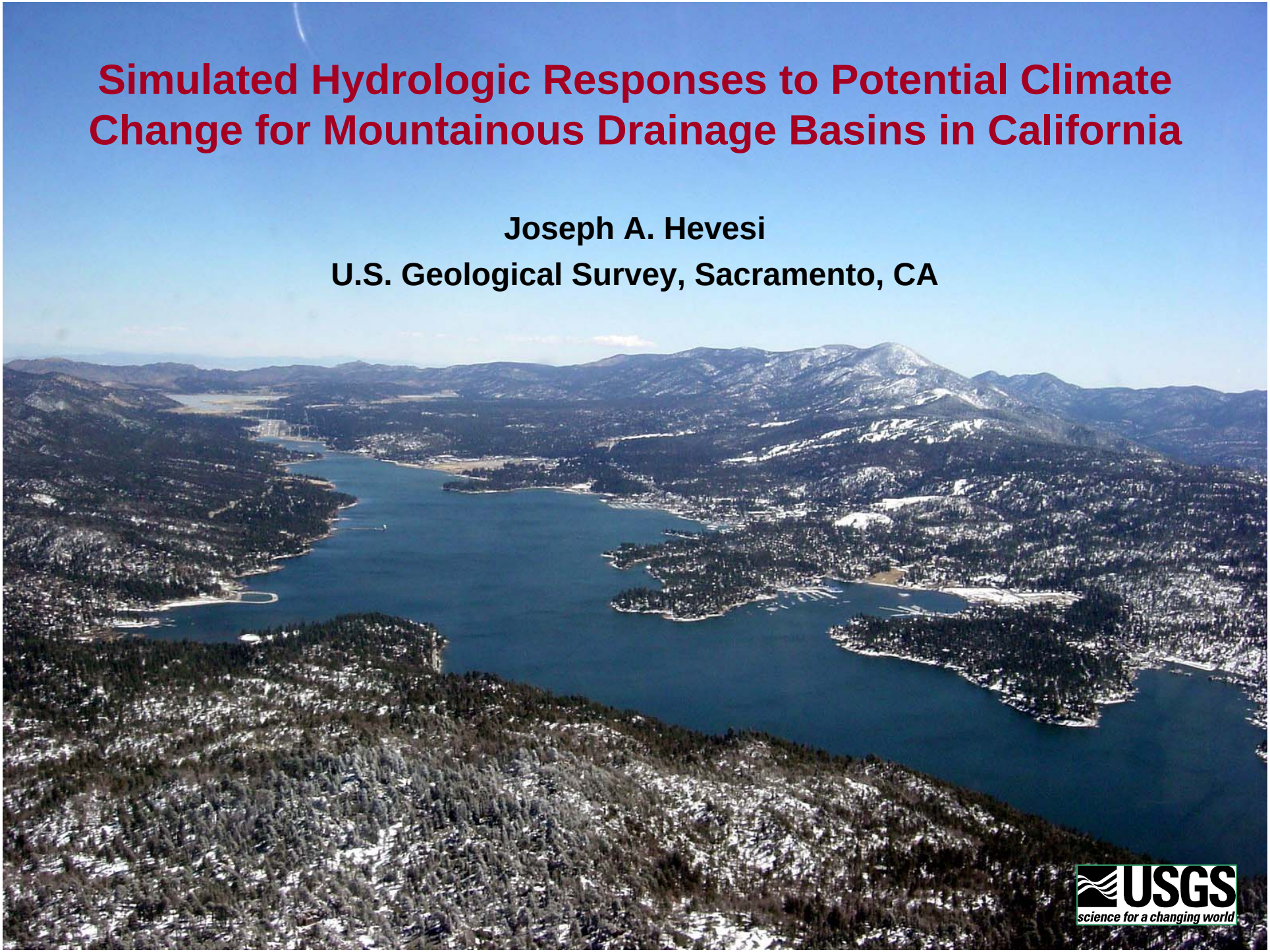
Simulated Hydrologic Responses to Potential Climate Change for Mountainous Drainage Basins in California

Joseph A. Hevesi

U.S. Geological Survey, Sacramento, CA



Overview

- **Watershed-scale, precipitation-runoff models are often applied to ground-water and surface-water studies (INFIL3.0, HSPF, PRMS/GSFLOW)**

- **The precipitation-runoff models are often well suited to evaluate hydrologic responses to climate change**
  - Simple scaling (sensitivity analysis)
  - Surrogate climate inputs (modified records)
  - Analog climate inputs (records from analog sites)
  - Predicted inputs (from GCMs)

- **Hydrologic response to climate change may affect ecohydrology, natural hazards, resource management**
  - Soil moisture & snow melt
  - Streamflow and recharge (peak flow, base-flow, timing)
  - Surface water – ground water interactions

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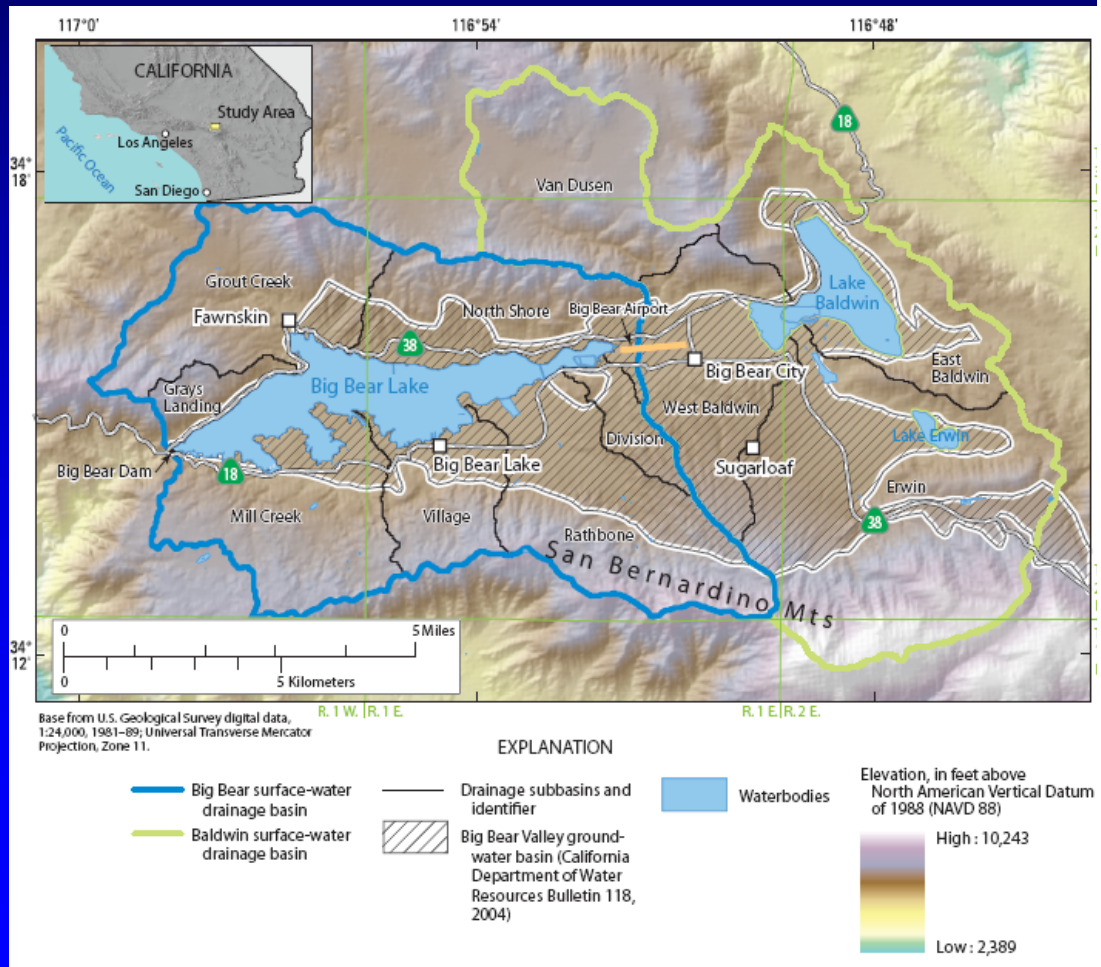
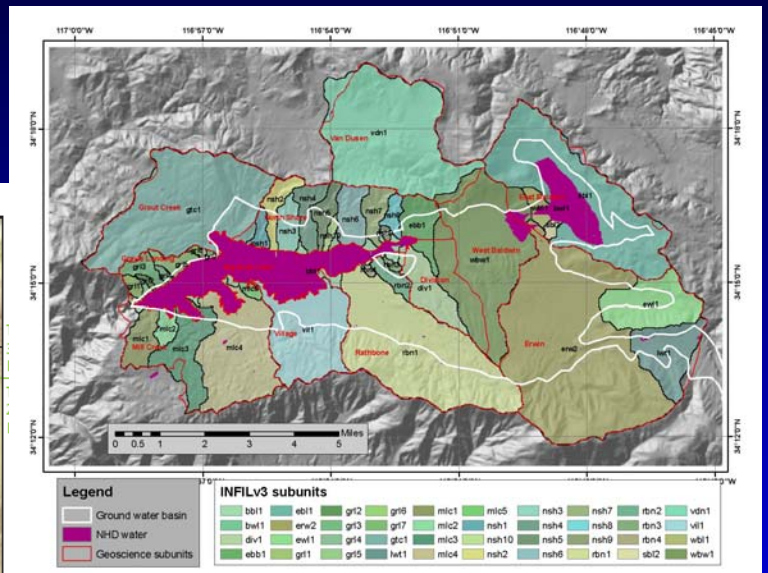
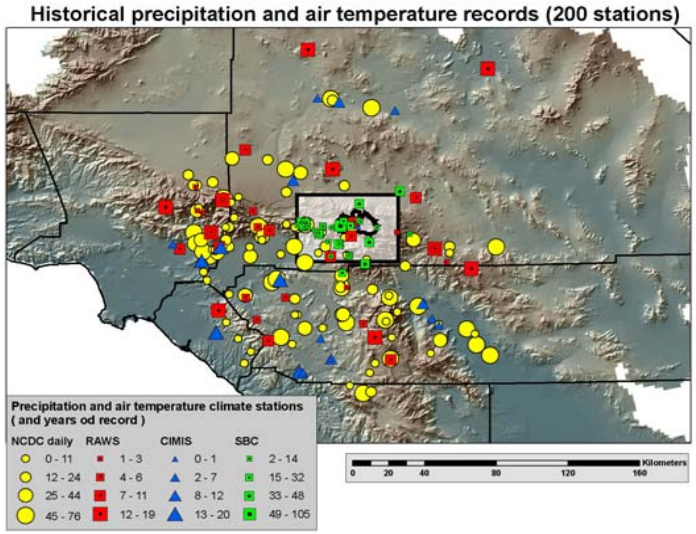
GEOHYDROLOGY OF BIG BEAR VALLEY, CALIFORNIA: PHASE 1—GEOLOGIC FRAMEWORK, RECHARGE, AND GEOCHEMISTRY

Lorraine E. Flint, Peter Martin, Justin Brandt, Allen H. Christensen, Alan L. Flint, Joseph A. Hevesi, Robert Jachens, Justin Kulongoski, Michelle Sneed

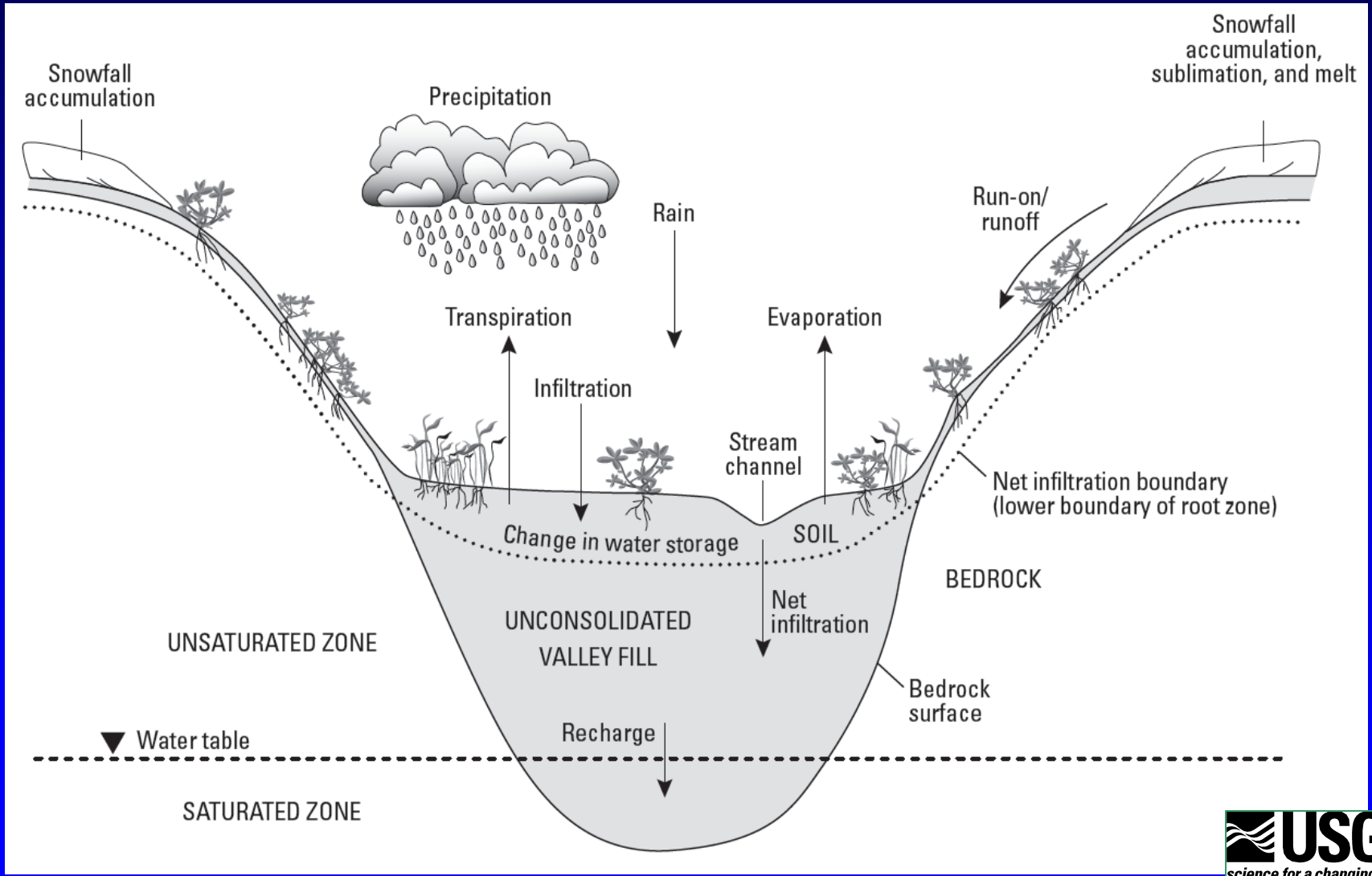






INFIL3.0: Distributed Parameter Recharge Modeling

http://water.usgs.gov/software/ground_water.html



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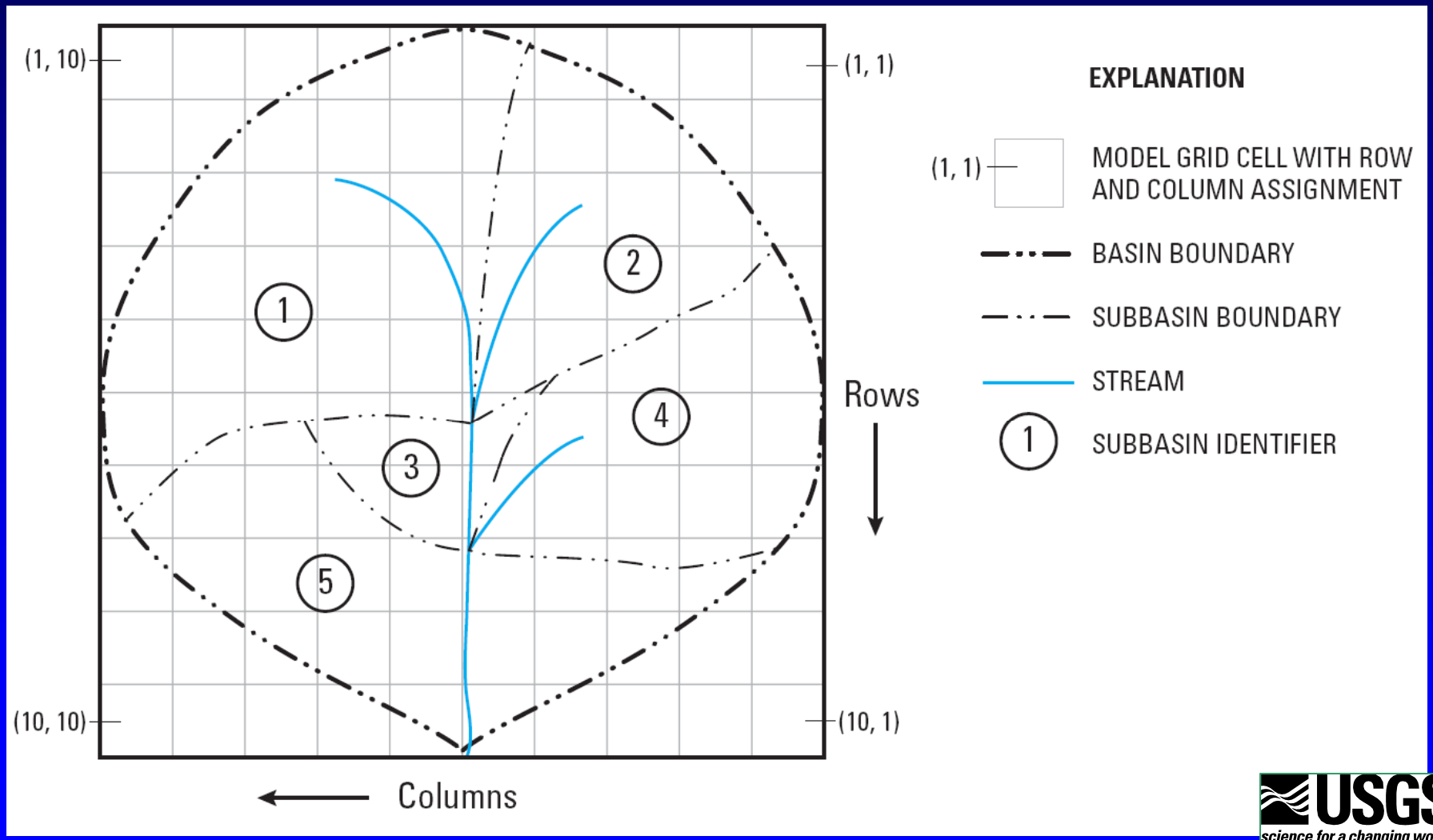
Distributed Parameter Recharge Modeling

Watershed area is represented using Hydrologic Response Units (HRUs)
HRUs are defined using a grid-based, horizontal discretization
HRUs are connected into a drainage network using convergent flow routing



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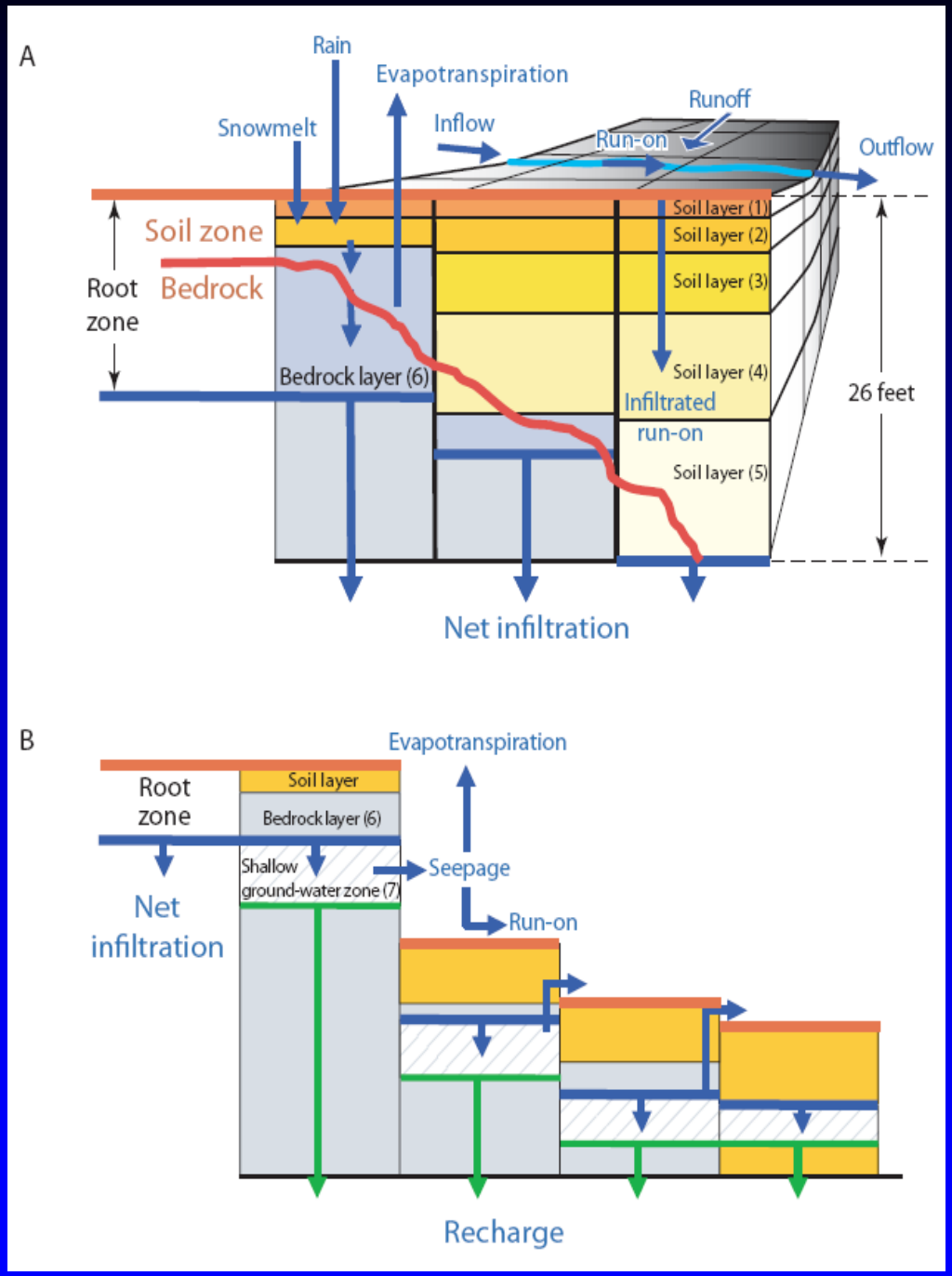

Modified INFIL3.0 (seepage model)

- Shallow ground-water zone added beneath the root zone
- Zone allows for down-slope routing of ground-water in the upper unsaturated-zone (seepage flow)
- Lake model added to simulate volume of water in Big Bear and Baldwin Lakes

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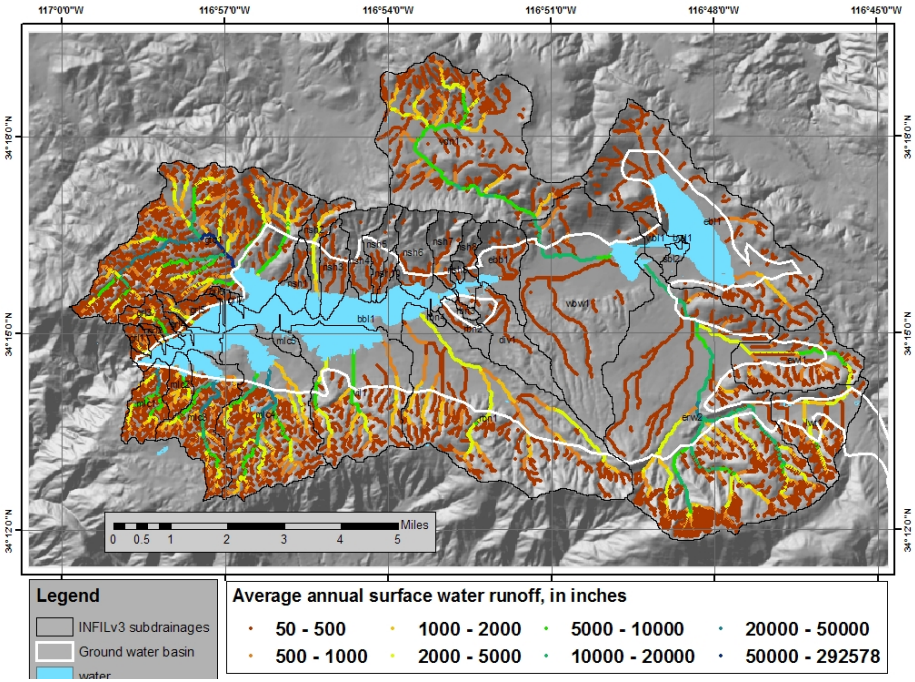
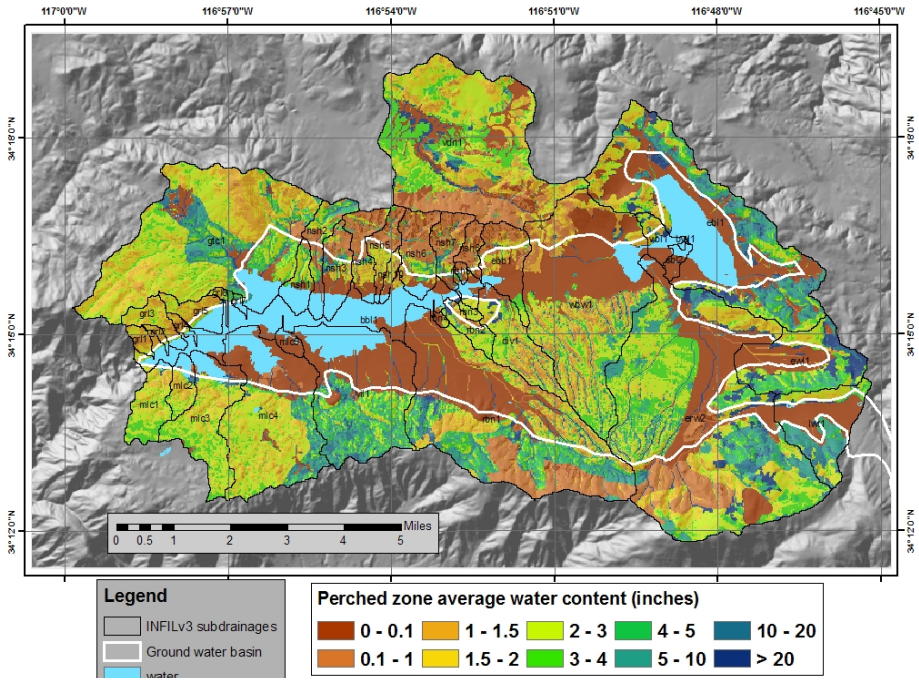

117°0'0"W
116°57'0"W
116°54'0"W
116°51'0"W
116°48'0"W
116°45'0"W
34°18'0"N
34°15'0"N
34°12'0"N
Miles
0 0.5 1 2 3 4 5
Legend
INFILv3 subdrainages
Ground water basin
water
Average annual surface water runoff, in inches
50 - 500
500 - 1000
1000 - 2000
2000 - 5000
5000 - 10000
10000 - 20000
20000 - 50000
50000 - 292578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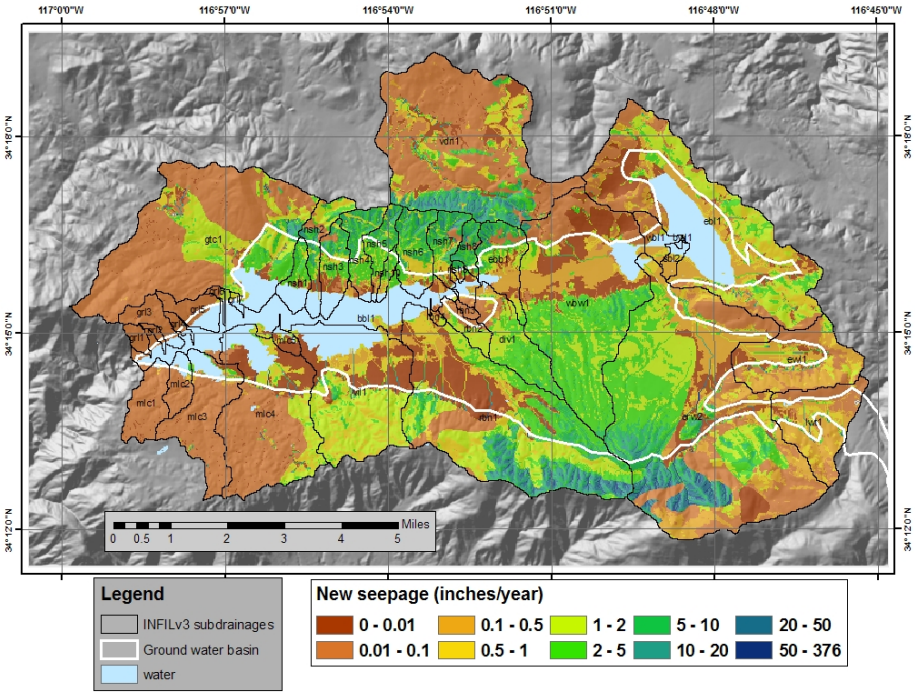
34°15'0"N
34°12'0"N
Miles
0 0.5 1 2 3 4 5
Legend
INFILv3 subdrainages
Ground water basin
water
Perched zone average water content (inches)
0 - 0.1
0.1 - 1
1 - 1.5
1.5 - 2
2 - 3
3 - 4
4 - 5
5 - 10
10 - 20
> 20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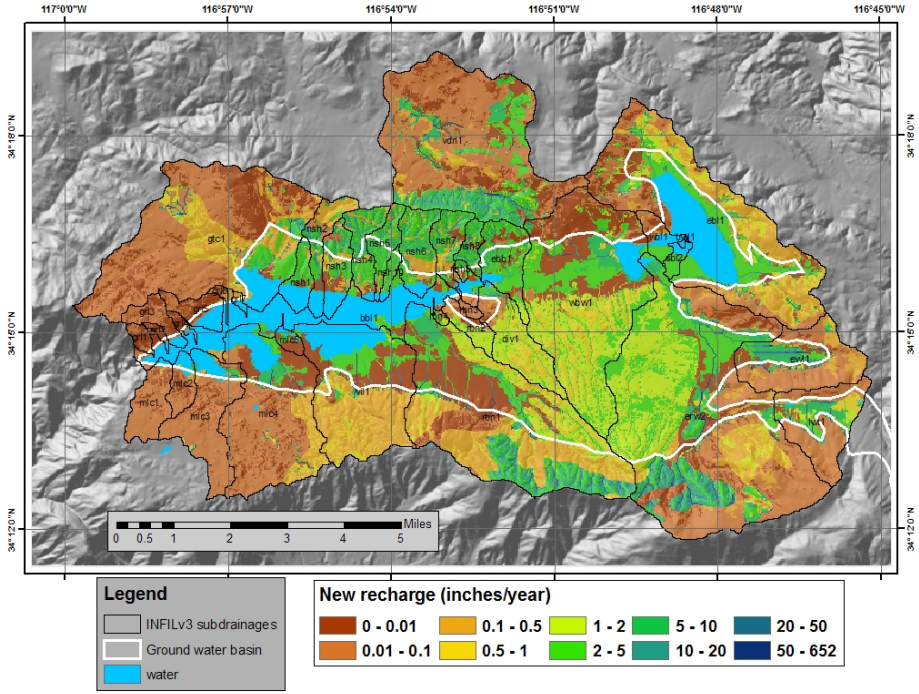
116°45'0"W
34°18'0"N
34°15'0"N
34°12'0"N
Miles
0 0.5 1 2 3 4 5
Legend
INFILv3 subdrainages
Ground water basin
water
New seepage (inches/year)
0 - 0.01
0.01 - 0.1
0.1 - 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 376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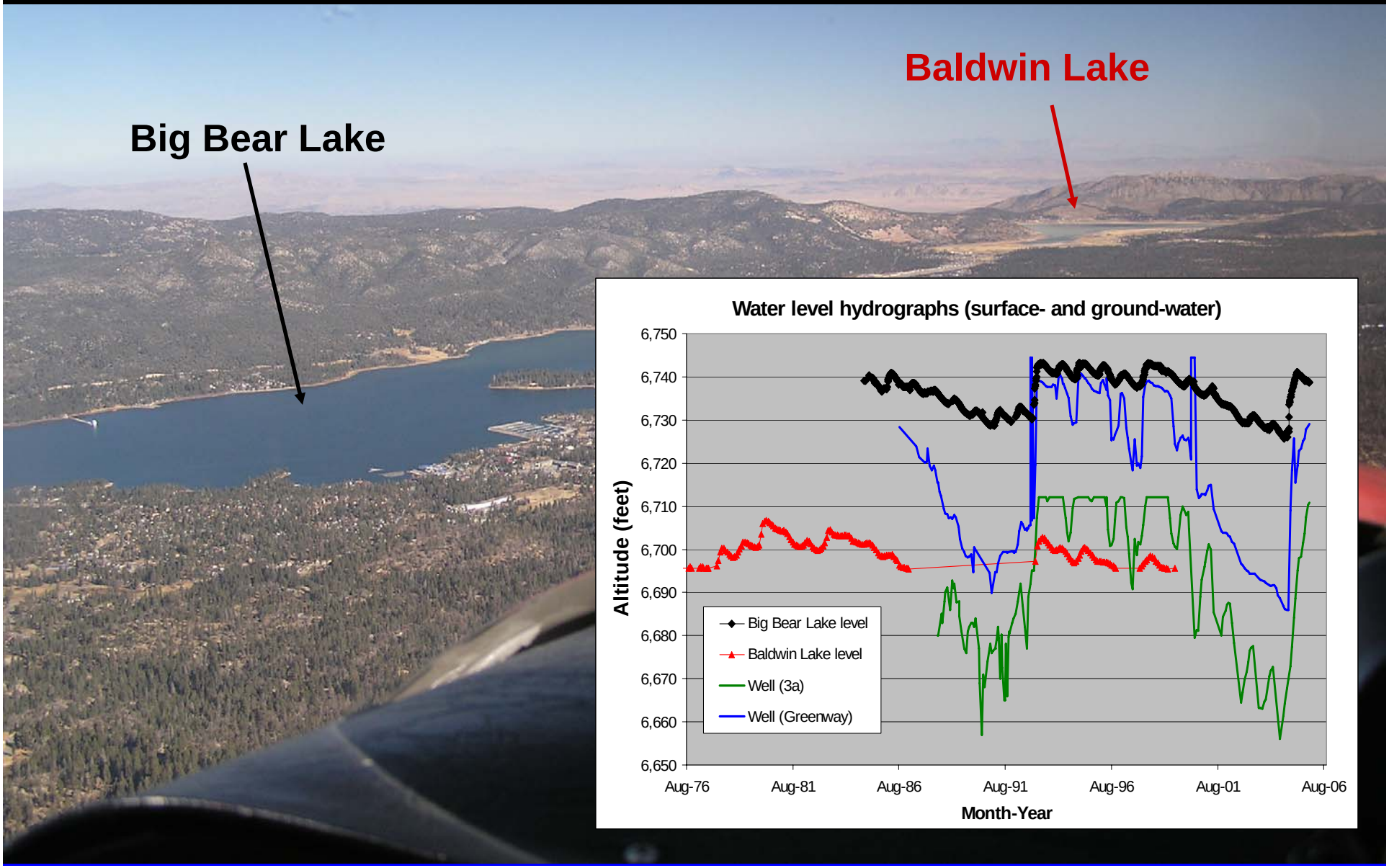
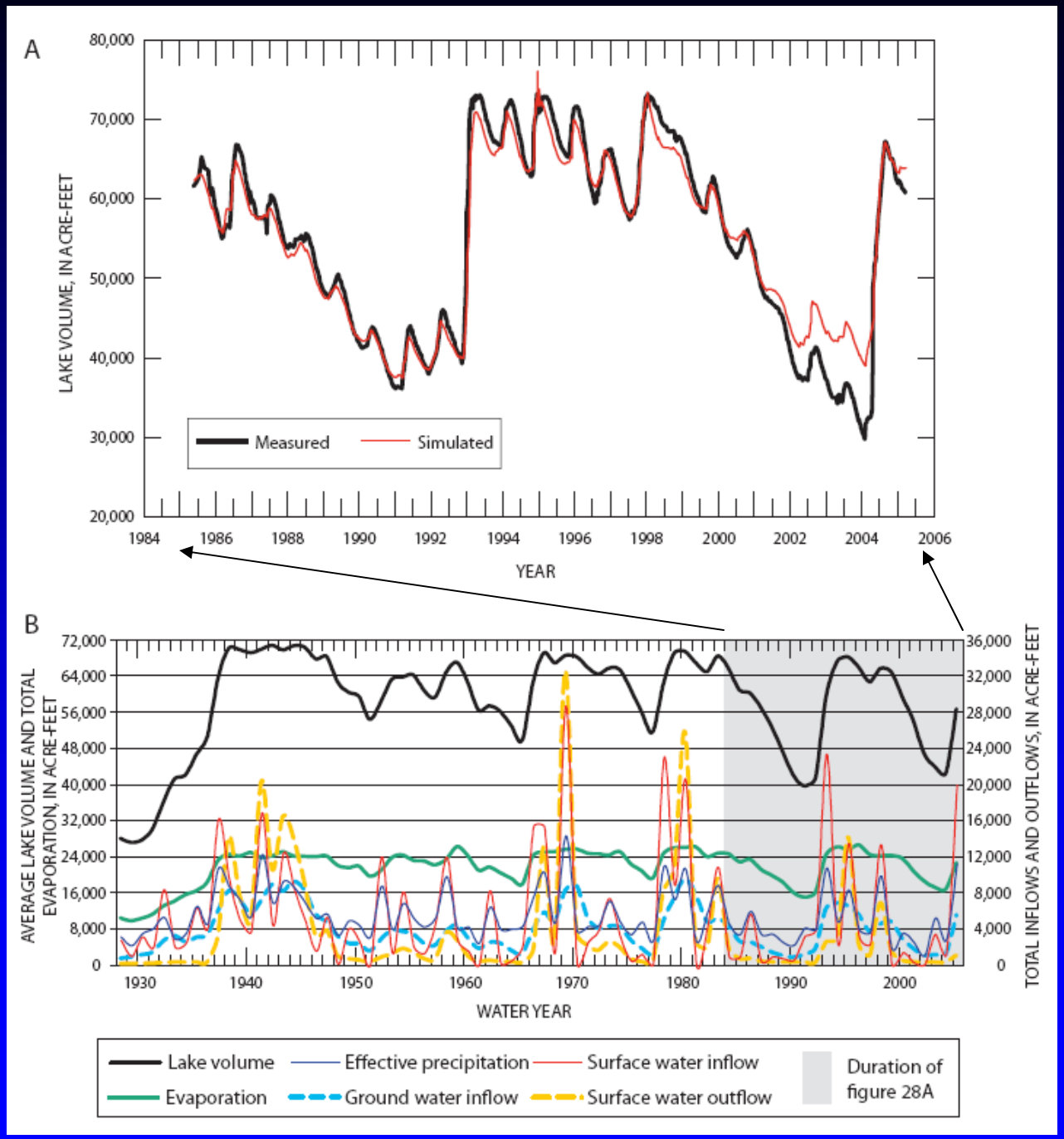
116°48'0"W
116°45'0"W
34°18'0"N
34°15'0"N
34°12'0"N
Miles
0 0.5 1 2 3 4 5
Legend
INFILv3 subdrainages
Ground water basin
water
New recharge (inches/year)
0 - 0.01
0.01 - 0.1
0.1 - 0.5
0.5 - 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 652

Model Calibration:

No sreamflow records. However, lake-level records available for both lakes
Ground-water levels could be used if ground-water model included





Big Bear Lake model calibration

Surface-water inflow = 5,400 acre-ft/yr

Ground-water inflow = 3,100 ac-ft/yr

All upstream Recharge used in lake water balance

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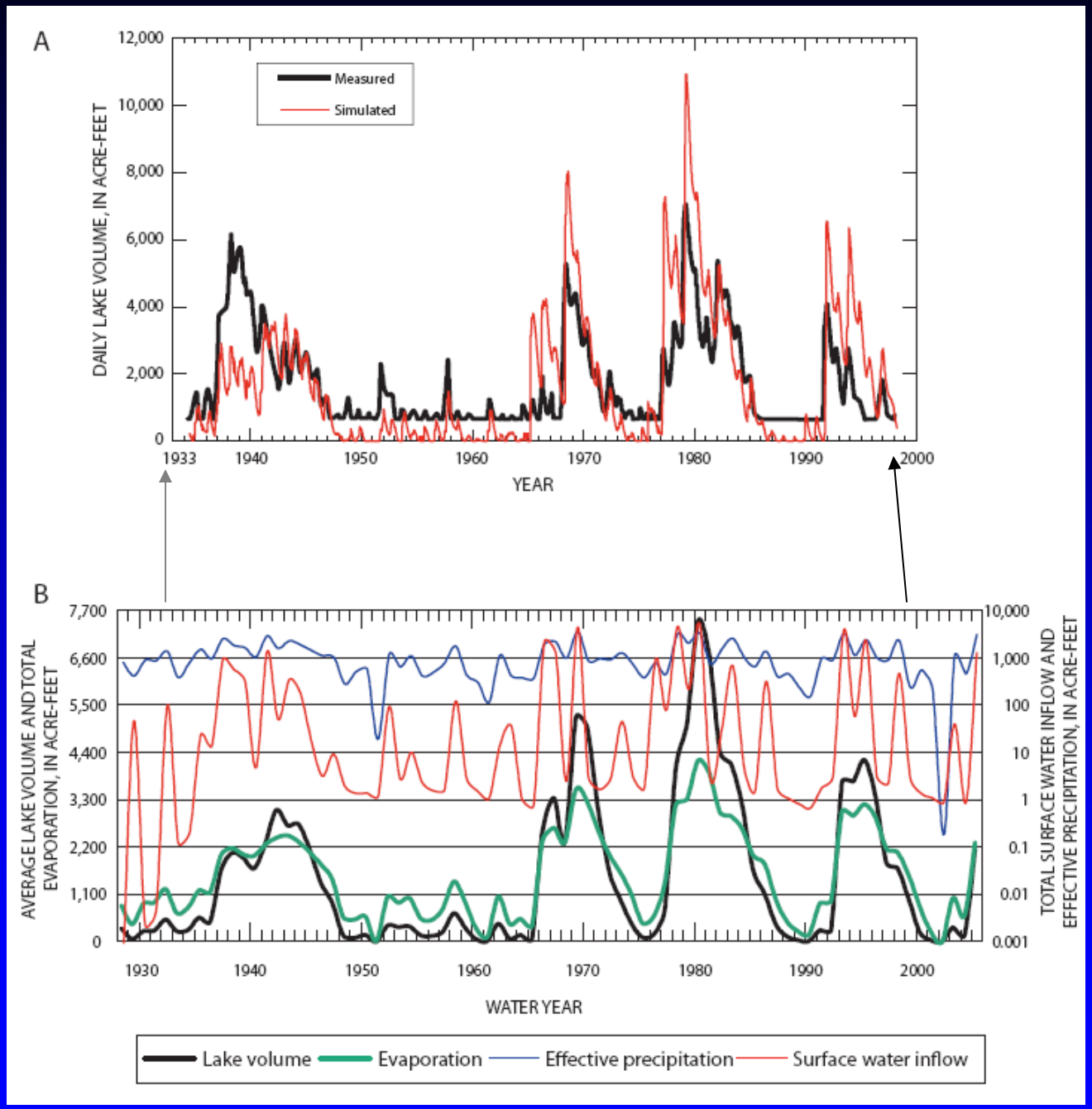

Baldwin Lake model calibration

Surface water inflow = 500 acre-ft/year

Ground-water inflow = 140 acre-ft/year

30% of upstream Recharge used in lake water balance

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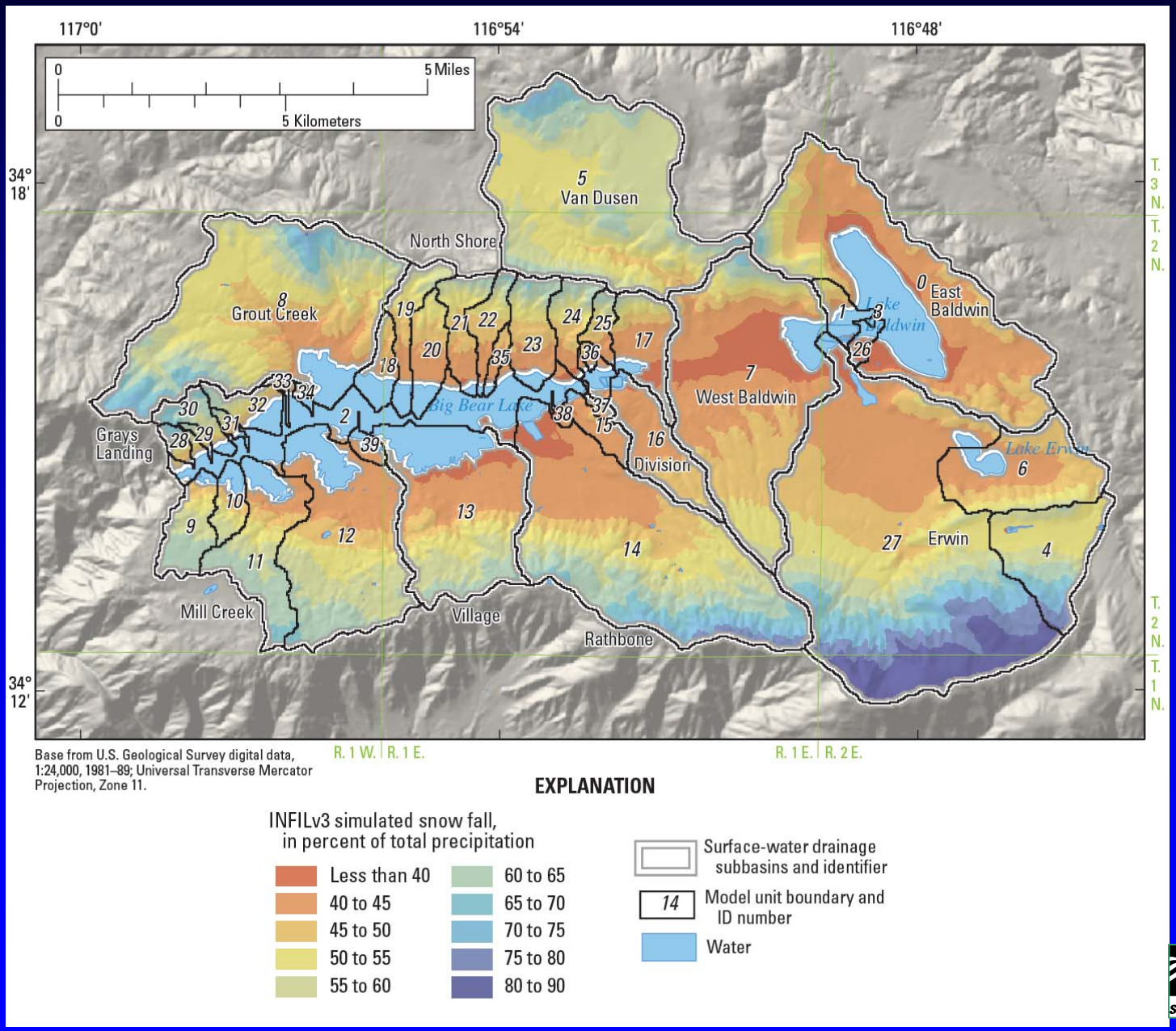
Simulated snow fall, as percent of total precipitation



Base from U.S. Geological Survey digital data, 1:24,000, 1981–89; Universal Transverse Mercator Projection, Zone 11.

EXPLANATION

INFILv3 simulated snow fall, in percent of total precipitation

- Less than 40
- 40 to 45
- 45 to 50
- 50 to 55
- 55 to 60
- 60 to 65
- 65 to 70
- 70 to 75
- 75 to 80
- 80 to 90

Surface-water drainage subbasins and identifier

14 Model unit boundary and ID number

Water

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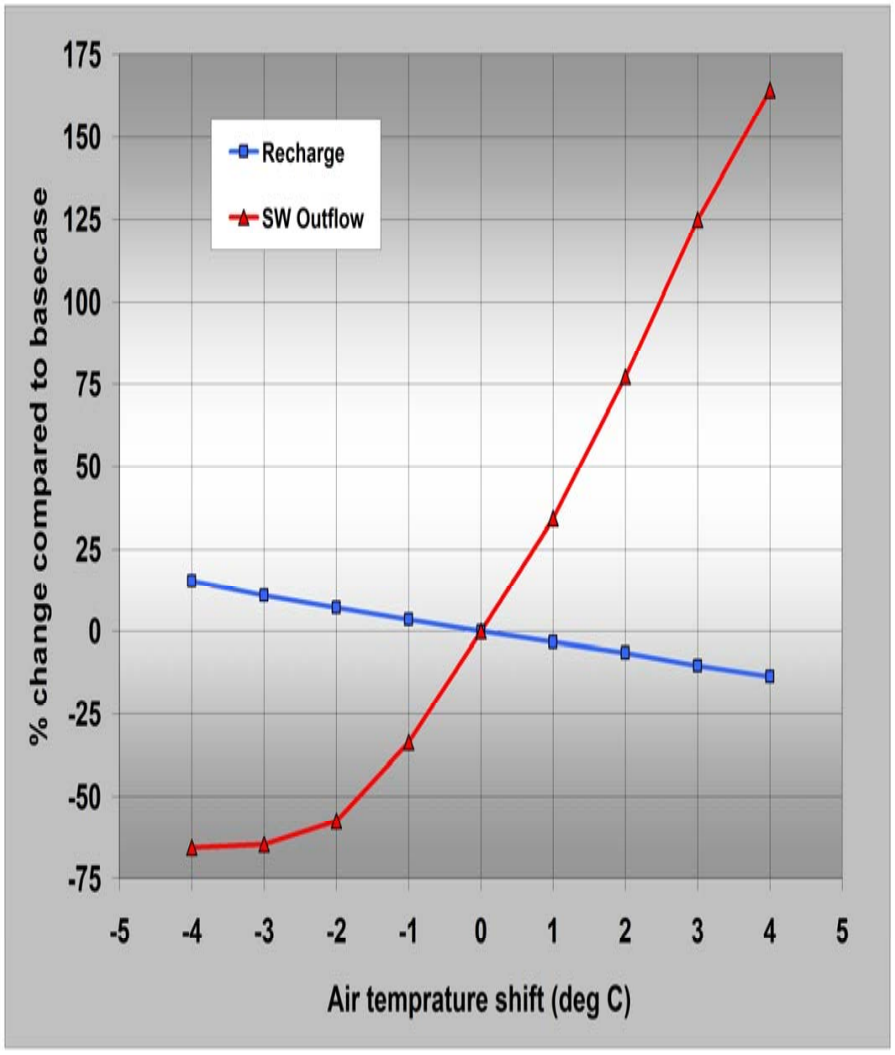
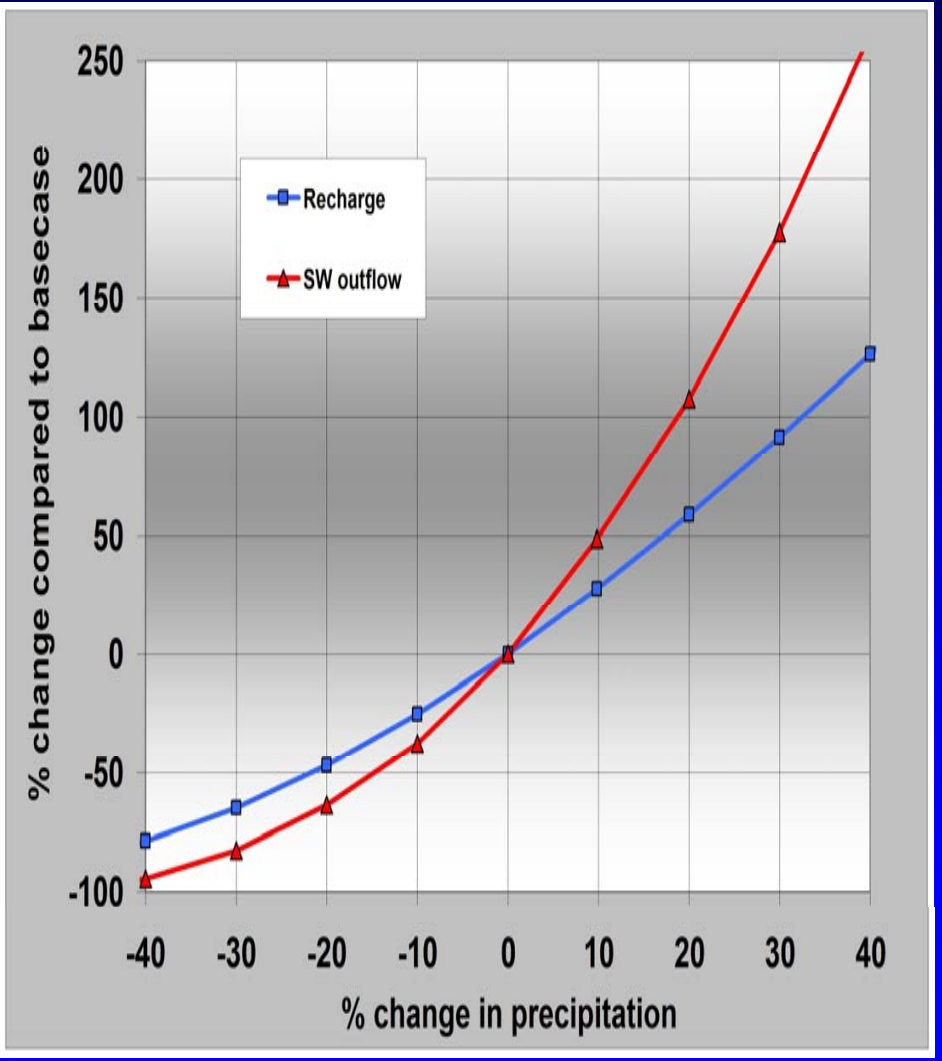
Baldwin Lake sub-basin: Sensitivity of simulation results to climate (air temperature and precipitation)

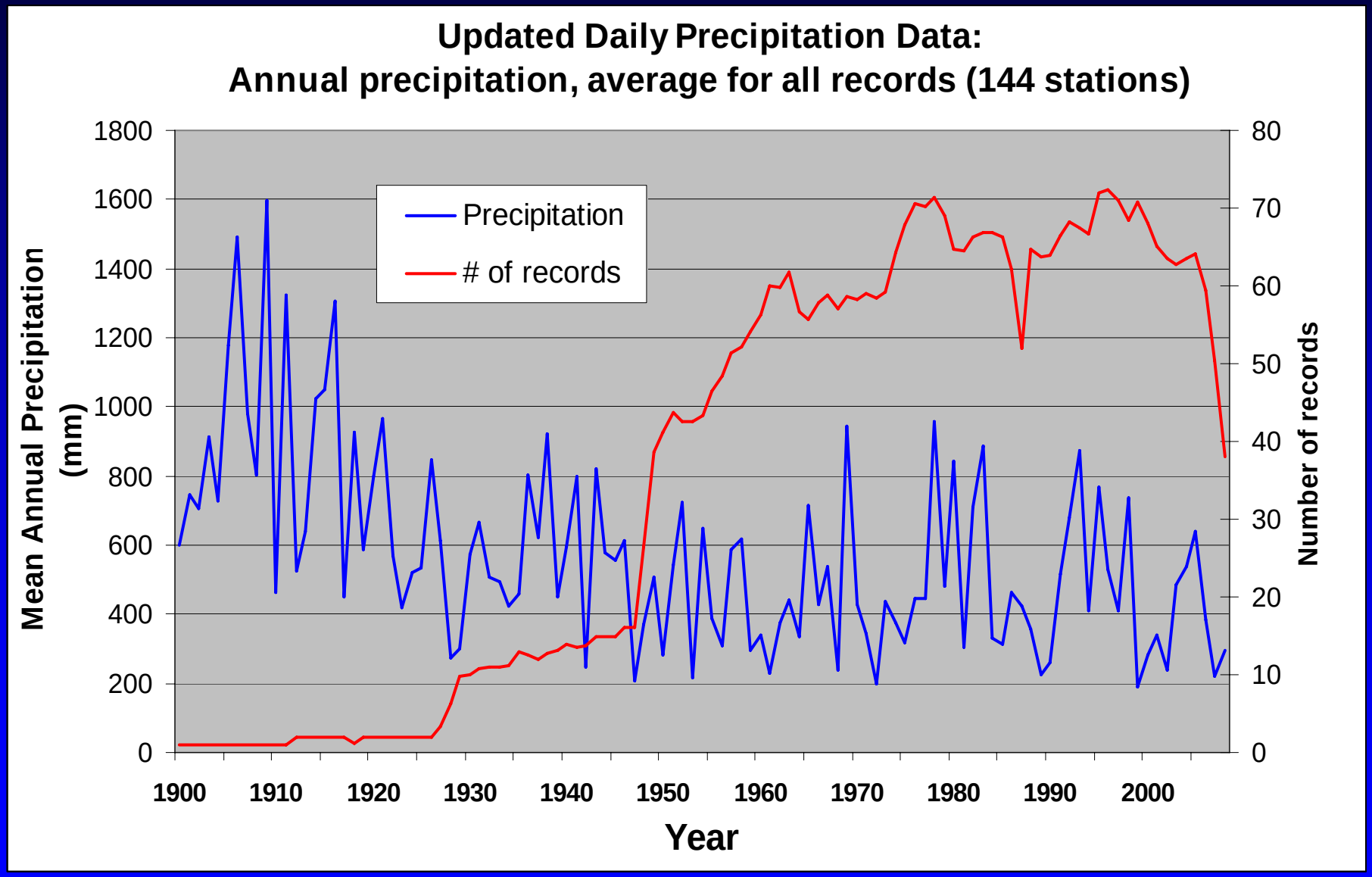
Change in air temperature

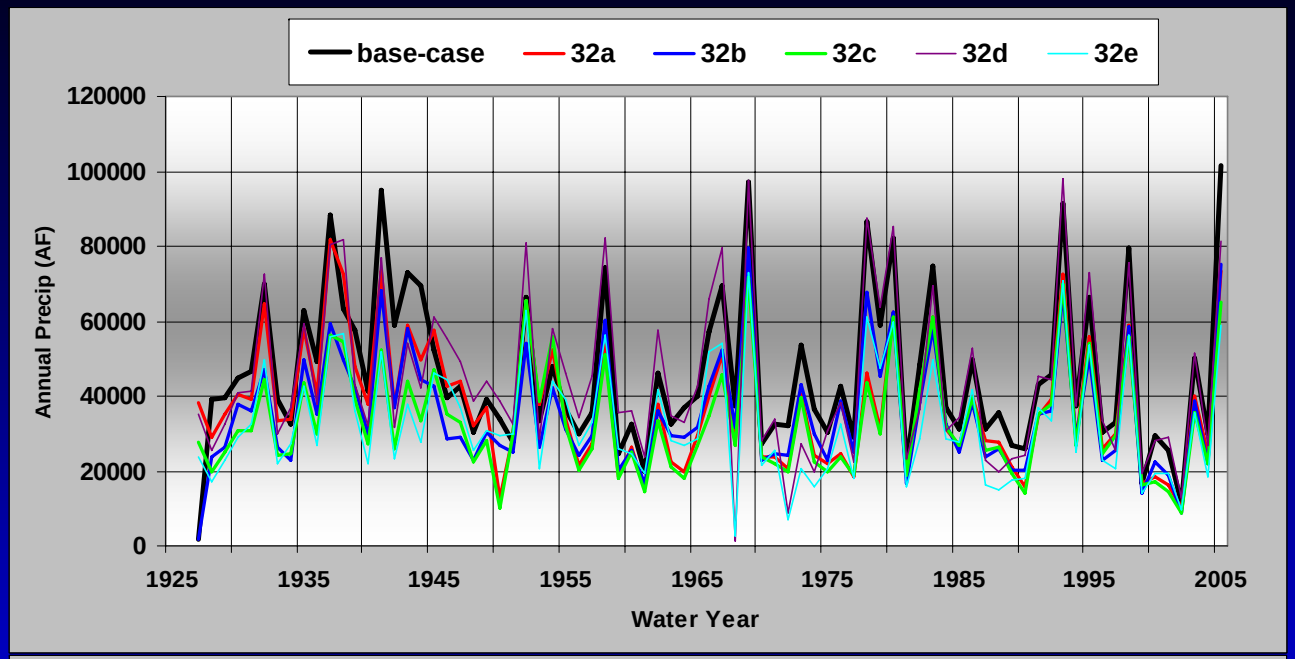


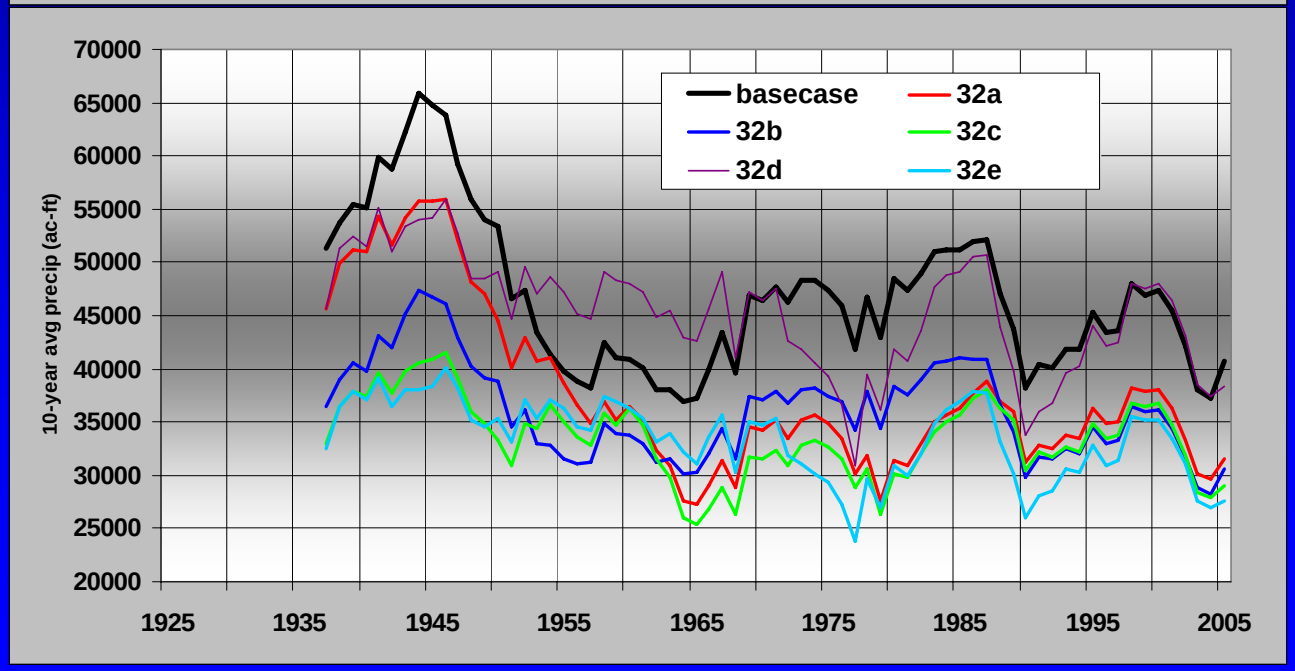
Change in precipitation



Uncertainty in climate inputs







Uncertainty in precipitation input:

1. Selected records

2. Spatial interpolation

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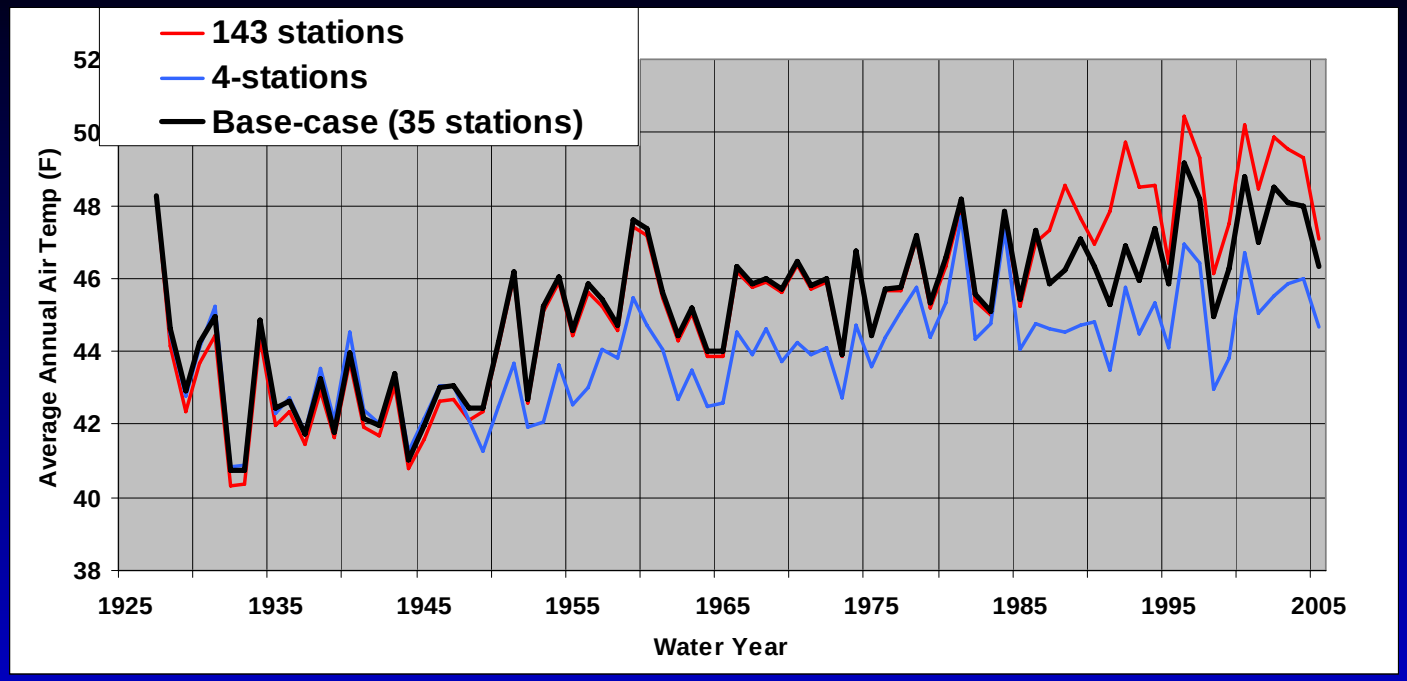
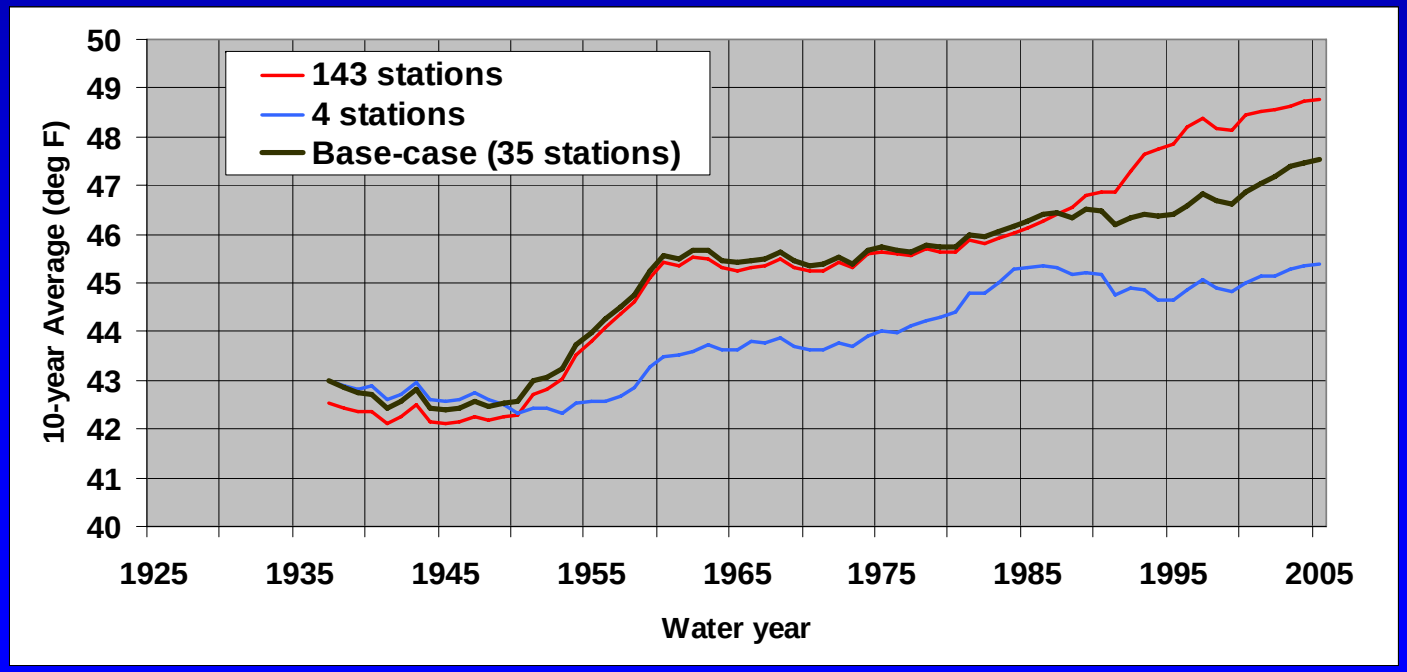


Uncertainty in air temperature inputs



Climate change

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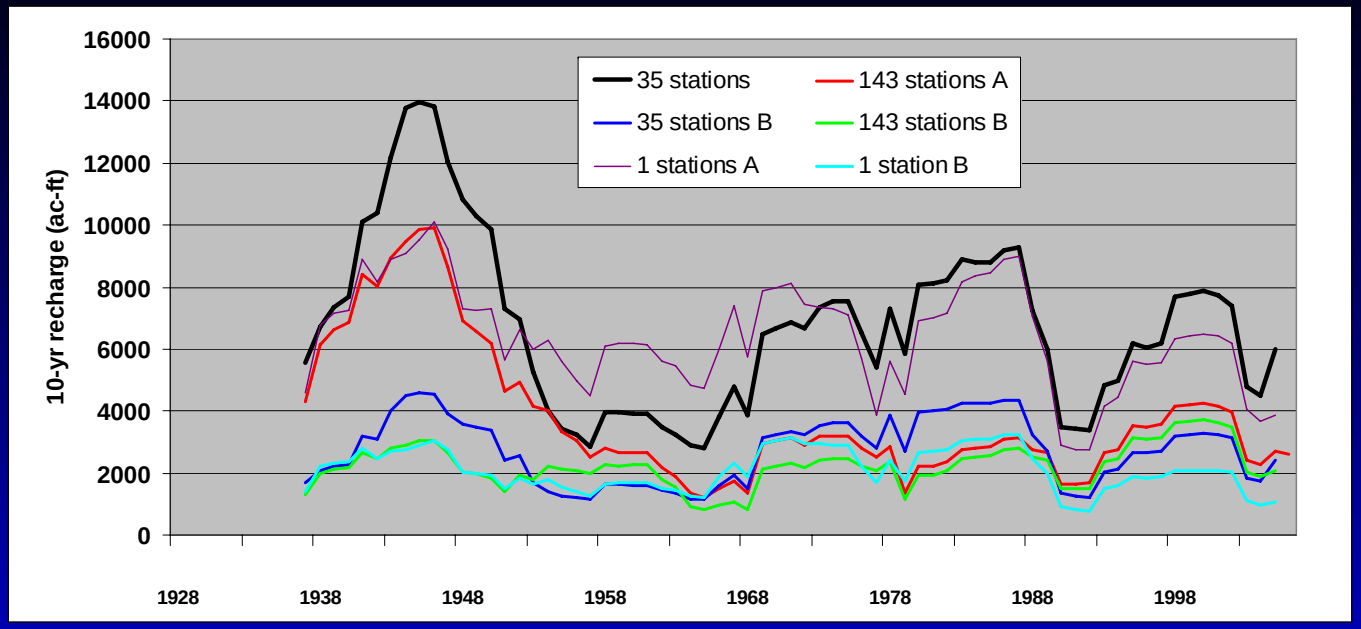

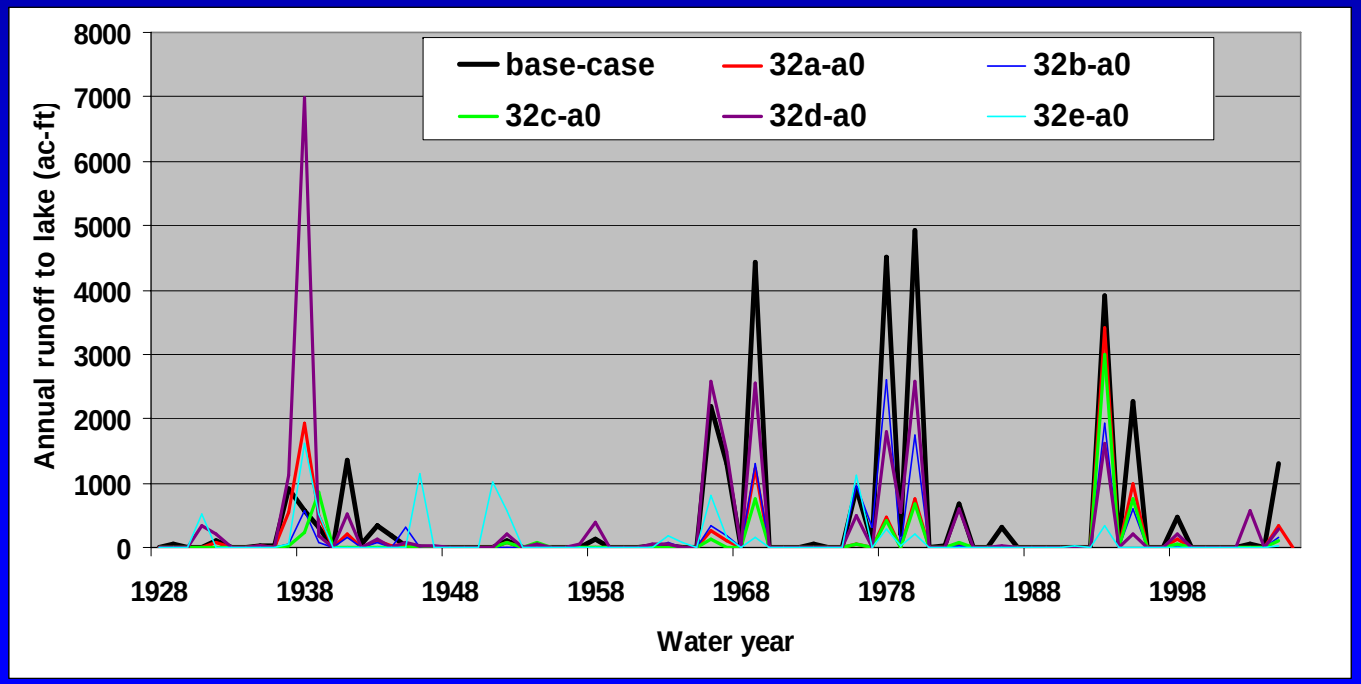

Effect of climate uncertainty on simulated recharge and runoff for the Baldwin Lake sub-basin

Maximum recharge = 6000 acre-ft

Minimum recharge = 2000 acre-ft

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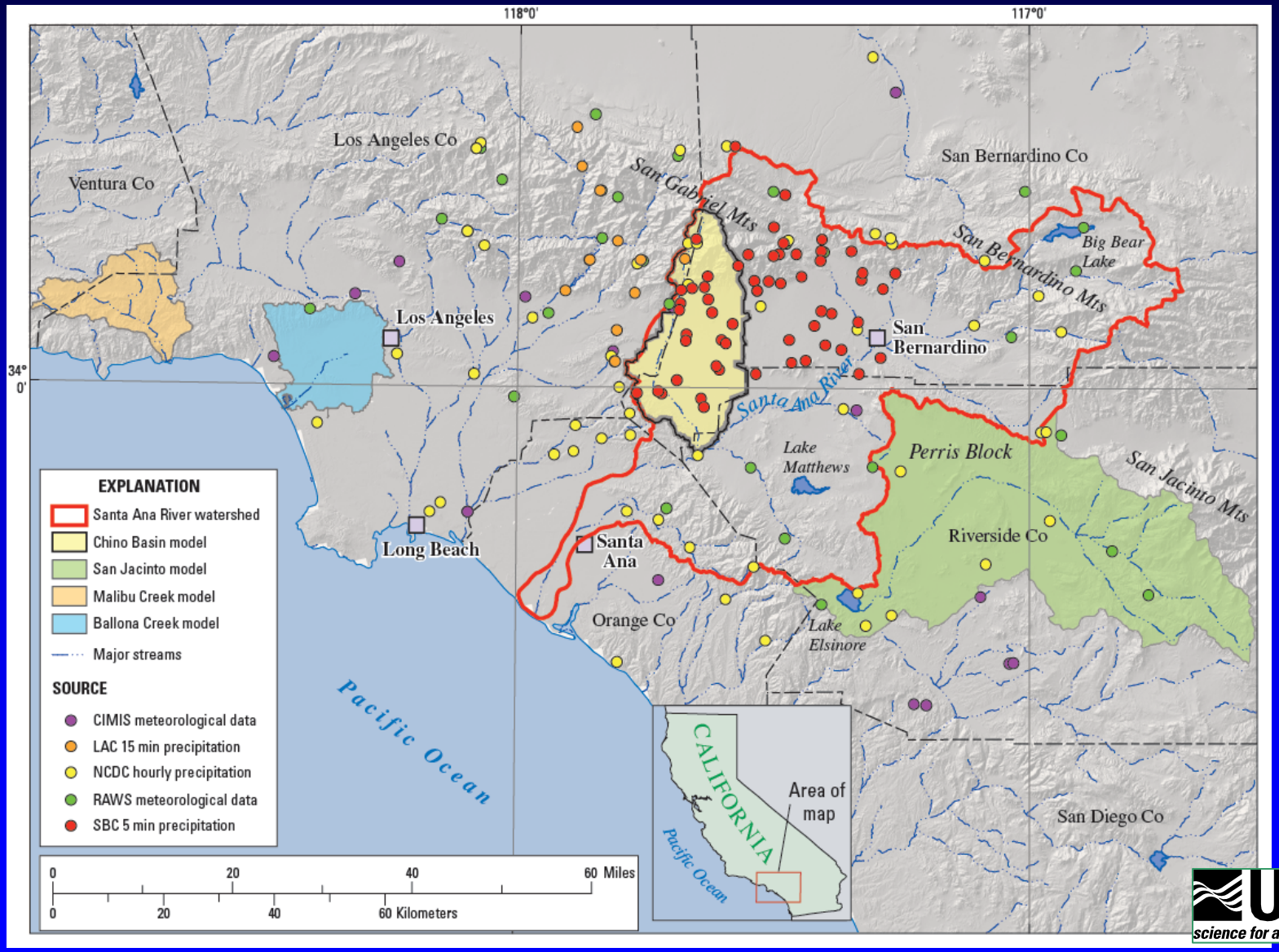
Using a Watershed Model (HSPF) to Evaluate Sources and Transport of Pathogen Indicator Bacteria in the Chino Basin, San Bernardino County, California

Joseph A. Hevesi, Lorraine E. Flint, Clinton D. Church, and Gregory O. Mendez



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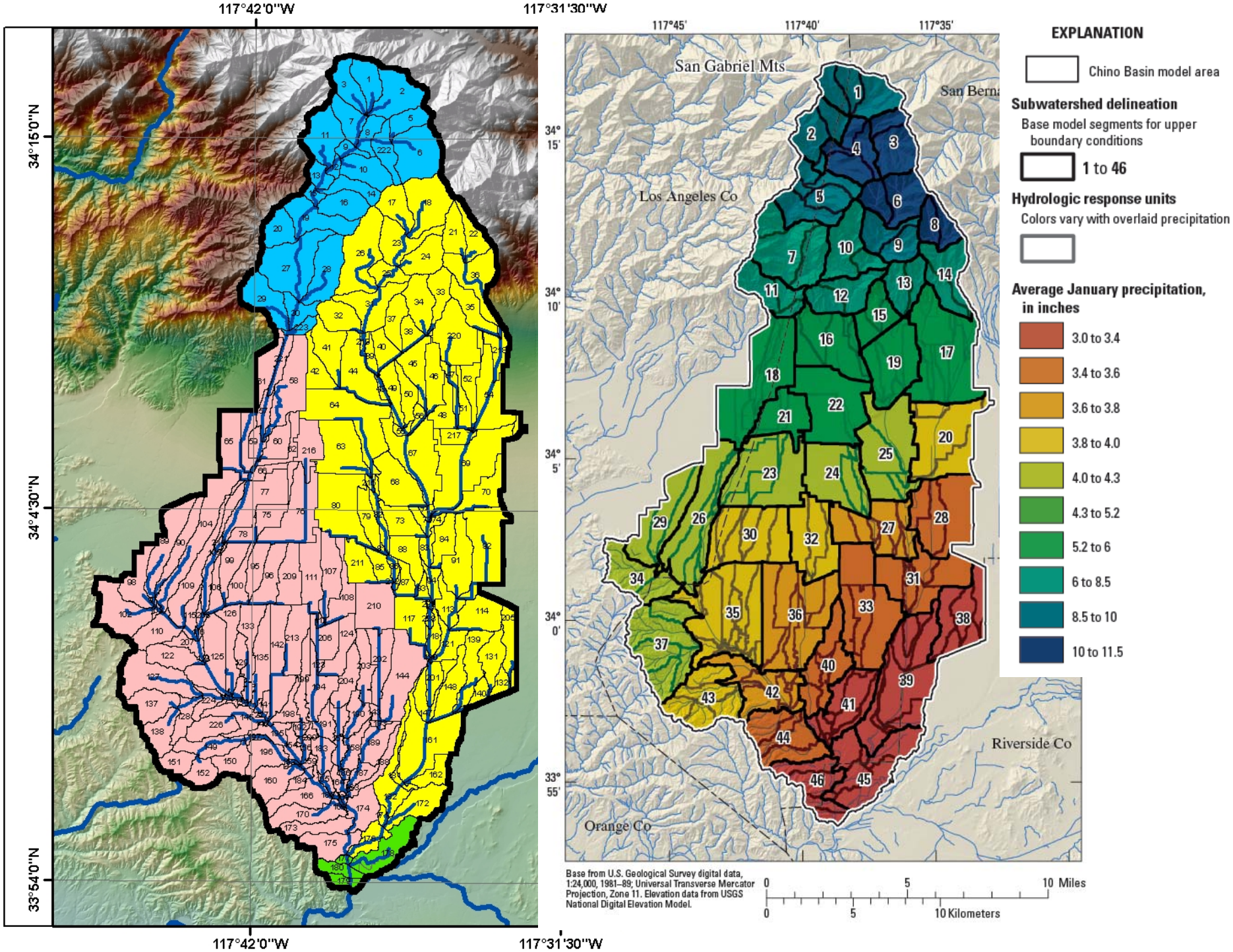
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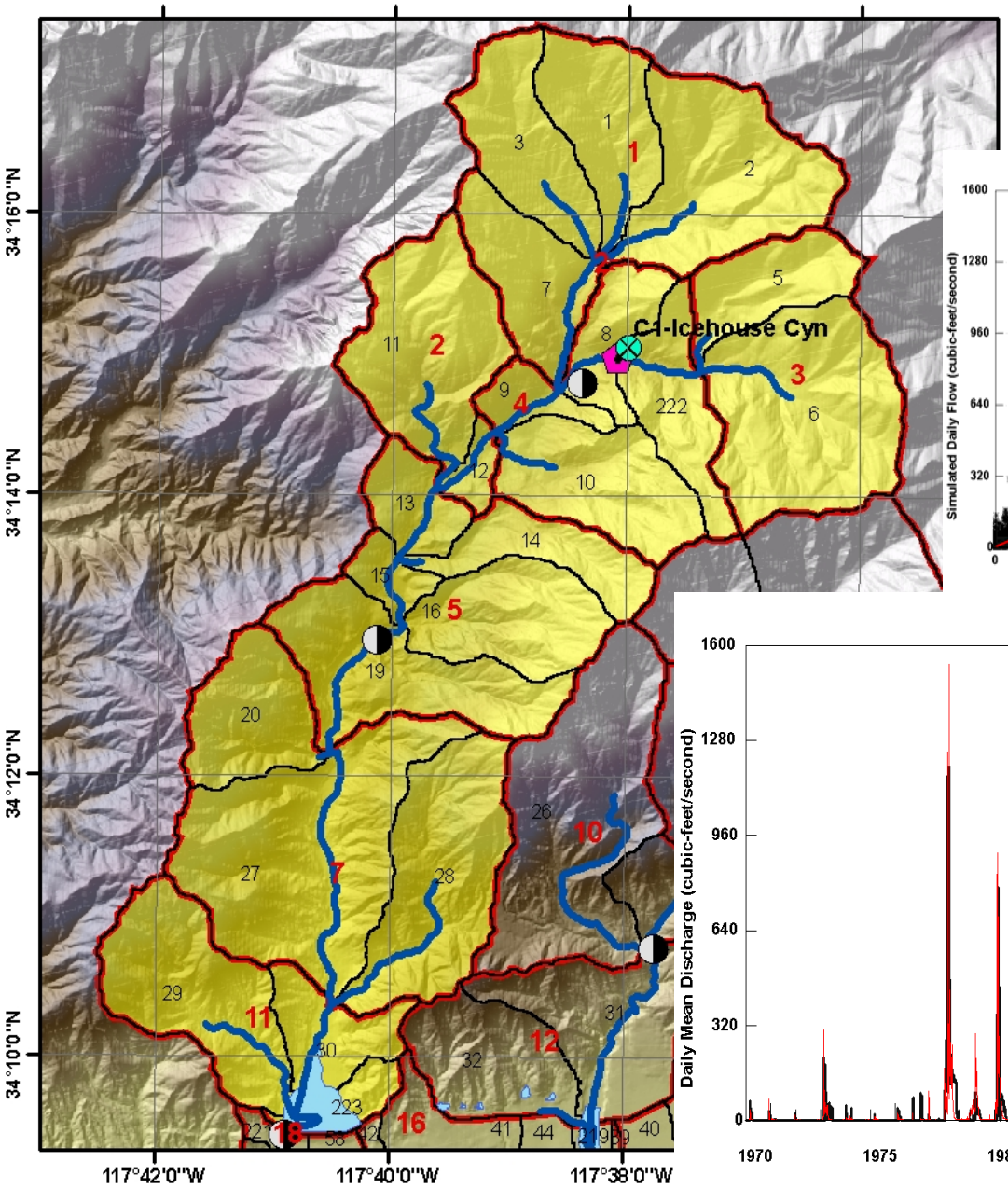
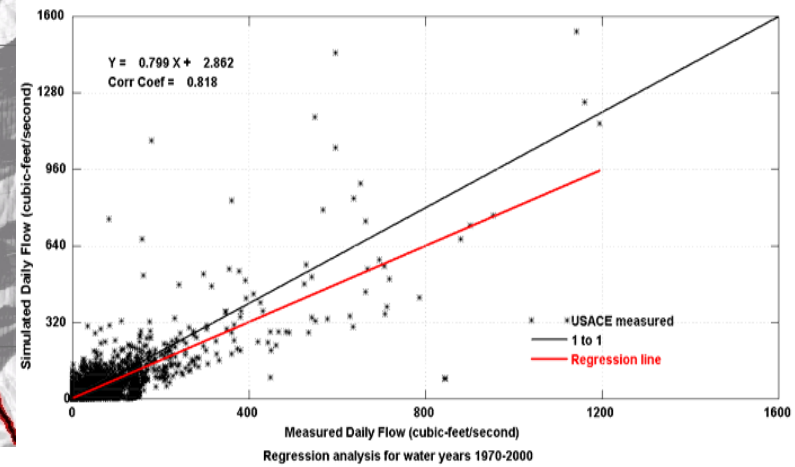
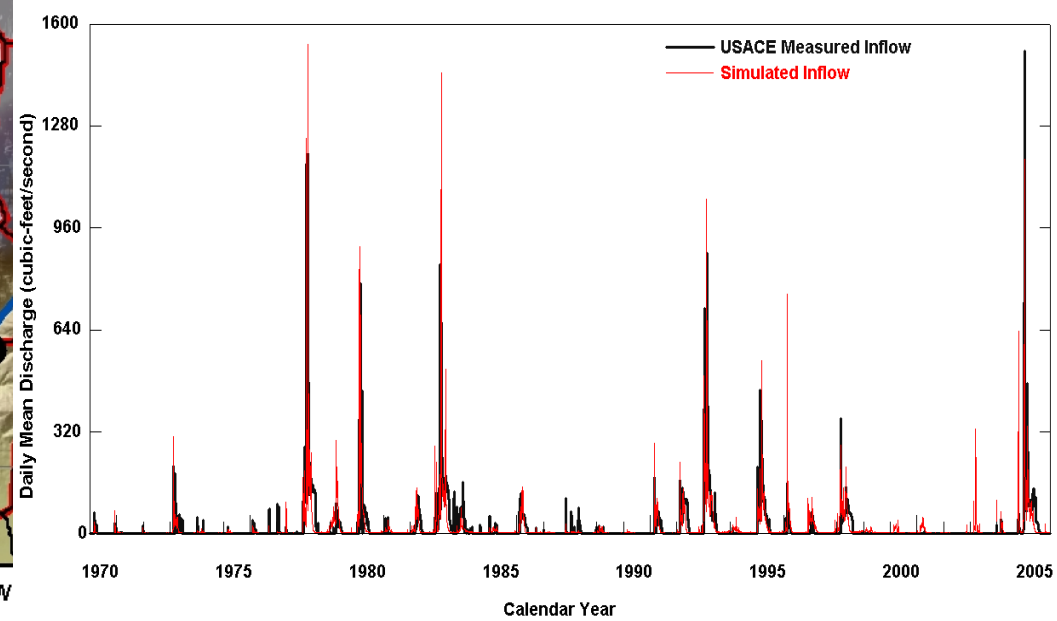
33°54'0"N
117°45'
117°40'
117°35'
34° 15'
34° 10'
34° 5'
34° 0'
33° 55'
San Gabriel Mts
San Berna
Los Angeles Co
Riverside Co
Orange Co
EXPLANATION
Chino Basin model area
Subwatershed delineation
Base model segments for upper boundary conditions
1 to 46
Hydrologic response units
Colors vary with overlaid precipitation
Average January precipitation, in inches
3.0 to 3.4
3.4 to 3.6
3.6 to 3.8
3.8 to 4.0
4.0 to 4.3
4.3 to 5.2
5.2 to 6
6 to 8.5
8.5 to 10
10 to 11.5
Base from U.S. Geological Survey digital data, 1:24,000, 1981–89; Universal Transverse Mercator Projection, Zone 11. Elevation data from USGS National Digital Elevation Model.
0 5 10 Miles
0 5 10 Kilometers

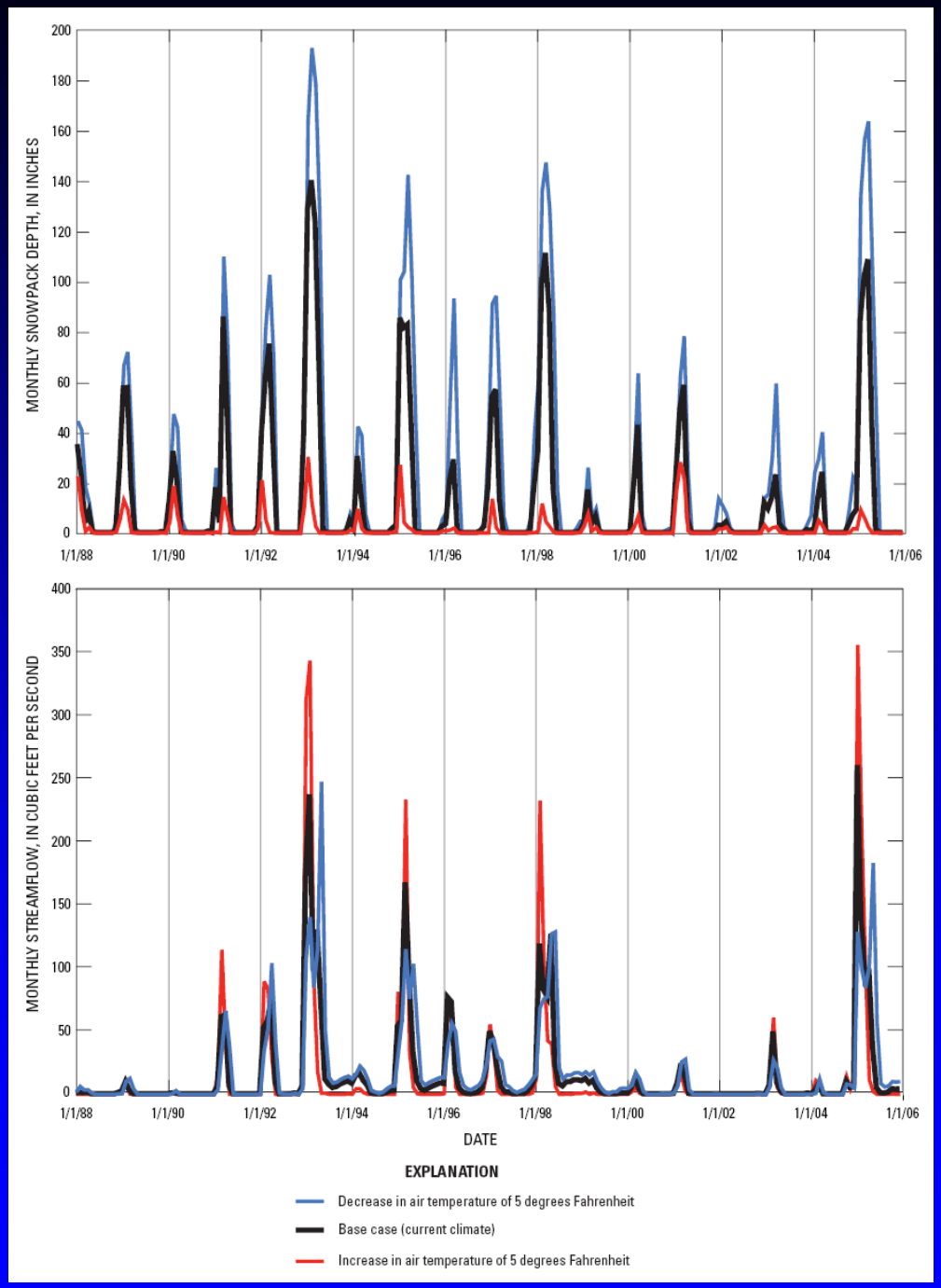
San Antonio Canyon sub-model







San Antonio Canyon climate scenarios: HSPF simulated snow depth and streamflow



- **Red: + 5 deg F air temperature shift: higher winter peak flow, less spring and summer baseflow**
- **Blue: - 5 deg F air temperature shift: lower winter flow, higher spring and summer baseflow**

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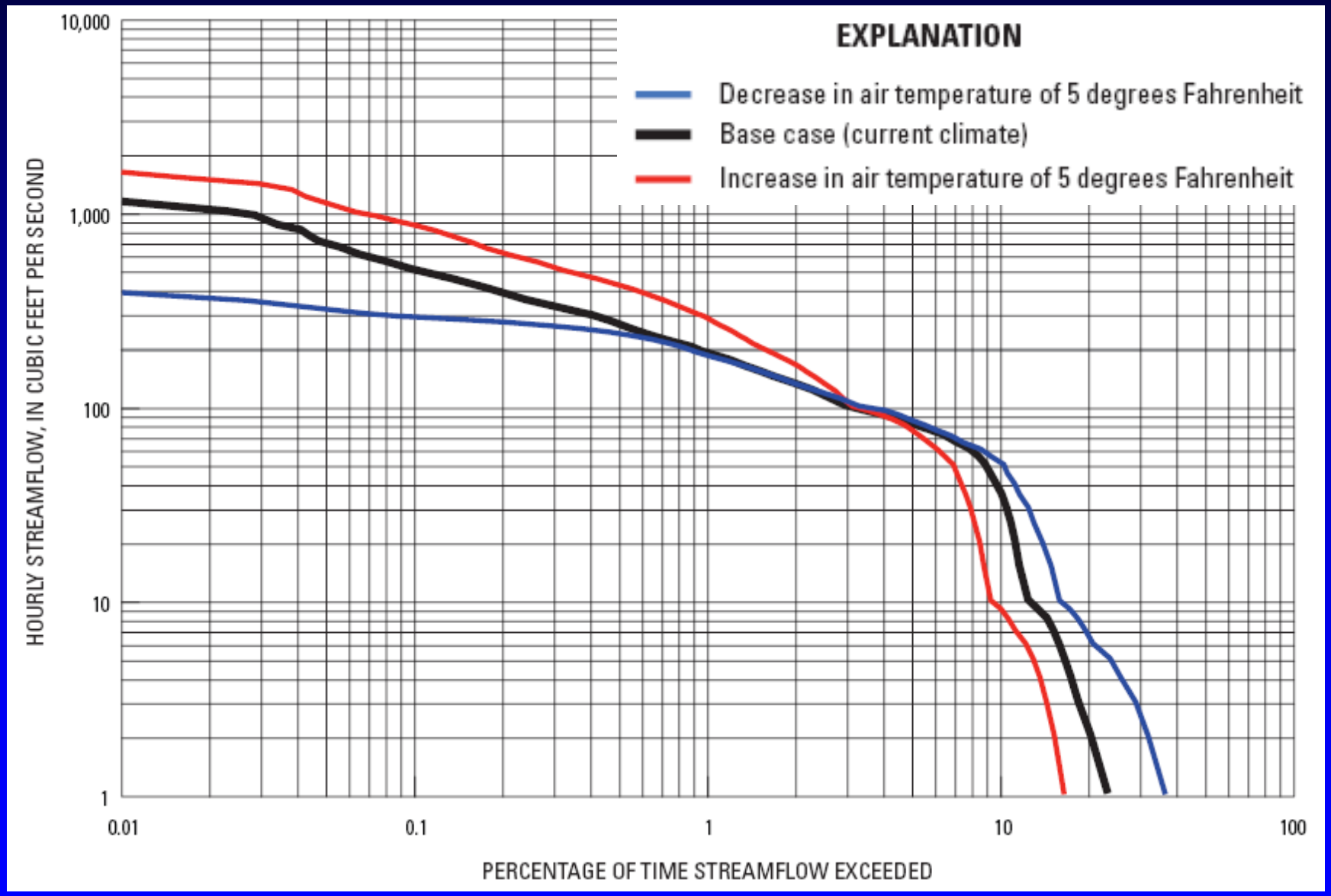
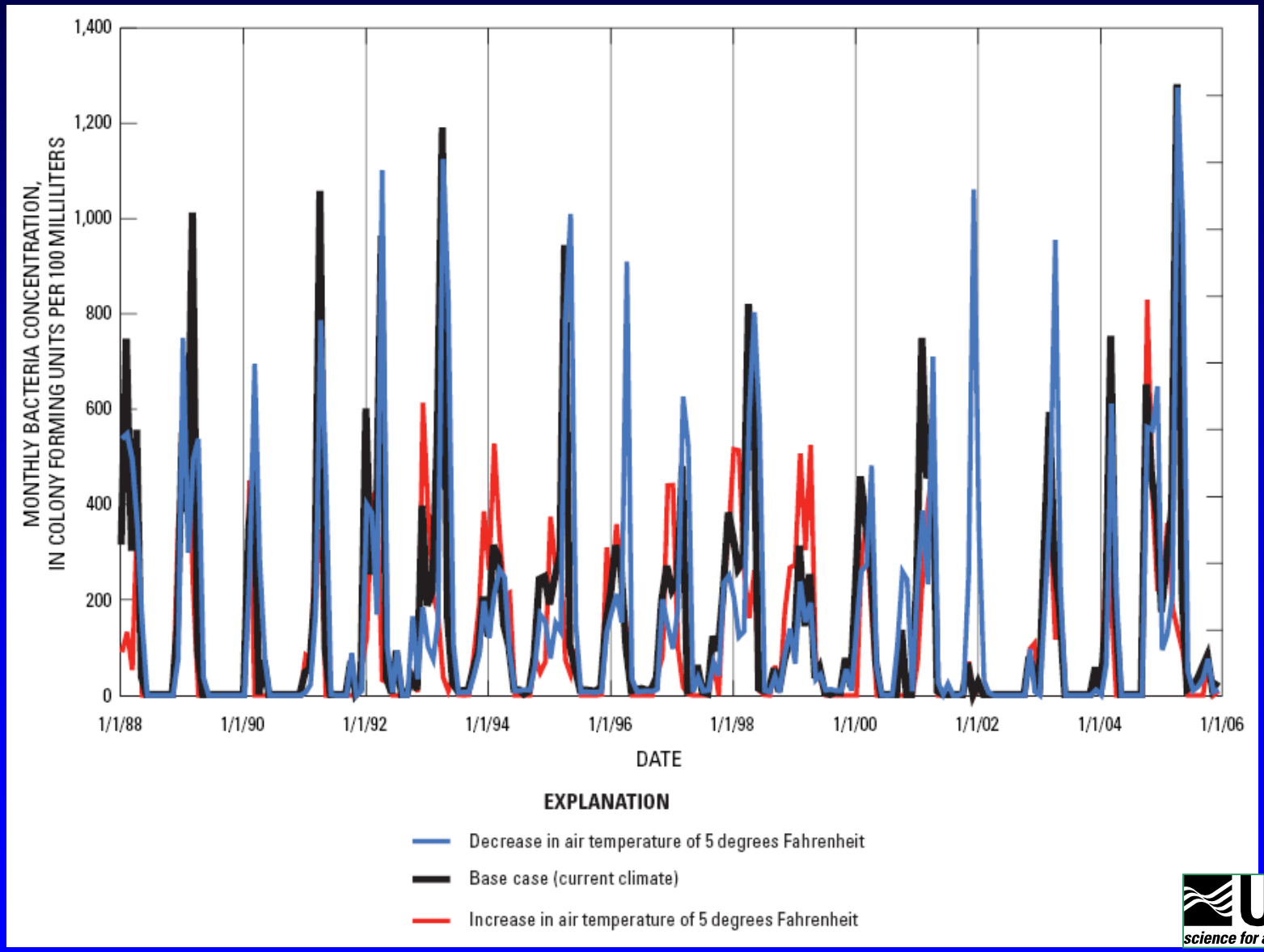
San Antonio Canyon HSPF Simulated Streamflow



San Antonio Canyon HSPF simulated bacteria concentration



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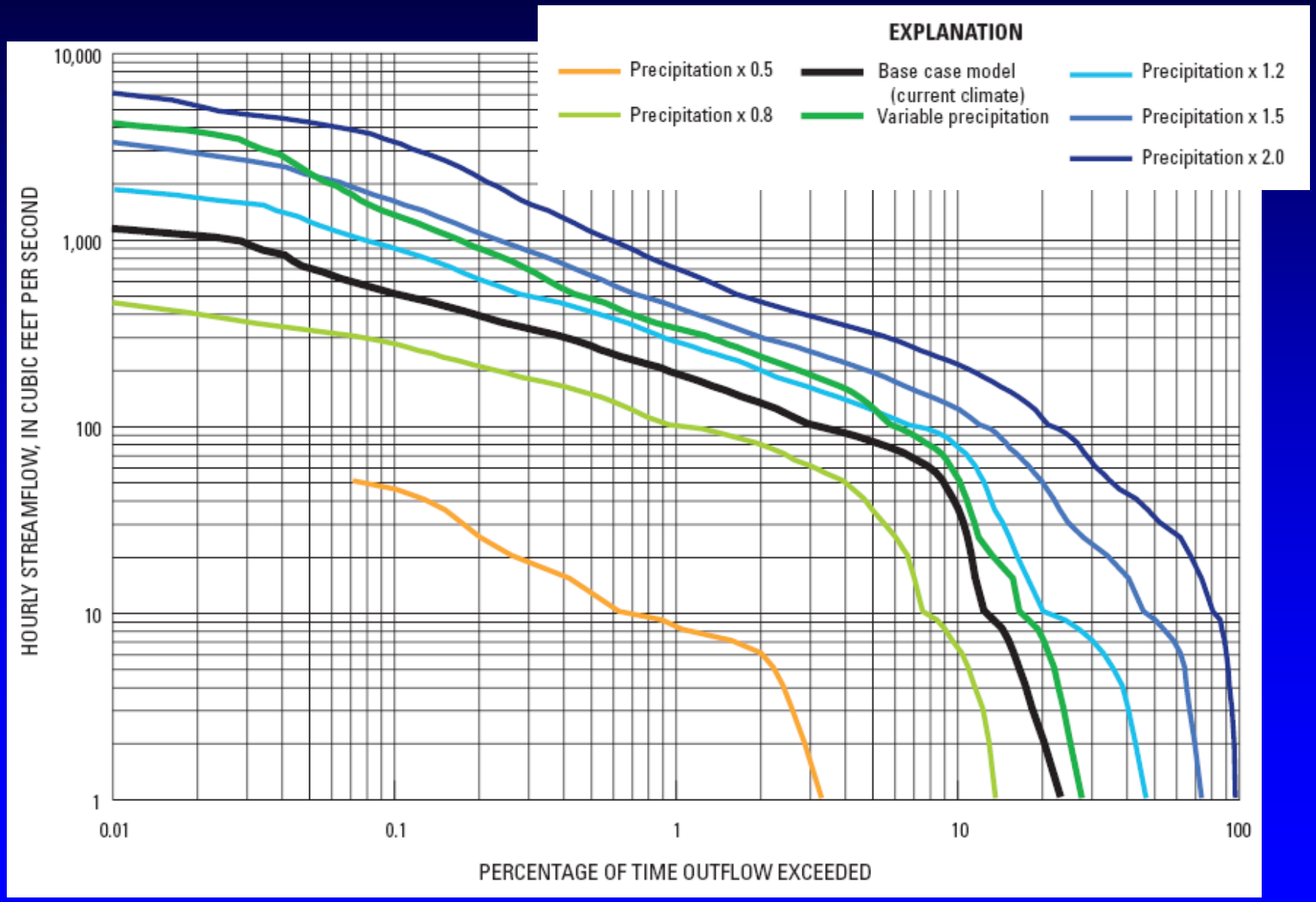
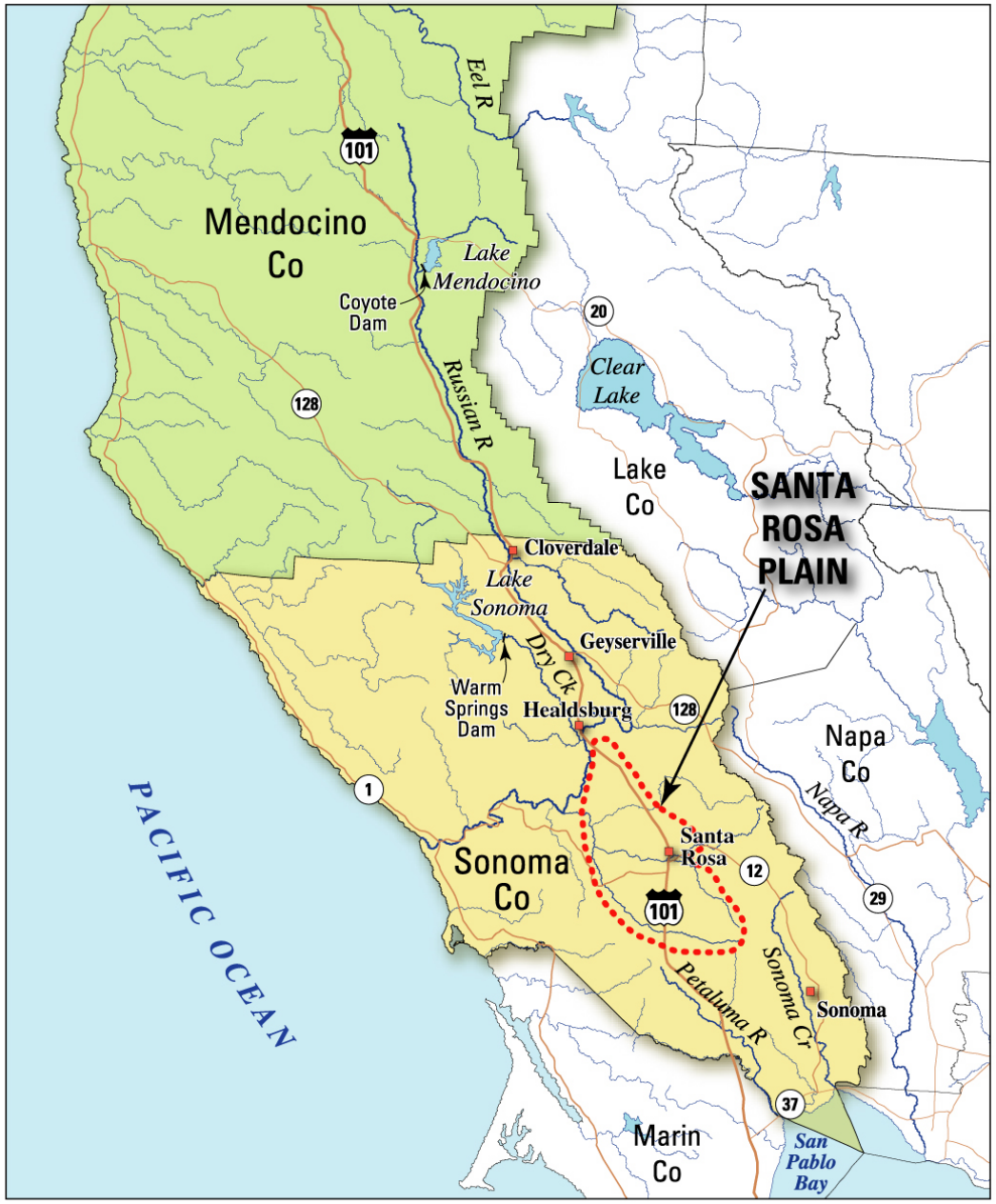
San Antonio Canyon HSPF Simulated Streamflow





Santa Rosa Plain ground-water study

- Database/GIS
  - Kathryn Koczot
  - Andy Morita
- Data Collection/Interpretation
  - Loren Metzger
  - Chris Farrar
- Geologic Modeling
  - Victoria Langenheim
  - Robert McLaughlin
  - Robert Jachens
- Lithologic Modeling
  - Don Sweetkind
  - Emily Taylor
- SW & GW Modeling
  - Linda Woolfenden
  - Diane Rewis
  - Joe Hevesi
  - Tracy Nishikawa
  - Eric Reichard

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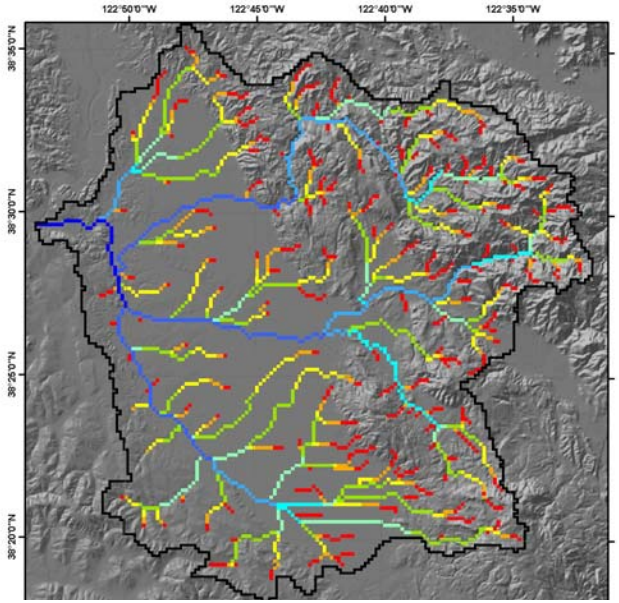
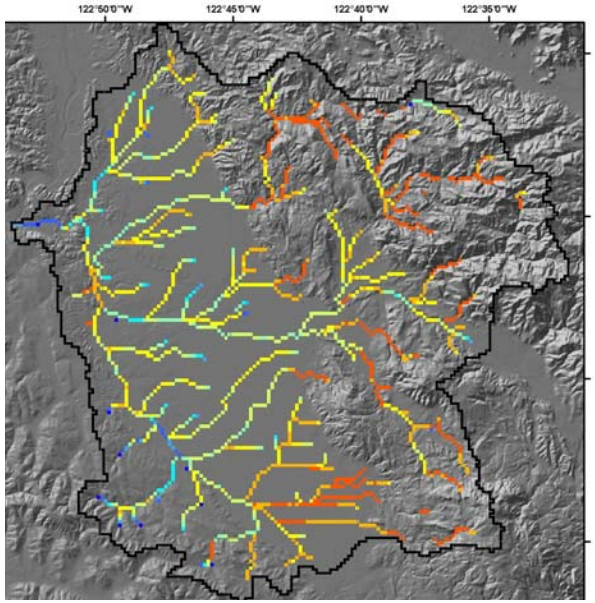
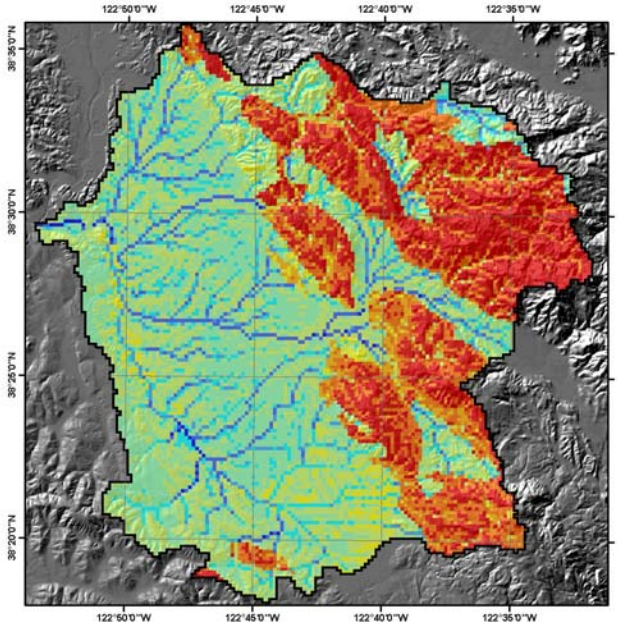
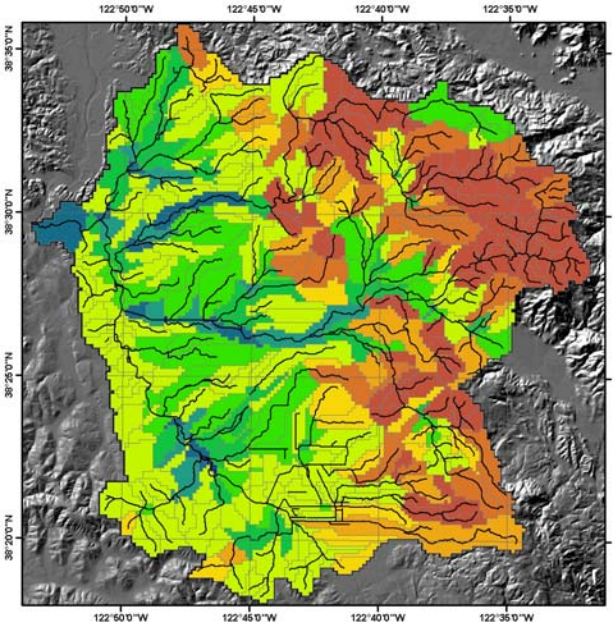
Santa Rosa Plain Recharge Model (INFIL3.0)









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GSFLOW: Coupled Ground-water and Surface-water FLOW model based on the USGS Precipitation-Runoff Modeling System (PRMS) and Modular Ground-Water Flow Model (MODFLOW-2005)

Markstrom, S.L., Niswonger, R.G., Regan, R.S., Prudic, D.E., and Barlow, P.M., 2008

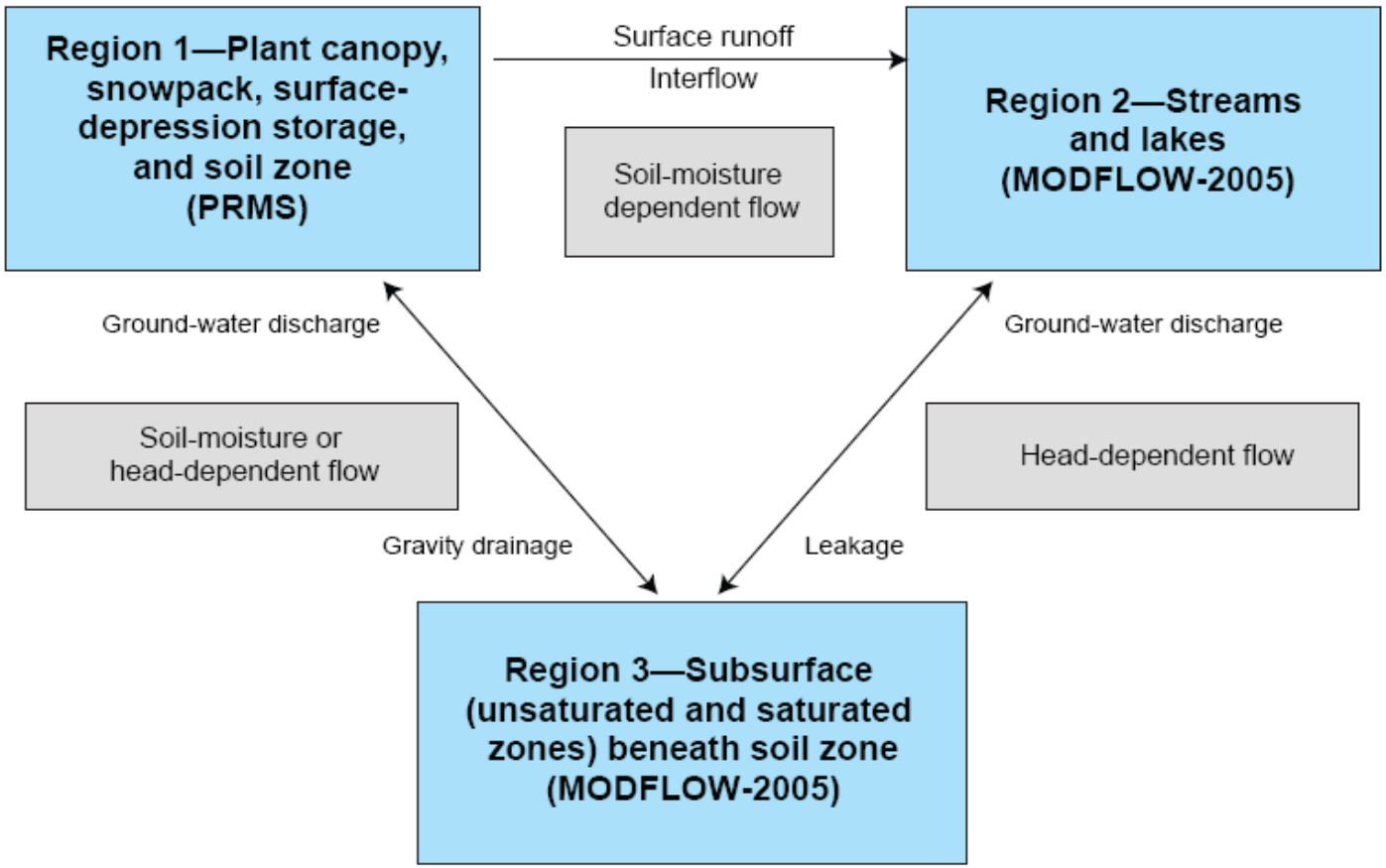

Figure 11. Schematic diagram of the exchange of flow among the three regions in GSFLOW. The dependency on soil moisture and head in the computation of flow among the regions also is shown.

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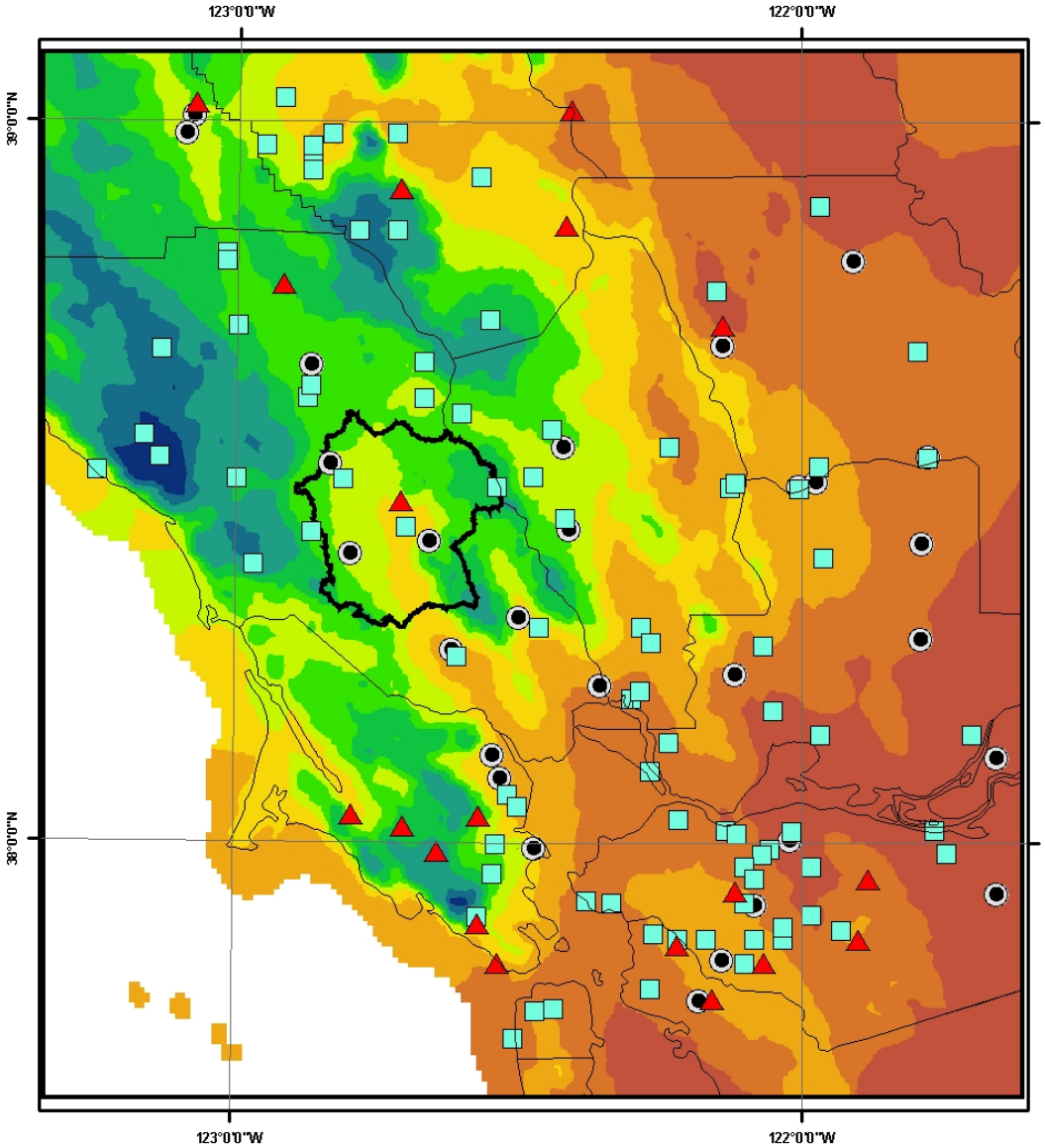
Spatially-interpolated climate inputs



PRISM 1971-2000 average January precipitation (inches)

- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Climate records

- RAWS (hourly)
- CIMIS (hourly)
- NCDC (daily)

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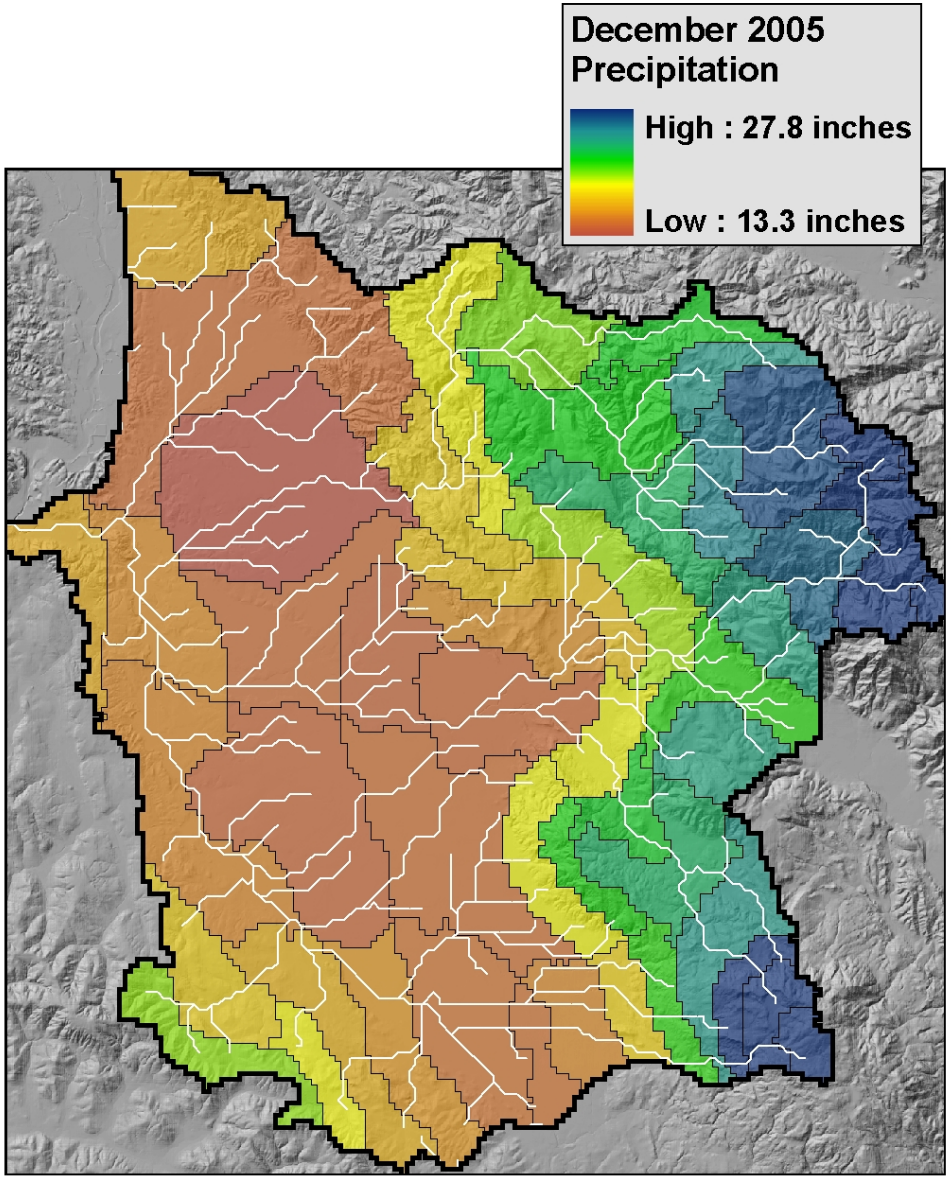
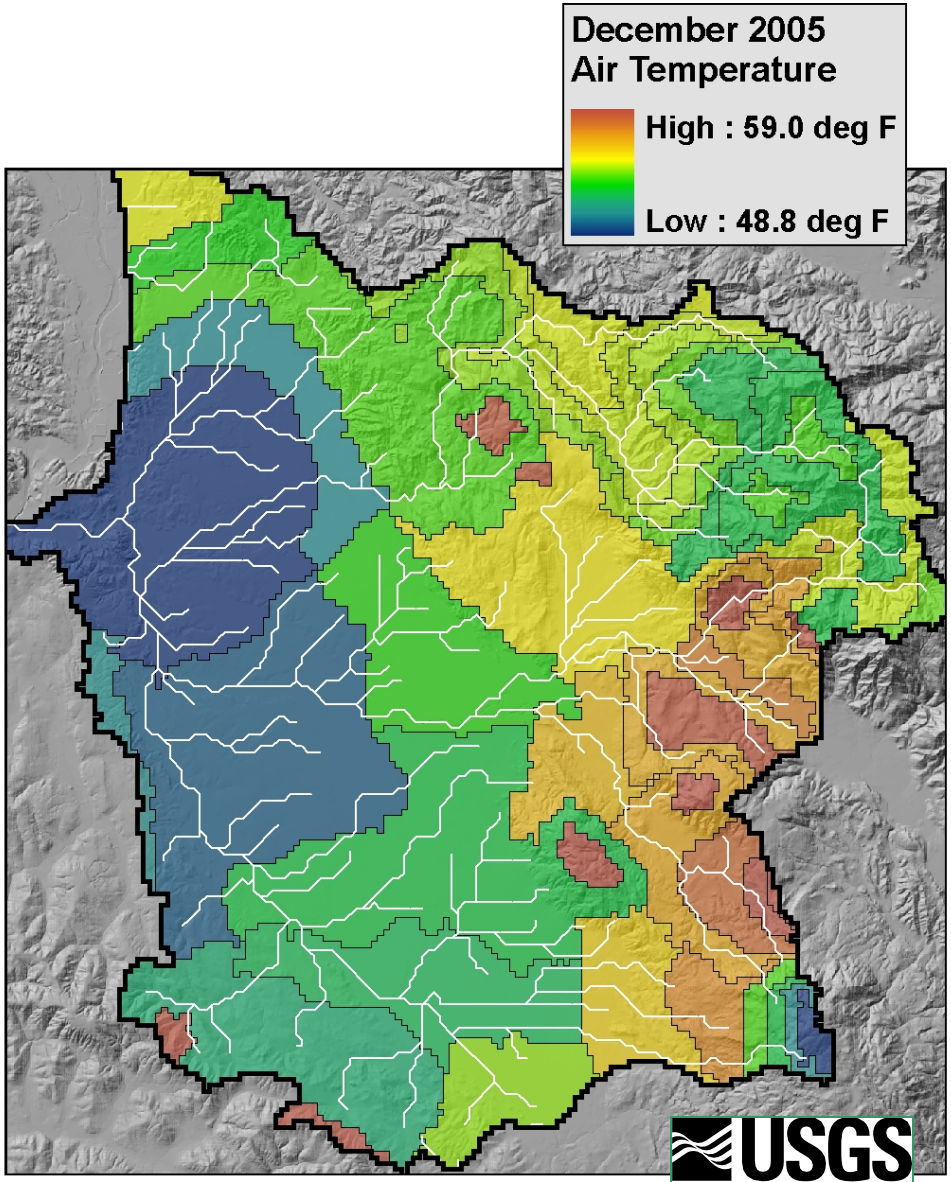
December 2005 Distributed Climate Input





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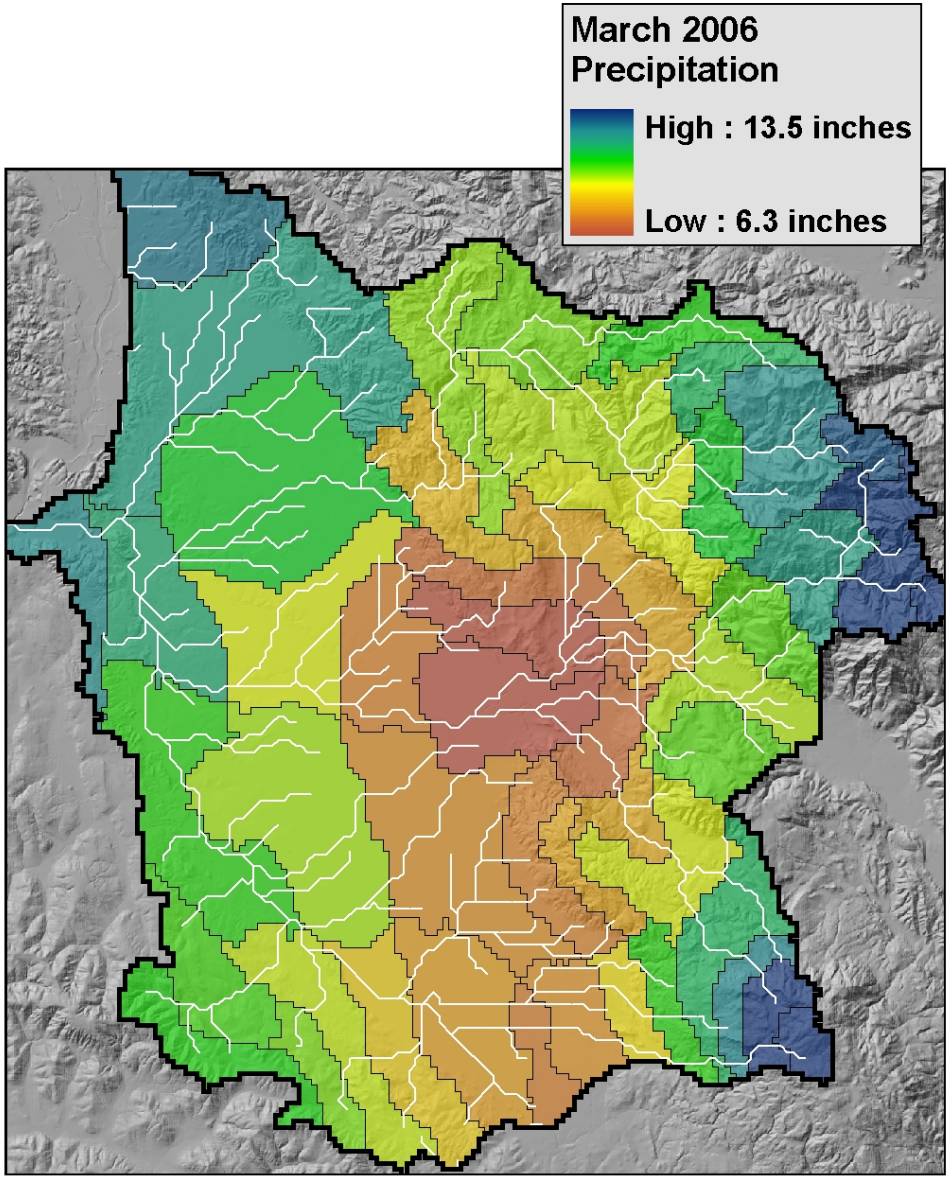
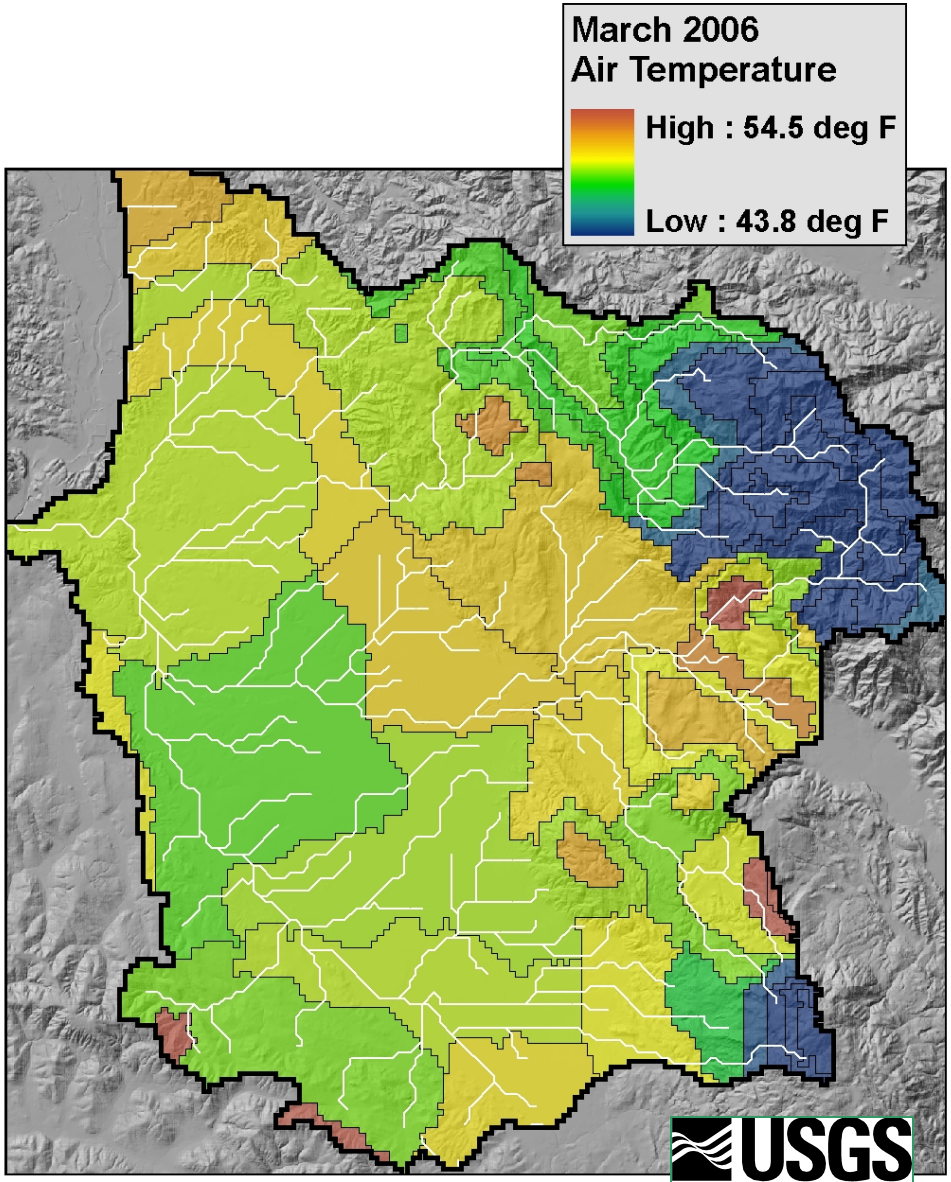
March 2006 Distributed Climate Input





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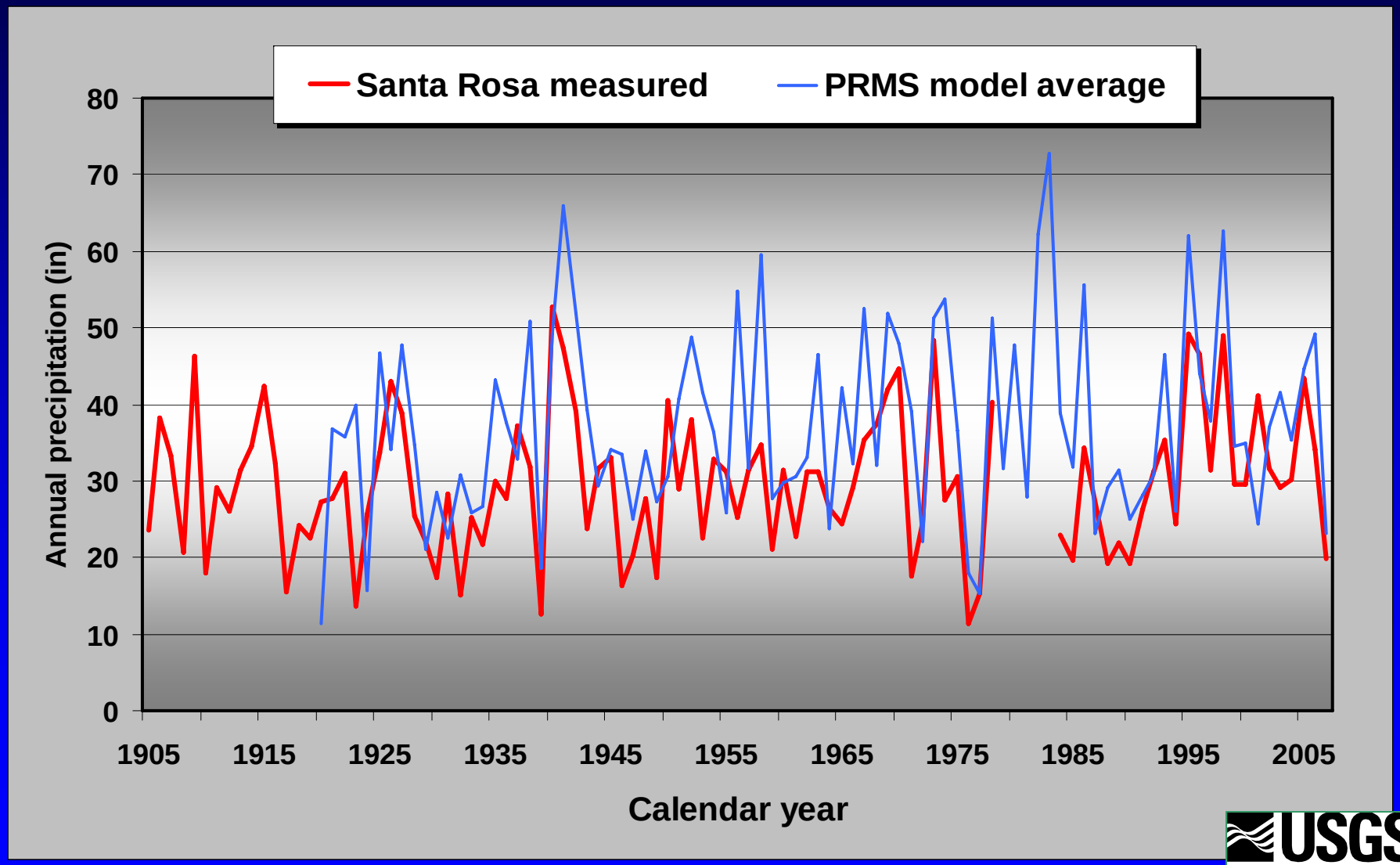
Comparison of precipitation interpolated for PRMS model area with record at Santa Rosa



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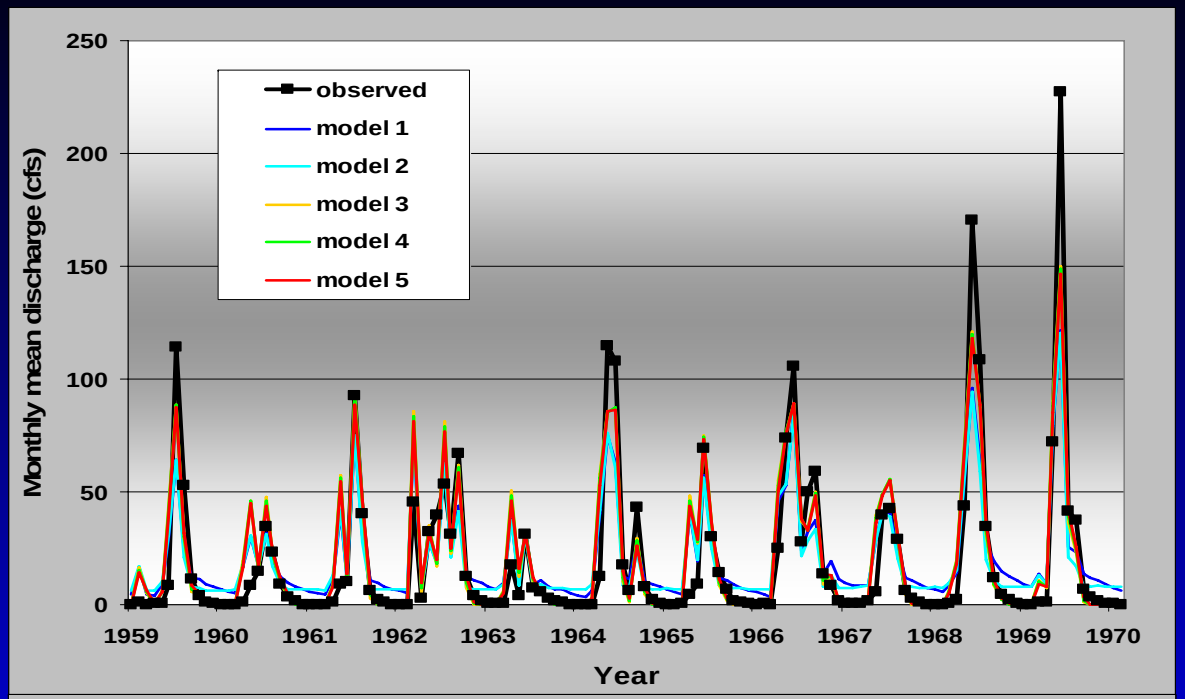
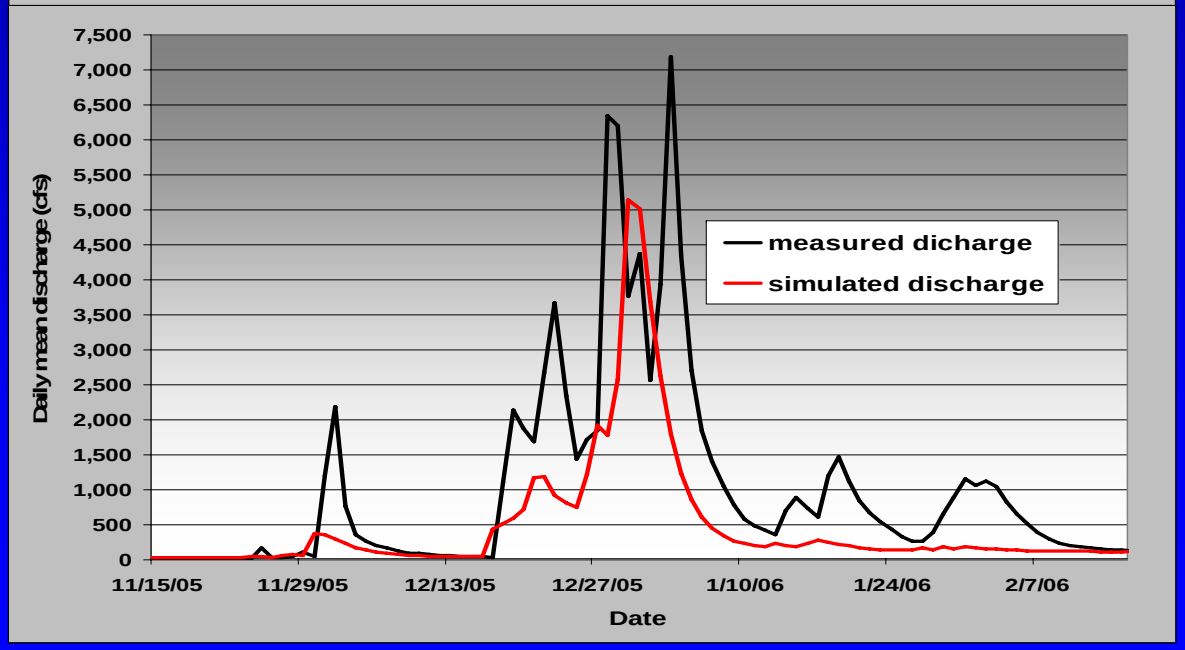
PRMS model calibration (preliminary models)



Santa Rosa Creek (gage 11465800)



Mark West Creek (gage 11466800)

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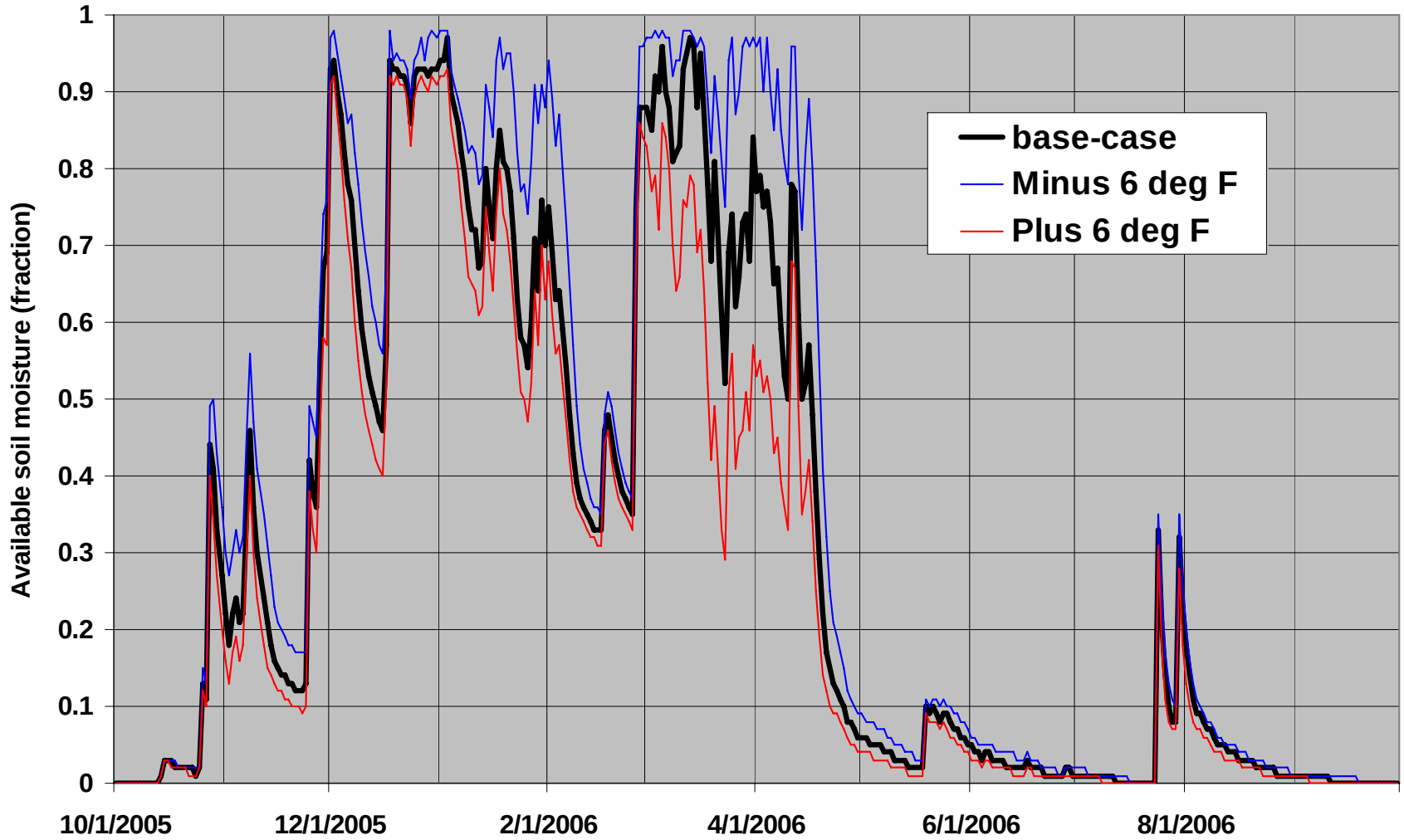
PRMS simulated soil moisture



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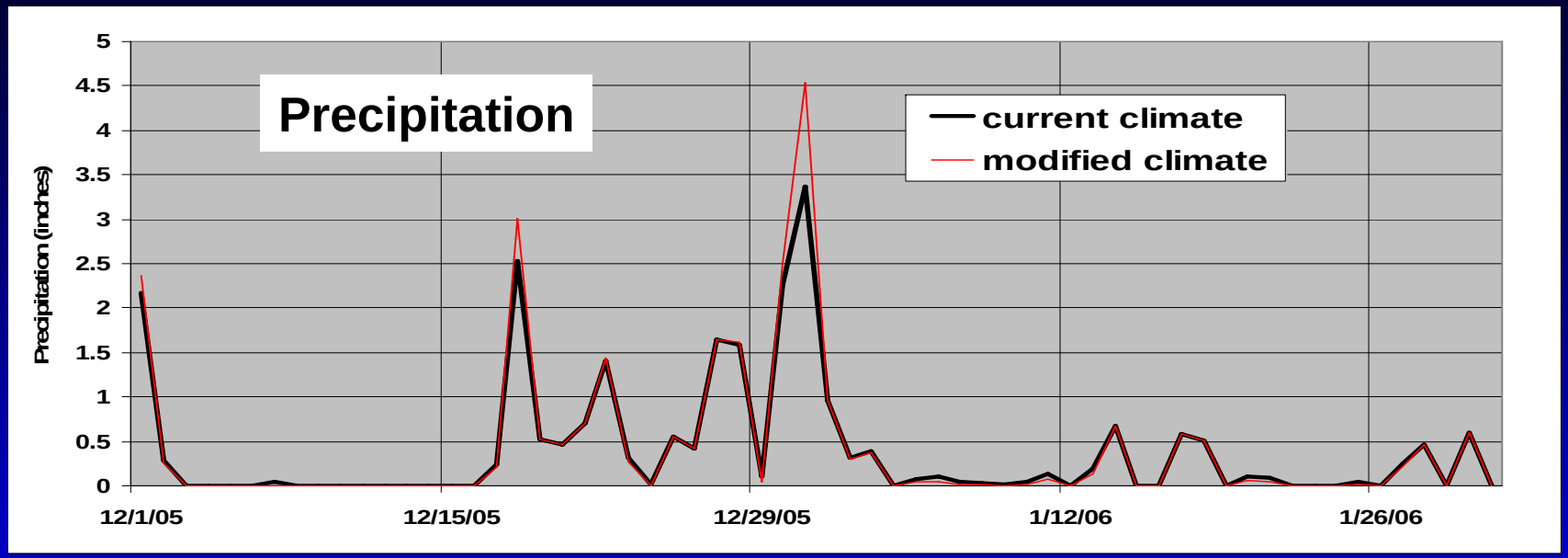
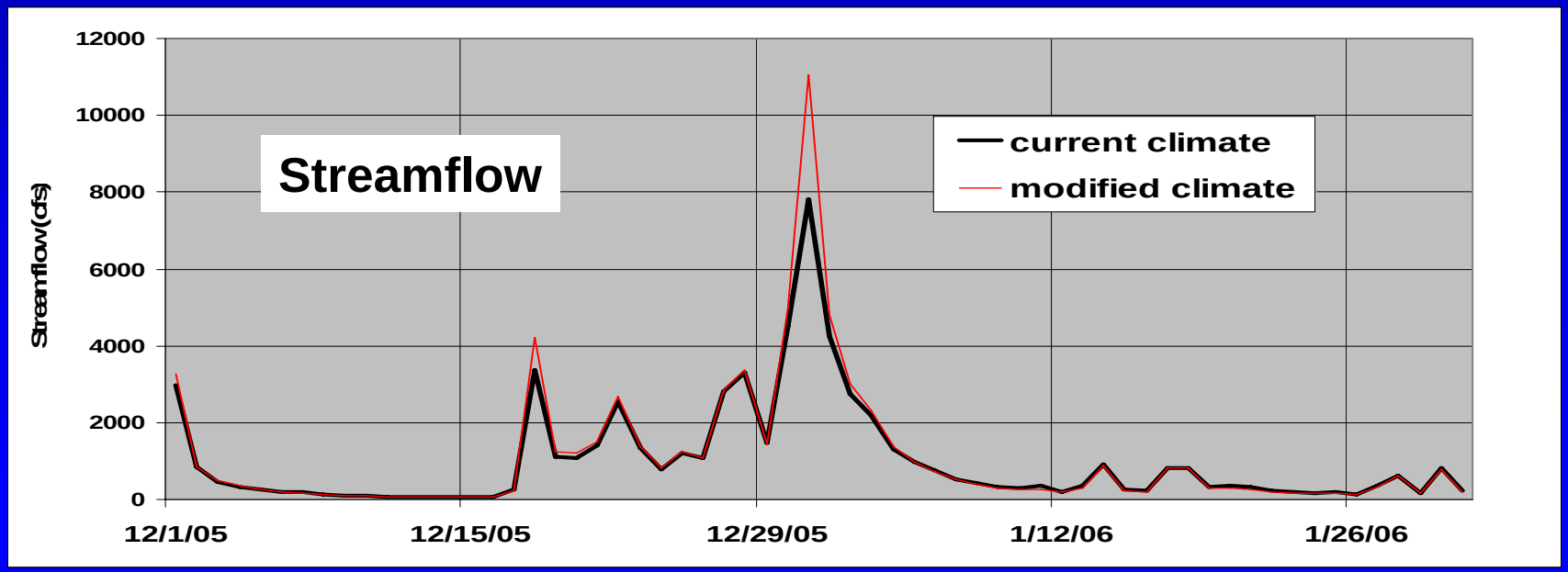
Modified climate: increased precipitation intensity





Preliminary findings

- Simulated streamflow can be very sensitive to air temperature changes for basins where snowfall is prevalent
- Higher air temperature causes higher peak flows in winter, along with a decrease in recharge and lower base flow in spring and summer
- Simulated recharge and runoff are more sensitive to changes in precipitation for drier (semi-arid) basins
- Model calibration sensitive to uncertainties in existing (historical) records that characterize current climate, especially for locations where spatial variability is high.

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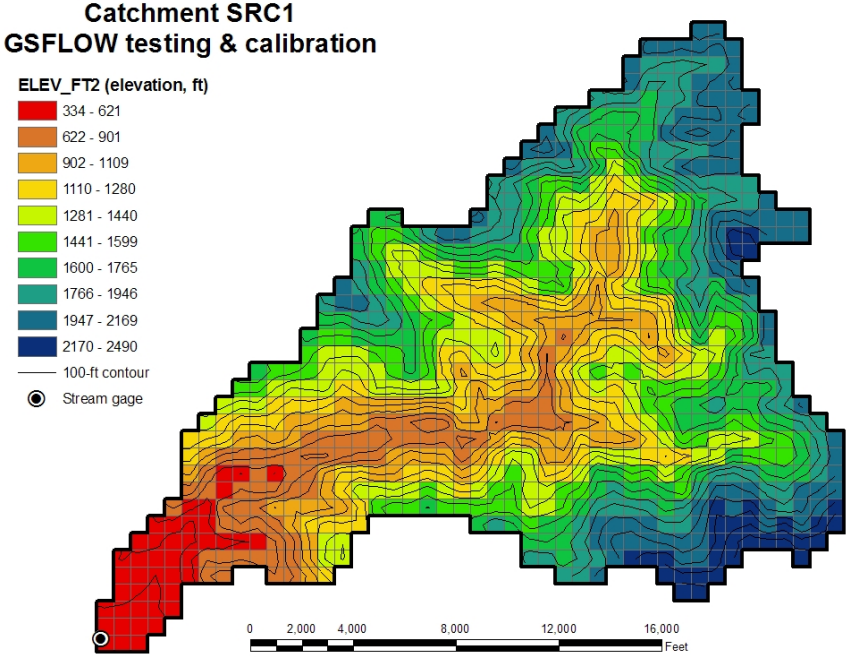
Analysis of surface-water and seepage contributions to recharge:

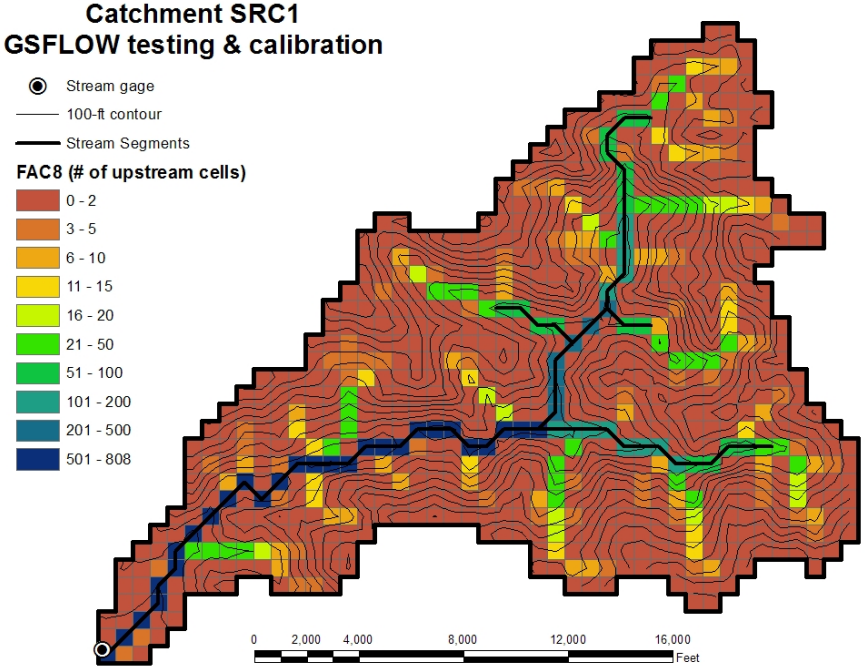
	Big Bear Lake Basin (acre-feet/year)				
	Base case model	De-coupled Runoff	Percent change	No seepage flow	Percent change
Precipitation	44,200	44,200	0	44,200	0
ET	32,300	30,900	-4	29,400	-9
Recharge	4,000	1,800	-55	7,600	90
SW outflow to lake	5,400	9,100	69	4,900	-9

	Baldwin Lake Basin (acre-feet/year)				
	Base case model	De-coupled Runoff	Percent change	No seepage flow	Percent change
Precipitation	44,000	44,000	0	44,000	0
ET	35,000	33,300	-5	32,700	-7
Recharge	6,000	2,400	-60	8,400	40
SW outflow to lake	500	5,800	1,100	440	-12

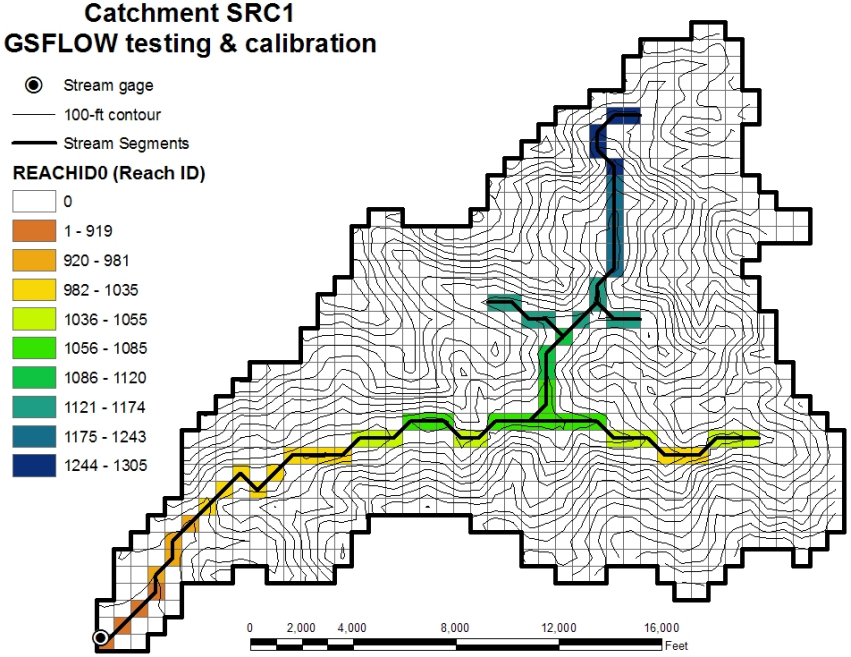
Catchment SRC1
GSFLOW testing & calibration



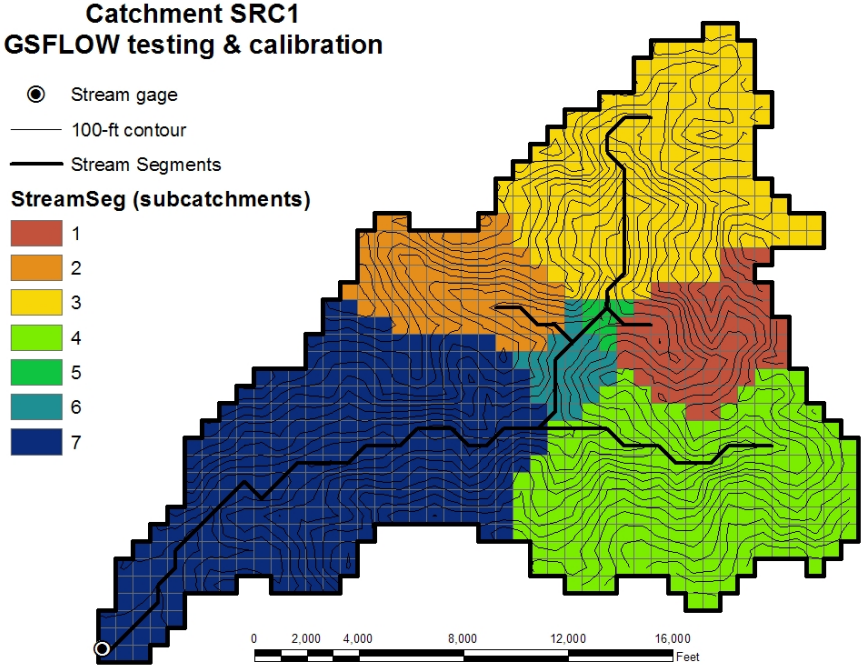
Catchment SRC1
GSFLOW testing & calibration



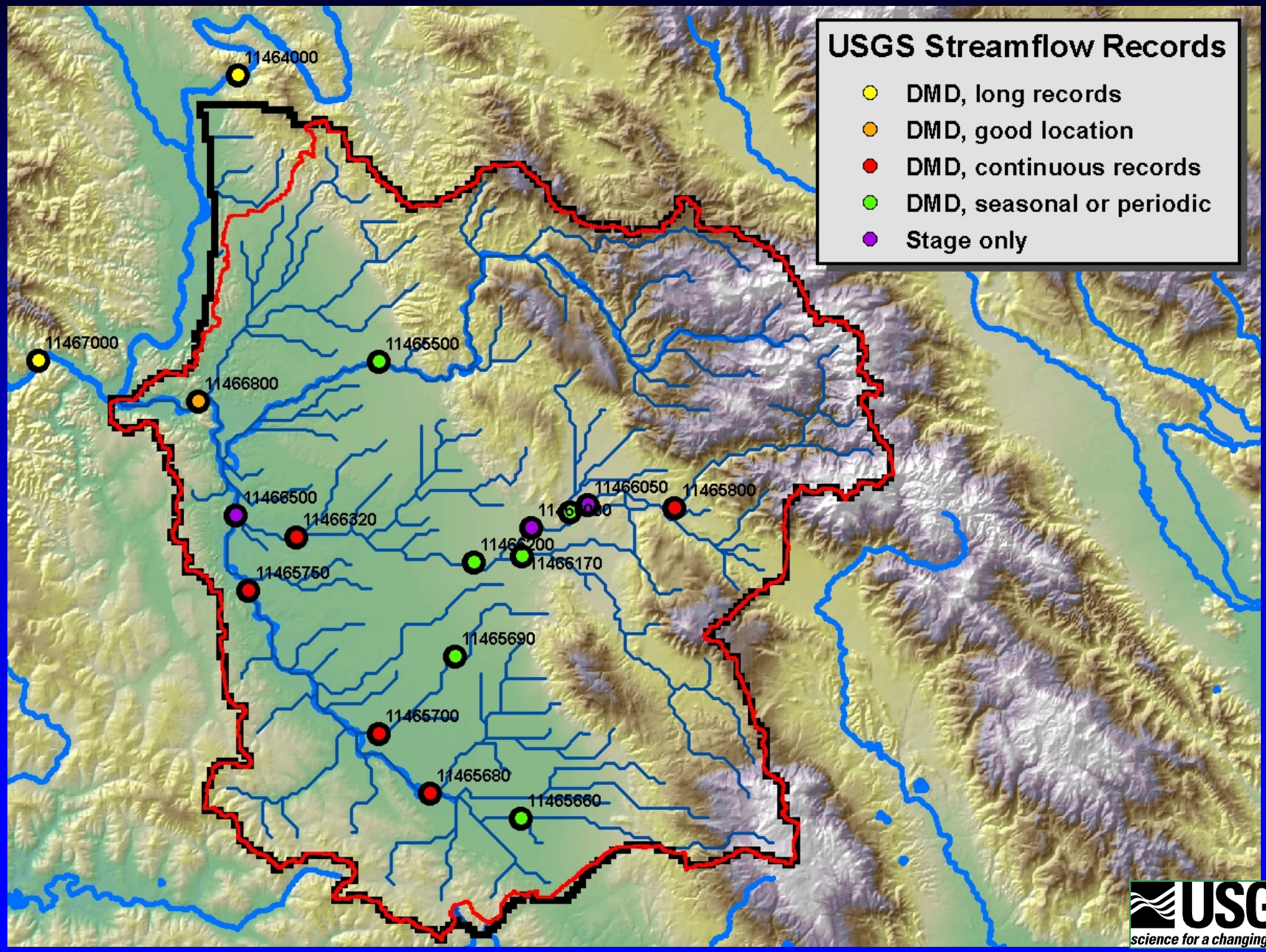
Catchment SRC1
GSFLOW testing & calibration



Catchment SRC1
GSFLOW testing & calibration



PRMS model calibration



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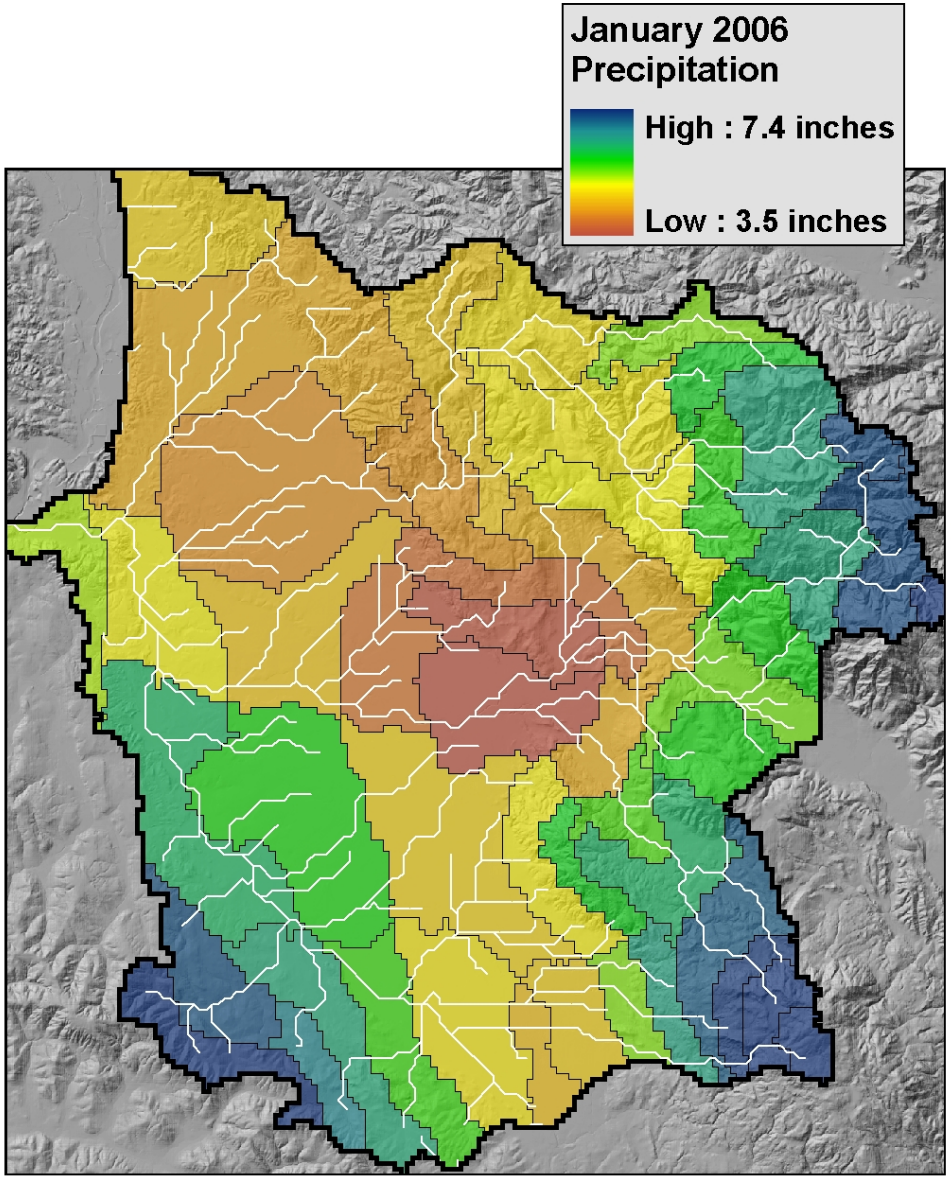

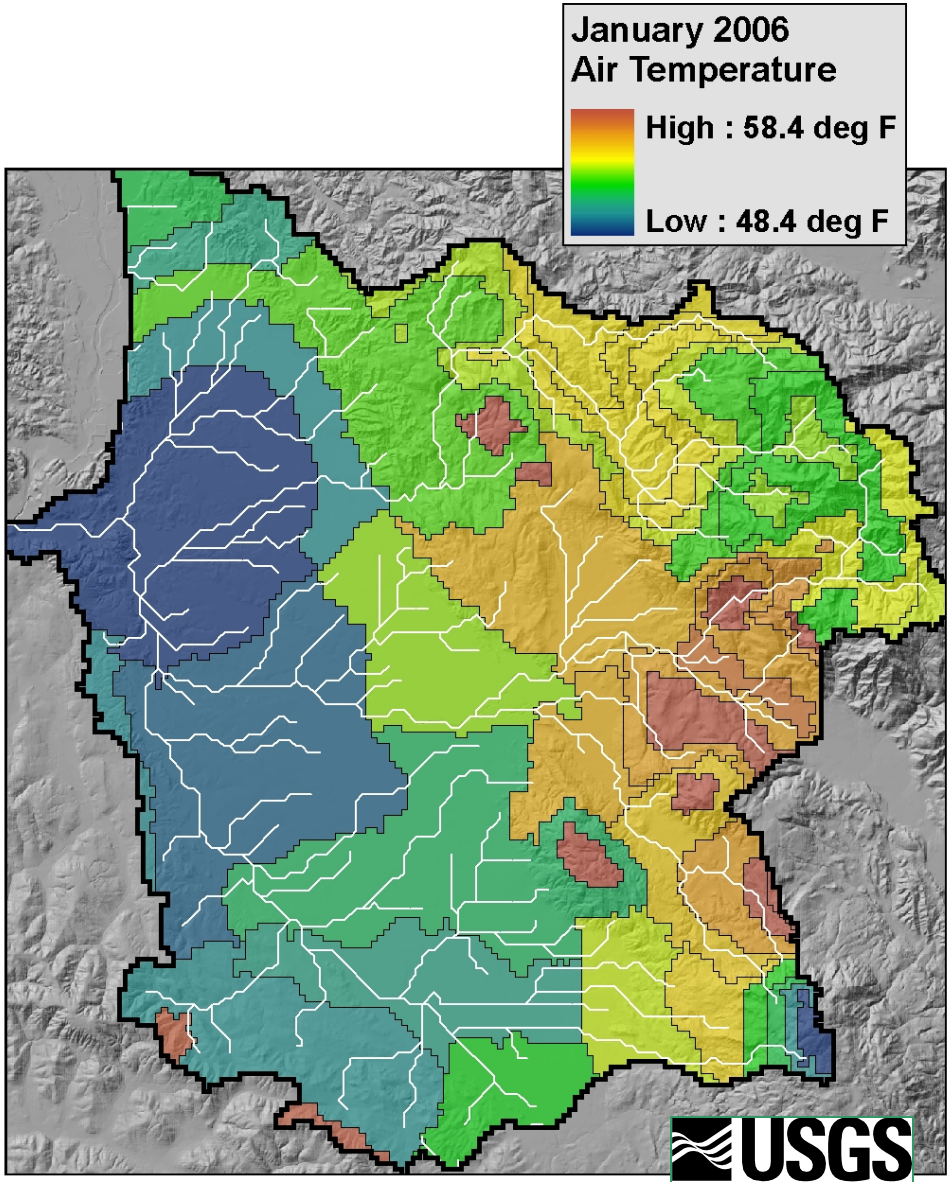

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