

# Integrating Climate Impacts Into Groundwater-Surface Water Models: A Pilot Study Using Existing Data and Open Source Models

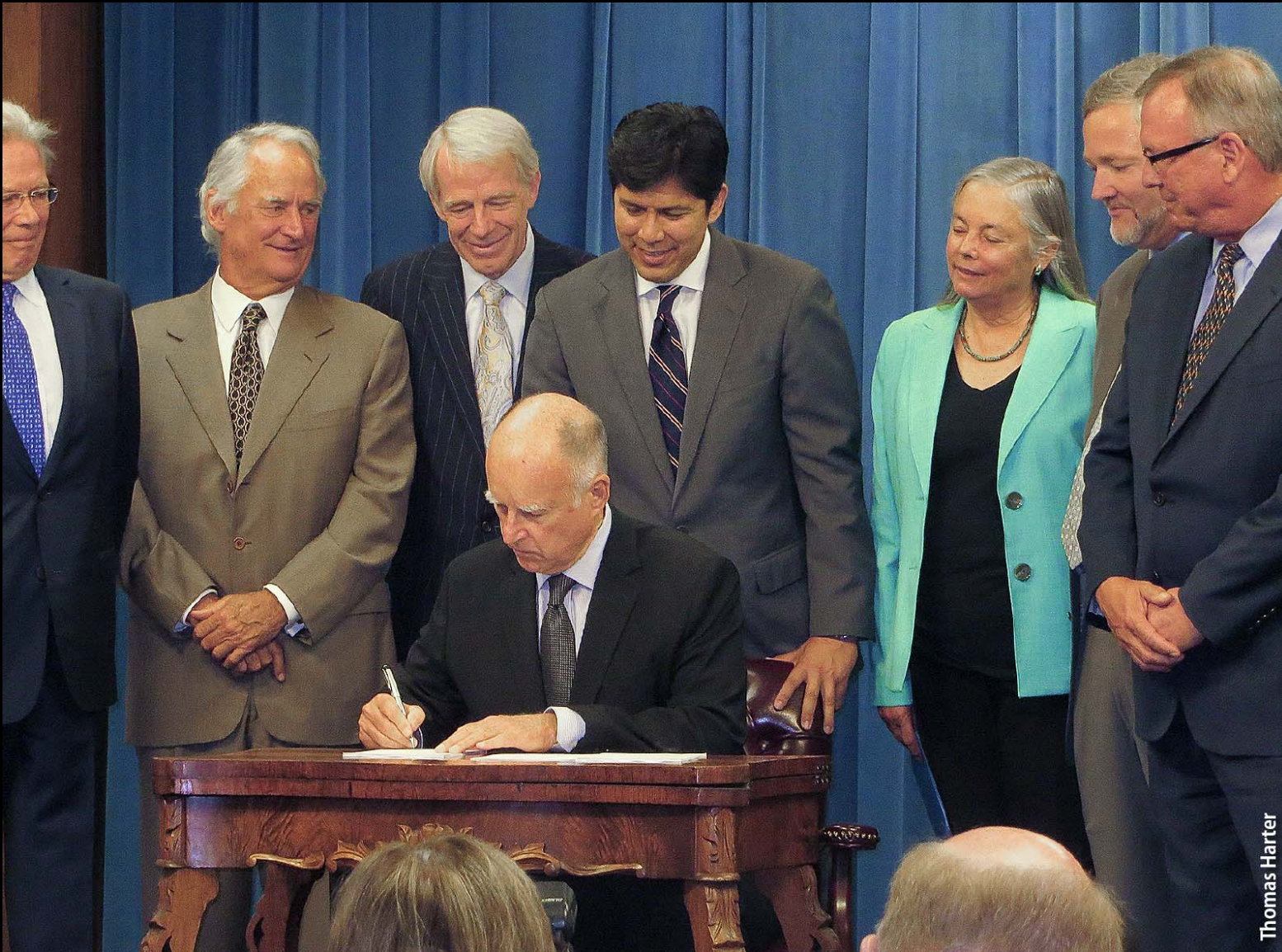
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Senior Climate Scientist  
Union of Concerned Scientists

# The Big Water Supply Shift





# The Sustainable Groundwater Management Act



Thomas Harter

# Undesirable results

- Chronic lowering of groundwater levels
- Reduction in groundwater storage
- Seawater intrusion
- Water quality degradation
- Land subsidence
- Depletions of interconnected surface waters



# Measuring What Matters

*Setting Measurable Objectives to Achieve Sustainable Groundwater Management in California*



[ Union of  
Concerned Scientists

[ucsusa.org/measuringwhatmatters](https://ucsusa.org/measuringwhatmatters)

# Effective measurable objectives

- Define clear baselines;
- Set quantitative thresholds;
- Develop protective triggers that require action before reaching a threshold;
- Incorporate regular measurement and monitoring;
- Account for uncertainty; and
- Adapt to changing conditions and new information.

# Groundwater Sustainability Plan Regulations

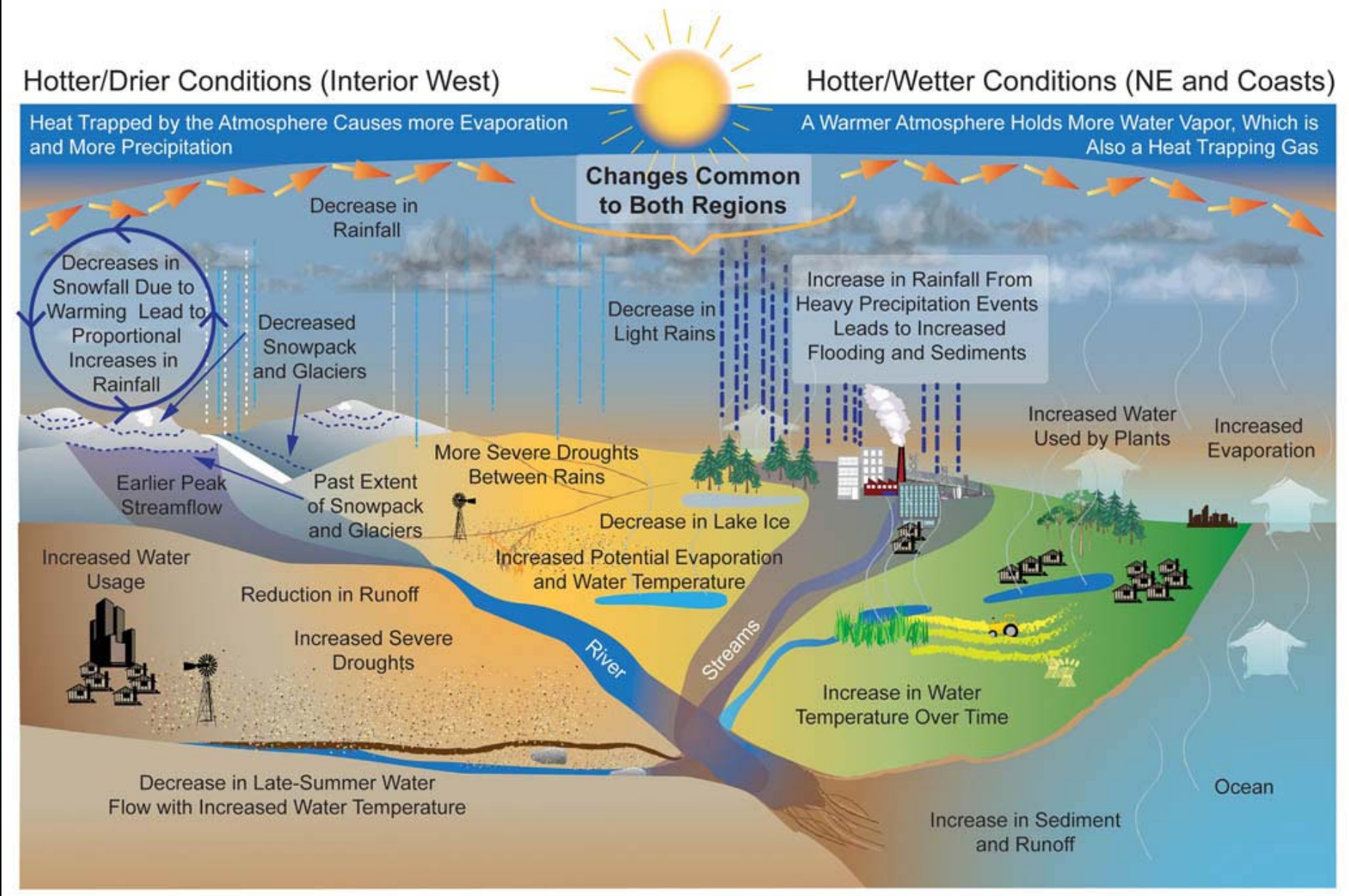
- Section 354.18 Water Budget

“Projected hydrology shall utilize 50 years of historical precipitation, evapotranspiration, and streamflow information as the baseline condition for estimating future hydrology. **The projected hydrology information shall also be applied as the baseline condition used to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change and sea level rise.**”

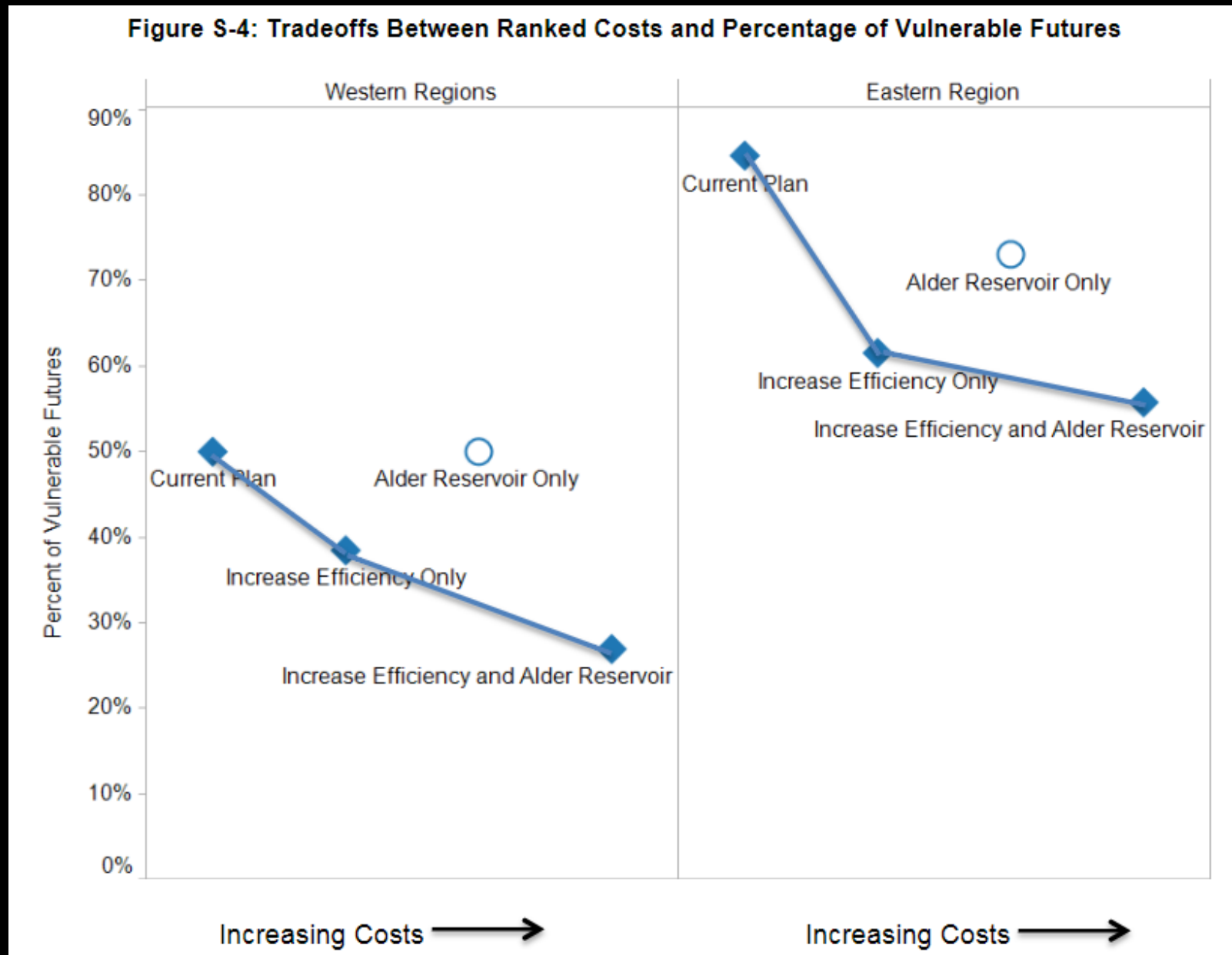
**How do we “evaluate future scenarios of hydrologic uncertainty?”**



# Mostly Qualitative Analysis...



# ...Versus Quantitative Analyses



*What can be accomplished  
using existing data, open  
source models, and a small  
budget?*



# What kind of data and open source models exist?

- **Open source**: publicly release the calculations and computer codes that drive model results. **Do not require user licenses and, typically, can be downloaded by anyone with internet access**
- *The Devil is in the Data: The Role of Science, Data, and Models in California's Historic Sustainable Groundwater Management Act (CJPP 2016)*



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Article

## The Basin Characterization Model Downscaled Climate and Hydrology Datasets



A sample comparison of historical and modeled future data.  
Top: April snowpack. Bottom: Max temperature.

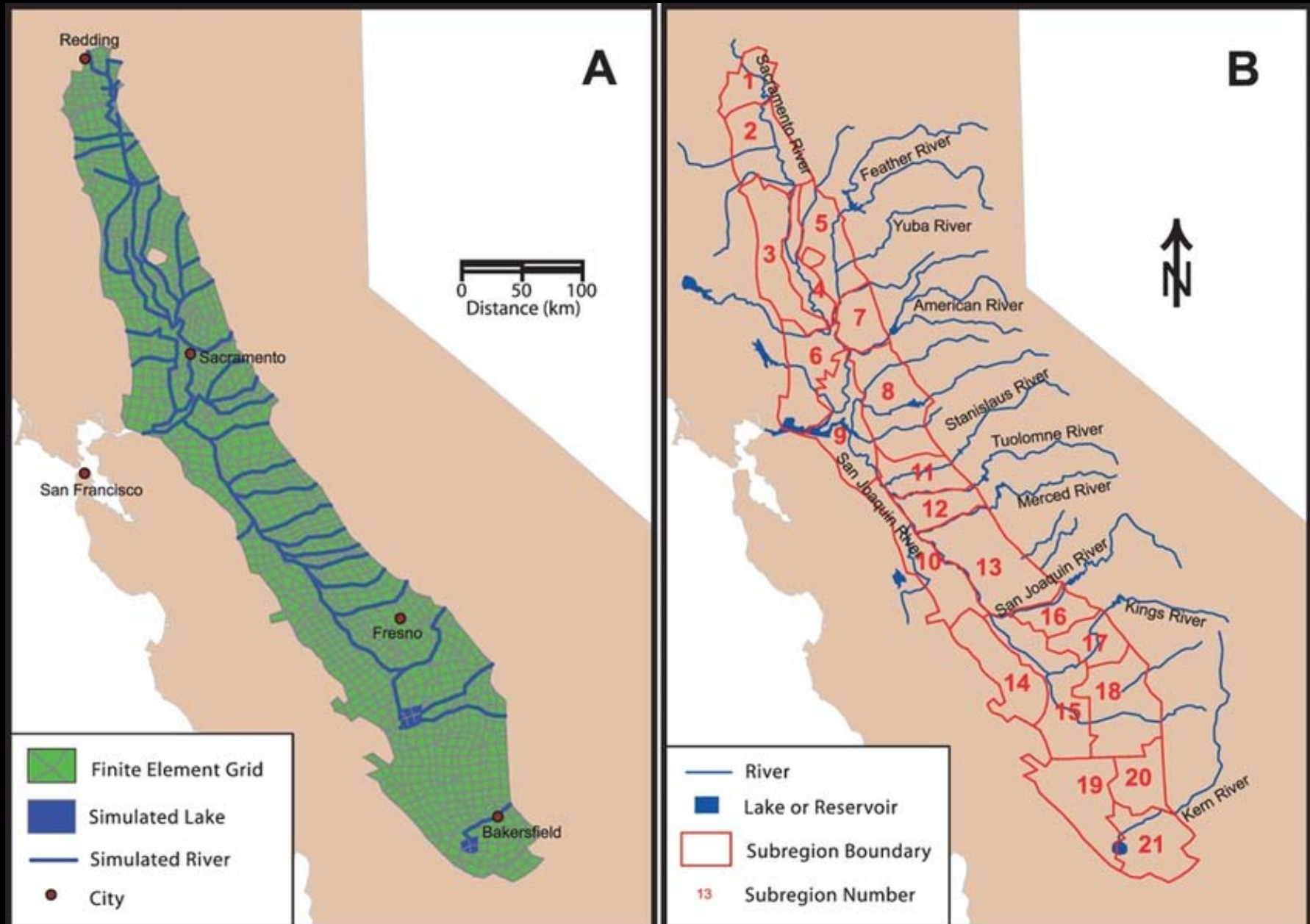
### About the Datasets

The Basin Characterization Model (BCM) datasets provide historical and projected climate and hydrology data at a 270 meter resolution. These data have formed the basis for multiple research projects and vulnerability assessments applying climate change projections to conservation decision-making, providing a common base-layer and set of assumptions across these projects.

### Table of Contents

- [Intro to the BCM](#), a quick overview of the model,
- [California Basin Characterization Model: A Dataset of Historical and Future Hydrologic Response to Climate Change: U.S. Geological Survey Data Release](#), A more detailed description of the model and dataset from its creators,
- [Recorded webinar](#), background information and uses of the data, and demo of how to access the data on the Commons,
- [How to Get the Data](#),
- [Quick Comparison of BCM Dataset versions](#),
- [What's new in the 2014 dataset](#),
- [Appropriate uses of the datasets and limitations](#),
- [Examples of projects that used the BCM datasets](#),
- [More Resources](#).

# C2VSIM





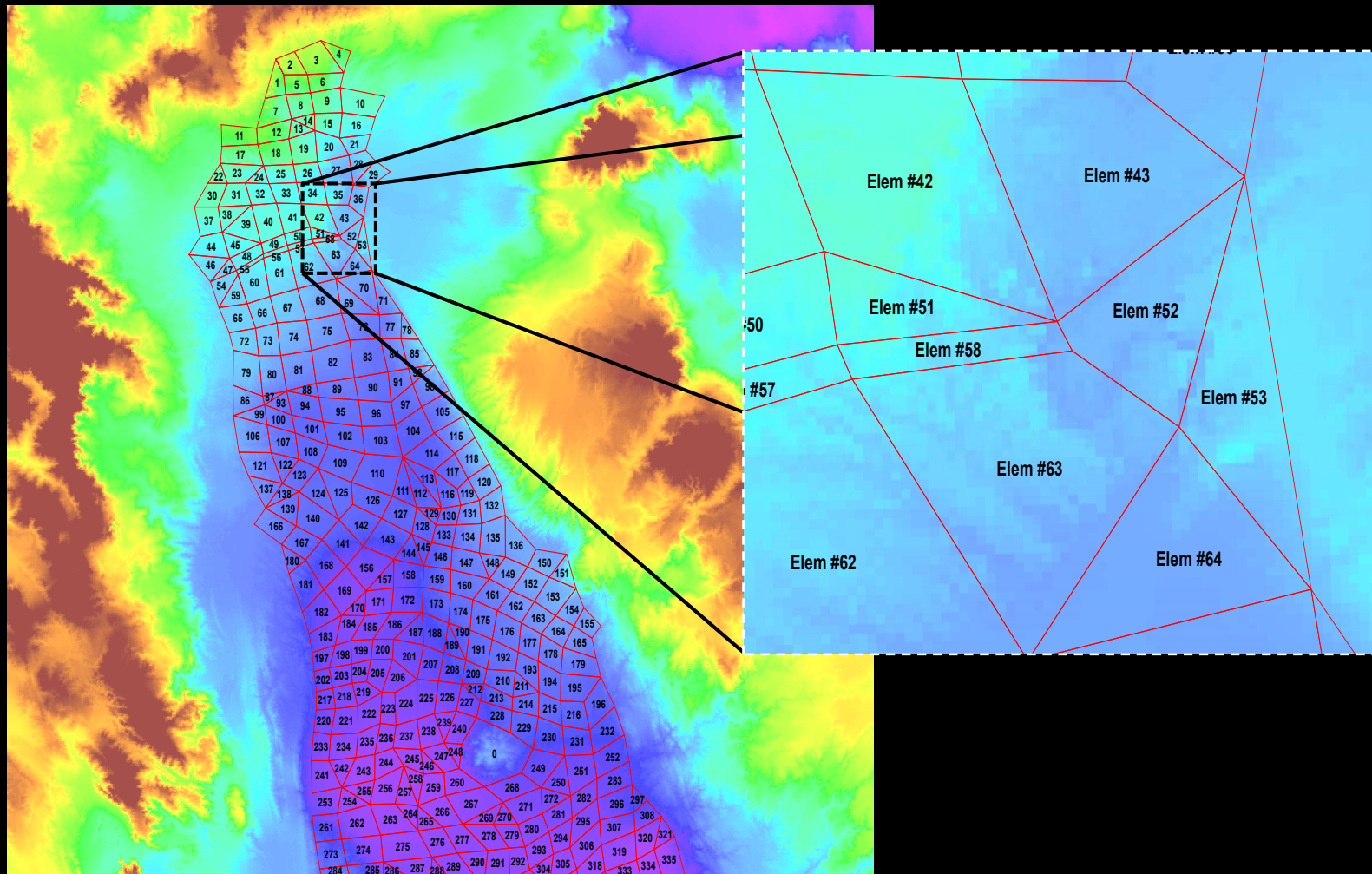
# Pilot study focused on precipitation

- We applied bias corrected, downscaled **precipitation datasets** derived from global climate models (GCMs) for the BCM to the integrated groundwater-surface water model, C2VSIM
- We only looked at **the wettest and driest scenarios to capture the range of possible futures**
- Compared to a historic hydrology baseline

# Pilot study's limitations

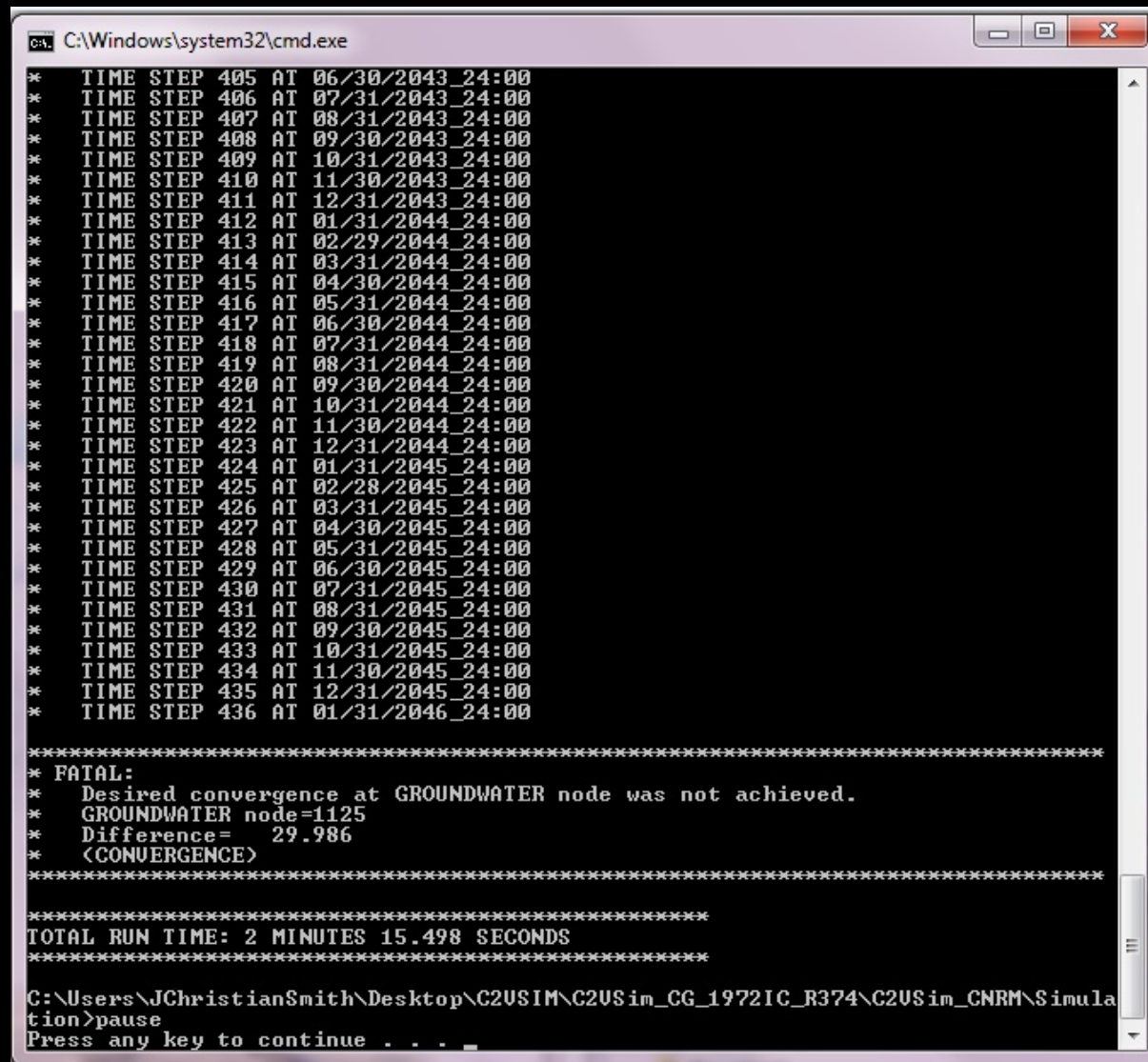
- Only analyzed sensitivity to precipitation, not reservoir outflows or evapotranspiration estimates
- Limited by the refinement of the C2VSIM grid
- As such, the pilot study represents a coarse-scale precipitation sensitivity analysis (the first step of a robust decision making analysis)

# Aggregation of PRISM precipitation data for C2VSim elements





# The actual process no one talks about...“FATAL ERROR”



```
C:\Windows\system32\cmd.exe
* TIME STEP 405 AT 06/30/2043_24:00
* TIME STEP 406 AT 07/31/2043_24:00
* TIME STEP 407 AT 08/31/2043_24:00
* TIME STEP 408 AT 09/30/2043_24:00
* TIME STEP 409 AT 10/31/2043_24:00
* TIME STEP 410 AT 11/30/2043_24:00
* TIME STEP 411 AT 12/31/2043_24:00
* TIME STEP 412 AT 01/31/2044_24:00
* TIME STEP 413 AT 02/29/2044_24:00
* TIME STEP 414 AT 03/31/2044_24:00
* TIME STEP 415 AT 04/30/2044_24:00
* TIME STEP 416 AT 05/31/2044_24:00
* TIME STEP 417 AT 06/30/2044_24:00
* TIME STEP 418 AT 07/31/2044_24:00
* TIME STEP 419 AT 08/31/2044_24:00
* TIME STEP 420 AT 09/30/2044_24:00
* TIME STEP 421 AT 10/31/2044_24:00
* TIME STEP 422 AT 11/30/2044_24:00
* TIME STEP 423 AT 12/31/2044_24:00
* TIME STEP 424 AT 01/31/2045_24:00
* TIME STEP 425 AT 02/28/2045_24:00
* TIME STEP 426 AT 03/31/2045_24:00
* TIME STEP 427 AT 04/30/2045_24:00
* TIME STEP 428 AT 05/31/2045_24:00
* TIME STEP 429 AT 06/30/2045_24:00
* TIME STEP 430 AT 07/31/2045_24:00
* TIME STEP 431 AT 08/31/2045_24:00
* TIME STEP 432 AT 09/30/2045_24:00
* TIME STEP 433 AT 10/31/2045_24:00
* TIME STEP 434 AT 11/30/2045_24:00
* TIME STEP 435 AT 12/31/2045_24:00
* TIME STEP 436 AT 01/31/2046_24:00

*****
* FATAL:
*   Desired convergence at GROUNDWATER node was not achieved.
*   GROUNDWATER node=1125
*   Difference= 29.986
*   <CONVERGENCE>
*****

*****
TOTAL RUN TIME: 2 MINUTES 15.498 SECONDS
*****

C:\Users\JChristianSmith\Desktop\C2USIM\C2USim_CG_1972IC_R374\C2USim_CNRM\Simula
tion>pause
Press any key to continue . . .
```

# Some key questions

- How sensitive are these variables to precipitation?
  - groundwater storage
  - land subsidence
  - gain from streams
- Does precipitation matter?
- Which climate scenario is more likely?

# Results

Scenario	Ending Storage (AF)	Gain from Streams (AF)	Cumulative Subsidence (AF)
<b>BASE CASE</b>	1,952,800,592	89,588	181,600,295
<b>CNRM (wettest)</b>	2,203,322,252	154,670	150,721,906
<b>MIROC (driest)</b>	1,772,125,777	42,051	198,211,693



# Some key conclusions

- How sensitive are these variables to precipitation?
  - groundwater storage (+/- 10%)
  - land subsidence (+/- 20%)
  - gain from streams (+/- > 50%)
- Do changes in precipitation matter? **Yes, and it matters more for certain URs**
- Which climate scenario is more likely? **Climate scenarios are not probabilities, they are all equally likely to occur**

# Robust decision-making (RDM)

- RDM helps water managers iteratively evaluate **robust** strategies – those that **perform well in terms of management objectives over a wide-range of plausible futures** but may perform less well under an assumption that one future may be most likely to occur.
- Also called “stress testing” by DWR’s climate change TAG

*Why* do we “evaluate future scenarios of hydrologic uncertainty?”

# Philosophical answer...

- Sustainability will be achieved in the future (sustainable yield to be achieved 2040)
- Unless you plan for future changes, sustainability may allude you
- Since the passage of SGMA, there are clear consequences for not achieving sustainability



# Practical answer...

- Stop chronic lowering of groundwater levels  
at particular elevations
  - Develop management actions to keep groundwater above those elevations
  - Analyze under which conditions those management actions will fail to maintain elevations above the threshold
  - Reconsider management actions to avoid crossing thresholds

# For more information

[www.ucsusa.org/measuringwhatmatters](http://www.ucsusa.org/measuringwhatmatters)

[www.ucsusa.org/sustainablegroundwater](http://www.ucsusa.org/sustainablegroundwater)

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