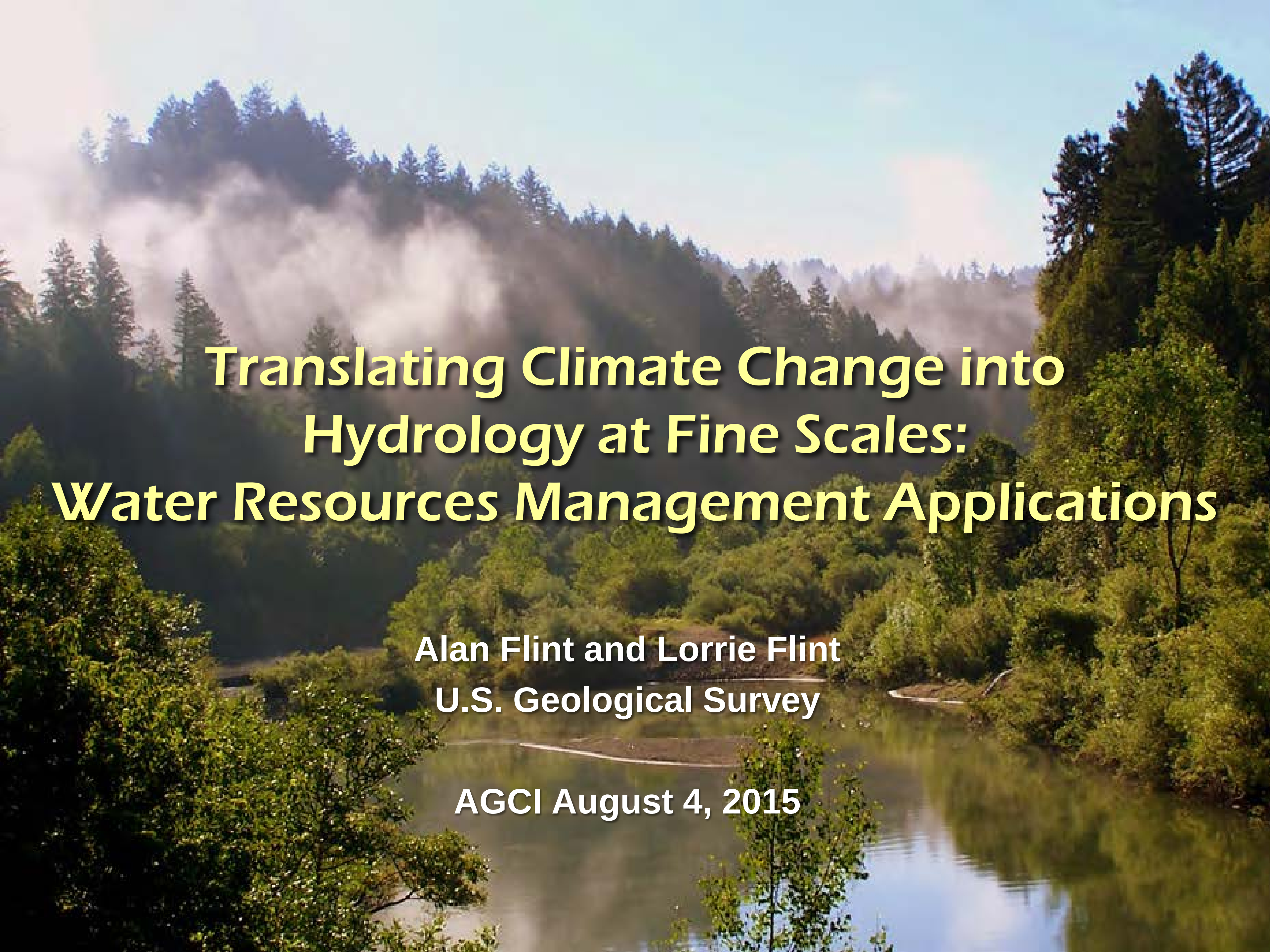

Translating Climate Change into Hydrology at Fine Scales: Water Resources Management Applications

Alan Flint and Lorrie Flint

U.S. Geological Survey

AGCI August 4, 2015

Tools for Natural Resource Management

- Tools to aid decision making should provide information
  - At multiple spatial scales, from regions to watersheds to hillslopes
  - That addresses both watershed hydrology and regional landscape ecology
  - That provides historical analogs and future projections
  - Relying on deterministic processes to reduce uncertainty (reduces the impact of potential increases in downscaling climate uncertainty)

Tools for Natural Resource Management (and outline)

- Describe modeling tools and downscaling methodology (nuts and bolts)
- Four examples of applications for water resource management
  - Improved watershed characterization for forecast-informed reservoir operations
  - Improved springtime snowmelt forecasts for Sierra Nevada
  - Location and preservation of important recharge source areas
  - Adaptation of highly managed refuges in uncertain future
- Lorrie gets to talk about the fun stuff, wine grapes and fuzzy animals

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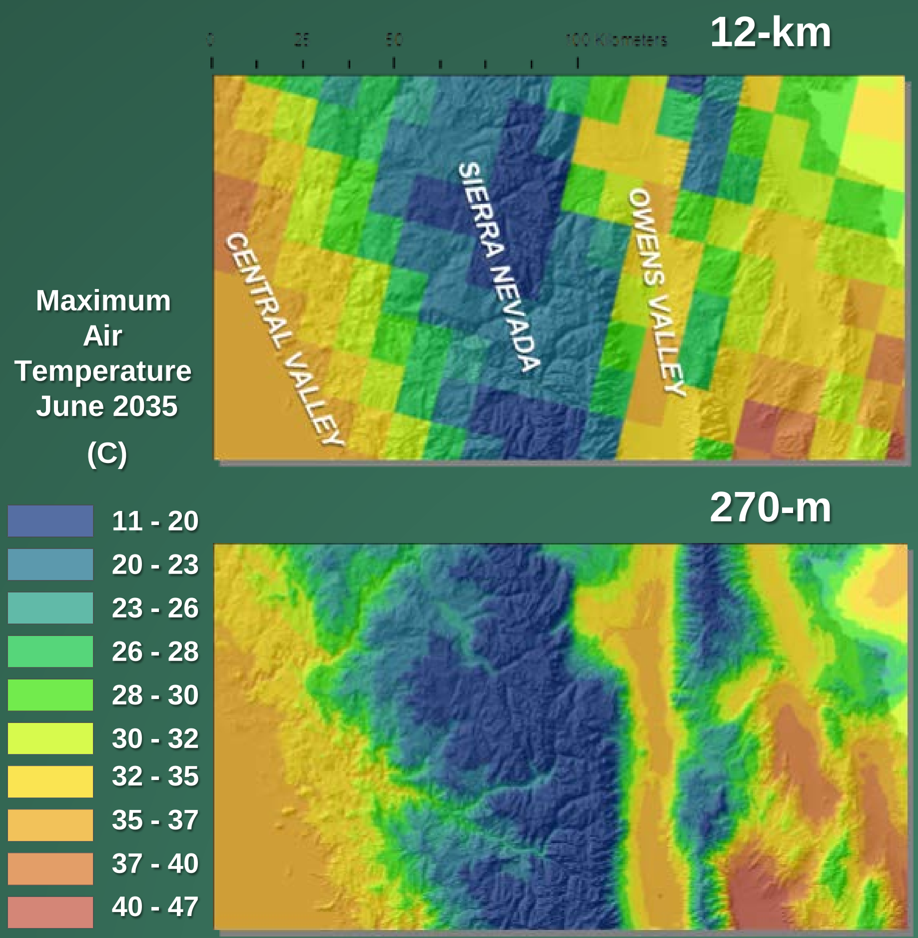
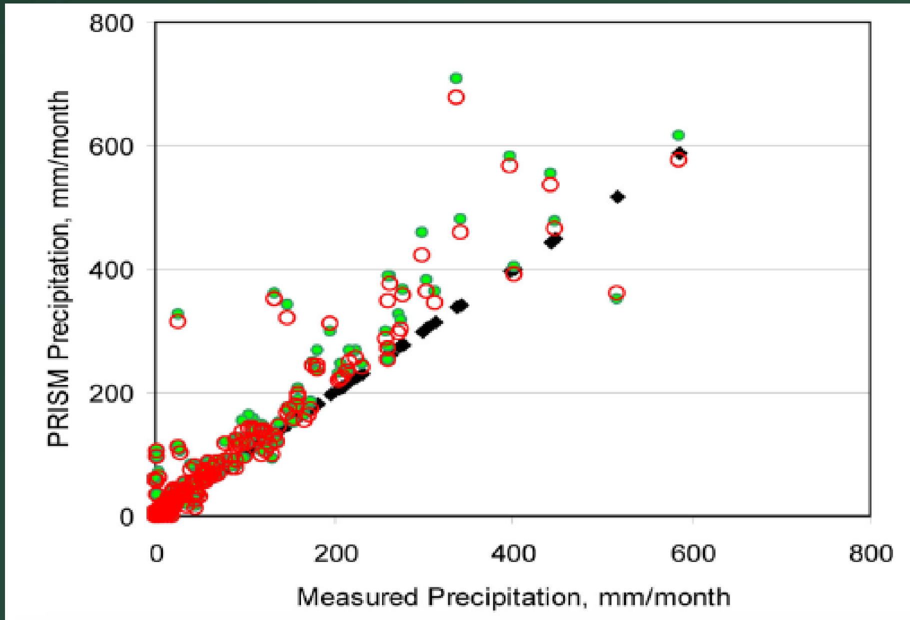
Downscaling Gridded Climate and Climate Change Projections

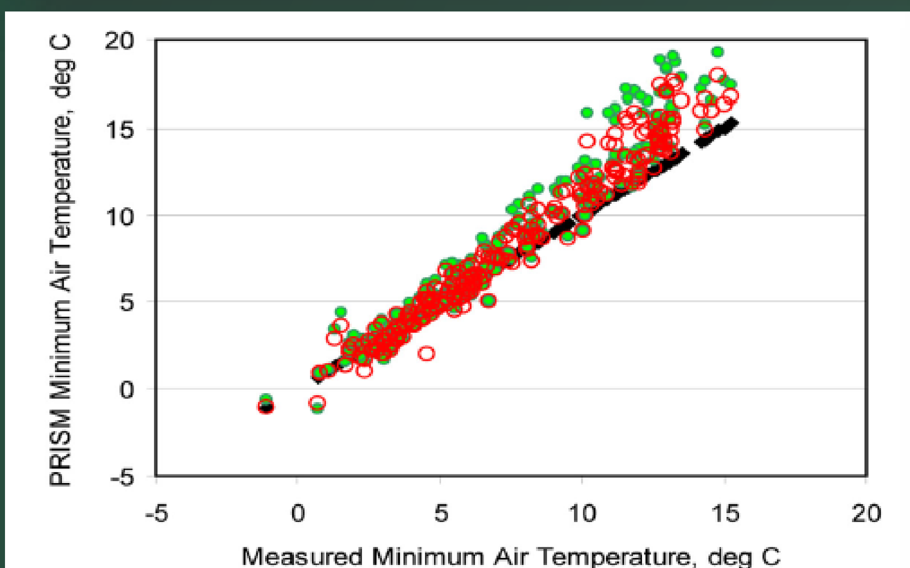
- Available future climate model data at 2.5 degree resolution are downscaled to 1/8 degree (12-km, CA), or other scales, BCSD, LOCA, Dynamic downscaling
- These data are further downscaled to 270-m using a gradient-inverse-distance-squared (GIDS) approach for model application
- GIDS methodology develops a regression relation between the climate variable and northing, easting, and elevation for every time step for every grid cell to spatially interpolate to the fine scale

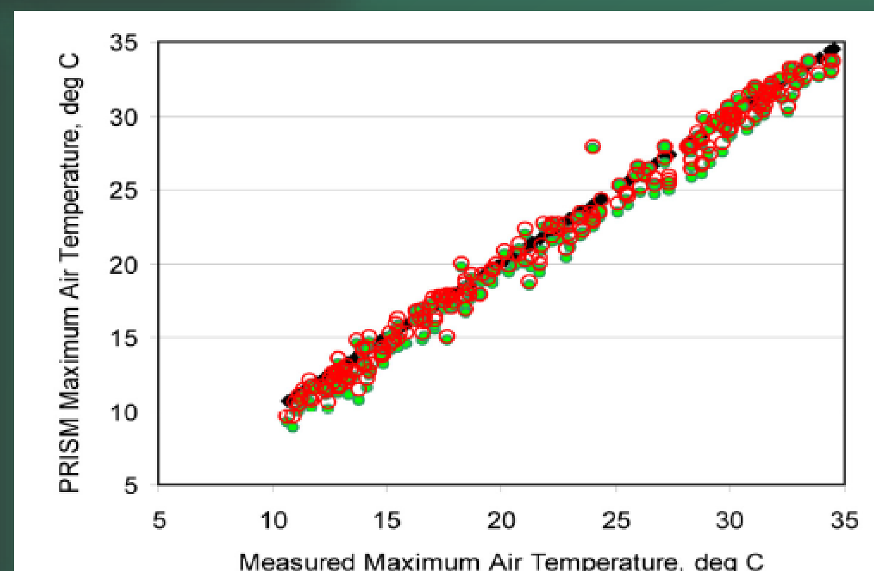


Example of Skill: Matching downscaled results to measured data

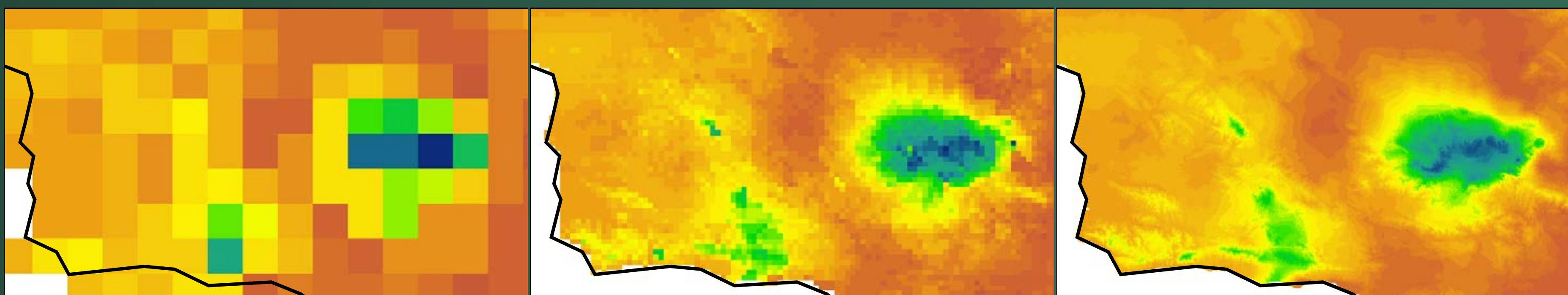


◆ CIMIS measured data ● PRISM 4 km ○ PRISM Downscaled to 270 m



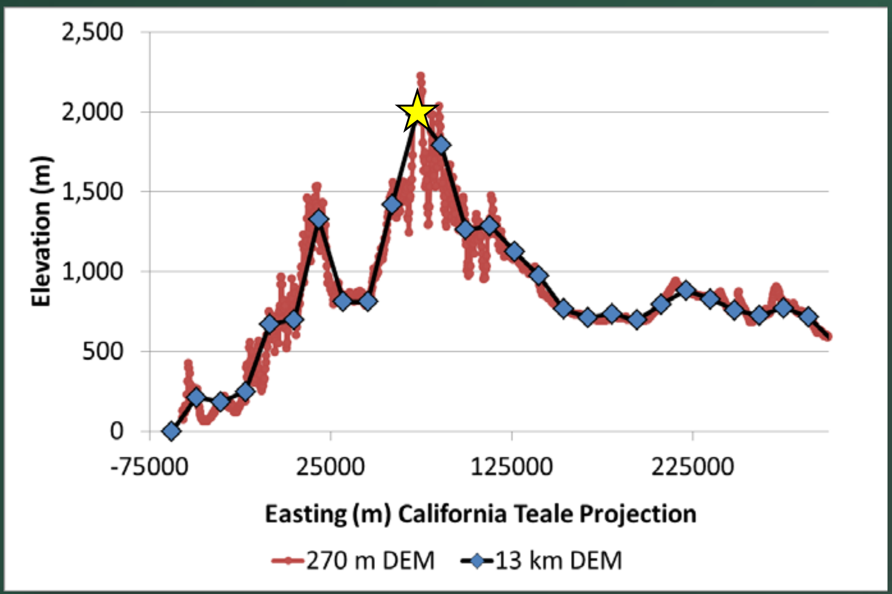


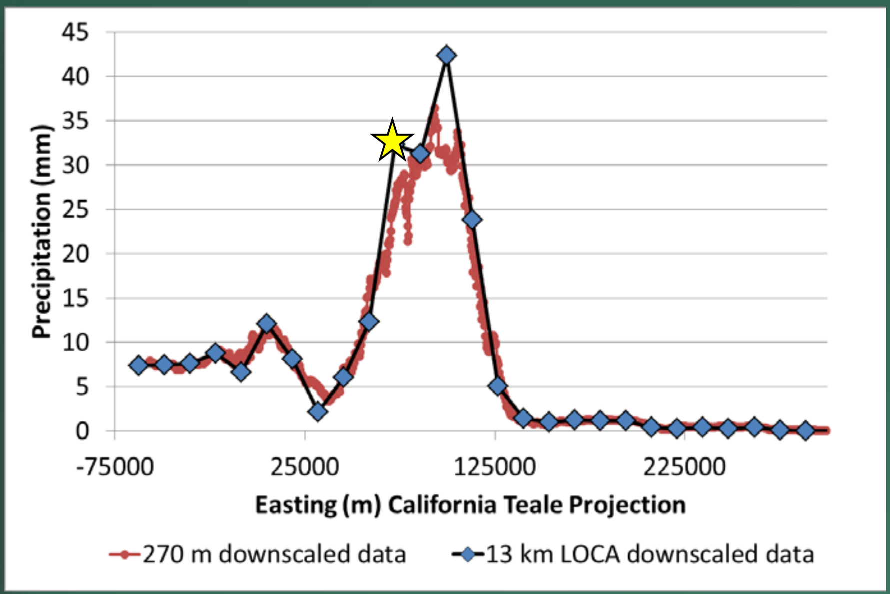
LOCA Precipitation Grid Spatially Downscaled, Mount Pinos in the Transverse Range of Southern California



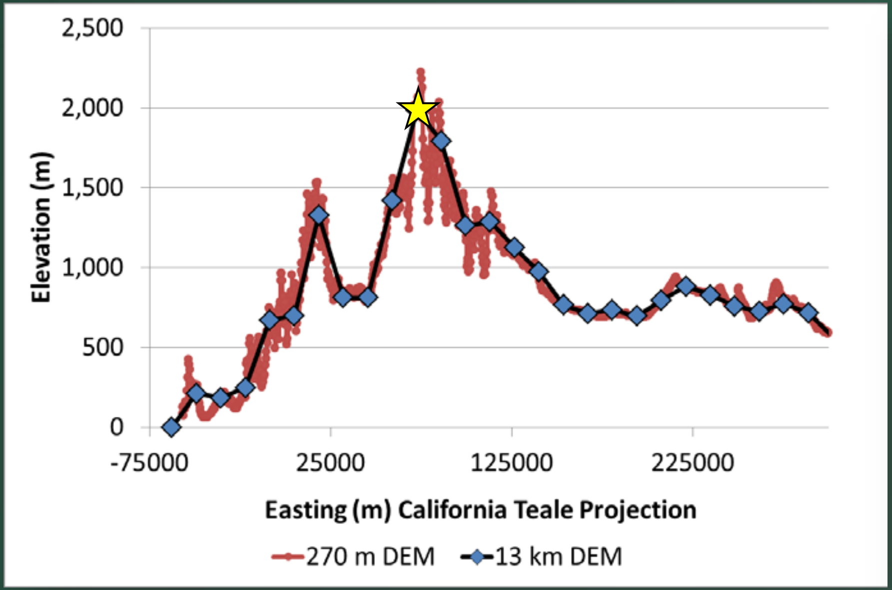
13 km   2 km   270 m

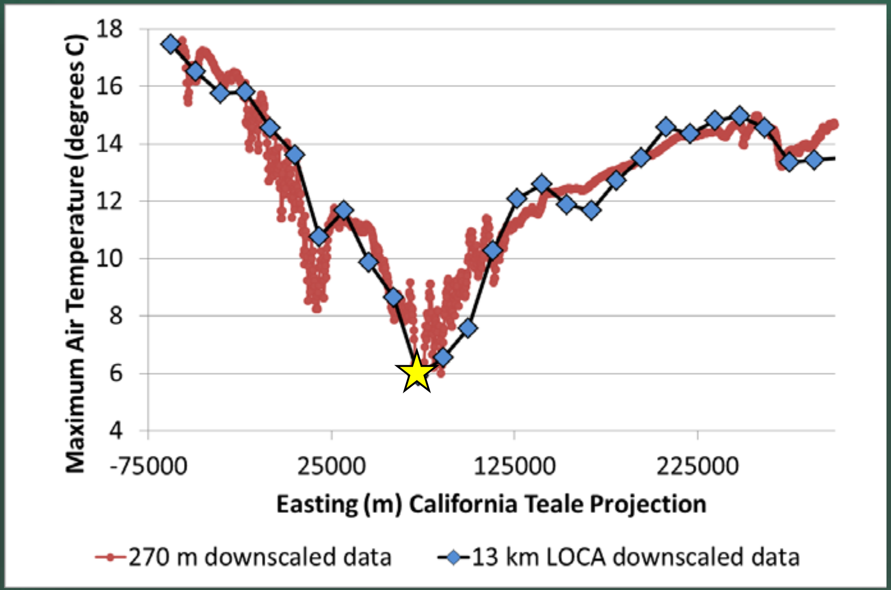
Fine scale downscaling is preserving local extremes of precipitation from the Pacific Coast near Santa Barbara to the Central Valley of California (in progress)



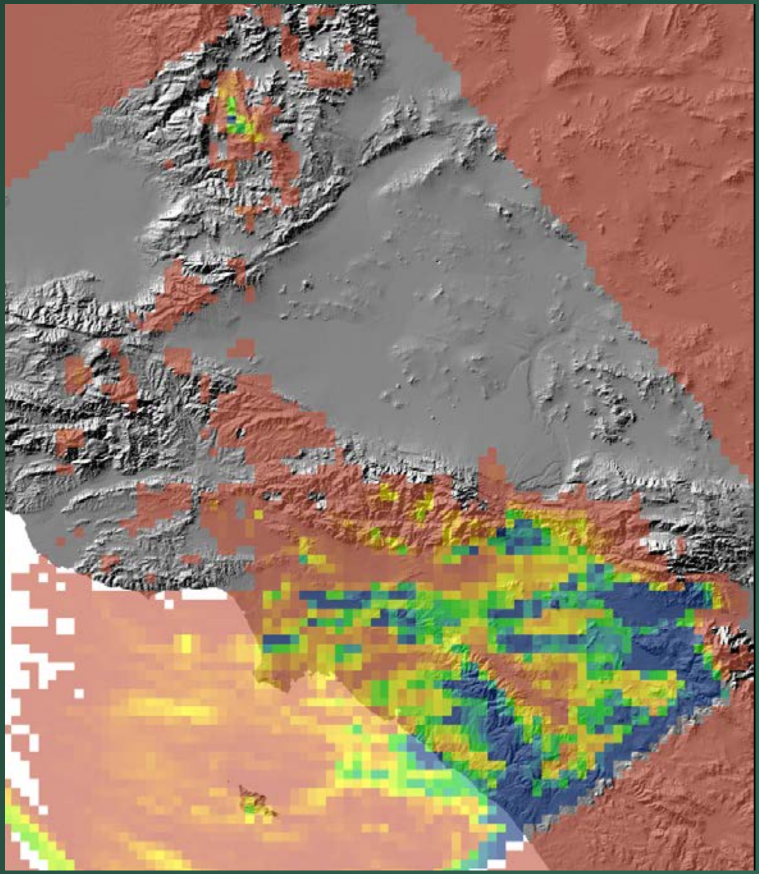


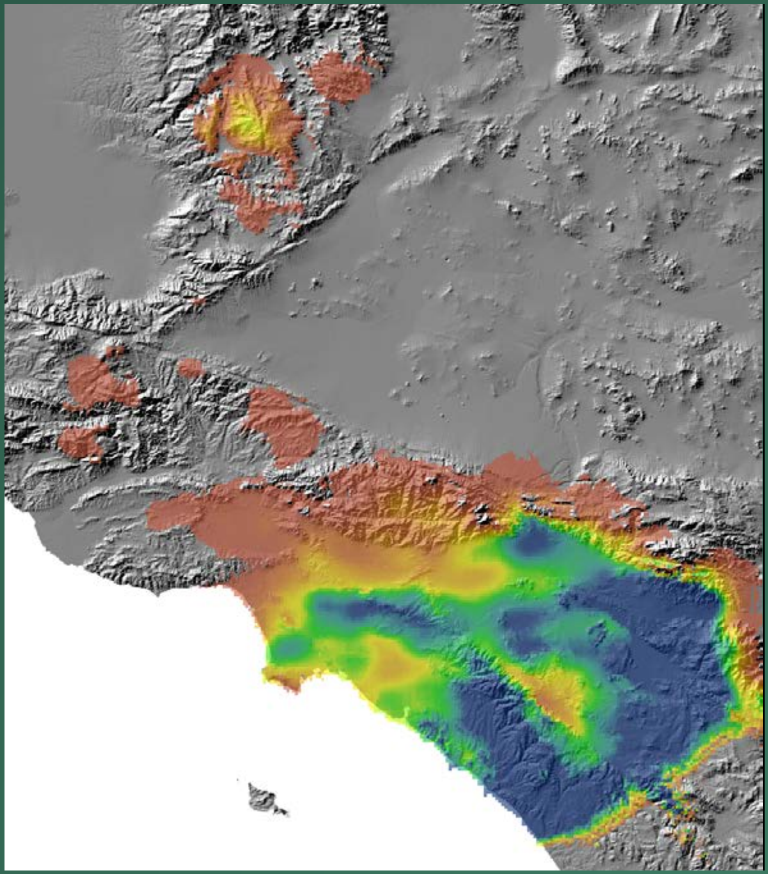
Fine scale downscaling is preserving local extremes of Tmax going from the Paciffic Coast over an elevational gradient to the the Central Valley



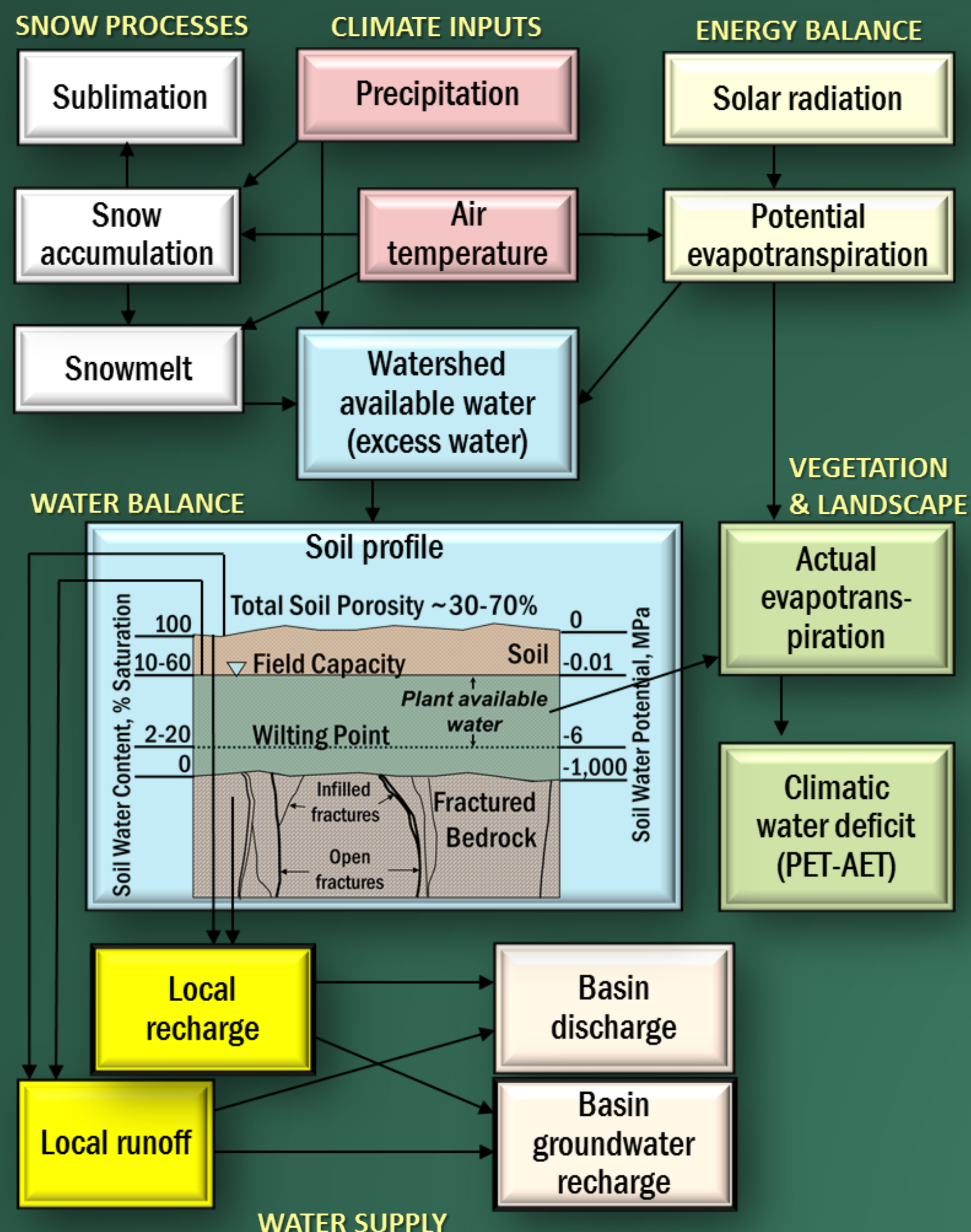


Example of the spatial structure of downscaling one day of a dynamically downscaled regional model (new effort)





Basin Characterization Model



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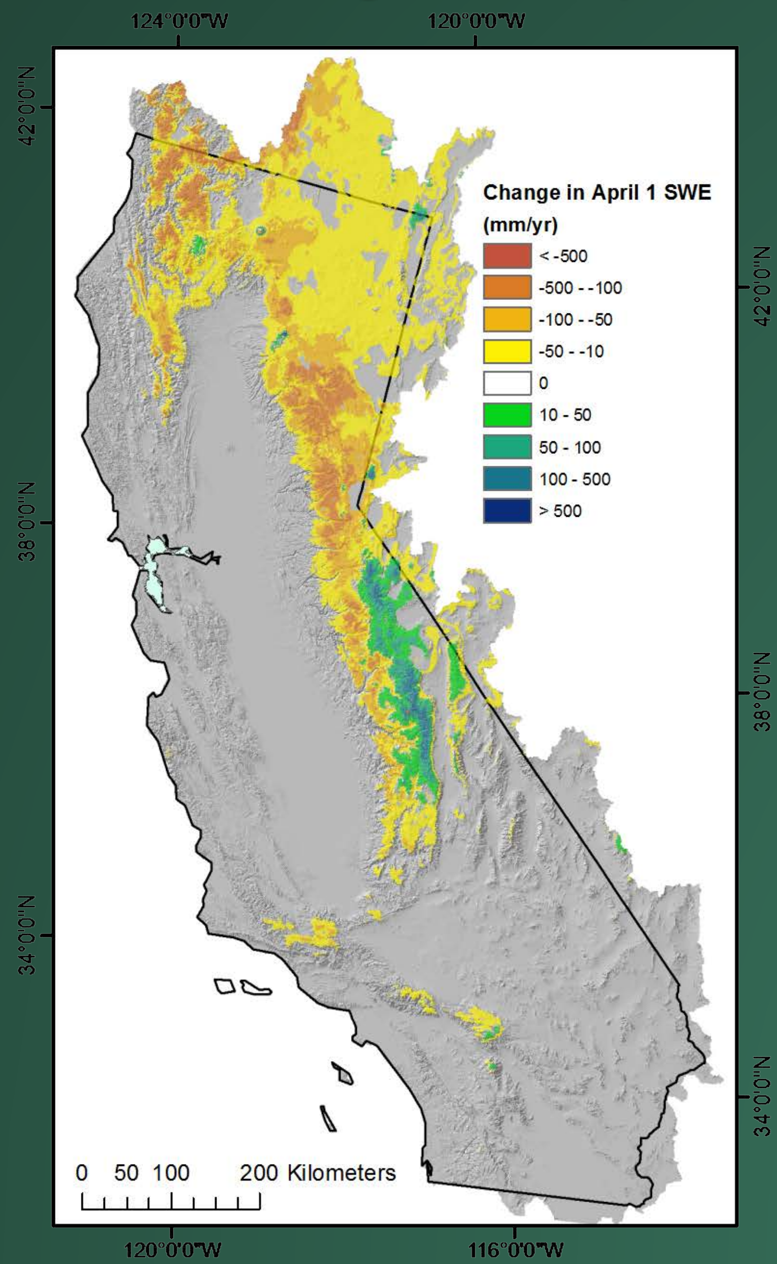
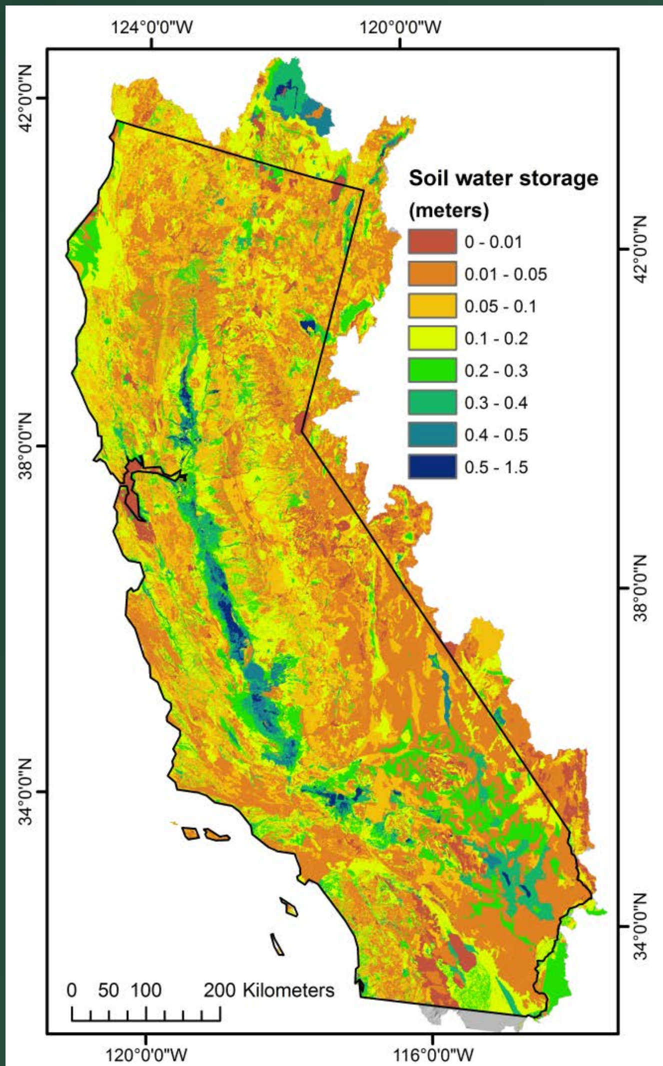
Changes in April 1st snowpack (SWE)

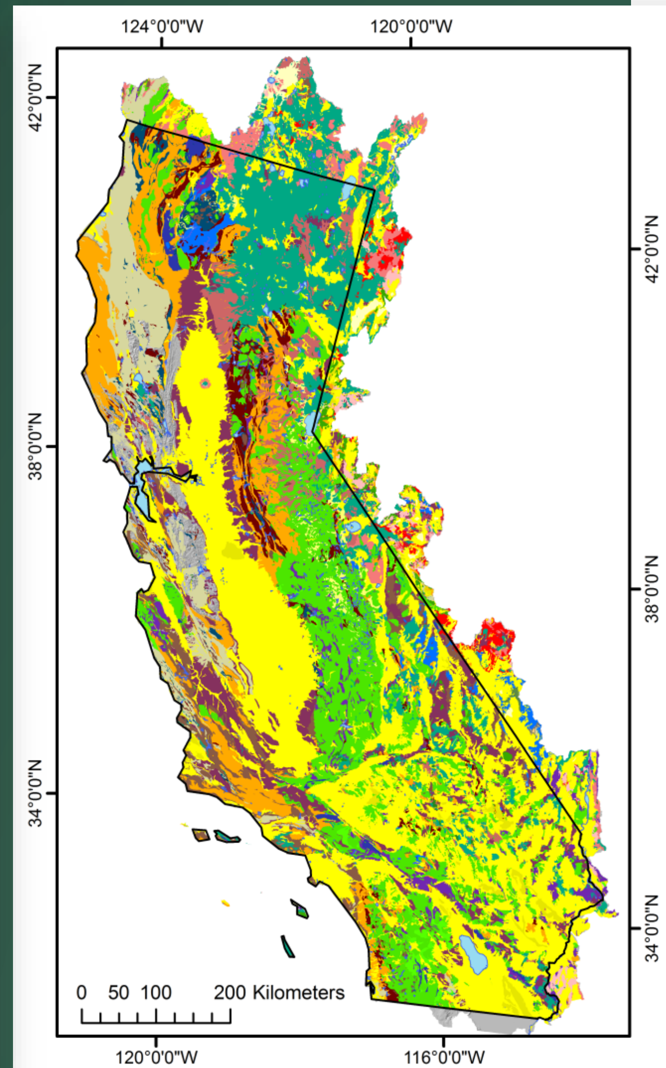


- Change from baseline (1951-1980) to current (1981-2010)
- Decreases due to warming at all but the highest elevations

Soil properties (SSURGO)

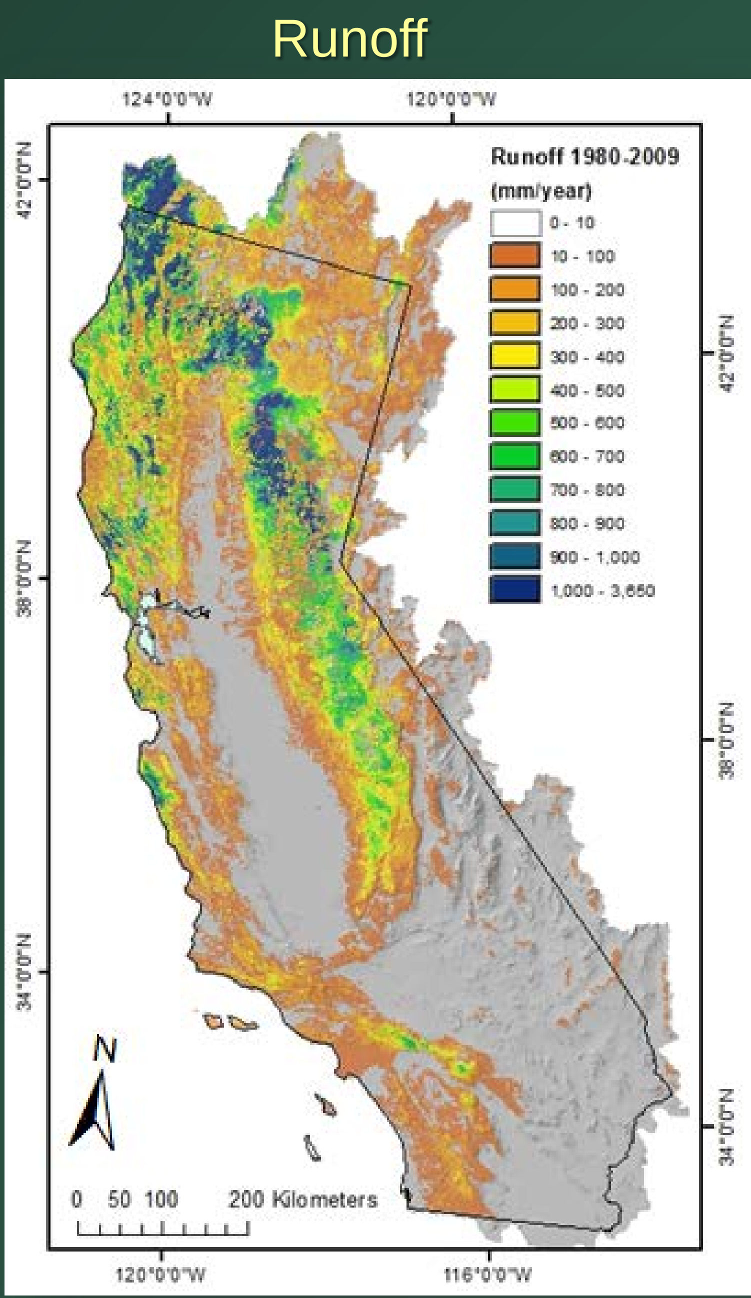


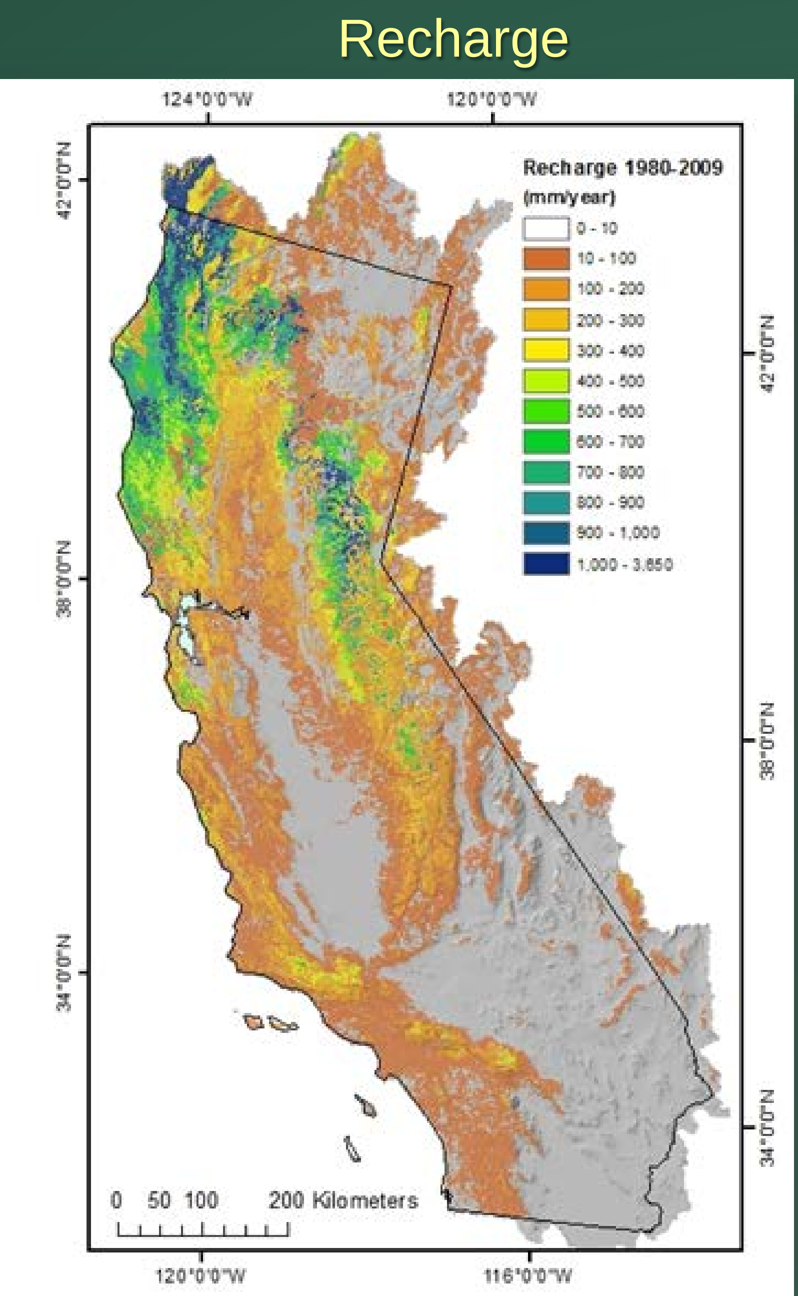
Geology and bedrock permeability



K (mm/day)	Geologic type
3,500	Alluvium - ash
1,370	Alluvium - valley fill
10	Carbonates - limestone
200	Conglomerate
0.27	Gabbro
1.5	Granite
4	Granite - quartz monzonite
0.5	Metamorphics - gneiss/schist
50	Metamorphics - serpentinite
2	Metasediments
0.01	Metavolcanics
0.05	Quartzite
20	Sandstone
1.37	Sandstone - clay/siltstone
10	Sandstone - shale
0.27	Volcanics - andesites
2	Volcanics - ash-flow tuffs
3	Volcanics - basalts/lava flows
100	Volcanics - pyroclastics
0.1	Volcanics - rhyolites
0	Water

64 geologic types

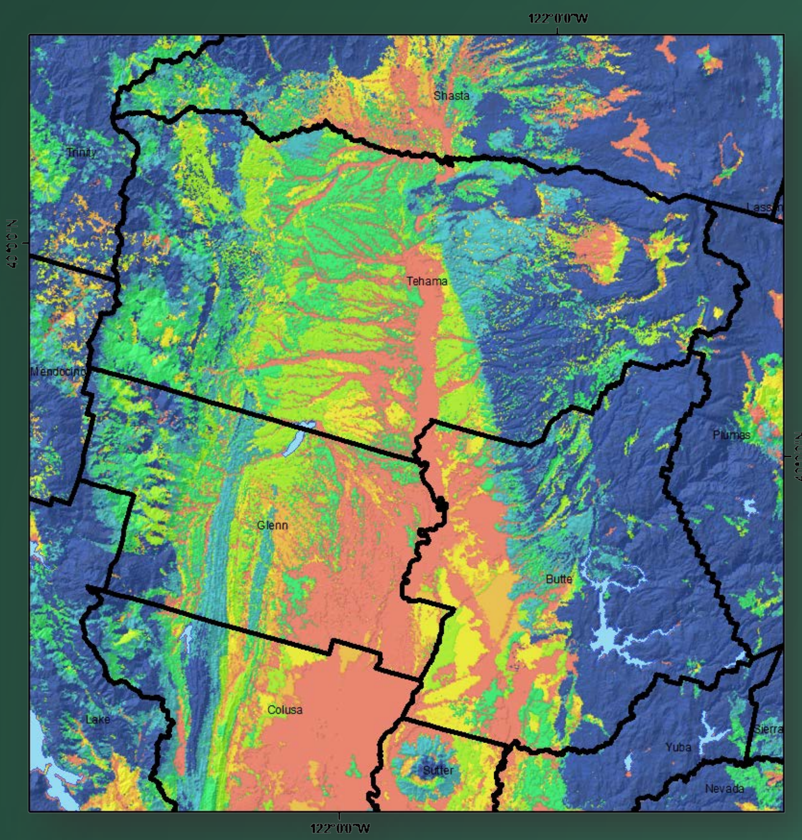

Runoff
124°0'0"W
120°0'0"W
42°0'0"N
38°0'0"N
34°0'0"N
Runoff 1980-2009
(mm/year)
0 - 10
10 - 100
100 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1,000
1,000 - 3,650
N
0 50 100 200 Kilometers
120°0'0"W
116°0'0"W


Recharge
124°0'0"W
120°0'0"W
42°0'0"N
38°0'0"N
34°0'0"N
Recharge 1980-2009
(mm/year)
0 - 10
10 - 100
100 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
700 - 800
800 - 900
900 - 1,000
1,000 - 3,650
0 50 100 200 Kilometers
120°0'0"W
116°0'0"W

Runoff and Recharge

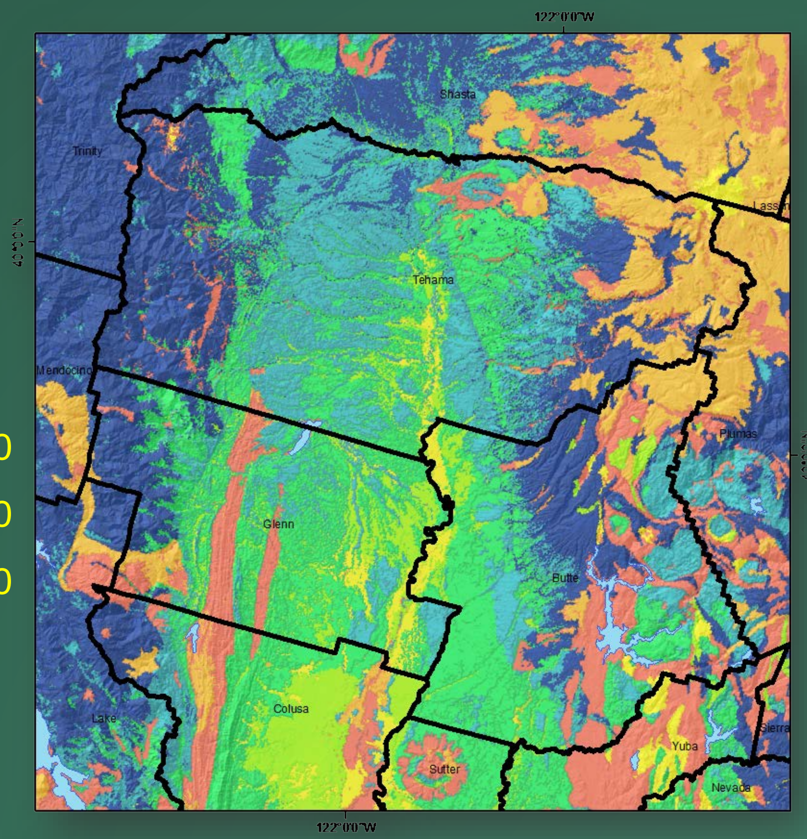
Take advantage of Fine Scale Soil Data

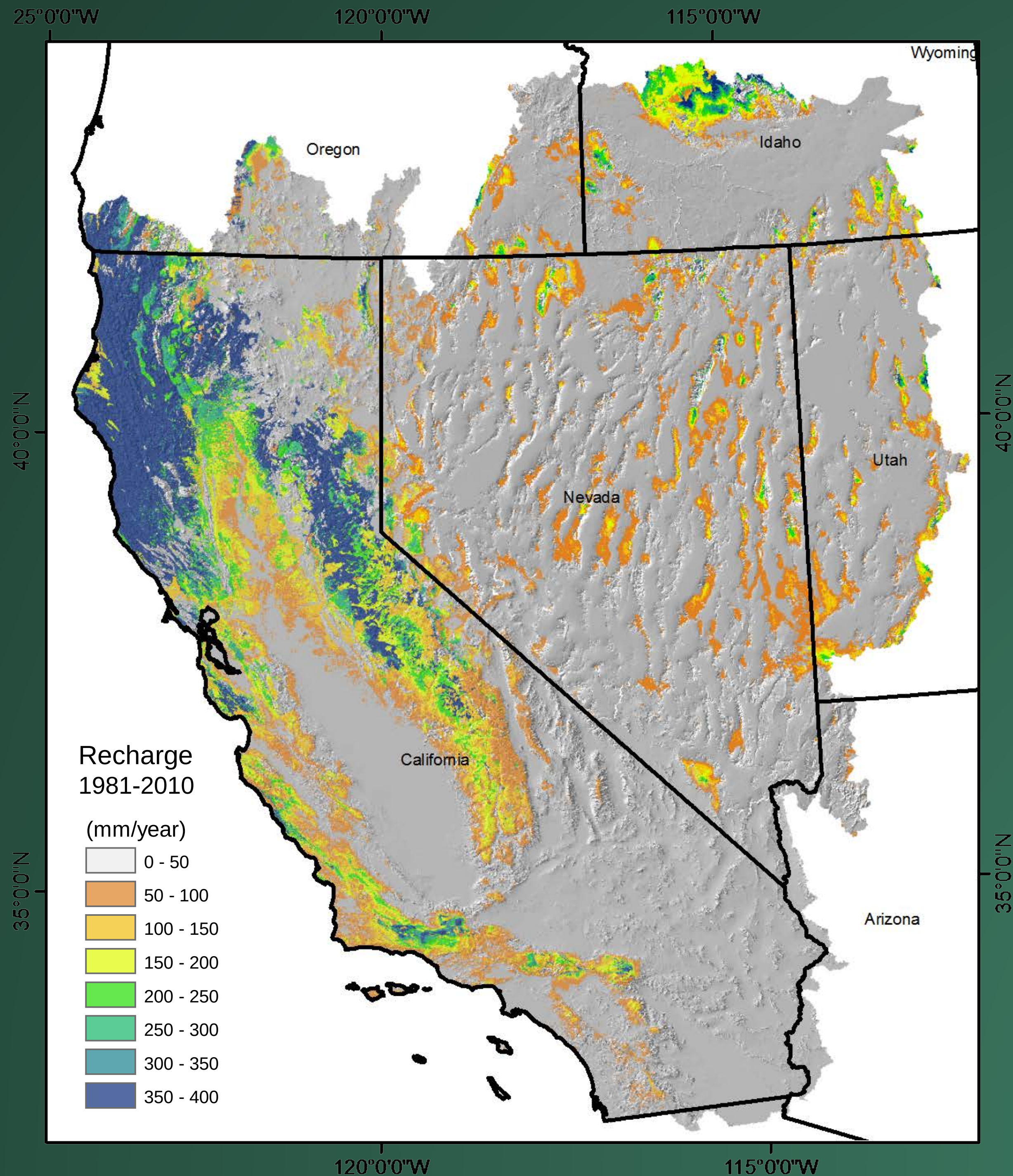
Runoff or Recharge
1980-2009



(mm/year)

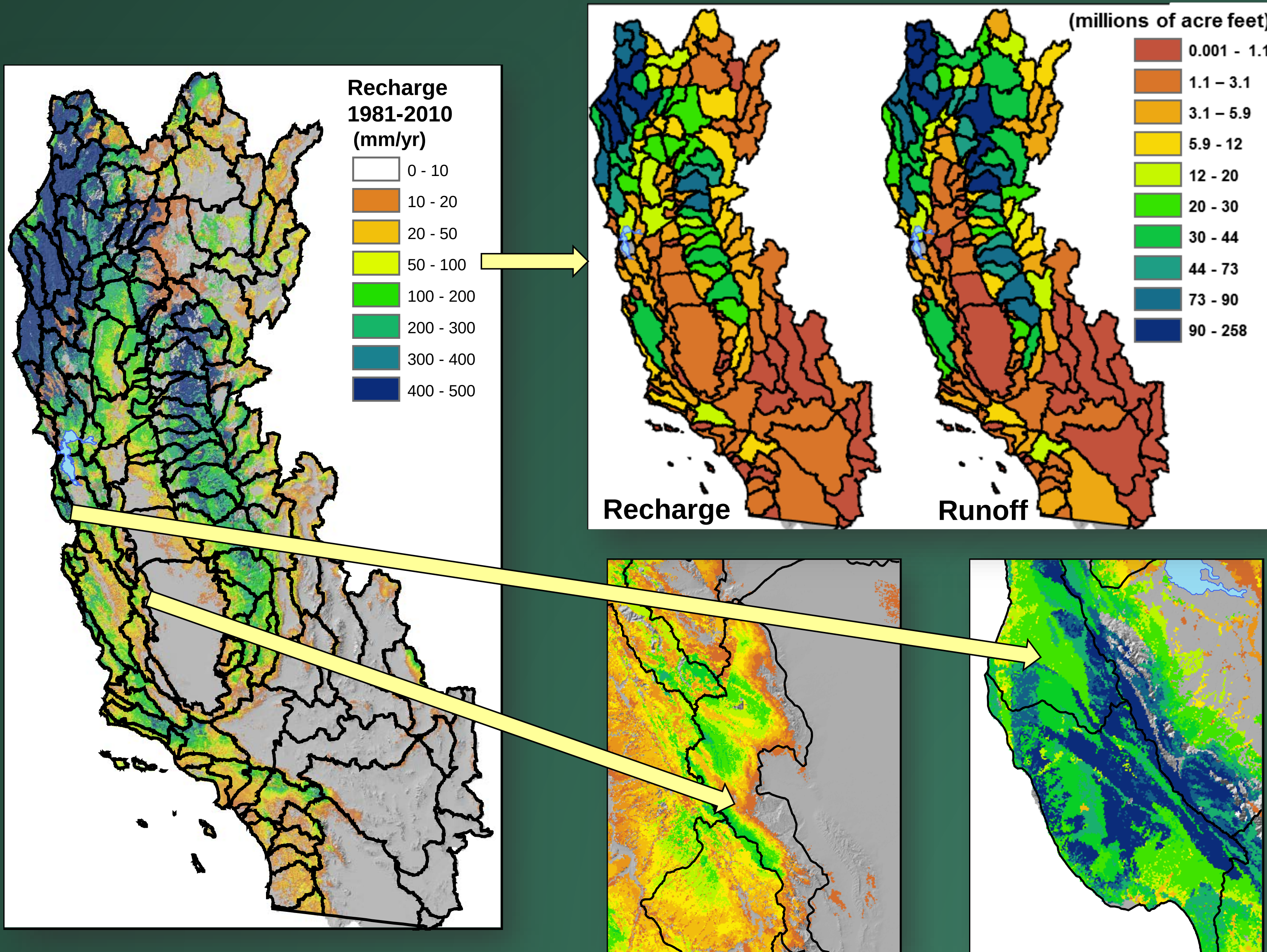
- 0 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 400





Recharge at a fine spatial scale (270 m) over large areas (upper and lower CO just added)

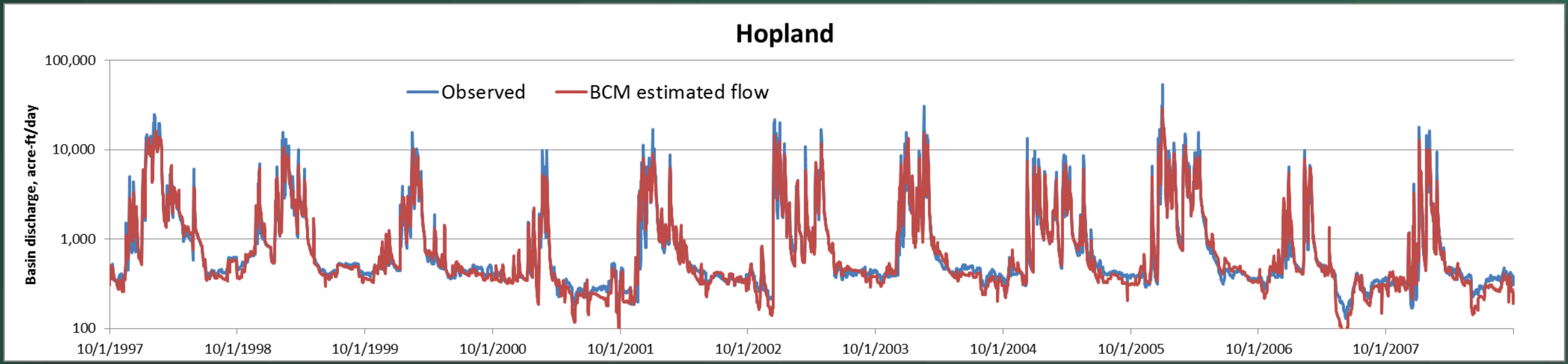
Monthly data Historical and 18 futures available online and being used today (1896-2100)



Westlands

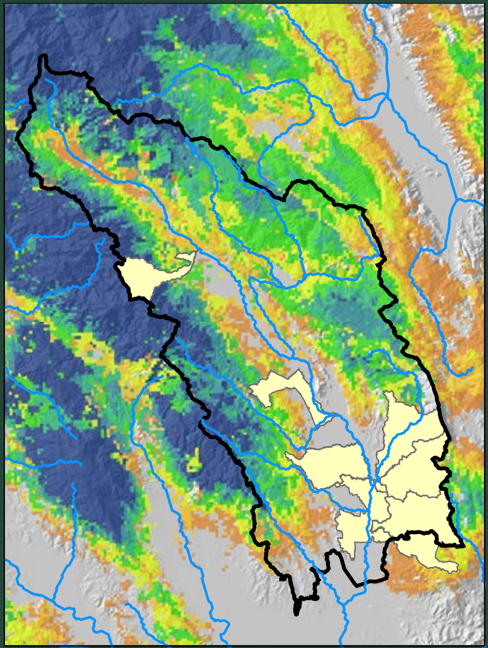
Santa Cruz

Calculating Basin Discharge from Recharge and Runoff to Match Streamflow Measurements



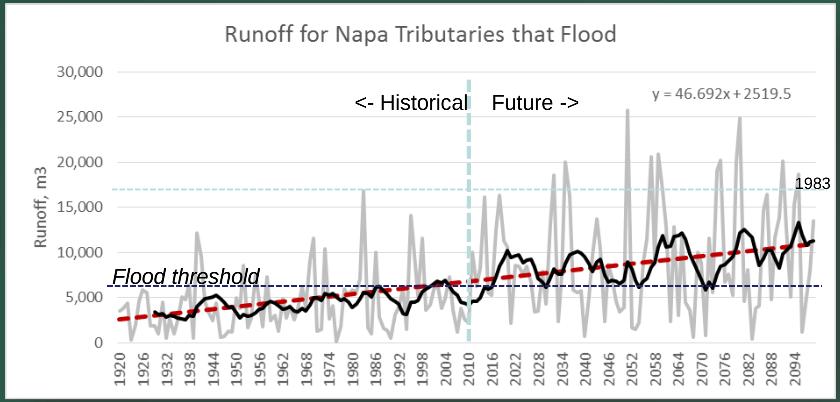
- Monthly or daily model results
- Calibrated to streamflow measurements for characterizing
  - extreme conditions, floods, droughts
  - environmental flows

Napa Tributaries that Flood



Runoff

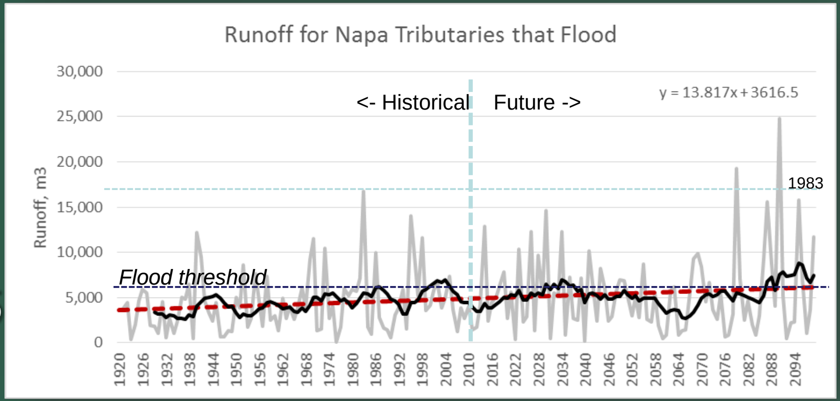
Warm &
High Rainfall
CNRM 8.5



10 years exceeding historical peak threshold in future

35 more years than flood threshold

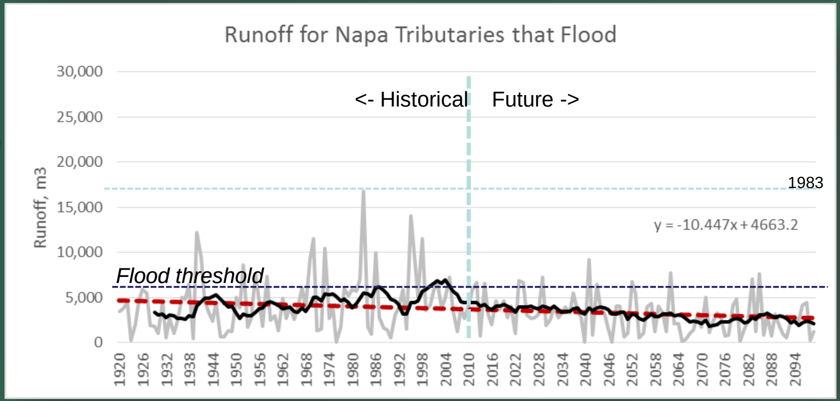
Warm &
Moderate
Rainfall
CCSM4 8.5



2 years exceeding peak threshold

20 more years than flood threshold

Hot &
Low Rainfall,
MIROC 8.5

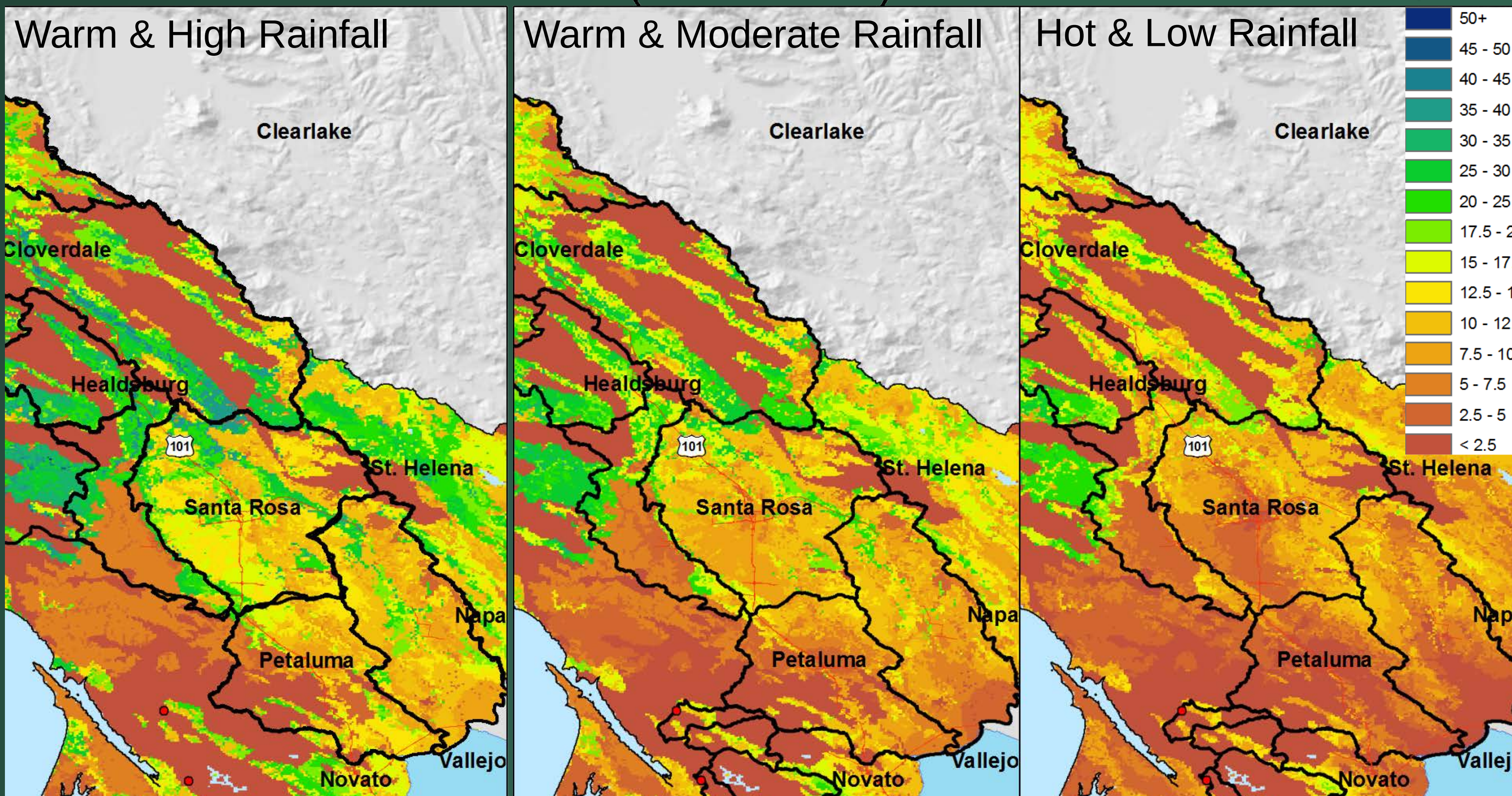


None exceed peak threshold

11 exceed flood threshold

Projected Recharge, resilient areas get recharge in all scenarios, (2070-2099)

(inches)



Watershed characterization for improved reservoir operations

(Example 1)

- Lake Mendocino provides water to 600,000 people in the Russian River basin
- Flood control pool operated by USACE, conservation pool operated by SCWA
- Need forecast-informed reservoir operations to maintain optimum water in reservoir to maintain water supply and fisheries, yet not compromise dam safety and promote downstream flooding
- Need improved watershed characterization for runoff simulations on the basis of forecasts
- Incorporate field measurements of soil moisture into model development to reduce uncertainties

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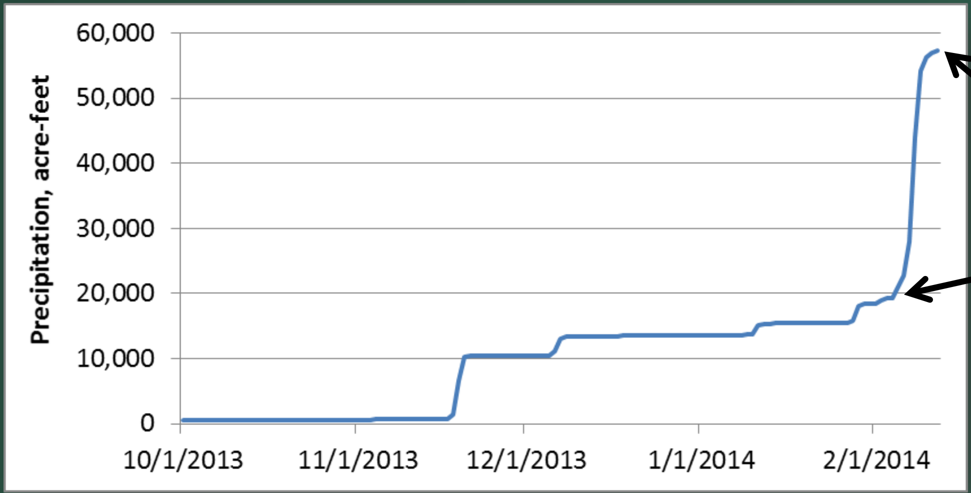
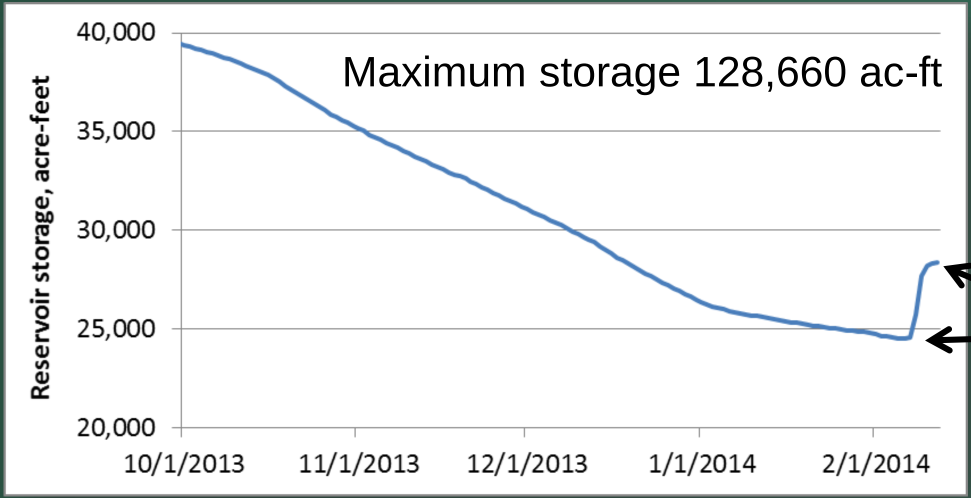
Lake Mendocino 2014

Precipitation



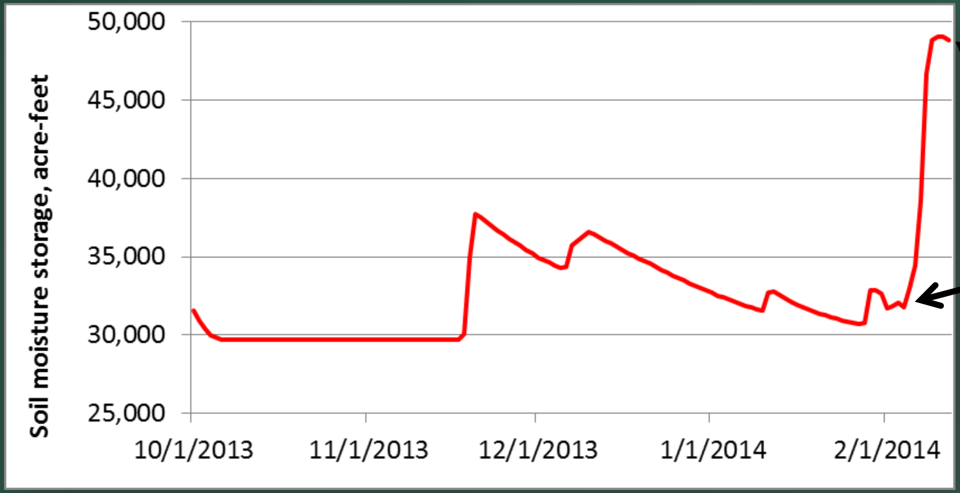
Feb 5-12, 2014
37,921 acre-feet of precipitation in watershed

Reservoir Storage



Feb 5-12, 2014
3,823 acre-feet increase in reservoir storage

Soil Moisture Storage



Feb 5-12, 2014
16,362 acre-feet increase
in stored soil water

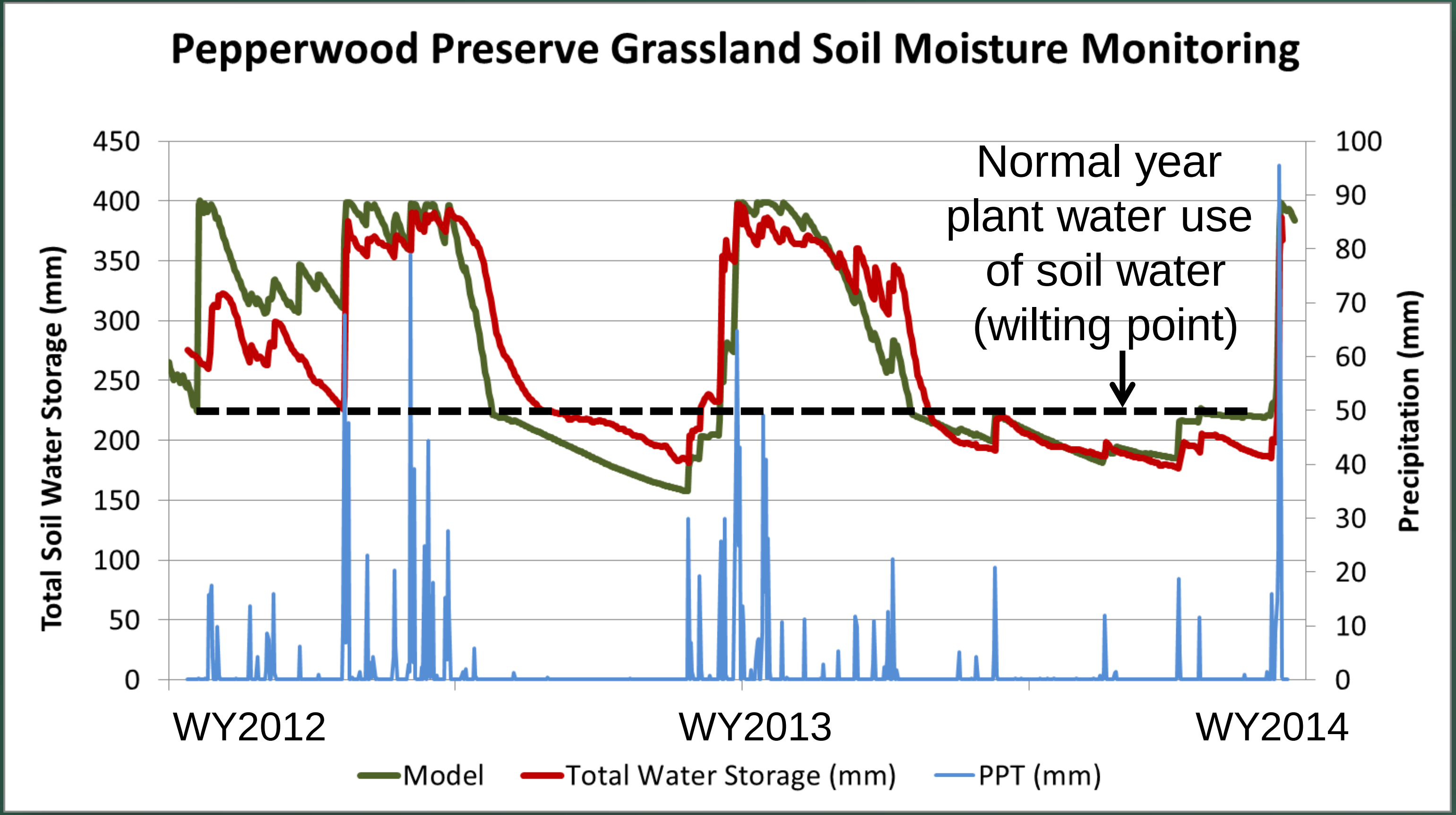
10% of precipitation made it to reservoir
(including 3% precip directly on res + 7% from runoff)

7% lost to PET
44% of precipitation replenished dry soils

39% of precipitation went to fill the shallow unsaturated zone >> ***recharge***

Soil Moisture Monitoring

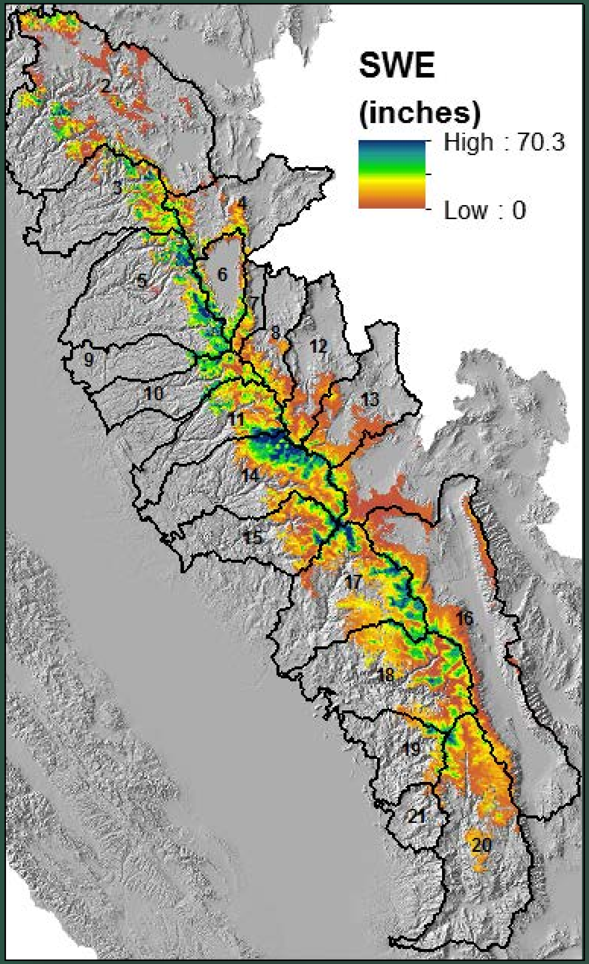
(headwaters of Mark West Creek)

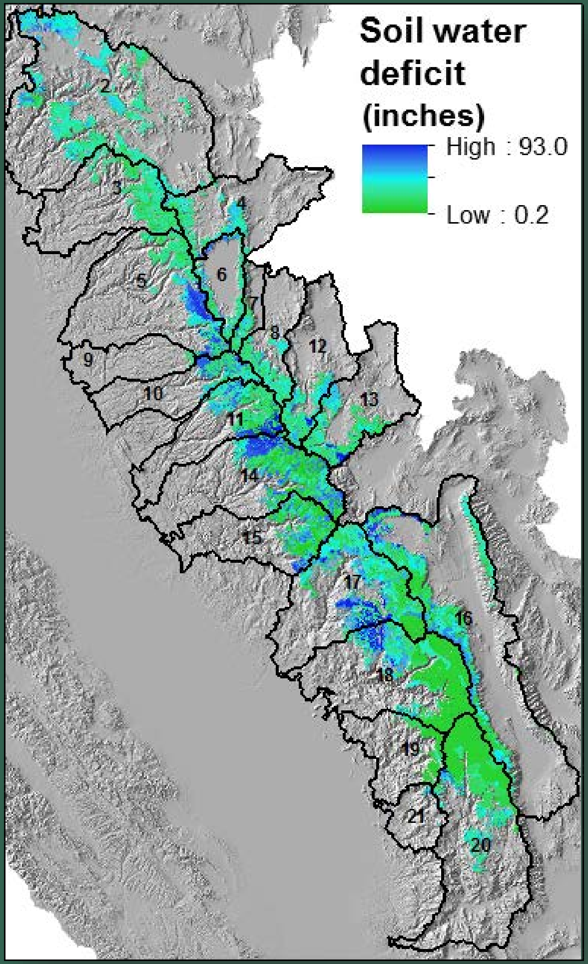


Data US Geological Survey

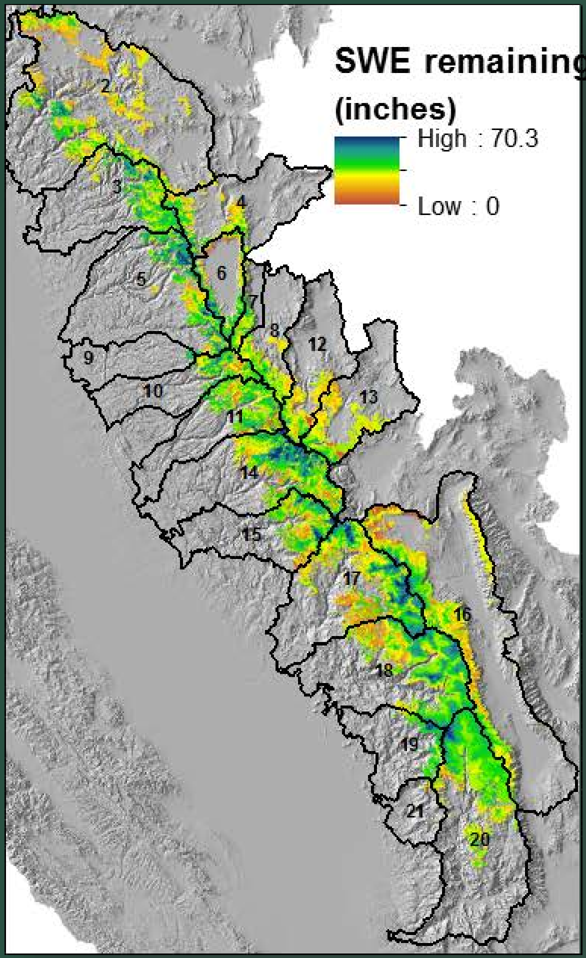
Sensitivity of springtime runoff to soil moisture status Sierra Nevada (March 2014)

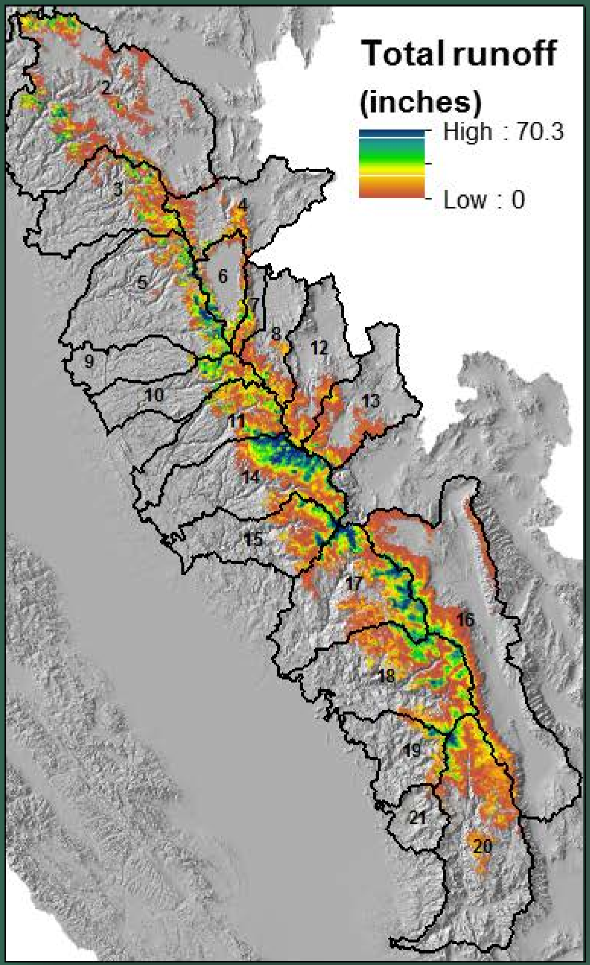
(Example 2)





Forecasted Water Supply
Or How will your Reservoir Respond?





Of the 337,000 AF of SWE 324,000 was needed to meet soil demand (4%)

Runoff as % of SWE for basins ranged from 0 to 38%

Urbanization Projections from USGS Land Carbon Group using SRES A2

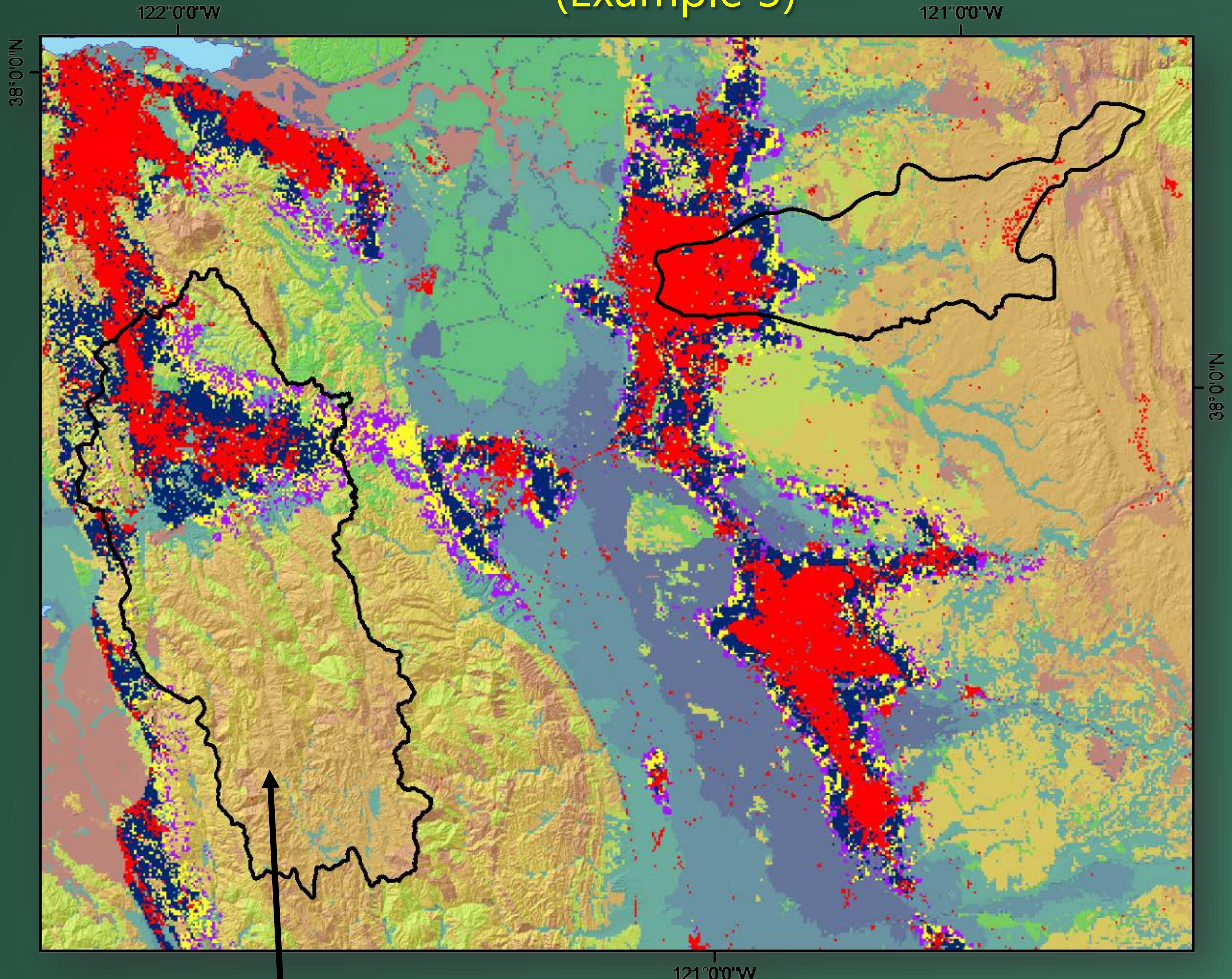
(Example 3)

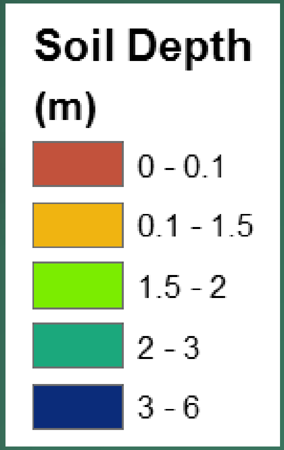
current

2040

2070

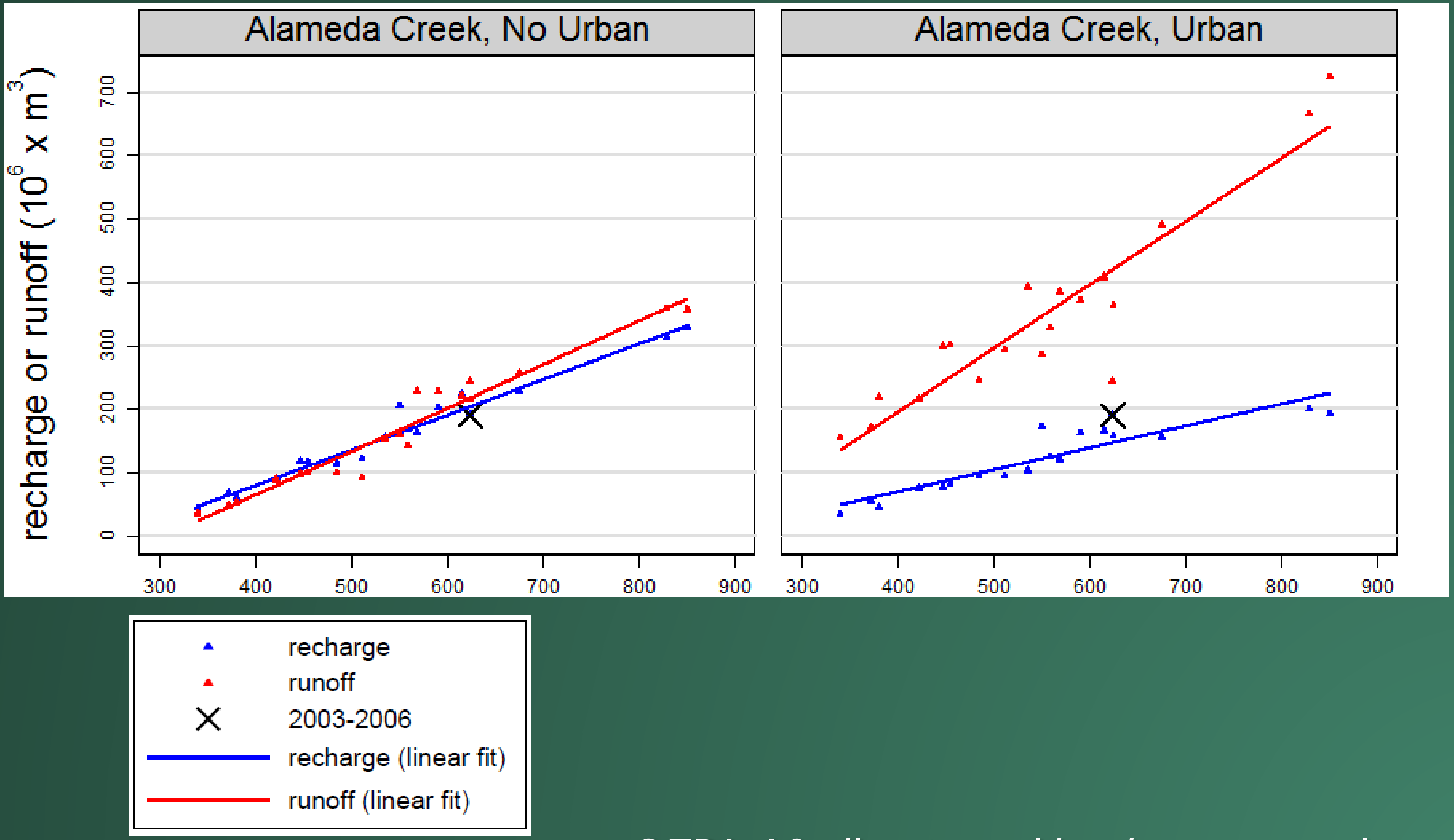
2100



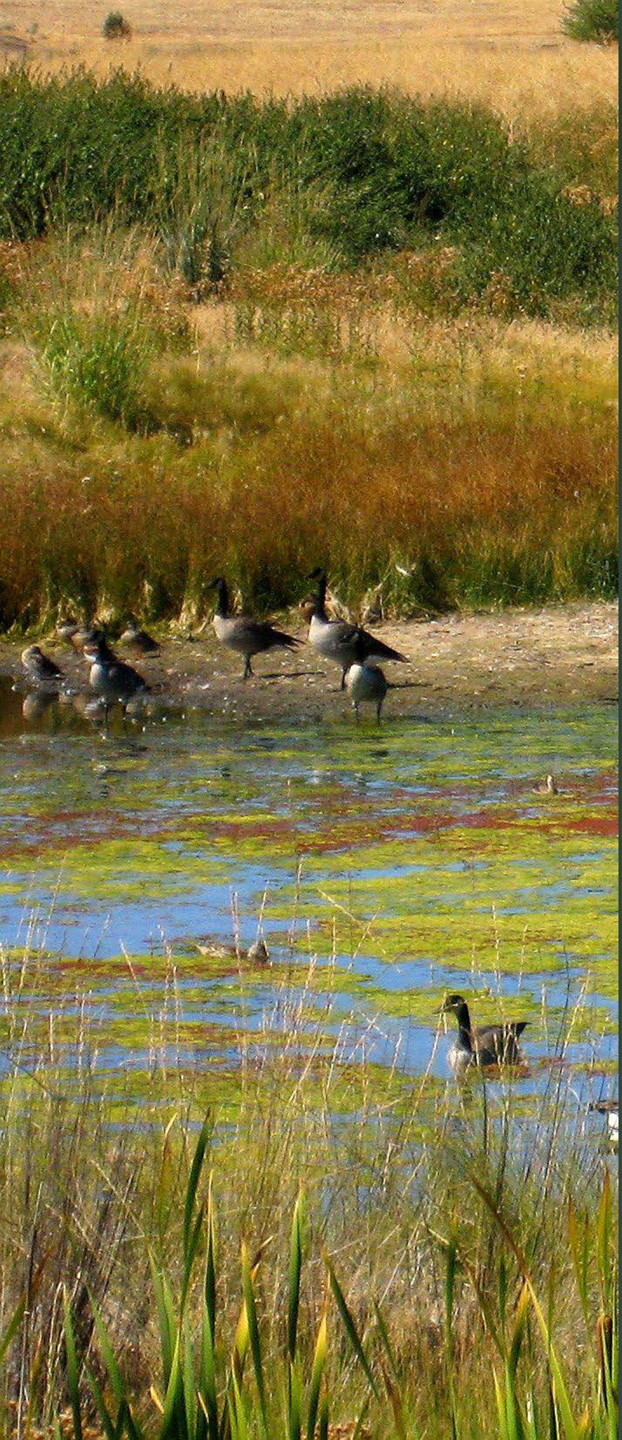


Alameda Creek drains to the south SF Bay

Recharge and Runoff vs. Precipitation due to increase in impervious surfaces



GFDL A2 climate and land use scenario



Adaptation Planning for Managed Wetlands: Modoc National Wildlife Refuge

(Example 4)

- Uncertain futures required the development of a conceptual model framework that links modeled parameters from BCM to refuge management outcomes
- changes in deficit and recharge and magnitude, timing, and frequency of water inputs were used to develop wet and dry water year types to assess projected refuge sensitivity to futures
- Project results were used to develop planning strategies for future refuge management

Summary

- We are using various downscaled climate models (CMIP3, CMIP5)
  - Constructed Analogs
  - Bias Corrected Statistically Downscaled
  - Localized Constructed Analogs
  - Dynamically Downscaled
- GIDS spatially downscaled to finer scales (800m-90m)
- Modified GIDS spatially downscaled to preserve and enhance extremes (if warranted) to fine scales
- Use regional hydrologic model to translate climate change to hydrologic response for California, the Great Basin, the Upper Colorado, and the Lower Colorado