

Improving Sub-Seasonal to Seasonal Precipitation Forecasting for Water Management



WESTERN
STATES
WATER
COUNCIL

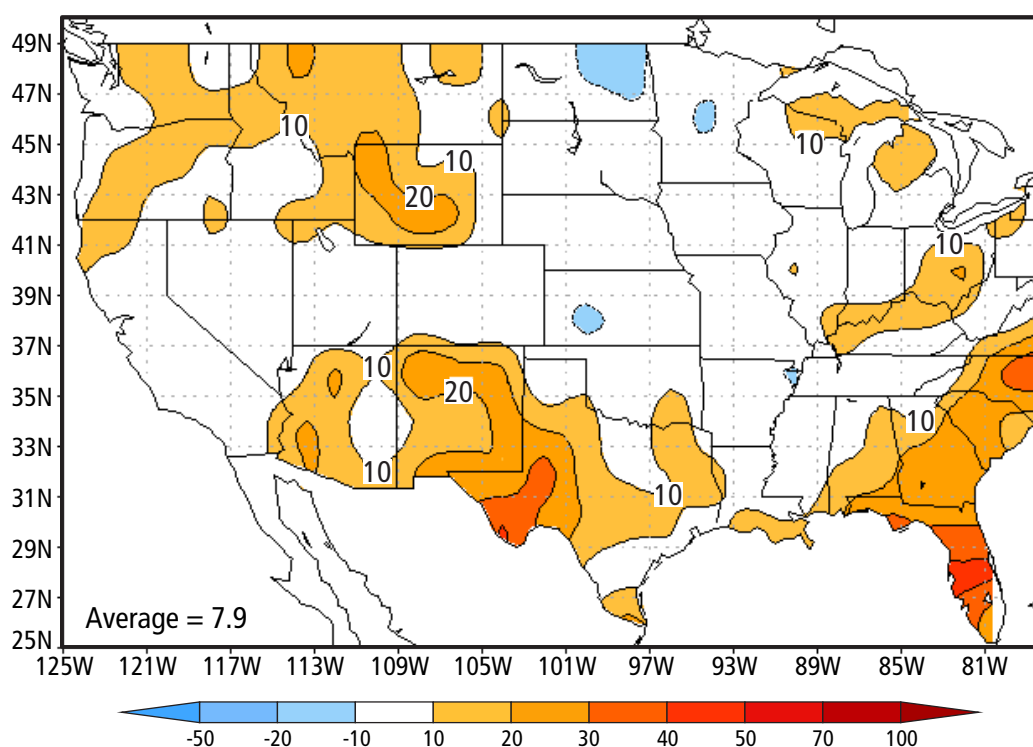
The Western States Water Council asks that the federal government provide resources for pilot projects to improve subseasonal to seasonal (S2S) precipitation forecasting to support water management in the western states, pursuant to the Weather Research and Forecasting Innovation Act. Pilot projects are needed for forecasts of winter precipitation (which provides the snowpack sustaining water supplies in mountain areas) throughout the West, and spring/summer precipitation for agricultural water supply in the Plains states.

Western States experience great subseasonal, seasonal, and annual variability in precipitation, with serious impacts and consequences for water supply planning and management, drought and flood preparedness and response, water rights administration, and operation of water projects. Sound decision-making to protect life and property by reducing flood risks and to inform decisions involving billions of dollars of economic activity for urban centers, agriculture, hydropower generation, and fisheries depends on our ability to observe, understand, model, predict, and adapt to precipitation variability

Public Law 115-25, Weather Research and Forecasting Innovation Act of 2017

This statute, enacted in 2017 and reauthorized in 2019 as part of National Integrated Drought Information System reauthorization, directs NOAA to “collect and utilize information in order to make usable, reliable, and timely foundational forecasts of subseasonal and seasonal temperature and precipitation.” The statute further requires submission of a report to Congress that describes “specific plans and goals for the continued development of the subseasonal and seasonal forecasts” and “an identification of research, monitoring, observing, and forecasting requirements” needed to meet the statutory goals.

Seasonal (Lead 0.5 months) Precipitation Heidke Skill Score DJF Manual Forecasts from 1995 to 2019



Historical skill of NOAA’s three-month precipitation outlook for the December, January, and February period. White areas on the map denote no more skill than simply predicting the historical average climate conditions. Figure credit: NOAA



The international Colorado River Basin has experienced prolonged drought conditions, resulting in declining reservoir elevations in Lake Mead and Lake Powell. Water agencies in the seven Colorado River Basin states have been taking unprecedented steps to manage the risk of shortage, including executing historic drought contingency plans with the Department of the Interior in 2019. Drought risk management programs in the contingency plans cost money and/or water. Skillful seasonal precipitation forecasts would help support decisions to balance costs against risks of shortage. Photo credit: U.S. Bureau of Reclamation



on operational time scales ranging from a few weeks to a season or more.

Current skill in S2S forecasting is not adequate to support water management decision-making, and **the federal government should place a priority on improving S2S precipitation forecasting capability to support water management.** Water is the life-blood of the West, which experiences far greater variability in annual precipitation than does the eastern half of the country. Managing water in the West is about managing for the extremes of droughts and floods, and the need to store water when available to manage it during drier times for cities, farms, energy, and the environment. Better longer-term precipitation forecasts are a necessary tool for more efficient water resource management.

Will this winter (or summer) be wet or dry?

This is a critical question asked every year by state, local, federal, and tribal water managers, as well as by cities, farmers, and hydroelectric powerplant operators. Although the skill of conventional short-term weather forecasts (which go out as far as two weeks in advance) has

improved over the past several decades, the same cannot be said for the critical longer-term forecasts important for water management. These longer forecasts – called subseasonal to seasonal (S2S) forecasts by atmospheric scientists – span time periods of several weeks out to one or two years. The skill of available forecasts, such as those produced by the National Weather Service's (NWS') Climate Prediction Center (CPC), is minimal.

As documented by NOAA's National Centers for Environmental Information, disasters at both wet and dry extremes of the hydrologic cycle are responsible for billions of dollars in losses. Water managers could employ improved S2S forecasts to prepare for and respond to drought and flooding, reducing loss of lives and property, as well as economic and environmental losses. Similarly, decision makers in other sectors affected by water management (agriculture, fisheries, hydroelectric power generation, emergency management) share a common interest in more skillful and useful forecasts.

Lead time is critical in making water management decisions. Improving seasonal precipitation forecasts would

National Weather Service California Drought – 2014 Service Assessment

In 2015 NOAA released its first-ever service assessment for drought, for the California drought which had then completed its third year. NOAA conducts service assessments to evaluate its performance after significant hydrometeorological, oceanographic, or geologic events. The assessments are triggered by factors such as major economic impacts to a large area or population, or extensive national public interest. Assessments are used to evaluate the effectiveness of products and services made available to stakeholders, to help NOAA continuously improve the services it provides. The drought assessment's top finding was the input received from numerous stakeholders regarding the need for seasonal prediction capability focused on cool-season mountain precipitation, both in California and in the Colorado River Basin.

"A majority of the stakeholders interviewed for this assessment noted one of the best services NOAA could provide is improved seasonal predictions with increased confidence and better interpretation. These seasonal precipitation products, produced by NOAA's Climate Prediction Center (CPC), are national in scale and are not designed to provide regional forecast information – information which is most relevant to decision makers interviewed by this team. For instance, state and federal officials managing California's water supply have a major unmet need for skillful predictions targeted at cool-season snowpack for the Sierra Nevada Mountains."

Improving the skill of S2S precipitation forecasting to make it usable for water management is scientifically challenging. In 2016 the National Academy of Sciences released a report on a national research agenda for improving S2S forecasting. The report identified key strategies for the next decade and made 16 specific recommendations for a research agenda. It noted that: "More skillful and useful S2S forecasts – developed through sustained engagement with users and advances in basic knowledge and technological capabilities – could radically improve the basis for decision making on S2S timescales. There are also emerging science and technical capabilities that make rapid advances in S2S forecasts more likely than envisioned even 5 years ago."

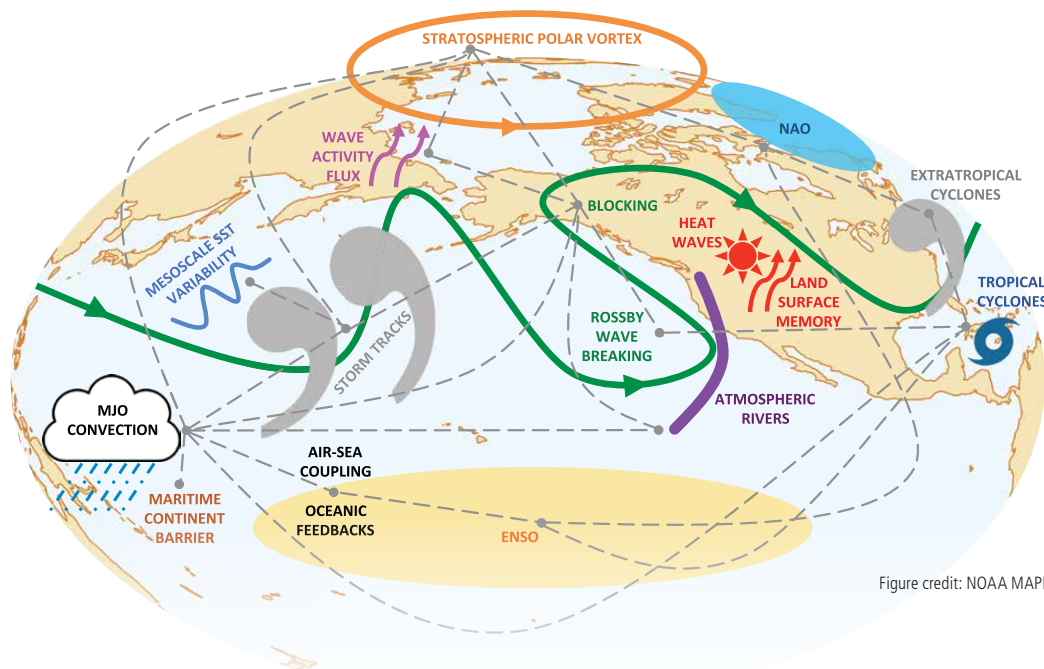


Figure credit: NOAA MAPP

Examples of Subseasonal and Seasonal Water Management Decisions

Subseasonal Decisions

Will the rest of this winter be wet or dry?

- » How much water will we be able to provide to our wholesale customers this spring? When can we plan to make an announcement?
- » Will we hit hydrologic shortage triggers that require extraordinary conservation measures, or a need to negotiate contracts or adopt special regulations?
- » Could we have an unusually wet late spring that would result in elevated flood risks or reduced agricultural irrigation needs?
- » If it looks like the rest of the winter will be dry, can we use some of the flood control storage space to save more water for our customers?
- » The winter has been very dry through December; are dry conditions likely to persist the rest of the winter?
- » When will we have to begin curtailing surface water rights and diversions on intensively used rivers?

Seasonal Decisions

Will this winter be wet or dry?

- » Do we need to seek drought response funding, reprogram other funds, or raise water rates?
- » Do we need to budget for enhanced water conservation outreach activities?
- » Should we make plans and adopt regulations for operating a drought water bank?
- » Should we purchase supplemental water supplies from groundwater or other sources to be able to meet our needs?
- » Should we begin negotiating contracts for one-time sale of surplus wet-weather water?
- » Can we set up a temporary groundwater recharge and banking program to take advantage of expected wet conditions?
- » Should we intensify flood fighting training and emergency preparedness outreach in vulnerable areas?

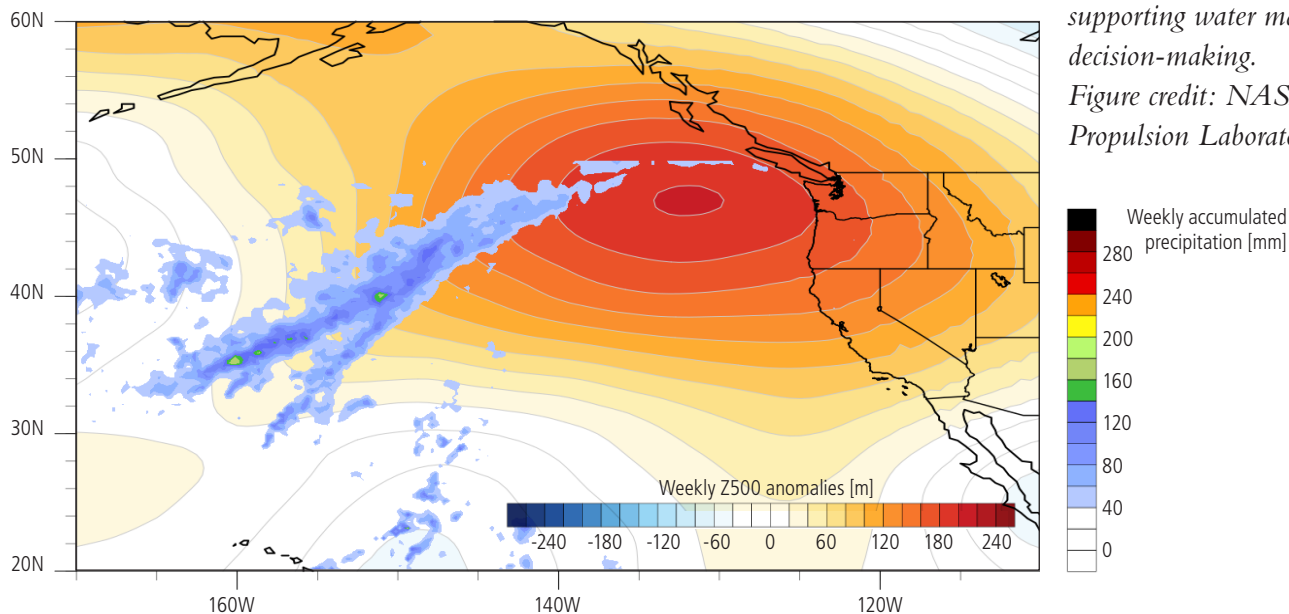
provide longer lead times for decision-making. Longer lead times are especially useful in planning and managing for the extremes of droughts and floods. Skillful subseasonal forecasts would allow for more efficient operation of water infrastructure, such as balancing reservoir operations between the competing objectives of flood control and water storage. Absent good predictive capability weeks ahead, reservoir operators must manage as conservatively as possible to ensure that space will be available to hold winter-spring runoff and manage floods. Better forecasts would allow

Atmospheric ridging blocks precipitation from reaching the West Coast during a drought year. The atmospheric feature nicknamed the “Ridiculously Resilient Ridge” was a key feature of the driest years of California’s 2012-16 drought. California Department of Water Resources (CDWR) has contracted with the National Aeronautics and Space Administration (NASA) for research on development of experimental subseasonal forecasts of winter ridging, to explore

the skill of this approach for supporting water management decision-making.

Figure credit: NASA Jet Propulsion Laboratory

24-30 December 2013



operators to retain more water in storage while still providing flood protection – the equivalent of developing new water supplies at minimal cost.

Opportunities for improving forecasting

S2S forecasting has historically occupied a research gap between conventional numerical weather modeling and century-scale climate modeling. Significant scientific progress has been achieved at the weather and century-scale ends of this spectrum, thanks to ongoing federal investment. According to the American Meteorological Society, the skill of five- to six-day NWS temperature forecasts in 2012 is equivalent to that of three- to four-day forecasts in 1992. Substantial federal support from 1990 onwards for the U.S. Global Change Research Program resulted in major progress in developing increasingly complex climate models. However, similar progress and investment have not occurred at the S2S time scale so important for western water management.

Improving S2S precipitation forecasting is a scientifically challenging subject that will require a commitment of dedicated, sustained funding. There is precedent within NOAA, given its Hurricane Forecasting Improvement Program (HFIP), for a similar



Late winter/early spring in South Dakota farm country in 2019. The Great Plains have been hit by devastating floods and droughts in the last decade. The flash drought of 2017 caused an estimated \$2.5 billion in damages to agriculture in the Dakotas and Montana; neither the drought's swift onset nor its severity was forecast. The flash drought was sandwiched between massive flooding in 2011 and 2019 that also caused billions of dollars in damages to communities and farms. Photo credit: South Dakota State Climatologist

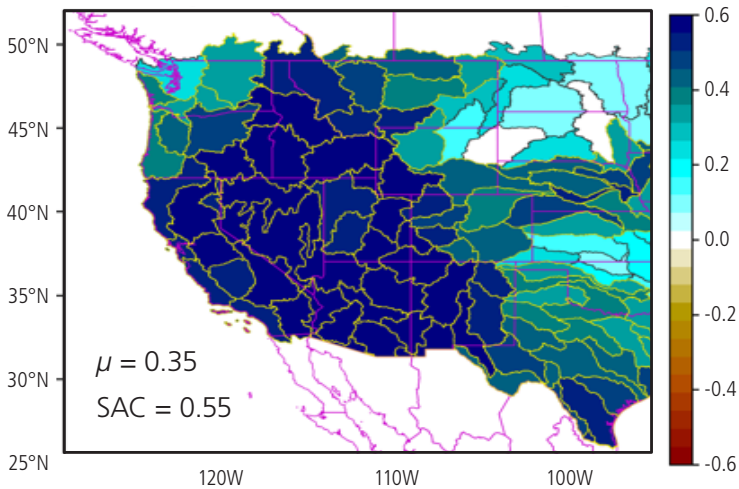


The U.S. Bureau of Reclamation's (USBR's) dry Folsom Lake in 2014. NOAA outlooks rely heavily on the El Niño-Southern Oscillation (ENSO) as a source of predictability. NOAA's early winter forecast in 2014 called for a weak to moderate El Niño with above-normal precipitation for California; ENSO conditions were neutral and California had one of its driest years on record. In 2015, NOAA correctly predicted the onset of strong El Niño conditions, but the expectation of a wet Southern California and dry Pacific Northwest was met with continued drought in Southern California and flooding in the Pacific Northwest, illustrating how much work remains to be done to improve seasonal forecasting. Photo credit: CDWR

Drought in the Western and Plains states in 2013 caused an estimated \$11.7 billion in losses. Numerous states, including Texas where this photo was taken, were affected. U.S. Department of Agriculture (USDA) disaster assistance payments are typically the federal government's greatest costs associated with droughts. Photo credit: USDA

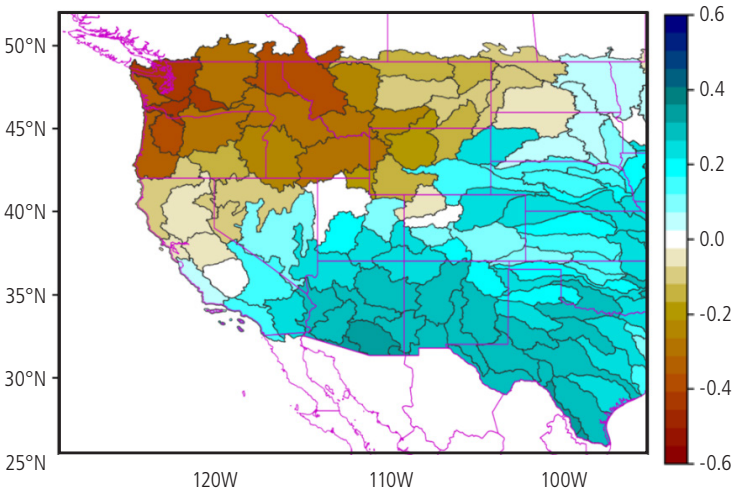
Preliminary experimental work being performed by NOAA's Earth Systems Research Laboratory (ESRL) under a contract with CDWR is compared to observed precipitation. ESRL developed a preliminary statistical model for S2S precipitation using sea surface temperatures and sea level pressure. This work demonstrates a potential opportunity for improving S2S forecasting precipitation through NOAA investment in statistical modeling. Figure credit: NOAA

Precipitation Anomaly Correlation with Merged SST/SLP model (1981-2018)



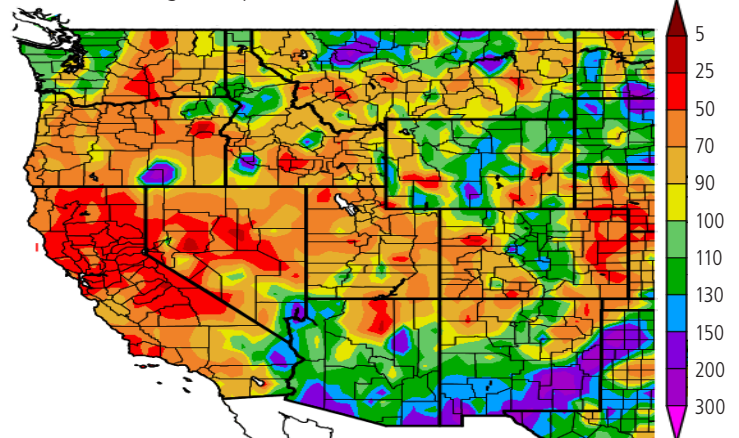
Skill of ESRL model tested against historical conditions (dark blue areas have greatest skill).

Precipitation Anomaly Correlation with Merged SST/SLP model forecast 2019/2020



Experimental forecast made in early October 2019 for the 2019-2020 winter; brown areas represent dry, blue areas wet.

Percent of Average Precipitation (%) 10/1/2019 – 3/8/2020



Observed water year precipitation.

Generated 3/9/2020 at WRCC using provisional data. NOAA Climate Centers

focused commitment of resources for improving forecasting skill. As with HFIP, there is no silver bullet for improving S2S forecasting. Necessary ingredients for making progress include investment in all aspects of the subject (human resources, high-performance computing, observing systems, and transition of research innovations to operations), well-defined metrics and timelines for evaluating success, and strong project management focused on operational outcomes. Regional pilot projects in areas where NOAA's current predictive skill is minimal are key to accelerating advancement of forecasting skill. Pilots provide opportunities to test tools such as statistical models or hybrid statistical-dynamical tools that can enhance information provided by NOAA's dynamical models.

The vision in a 2016 National Academy of Sciences report that S2S forecasts could be as widely used a decade from now as conventional weather forecasts are today needs to be realized. The Weather Research and Forecasting Innovation Act provides a path forward. The Western States Water Council asks that the federal government provide resources to implement the act.

Member states:



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