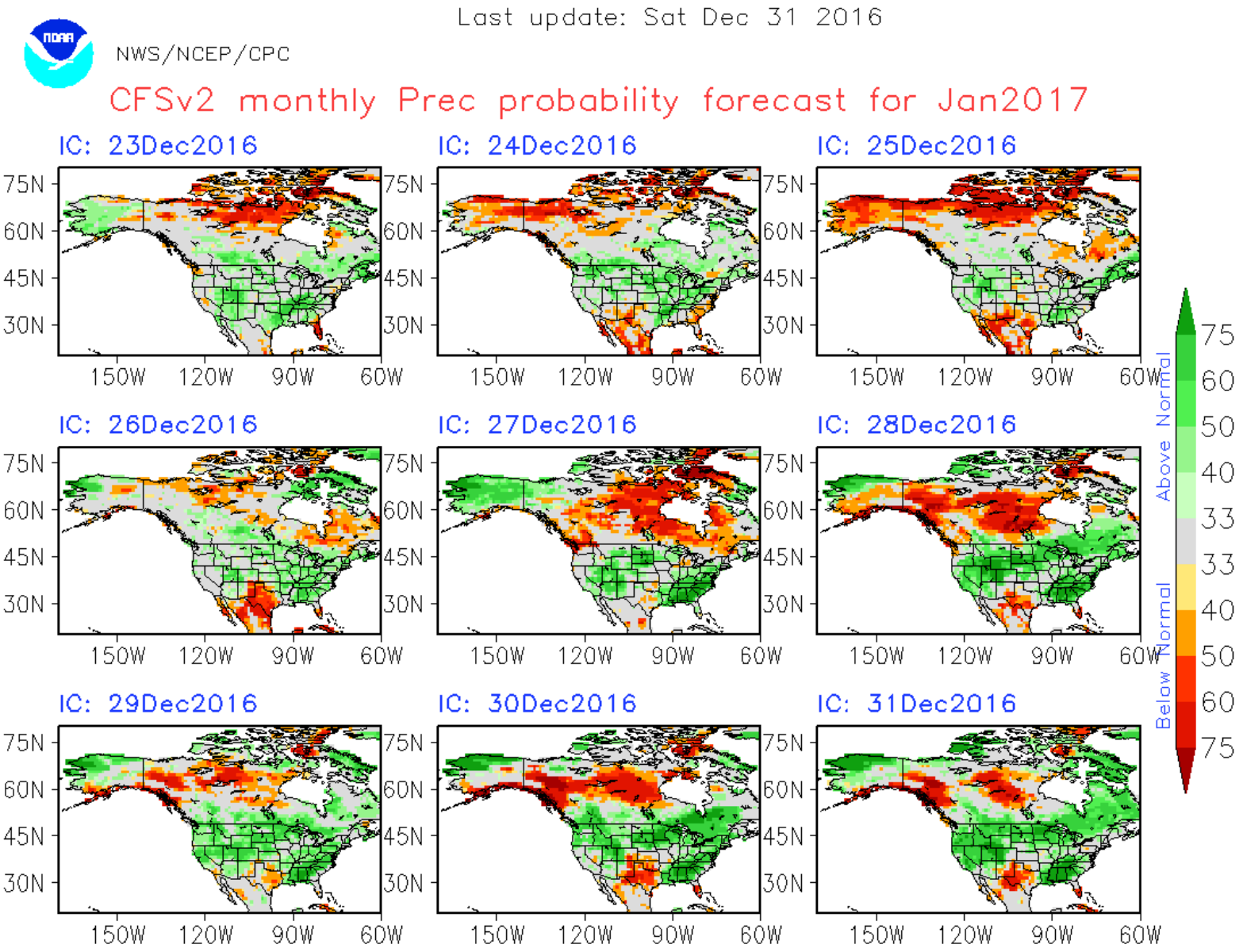
WEEKLY SSTs



WEEKLY SSTs

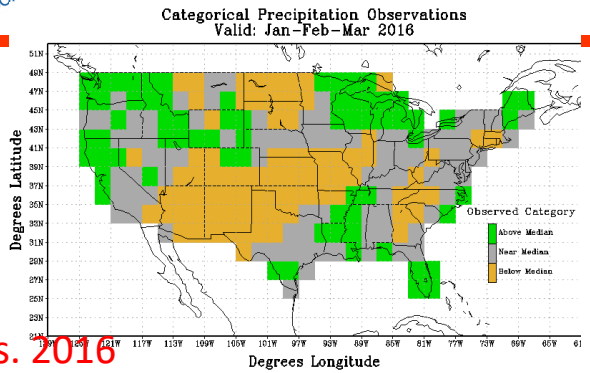


CFS Probabilistic Forecasts for January 2017

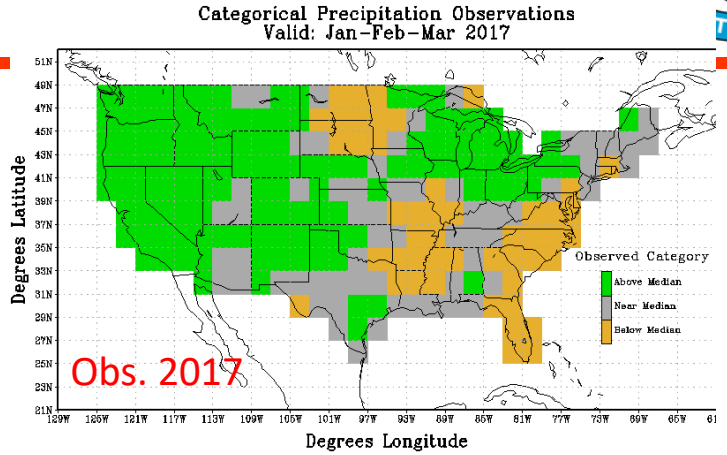


Seasonal Forecasts

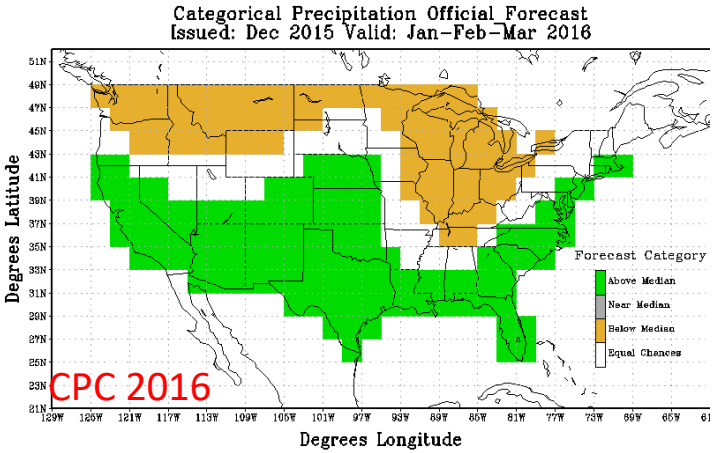
CPC Seasonal Forecast and Observations for JFM 2016 and JFM 2017



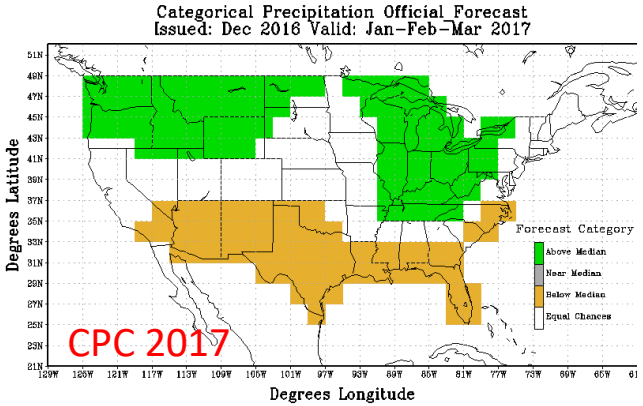
Obs. 2016



Obs. 2017



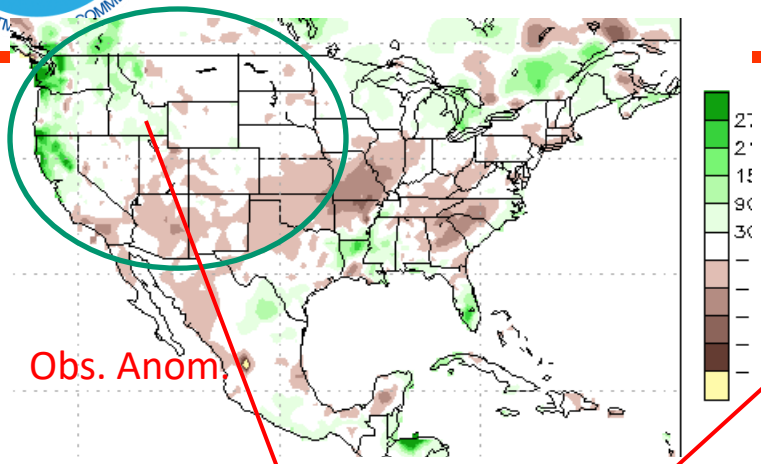
CPC 2016



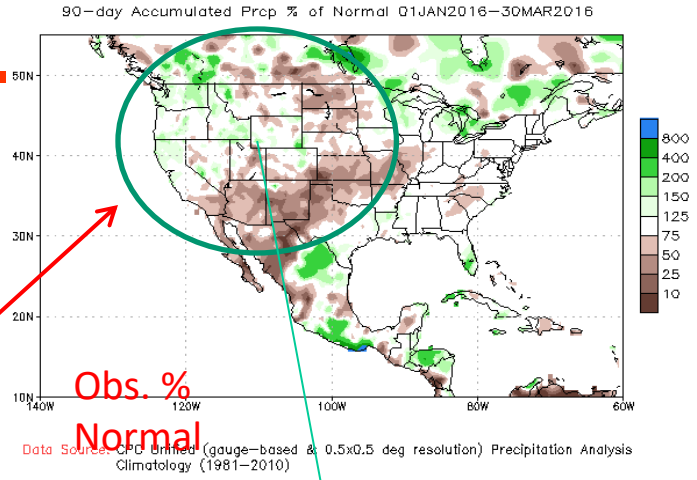
CPC 2017

State of the art NMME misses major precipitation anomalies in Weste

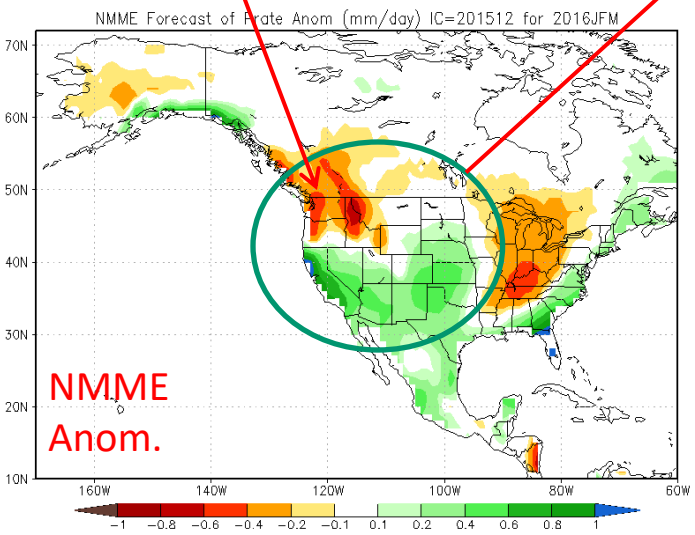
NMME Precipitation Forecast for JFM 2016
One Month Lead



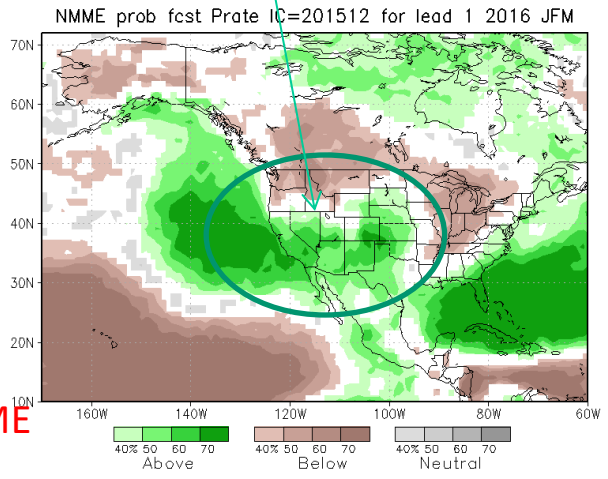
Obs. Anom.



Obs. % Normal



NMME Anom.

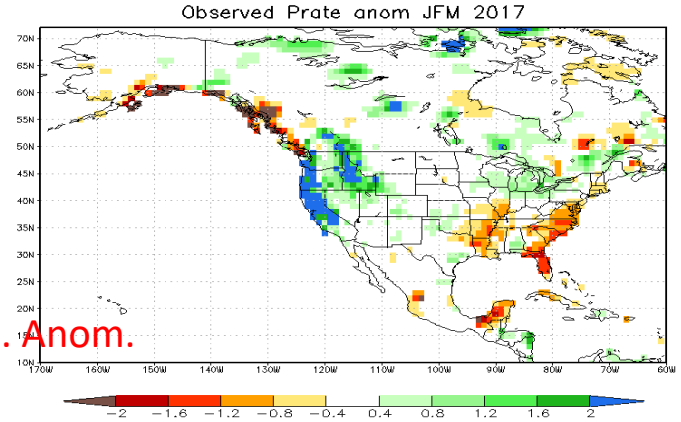


NMME Prob.

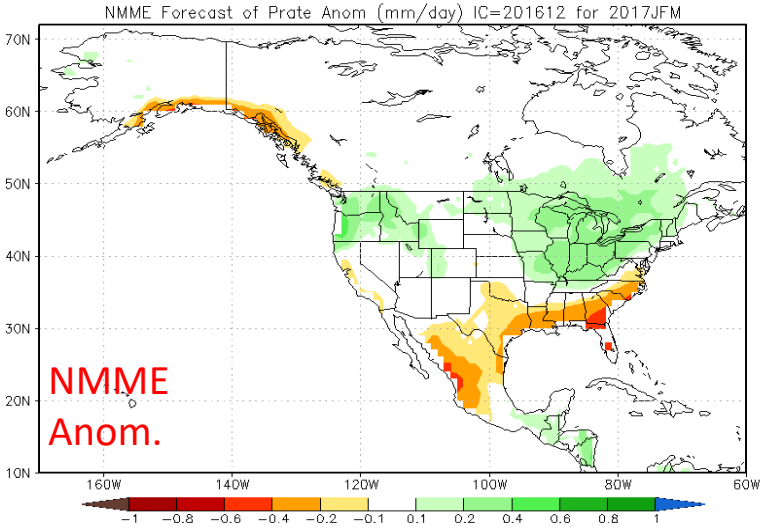
State of the art NMME misses major precipitation anomalies in Western/Central US.

NMME Precipitation Forecast for JFM 2017
One Month Lead

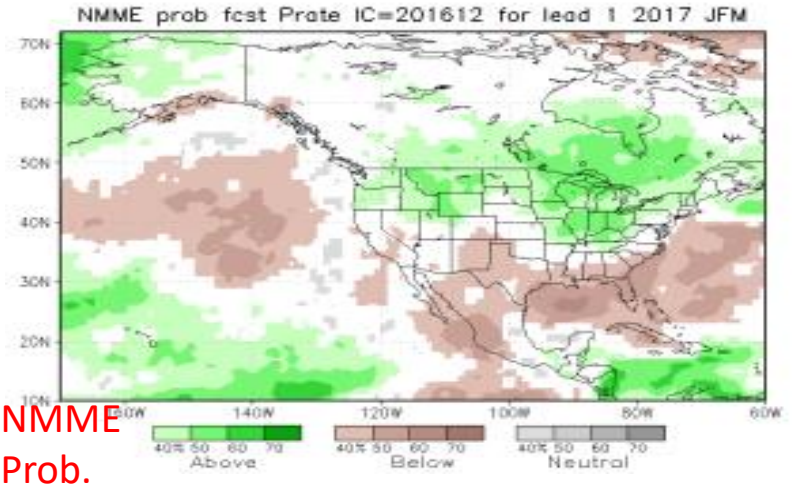
Obs. Anom.



NMME Anom.



NMME Prob.



State of the art NMME misses major precipitation anomalies in Western/Central US.

Summary of CPC Week Two to Seasonal Outlooks for Western Precipitation in 2015-2016

- CPC Week Two outlooks were skillful in both years as measured by Hedike Skill Score. Numerical guidance provided useful forecasts upon which forecasters could add value.

- CPC Monthly and Seasonal Outlooks were not skillful for must of the west. The available tools forecast canonical El-Nino/La-Nina precipitation patterns in 2016 and 2017, respectively. Forecasters were unable to overcome the incorrect signal found in the tools, especially dynamical models such as the NMME.

- CPC is conducting an evaluation of NMME models to see if objective weighting and calibration improves this situation.

Strategic Priority: Understanding why Models Didn't Perform Well in Predicting Winter Precipitation in the West for 2014-2017

Is there less predictability in the system then we previously believed?

Do the current generation of models misrepresent or not represent at all key processes?

Was the forced signal overwhelmed by atmospheric transients?

This is a golden opportunity for the short-term climate forecasting community to explore these issues to see if this was predictable and, if so, why our tools fell short.

NB: Circa 1999 based on successful predictions for record 1997-98 El-Nino and 1999 La-Nina then CPC Director Ants Leetma declared that seasonal prediction problem was solved. Unfortunately, this proved to not be the case! **We need strategic investment in the most promising tools to push the subseasonal to seasonal skill envelope and there is plenty of room for improvement (DGD, 2015-2017)**

Science Challenges to Improving Subseasonal to Seasonal Precipitation Forecasts

Science Challenge: Forecast Error Sensitivity Due to Lack Of Observations in Central/Eastern Pacific

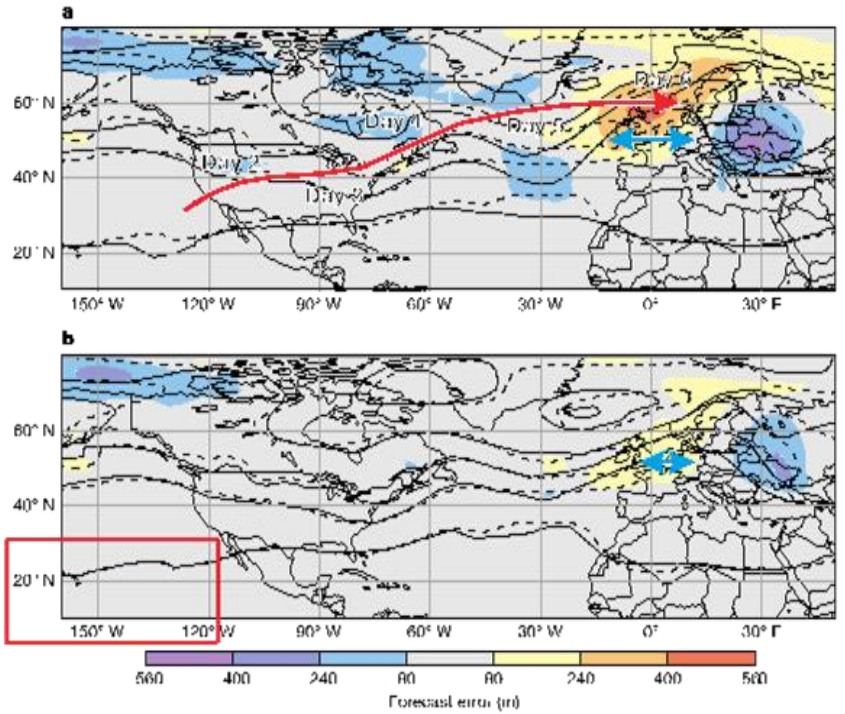
Bauer et al paper (2015)

"area [that] was characterized by very large 24-h forecast errors of upper-level winds because of the paucity of wind observations there"

(From Webb/Dole: ENRR Field Campaign)

BOX 1

Sensitivity of forecasts to initial conditions and error propagation



Box 1 Figure Maps showing the long-range impact of model initialization on the European forecast. Panel a shows the day 6 mean forecast error (the height of the 500 hPa pressure level in metres) of the flow at around 5 km height (colour-coded shading), the forecast itself (solid isolines) and the verifying analysis (dashed isolines) valid on 15 February 2014. Over the western US, the jet stream extended far to the south, aligned with a lower level trough. The long red arrow indicates the wave path of an atmospheric wave disturbance guided by the westerly flow. The presence of a large-scale dipole error pattern highlights the lag between forecast and analysed state (blue double-headed arrow). The large forecast errors over Europe were mostly produced by a phase-shift of the wave that increased with time. Back tracking the wave propagation path identifies the tropical East Pacific (boxed in **b**) as a likely location of a possible forecast error source. This area was characterized by very large 24-h forecast errors of upper-level winds because of the paucity of wind observations there. When running an experiment where the area in the box in **b** is relaxed towards the analysis rather than evolving in the forecast, the strong initial growth of forecast errors is reduced and, six days later, the lag of the wave patterns between forecast and analysis is reduced over Europe (blue double headed arrow), producing about half of the original forecast errors. This experiment demonstrates the long range impact of model initialization, the linkage between tropics and mid-latitudes, and thus shows an example of how predictive skill in the one-week time range can be increased.

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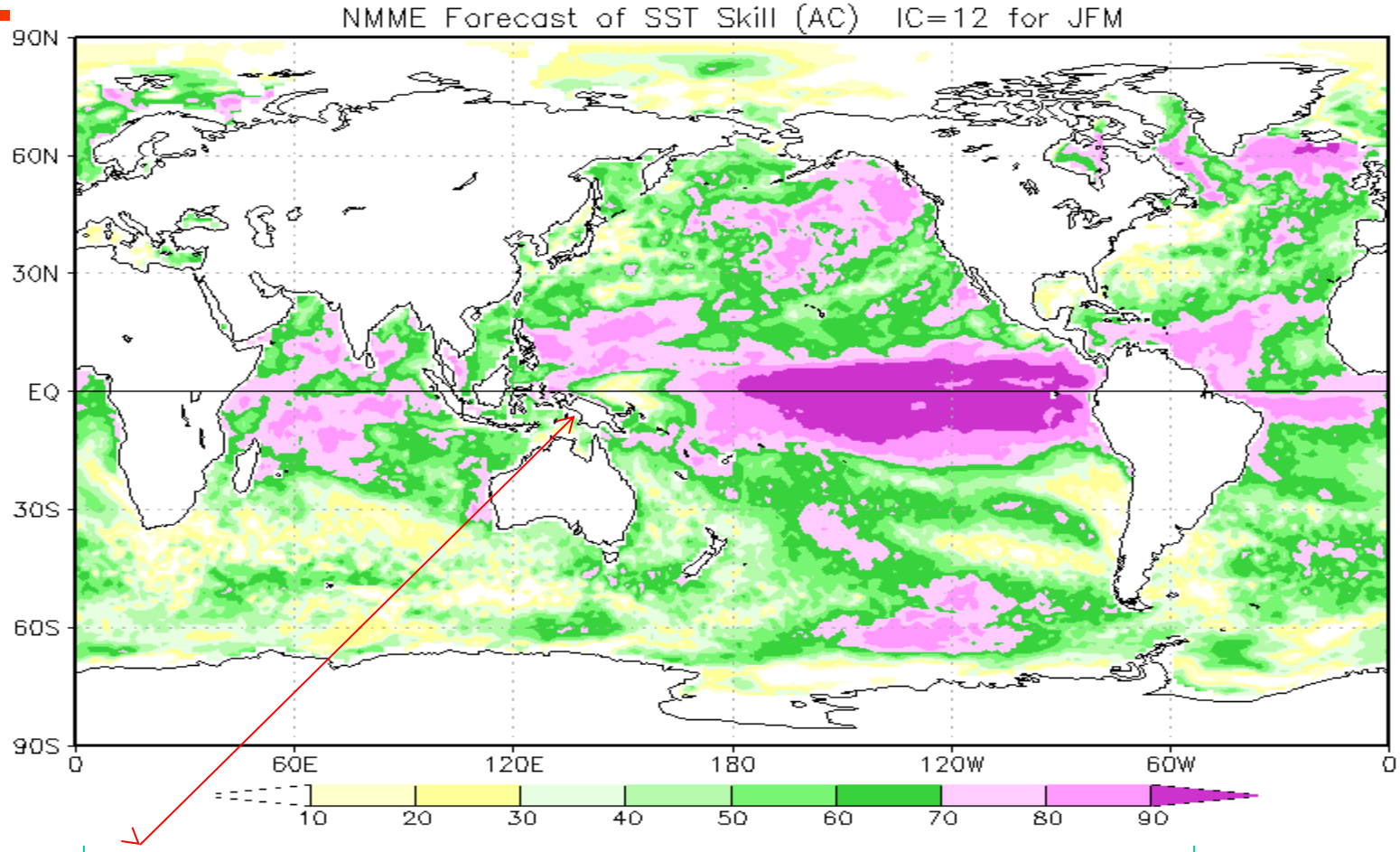
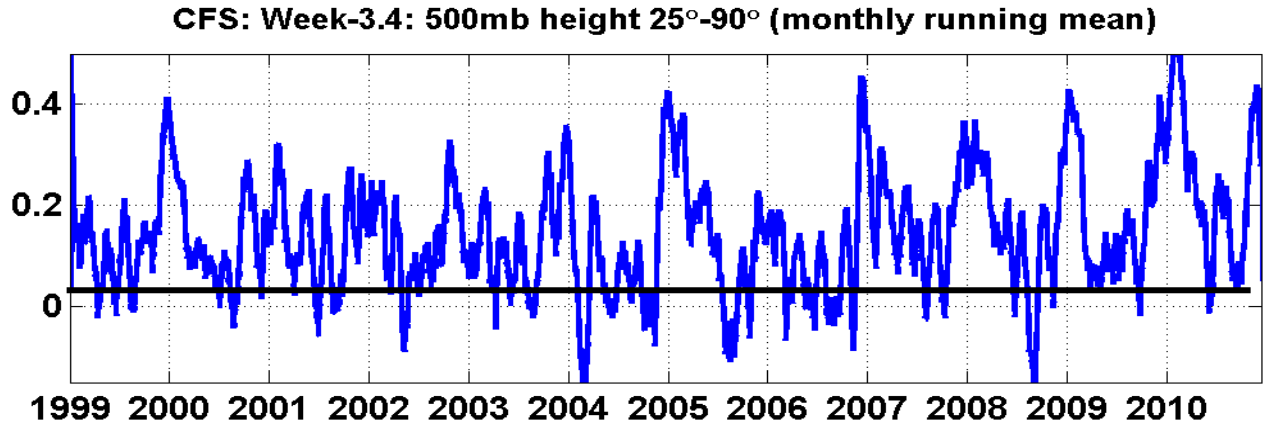
Science Challenge: Inability of State of the Art Dynamical Models (NMME) to Accurately Forecast SST Variability at 1 Month Lead in Tropical Western Pacific and Indian Oceans

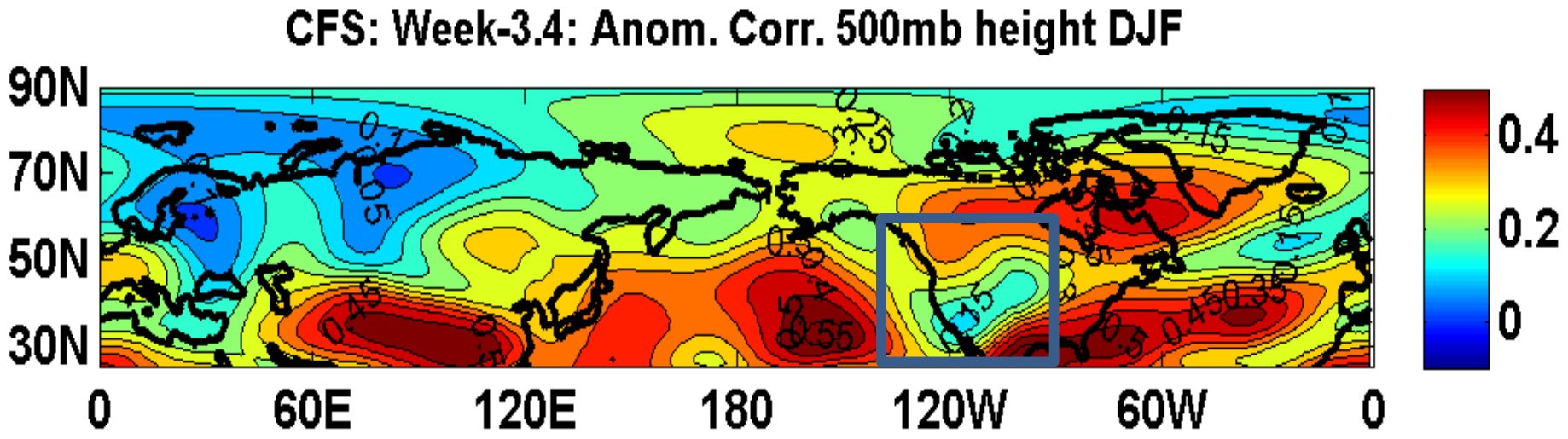


State of the Art MME Dynamical Forecast System has Low Skill in Predicting Near-Equatorial Western Pacific SST. How important is SST in this region in driving anomalies over the US?

Science Challenge: Prediction Skill Minima for Upper-Level Flow Over Western US



Dec-Jan-Feb
1999-2011



Minima in prediction skill for upper level flow over western US at subseasonal to timescale.

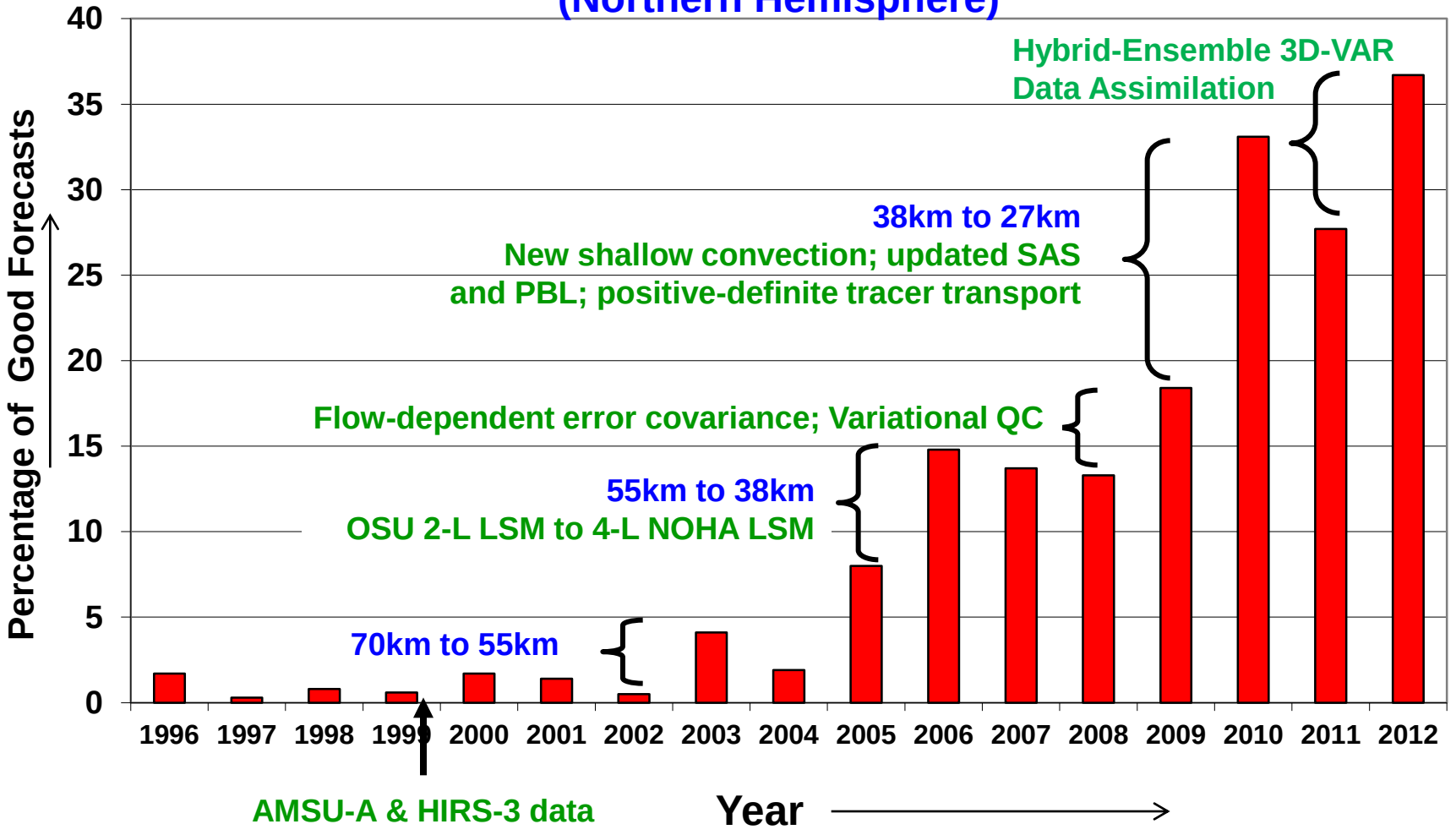
Strategy for Improving Monthly/Seasonal Forecasts

- Ultimately, subseasonal to seasonal climate forecasts are average of weather.
- Hypothesis: Need to represent weather systems with fidelity in order to get statistics correct, thus enabling more skillful monthly/skillful forecasts. How do we do that?
  - Increased resolution
  - Improved physics
  - Improved initialization (data assimilation)

Given limited resources should we be focusing on developing one model so that we can dedicate sparse computing and scientific resources to improve one model?

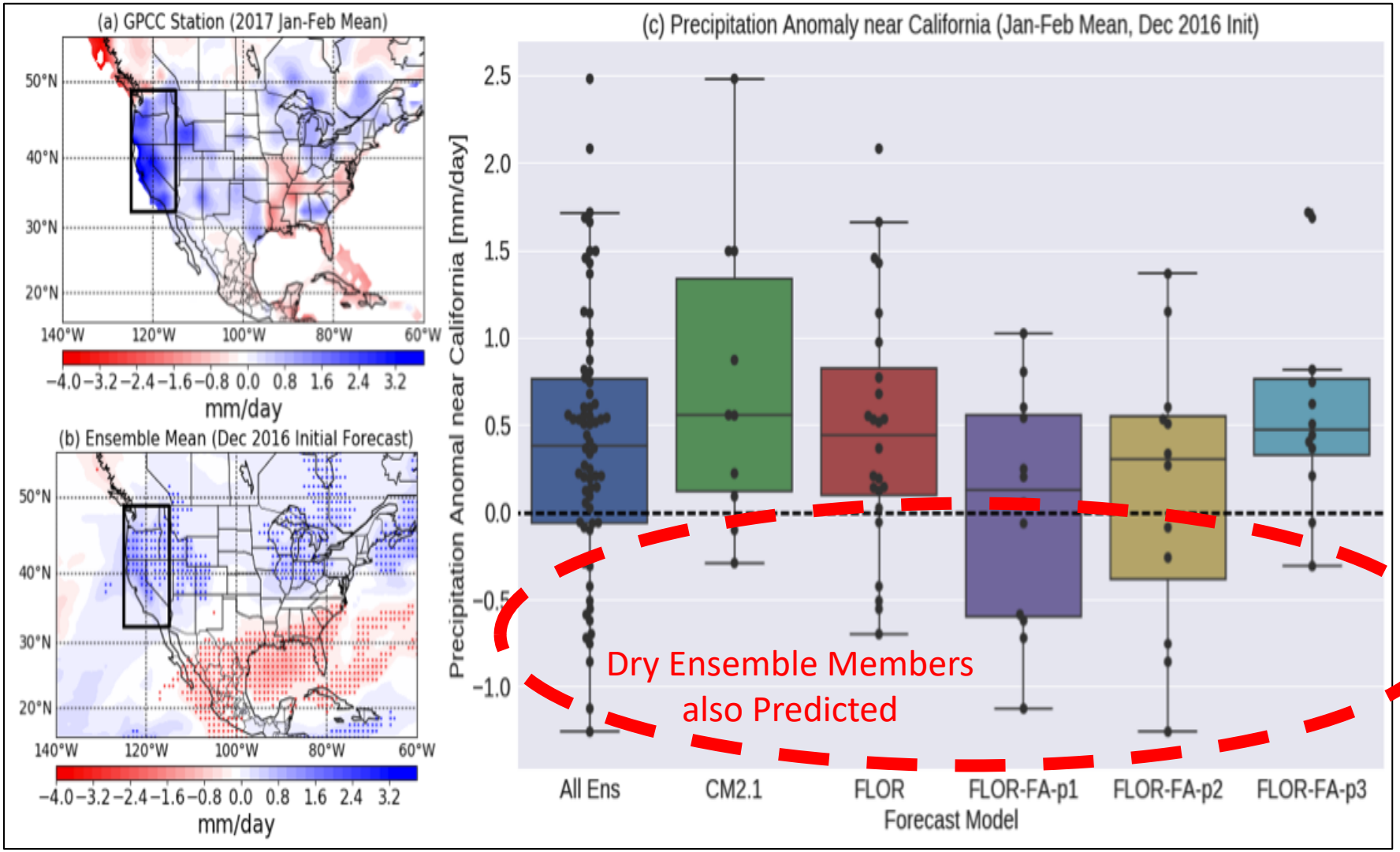
GFS Skill Improvement Due to Resolution, Data Assimilation and Physics Upgrades

Percentage of GFS 5-Day 500mb Anomaly Correlation Greater Than 0.9 (Northern Hemisphere)



GFDL Experimental Predictions For 2017 Winter Precipitation and Research on Improving Precipitation Forecasts for the West

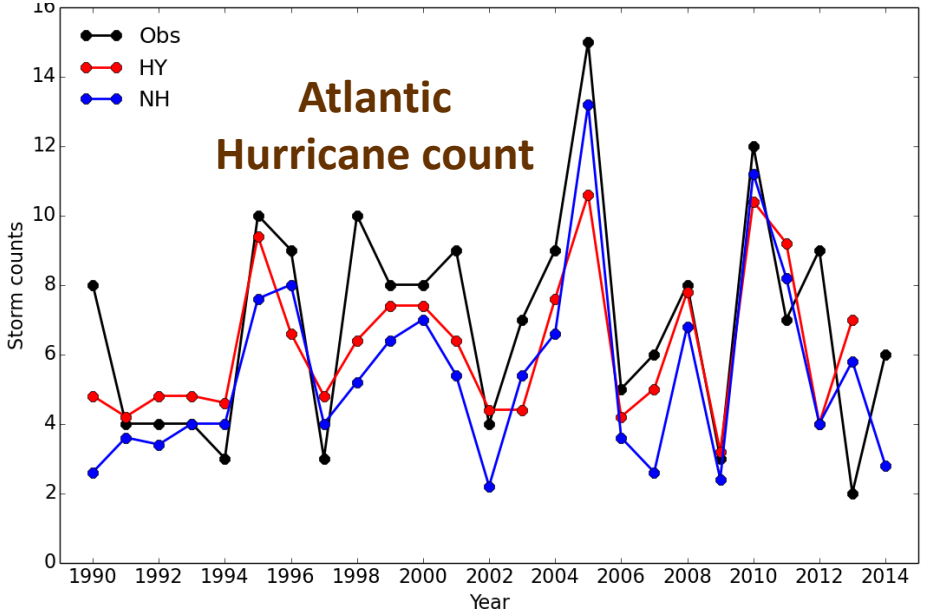
Prediction of Jan/Feb 2017 Precipitation from December 1, 2016



Courtesy of H. Murakami, X. Yang, S. Kapnick, T. Delworth

Seasonal prediction of hurricanes in HiRAM

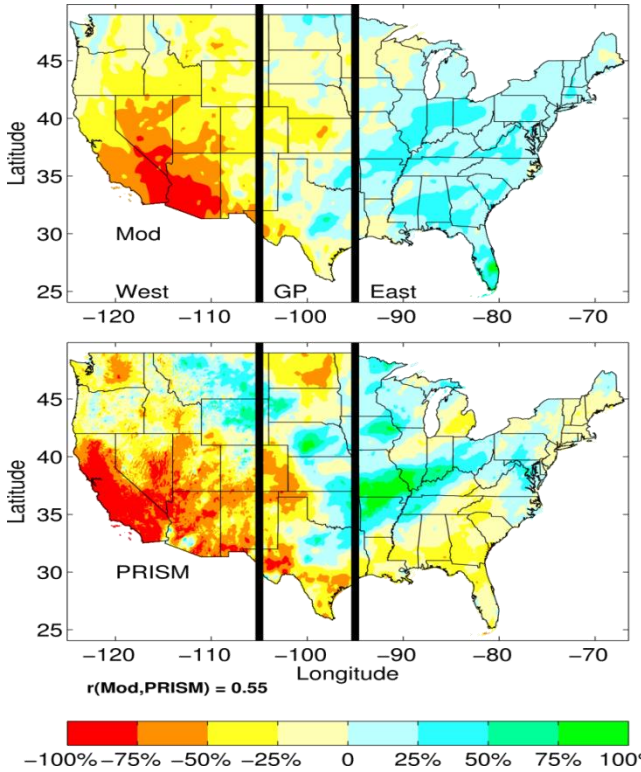
25-km resolution Hydro./Non. Hydro. FV3



Correlation	HY	NH	RMSE	HY	NH
1990-2010	0.88	0.86	1990-2010	1.91	2.28
2000-2010	0.94	0.96	2000-2010	1.90	2.02
1990-2014	0.72	0.76	1990-2014	2.34	2.50

Chen and Lin (2013), Chen et al. (2017, in preparation)

Seasonal prediction of drought event in HiRAM



25km Hydro. FV3

2008 MAM

Courtesy of Zhitao Yu

Seasonal variation of the correlation

$$\frac{P - P_{Cli\ \ o}}{P_{Cli\ \ o}}$$

***P* = total precipitation**