Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
43rd NOAA Annual Climate Diagnostics and Prediction Workshop
Santa Barbara, CA, 23-25 October 2018

Untangling Seasonal Predictions over California During 2015/16 El Niño and the Parable of Blind Men and an Elephant: What Next?

Arun Kumar and Mingyue Chen
Climate Prediction Center, NOAA/NWS/NCEP

ABSTRACT

In the backdrop of an extended drought and growing concerns for water management related issues over Southern California (SCA), anticipation of a large amplitude El Niño during the winter of 2015/16 generated expectations for above normal rainfall, thus building hopes for a much needed drought relief. Expectations for above normal SCA rainfall were generated by the average rainfall response to El Niño sea surface temperature (SST) anomalies inferred based on the analysis of the observational data, supported further by model simulations. Indeed, seasonal forecasts based on North American Multi-Model Ensemble (NMME), and official predictions for December-January-February (DJF) 2015/16 indicated increased odds for the above normal seasonal mean rainfall anomaly. The observed DJF 2015/16 SCA rainfall anomalies, however, were below normal. The discrepancy between the expectations for above normal predicted rainfall versus below normal observed rainfall anomalies led to questions about the accuracy of seasonal predictions, and since then, has also led to a series of studies analyzing the atmospheric response during the winter of 2015/16. Despite vigorous attempts, a consensus on the question of the forecast performance during one of the biggest El Niño in the historical record has not emerged. This note proposes pathways to resolve some fundamental questions in the context of understanding atmospheric response to ENSO SSTs that are critical for the practice of seasonal predictions.

1. Background

In the backdrop of an extended drought and growing concerns for water management related issues over Southern California (SCA), anticipation of a large amplitude El Niño during the winter of 2015/16 generated expectations for above normal rainfall, thus building hopes for a much needed drought relief. The expectations for above normal SCA rainfall were supported by the rainfall composites during El Niño (inferred based on historical data), and also from dynamical model predictions using multi-model ensembles. Indeed, relying on such information, official seasonal forecast from Climate Prediction Center (CPC) indicated increased odds for above normal rainfall for December-January-February (DJF) 2015/16 seasonal mean. The observed seasonal mean rainfall anomalies over the SCA, however, were below normal (Fig. 1). An apparent discrepancy between various seasonal forecasts (for increased odds for above normal SCA rainfall) and observations led to the perception of a failed forecast during one of the strongest El Niño's in the historical record. This led to a series of studies that attempted to explain why the observed seasonal mean rainfall anomalies may have differed from the historical expectations as well as from model based predictions. Possibilities addressed included:

- Whether the uniqueness in the spatial structure of 2015/16 El Niño SST conditions altered the atmospheric response? In other words, while seasonal forecasts keyed more on the mean El Niño response, they failed to take into account the changes in atmospheric response to the "flavors of El Niño."
- Did a general warming of tropical SSTs (that has occurred in recent decades) have led to changes in atmospheric response to El Niño?
- Was drying over SCA due to extreme drought conditions modulated the canonical atmospheric response to El Niño?

Correspondence to: Arun Kumar, Climate Prediction Center, NOAA/NWS/NCEP, 5830 University Research Court, College Park, MD 20740; E-mail: arun.kumar@noaa.gov

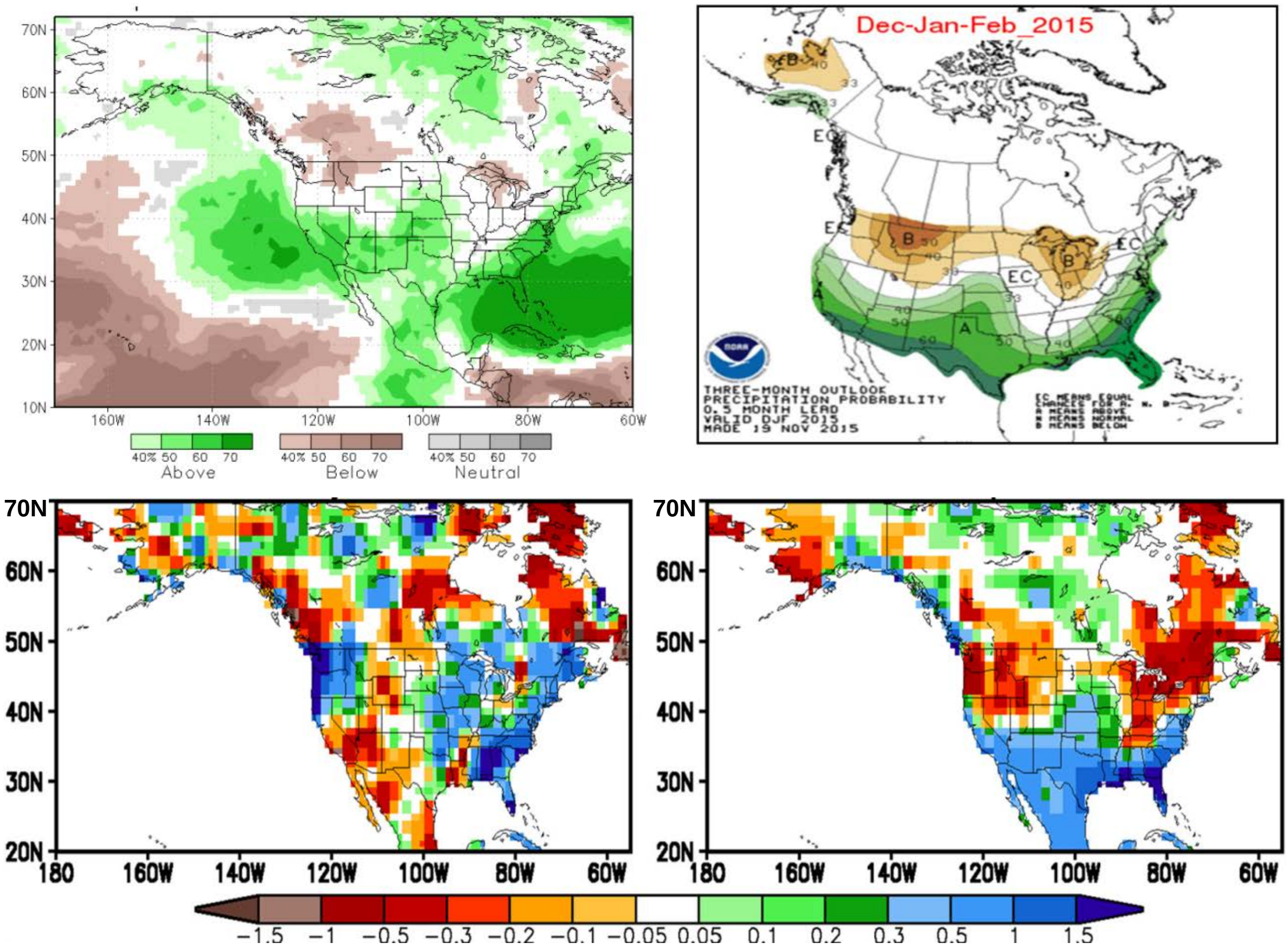

Fig. 1 (top left) NMME prediction of DJF 2015/16 rainfall anomaly; (top right) CPC's DJF 2015/16 forecast for rainfall. Forecast is in terms of probability for rainfall to be in the above normal (green) or below normal (yellow) category; (bottom left) observed DJF 2015/16 rainfall anomaly; and (bottom right) observed DJF composite rainfall anomaly during El Niño.

- Did recent decline in sea-ice may have played a role?
- Were the boundary conditions in the seasonal prediction systems themselves predicted well enough?
- How model biases may have influenced our inferences about the atmospheric response to El Niño?
- What was the role of atmospheric noise (or internal variability) in influencing observed seasonal mean rainfall anomalies? Under the influence of atmospheric internal variability, was discrepancy between the forecast and the observed outcome a consequence of incorrect forecast (*i.e.*, the response to El Niño) or just a consequence of internal variability having a large contribution to a single observed outcome?

Such questions present a baffling array of choices and the papers that have appeared in peer reviewed literature did not lead to a consensus viewpoint as to why forecast and observed anomalies may have differed, and if anything, likely added to further confusion. Given an already long history of research efforts spanning almost 40 years (using observational and model simulations) in quantifying atmospheric response to ENSO SSTs (Madden 1976; Horel and Wallace 1981; Kumar *et al.* 2007; Jha *et al.* 2017), and that we are still continually surprised by discrepancies between seasonal forecasts and observed outcomes, particularly during years with large amplitude anomalous boundary forcings, begs the question as what needs to be done to reach a consensus on some of the fundamental science questions that are of importance for the practice of seasonal predictions.

2. Thoughts on next steps

Some of the key science questions in the context of the practice of seasonal prediction are:

- What are the limits of ENSO related predictability for seasonal mean atmospheric variability?
- How linear is the atmospheric response to ENSO, for example, to the amplitude of the ENSO associated SST anomalies?
- How much flavors of ENSO should matter in constructing seasonal forecasts from one-year-to-another?
- How does the spread of the seasonal mean change under the influence of ENSO SSTs?
- To what extent model biases influence the realization of ENSO related predictability in the observed system?
- If the role of internal atmospheric variability in shaping observed seasonal means (particularly in extratropical latitudes) is large, and consequently the signal-to-noise (SNR) is small, how best the user expectations can be managed?

As mentioned earlier, despite a long history of research in understanding atmospheric response to ENSO, clear answers have not yet emerged or have been internalized by the seasonal forecasting community. Towards answering these questions, it is understood that the historical observational record is not long enough to provide enough samples of ENSO events for us to address above questions with any confidence. The answers, therefore, have to rely on model simulations where a large realization of atmospheric state under unique boundary focings can be generated. The model based approach, however, gets criticized because of model biases (on various spatial and temporal scales) could easily influence the inferences about atmospheric responses to ENSO. To place confidence in model based results, there is a critical need to establish metrics to assess if models are good enough to address the questions we are posing

Besides developing some metrics to assess "goodness" of the model to address a specific question (Kumar *et al.* 1996), the second pathway to establish "what factors in boundary conditions really matter in determining atmospheric response to ENSO" has to rely on community based multi-model approach. An example of such an approach was the effort under the US CLIVAR Drought Working Group (DWG) that attempted to establish which SST forcings may be important for modulating drought conditions over the US (Schubert *et al.* 2009). Building on that effort, the approach we propose would call for a (CMIP like) periodic and coordinated multi-model assessment under a varying degree of ENSO responses. It is possible that such an effort may still not lead to clear answers, however, an appropriate guidance to the practitioners of the seasonal forecasters can still be provided and could as well state that "at present no clear inference about the role of a particular aspect of ENSO SST forcing in modulating atmospheric response can be given."

In our attempts to establish what really matters in determining the atmospheric response to ENSO, it is also conceivable that not every detail in boundary condition matter, for such a scenario will make the practice of seasonal predictions an impossible endeavor. Further, scale analysis (or Taylor's expansion) is one of the basic tenets of making scientific advances, and is also likely to be true in quantifying ENSO response beyond what is inferred based on simple regression or composite based approaches (which quantify the first order influence of "average or canonical" ENSO SSTs on the atmospheric variability). The fact that establishing consensus beyond the first order response has proven to be such a difficult task may point to the fact that higher order influences of variations in ENSO on the atmospheric response are small (as they should be if the implicit meaning of *higher order response* does carries forward); however, such indications remain to be confirmed based on a periodic assessment of atmospheric responses to ENSO using multi-model approach.

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