Declining water quality in Sierra Nevada mountain streams under projected climatic changes

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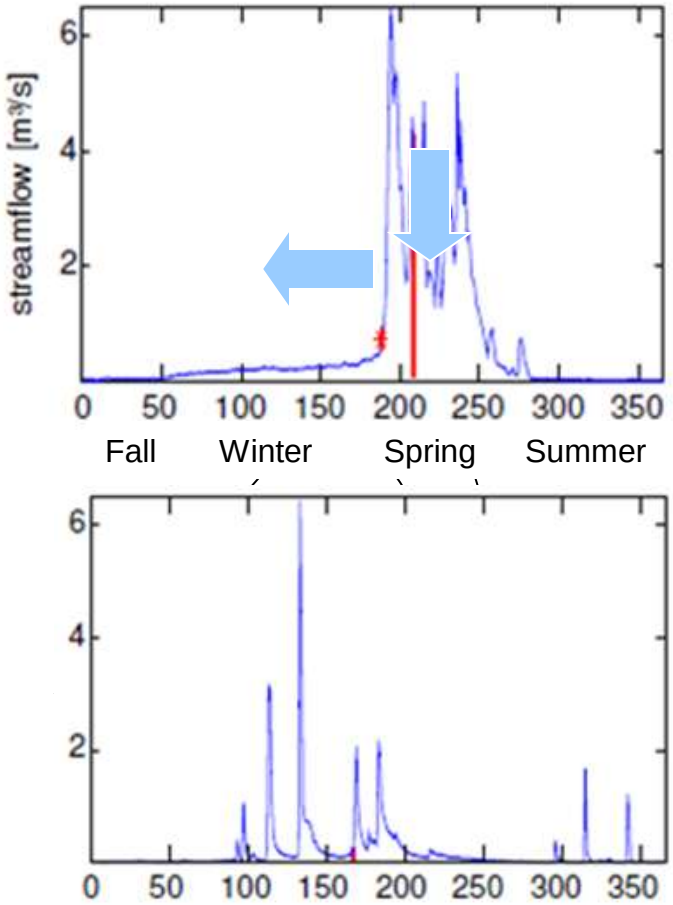
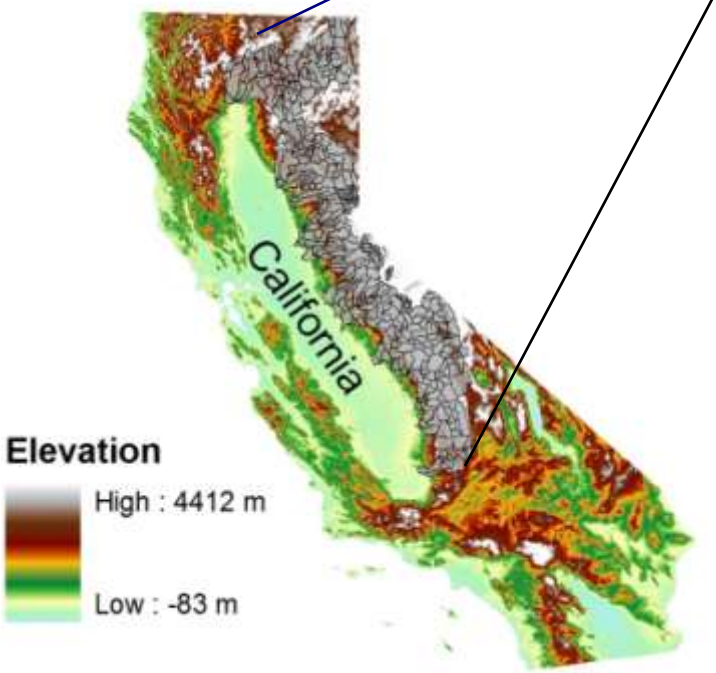
Warmer air temperatures = volume and timing shifts in highly seasonal mountain systems:



- Less snow storage (regime shifts)
- Earlier melt and stream runoff
- Lower snowmelt runoff peak
- Lower summer flows
- Warmer stream temperatures/chemistry ?
- Sed transport ?



Subwatershed scale - what can we learn from comparisons across the region?

Driving questions:

- How do we predict future changes in stream temperatures with today's hydrologic models?
- How might future climatic changes impact the hydrology and water quality in unimpaired western mountain basins?
  - Temp, DO, Sediment
- What are differences across GCMs, emission scenarios, different regions and elevations
- What could the projected changes mean for aquatic ecosystems?

Commonly stream temperature is modeled solely as function of air temperatures

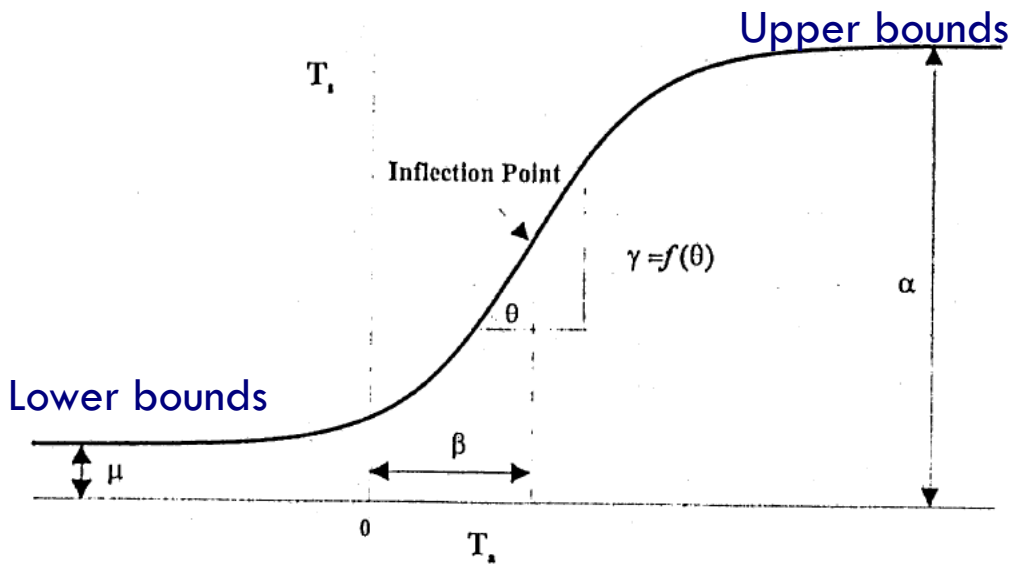
S-shaped function

- SWAT: stream temp from air temp relationship by *Stefan and Prued'homme* [1993]

  $T_{water} = 5.0 + 0.75 * T_{air}$

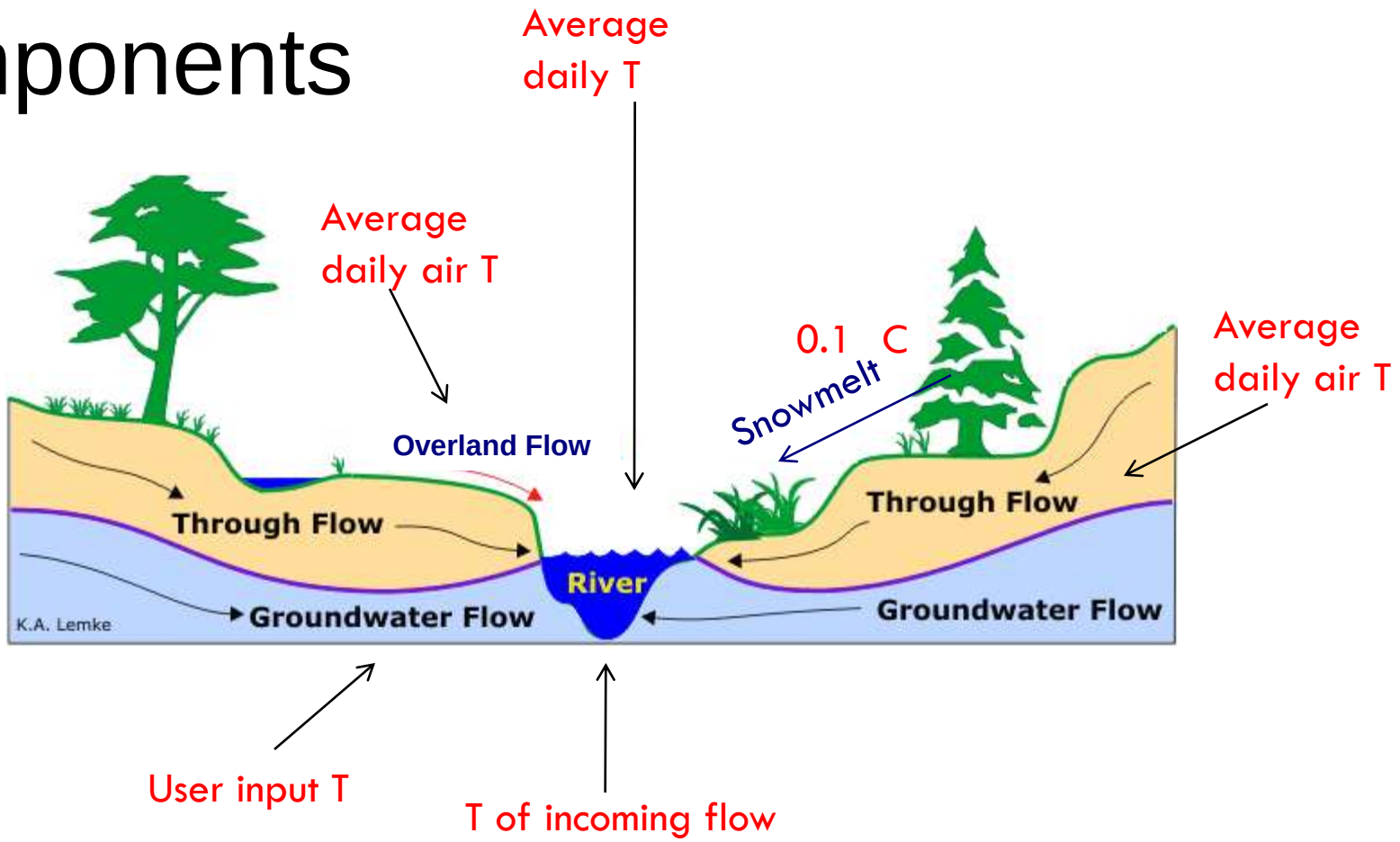
  T_{water} = ave daily water temperature (°C)

  T_{air} = ave daily air temperature (°C)



Mohseni et al., 1998

New stream temperature model based on air temp & hydrologic components

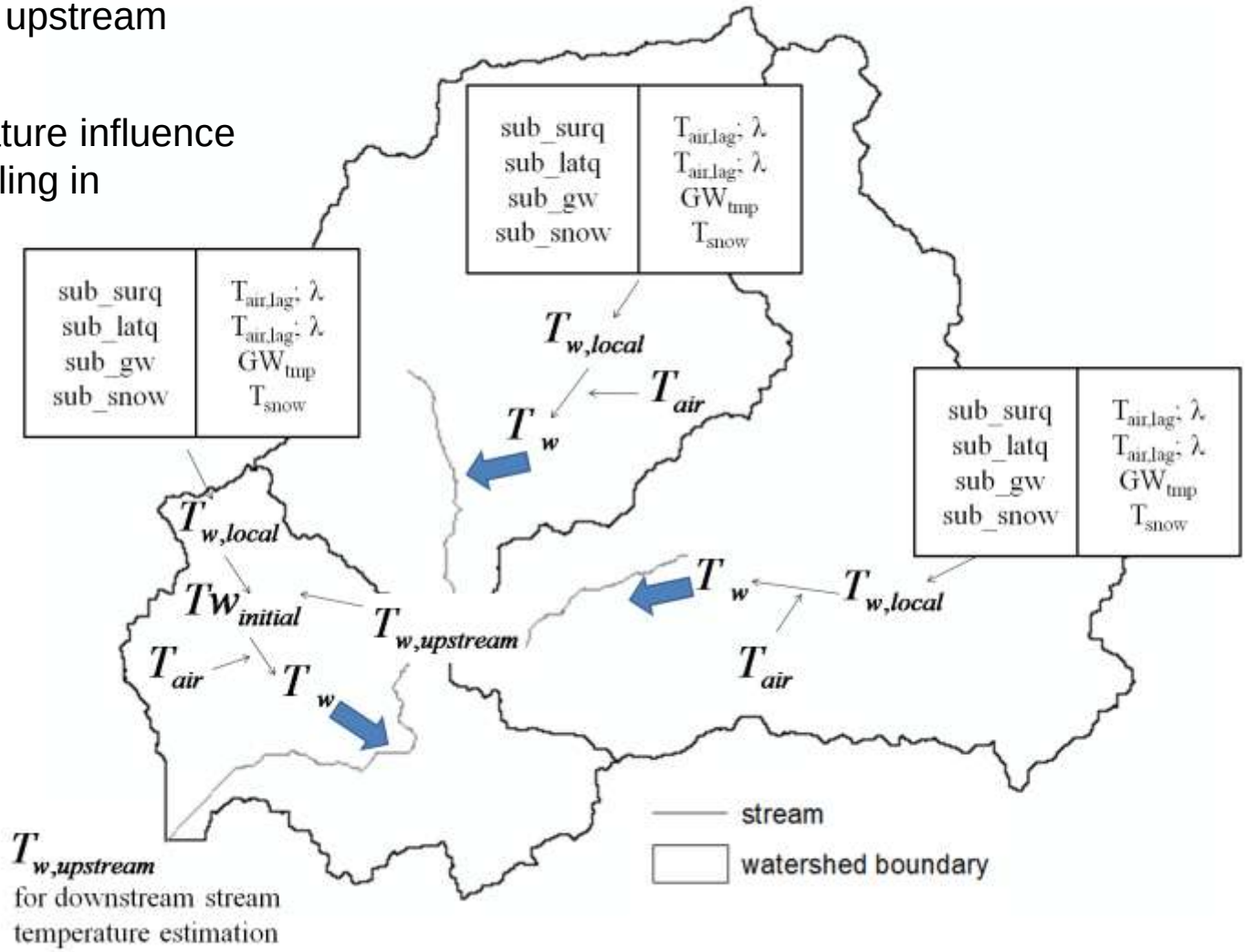


New stream temperature model approach

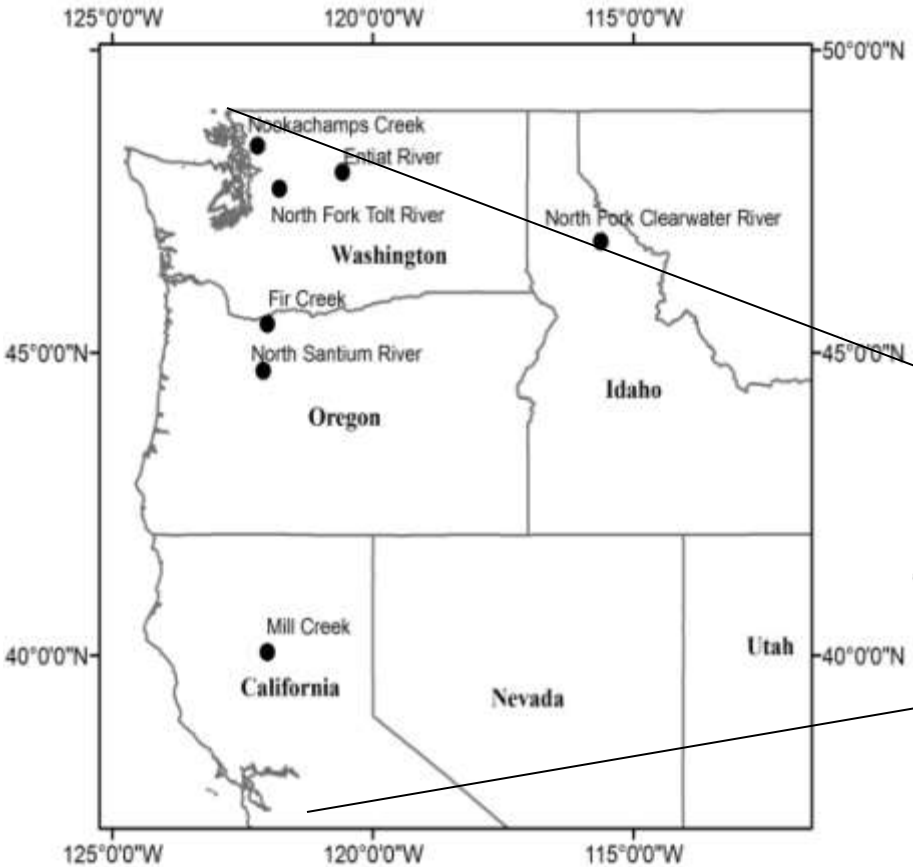
Step 1: Calculate water T from local hydrologic inputs

Step 2: Mixing with upstream water

Step 3: Air temperature influence while water is traveling in subbasin

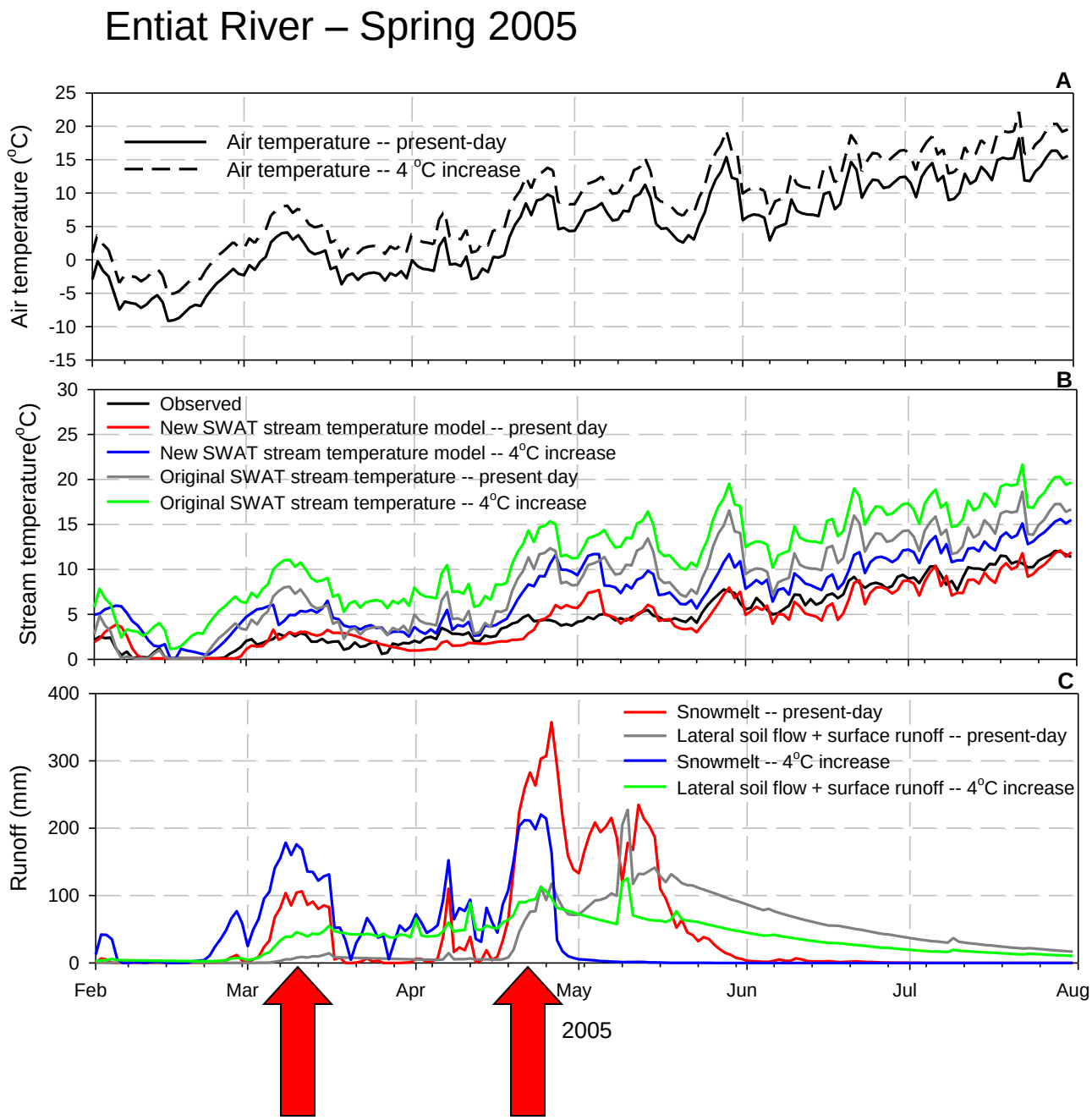


Model tested with 7 high quality sites in North American West

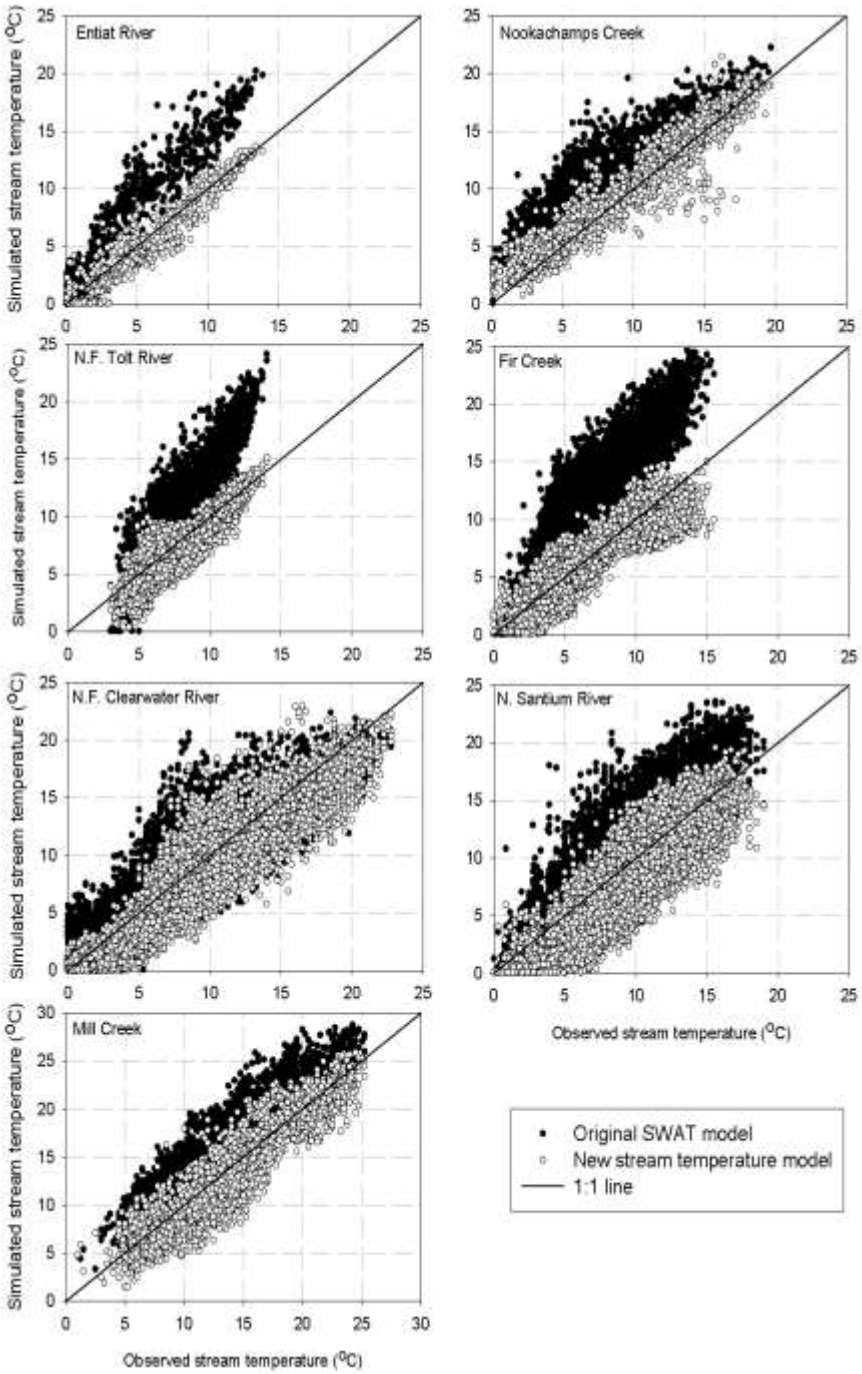


- 7 sites:
  - Snowmelt dominated
  - Differing elevations
    - 400 m to 1,400 m
  - High quality stream temp. data

Comparison of old SWAT and new stream temp model with observations and under 4 degC increase:



New stream temperature model generally matches observed records better than original



Hydrologic components (snowmelt, surface flow, ET, subsurface flow, soil storage, groundwater, streamflow)

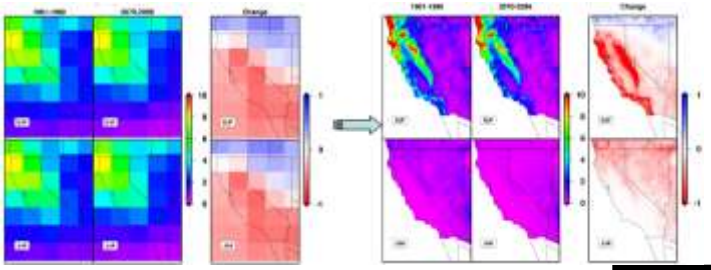
Water quality (stream temperature, dissolved oxygen, sediment)

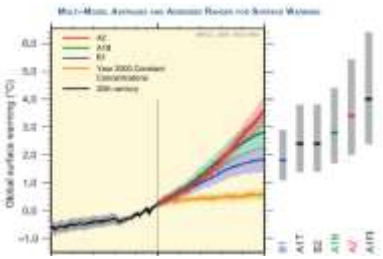
For 16 GCMs, 2 emission scenarios, subbasin scale, through 2100

Approach

SWAT hydrologic simulations, water quality subbasin

New stream temperature model

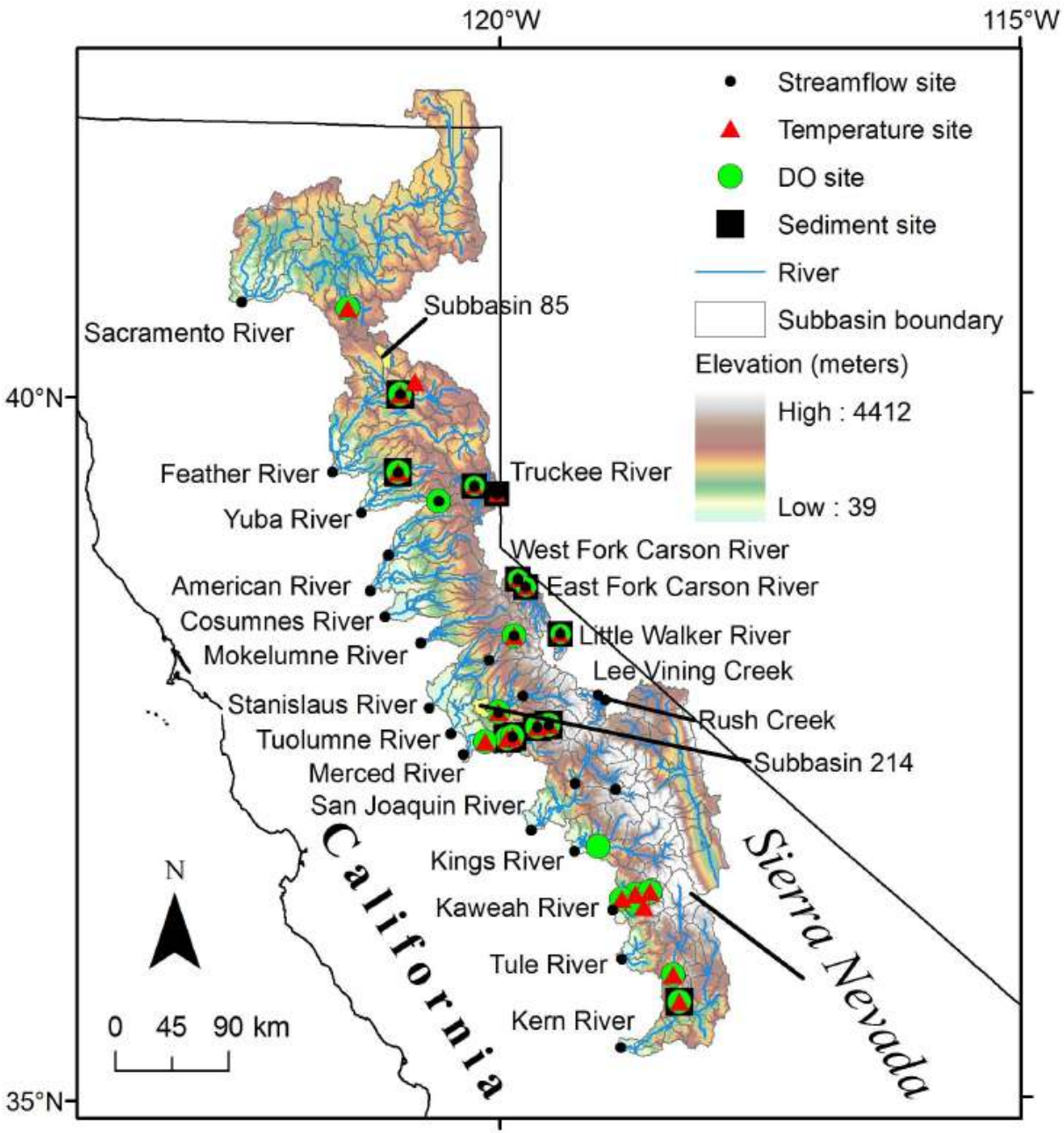




16 GCMs, statistically downscaled output (monthly)

2 emission Scenarios B1, A2

Watershed Delineations Topography Landuse Soil



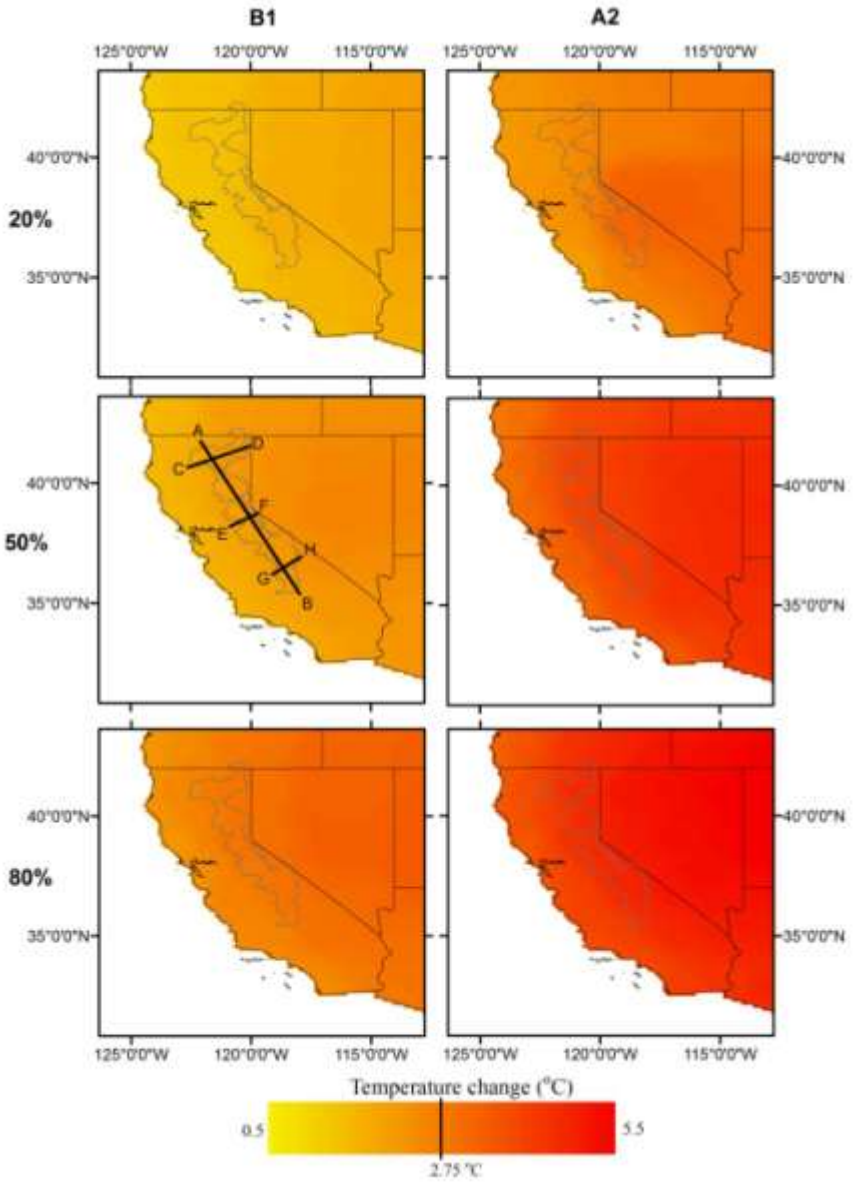
Multiple calibration sites

Automated calibration using SUFI-2

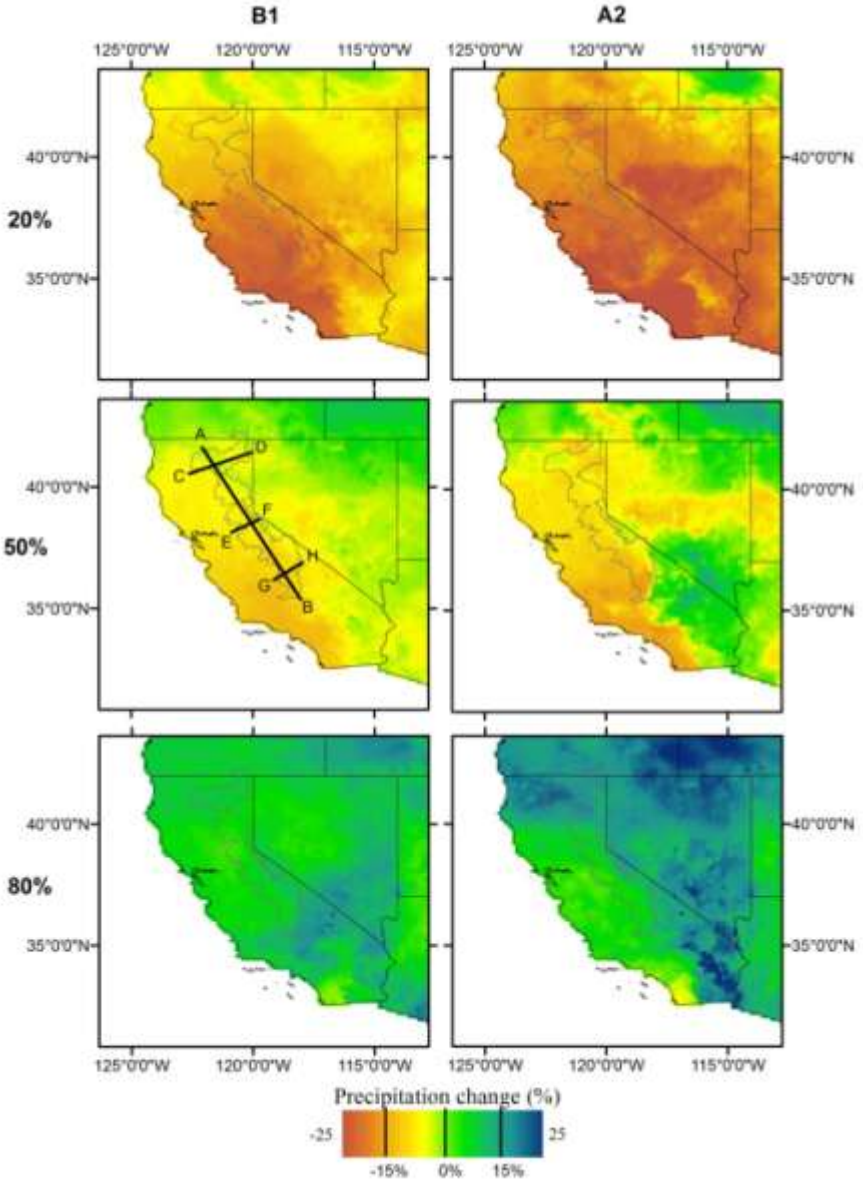
Split sample approach for calibration and validation

Air temperature changes:

Expect warming by 2-5 C

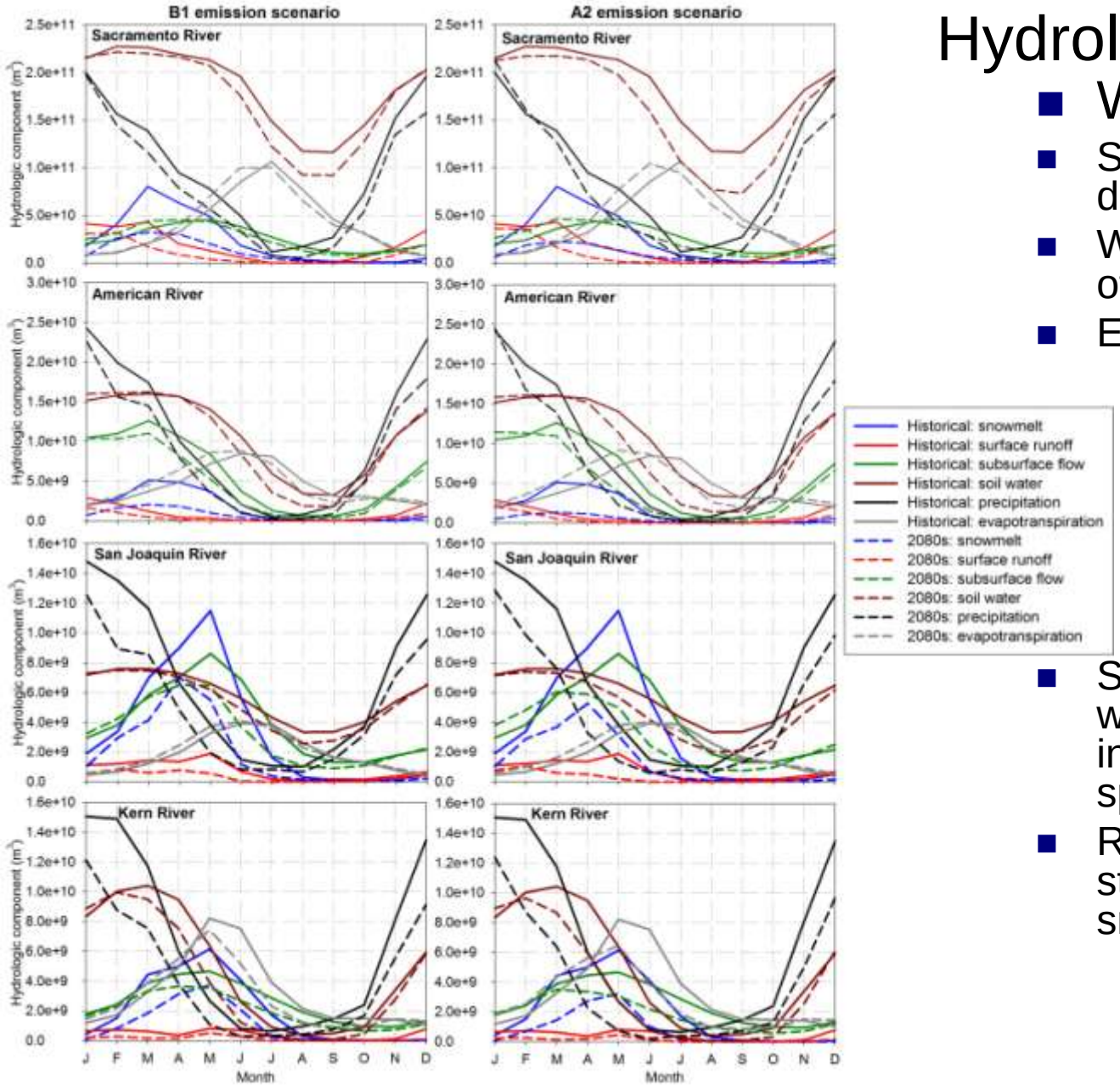


Precipitation changes more variable, generally drying



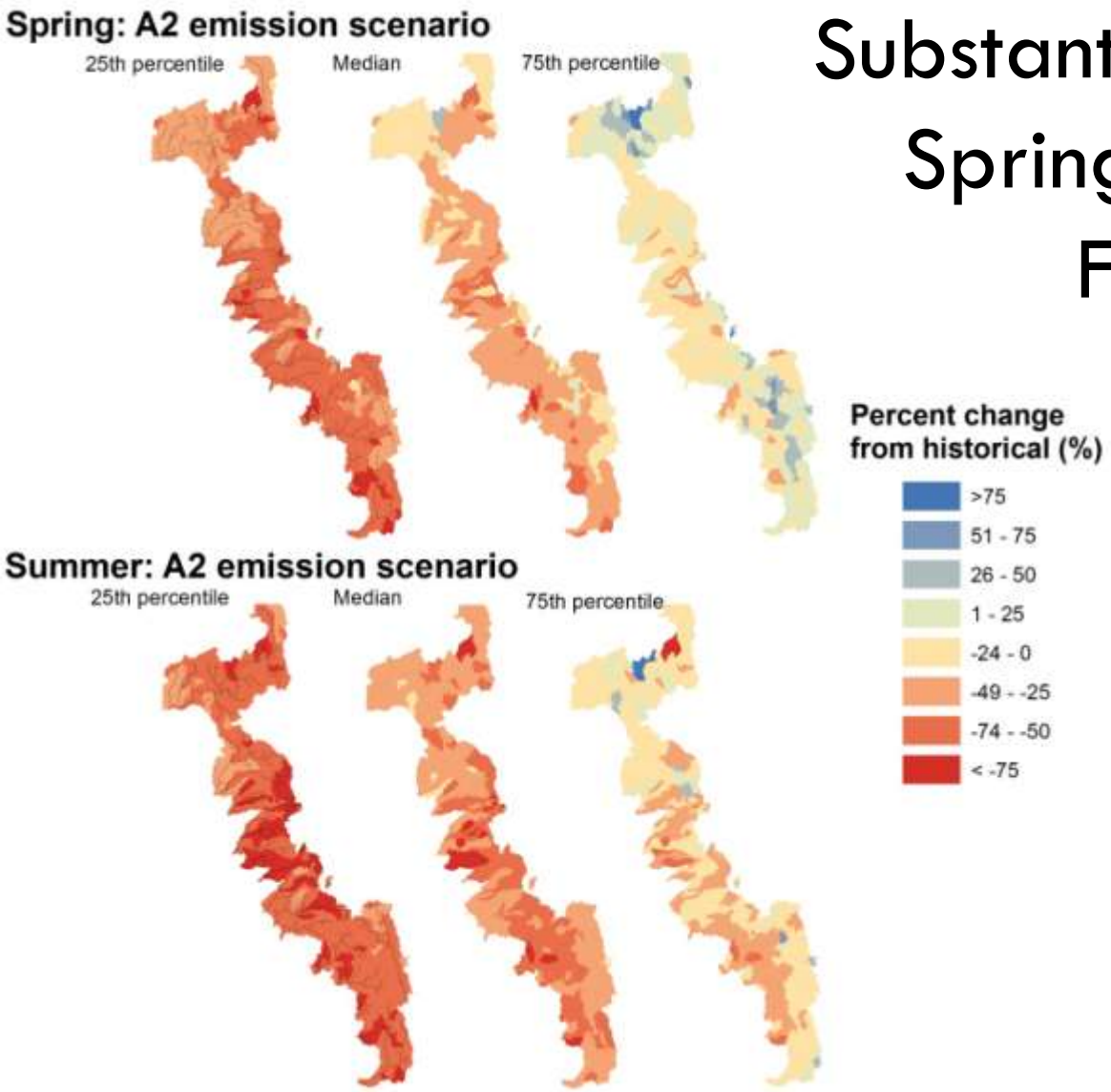
Hydrologic Components

- Western Sierras
- Snowpulse advanced and diminished
- Winter and spring declines of surface runoff
- Earlier ET



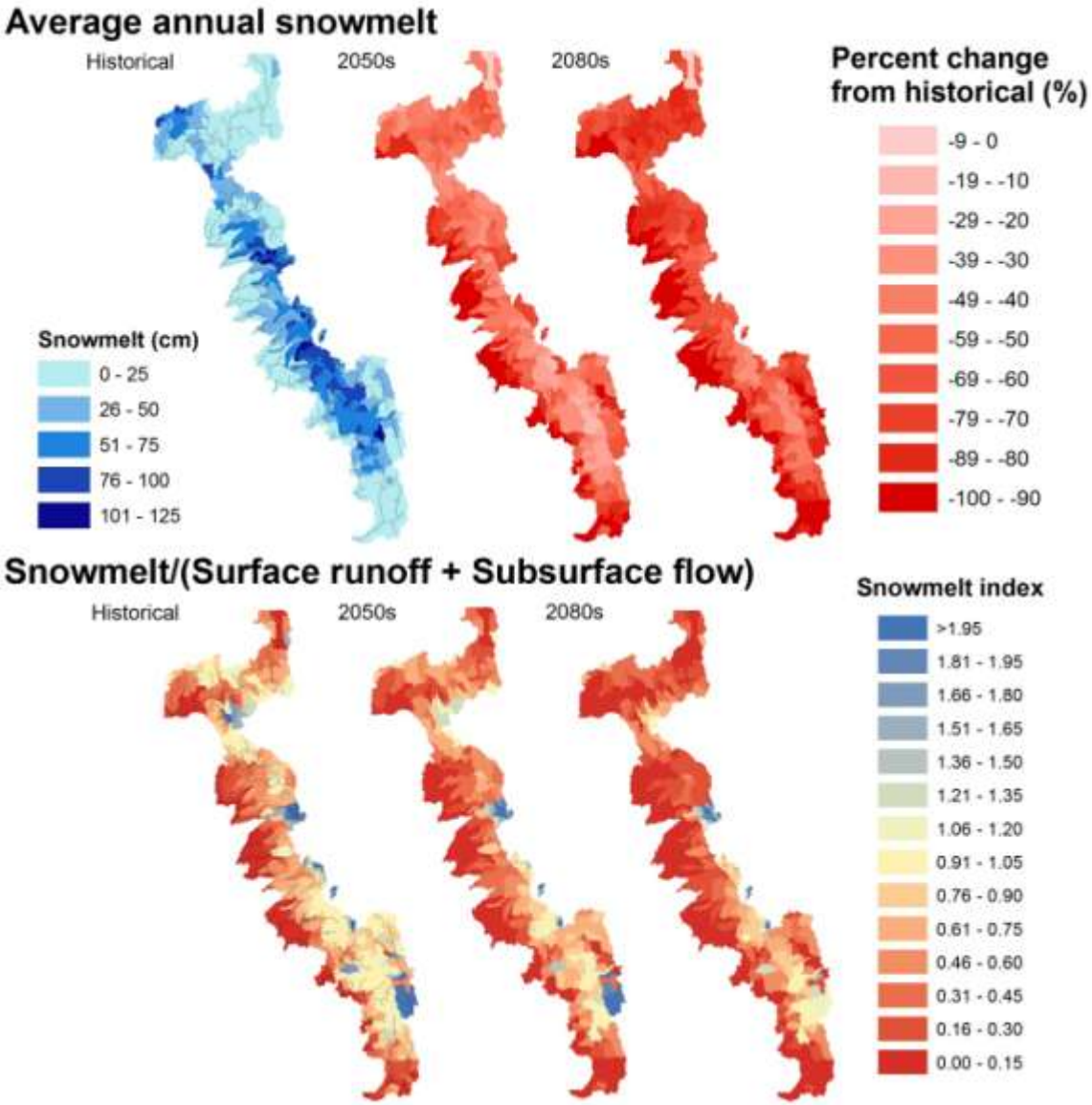
- Subsurface flows and soil water storage shift to earlier in the season, declines for spring and summer
- Regional differences in soil storage and importance of snowmelt runoff pulse

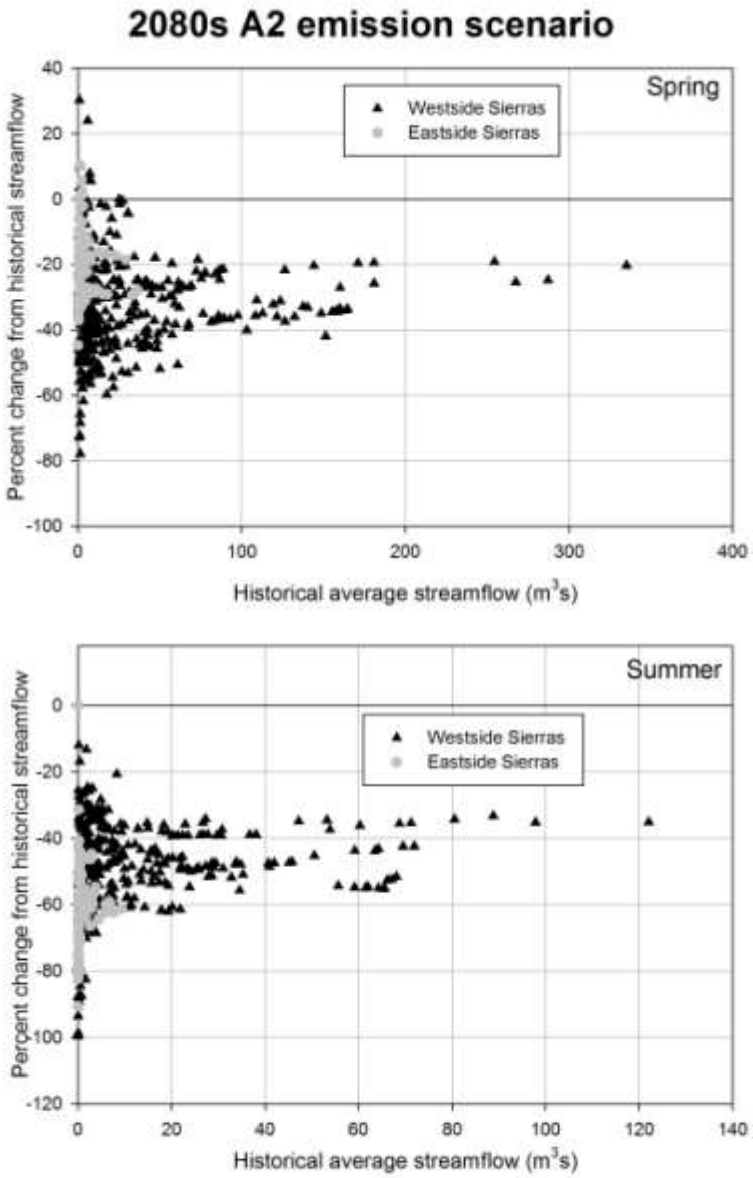
Substantial changes in Spring and Summer Flows by 2100



- Substantial flow decreases in headwaters and downstream basins
- Decreases in spring and summer

Substantial decreases in the relative contribution of snowmelt





% change in flow vs. basin size

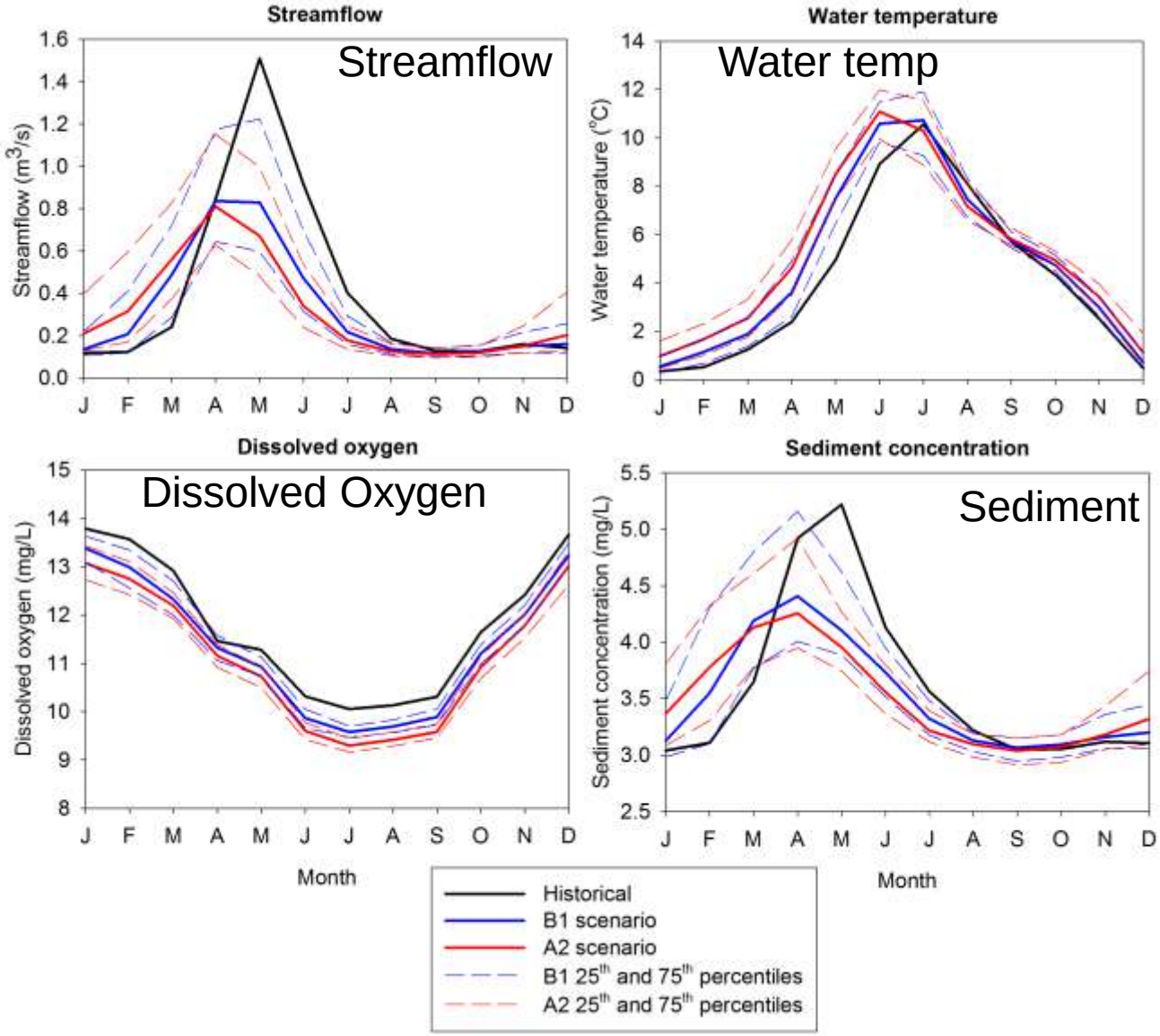
Large basins:

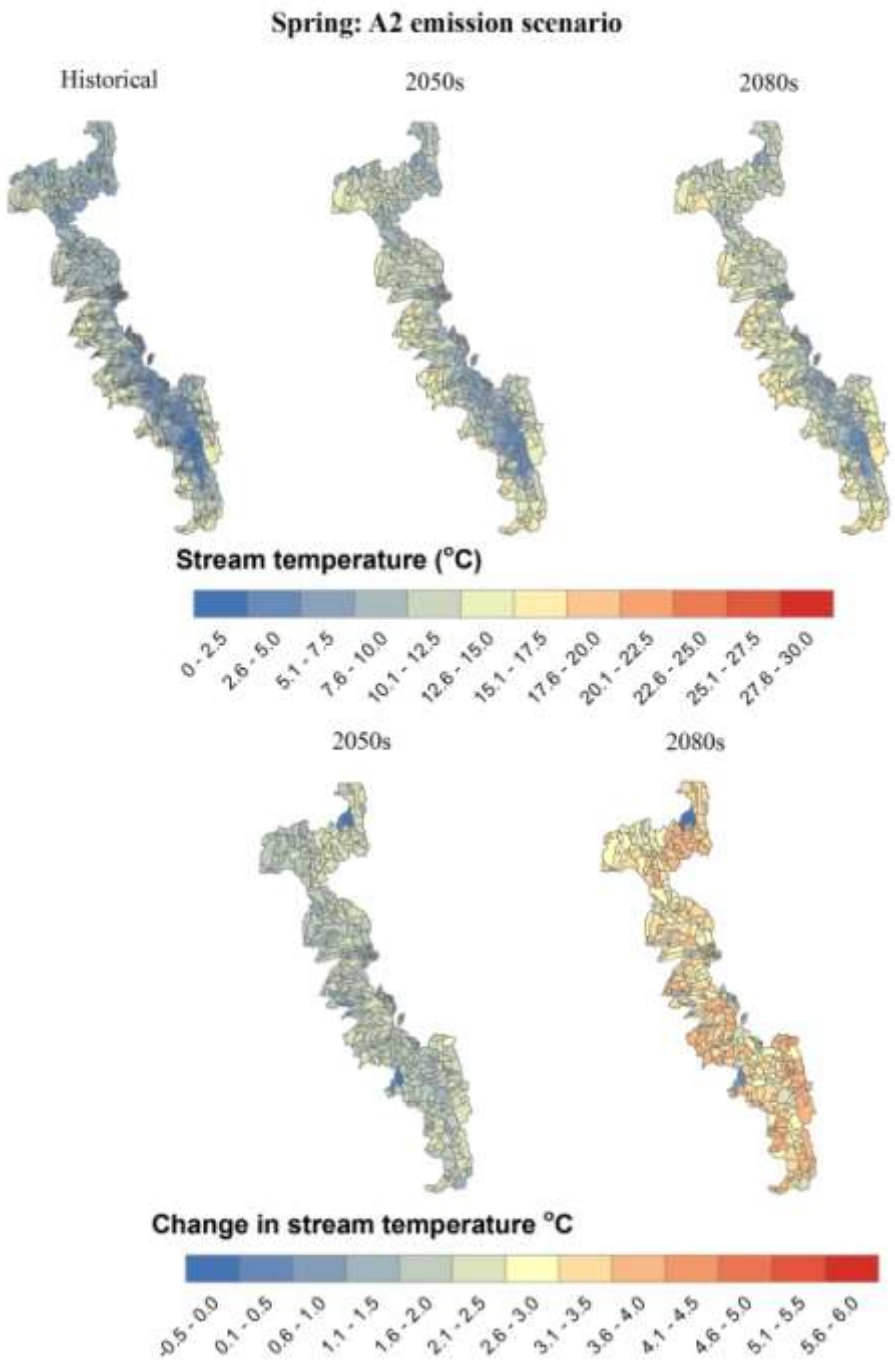
- ~20-40% less flow in Spring
- ~30-60% in Summer

Sagehen Creek

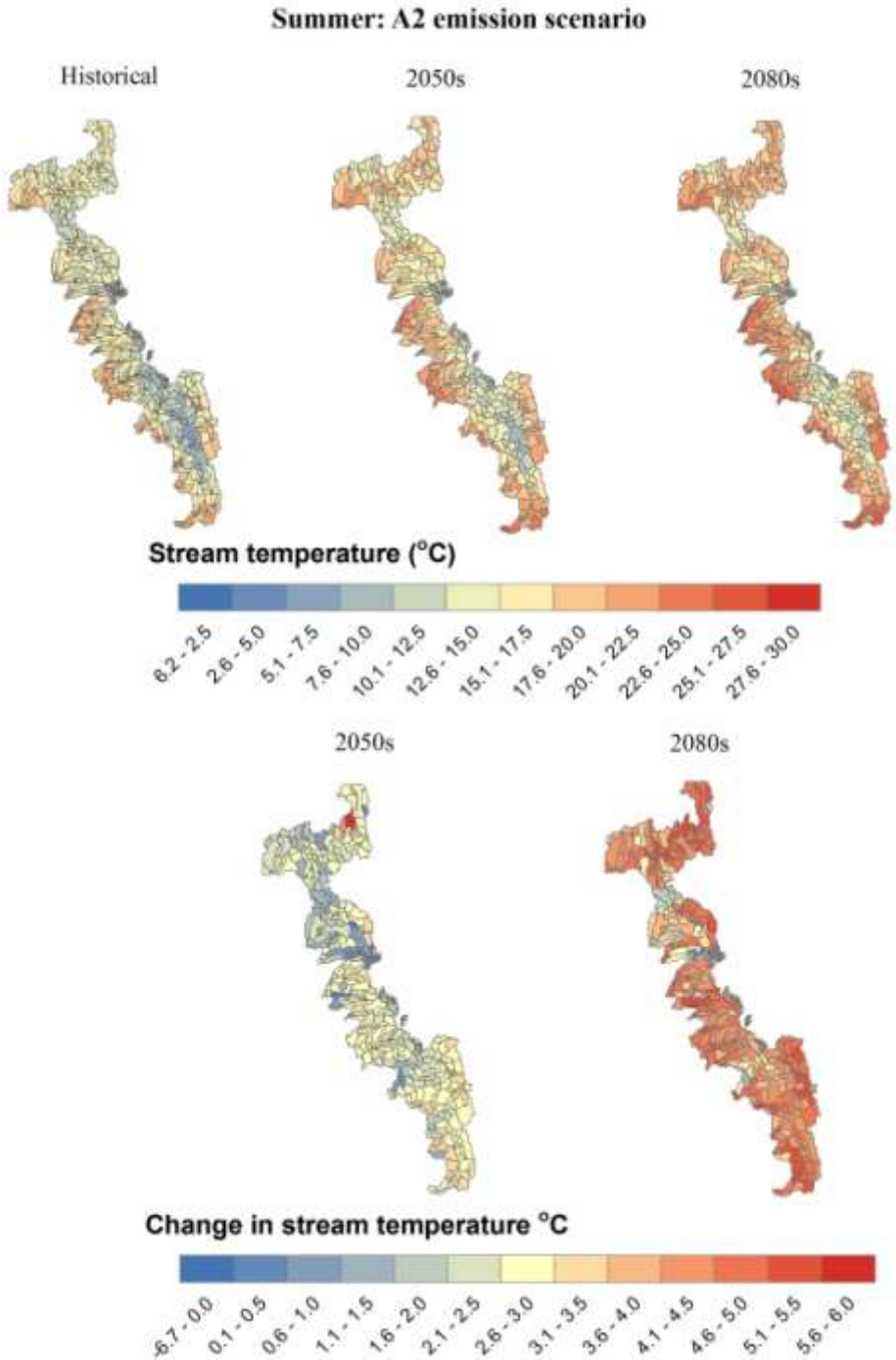
Contains Rainbow Trout !

2080's



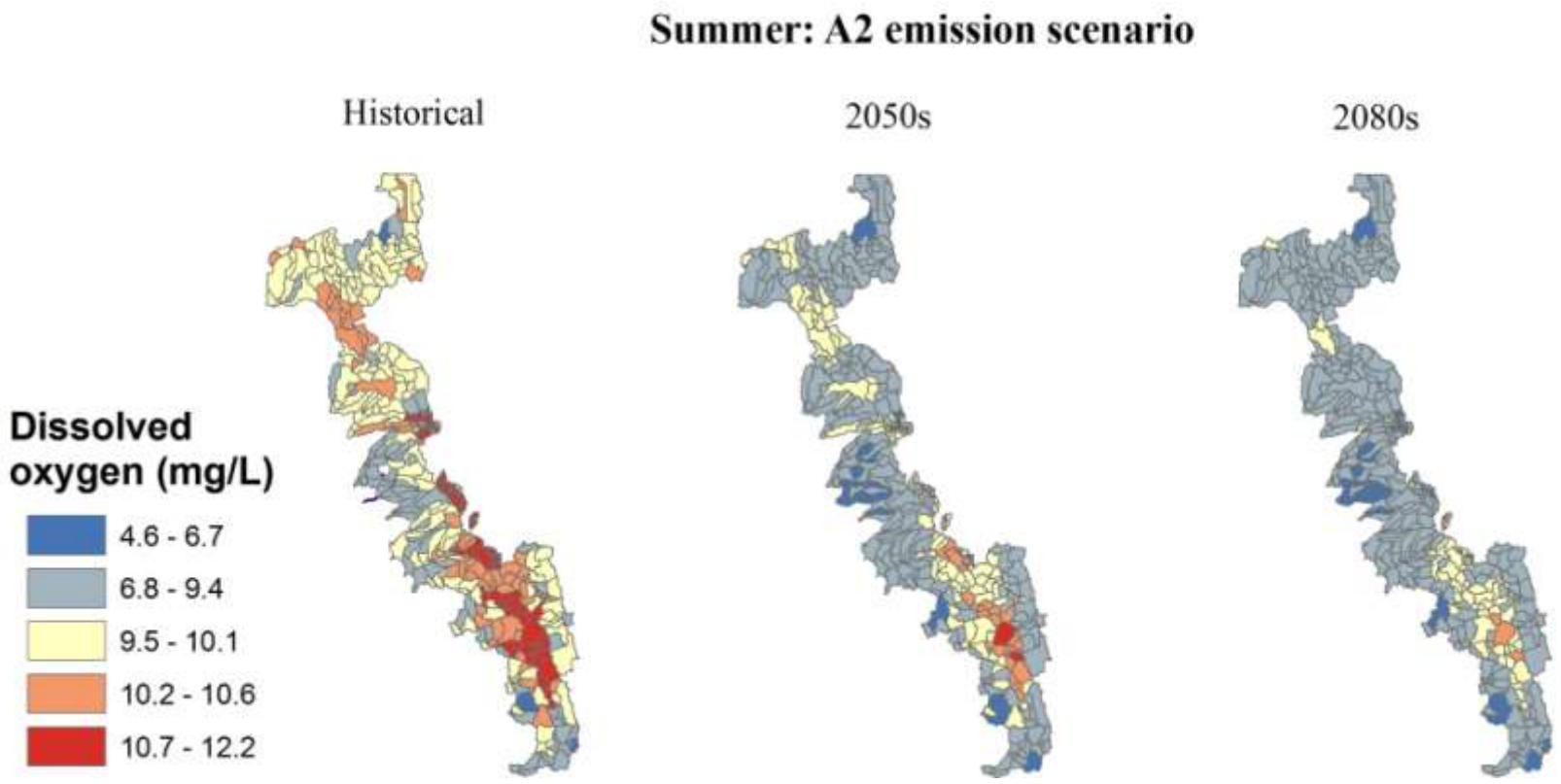


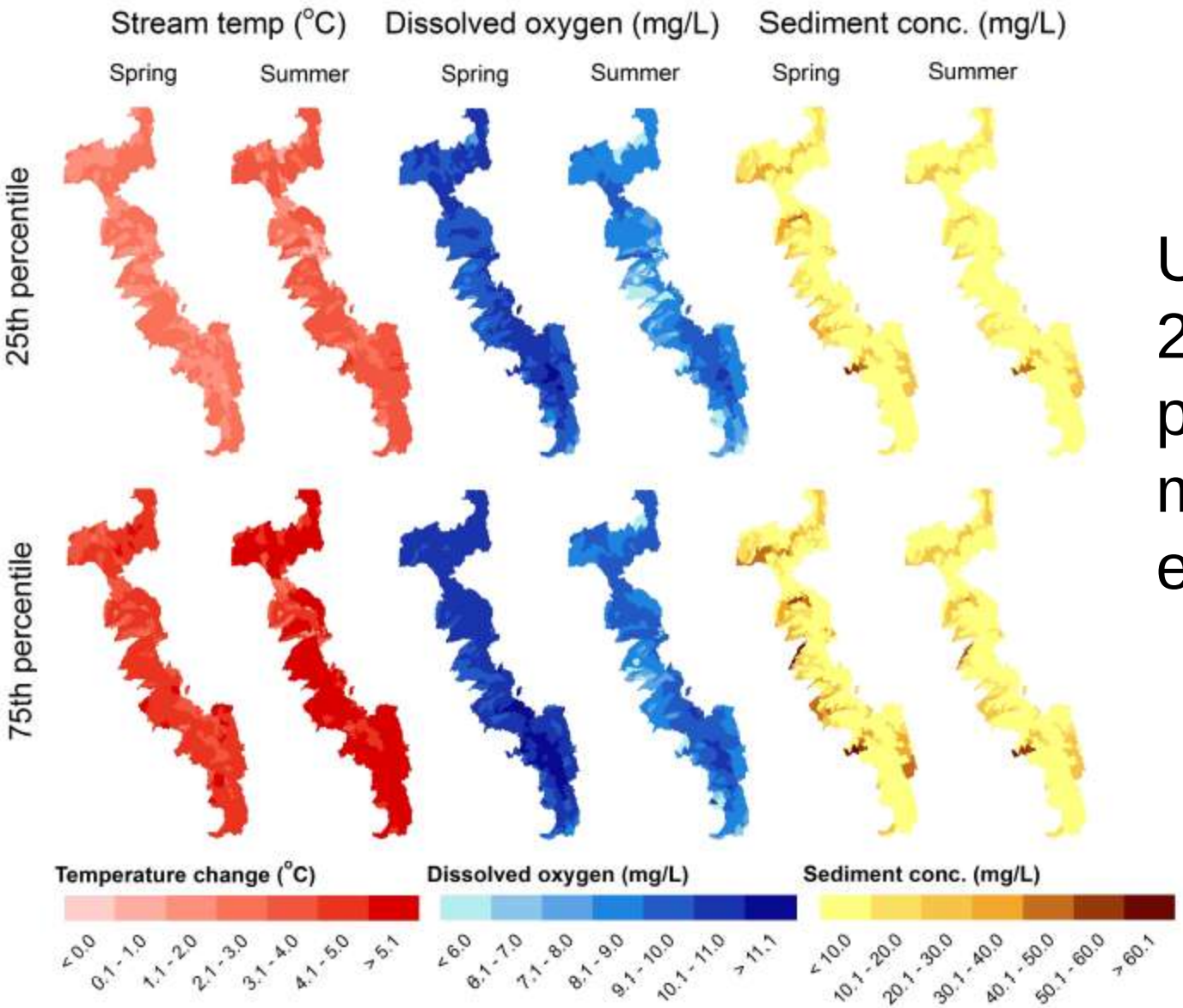
Spring stream temperature increases of 1-4 C by the end of the century (A2)



Summer stream temperatures increases of 2-6 C by end of century (A2)

Historic and projected DO levels

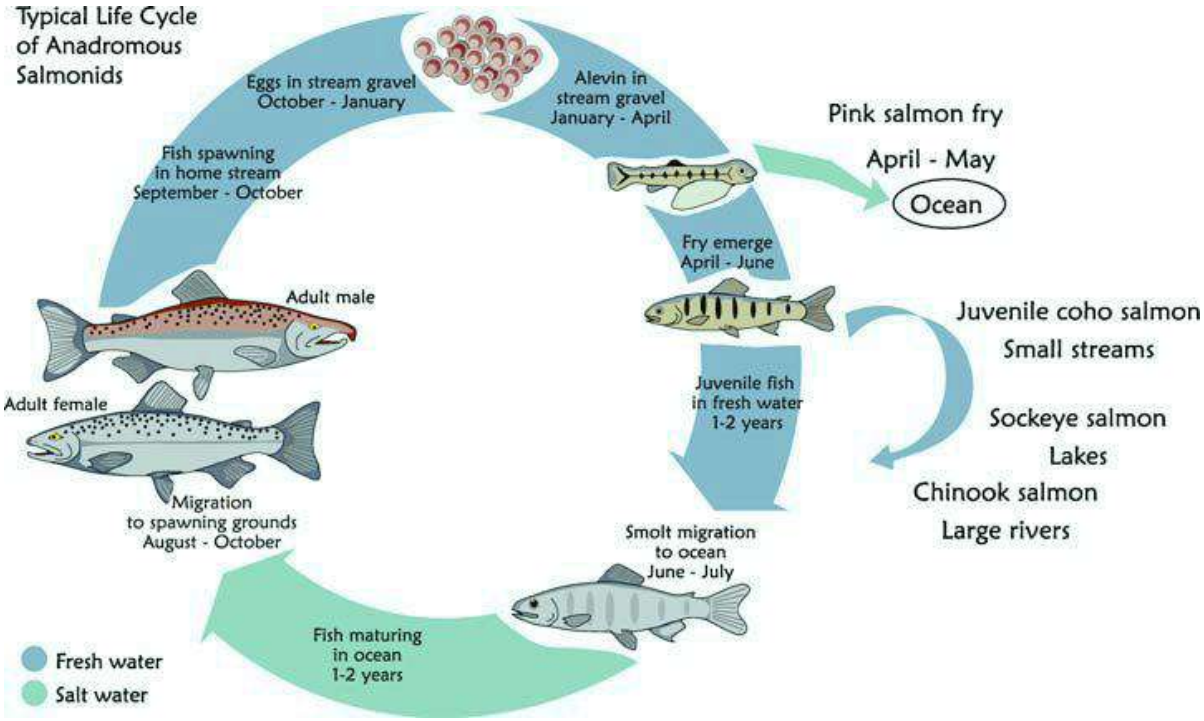




Uncertainty? 25% and 75% percentile for model ensembles

Pacific salmon

- Warmer temperatures above optimum
  - Change migration timing
  - Reduce growth rates
  - Reduce available oxygen
  - Increase susceptibility to toxins, parasites, predators, disease
- Reduced flows
  - Further increase temperatures
  - May not be enough flow for migration
- Very high flows may wash away gravel at spawning sites.



What do the higher temperatures mean for fish?

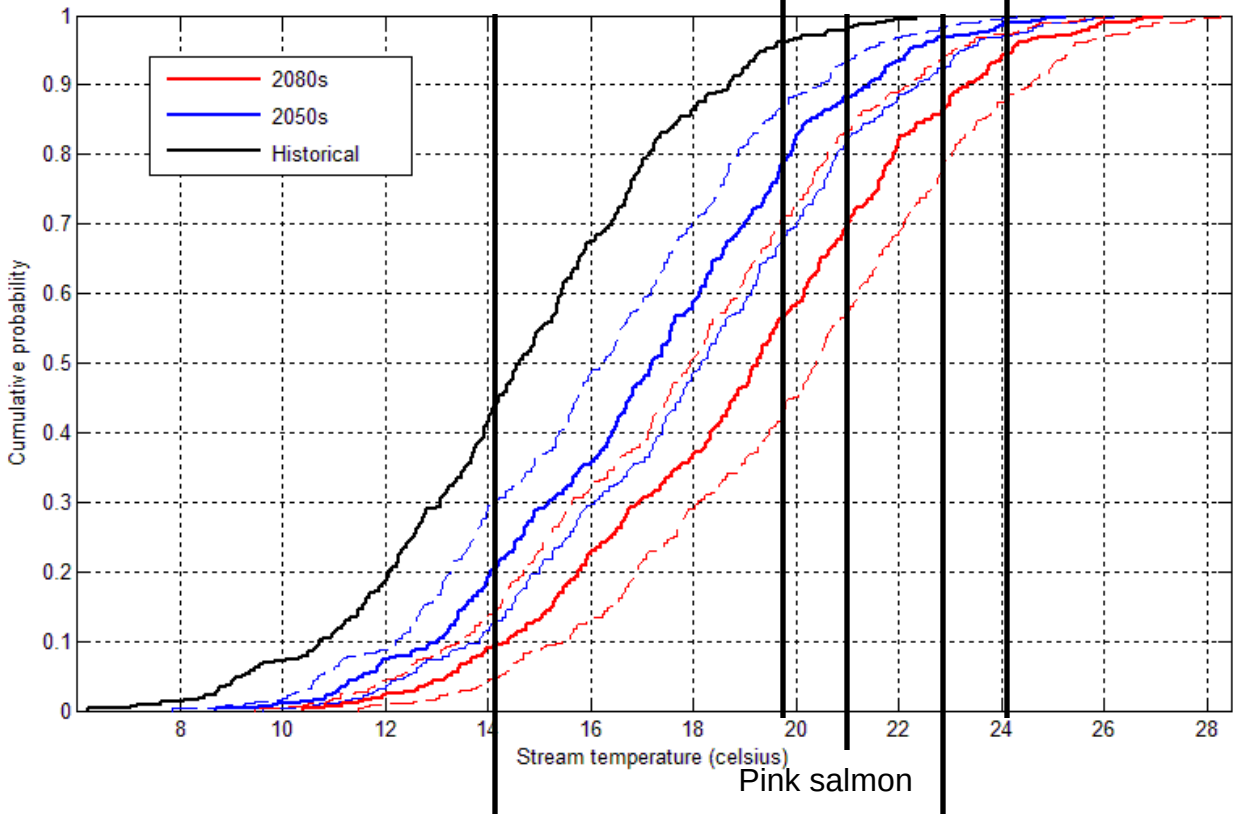
Rainbow trout,

Chinook salmon

Maximum weekly upper thermal tolerances for salmonids after Eaton and Scheller, 1996)

Summer (A2) All Watersheds

Chum salmon



Pink salmon

Best temperature for spawning rearing, migration

Cutthroat trout,

Coho salmon

What we have learned

- need to examine if existing tools can capture changes, development of new tools
- Projected climatic change impacts
  - Earlier timing of runoff
  - Earlier timing of other hydrologic components (soil storage, subsurface flow, groundwater flow)
    - Decreasing moisture availability not only in stream but throughout watershed
    - Effects of plants not considered
  - Substantial effects on stream water quality
    - Increasing stream temperature, decreasing DO, especially in summer
    - Shifts in the timing and volumes of sediment transport
- What else?
- Systematic examination of occurrence of extreme conditions
- Systematic examination of potential ecologic consequences
- Region-to-region comparisons
- More model testing