Where Do Seasonal Climate Predictions Belong in the Drought Management Toolbox?

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Where Do Seasonal Climate Predictions Belong in the Drought Management Toolbox?

By Michael A. Crimmins and Mitchel P. McClaran

On the Ground

- Seasonal climate predictions, based largely on the status of the El Niño-Southern Oscillation, are one such tool but need to be used with prudence, understanding when and where they perform the best.
- Advance planning and preparation for drought includes finding the right place for uncertain climate predictions in management decision making, as well as working to reduce overall exposure to drought risks.

Keywords: drought, seasonal climate prediction, forecasts, El Niño-Southern Oscillation.

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Drought is a menacing natural hazard to ranchers and rangeland managers alike. Its impact on forage production and water resources have been studied for decades, with many tools to manage and anticipate its impacts emerging from this work. Seasonal climate predictions provide an additional tool to prepare for drought. Those predictions have been improving in recent decades, especially for winter precipitation predictions because of connections with sea surface temperature and pressure anomalies that manifest during El Niño-Southern Oscillation events. However, their limited predictive power in the summer growing season for most regions and coarse spatial resolution have limited their adoption by ranchers and rangeland managers. Therefore, rather than a panacea, seasonal climate predictions are better viewed as only one of many tools to increase preparation for future drought.

What Are Seasonal Climate Predictions?

Seasonal climate predictions sit at the intersection of weather forecasts that cover the timescale of hours to about 2 weeks and long-term climate projections, which typically extend beyond 1 year and out to a century.[1] Prediction of weather and climate at any timescale is challenging, but this intermediate seasonal timescale of beyond several weeks to about a year brings its own set of challenges. Seasonal climate predictions are structured to examine slowly evolving components of the climate system and then suggest how they may affect the expected average climate for the next month or coming seasons. These slowly varying components of climate include things like sea surface temperatures in the large ocean basins, sea ice and snow cover at higher latitudes, and soil moisture levels over large continental areas.

The El Niño Southern Oscillation

One of the most reliable climate phenomena used in seasonal climate predictions is tracking and attempting to forecast the state of the El Niño-Southern Oscillation (ENSO). ENSO is a somewhat regular (on the order of 2–7 years) shift in sea surface temperatures along the equator of the Pacific Ocean basin. Normally, temperatures are cooler in the eastern Pacific and warmer in the western Pacific due to easterly winds causing upwelling of cool water in the east and the movement of warmer surface water to the west. In some years, stronger than average easterly winds will intensify this pattern of cool east-warm west sea surface temperatures, which is termed a La Niña event. During El Niño events, these easterly winds weaken, causing warm water to slosh back to the central and eastern Pacific with warmer than average sea surface temperatures in these regions.

The location and extent of warm sea surface temperatures is critical in determining where anomalous tropical convection occurs and, in turn, its impact on global circulation patterns. Across the continental United States, the impact of ENSO is strongest during the winter season when the storm track driven by the position of the jet stream is typically disrupted

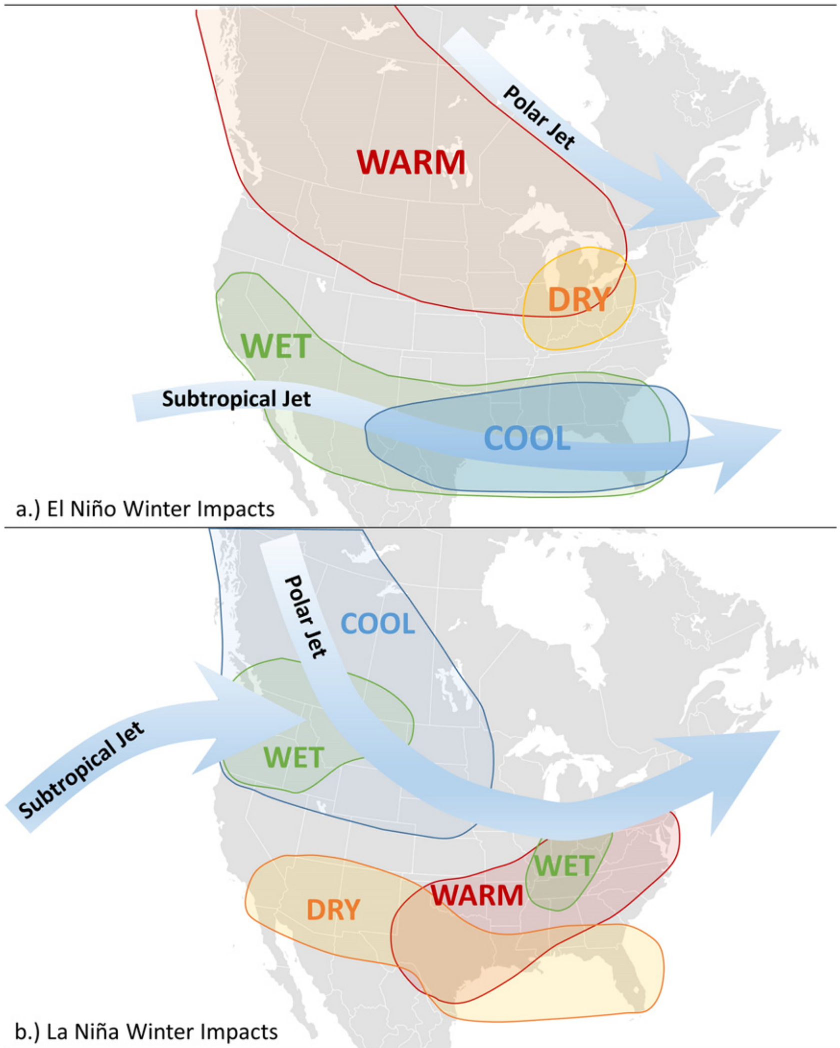

Figure 1. Typical wintertime circulation pattern and climate anomalies that emerge across the United States during strong El Nino (top) and La Nina (bottom) events (adapted from NOAA-CPC).

and precipitation anomalies emerge. During El Niño events, the winter jet stream often splits in the east Pacific with a stronger than average subtropical jet stream that steers a parade of storms across the southern states and subsequently above-average precipitation (Fig. 1). In contrast, during La Niña events the winter storm track is more likely to enter the Pacific Northwest, bringing above average precipitation to this region and leaving the southwest United States with below-average winter precipitation.

This relatively consistent pattern of winter precipitation being associated with ENSO conditions becomes a major part of forecasting seasonal precipitation patterns, especially winter precipitation. A seminal paper by Redmond and Koch[2] showed that the state of ENSO (as measured by a metric called the Southern Oscillation Index) in the July to November period was highly correlated with precipitation amounts in the following October to March season in the Pacific Northwest and southwest United States due to the slowly evolving state of El Niño and La Niña conditions. ENSO events typically develop in the northern hemisphere in late spring and early summer, peak in strength in the following December to February period, and then subside back to neutral conditions through the following spring.

The slowly varying nature of ENSO status tied to the annual cycle provides insight into potential conditions the following winter at a longer lead time (often up to 6 months). In contrast, the impact of ENSO on summer circulation patterns across the continental United States is very weak, leaving little predictive value for summer precipitation patterns. This is a particularly vexing issue for those rangelands where the majority of forage production is tied to the amount and timing of summer precipitation.

Interpreting Seasonal Climate Predictions

There is no single piece of data, information, or modeling result that can be used to make a seasonal climate prediction. Rather, a suite of tools is used by forecasters to manually develop a seasonal climate outlook product. These tools include statistical and dynamical models of varying complexity that need to be evaluated and integrated into this product based on tools past performance and expert judgement.[3] The National Oceanic and Atmospheric Administration Climate Prediction Center (NOAA-CPC) issues a suite of seasonal climate outlooks the third Thursday of each month for the coming month and overlapping 3-month periods to cover a year from the current date. The outlooks include precipitation and temperature information represented in probabilities of observing the seasonal mean (or "normal" for the most recent 30-year normal period) for temperature or total for precipitation falling in one of three categories (terciles). These terciles (thirds of the full distribution) represent above (67th–100th percentile), normal (34th–66th percentiles), and below (1st–33rd percentiles) normal conditions based on the historical data for that location.

The outlooks are typically depicted as maps of probability anomalies for each of these three categories. For example, green colors show the shift in odds toward wetter than median conditions, and brown shows a shift in the odds toward drier conditions. Median is used as the measure of central tendency for precipitation rather than average because of the nature of typical precipitation distributions, which often consist of many small values and only a few large values. White colors on the map indicate equal chances of observing total precipitation or average temperature over this season in any one of the three categories, effectively communicating that there is not enough information to shift the odds in any direction and make a useful forecast.

The 3-month precipitation outlook made in October of 2015 shown in Fig. 2 has a very large shift in odds toward wetter than median conditions across much of the southern states and drier than median conditions across the northern states for the upcoming December to February season. Looking at Arizona in particular, the 50% probability anomaly indicates that there is a 50% chance of seeing above-normal (upper third of the historical distribution) total December to February precipitation, a 33% chance of observing normal (middle third of distribution) precipitation, and only a 16% chance of observing below-normal precipitation over this period. The exact opposite forecast is being made for Montana with a 50% chance of below-median precipitation (bottom third of local distribution) and implicitly a 16% chance of above-median precipitation. In between the dry signal to the north and wet signal to the south is the dreaded equal chances depiction, which indicates that total precipitation between December to February is equally likely to be wetter, drier, or simply near median values.

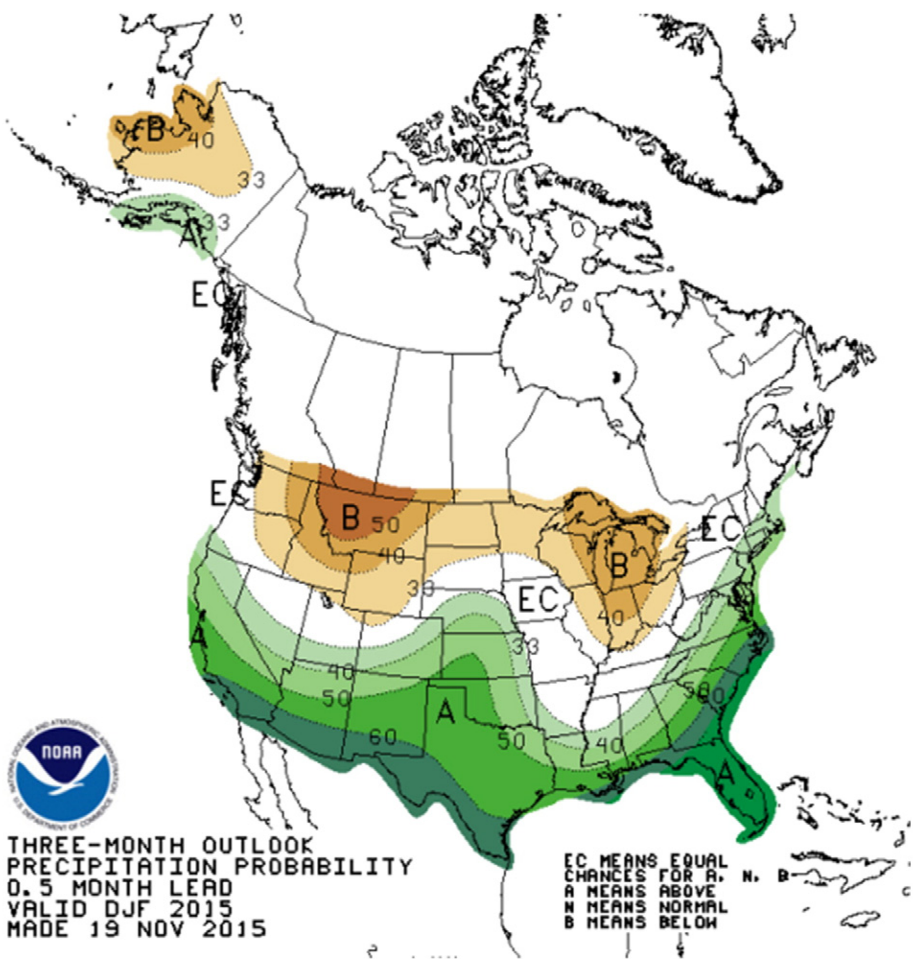

Figure 2. Three-month precipitation outlook made in October 2015 for the December-January-February period (NOAA-CPC).

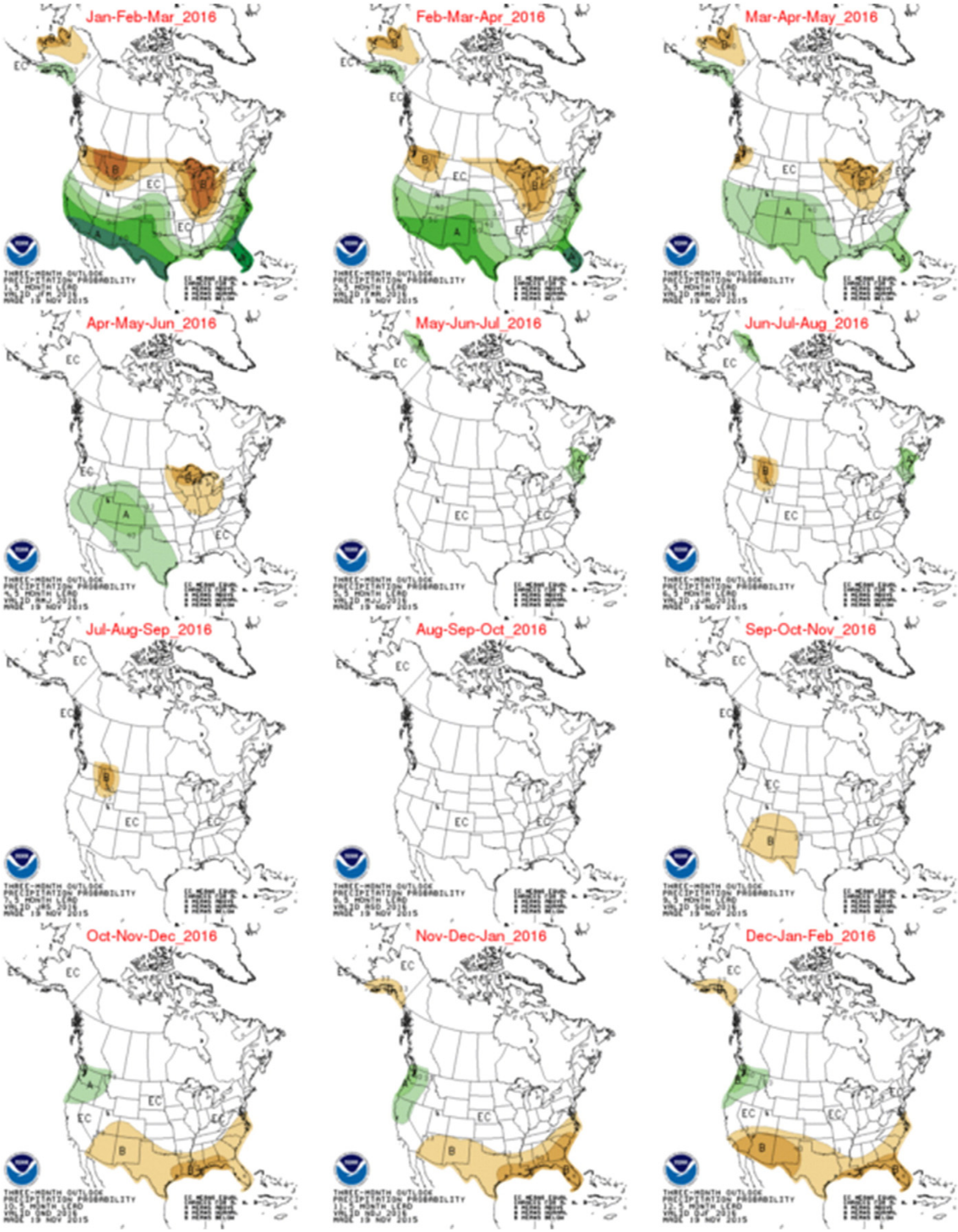

Figure 3. All 3-month precipitation outlooks from December to February 2015 out through November to January 2016 issued in October of 2015 (NOAA-CPC).

The outlook depicted in Fig. 2 was made on 15 October 2015 during the very strong El Niño event of 2015 to 2016 and subsequently relies largely on the typical precipitation pattern associated with El Niño events during the winter. The probability anomalies are also quite high because of the strength of sea surface temperature anomalies for this event. However, none of these values are close to 100%, which illustrates that there is not absolute confidence in any of the predictions for a tercile category. For example, even with this strong forecast of wetter conditions across the Southwest, there is still a 16% chance of the December to February period ending up below normal and in that lowest third of historical total precipitation values.

These outlooks convey uncertainty by the magnitude of the shifts in the odds from one tercile category to the next. Fig. 3 shows all 3-month overlapping precipitation outlooks issued in October 2015 out through January 2017. This figure illustrates how uncertainty inherently increases as the outlook extends out in time. The magnitude of the probabilities is relatively high at shorter timescales due to the strong influence of the very strong El Niño event underway. The magnitude of probabilities rapidly declines by the following summer where by the August to October season almost the entire continental United States is depicted with an equal chances outlook. Precipitation outlooks during ENSO-neutral years are very difficult to produce and may have weak to nonexistent probability anomalies at all timescales. Temperature outlooks, on the other hand, use the magnitude of increasing temperature trends in conjunction with phenomena like ENSO to make more confident forecasts in more seasons.[4]

Seasonal precipitation outlooks are also directly integrated with the US Drought Monitor in two additional products updated each month by the NOAA-CPC. The US monthly and seasonal drought outlooks[i] take the depiction of drought conditions provided by the US Drought Monitor toward the end of each month and then use the precipitation outlook for the next month and 3-month period to suggest the potential in drought tendencies over these periods. The outlooks show areas where drought conditions may continue or worsen based on an outlook of drier than average conditions or improve based on an outlook of above average precipitation.

Forecast Skill

Understanding the performance of seasonal climate predictions provides an important reality check on the utility of these products. The historic patterns of performance can lend some insight into which geographic regions in the United States have "signals" like the one arising from ENSO.

The NOAA-CPC has several online tools to examine the past performance or "skill" of its seasonal outlooks.[ii] Fig. 4 shows two maps from the simple NOAA-CPC Verification Summary tool in the format of Heidke Skill Scores (HSS) for precipitation forecasts made for two seasons, winter (January–February–March) and summer (July–August–September) over the period of 1995 to 2015. HSS are a simple way of tallying up past forecast "hits" and "misses" and then representing these totals in score values depicted on a map. The values can range from 100 to −50, with 100 indicating a series of perfectly correct forecasts and −50 perfectly incorrect forecasts. Negative scores indicate that a randomly generated forecast based on chance or rolling the dice would have performed better than the issued forecast. Any values above zero indicate that forecasts have performed better than chance in the past and are skillful.

The hits and misses are based on accurately forecasting values that fall within the tercile forecast categories. If an area was forecast to receive above-normal precipitation (highest tercile) over a 3-month period and that total occurred, then this would be considered a hit, or a correct forecast. If the area received total precipitation that was in the lowest tercile even though it was forecasted to be in the highest tercile, this would be a miss.

The HSS values on the maps in Fig. 3 show a couple of interesting patterns relative to the tally of past hits and misses for forecasts. The winter (January–February–March) season precipitation forecast has relatively high HSS values with a bullseye across the southwest United States. These scores of 30 to 50 indicate that this area often has relatively skillful winter season forecasts. This high forecast skill reflects the strong influence of ENSO-driven teleconnection patterns with El Niño events often bringing above-median winter precipitation to this region and La Niña events bringing a reliably dry pattern.

It should also be noted that the forecast lead for these maps is only 0.5 months. This means that the HSS values were calculated from forecasts made the middle of the month before the seasonal forecast being examined meaning in the January to March example, the forecast was made in December immediately before the season began. As discussed before, as the lead of the forecast increases the uncertainty also increases. These short-lead forecast verifications can then be thought of as a "best-case" of forecast performance.

In contrast to the winter precipitation forecast, the second map in Fig. 3 shows the past performance of mid-summer forecasts (July–September) for precipitation. The magnitude of the HSS values is quite a bit lower with only the Pacific Northwest observing a coherent region of skillful forecasts due largely to trends in declining summer precipitation over the past several decades.[4] This means that relying on what happened last summer and many of the previous summers for this region is a fairly good bet and has led to skillful forecasts based on this trend. However, the rest of the continental United States is largely devoid of a useable summer season forecast signal. Most notably, the HSS values are close to zero across all of the southwest United States where the North American Monsoon brings important summer season precipitation and subsequent forage production to grazing systems across this region. The monsoon system and resultant

[i] U.S. monthly and seasonal drought outlooks are available at http://www.cpc.ncep.noaa.gov/products/Drought/.

[ii] For an example see http://www.cpc.ncep.noaa.gov/products/verification/summary/index.php.

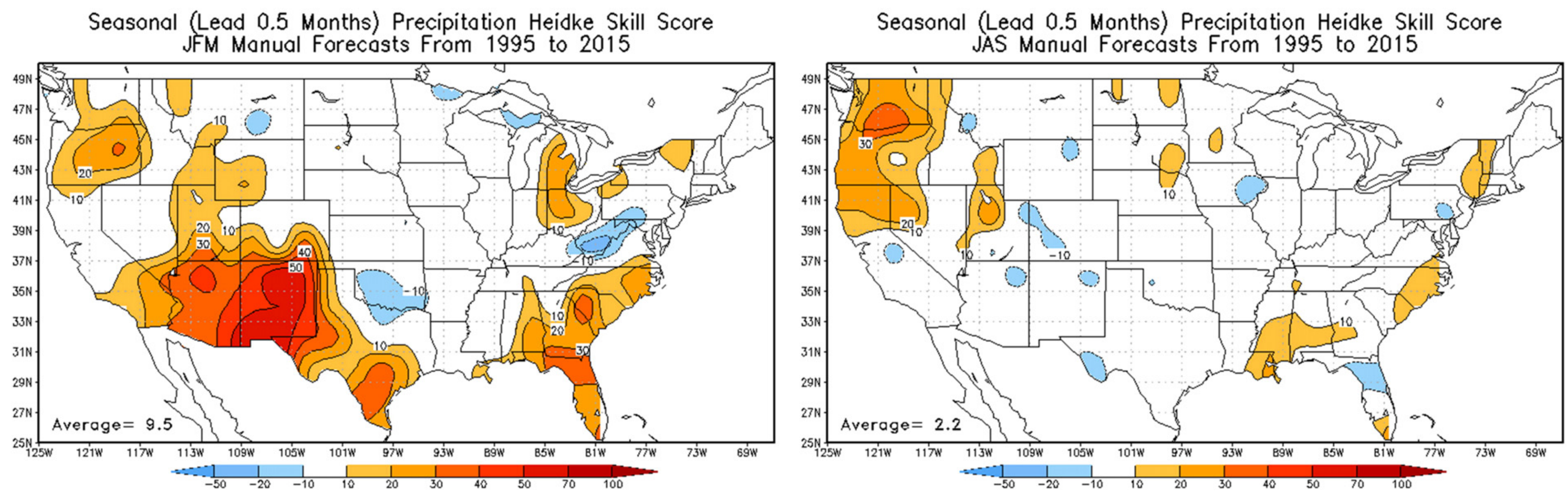

Figure 4. Seasonal Heidke Skill Score maps for the January to March season (left) and July to September season (right) (from NOAA-CPC http://www.cpc.ncep.noaa.gov/products/verification/summary/index.php?page=map).

summer season precipitation are notoriously hard to predict across the Southwest, and seasonal climate forecasts have little to build on given the weak connections between large-scale seasonal climate phenomena like ENSO.[5]

Include Many Tools in the Drought Planning Toolbox

Given the generally low accuracy of seasonal climate predictions and the coarse precision of terciles, it is not surprising that ranchers and rangeland managers in Arizona do not rely entirely on them to prepare for inevitable, but unpredictable, drought conditions.[6] For example, about 70% of ranchers and Forest Service managers we[iii] are working with in Arizona feel that seasonal forecasts are accurate less than 60% of the time, and about 80% of them want accuracy to be > 70% before they will rely on the forecasts.

Given the low forecast skill and coarse resolution of tercile-based predictions, serious use of these seasonal climate predictions may be limited to the more risk tolerant of ranchers and rangeland managers.[7] These uses may include short-term decisions about securing additional forage through assignment of reserve pastures or securing additional sources of forage, purchasing insurance, and timing of cattle sales/purchases to avoid sell-off price depression or herd-expansion price inflation.

More importantly, being prepared for drought does not start with, or necessarily rely on, a seasonal forecast. In southern Arizona, ranchers who increased their preparation for drought in the previous 10 years placed greater importance on practices of developing drought plans, rotational grazing, and reserve pastures than those who had not increased their preparation. In contrast, satisfaction with drought information and forecasts was equally low (only ~ 25% were satisfied) among all ranchers, regardless of their level of increased preparation for drought.[8]

When describing approaches to drought preparation, ranchers regularly reference the historic record of drought conditions and the "stories" about the practices that were successful in dealing with those conditions.[7] This connection with historic climatology and background risk of drought suggests that new drought information tools that focus on empirical likelihoods (based on climatology) of increasingly severe drought conditions could be more attractive to ranchers and rangeland managers than a probabilistic outlook with limited skill. For example, the US Climate Division's Drought Prediction Tool: SPI Persistence Forecast[9] reports the likelihood of a future drought deficit when a rainfall deficit develops at the beginning of the growing season. It uses the frequency of occurrences in the historic record for these estimates. Such a tool could be used to define the array and likelihood of different drought scenarios that should be addressed in a drought management plan. These tools would be even more attractive if they incorporated the empirical, real-time records collected by ranchers at the ranch-scale rather than the typical regional, climate division scale, especially where there is considerable small-scale spatial variability in precipitation.

Currently, seasonal climate predictions are only a useful tool for providing some advance warning of impending drought conditions in winter for some regions during ENSO events. Given these conditions, only the most risk tolerant operators are likely to use these "forecasts of opportunity" to make significant changes. More importantly, this examination of the relatively low skill and coarse precision of seasonal climate predictions helps interpret why increased drought preparedness by ranchers is more strongly related to the development of drought management plans and grazing plans that allow flexibility in the event of drought conditions than on the drought information tools that are currently available. They cannot replace careful planning and preparedness for drought events. Seasonal outlooks can be used to anticipate drought or the onset or intensification of drought conditions in certain instances, and may be used to ready the trigger on already developed responses and management plans.

[iii] On-going NOAA-OAR-CPO-2014-2003692 project "Using a co-development process to improve, integrate and encourage use of drought information and adaptive management of livestock grazing on National Forests".

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