Linking the Central Valley Groundwater-Surface Water Simulation Model (C2VSim) to the Central Valley Production Model

IWFM User's Group
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Acknowledgements

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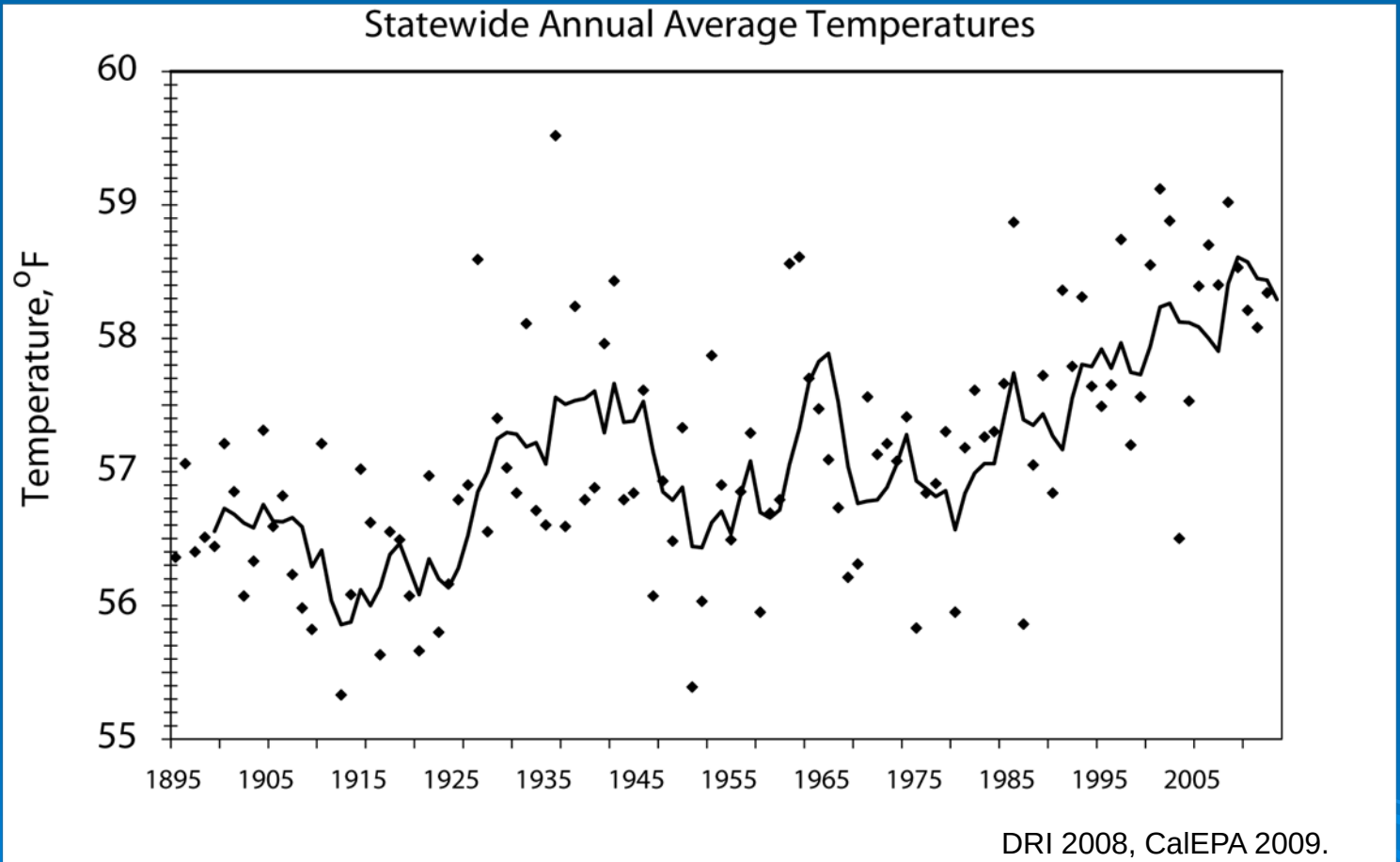
Sebastian Vicuna, UCB/CIBC

Can we simulate the impacts of reduced surface water on the groundwater flow system?

- Climatic changes may lead to surface water reductions
- IWFM:
  - Dynamically calculates groundwater pumping need
  - Incorporate economics by emulating Central Valley Production Model results with logit functions
- 12 drought scenarios
  - Constant crop acreages
  - Dynamic adjustment of crop acreages
- Collaborators:
  - Norm Miller & Larry Dale, UCB/LBNL, Sebastian Vicuna, CICG

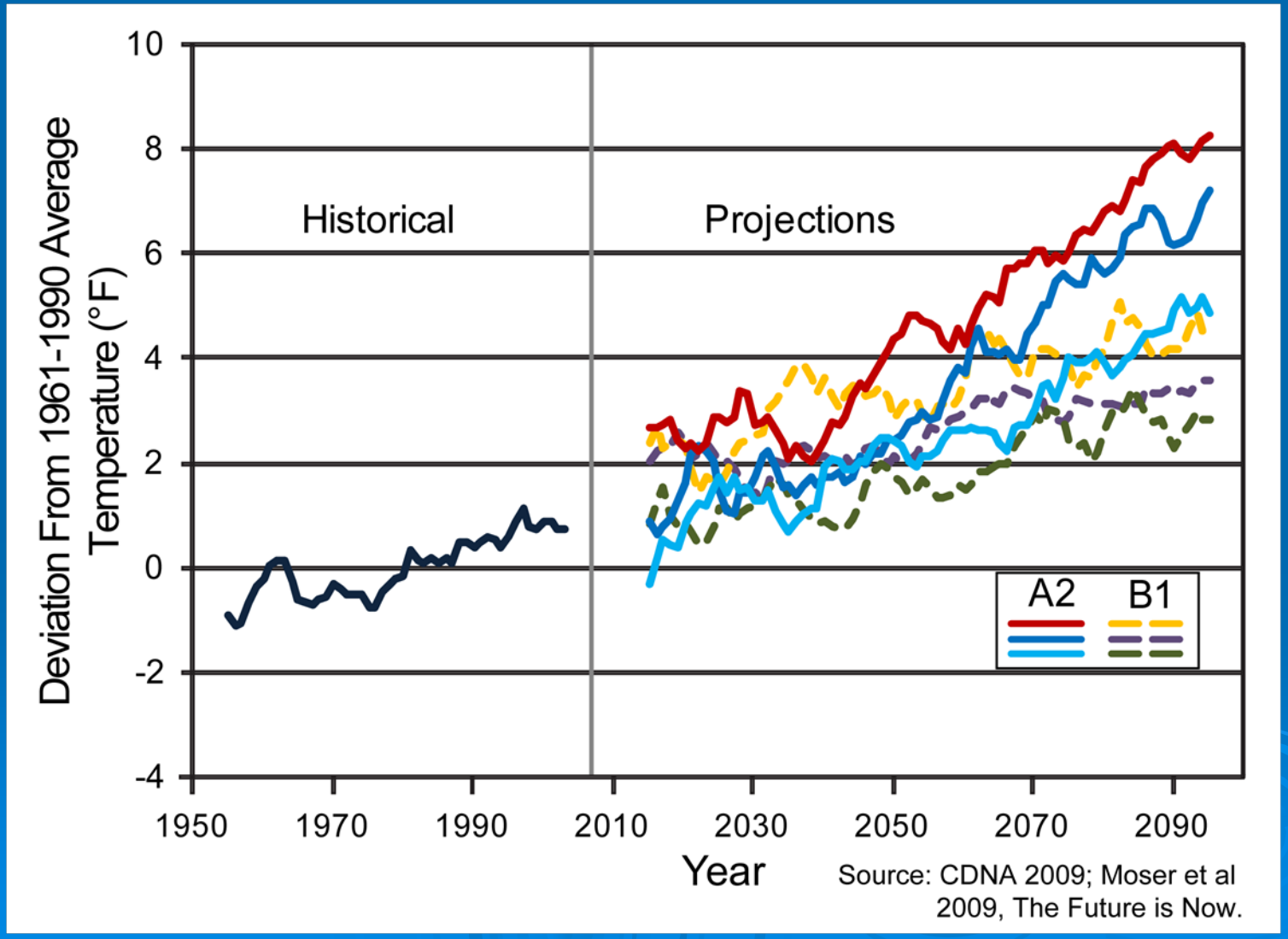
Climate Change



DRI 2008, CalEPA 2009.

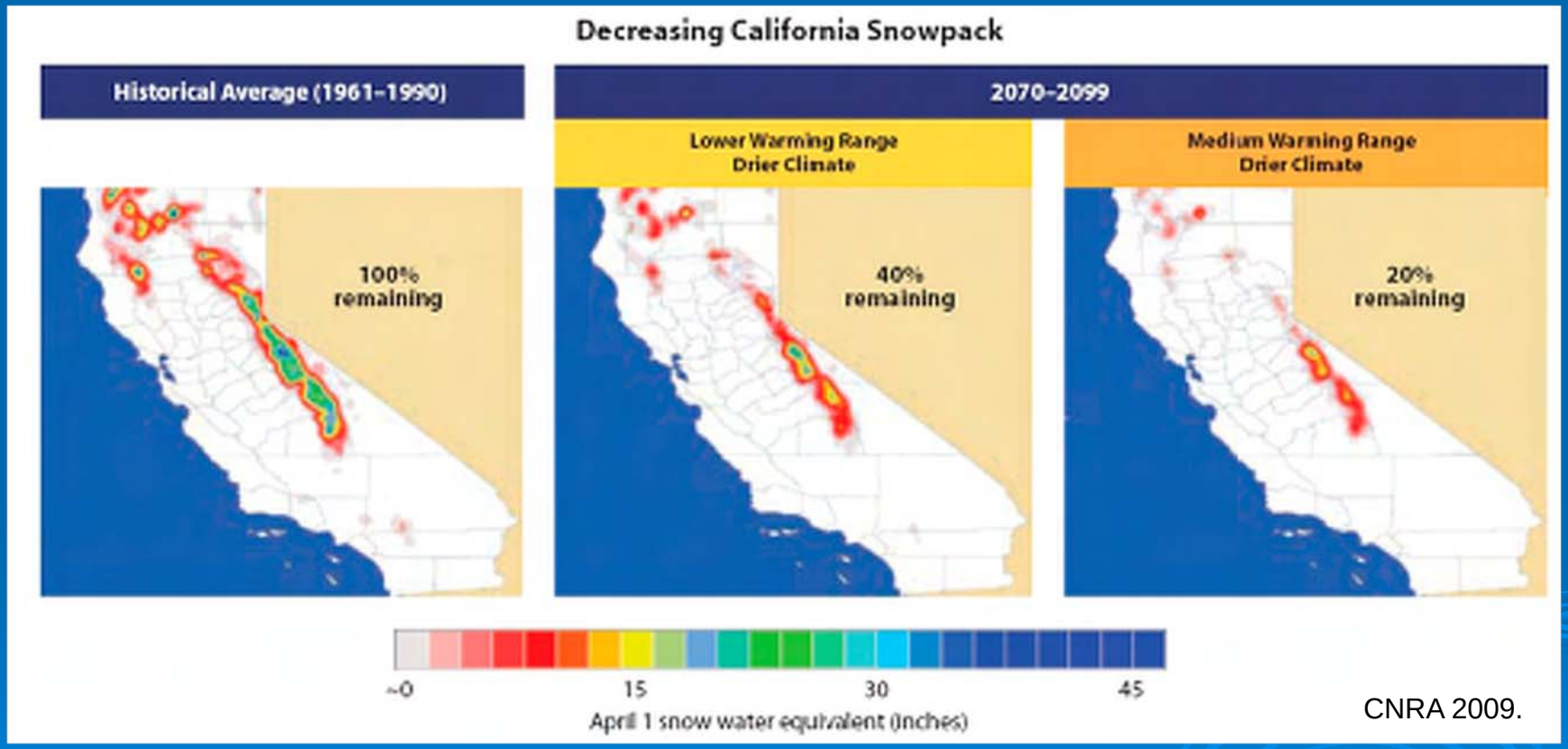
California annual average temperatures. Bold line is the 5-year running average.

Climate Change



Climate Change

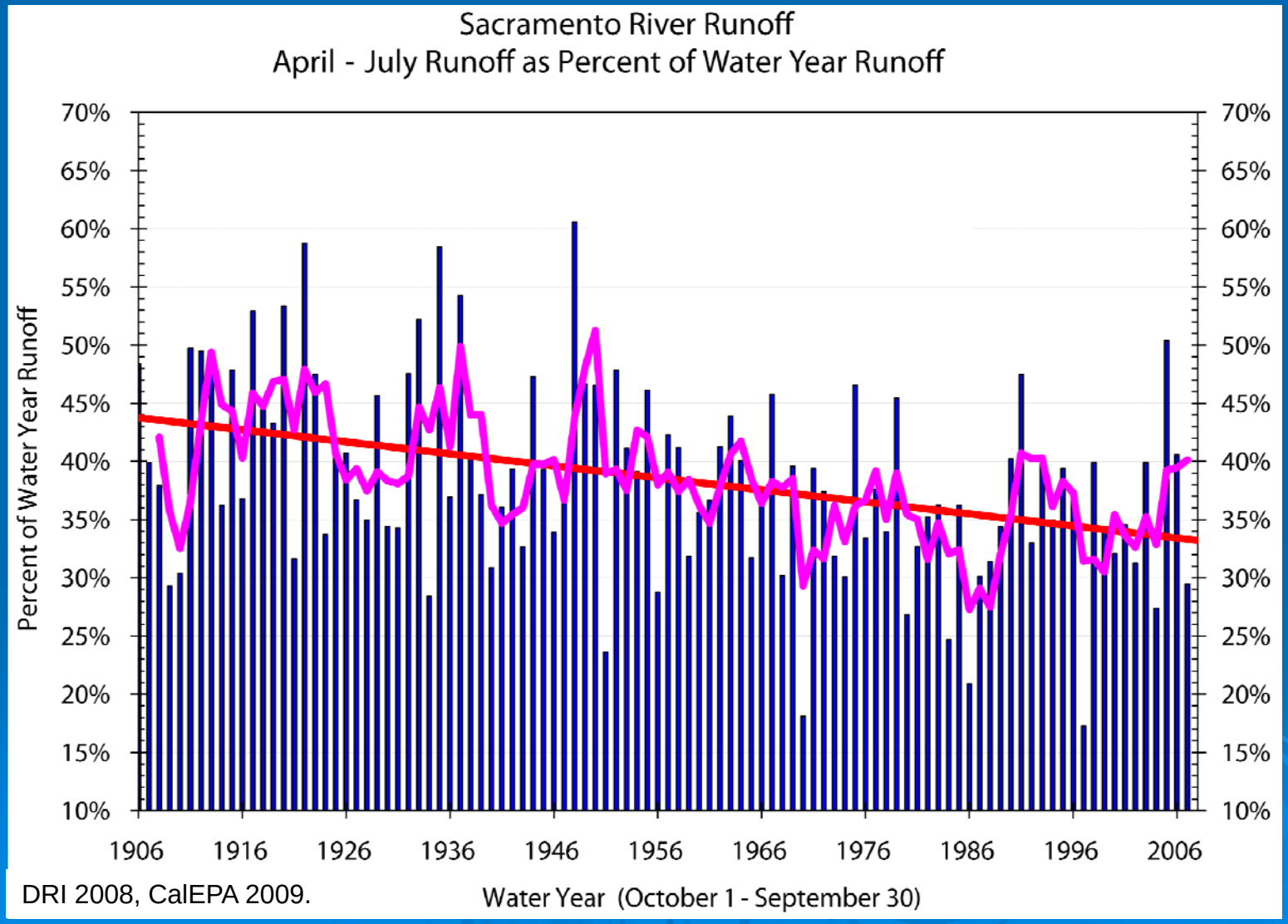
10% snowpack reduction at higher elevations in the Sierra Nevada



CNRA 2009.

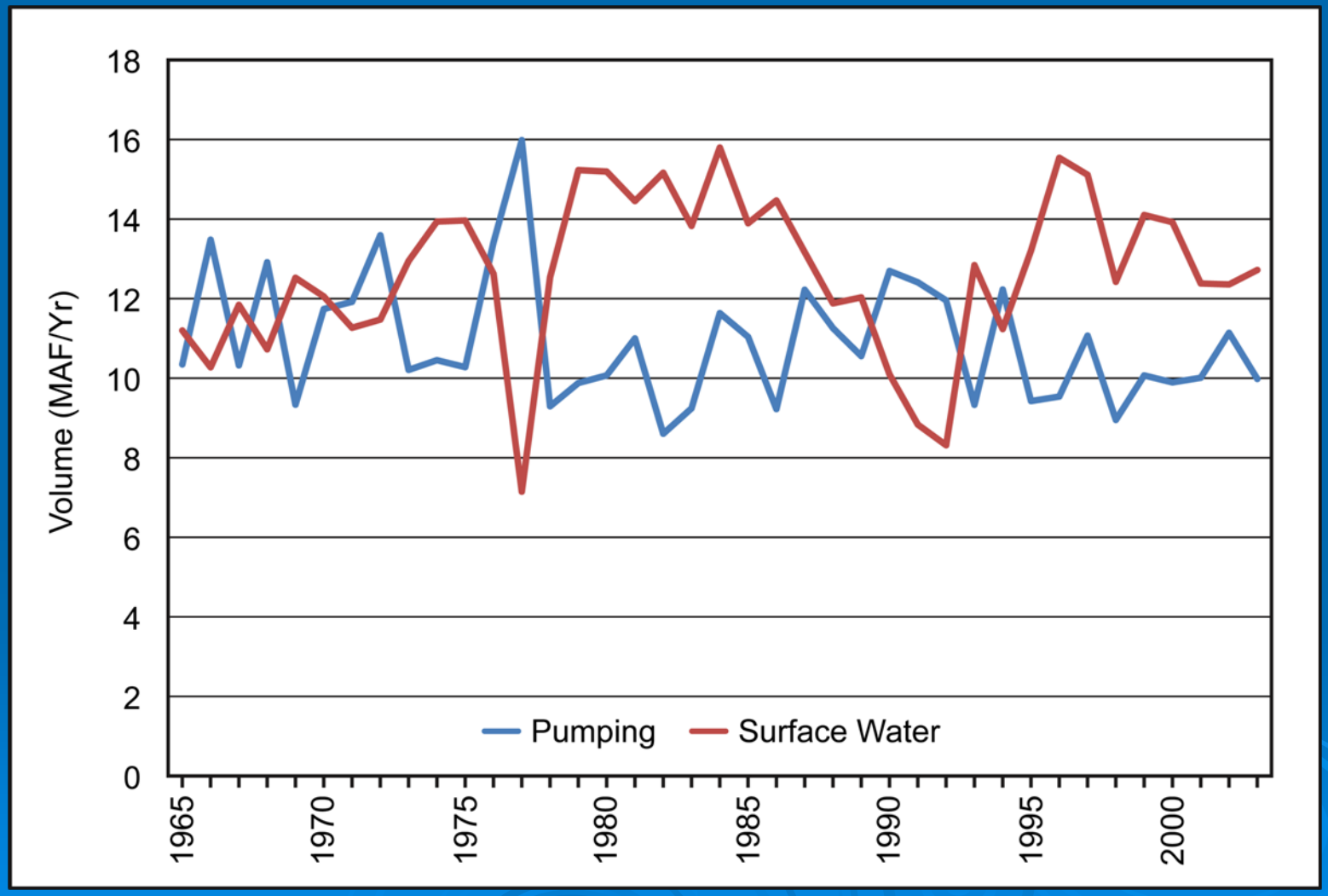
Continued warming could reduce snowpack volume by 25% by 2050

Climate Change

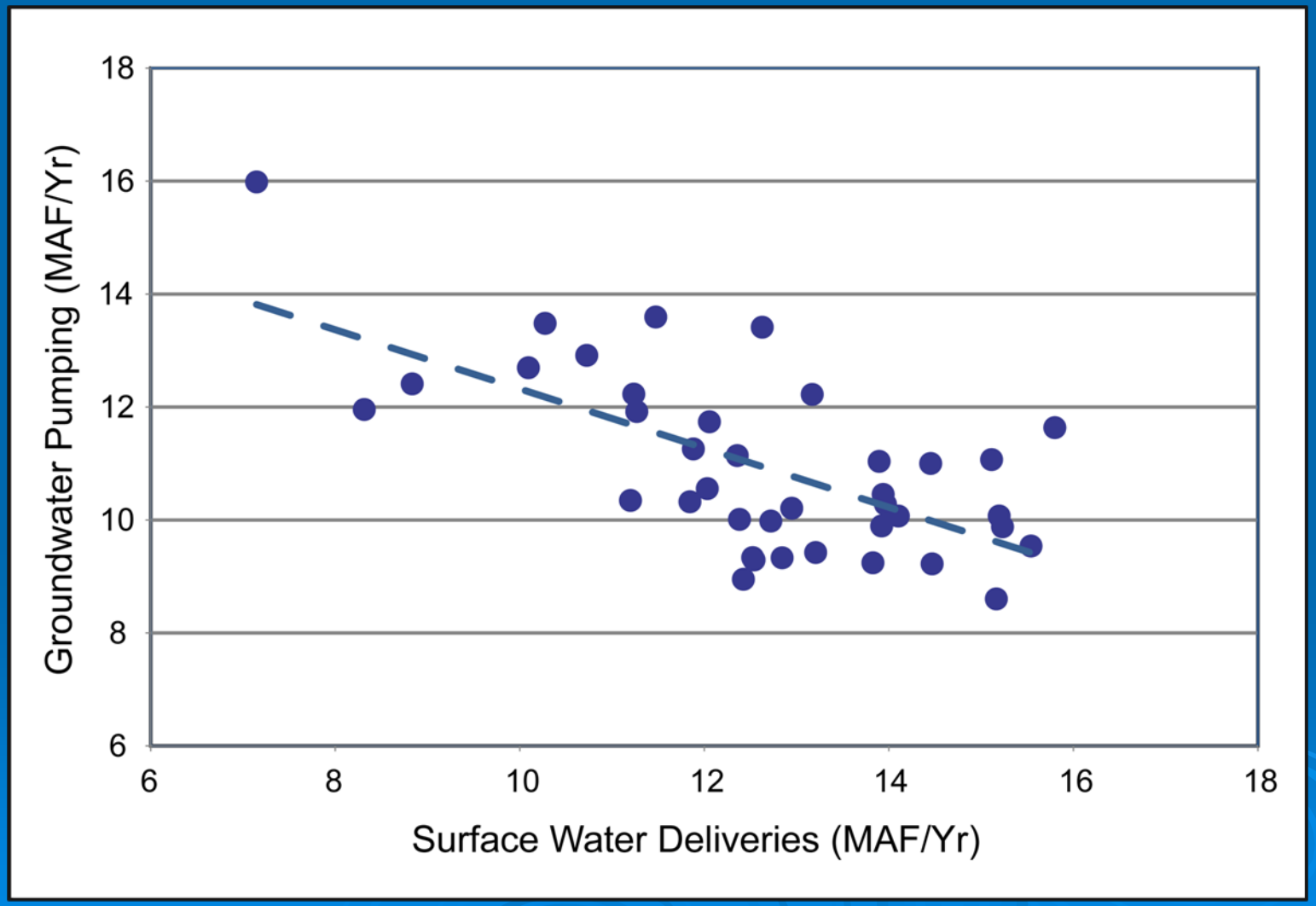


DRI 2008, CalEPA 2009.

Groundwater and Surface Water Use



de facto Conjunctive Use



Planning Issues

- Potential impacts of climate change on Central Valley water resources
- Potential strategies for adapting to these changes
- Problems with ‘stationarity’ – changes in:
  - agricultural and urban demand
  - surface water availability
  - environmental flow requirements
  - physical infrastructure
- Groundwater pumping impacts:
  - Increased pumping costs
  - Subsidence
  - Water quality
  - Affects on river flows

Research Questions

- Sensitivity of groundwater levels to climate-dependent inputs and groundwater pumping
- Will the surface water-groundwater system reach a new equilibrium after extended surface water reductions
- To what extent will changes in cropping patterns reduce impacts on groundwater levels

C2VSIM Simulation of Reduced Surface Water Availability Scenarios

Joint LBNL-DWR Project

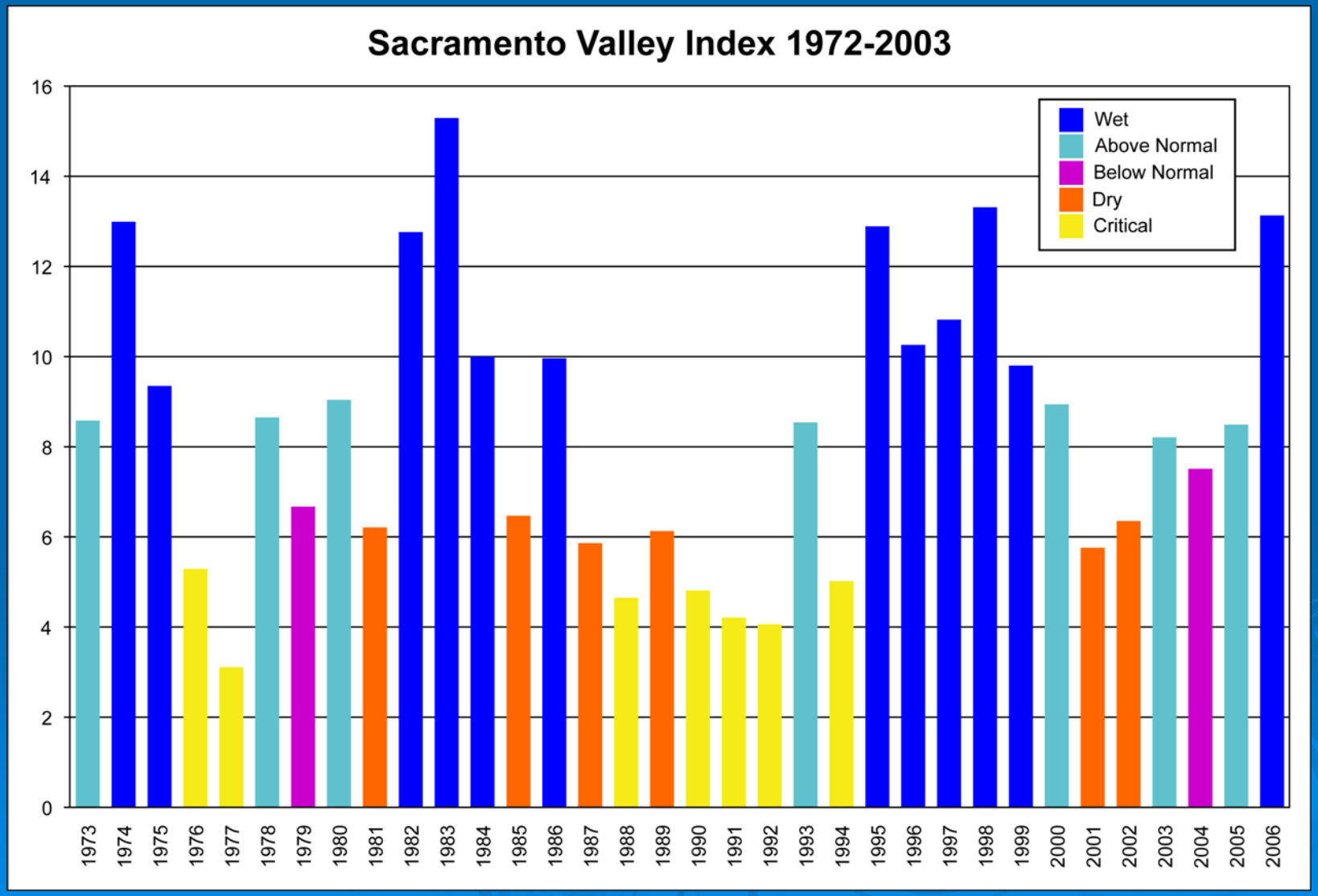
- 30%, 50% and 70% reduction
- 10, 20, 30 and 60 years
- Climate model results to Calsim for rim inflows
  - Prepare C2VSIM inflow & diversion files
- C2VSIM runs
  - October 2003 as initial condition
  - 10-yr run-up, drought period, 10-yr recovery

  1. Turn on groundwater adjustment
  2. Post-process results

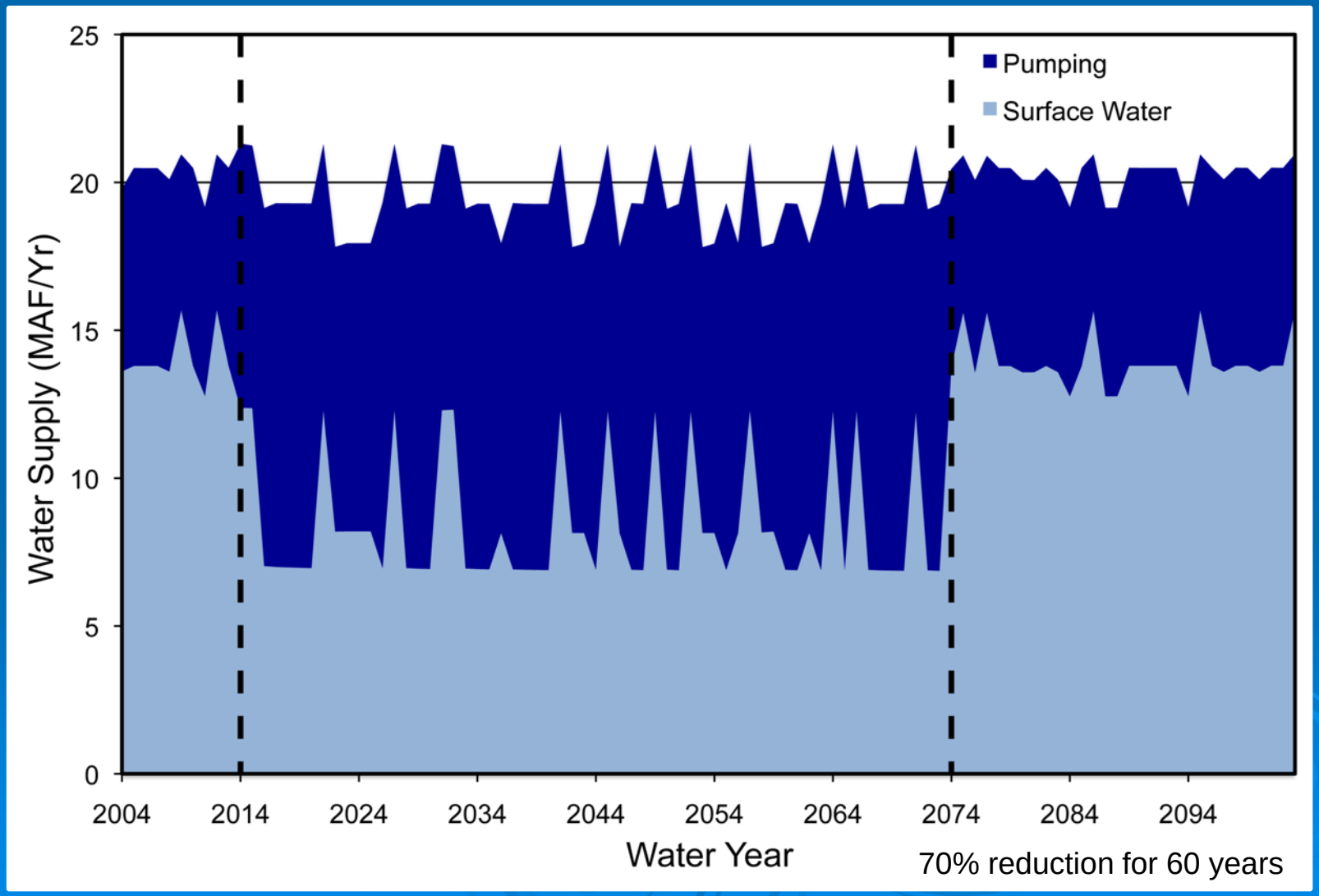
Methods

- Construct 10-year monthly valley-rim inflows for base case, slight, moderate and severe droughts from historical 1972-2003 data
- Develop diversion scenarios using CALSIM-II
- Determine economic parameters: CVPM and logit
- Integrated hydrologic simulations with C2VSIM
  - 10-year spin-up at ‘average’ conditions
  - 10-, 20-, 30- or 60-year drought
  - 30-year recovery period
  - Calculate groundwater pumping to meet demands
- Fixed crops vs variable crops
  - Fixed agricultural water demand with 2003 crops
  - Variable agricultural water demand with CVPM

Sacramento Valley Index

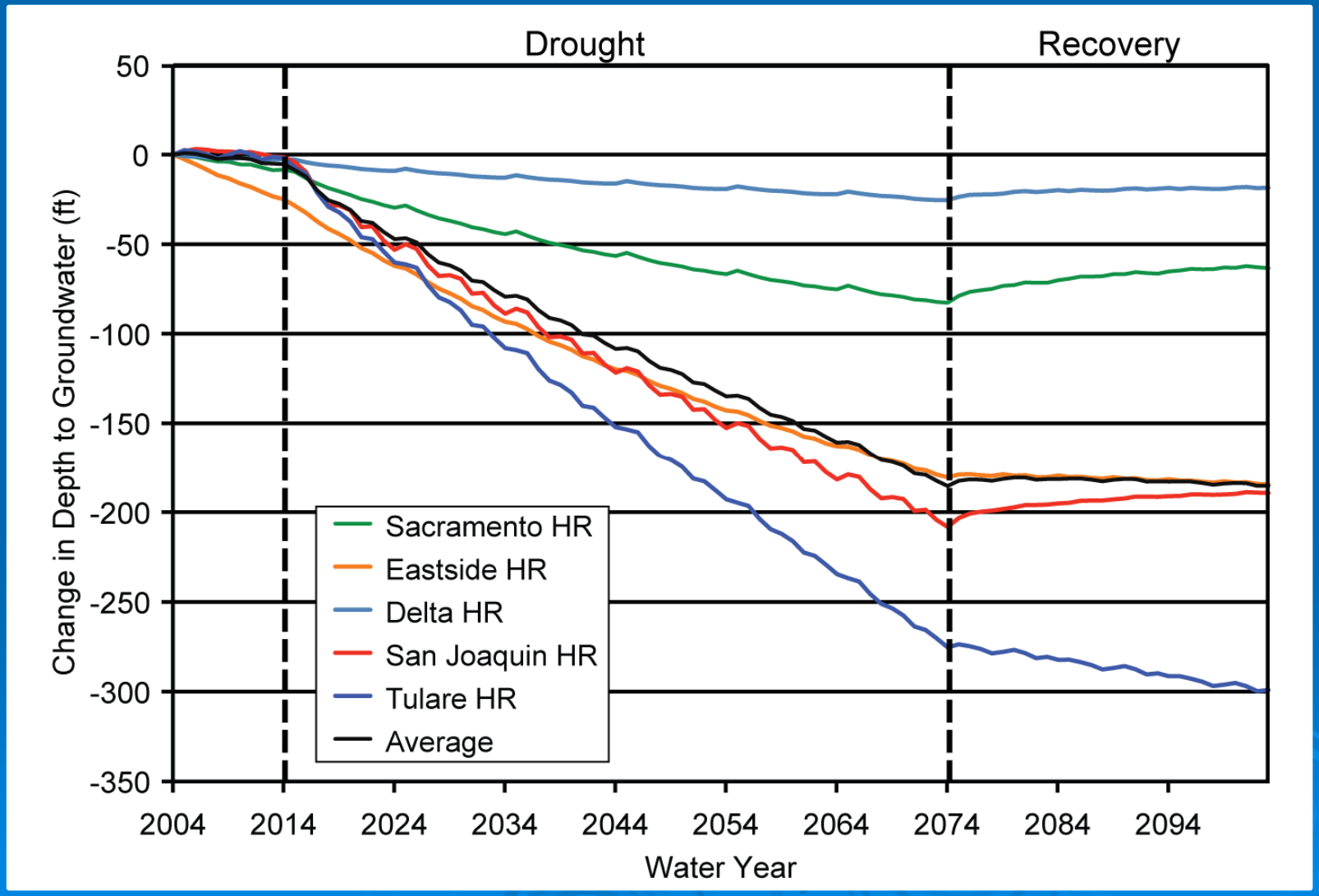


Water Sources

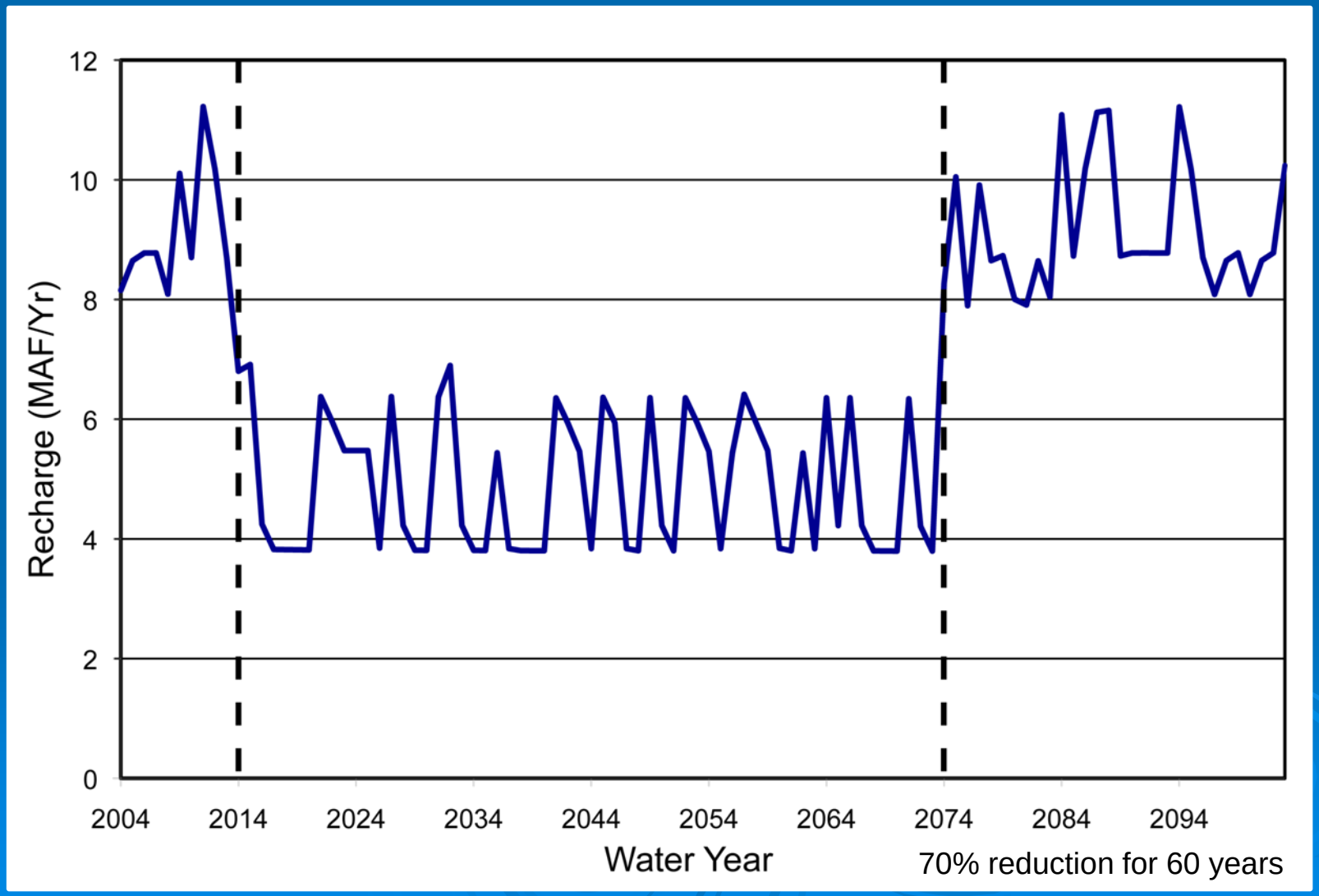


Depth to Groundwater – Constant Crops

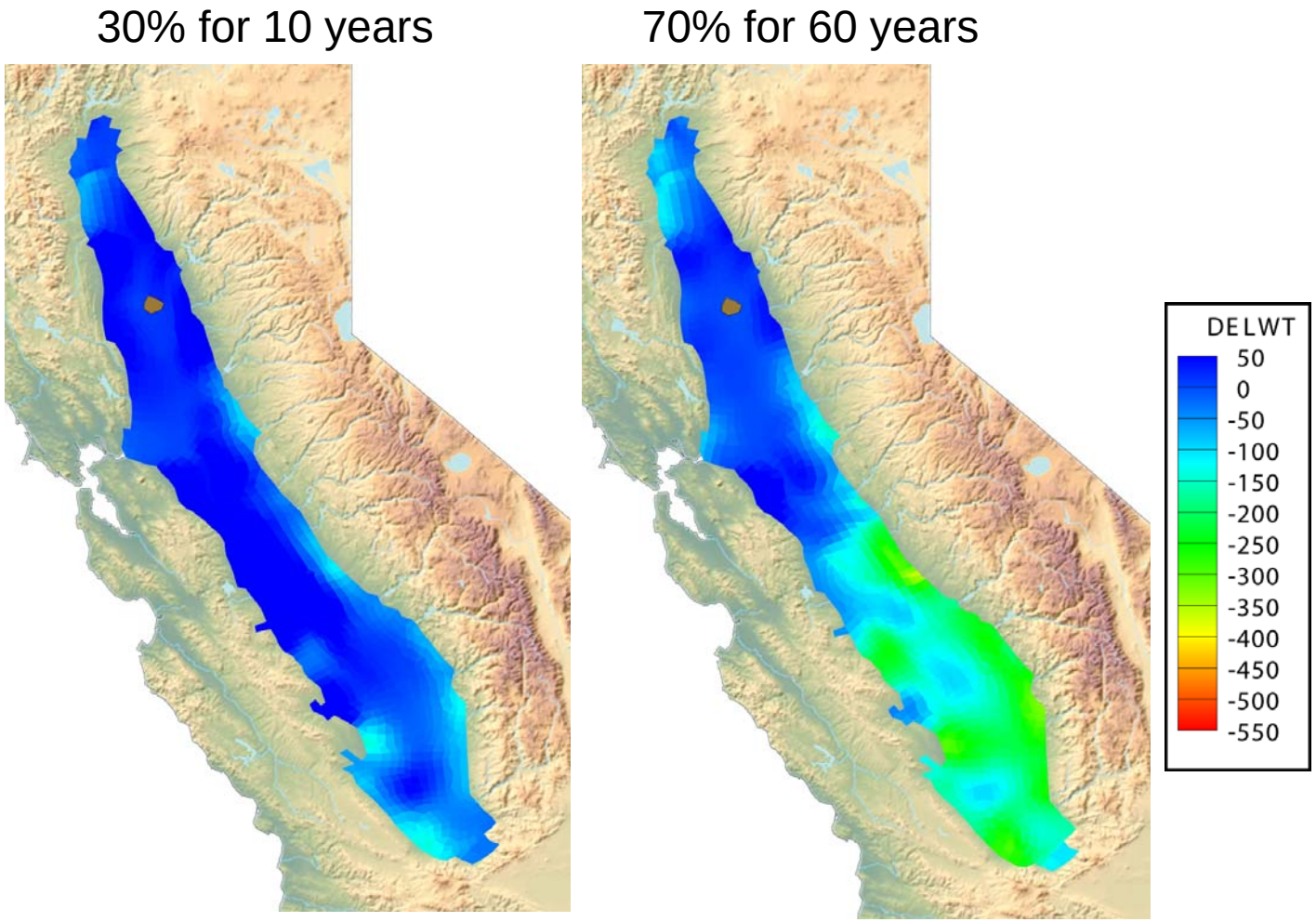
Severe drought for 60 years



Recharge

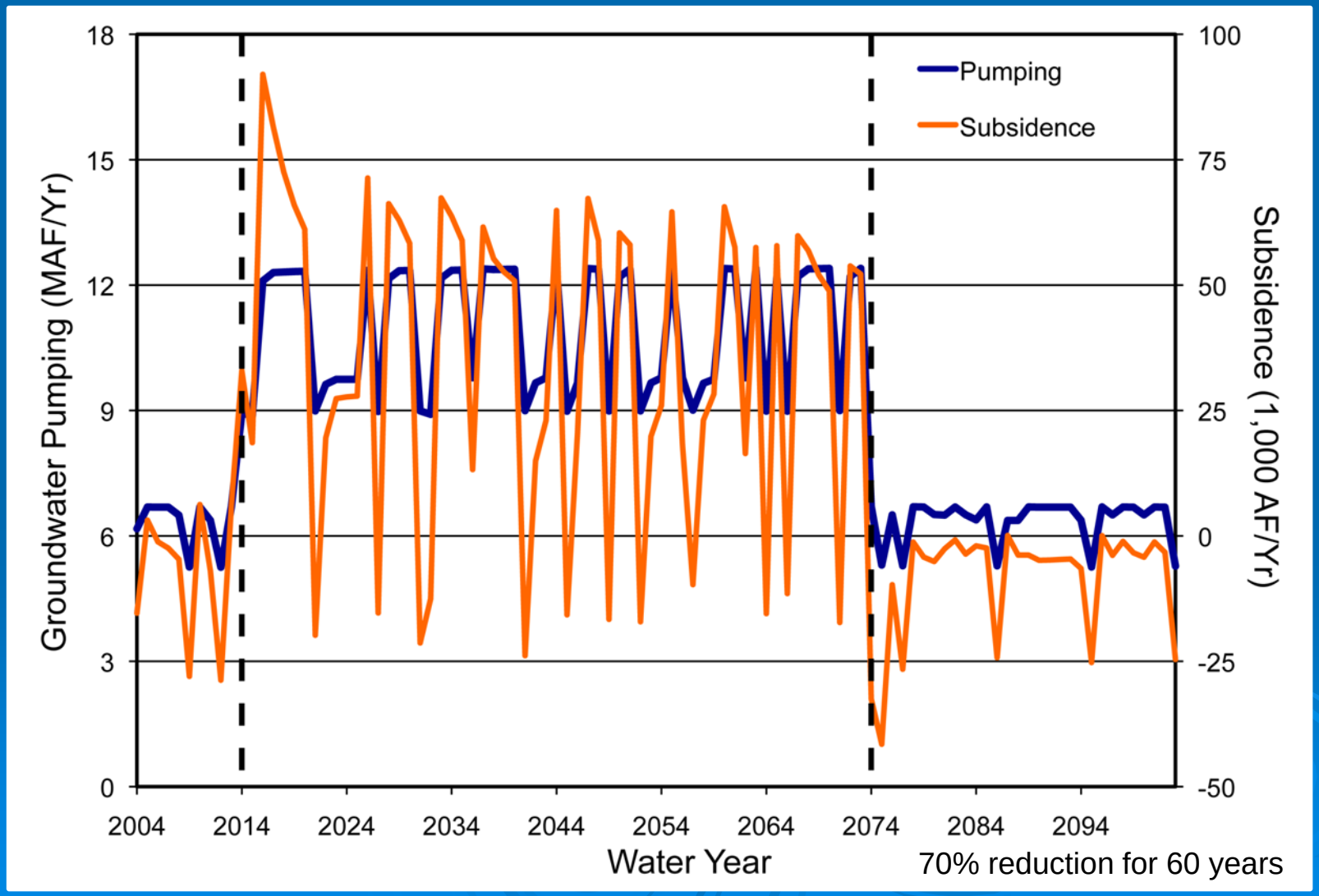

12
10
8
6
4
2
0
Recharge (MAF/Yr)
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
Water Year
70% reduction for 60 years

Relative Water Level Change



Relative WT Change (Feet)

Land Subsidence



Incorporating Variable Demand

- Crop mix is a function of water cost
  - Surface water availability
  - Depth to groundwater
  - Crop Water Demand
  - Crop Production Costs and Returns
- Incorporate Logit equation in IWFM application
- Determine Logit equation parameters from a series of simulations conducted with the Central Valley Production Model

Central Valley Production Model

Economic Model

- Positive Mathematical Programming Model
- Crop Production Costs
- Impact of Yields on Prices
- Crop Distribution in Central Valley

Emulate CVPM in IWFM

- Use Logit Equation to Determine Crop Mix
- Determine Parameters with Multiple CVPM Runs

C2VSIM and CVPM

- 21 Subregions
- Crops
- Time Step

Logit Equation

Predicts the share of each crop in each region

$$\alpha_{ir} = \frac{e^{x_r \beta_{ir}}}{1 + \sum_j e^{x_r \beta_{jr}}}$$

where ***i*** **and** ***j*** **are crops**
r **and** ***s*** **are regions**
x **is a vector of regional explanatory variables**
β is a vector of estimated coefficients

Crop water use is calculated from the acreage as

$$a_{ir} = x_r \gamma_{ir}$$

where **γ is a vector of estimated coefficients that can vary by region and by crop**

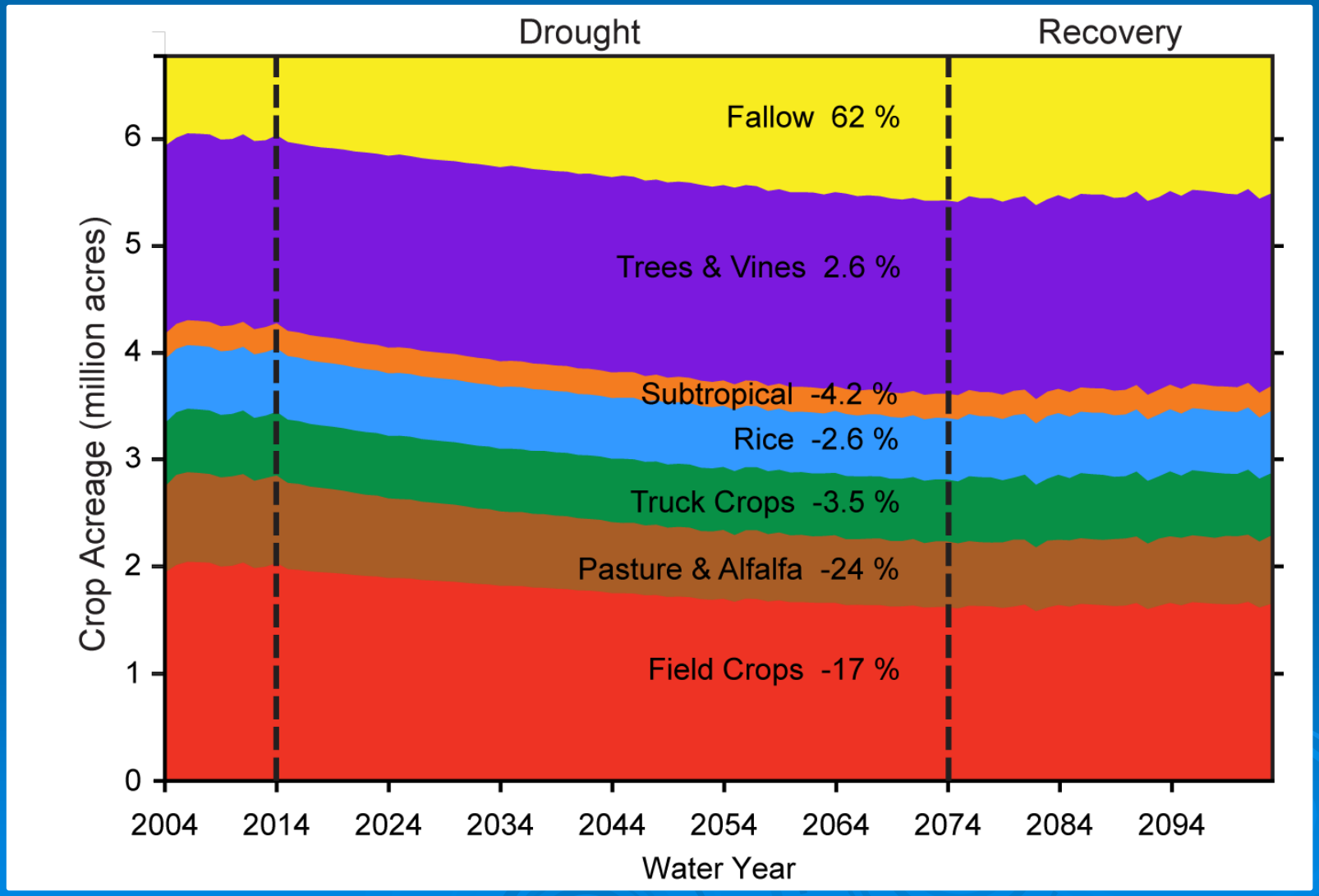
Multiple CVPM Runs

Regress results to obtain Logit parameters

groundwater depth	percent surface supply	reg3	reg3b	reg4	reg5	Cereal percent	Orchard percent	Pasture percent	Rice percent	Row percent	Fallow percent
110	1	0	1	0	0	25%	32%	18%	11%	14%	0%
160	0.8	0	1	0	0	25%	32%	17%	11%	14%	2%
160	0.85	0	1	0	0	25%	32%	17%	11%	14%	2%
160	0.9	0	1	0	0	25%	32%	17%	11%	14%	2%
160	0.95	0	1	0	0	25%	32%	17%	11%	14%	2%
210	0.8	0	1	0	0	24%	32%	17%	10%	14%	4%
210	0.85	0	1	0	0	24%	32%	16%	10%	14%	4%
210	0.9	0	1	0	0	24%	32%	16%	10%	14%	4%
210	0.95	0	1	0	0	24%	32%	16%	10%	14%	4%
260	0.8	0	1	0	0	24%	32%	16%	10%	14%	6%
260	0.85	0	1	0	0	24%	32%	15%	10%	14%	6%
260	0.9	0	1	0	0	24%	32%	15%	10%	14%	6%
260	0.95	0	1	0	0	24%	32%	15%	10%	14%	5%
310	0.8	0	1	0	0	23%	32%	15%	10%	14%	7%
310	0.85	0	1	0	0	23%	32%	15%	10%	14%	7%
310	0.9	0	1	0	0	23%	32%	15%	10%	14%	7%
310	0.95	0	1	0	0	23%	32%	15%	10%	14%	7%
60	1	0	0	1	0	32%	11%	3%	32%	22%	0%
75	1	0	0	0	1	10%	34%	7%	46%	3%	0%
85	1	1	0	0	0	16%	6%	9%	48%	21%	0%

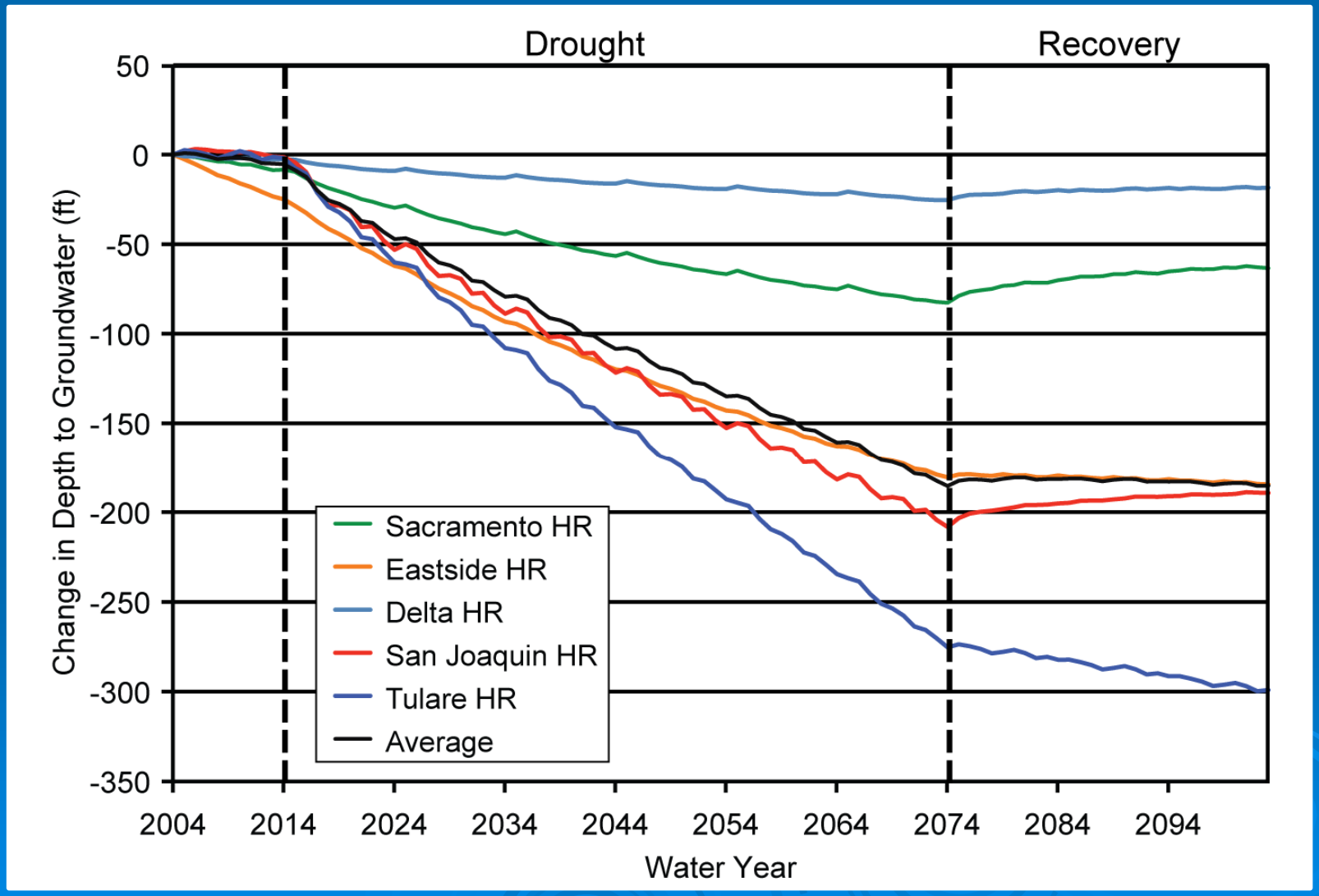
Crop Changes

Severe drought for 60 years



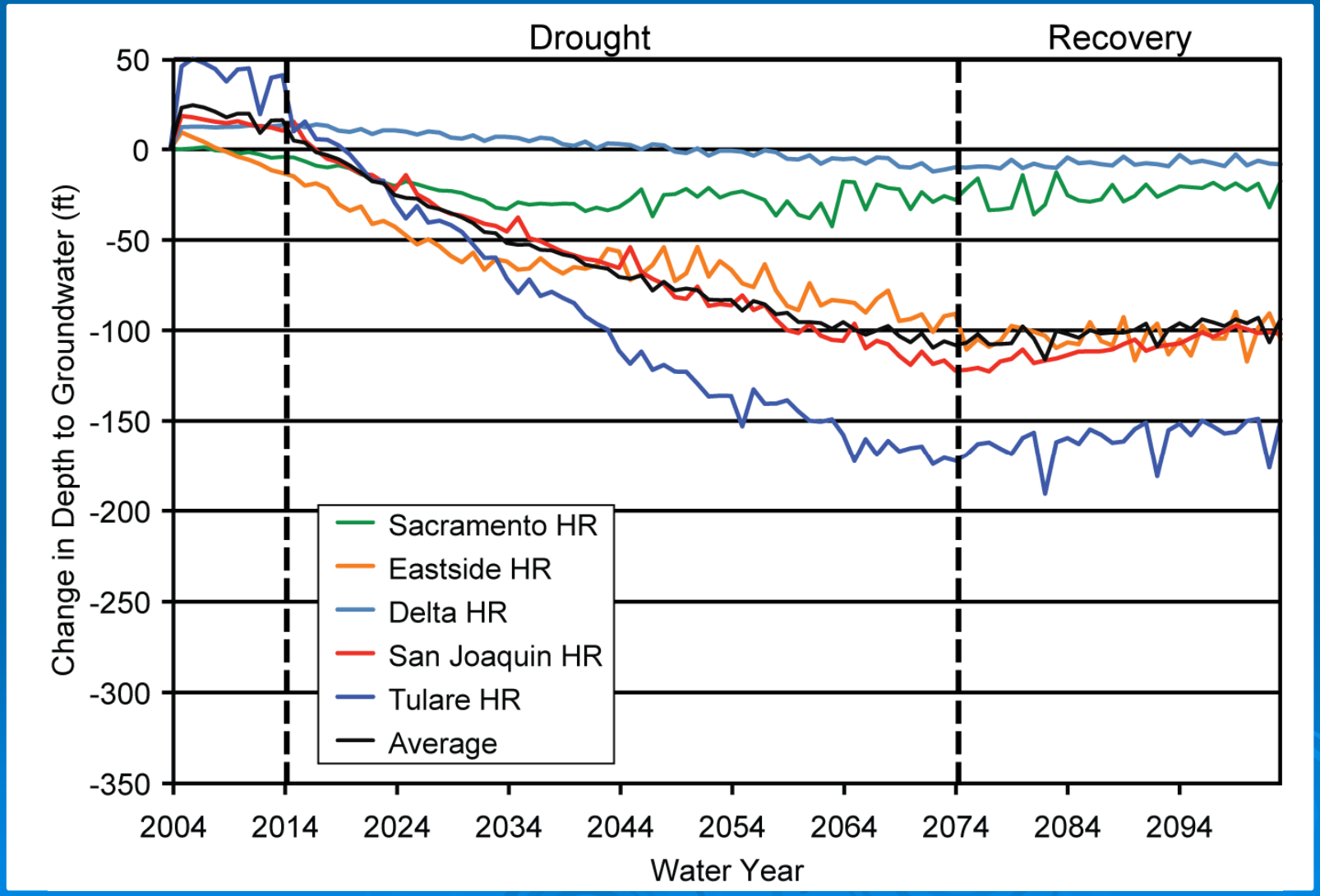
Depth to Groundwater – Constant Crops

Severe drought for 60 years

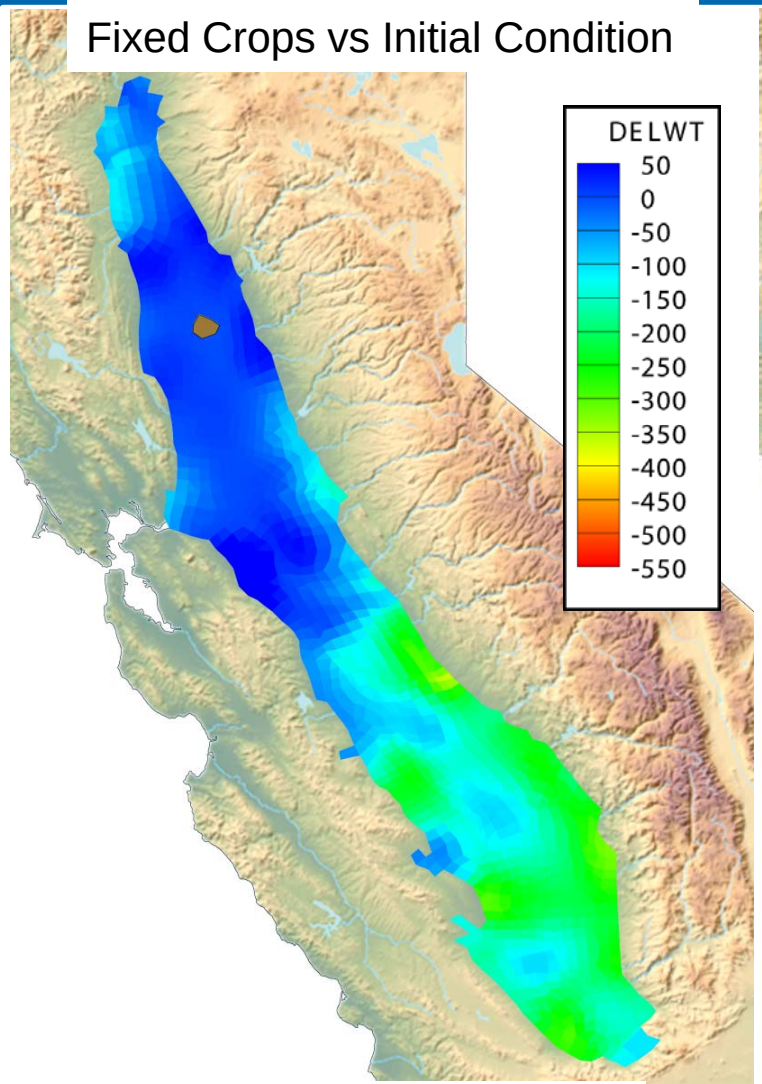


Depth to Groundwater – Adjusted Crops

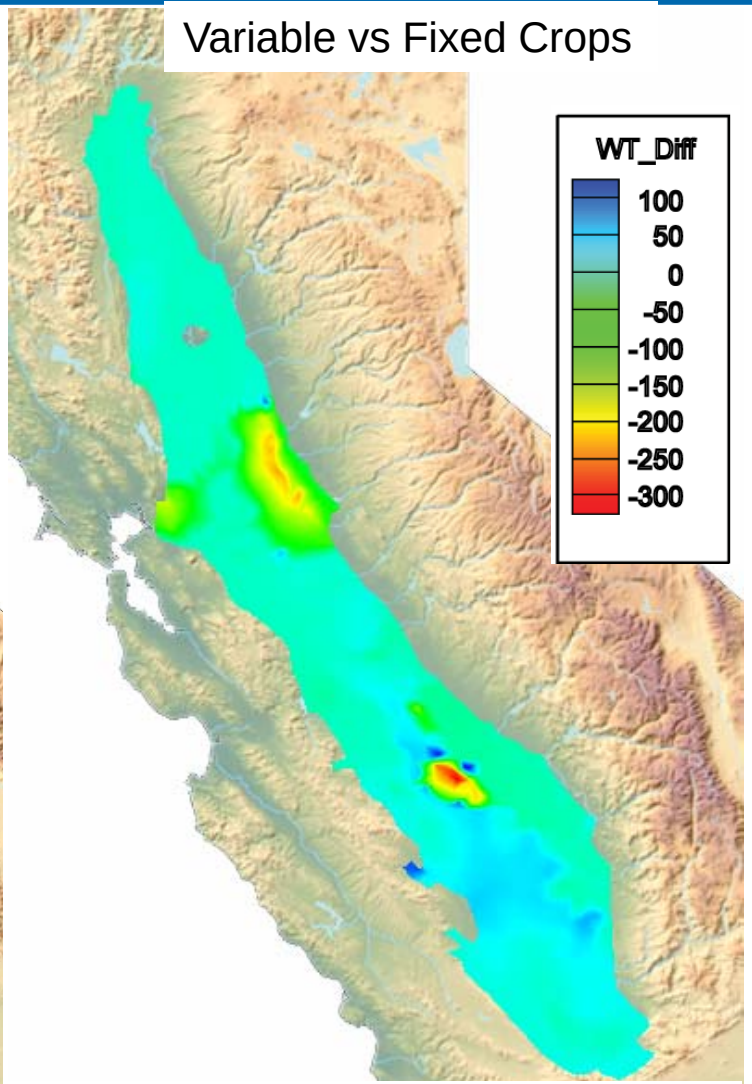
Severe drought for 60 years



Water Table at End of Drought



Relative WT Change (Feet)



Difference in Water Table Altitude (ft)

Findings

- Regional impacts of extreme drought
  - Moderate in north (Sacramento River Basin)
  - Locally severe in middle (San Joaquin River Basin)
  - Severe in south (Tulare Basin)
  - Extensive pumping can cause permanent subsidence and may lead to new equilibrium groundwater levels

- Modeling tools
  - C2VSIM can provide valuable insights into the impacts of climate change on Central Valley aquifers
  - C2VSIM can be tailored to investigate the impacts of specific stressors

N. L. Miller et al. 2009. Drought Resilience Of The California Central Valley Surface-Groundwater-Conveyance System. J. Am. Water Res. Assoc. 45(4):857-866.
L. L. Dale et al. *In preparation*.

Questions?