Hydrology of the Recent California Drought and Comparison with Past Droughts

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Multiyear droughts place a lot of stress on the Bay -Delta system. Water years 2012-15 turned out to be a severe 4 year drought in California. Other notable droughts of the past 100 years included 1918-20, 1924-26, 1929-34, 1976-77, 1987-92, and 2007-9. Using the Sacramento-San Joaquin 8 river runoff as a base, water year 2015 was the 4th driest of the historical record. Water year 2015 was about 20 percent better than 2014 on the Sacramento, but worse on the San Joaquin river system where 2015 was the 2nd driest, exceeded only by the severe 1977 water year. For the combined 8 river runoff, the recent 2015 water year was the 6th driest in a record of 110 years. The 4 year runoff, WY 2012-15, for the 8 river system was the driest 4 year set of record, exceeding slightly the previous record of 1931-34. However, on the southern group, the 4 rivers of the San Joaquin river system, the 4 year runoff was by far the worst in a 115 year historical record and about 20 percent drier than any 4 years in a reconstructed record of over 1000 years estimated from tree rings. The drought was most severe over central California, including the Central Coast, San Joaquin Valley, and southern Sierra. Figure 1 compares multi-year droughts of the Sacramento and San Joaquin River basins. Other charts will show precipitation deficits, reservoir storage comparisons, State Water Project supply deficits and the April 1 snowpack history. 2015 was notable with a new record low snowpack of only 5 percent on April 1.

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Drought Water Right Curtailment

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California's water rights system allocates water based on priority, where lower priority, "junior" rights are curtailed first in a drought. The Drought Water Rights Allocation Tool (DWRAT) was developed to integrate water right allocation models with legal objectives to suggest water rights curtailments during drought. DWRAT incorporates water right use and priorities with a flow-forecasting model to mathematically represent water law and hydrology and suggest water allocations among water rights holders. DWRAT is compiled within an Excel workbook, with an interface and an open-source solver. By implementing California water rights law as an algorithm, DWRAT provides a precise and transparent framework for the complicated and often controversial technical aspects of curtailing water rights use during drought. DWRAT models have been developed for use in the Eel, Russian, and Sacramento river basins. In this study, an initial DWRAT model has been developed for the San Joaquin watershed, which incorporates all water rights holders in the basin and reference gage flows for major tributaries. The San Joaquin DWRAT can assess water allocation reliability by determining probability of rights holders' curtailment for a range of hydrologic conditions. Forecasted flow values can be input to the model to provide decision makers with the ability to make curtailment and water supply strategy decisions. Environmental flow allocations will be further integrated into the model to protect and improve ecosystem water reliability.

Keywords: water rights, drought, modelling, curtailment, allocation, supply, law, reliability, forecast
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An Innovative Ensemble Modeling System for Improved Water Supply Forecasts in the Sacramento-San Joaquin Delta

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Problem Statement: The Sacramento-San Joaquin Delta receives a substantial portion of its water supply from upstream reservoirs to meet its water quantity and quality objectives and thus maintain a healthy ecosystem. Increasing water demand, increasing occurrence of hydroclimatic extremes, and warming climate pose great challenges to the reliability of water supply to the Delta. Providing reliable water supply forecasts with lead time up to months remains to be a practical solution to these challenges.

Approach: This study describes an innovative ensemble water supply forecasting system, the Hydrologic Ensemble Forecast Service (HEFS), currently employed at the California-Nevada River Forecast Center (CNRFC). The system provides ensemble streamflow forecasts up to one year by digesting the meteorological forecasts from the Global Ensemble Forecast System (GEFS). This study further assesses the forecast skill of the system for eight reservoirs draining into the Delta.

Results: The system provides satisfactory water supply forecasts for the Delta. On April 1st, the bias of median forecasts varies from -7.8% (Pine Flat) to 1.6% (Millerton Lake). The skill shows high sensitivity to extreme conditions but low sensitivity to ensemble size, forcing data, and the length of the study period.

Conclusions/Relevance: From a scientific perspective, the HEFS constitutes a significant step in the transition from traditional regression-based forecasting to ensemble forecasting in operations. As the skill of the meteorological (GEFS) forecasts continues to increase, the forecast skill of the HEFS will increase accordingly. Additionally, as skill develops in longer-range climate forecasts, that skill can be leveraged in this process as well. From a practical standpoint, the system serves a viable tool in providing critical information for water resources managers. They can capitalize on the ensemble nature of the products of this system and make uncertainty-informed, timely and effective decisions in maximizing the reliability of water supply for the Delta.

Keywords: Water Supply Forecast; Sacramento-San Joaquin Delta; Hydrologic Ensemble Forecast Service
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Comparing Methods to Estimate Consumptive Use in the Sacramento-San Joaquin Delta: Preliminary Findings

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Understanding consumptive use (CU) in the Sacramento-San Joaquin Delta (the Delta) is critical for water rights administration, management and operations, agricultural water management, and environmental and water quality protection. This research presents preliminary findings of a comparative study to improve understanding of consumptive water use in the Delta by coordinating modeling, measurement and other information from a variety of independent research and estimation efforts. Methods compared include CalSIMETAW, DETAW, METRIC, Priestley Taylor, SIMS and DisALEXI. In addition, direct field measurements of ET from bare soil were taken at several fields using eddy covariance and surface renewal stations. Preliminary findings indicate that the median estimates from the ensemble is broadly consistent with the 2013 California Water Plan, around 1.5 MAF. Summaries by crop, month and region are also part of the report. In addition, preliminary findings show that bare soil evapotranspiration at the end of the irrigation season was close to zero in four locations selected for field measurements during September-October of 2015. A final report on the 2014-2016 water years will be available in the spring of 2017. Improving quantitative understanding of CU in the Delta has the potential of increasing transparency and accuracy of models and reducing costs of water accounting statewide.

Keywords: evapotranspiration, consumptive use, remote sensing, field measurement, land use, management
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Multi-Year Persistence of the 2014-15 West Coast Marine Heat Wave

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Between the winters of 2013/14 and 2014/15 during the strong North American drought, the northeast Pacific Ocean experienced its largest marine heatwave ever recorded. Here we combine observations with an ensemble of climate model simulations to show that teleconnections between the North Pacific and the weak 2014/2015 El Niño linked the atmospheric forcing patterns of this event. These teleconnection dynamics from the extra-tropics to the tropics during winter 2013/14 and then back to the extra-tropics during winter year 2014/15 are a key source of multi-year persistence of the North Pacific atmosphere and ocean. The corresponding ocean anomalies map onto known patterns of North Pacific decadal variability, specifically the North Pacific Gyre Oscillation (NPGO) in 2014 and the Pacific Decadal Oscillation (PDO) in 2015. A large ensemble of climate model simulations predicts that the winter variance of the NPGO- and PDO-like patterns increases under greenhouse forcing, consistent with other studies suggesting an increase in the atmospheric extremes that lead to drought over North America.

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