CPC use of NMME and Sub-Seasonal to Seasonal (S2S) Prediction Challenges

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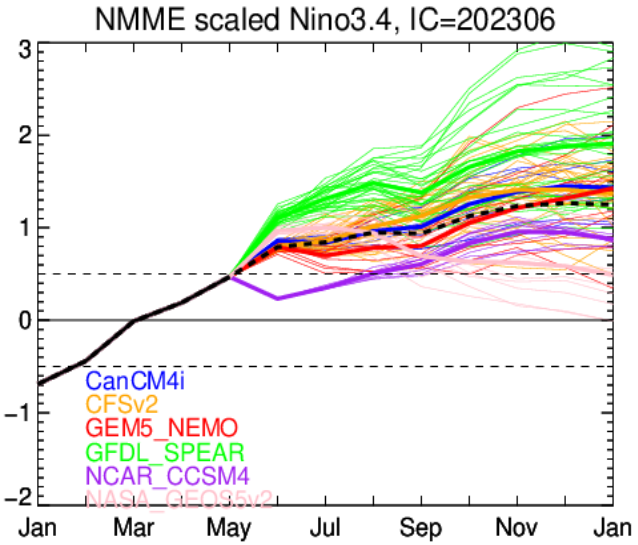
Outline

- Bottom line upfront on CPC use of NMME
- Sub-seasonal to seasonal (S2S) science challenges
  - Regime transition
  - Seasonal two-category misses
  - Inability to predict below-normal temperature on S2S timescales
  - Inability to predict S2S variability beyond canonical ENSO response
  - Predicting the spatial distribution of tropical convection variability
  - Predicting sea surface temperature anomalies outside of the central and eastern Equatorial Pacific
  - Double intertropical convergence zone (ITCZ)
- Summary of CPC thoughts on NMME
- Summary of S2S science challenges (personal reflection)

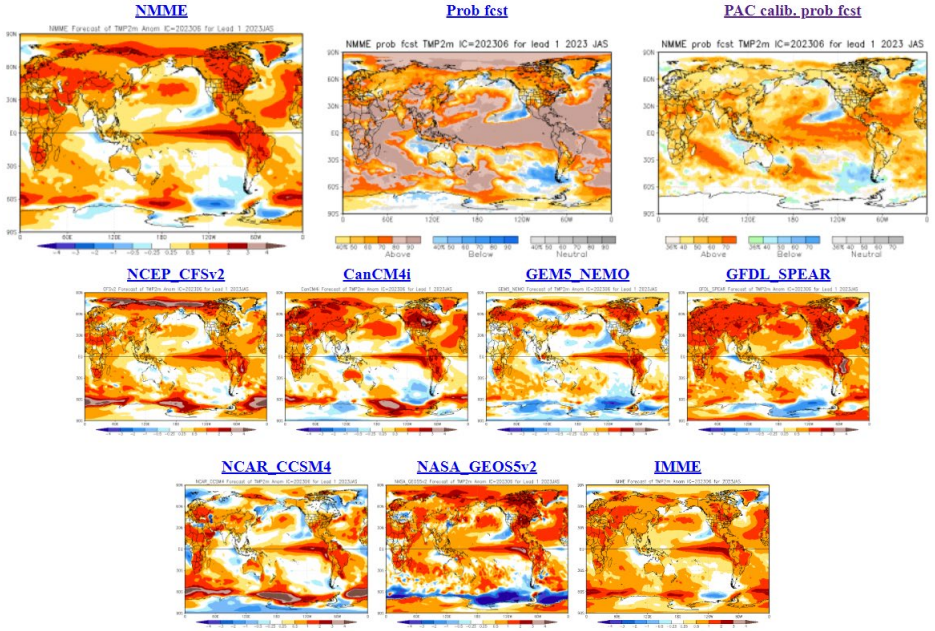
Bottom Line Up Front on CPC Use of NMME

- The North American Multi-Model Ensemble (NMME) is a critical component of CPC research and operations (domestic and international).
- CPC wants to see the NMME continue.
- CPC would benefit from having the reforecasts for all NMME models be for the 1982 to present period.

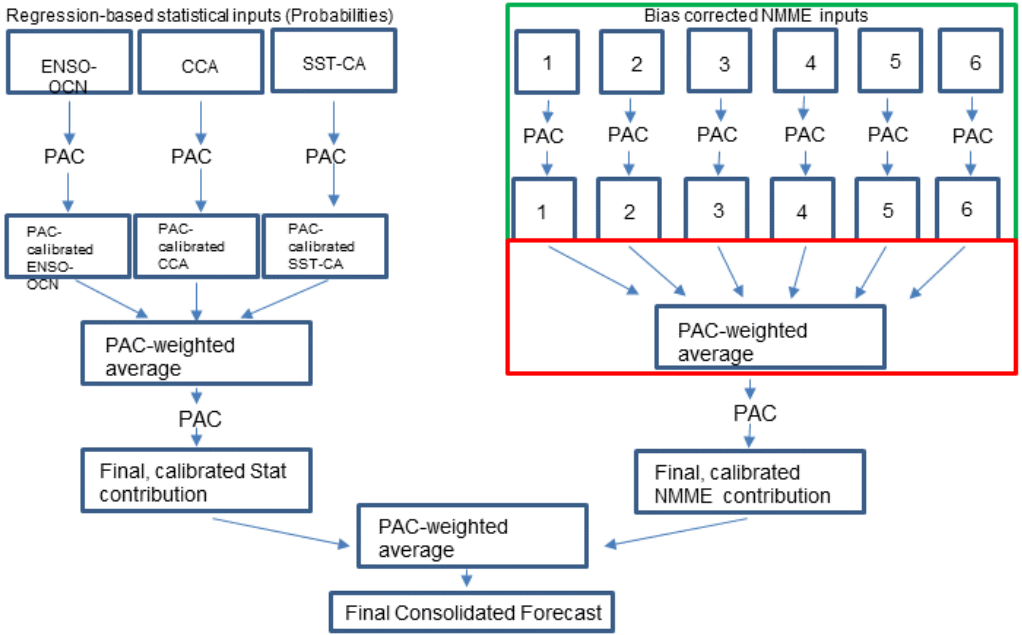
CPC Use of NMME for Domestic Monthly and Seasonal Predictions



NMME Forecast for July-August-September 2023



Consolidation for Monthly Statistical and Dynamical Tools



Consolidation is an objectively (skill) weighted and calibrated first guess for forecasters for our monthly outlooks.

Uses the Probability Anomaly Correlation (PAC) method for calibration and weighting.

Inputs models include statistical tools and the North American Multi-Model Ensemble (NMME).

CPC Use NMME for International Desk Products

Provide access to real time global and regionalized weather and climate forecasts, enabling decision making in agriculture and water around the world.

NCEP CFSv2 and NMME

SEASONAL FORECASTS	MONTHLY FORECASTS	DATA DOWNLOADS	VERIFICATION

SEA SURFACE TEMPERATURE

Region | Model	Anomalies	StdAnom	Masked StdAnom	SkillMaps	ProbAnom	3Category Prob
Global	●	●	●	●	●	●
Pacific	●	●	●	●	●	●
Atlantic	●	●	●	●	●	●
Indian Ocean	●	●	●	●	●	●
Atlantic&Indian	●	●	●	●	●	●

PRECIPITATION

Region | Model	Anomalies	StdAnom	Masked StdAnom	SkillMaps	ProbAnom	3Category Prob
Global	●	●	●	●	●	●
Africa	●	●	●	●	●	●
CAM&Caribbean	●	●	●	●	●	●
Maritime-CONT	●	●	●	●	●	●
Central Asia	●	●	●	●	●	●
East Asia	●	●	●	●	●	●
South Asia	●	●	●	●	●	●
South America	●	●	●	●	●	●

2-METER AIR TEMPERATURE

Region | Model	Anomalies	StdAnom	Masked StdAnom	SkillMaps	ProbAnom	3Category Prob
Global	●	●	●	●	●	●
Africa	●	●	●	●	●	●
CAM&Caribbean	●	●	●	●	●	●
Maritime-CONT	●	●	●	●	●	●
Central Asia	●	●	●	●	●	●
East Asia	●	●	●	●	●	●
South Asia	●	●	●	●	●	●
South America	●	●	●	●	●	●

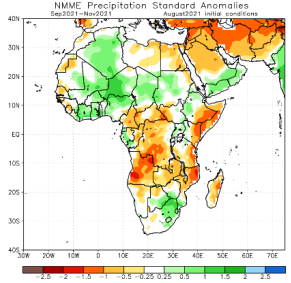
http://www.cpc.ncep.noaa.gov/products/international/index.shtml

CPC International Desk Regionalized NMME Forecasts

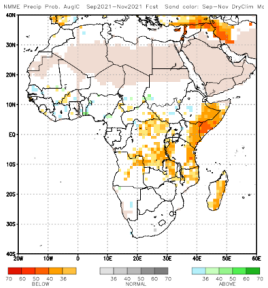
CFSv2, CanCM4i, GEM-NEMO, GFDL-SPEAR, NASA-GEOS5v2, NCAR-CCSM4, and the ensemble mean of all the models

https://www.cpc.ncep.noaa.gov/products/international/nmme/nmme.shtml

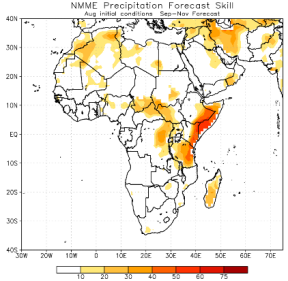
Deterministic



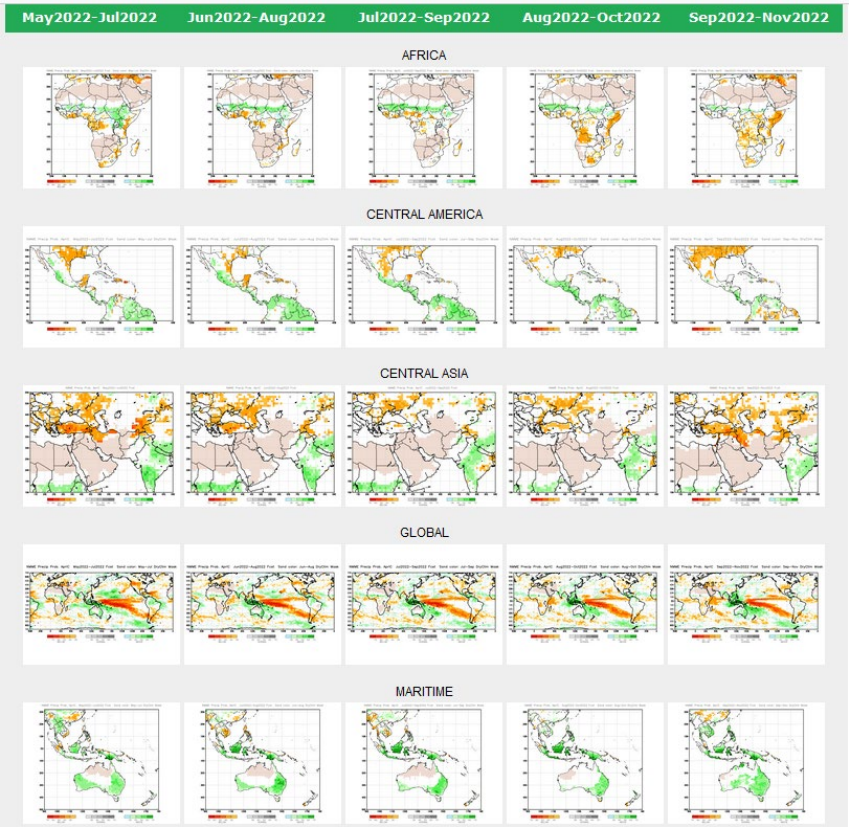
Probabilistic



Forecast Skill

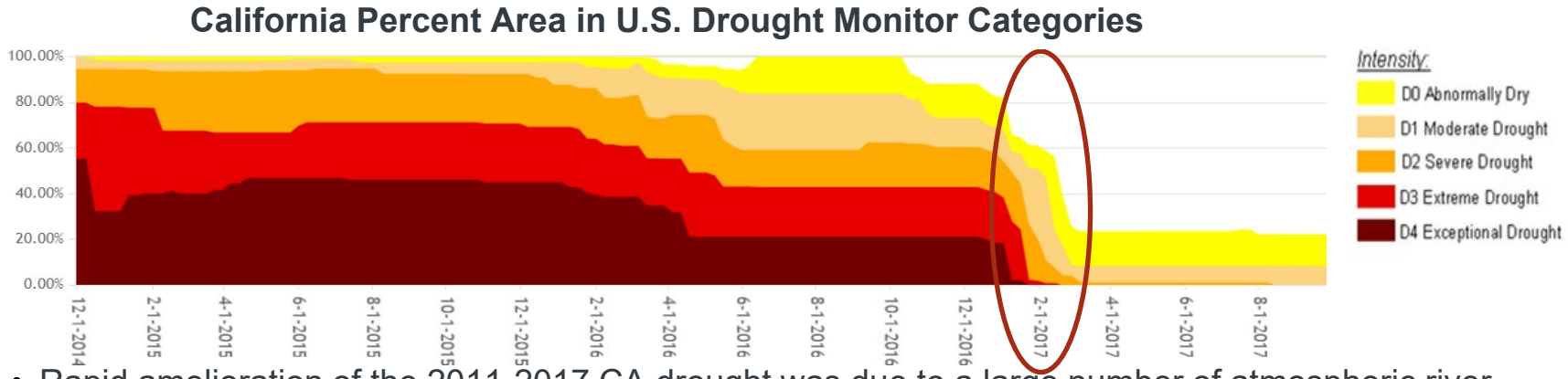


Regionalized NMME Forecasts



Precipitation Prediction Science Challenge Example

Failure to Predict Drought Amelioration

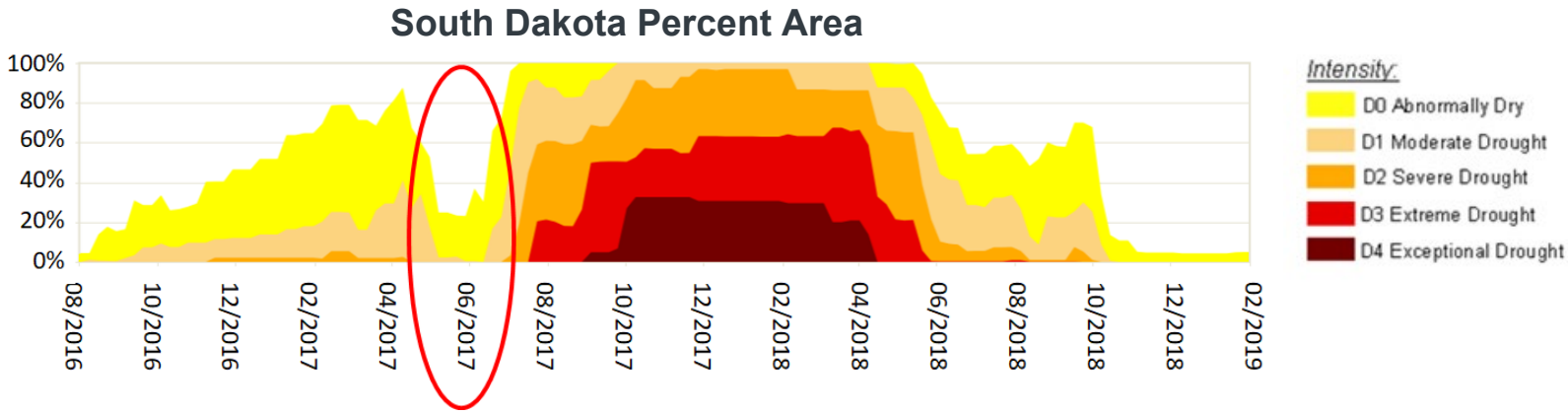


- Rapid amelioration of the 2011-2017 CA drought was due to a large number of atmospheric river events. They formed and penetrated to CA after persistent large-scaling ridging over the eastern Pacific broke down.
- This occurred despite an ongoing La Niña, which tends to support ridging and below-normal precipitation in this region. The same thing happened in the 2022-23 winter.

All models failed to predict this regime transition of the large scale atmospheric state and subsequent heavy rains beyond about two weeks lead. Sub-seasonal modes of climate variability (MJO, SSW) frequently dominate the impact of ENSO.

S2S Precipitation Prediction Skill Gap: Regime Transition

Failure to Predict Flash Drought Onset



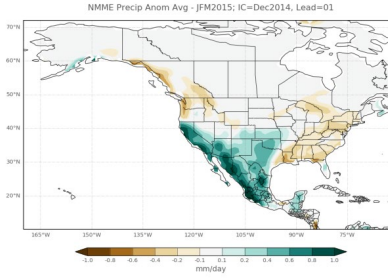
Transitioned from near normal conditions to severe drought over a ~60 day period.

Science challenges in this case for improved spring/summer precipitation for the Northern Plains include:

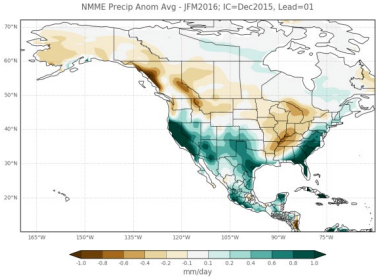
- Land-atmosphere interactions
- Warm-season continental convection

All models failed to predict the onset of this drought beyond about one week lead-time.

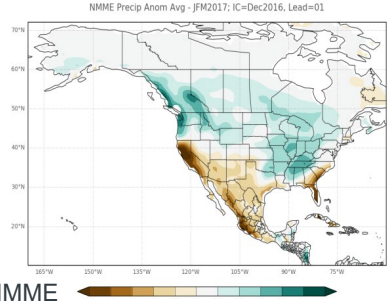
Key Science Challenges to Improving S2S Precipitation Prediction Skill



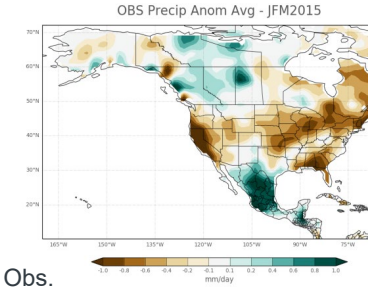
NMME 2015



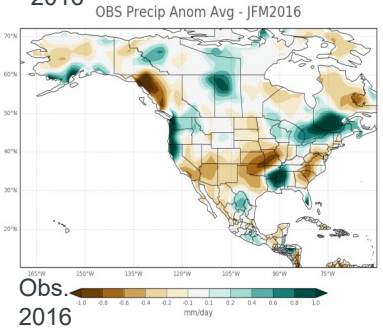
NMME 2016



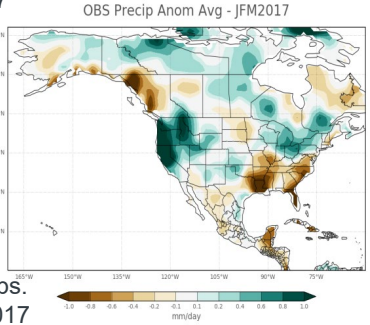
NMME 2017



Obs. 2015



Obs. 2016



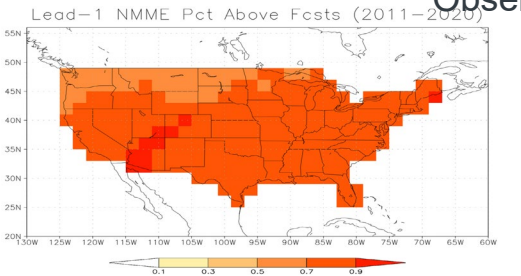
Obs. 2017

State of the art first season precipitation forecasts for winters of 2014-2017 were consistently of wrong sign over California and most of the west. Is this due to a limit in predictability, or missing or misrepresented physical processes?

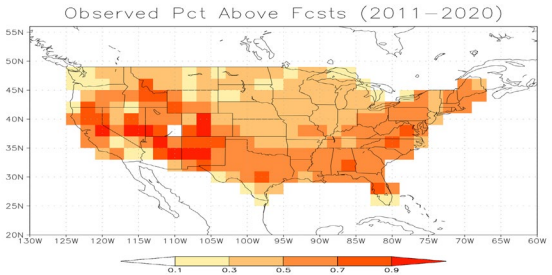
Frequency of Observed and NMME First Season Forecast Temperature Categories for 2011-2020

Above-normal temperatures occur and are forecast much more frequently than below normal. However, NMME forecast above normal 50% more often than Observed.

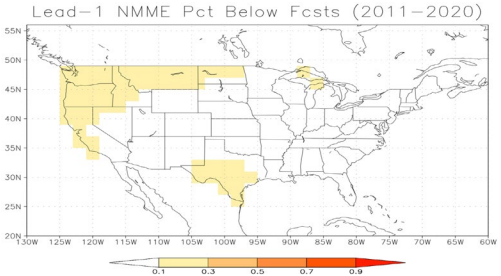
NMME Above



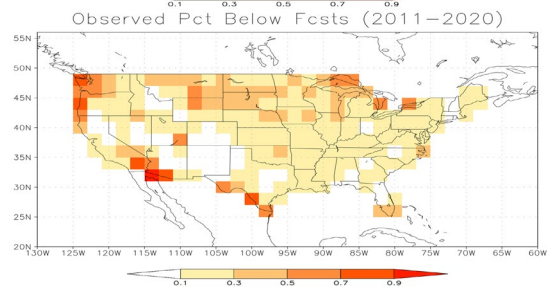
Obs. Above



NMME Below

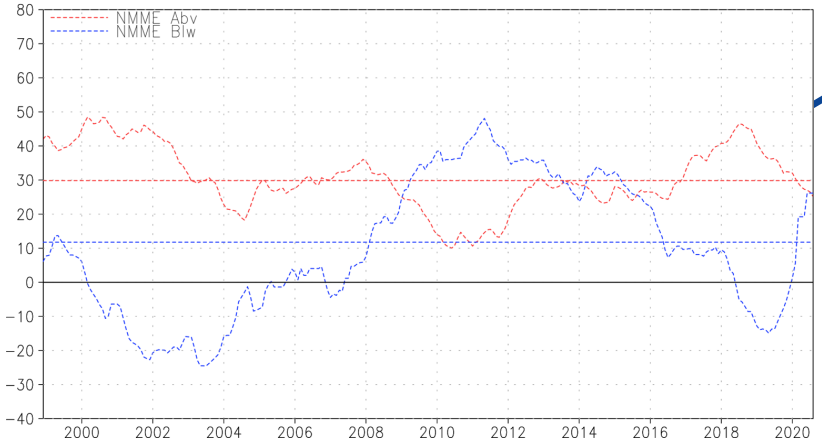


Obs. Below



Temperature Category	% Observed 2011-2020	% Forecast NMME 2011-2020
Above	50%	77%
Normal	27%	16%
Below	23%	7%

Time Series of NMME First SeasonTemperature Skill (S. Baxter)

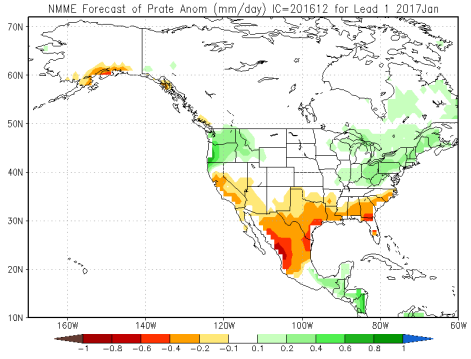


Forecasts of **above normal** dominate the overall skill. NMME forecasts **warm** over **cold** by ~7:1 ratio.

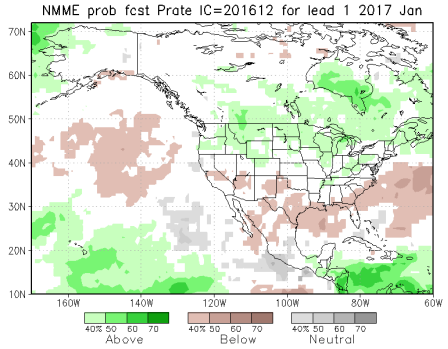
NMME **warm forecasts are generally more skillful**.

Over the 20 plus year period the NMME skill of above-normal forecasts is about 3 times that of below-normal forecasts.

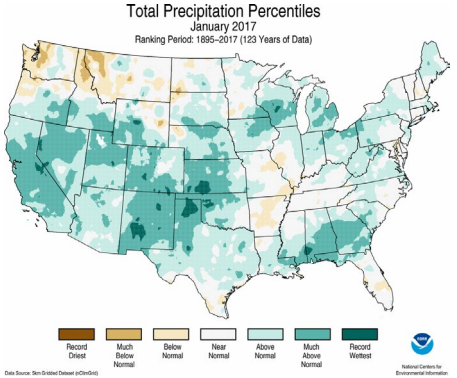
Key Science Gap: Inability to Predict Monthly Variability Beyond the Canonical ENSO Response



NMME Mean Anomaly



NMME Probabilities



Observed Anomalies

In early December 2016, the southwest US was in the fifth year of a then record drought. First month NMME forecasts for January 2017 called for below-normal precipitation for this region. By the second week of January 2017, the southwest US would start to experience above-normal precipitation associated with a large number of atmospheric rivers.

Major Systematic Errors Limiting S2S Prediction Skill: Magnitude and Spatial Distribution of Tropical Precipitation Variability (M. Chen)

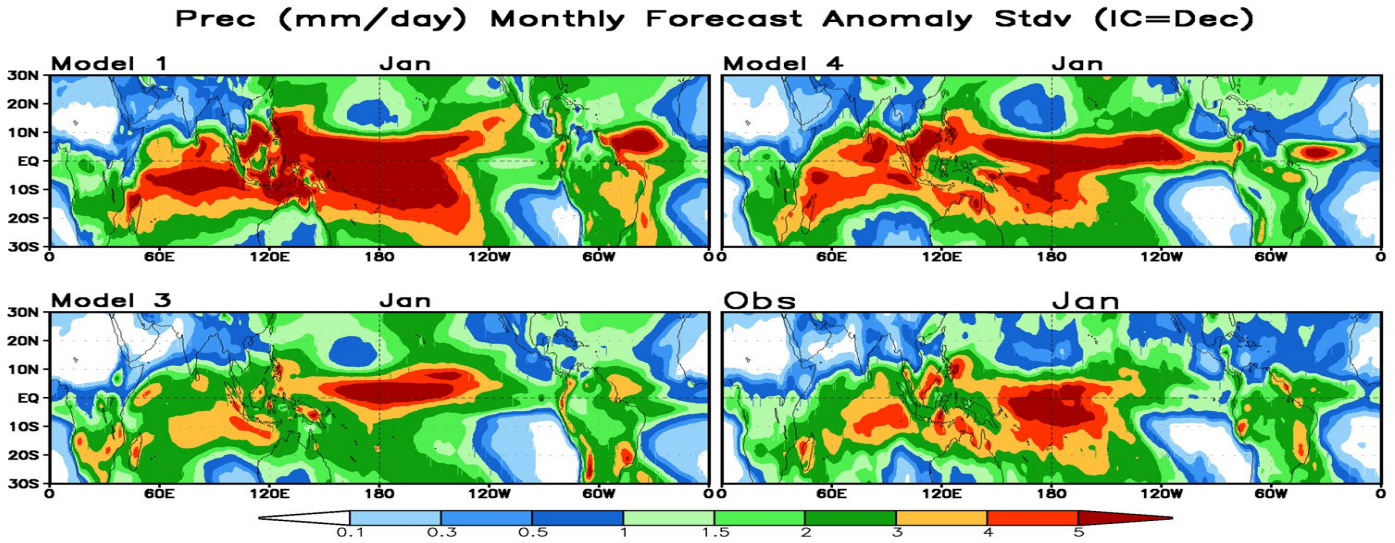
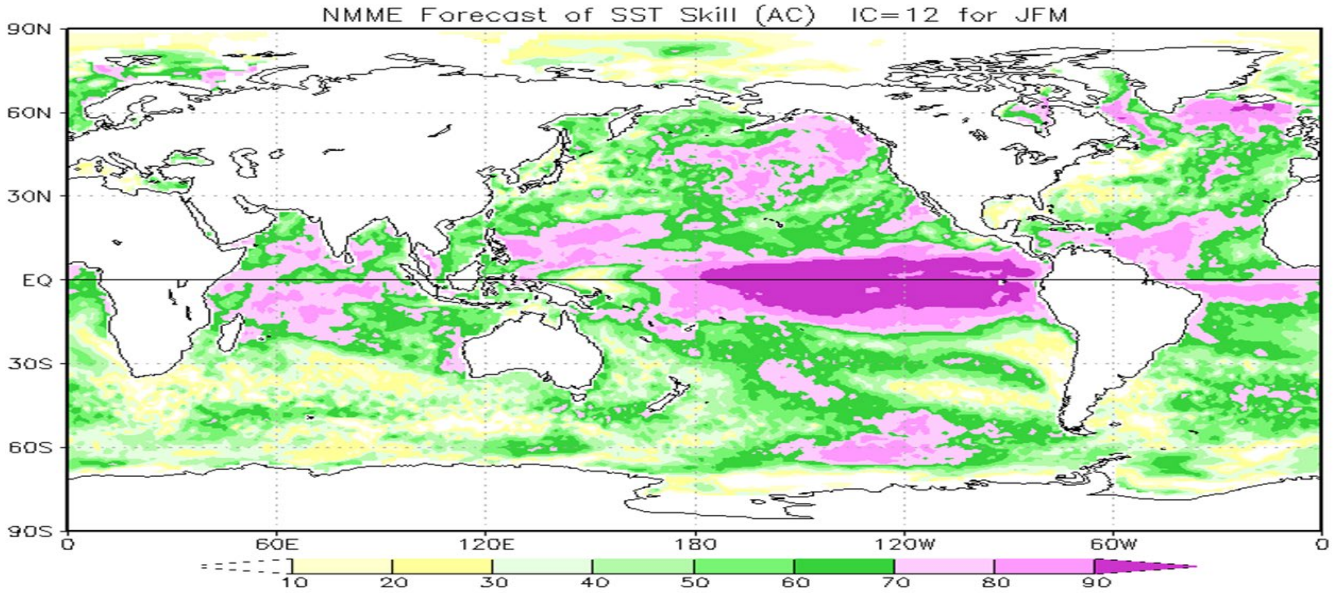


Figure compares standard deviation of precipitation from one month lead precipitation forecasts from 3 state of the art S2S models and observations. It demonstrates that models have errors of 100% or more in predicting mean statistics of tropical precipitation. Result is even worse if you remove large ENSO events.

Skill Gap in SST Prediction: Low Skill in Key Tropical Regions



Inability of dynamical models to predict tropical SST variability beyond a few weeks outside central/eastern Pacific for large El-Nino/La Nina Events

Major Systematic Error Limiting S2S Skill: Errors in Mean Tropical Precipitation

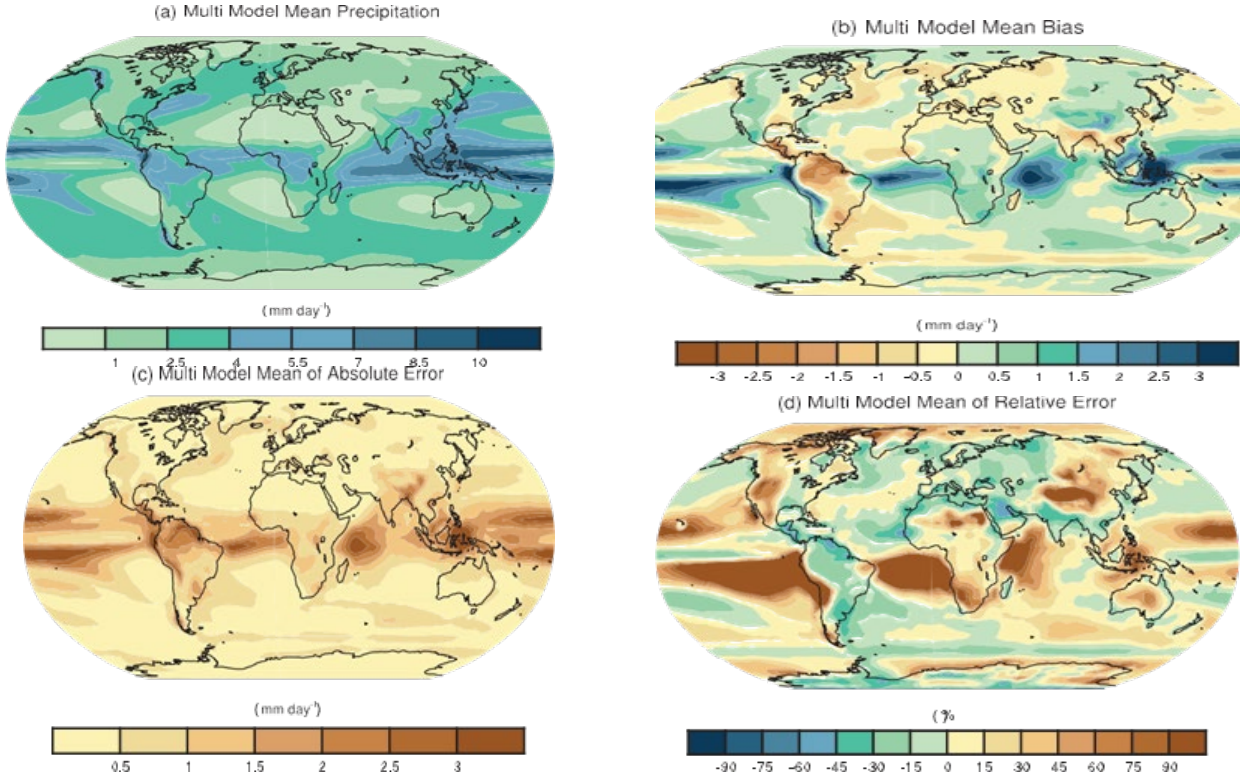


Figure shows that CMIP5 models have major errors in distribution of mean precipitation including the development of the erroneous double ITCZ , that is not found in nature. Coupled models used for S2S prediction have similar errors and these errors develop rapidly (order of 1 to 2 months).

Flato et al., 2013

Summary of CPC Use of NMME

- The North American Multi-Model Ensemble (NMME) is a critical component of CPC research and operations (domestic and international).
- CPC wants to see the NMME continue.
- CPC would benefit from having the reforecasts for all NMME models be for the 1982 to present period.

Final Thoughts on S2S Prediction Challenges (Personal View)

- **Many of the challenges to improving S2S prediction skill require applied, operationally relevant research. We need to ensure that there is sufficient funding to support this type of work in order to enable a healthy research enterprise, which will ultimately improve our operational products.**
  - **This needs to include funding for higher risk, higher reward research that may not transition to operations immediately but help advance our understanding and seed future innovation that does transition.**
- **Common standards/best practices for prediction tools so that stakeholders can make informed decisions and we can evaluate if we are making progress in improving forecast skill:**
  - **Forecast tools need to have an extended set of cross-validated reforecasts.**
  - **Comprehensive verification metrics should be available for the reforecasts.**
  - **An analysis of how well tools perform in previously challenging cases should be available, i.e. 2014-17 and 2022-23 winters.**
  - **Tools should have user-friendly interfaces that are co-developed with stakeholders, and that include skill and confidence estimates that are meaningful to stakeholders for specific decision making contexts.**