Analysis of Agricultural Water Supply-Demand Imbalance During the Unprecedented California Drought Using NASA Satellite Data

The Challenge: Understanding Agricultural Water Supply-Demand Imbalances

Drought conditions represent unique challenges for water resource management. Water users in the Central Valley of California rely on the seasonal melt of substantial mountain snow (Figure 1 – blue line) in the Sierra Nevada to augment limited groundwater stores. This runoff is stored in reservoirs in the Sierra Nevada foothills and released in summer when demand is highest (Figure 1 – orange line). Under normal conditions, that storage meets demand and shortages are minimal. Under drought conditions, runoff volumes are significantly reduced and demand far exceeds runoff and storage, making water shortages — known as supply-demand imbalances — much more common.

This project produces satellite-based tools to characterize agricultural water supply-demand imbalances during extreme drought conditions, provides these tools to water managers, and assesses the utility of these datasets to inform water resource decision-making during drought.

How water is managed during times of supply-demand imbalance has implications for drought management. Effective management during drought requires characterization of both the water supply and the demand. This poses unique challenges including the need to estimate anomalous snow distribution in the mountains, abnormal patterns of evaporation and plant water use (evapotranspiration or ET), and atypical crop cover patterns due to land fallowing decisions.

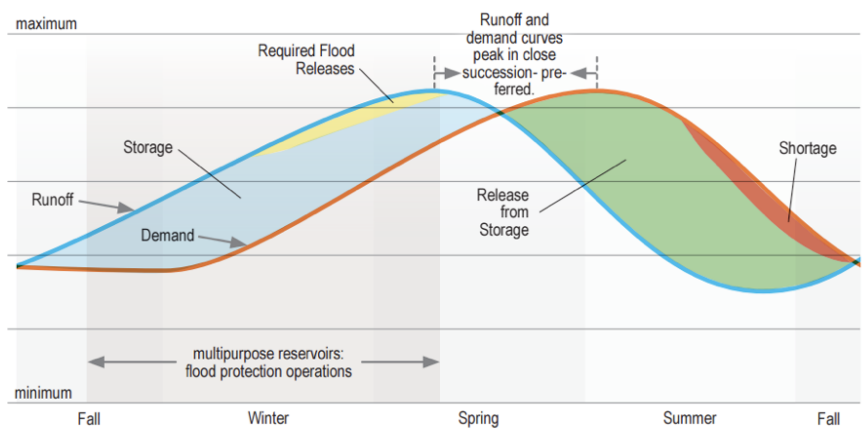

Figure 1. Theoretical time series of runoff and demand in California. Runoff (blue line) peaks in early spring a few months before demand (orange line) peaks in early summer. [Source: CA DWR]

This research project uses NASA satellite-based (MODIS) snow water equivalent (SWE) and (Landsat and MODIS) ET estimates – from the NASA Satellite Irrigation Management Support project (SIMS) – for years 2000 through the funding cycle (i.e., 2019). The primary objective of the work is to provide satellite-based tools for evaluating agricultural water supply-demand imbalances during extreme drought conditions. Related secondary and tertiary objectives aim to: migrate remotely sensed SWE and ET analyses into the California Department of Water Resources (CA DWR) computational environment; and to conduct quantitative and qualitative assessments of the utility of the SIMS ET, and MODIS-based snowpack information, to inform water resource decision-making during droughts. The research focuses on ingestion of remotely sensed observations within operational models used by the CA DWR.

The Impacts: Actionable information for decision-makers and stakeholders

By linking NASA products to existing water supply forecast procedures at the CA DWR, we provide information to support water management decisions. A strong partnership with CA DWR ensures effective integration of our products into decision-making processes with an emphasis on two-way communication. Namely, the participation by David Rizzardo, California's Chief of Water Supply Forecasting, and John Berggren (University of Colorado-Boulder), an expert in stakeholder decision support, ensure continual communication between researchers and stakeholders. The research is highly relevant to broader NASA strategic goals because it connects improved understanding of Earth System Science to mitigation and adaptation to global change – providing actionable information to decision-makers and stakeholders.

In addition to drought management, the data products produced under this project have been used to characterize runoff during floods such as occurred in February 2017 upstream of California's Oroville Dam. This "atmospheric river" event dropped up to 20 inches of rainfall on substantial mountain snowpack. The resulting flood wave threatened the structural integrity of the Oroville Dam, causing $870M in damages and requiring the evacuation of more than 180k downstream residents. Guided by CA DWR decision-makers, we used the satellite-based snow product to quantify the additional runoff produced by snowmelt during this large rain-on-snow flood event. The improved characterization of mountain snow distribution provided by our "real-time" snowpack maps (Figure 2) and advisory reports help to better inform forecasts and decisions. Thus, our partnership has the demonstrated potential to help the State of California prepare for and manage water supply extremes including both drought and flood.

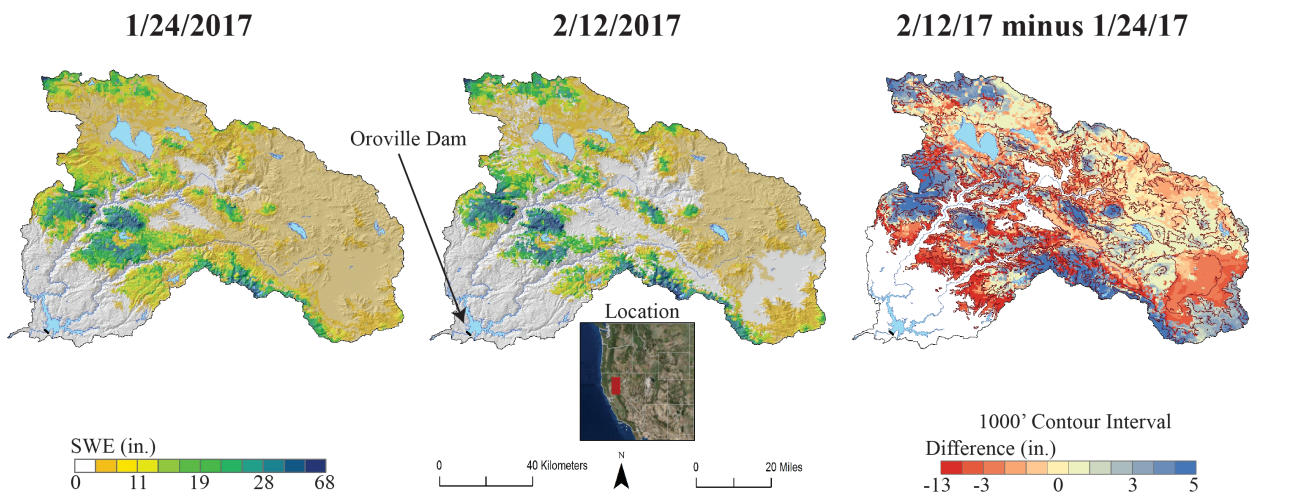

Figure 2. Real time spatial snow water equivalent (SWE) maps for the Feather River watershed before (1/27/17; left panel) and after (2/12/17; center panel) the flood that caused the Oroville Dam disaster. The right panel shows the SWE change between the two dates. Substantial melt at lower and middle elevations (red, orange and yellow colors) substantially contributed to the flood potential.

The scale of the problems addressed goes far beyond California. Globally, agricultural water demands are heavily reliant on seasonal snow to support over a billion people. These dependent commodities and populations are potentially vulnerable to a changing climate. Water managers across the globe will increasingly seek improved information on water supply, demand, and imbalances. This timely project uses satellite-based water supply and demand information to improve water resource management with careful attention to provide actionable decision support for agricultural producers.