California's Coupled Water and Energy Response to Climate Change

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Introduction

California's economy has relied heavily on groundwater recharge as a form of drought insurance. Groundwater recharge, which is sensitive to climate change, climate variability, and climatic extremes, is controlled by feedbacks between the atmosphere, land surface, and groundwater, and is impacted by conjunctive use and related electrical demands.

Our research group at Berkeley Lab, in collaboration with the California Department of Water Resources (CDWR), is investigating physical and economic sensitivities of California's water system and related energy resources to drought episodes.

The goal of this study is to quantify the impacts of drought on water storage and energy generation, and to illustrate the potential for conjunctive use of surface and subsurface storage to limit the adverse impacts of drought on water supply and hydropower generation.

Approach

We are working with the California Department of Water Resources (CDWR) using their Central Valley Groundwater-Surface Water Model (CVGSM). The CDWR is addressing global climate change in the current update of the California Water Plan, Update 2005 (Bulletin 160-05).

Rather than focus on causes of global climate change which are being addressed by other agencies and research institutions, the Water Plan looks at potential impacts of climate change on water resources in California and potential strategies for adapting to these changes.

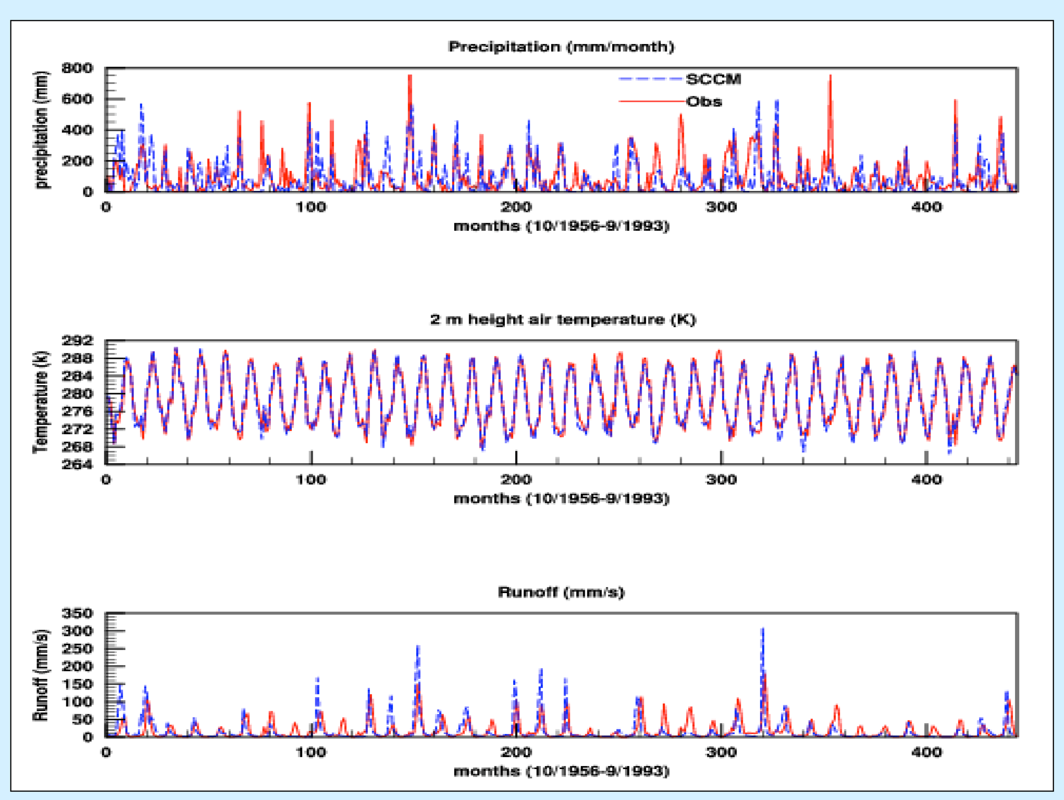
The study is divided into three parts:
(1) Simulate a series of droughts, including a 30 year climatic drought with changes in reservoir inflows.
(2) Project drought impacts on reservoir and aquifer storage, water supplies and electricity generation, with current reservoir management and groundwater practice.
(3) Evaluate a range of reservoir operating and groundwater pumping scenarios to illustrate potential cost savings.

Drought Study

The drought study consists of two parts;
(1) A local climate model simulation evaluated observations (Fig. 1), and 104 year simulation with a 30 year drought occurring after 30 years, followed a 54 year recovery.
(2) A set of prescribed precipitation perturbations representing scenarios with uniform reductions of 30% to 70%.

Both sets of data are used as input forcing to the CVGSM2 (Kadir et al. 2005) groundwater-surface water model, and its output is used to force the electricity groundwater model.

Of importance is quantification of how the water table responds after such depletion, and if there is a new equilibrium state.



Verification of SCCM simulation with observations

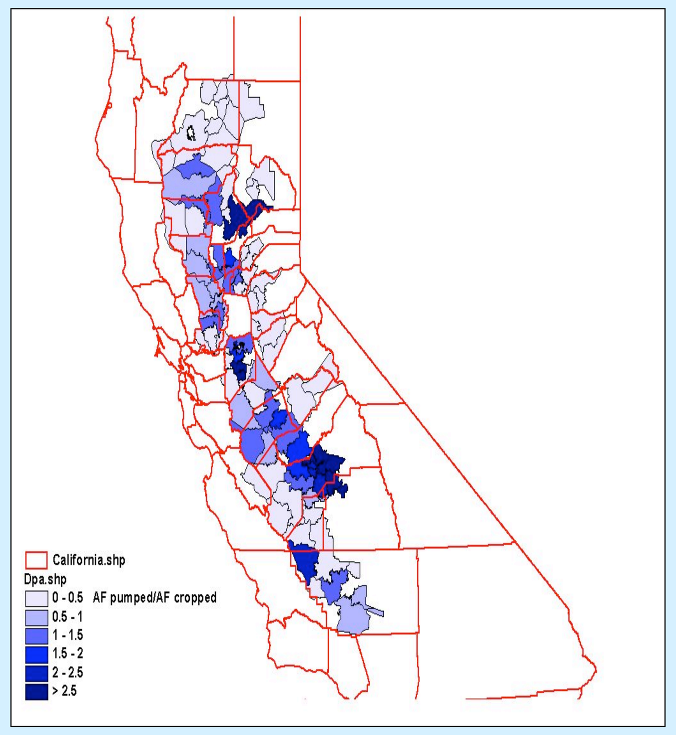
Research Questions

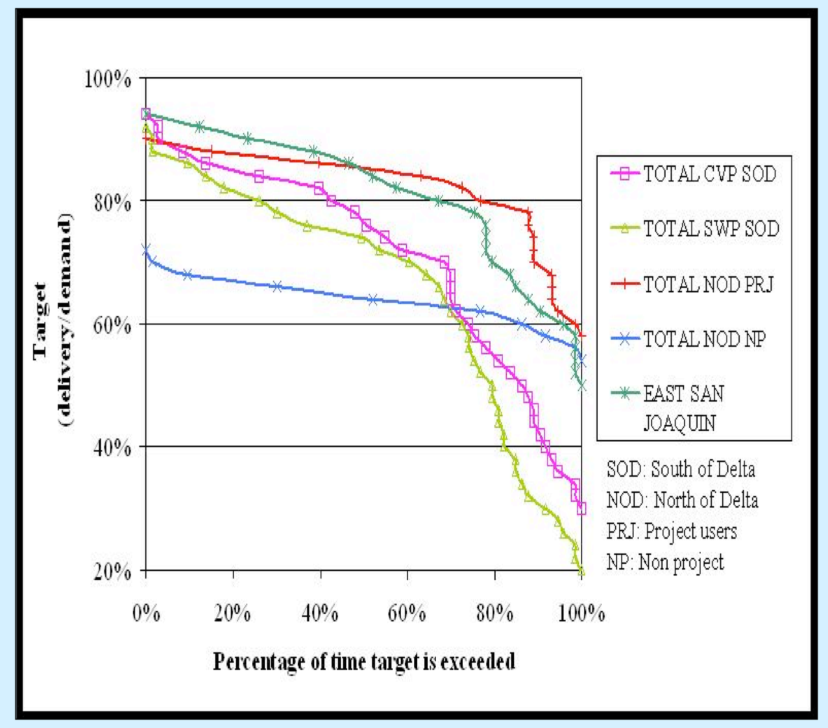
What are the climate drivers, their variabilities and sensitivities, impacting mountain-front recharge, snowmelt runoff, and net infiltration in the Sierra Nevada and Central Valley?

What is the sensitivity of the water table to such climate inputs and to pumping withdrawals? Will the California water-energy system reach a new equilibrium state under long term droughts or decreased snowmelt runoff?

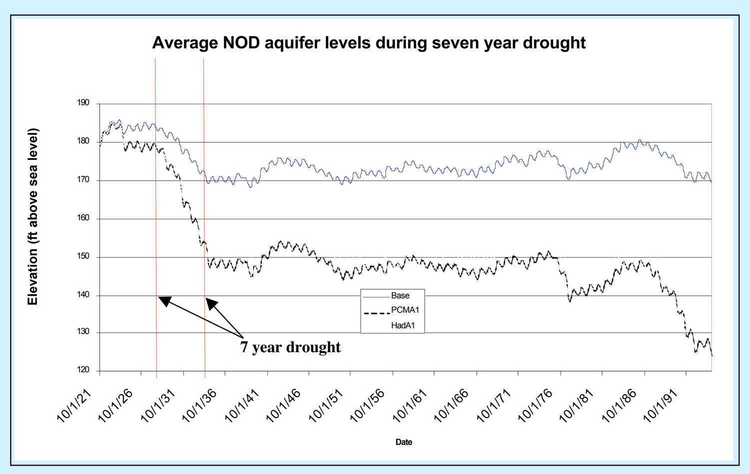
How can electricity-use data provide improved characterizations for Central valley groundwater pumping? What level of detail in a quantitative model is needed to develop energy costs and other constraints to forecast limits to groundwater availability?

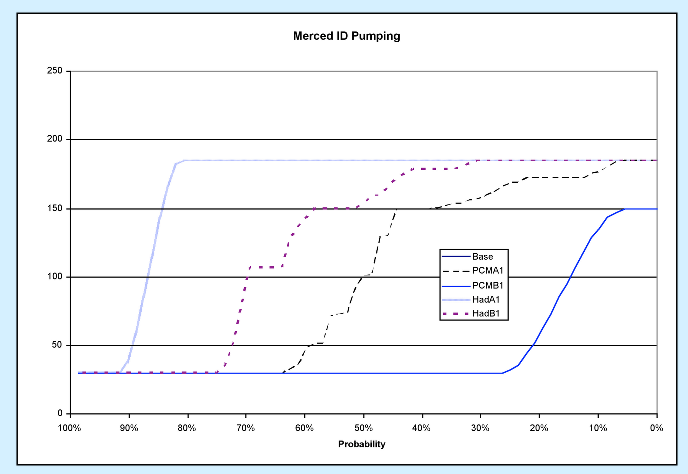
Data Characterizations





Pumping Response to AOGCM-forced Hydrology

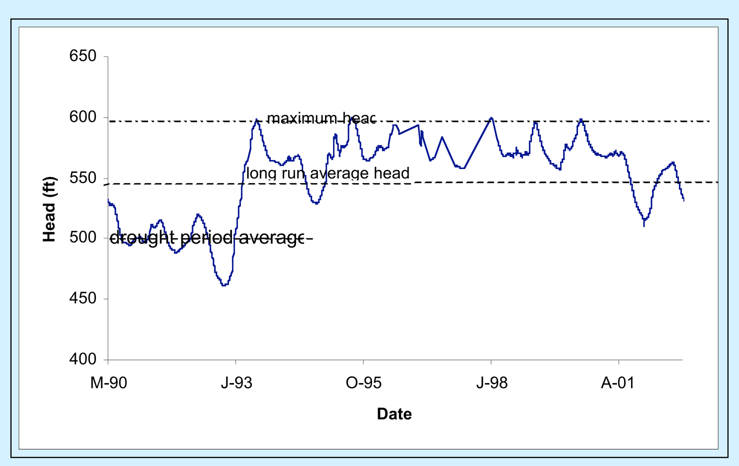


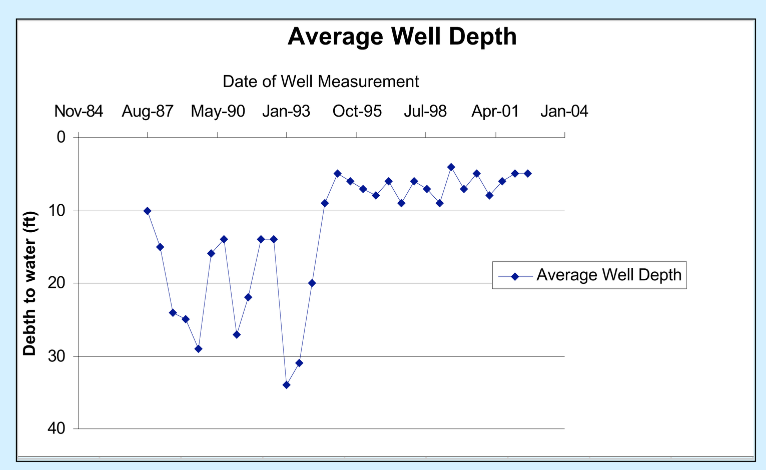


Drought shortages cause increased agricultural pumping and a drop in the groundwater table.

Modeled projections indicate recovery of groundwater after minor droughts, dramatic declines of groundwater table, after severe drought.

Reservoir and Aquifers Response to the 1987-1992 Drought





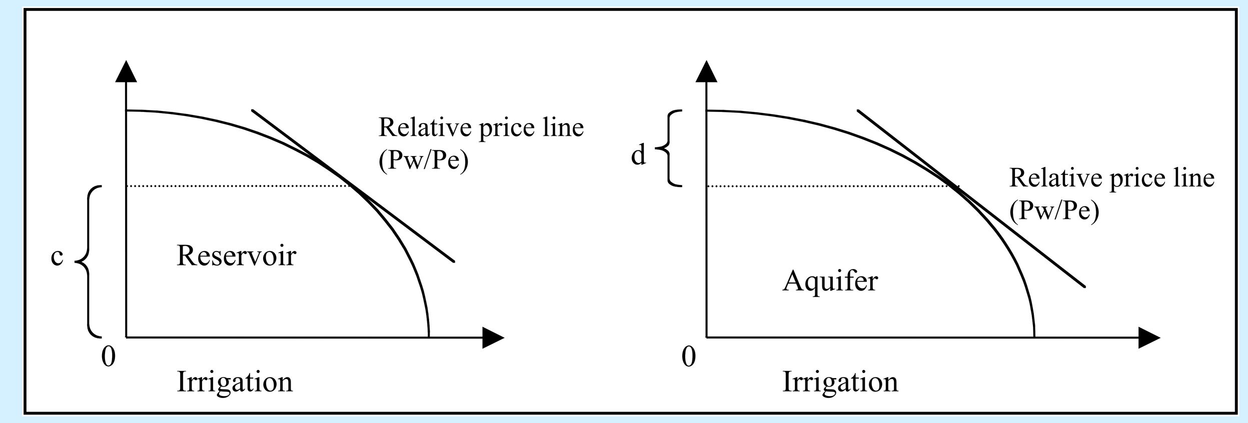
Merced basin reservoir storage recovers after the 87-92 drought. Decline in reservoirs and aquifers imply a drop in net hydropower generation, and a rise in groundwater pumping electricity use.

Groundwater Supply and Reliability Impacts

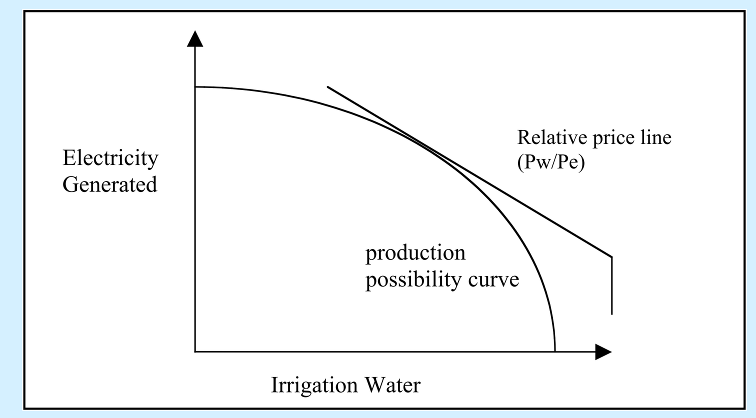
The statistical groundwater-pumping model estimates groundwater supply given information about physical parameters affecting groundwater and constraints on pumping (i.e. surface flows, groundwater depth, electricity use, weather and crop type). We calibrated the model, using agricultural electricity use data provided by the California Energy Commission (CEC) and PG&E. The value of water supply reliability model is a statistical model to estimate the value of water supply reliability as a function of agricultural land values, historical water supplies and other physical variables (e.g., climate, soil quality) that affect agricultural production.

1. Use simulation to represent system dynamics, e.g., linearized river-aquifer response functions.
2. Use optimization to obtain opt. management rules, e.g., stochastic dynamic programming.
3. Sequential Simulation + Optimization, e.g. optimal management rules (from 2) in a simulation model (from 1) to estimate impacts under different hydrologic scenarios

Development of Electric Pricing-pumping Models



- "physical" tradeoff between water and electricity (in the reservoir and aquifer) with
- "value" tradeoff between water and electricity (to the reservoir and aquifer users).



Basin reservoir water and electricity supply trade-off

Conclusions

Drought and climate change threaten the reliability of California's water and energy systems.

Global warming and long term drought is likely to deplete aquifers, increase electricity demand (cooling and pumping) and decrease hydropower generation.

This study is intended to illustrate the impacts of climatic events on water storage and electricity demands, and suggest water management techniques to counter some of these adverse impacts.

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