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Subject: Modeling of 1500s megadrought using a stochastic weather generator

Synopsis

DWR's Delivery Capability Report modeling uses a stochastic weather generator trained to learn patterns from historical data from 1948-2018. It was developed in collaboration with Scott Steinshneider and Naser Najibi from Cornell University.

Steinschner had a very talented grad student,, Rohini Gupta, who did a greatly needed analysis of the vulnerability of the SWP and CVP to an extended megadrought as a capstone to her PhD research. She drove the weather generator with precipitation changes inferred from 600 years of tree ring data. So Gupta's stochastically generated simulations include paleo information about California's climate variability on multiple scales -- including the 60 year dry period from 1520-1580. The Climate Change Technical Advisory Group recommended this modeling in their 2015 report, noting the limitations of CALSIM's method of perturbing the historic record (the Delta method.)

For her PhD research, Gupta used the reconstructed paleo flows to model CVP and SWP operations using a Python code that is publicly available. She modeled the storage in Shasta, Oroville, and San Luis reservoirs with the entire paleo record -- and then looked at a repeat of the worst 30 year megadrought in the 600 year record, during the extended dry period from 1520 to 1580. She called this 50 year period the "Renaissance megadrought." Her paper is here, just published in February 2025

[Exploring Water System Vulnerabilities in California's Central Valley Under the Late Renaissance Megadrought and Climate Change](#)

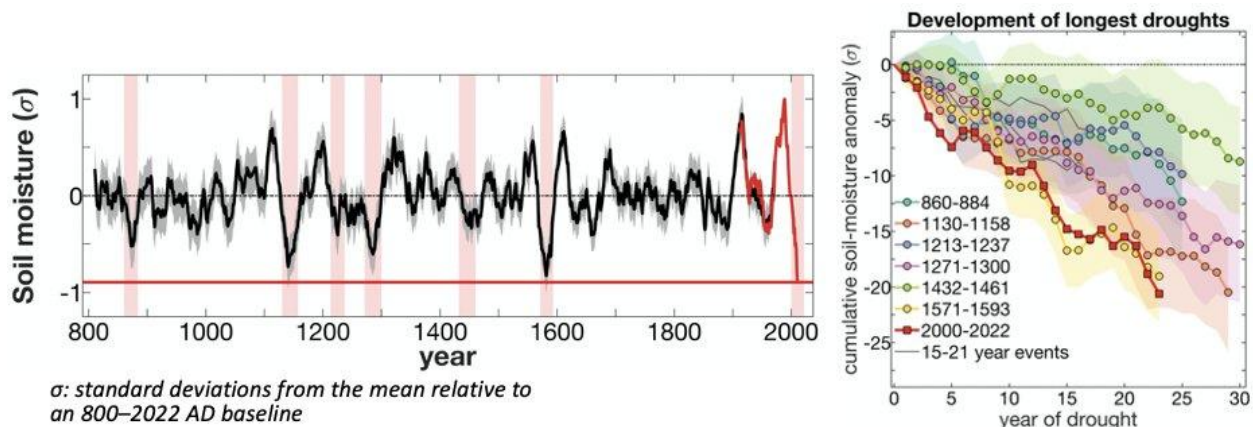
Some key points:

Gupta's modeling shows that the State Water Project essentially breaks in an extended megadrought. There are prolonged years of Oroville reservoir being drawn down to close to dead pool. There are also years of very low deliveries. This is the true "95th percentile" risk scenario.(30 years / Last 600 year paleo reconstruction) = 5% of years

Gupta's summary:

.. tree-ring records demonstrate that California experienced multiple persistent megadroughts over the past two millennia... Multiple studies have found the late 1500s megadrought to be the most severe prolonged drought period up until the end of the 20th century (Cook et al., [2022](#); Stahle et al., [2000](#)). Williams et al. ([2022](#)) reconstructed 1580 CE to be the driest year in the past 1,200 years and the period of 1571–1592 CE to be the second driest 22-year period after 2000–2021 CE. Zamora-Reyes et al. ([2022](#)) also highlights a peak in hydrologic variability during this period driven by an abnormally high frequency of dry extremes. Historical and archeological records indicate that these megadroughts likely contributed to the collapse of multiple Native American settlements across the Western U.S. (Cook et al., [2022](#); Stahle et al., [2000](#))

This graph from [Park Williams' updated assessment in 2023](#) on X/Twitter shows how the droughts developed:

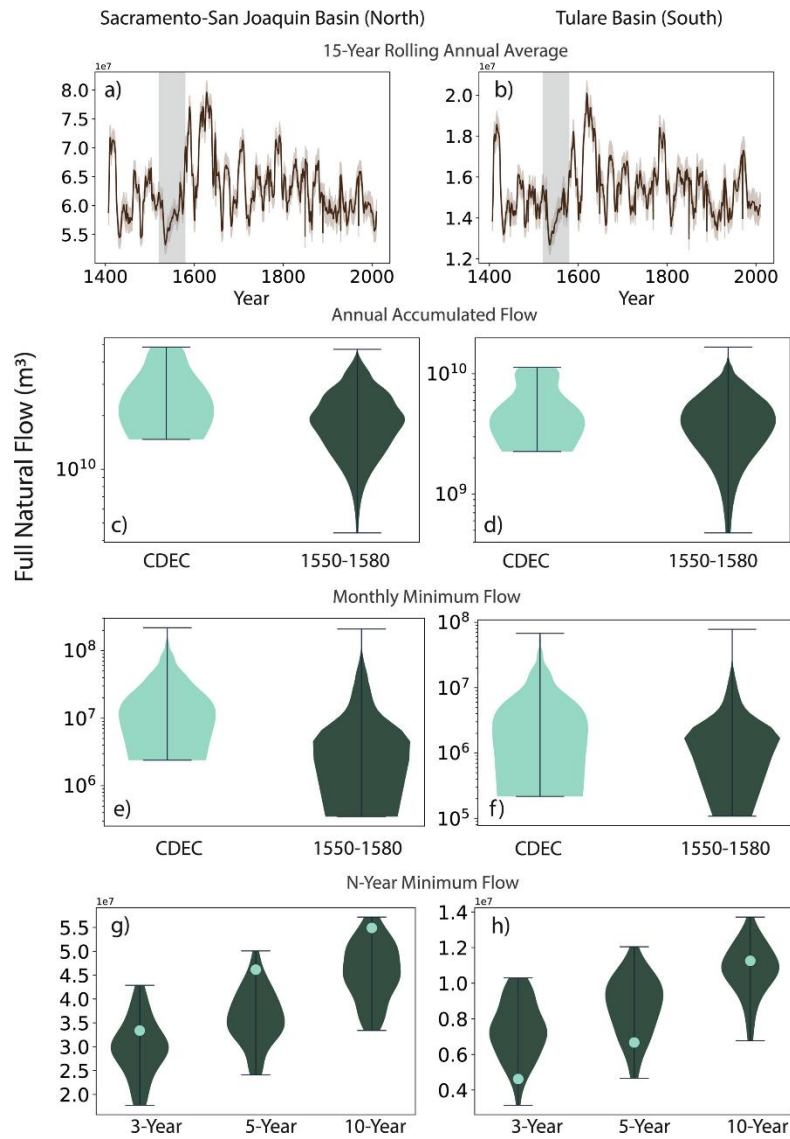


The pink shaded period in the late 1500s (above) is the most severe 21 years of what Gupta called the "Renaissance megadrought in California. It occurred during an extended dry period from about 1520 to 1580 -- 60 years. Gupta modeled the

most severe 30 year part of the drought, from 1550-1580. She called this period the "paleo drought" in her paper.

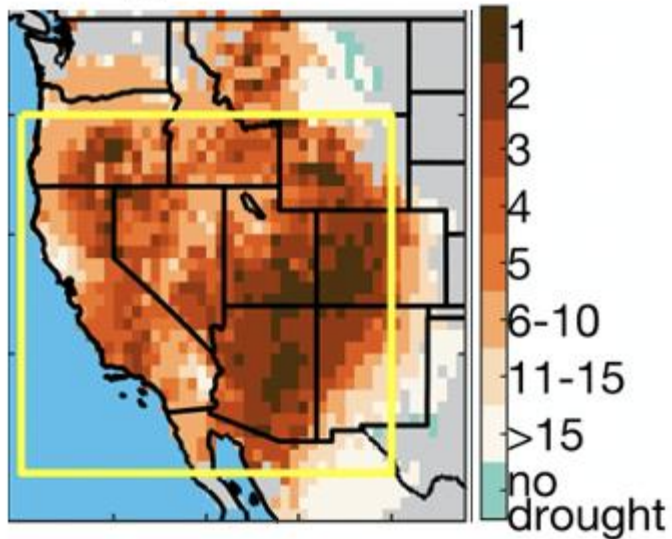
The violin plots below show the accumulated full natural flow from the CDEC observed dataset from 1997-2016, versus the 1550-1580 paleo drought. The accumulated paleo drought flows are **significantly** less than we saw during the first part of the megadrought from 2000-2016.

Panels (g) and (h) show the minimum 3-, 5-, and 10-year rolling average flow across the 30-year period. The aqua dots are the minimum rolling average flows for the CDEC data set. Notice that the 5 and 10 year minimum accumulated flows in the 1550-1580 paleo drought are a *LOT* worse in the Sacramento River basin, although the 3 and 5 year flows in the Tulare Basin are about as bad.

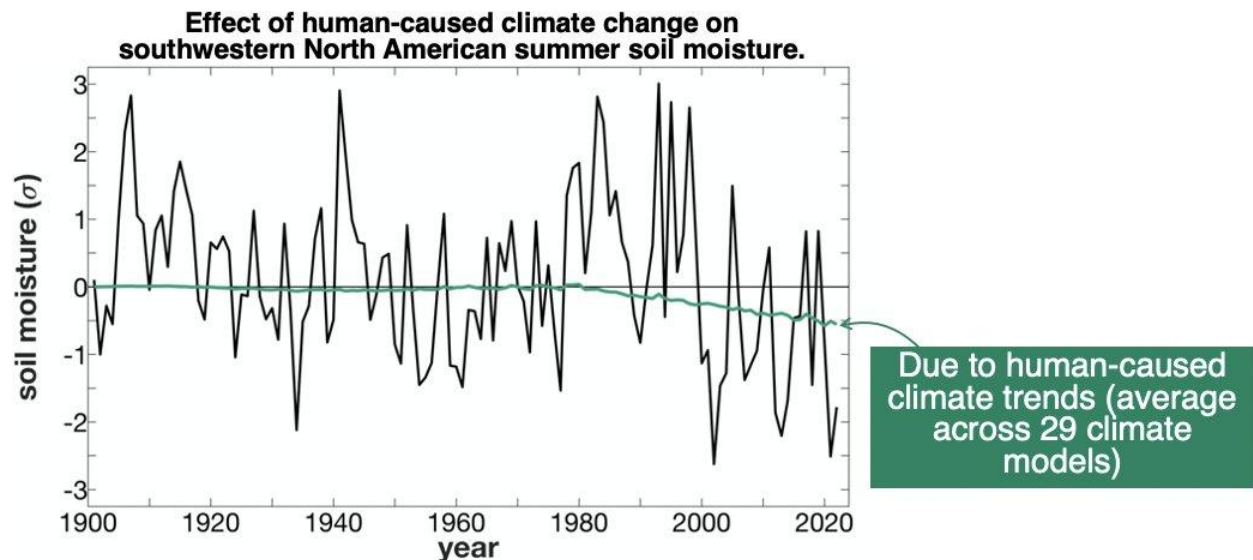


California was on the edge of the 2000-2022 megadrought in the Southwest, which was the worst in the 1200 year tree ring record. The paleo drought shows that California could see significantly drier conditions and significantly lower flows.

Local ranking of 23-yr drought severity in 2000-2022 compared to all other droughts since 800 AD



We expect that increased temperatures from climate change will cause more evapotranspiration and reduce runoff. This shows the effect of increased temperatures on the 2000-2022 soil moisture. From the study by Park Williams et al.



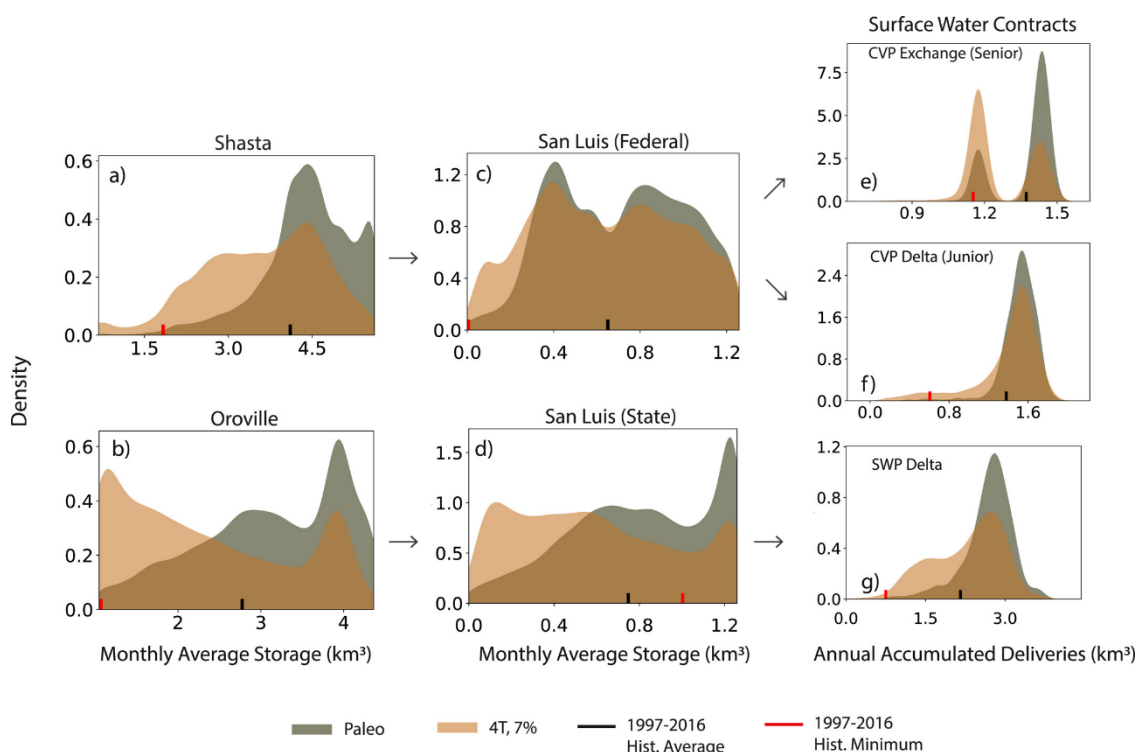
For their Risk-Informed scenario development, DWR used a temperature projection of about 3 C of land warming compared to the pre-industrial baseline of 1850-1900 to drive their stochastic weather generator (2 C from the 1992-2021 base period). Gupta used a projection of 4 C, which the IPCC WG1 AR6 report shows we could see by 2060 under the highest warming scenario.

Gupta looked at the SWP and CVP reservoir storage and deliveries in the paleo drought, shown in gray. And also the paleo drought with plausible hotter mid-century climate scenario, about 4 C of land temperature increase and

7% moisture holding (Clausius Clapeyron) scaling. We could well see this temperature increase with the Trump administration.

Below are Gupta's findings. In the megadrought plus increased temperatures due to climate change, Oroville and the state share of San Luis are drained to dead pool fairly often.

1 cubic kilometer is approximately 0.811 MAF. So the SWP annual accumulated deliveries in a repeat of the paleo megadrought are around 973 TAF. But in a repeat of the paleo megadrought with climate change, they go to significantly less than that.



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Deirdre Des Jardins

Climate change, pandemics, and societal change from a complex systems perspective

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"We aren't just failing to address the growing climate crisis to come; we're unprepared even for the impacts already here—in part because they keep surprising us with their intensity and in part because we can't seem to fathom our genuine vulnerability." – David Wallace Wells

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