

Groundwater & Sierra Nevada Snowpack

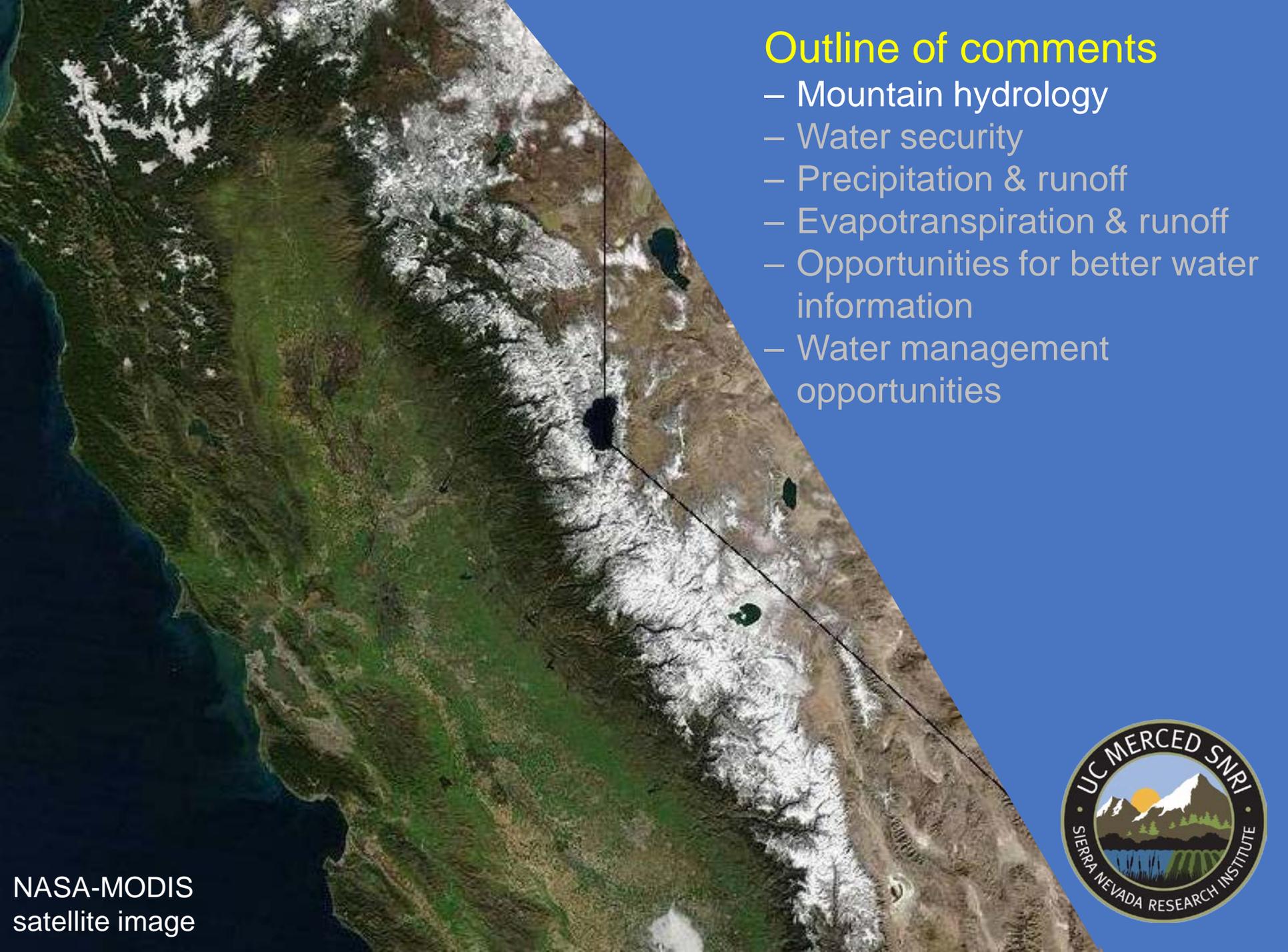
Martha Conklin
Professor & Director

Sierra Nevada
Research Institute

UC Merced



NASA-MODIS
satellite image



Outline of comments

- Mountain hydrology
- Water security
- Precipitation & runoff
- Evapotranspiration & runoff
- Opportunities for better water information
- Water management opportunities

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satellite image



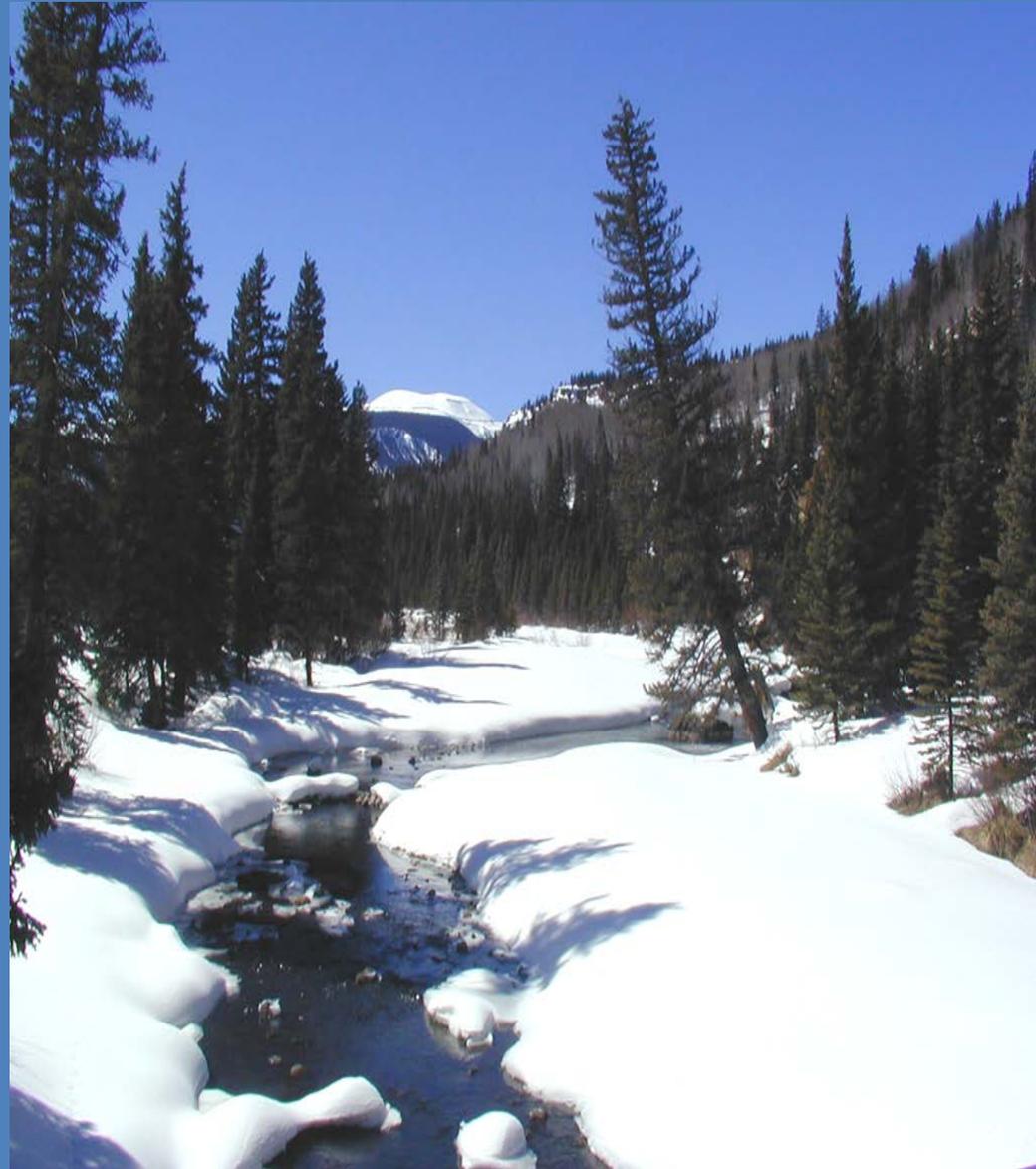
Much of the water supply for the semi-arid Western U.S. derives from mountain snowpacks

Warming by +2 to +6°C drives significant changes:

- rain-vs-snow storms *
- snowpack amounts *
- snowmelt timing *
- flood risk
- streamflow timing *
- low baseflows
- growing seasons *
- recharge?
- drier soil in summer

Precipitation changes?

Already observed (*)



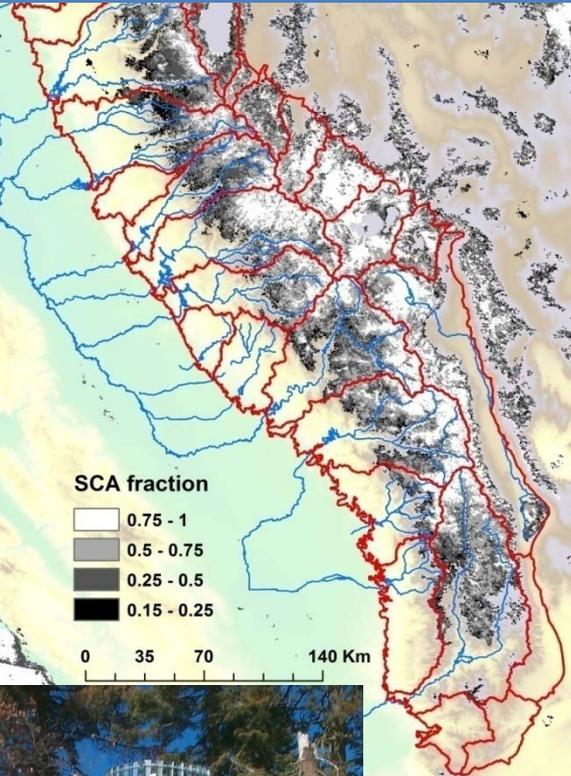
Fast facts



- About 2/3 of the precipitation that falls on the Sierra Nevada is evaporated/transpired by vegetation & 1/3 runs out in rivers
- In an average year, the Sierra Nevada receives 27% of the state's annual precipitation & provides more than 60% of the state's consumptive use of water

Basic water balance

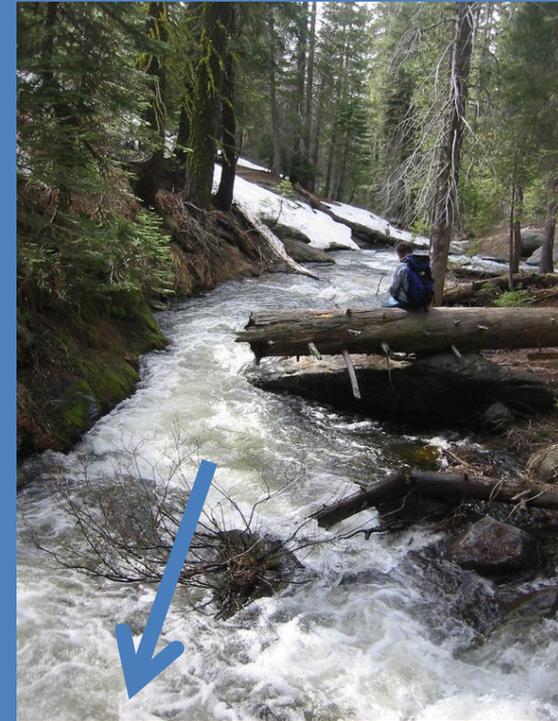
$$\text{Precipitation} = \text{Evapotranspiration} + \text{Runoff}$$



=



+



Groundwater recharge, mountain block vs. mountain front?



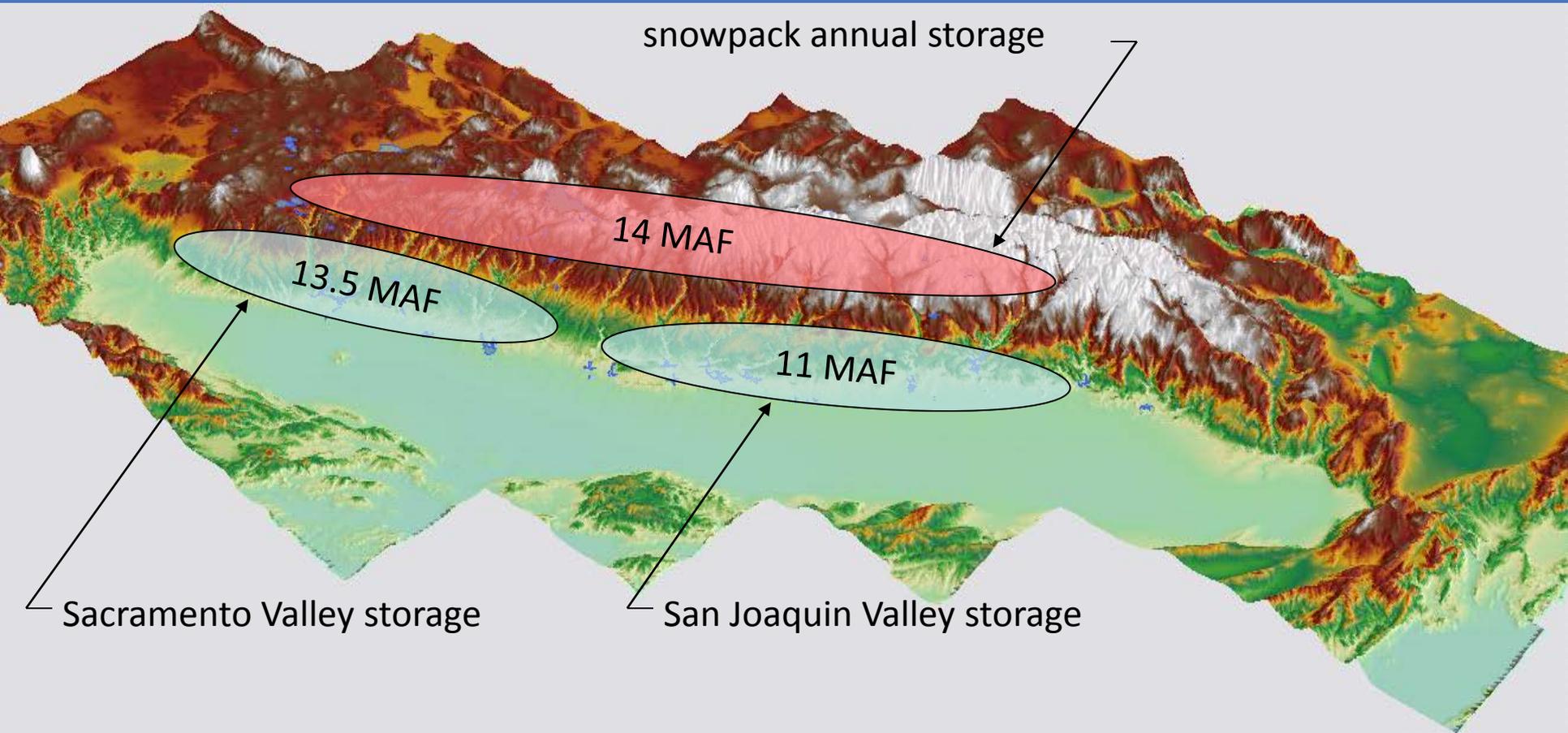
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Snowpack loss & water storage: 30-yr horizon



Likely loss of ~3.5 MAF of snowpack storage in next 1-3 decades

MAF: million acre feet

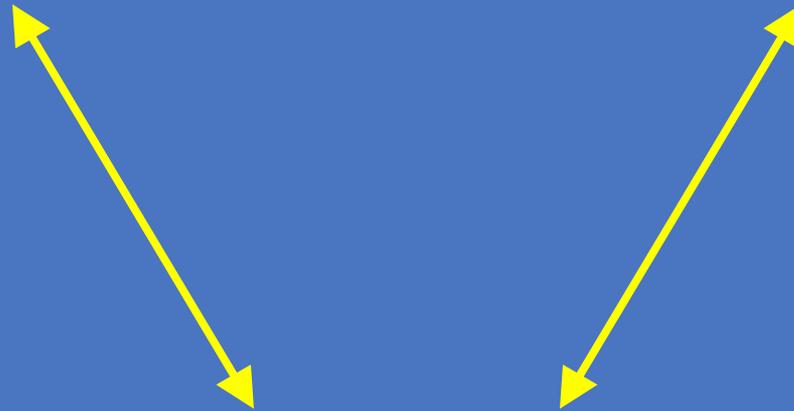
Data from DWR

Making a water-secure world – the three I's

INFRASTRUCTURE
to store, transport
& treat water



Stronger & more-
adaptable
INSTITUTIONS



Better & more-
accessible
INFORMATION

Water security: the reliable availability of an acceptable quantity & quality of water for health, livelihoods & production, coupled w/ an acceptable level of water-related risks

Water security lies at the heart of adaptation to climate change

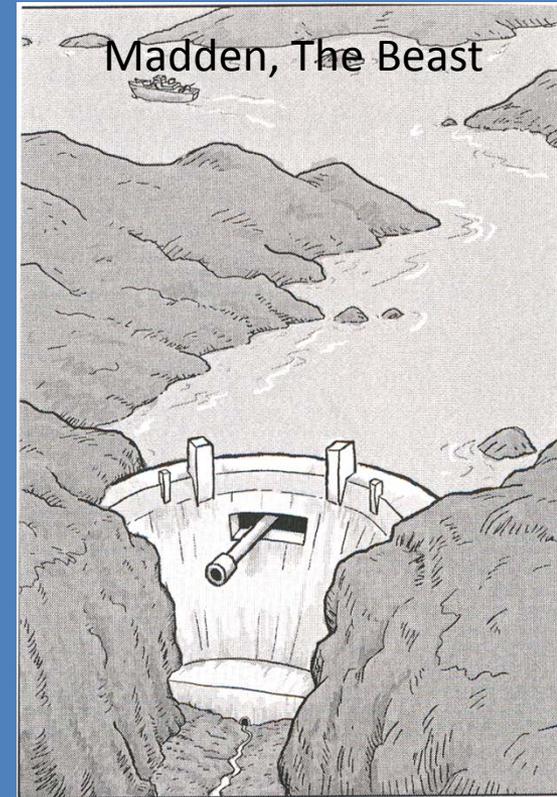
Includes both:

- ‘hard’ options to capture & control water
- ‘soft’ tools to manage demand as well as increase supply, e.g. water allocation, conservation, efficiency & land-use planning

General feeling in the water community that soft opportunities will be insufficient

What California is doing:

- Planning for infrastructure
- Collaboration & integration in planning, management
- More information-intensive decision support



**IN THE FUTURE,
WARS WILL BE FOUGHT
OVER WATER**



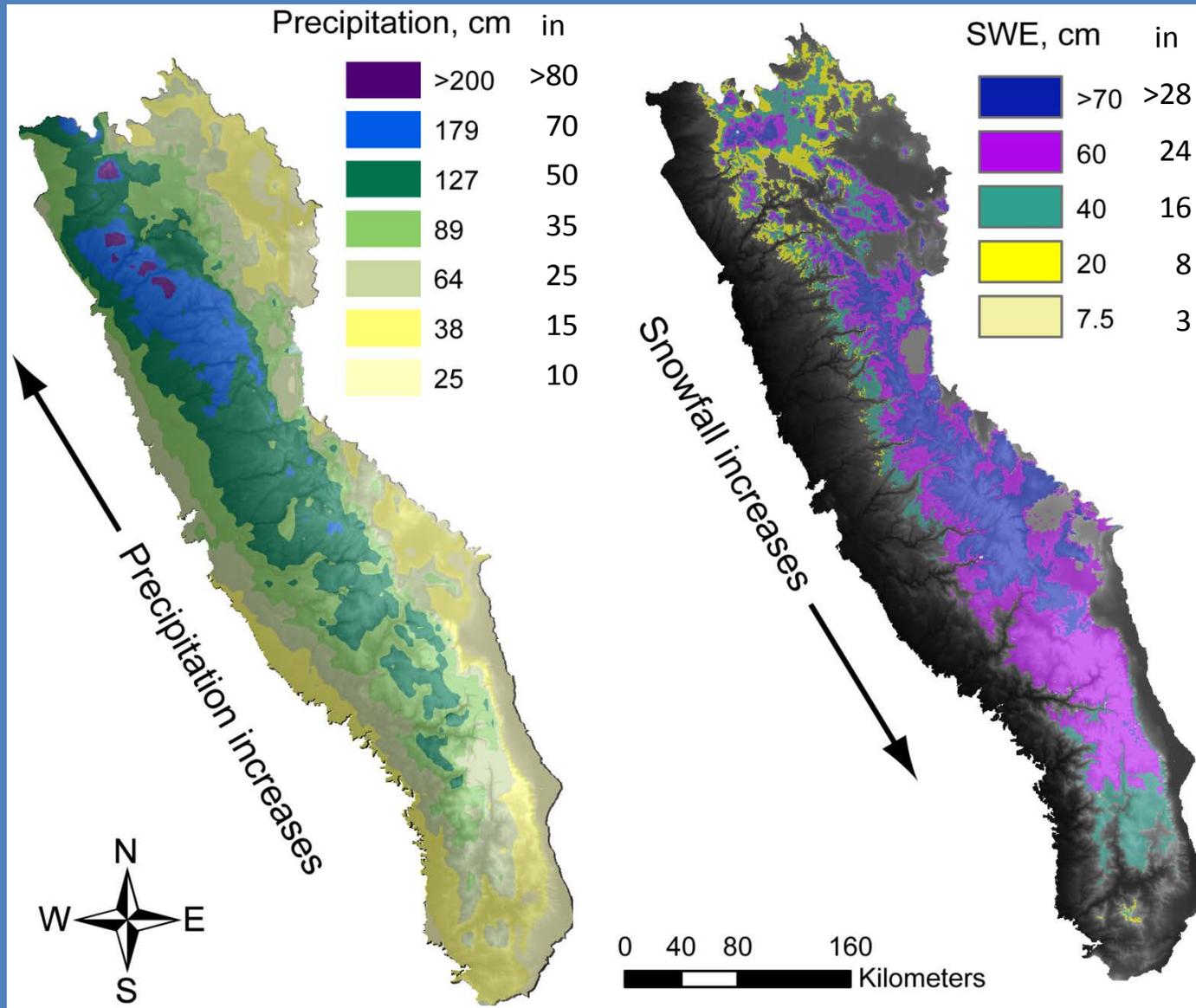
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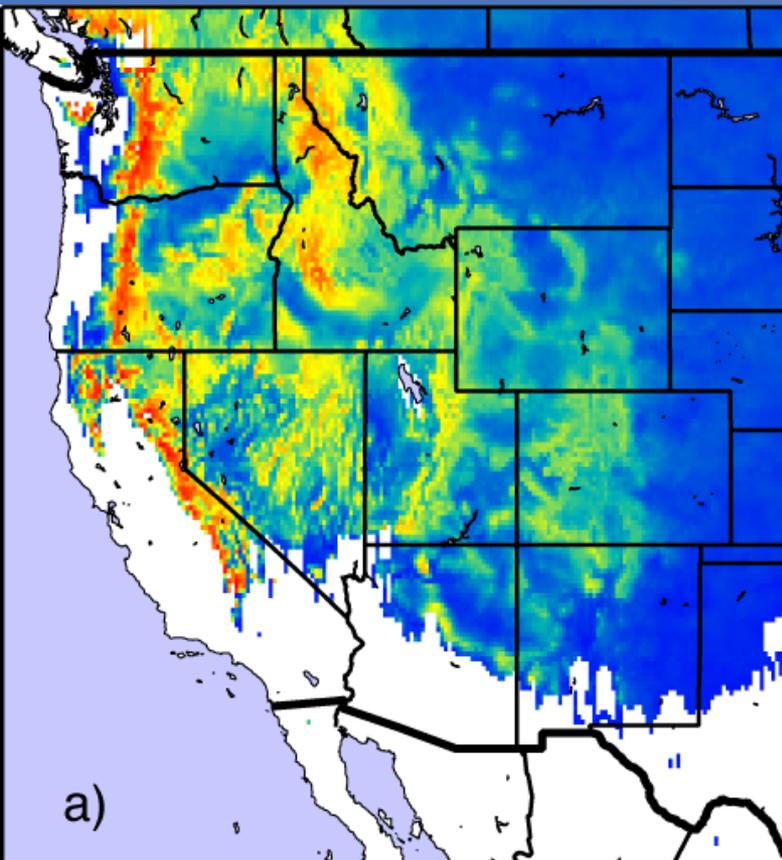


Sierra Nevada precipitation & snow water equivalent (SWE) – climatological estimate?



Influence of +3°C on SNOW vs RAIN

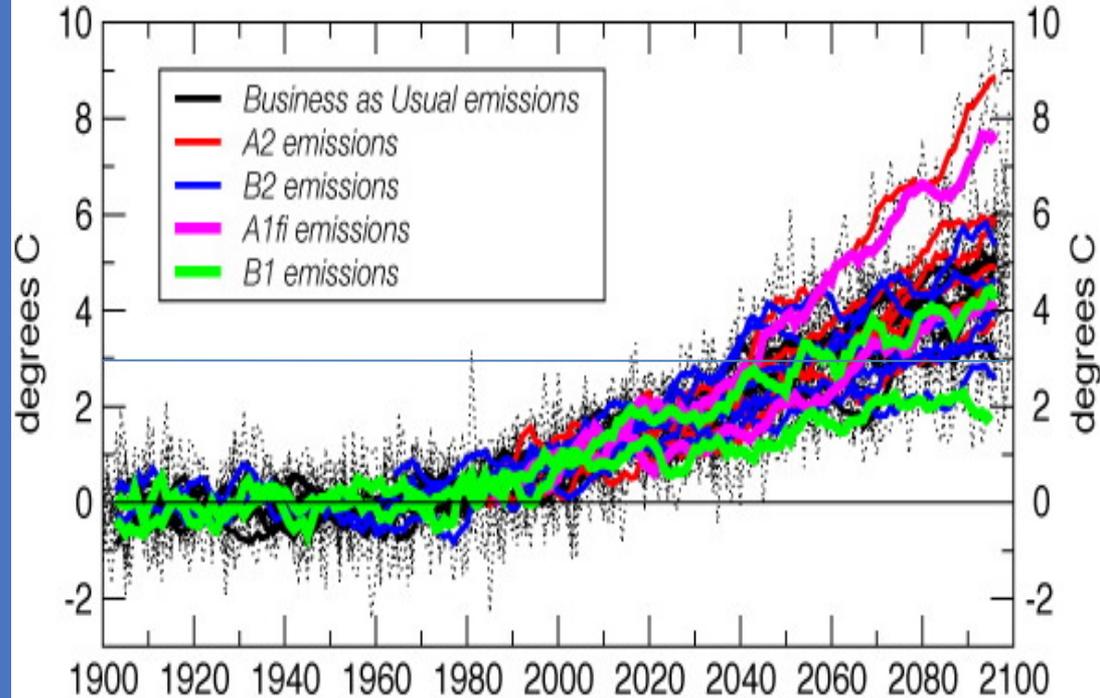
More rain, less snow



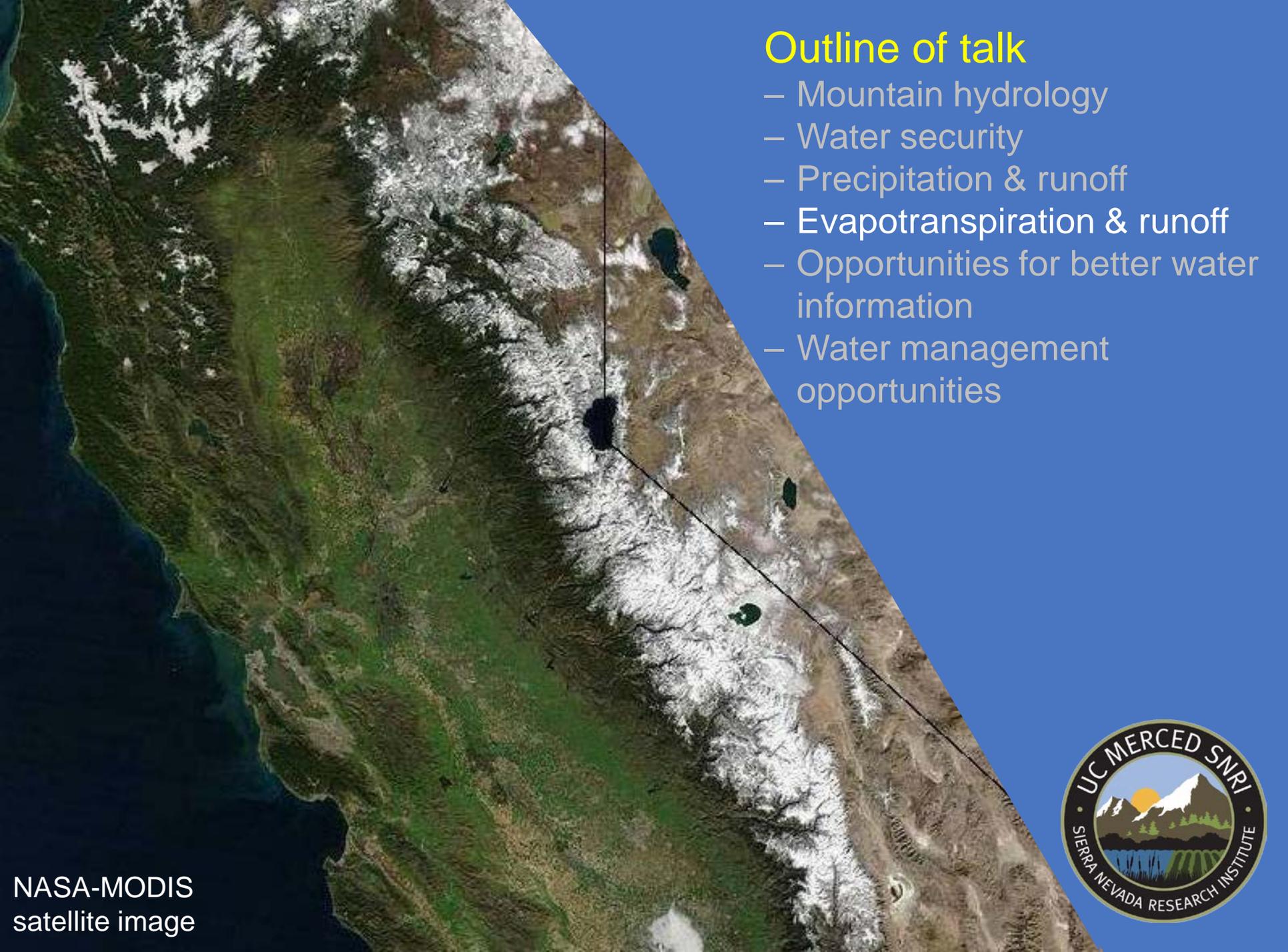
0.00 0.18 0.36
fraction of precipitation

Historical, 0 to -3°C

PROJECTED CHANGES IN ANNUAL TEMPERATURE, NORTHERN CALIFORNIA



Also earlier snowmelt
More winter floods – warm
snow becomes rain



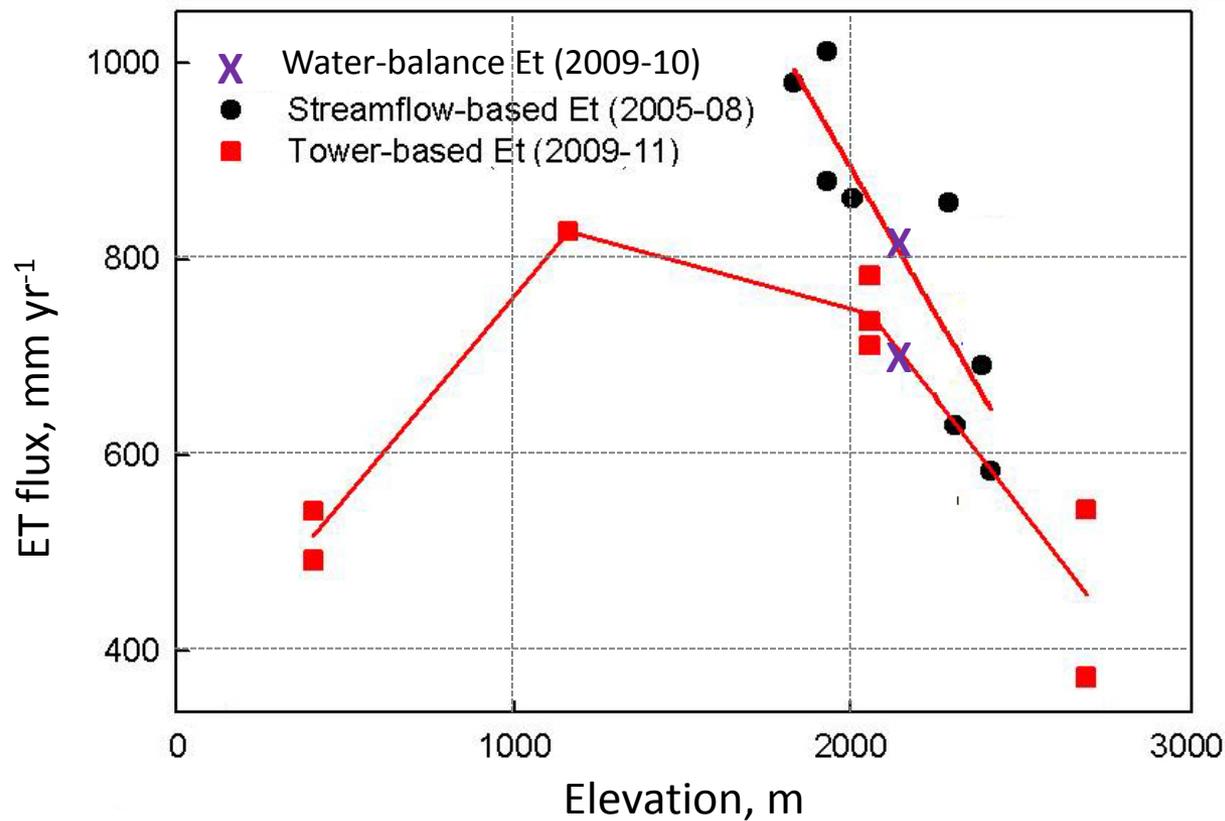
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Evapotranspiration (ET) across an elevation transect



- Lower elevation is water limited
- Higher elevation is cold limited
- Highest current ET in rain to rain-snow-transition region of mixed conifer forest – year-round growth



- How forest management is done will influence snow accumulation, snowmelt timing & water yield
- The knowledge base to inform adaptive management of Sierra Nevada forests is insufficient, given its value & cost

An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests

Malcolm North, Peter Stine, Kevin O'Hara, William Zielinski, and Scott Stephens

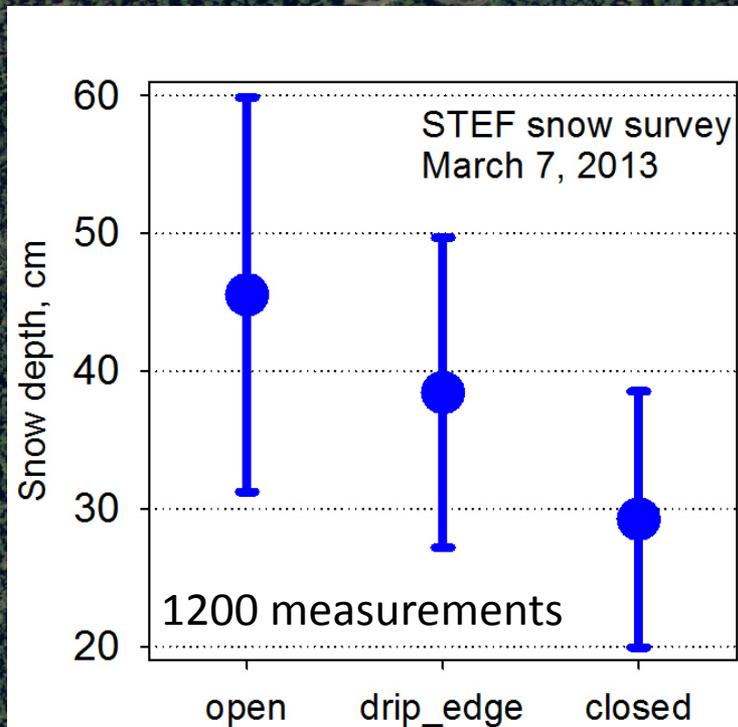
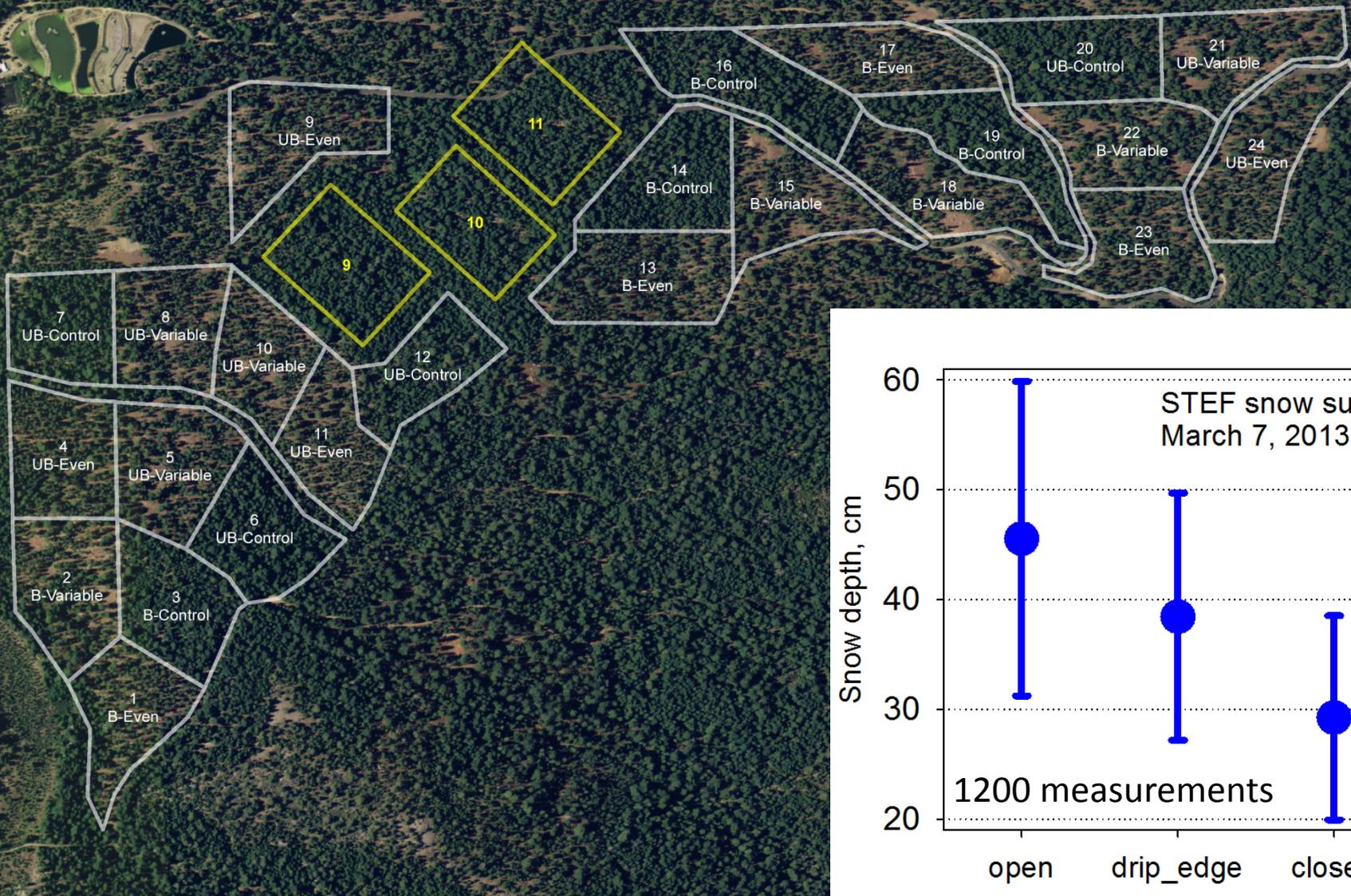
**Stanislaus - Tuolumne Experimental Forest
Variable Density Thinning Study
Post-Harvest (2012)**



Pacific Southwest
Research Station

General Technical Report
PSW-GTR-220
March 2009

Measuring forest effects on snow accumulation



Legend

- Variable Density Thinning Units
- 1929 Methods Of Cutting Units

Stanislaus - Tuolumne Experimental Forest Variable Density Thinning Study Post-Harvest (2012)

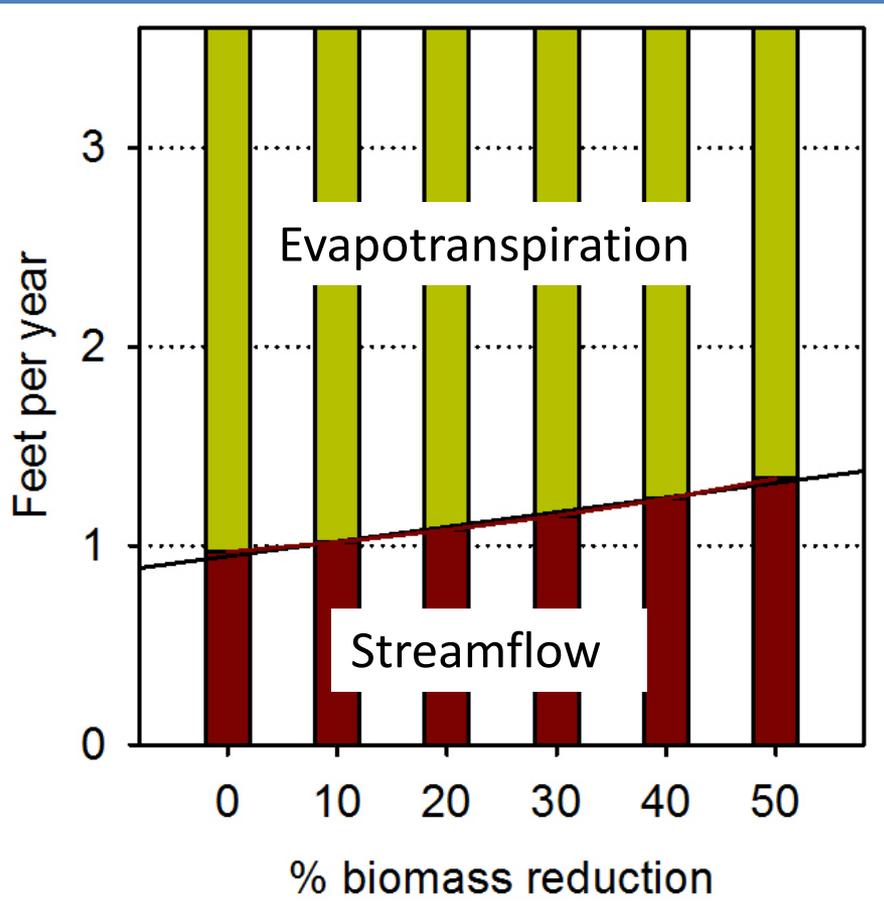


Variable thinning



Model results: thinning & water yield

Initial estimates – work in progress



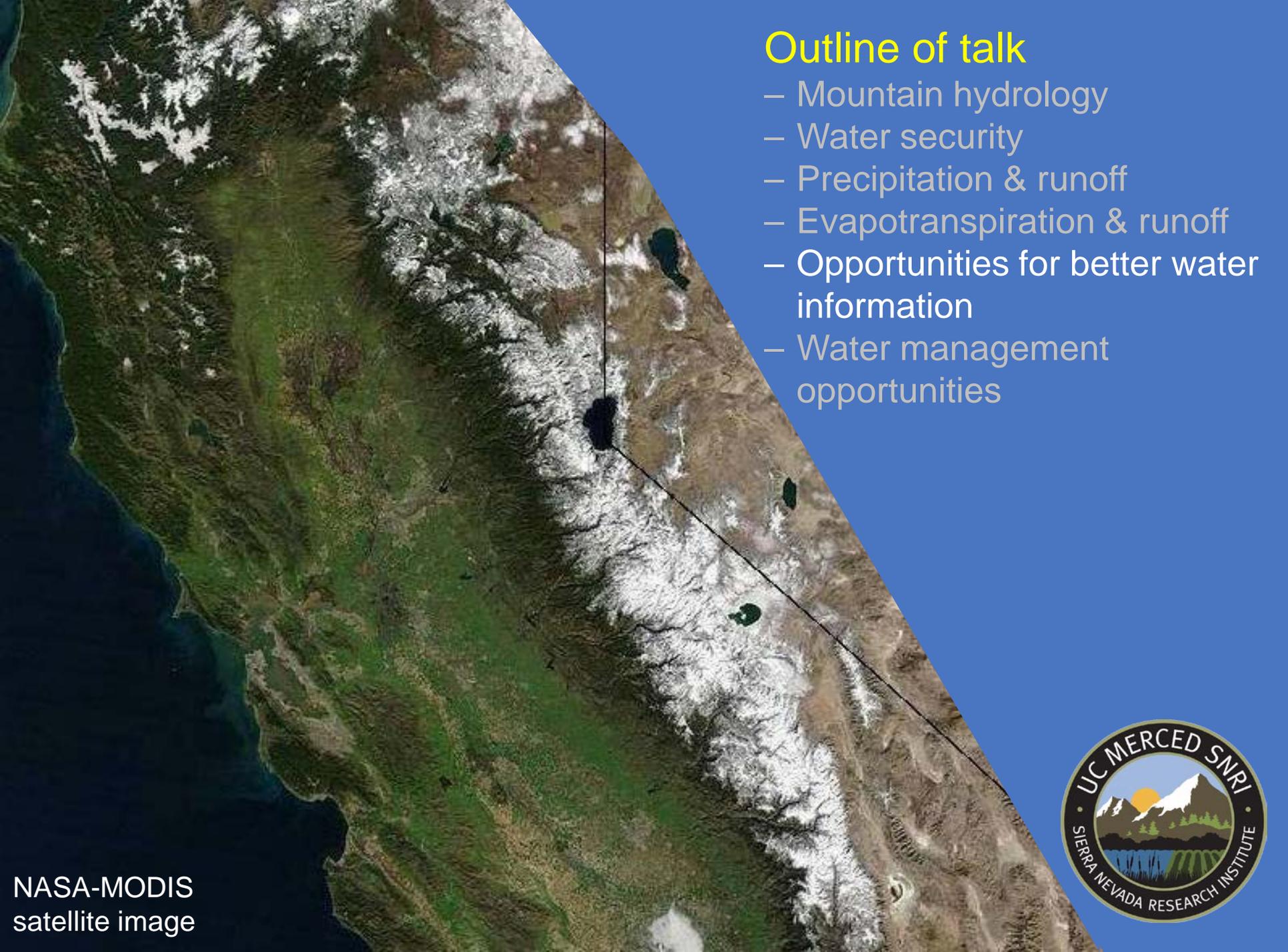
5-yr average, 2004-2008

30% increase in streamflow for 50% reduction in biomass

Rain-snow transition, 7000 ft elevation, KREW catchments

Estimates at Frazier show a 10% increase in streamflow with a 50% reduction in biomass

The slope of this line, or gain in runoff w/ different levels of vegetation management, is a critical research question



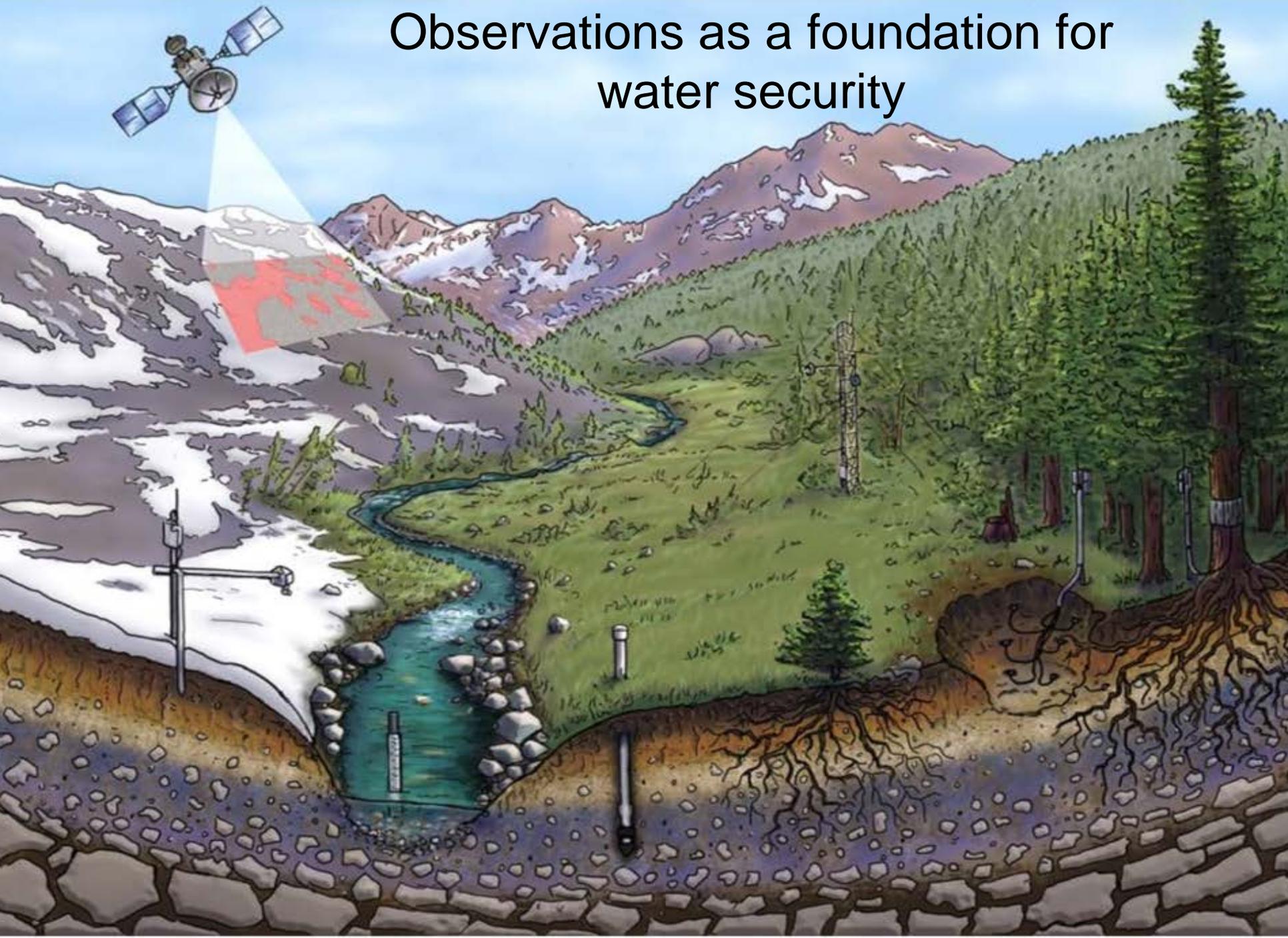
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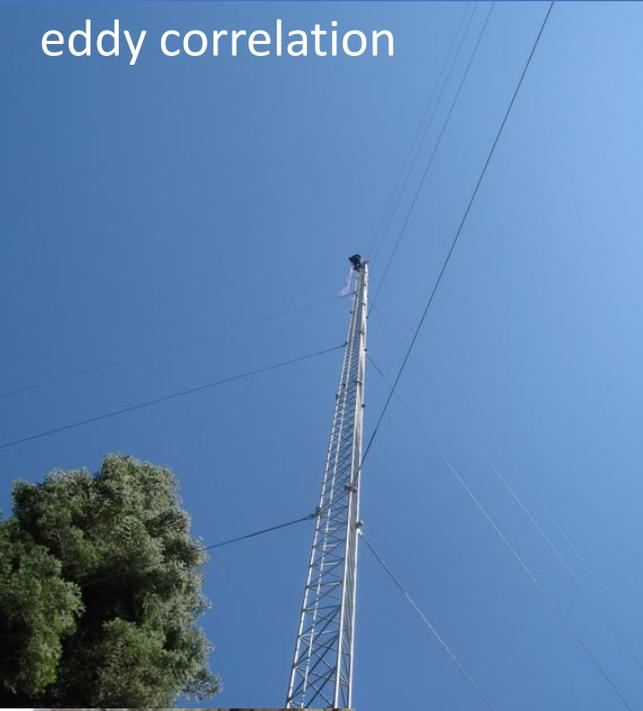


Observations as a foundation for water security

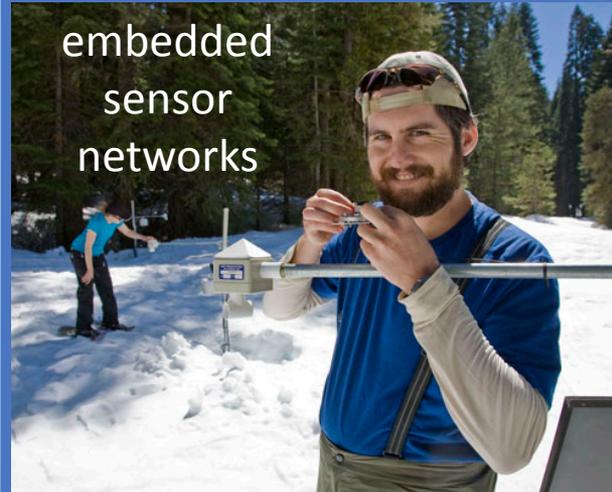


A new generation of integrated measurements

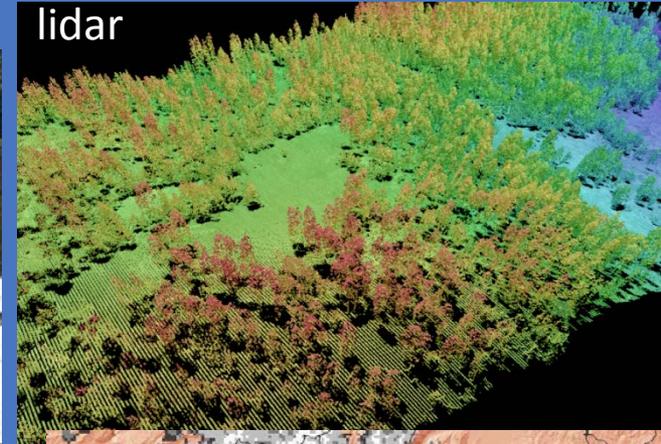
eddy correlation



embedded
sensor
networks



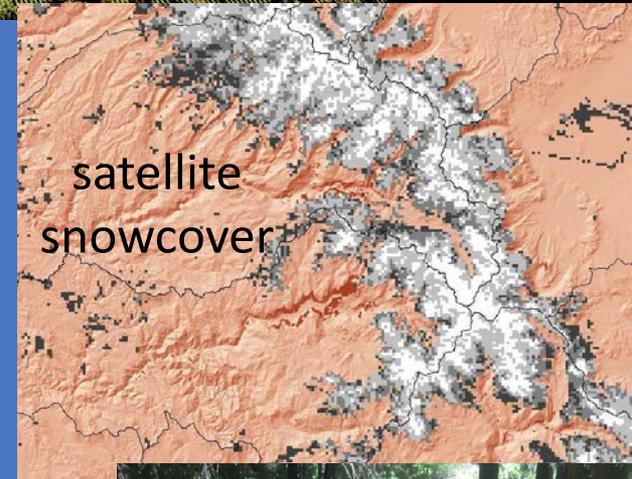
lidar



isotopes & ions



satellite
snowcover



low-cost
sensors



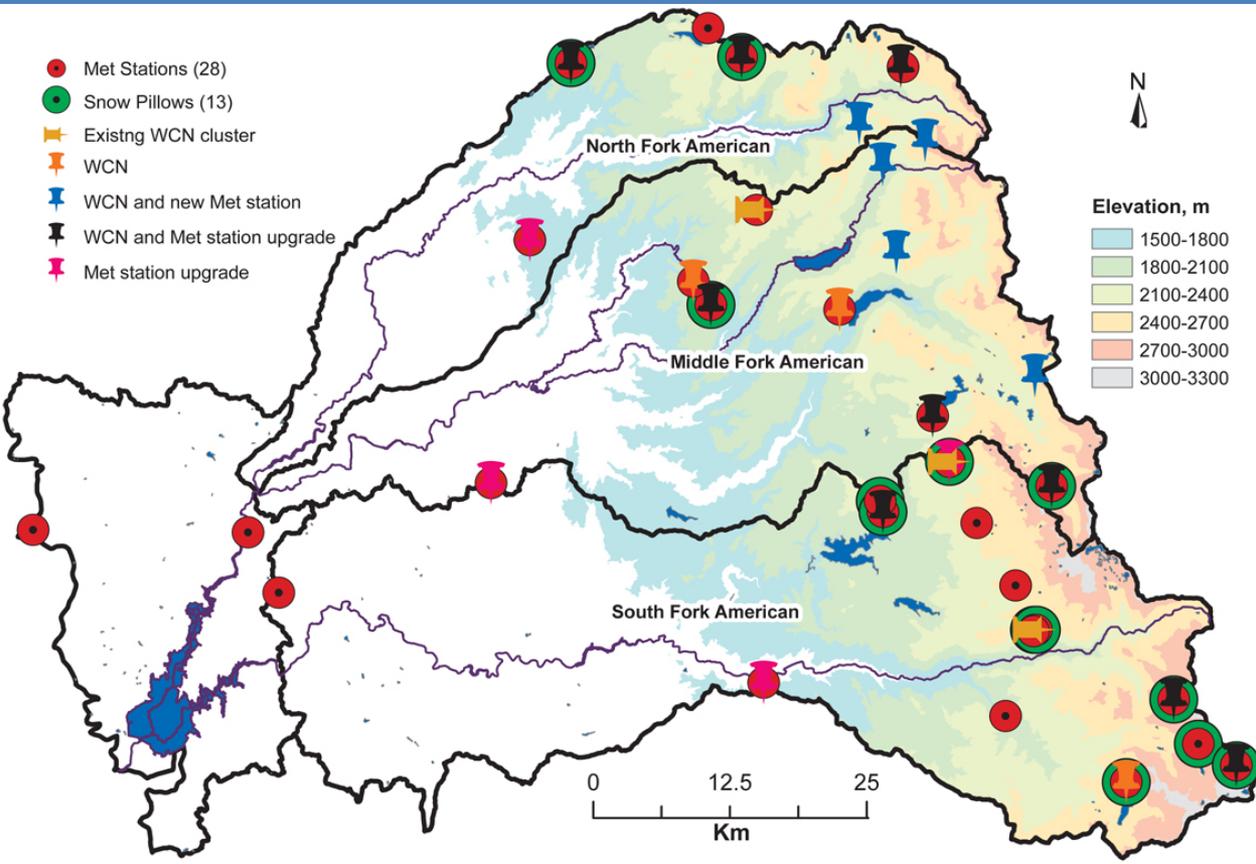
sap flow



sediment



Basin-wide deployment of hydrologic instrument clusters – American R. basin



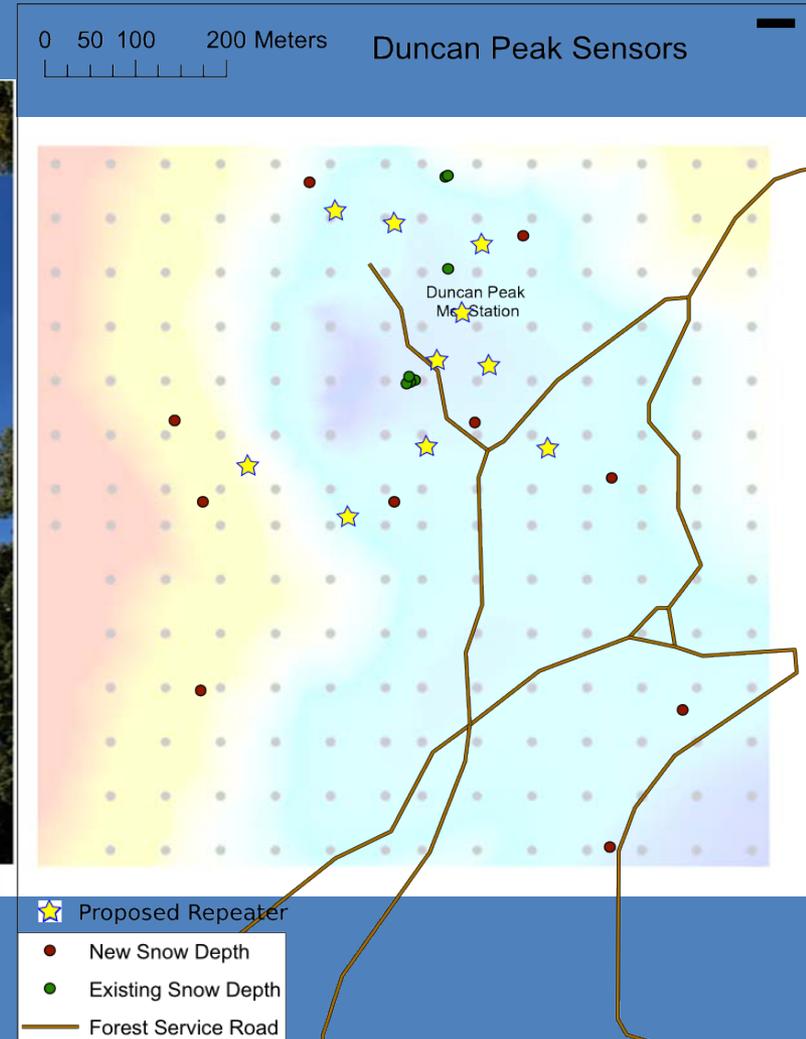
For both research & operations

Strategically place low-cost sensors to get spatial estimates of snowcover, soil moisture & other water-balance components

Network & integrate these sensors into a single spatial instrument for water-balance measurements.

Current setup: *wireless* nodes

Improved representation of the landscape:
topography & vegetation



Sites currently on line



28:C9 SS 2 29:2e
SS 10 2a.7a

2A:50
SS 6 28:C6
SS 5

SS 9
F9:9F F9:8B

28:65 29:D6

S
29:2F 20:CF

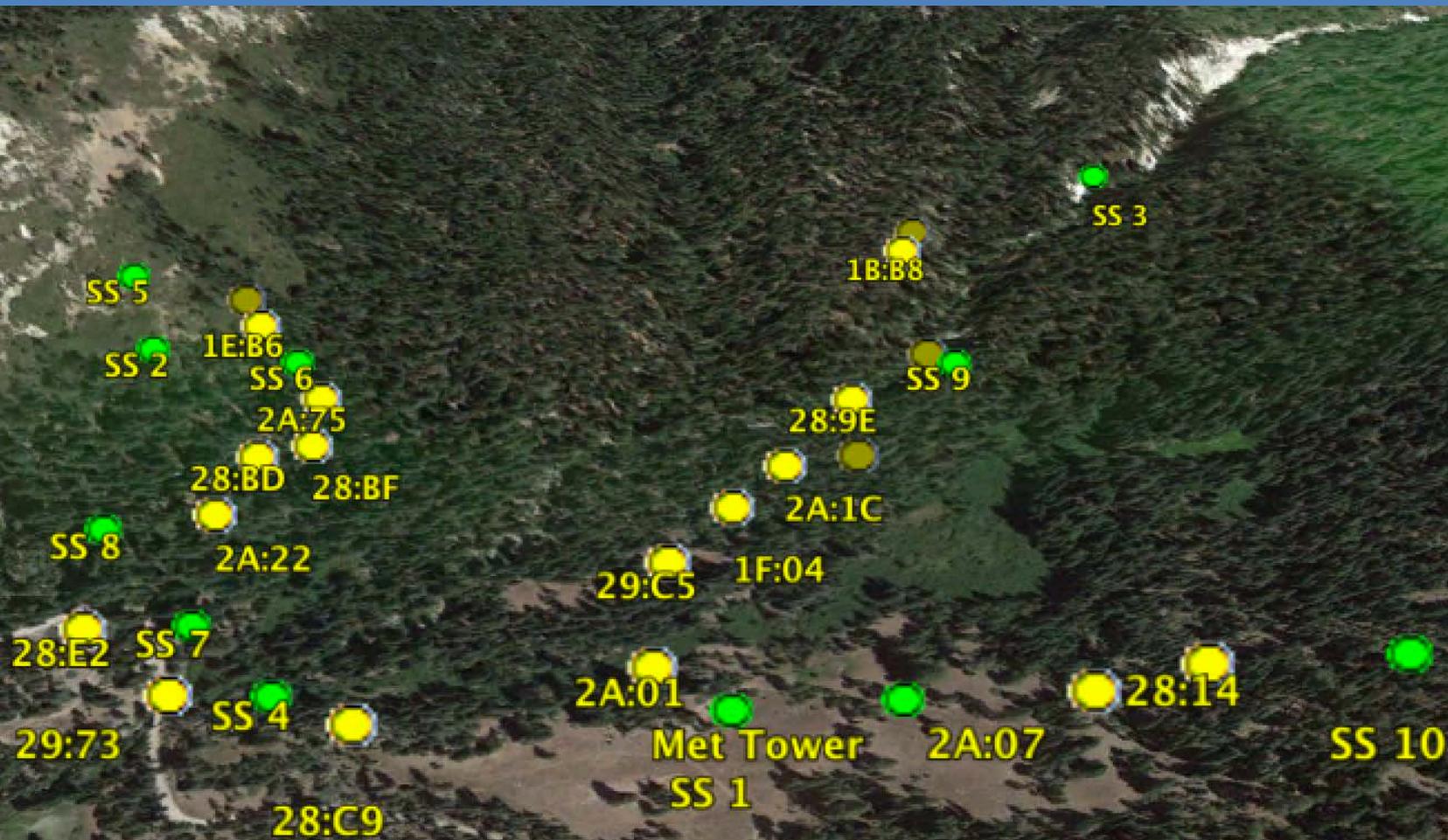
F9:50 A2 SS 8
SS 9

29:BC
SS 10 29:E6

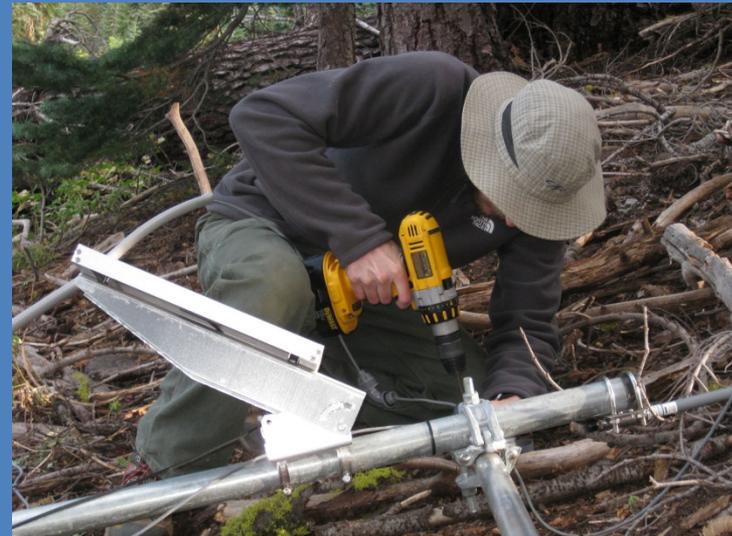
Image Landsat

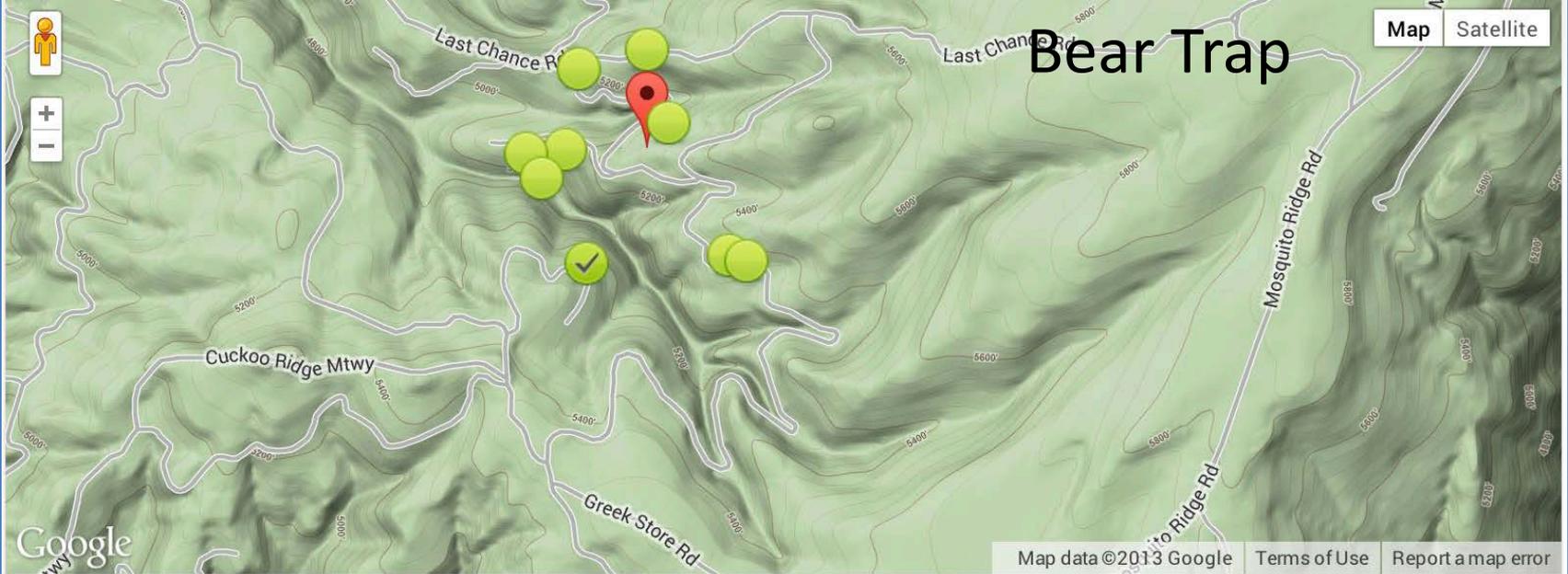
Google earth

Bear Trap: 10 sensor nodes, 1 met station & 20 repeater nodes



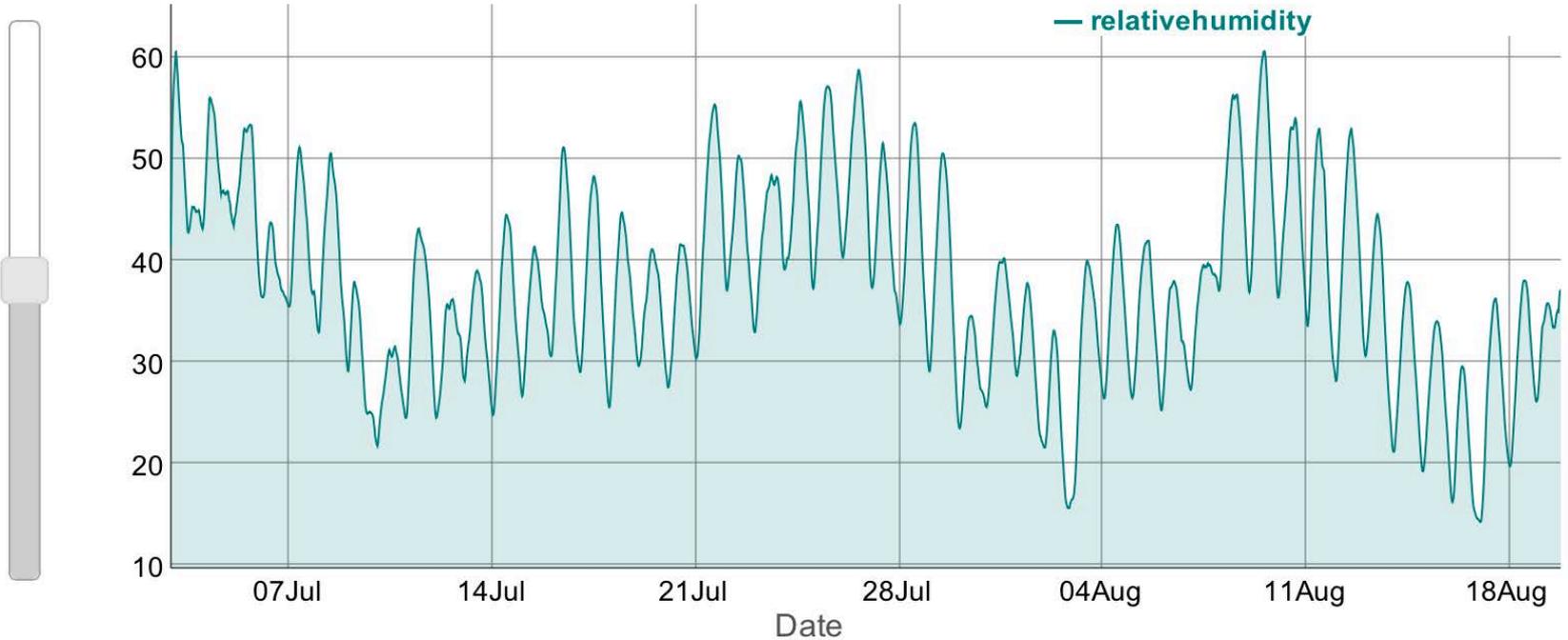
Node construction at Alpha site





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MAC: 00_17_0d_00_00_3f_f9_38

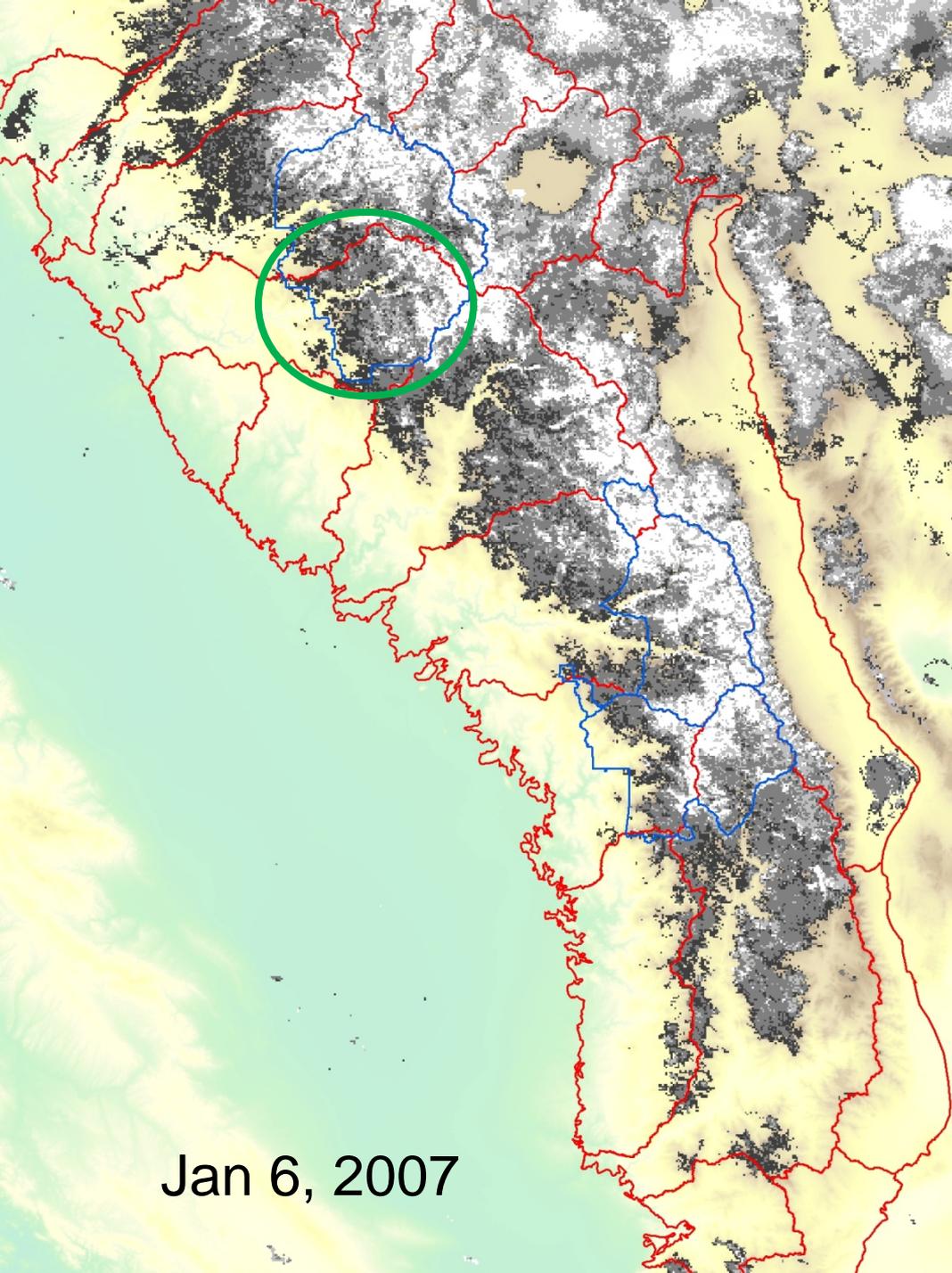


Voltage (V)
 Temperature1 (°C)
 Temperature2 (°C)
 Relative Humidity (%)
 Snow Depth (mm)
 TravelTime (ms)

Meadow piezometers & wells

- Chemical composition
- Levels and pressure





- Model Calibration
 - Limited field observations
 - Instead remotely sensed and regional data will be used

Sierra Nevada fractional snow covered area (SCA) from MODIS satellite

SCA is binned into 4 classes for ease of viewing

Pixel size: 500 m





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Some implications of steep elevation gradients in ET & runoff for water resources

Timing & amount of runoff are sensitive to small changes in temperature

Forest management is important for water yield & the timing of snowmelt runoff

Downstream beneficiaries have a stake in upstream watershed management

Better measurement & process understanding are critical to realizing benefits of management actions



Envisioning a more water-secure future for California through better water information

