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Supporting Information S1

How can we support the development of robust Groundwater Sustainability Plans? An illustrative example from Yolo County

Climate projections from paleo-climate reconstruction

The District's current planning process involves looking into the past 30-40 years of climate, water supply, delivery and revenue history (O'Halloran and Stephenson, pers.comm.). As mentioned in the main text, water supply shortages are a common feature for the District, with three years in recent history (1977, 1990 and 2014) when no surface water supply was available. This recent history also includes several periods when sufficient water supply was available. Hence, climate futures of interest to the District were those that reflected mean, drought and recent climate regimes.

We chose to construct monthly climate sequences that are analogs to reconstructed climate, based on tree-ring data, that go back to 901 AD. Tree-ring data help reconstruct historical (paleo) climate, far beyond the 100 year record of gauged data in California, by taking advantage of the greater longevity and climate sensitivity of several tree species in California and Oregon. *Juniper occidentalis, Quercus douglasii, Pinus ponderosa, Pinus jeffreyi* are sensitive to cool-season moisture, and can live for hundreds of years. Tree rings of these species are climate proxies; the width of the annual ring being limited by available moisture. Thus, ring-width variation is statistically associated with measures of available moisture such as rain or streamflow (Earle 1993). Tree-ring data have been used to reconstruct hydroclimatic variables including stream flows, precipitation, salinity, drought and snowpack (Malevich et al. 2013; Cook et al. 2007). Annual streamflows were related to several tree-ring chronologies by University of Arizona researchers to reconstruct and analyze climate from the year 900 AD for the Sacramento and San Joaquin rivers; and from the 1500s for the Klamath (Meko et al. 2014). Findings of the study relevant to our research include:

Paleoclimatic information captures a broader range of hydrologic variability than that provided by the observed record, thereby putting the short period of observed drought into perspective. Reconstructed climate also provides context for expected impacts of climate change by assessing future climate change projections in the context of past centuries (e.g., (Cook et al. 2015))

Paleo-climate analogs were created in the following manner. First, the reconstructed Sacramento River Index (SRI) was obtained from (Meko et al. 2014; http://www.treeflow.info/content/sacramento-river-four-rivers-index-ca-update), shown in Figure S1.1. Second, 30-year moving averages were created from the reconstructed SRI. The period closest to the mean of the collection of 30-yr moving averages was selected as representative of a mean climate sequence, and was found to be 1562-1591. The period with the most number of critical droughts was selected as representative of a severe drought sequence, and was found to be 1350-1379 (Figure S1.1). Third, synthetic time series of meteorological inputs were created for each climate sequence by matching the SRI for each year from the paleoclimatic record with the most similar year from the recent past (1950-2010) for which we have a distributed set of meteorological input data. Finally, the monthly meteorological records from the water years were assembled in order. The recent climate sequence was chosen as a repeat of 1980-2009 climate. Interestingly, this period's average SRI is close to that of the wettest period from paleo-climate reconstruction (1888-1917), corroborating the information that the past 100 years have been relatively wet in paleo-climate history. The result, in SRI dimensions is presented in Figure S1.2, with labels for each WY that was used in each climate projection.

Paleoclimate information has been recently used in water resources management modeling (Tingstad et al. 2014), who describe its benefits and challenges in their specific study area of southern California. The key advantage of this dataset in the context of our study is that it is perceived as credible despite a low level of belief in human-induced climate change amongst local stakeholders (Tingstad et al. 2014). While farmer belief in human-induced climate change is low, their perception of climate risk in the form of water supply variability is high (Haden et al. 2012; Niles et al. 2013). The same authors have found that farmer's perception of climate risk is shaped by climate-risk related experience and thereby to climate policy response. Given these findings, we believe that the agricultural community in our study area is more likely to accept climate regimes informed by the 'past' (i.e. via climates informed by paleoclimate) and thereby to see the value of this study with respect to engaging constructively with whatever shape the new SGMA policy will take. The primary challenge of this approach is there are no clear best practices as of yet that describe how to translate annual index-based reconstructions of climate (such as the Sacramento River Index used here) to a time series of climate variables at sub-annual time steps.

Figure S1.1. Wet, dry and mean climates from the reconstructed Sacramento River index (901-2014).

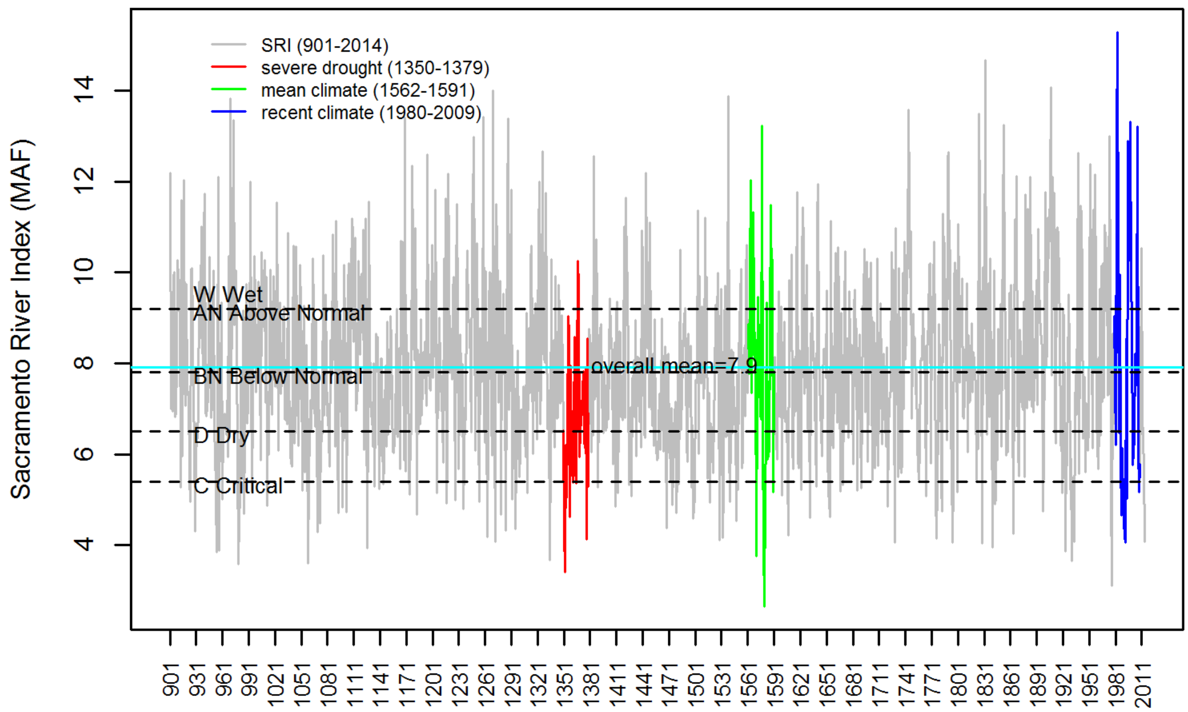
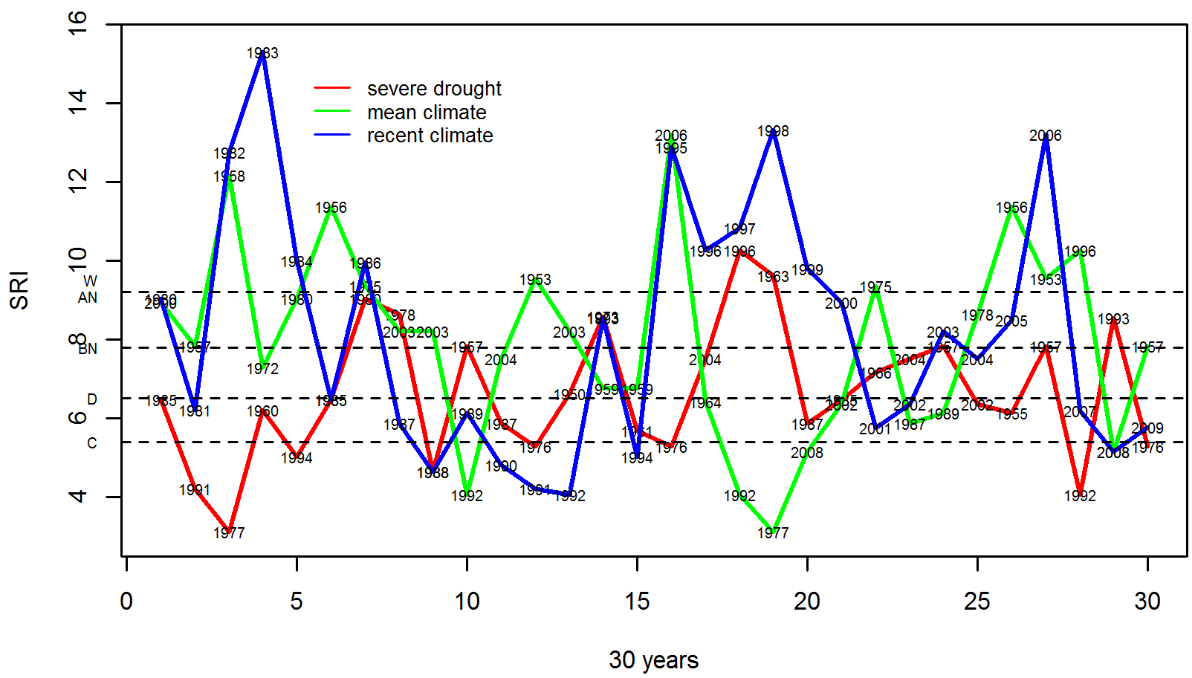


Figure S1.2. 30-year sequences of water years representing mean, wet and dry climate analogs based on reconstructed SRI. Labels are water years in each sequence.



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