Evaluation of Different Modes of Sierra Nevada Snow Observation

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Presented at the 2012 California Cooperative Snow Surveys Meeting

Agenda – Sierra Snow Observations

- *Satellite snow products (MODIS/MODSCAG)*: evaluation of the effects of forest cover
- *Snow pillows and trees*: the Dana Meadows snow pillow story
- *Doing hydrology backwards*: inferring mountain precipitation from streamflow records

Evaluating MODIS Snow Observations

Raleigh et al. (2013). Ground-based testing of MODIS fractional snow cover in subalpine meadows and forests of the Sierra Nevada. *Remote Sensing of Environment*.

Evaluating MODIS Snow Observations

- NASA's MODIS satellite imagery can provide an indication of snow cover
- How accurate is it? How does forest canopy impact its accuracy?
- Evaluation using new ground-based distributed snow cover observations

Evaluating MODIS Snow Observations

- We tested the MODSCAG snow retrieval product (Painter et al. 2009)
- We tested it against the following ground-based snow observations:
  - Time-lapse photography of snow cover
  - Distributed ground temperature sensors

Evaluating MODIS Snow Observations

- MODIS/MODSCAG snow cover retrieval (Painter et al. 2009)
- Provides fractional snow cover (fSCA) at 500m pixel resolution
- Twice daily temporal resolution
- Clouds? Trees?

Evaluating MODIS Snow Observations

- Time-lapse photography of snow cover (Pothole Dome, Tuolumne Meadows, Yosemite)
- Daily images for WY 2010

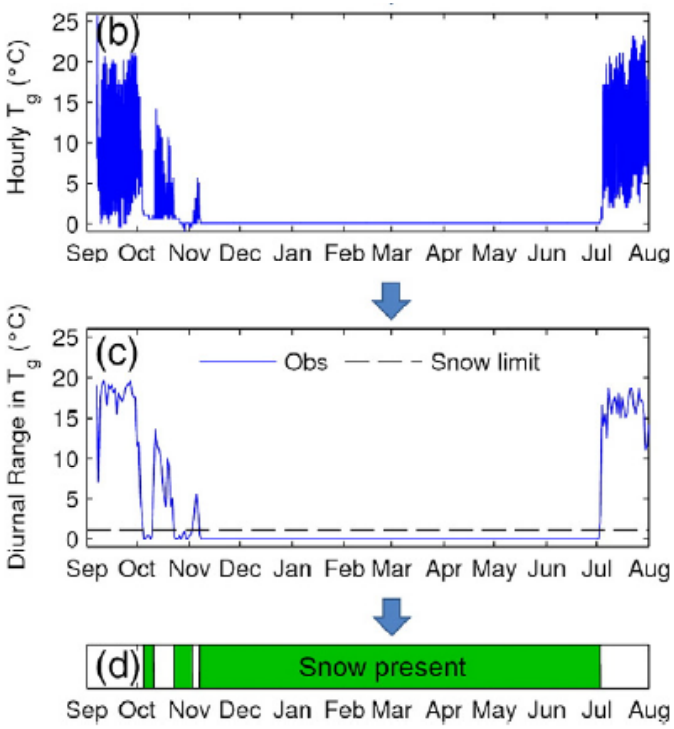
(a) 31 May 2010

(b) 5 June 2010

(c) 15 June 2010

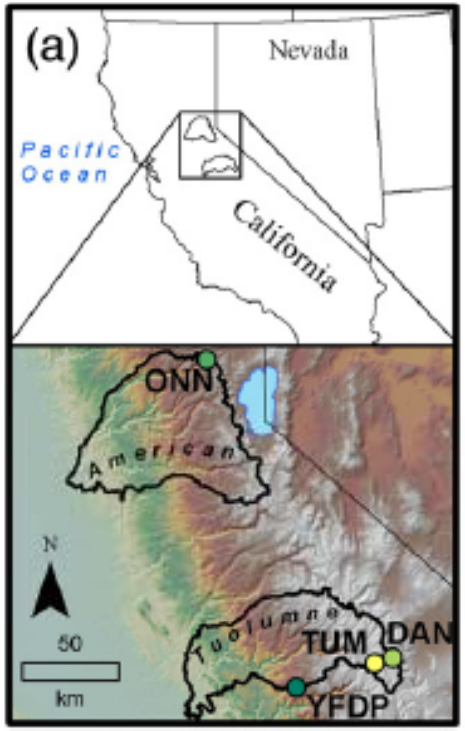
Evaluating MODIS Snow Observations

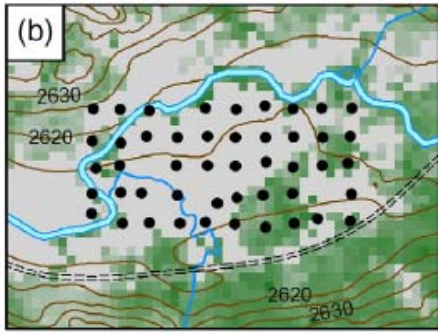
- Ground temperature sensing of snow presence
- iButtons provide distributed measurements of snow



Evaluating MODIS Snow Observations

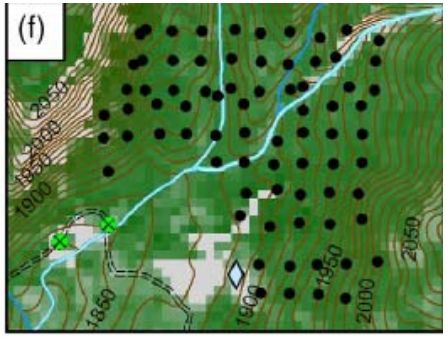
- Deployed >200 iButton sensors over four areas (WYs 2010-2012).



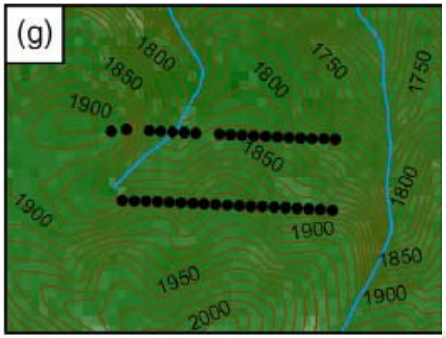


Dana Meadows

Tuolumne Meadows



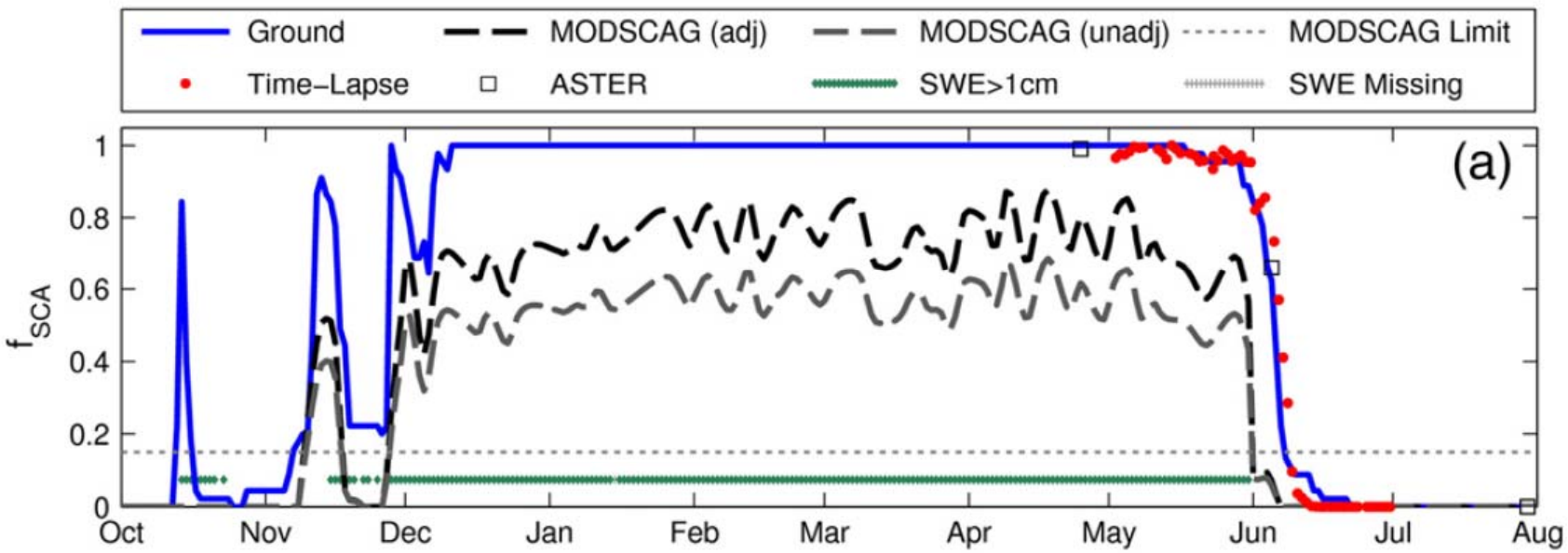
Onion Creek



Crane Flat

Evaluating MODIS Snow Observations

- How closely did MODSCAG match ground data?



Tuolumne Meadows – WY 2010

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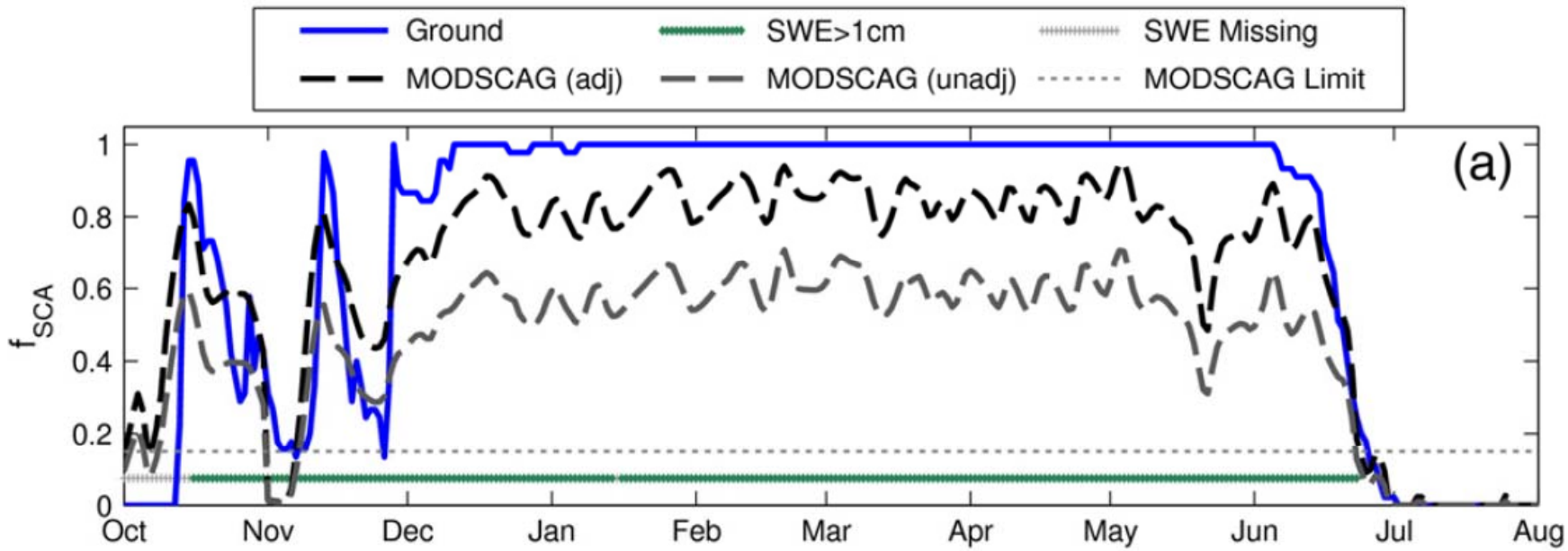

Dana Meadows – WY 2010

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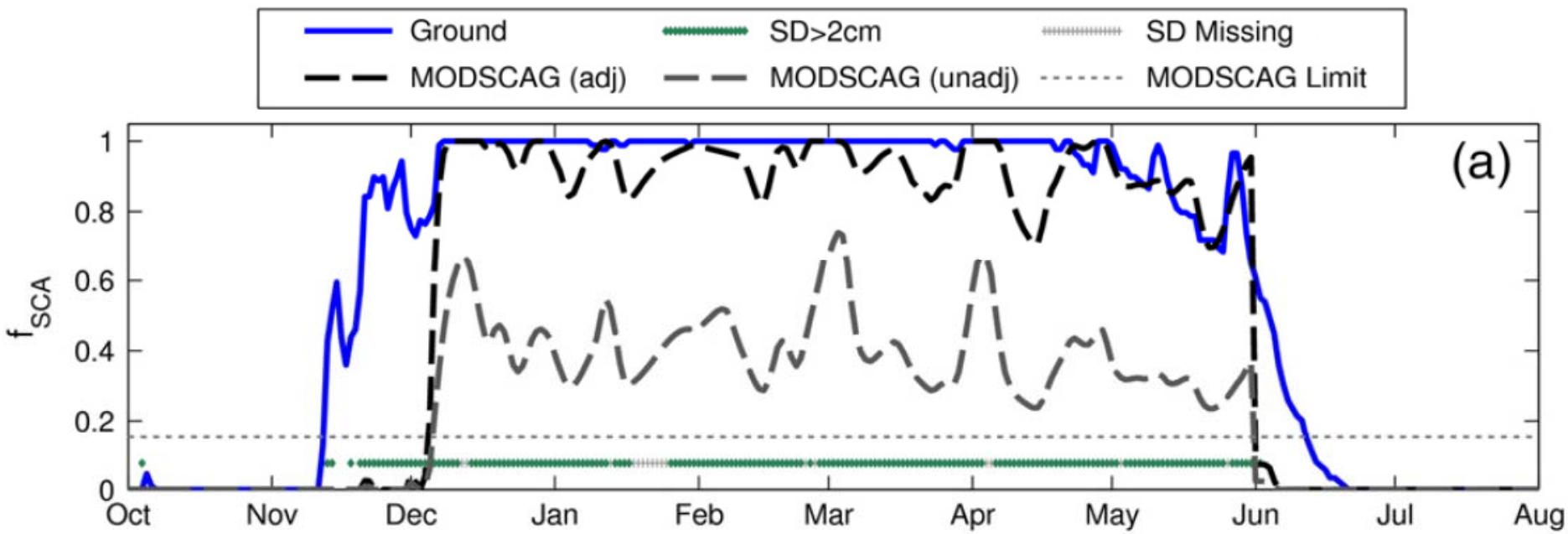

Onion Creek – WY 2010

Evaluating MODIS Snow Observations

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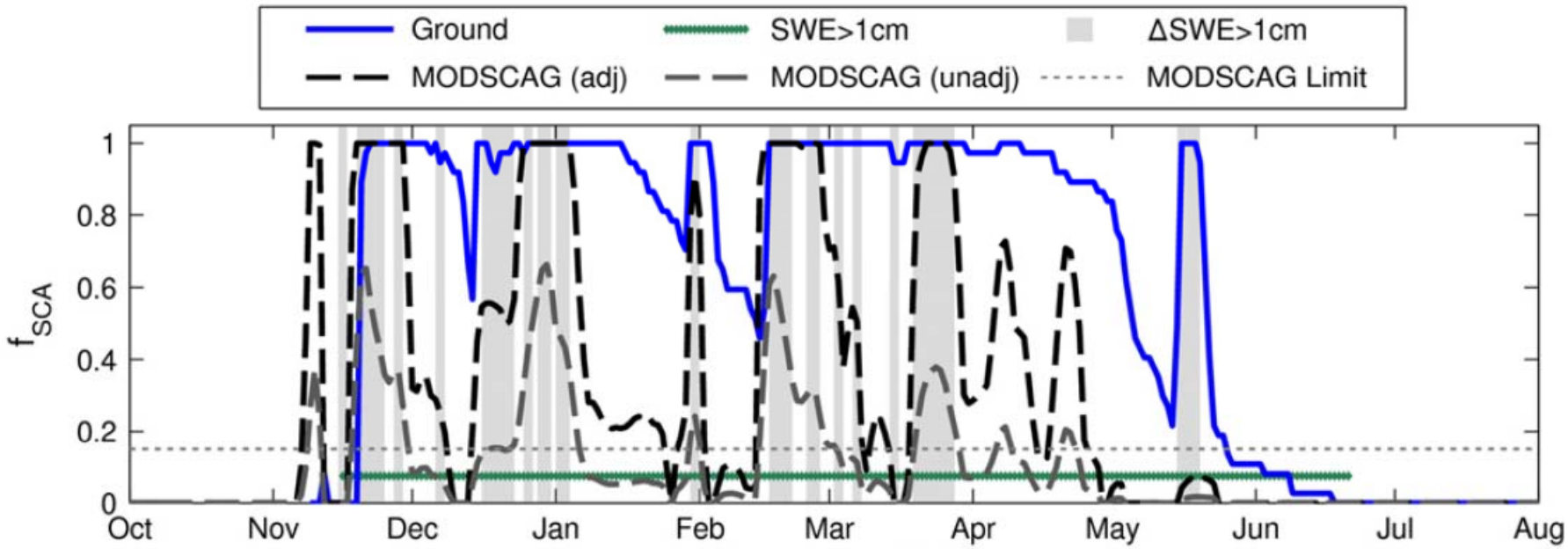

Crane Flat – WY 2011

Evaluating MODIS Snow Observations

- Canopy-adjusted MODSCAG matched ground observations best:
  - at a high altitude site with less tree cover (Dana Meadows)
  - during mid-winter when snowpack is deep
- Some underestimation of snow cover (-9% to -22%) for meadow sites

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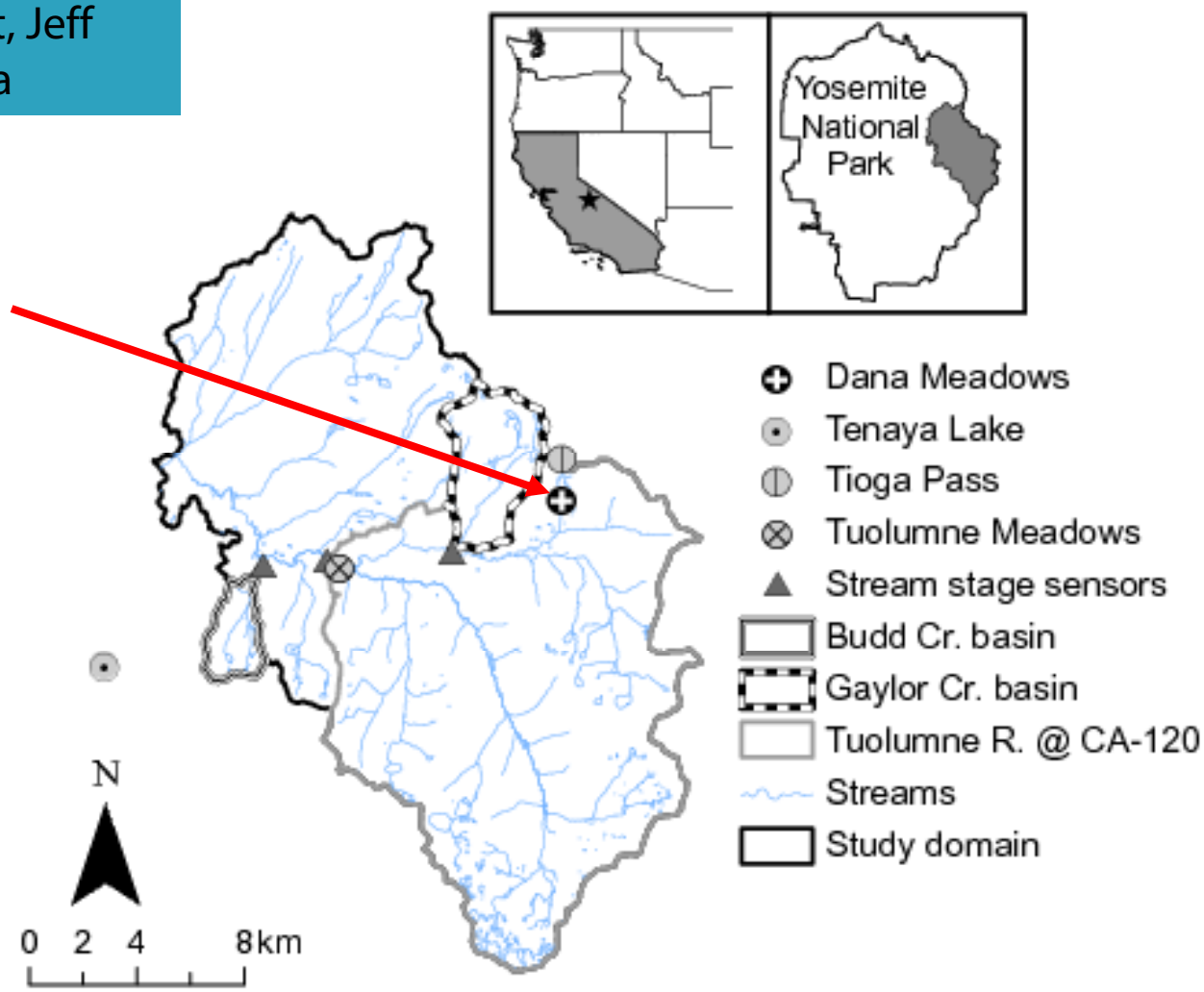
- MODSCAG and ground observations diverged when:
  - Snow is patchy in early and late season
  - Forest cover is very dense (Crane Flat)
- Significant underestimation (-9% to -37%) for forest sites

Snow Pillows and Trees

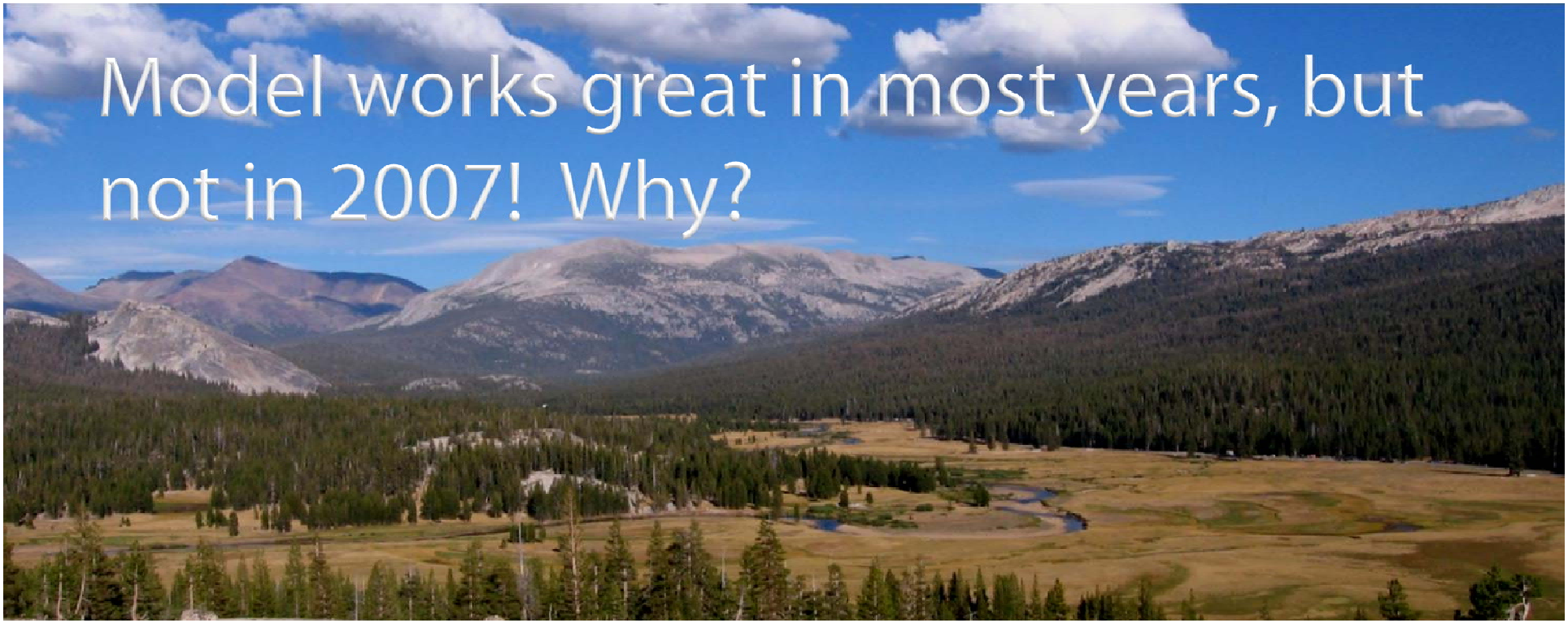
Motivation: Distributed hydrologic modeling for Tuolumne

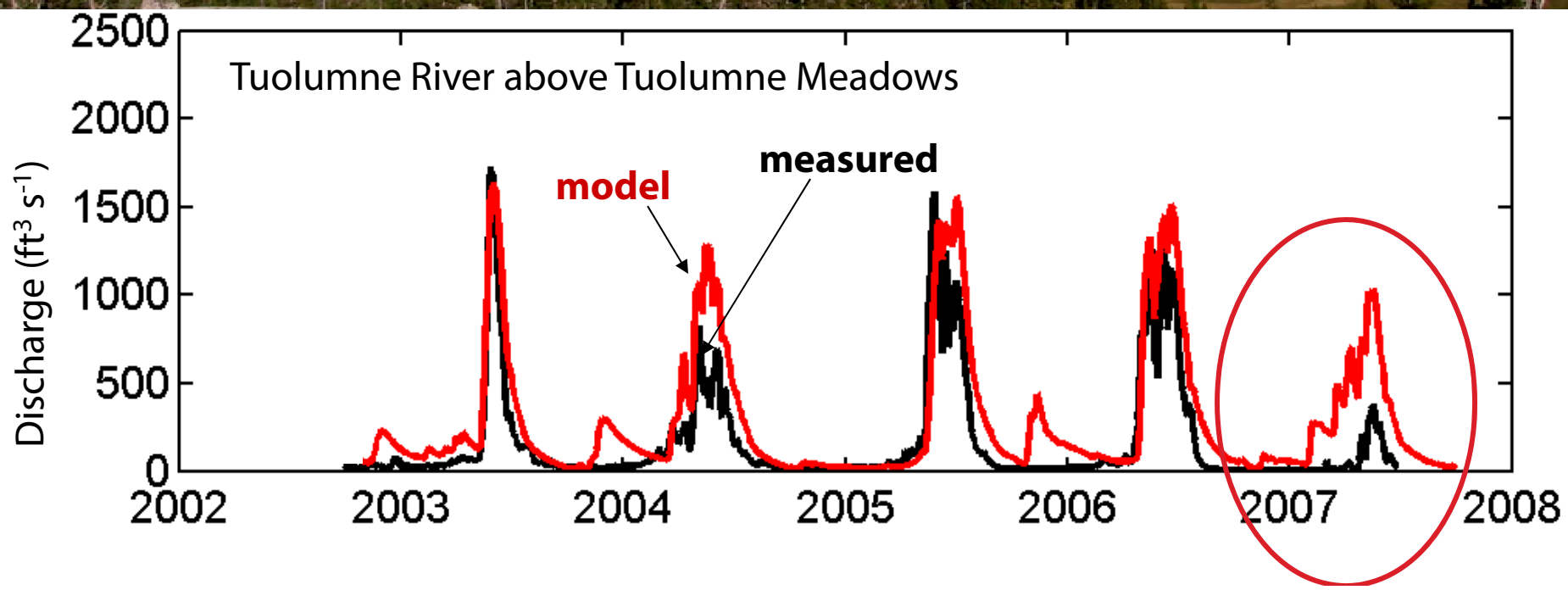
Modeling work by Fred Lott, Jeff Deems, and Nicoleta Cristea

- **We measure precipitation at a point (Dana) and distribute**
- **All snow** (elevations 2600m to 3400m, 8600-14000ft)
- Steep topography



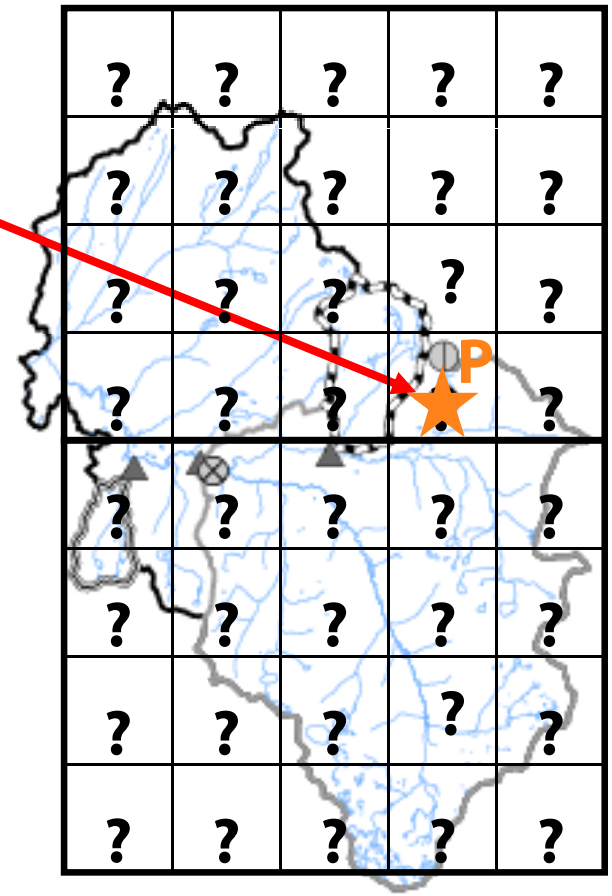
Model works great in most years, but not in 2007! Why?



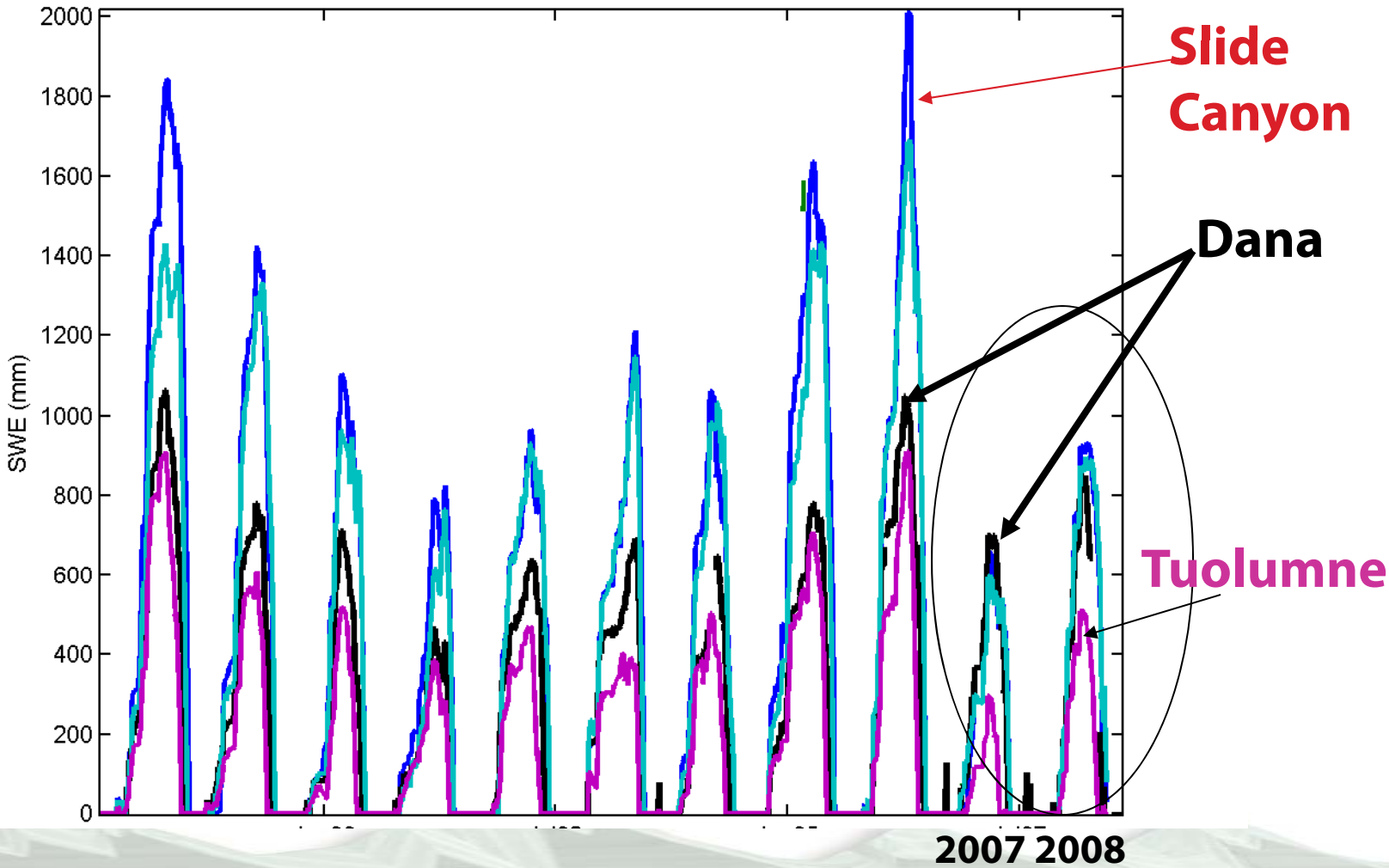


To be off by a factor of two in one year indicates a problem with precipitation

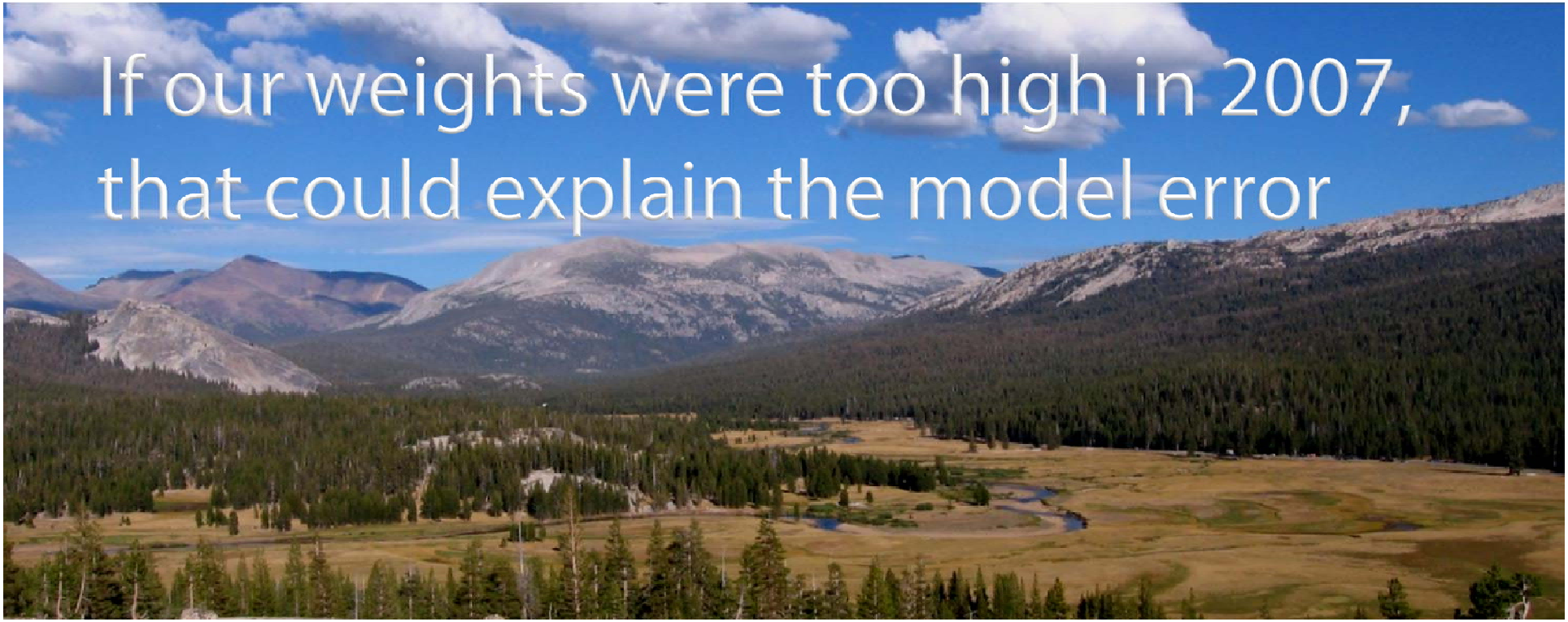
- **We measure precipitation at a point and map that value to everywhere else in the watershed**

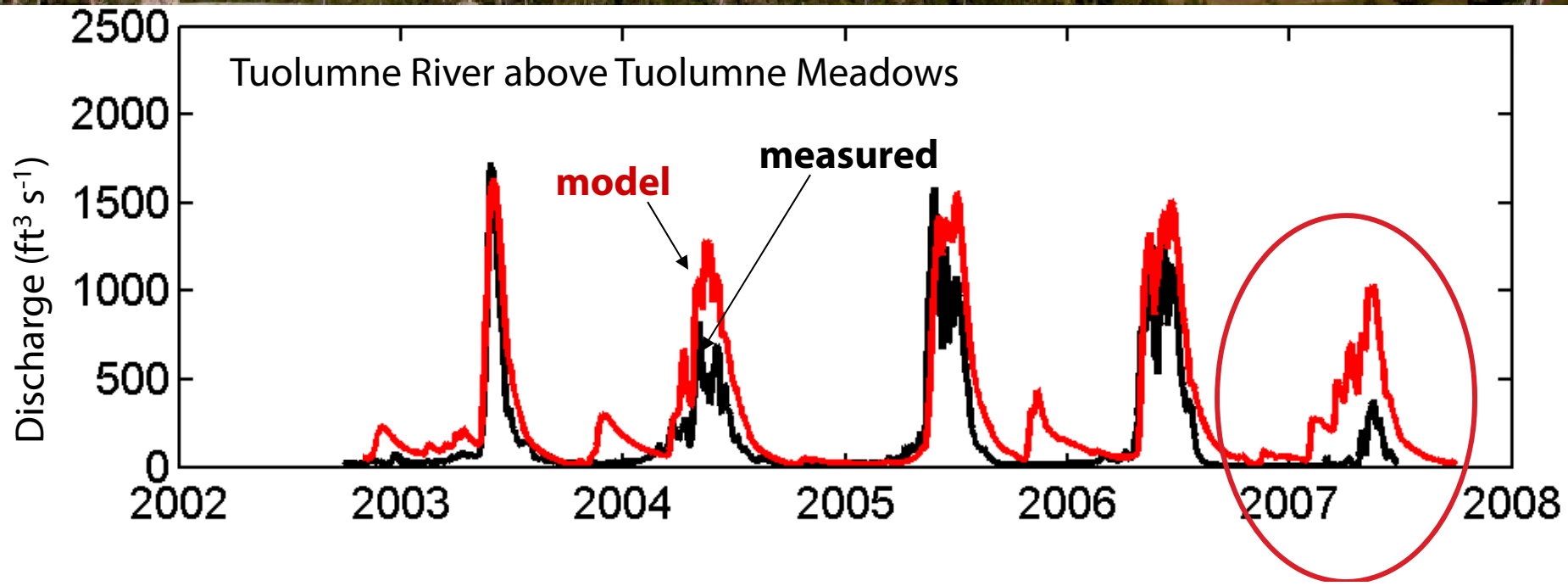


Snow pillow measurements show that ratios between stations can change

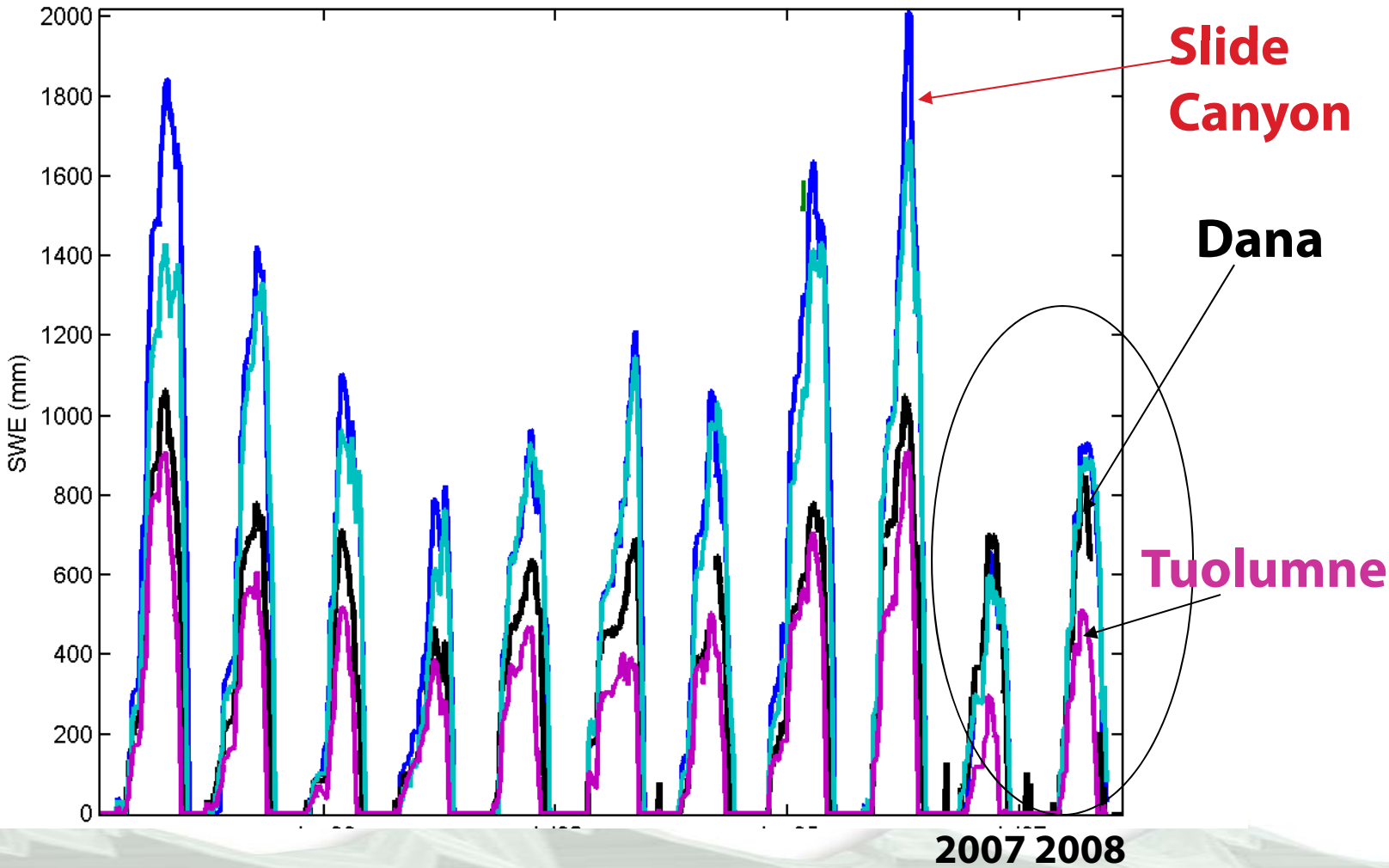


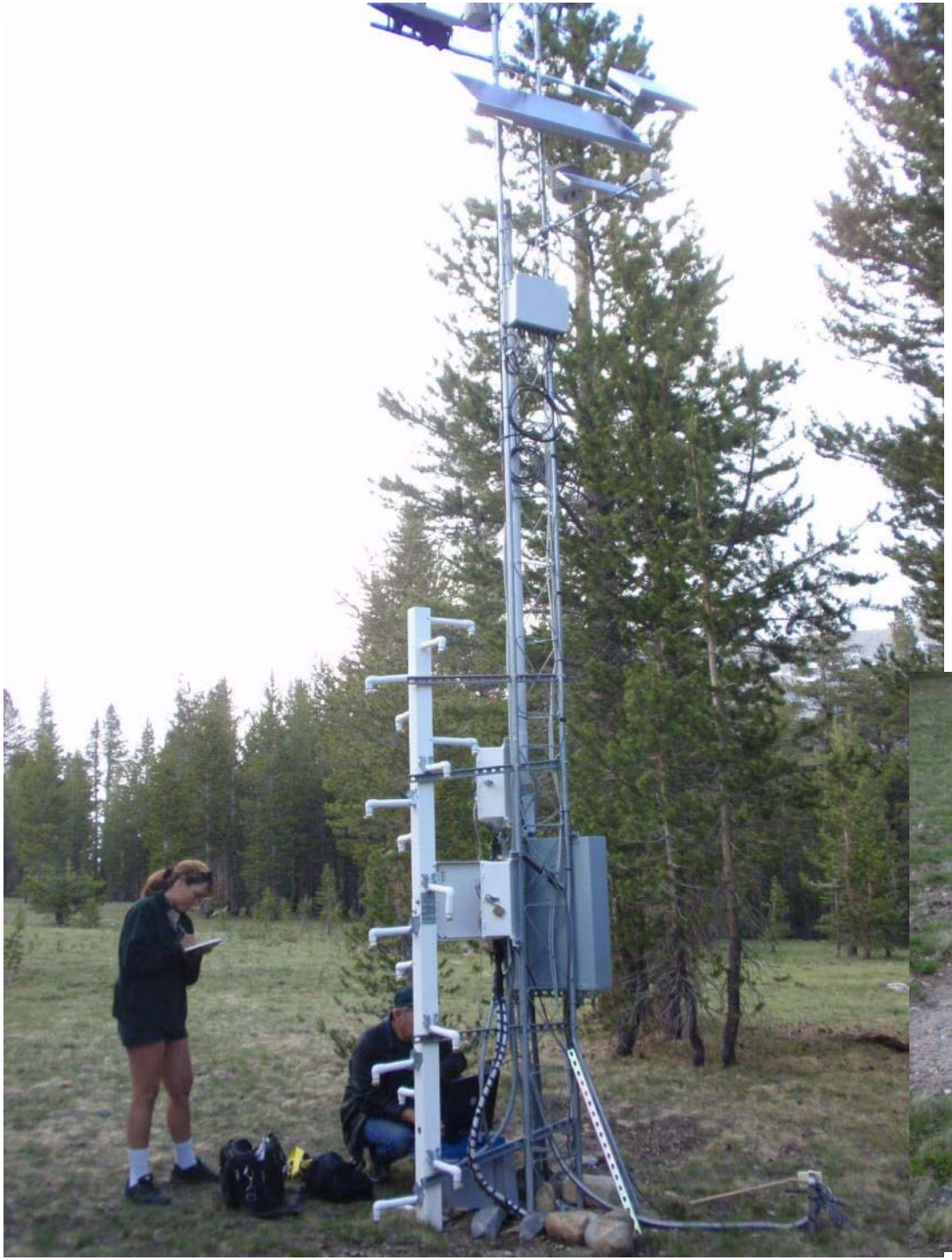
If our weights were too high in 2007, that could explain the model error





Recall that we used snow measurements at the Dana pillow to force our model

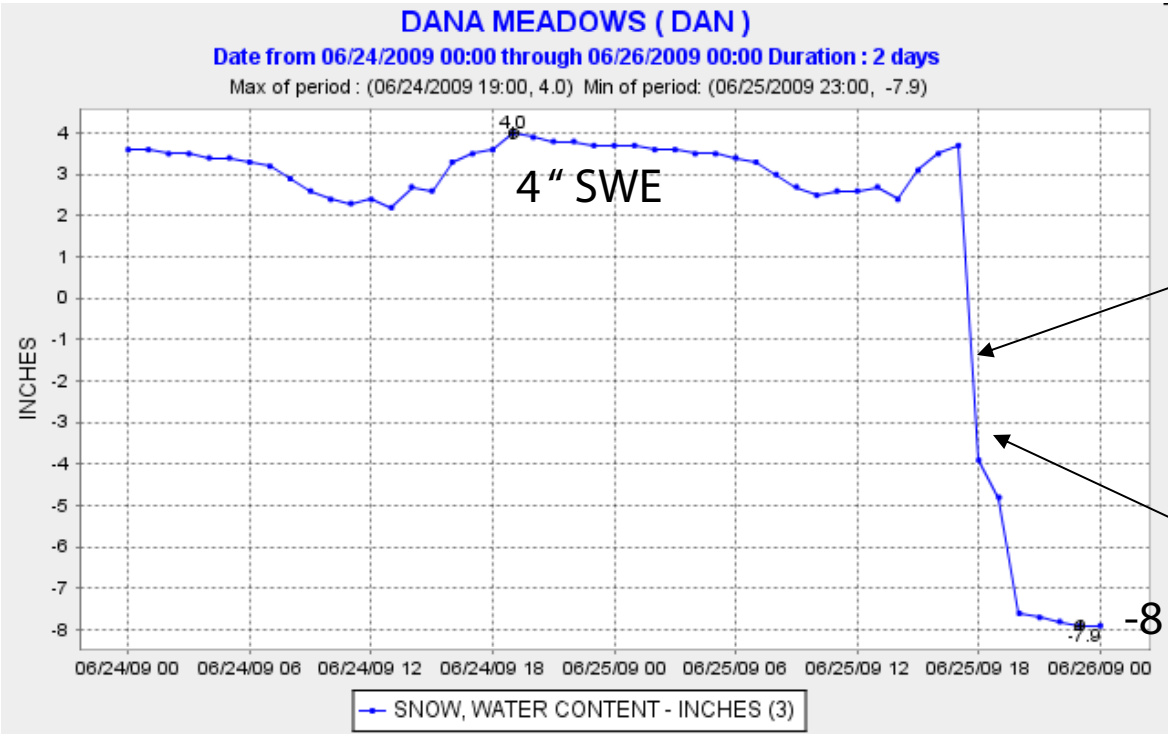




Let's visit the snow pillow

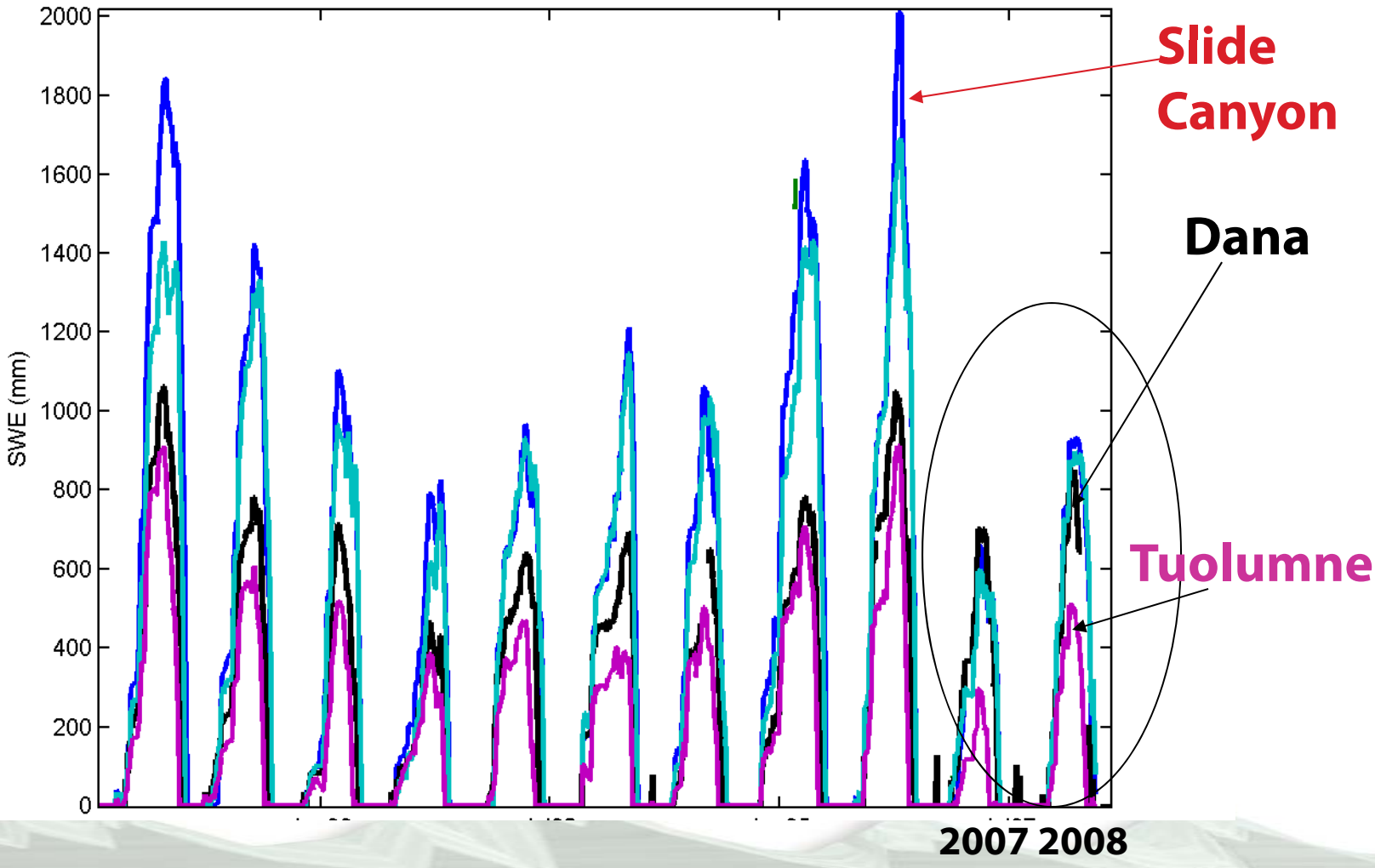
June 25, 2009

Dana snow pillow, evening of June 25, 2009



12" SWE difference before and after this event

How long does it take a tree to grow?



Doing Hydrology Backwards: Precipitation Estimation from Streamflow

Precipitation Estimation from Streamflow

- Mountain precipitation is a necessary input for modeling winter flood events
- BUT, direct precipitation estimates are sparse and frequently unreliable in these areas
- Estimation of mean areal precipitation (MAP) from gauges is very difficult

Precipitation Estimation from Streamflow

- However, streamflow from mountain basins is relatively well observed
- Snow accumulation observations also more widely available

Precipitation Estimation from Streamflow

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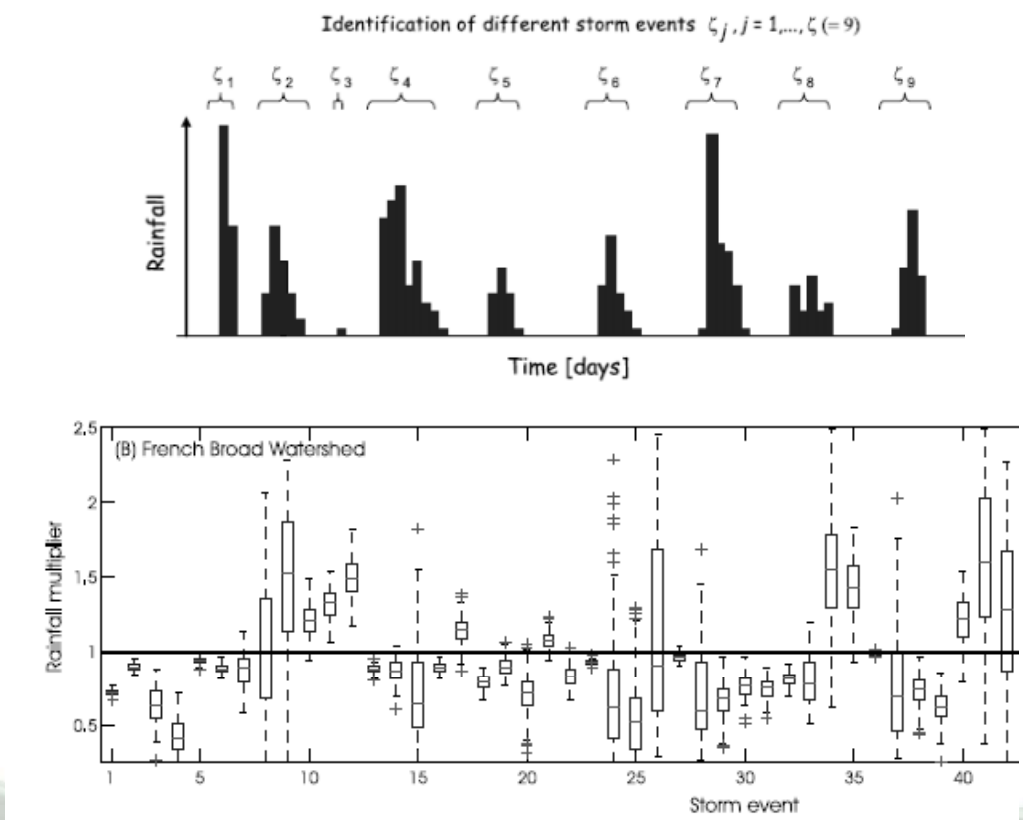
→ Can we infer rainfall **quantity** and **distribution** from streamflow and snow observations?

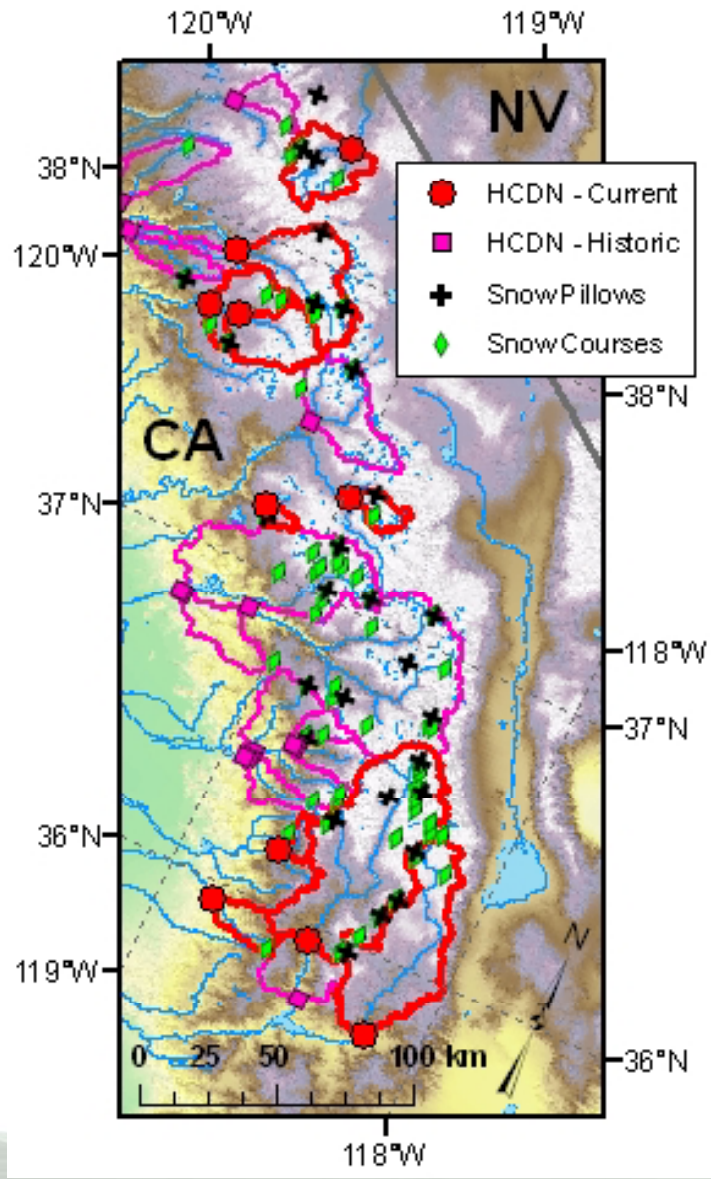
Precipitation Estimation from Streamflow

- This technique has been used with success in certain basins (Vrugt et al. 2008).

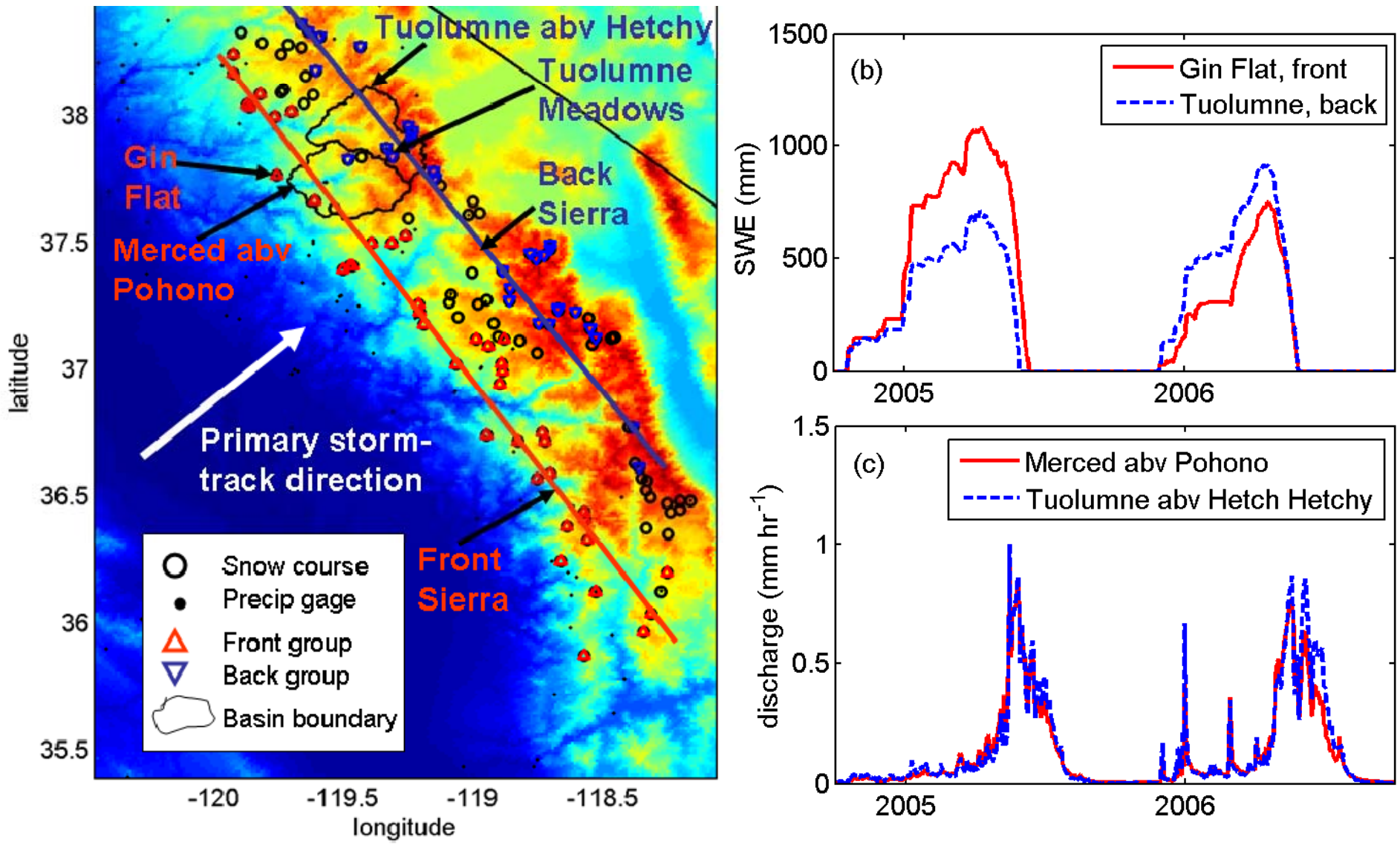


Precipitation Estimation from Streamflow

- Is there significant variation in the precipitation pattern over the Sierra?
- At the storm timescale? Annual timescale?

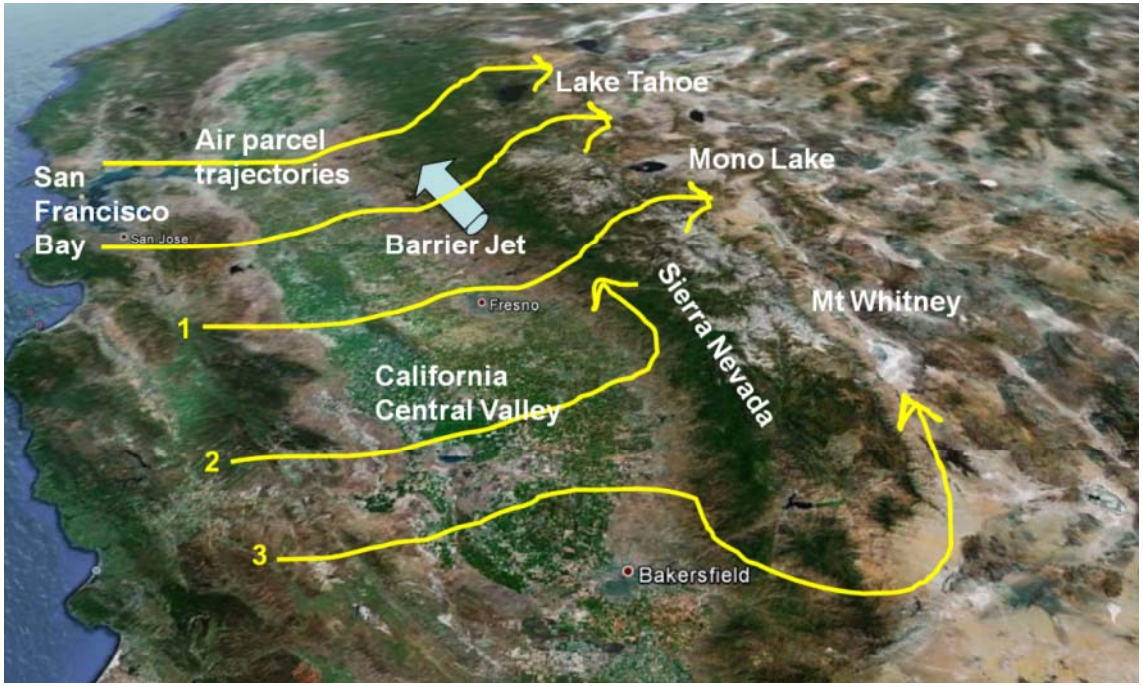


Precipitation Estimation from Streamflow



Precipitation Estimation from Streamflow

- Are these differences related to airflow trajectories over the range?



UW Mountain Hydrology Group:

- Dr. Jessica Lundquist
- Mark Raleigh
- Nic Wayand
- Nicoleta Cristea
- Susan Dickerson

References

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Vrugt, J. A., C. J. F. ter Braak, M. P. Clark, J. M. Hyman, and B. A. Robinson, 2008: Treatment of input uncertainty in hydrologic modeling: Doing hydrology backward with Markov chain Monte Carlo simulation. *Water Resources Research,* 44, 1-15.

Questions?

Thanks!

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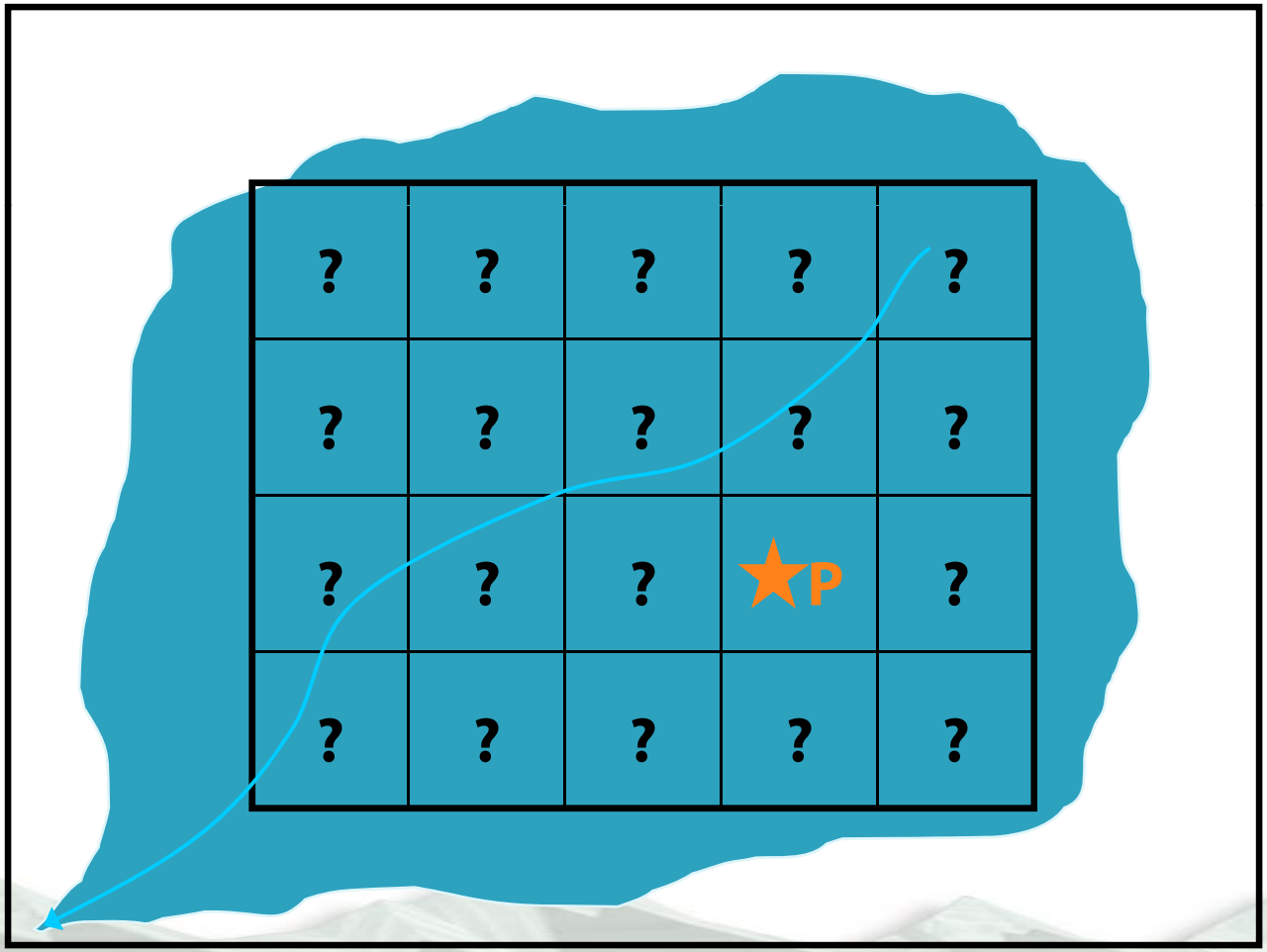
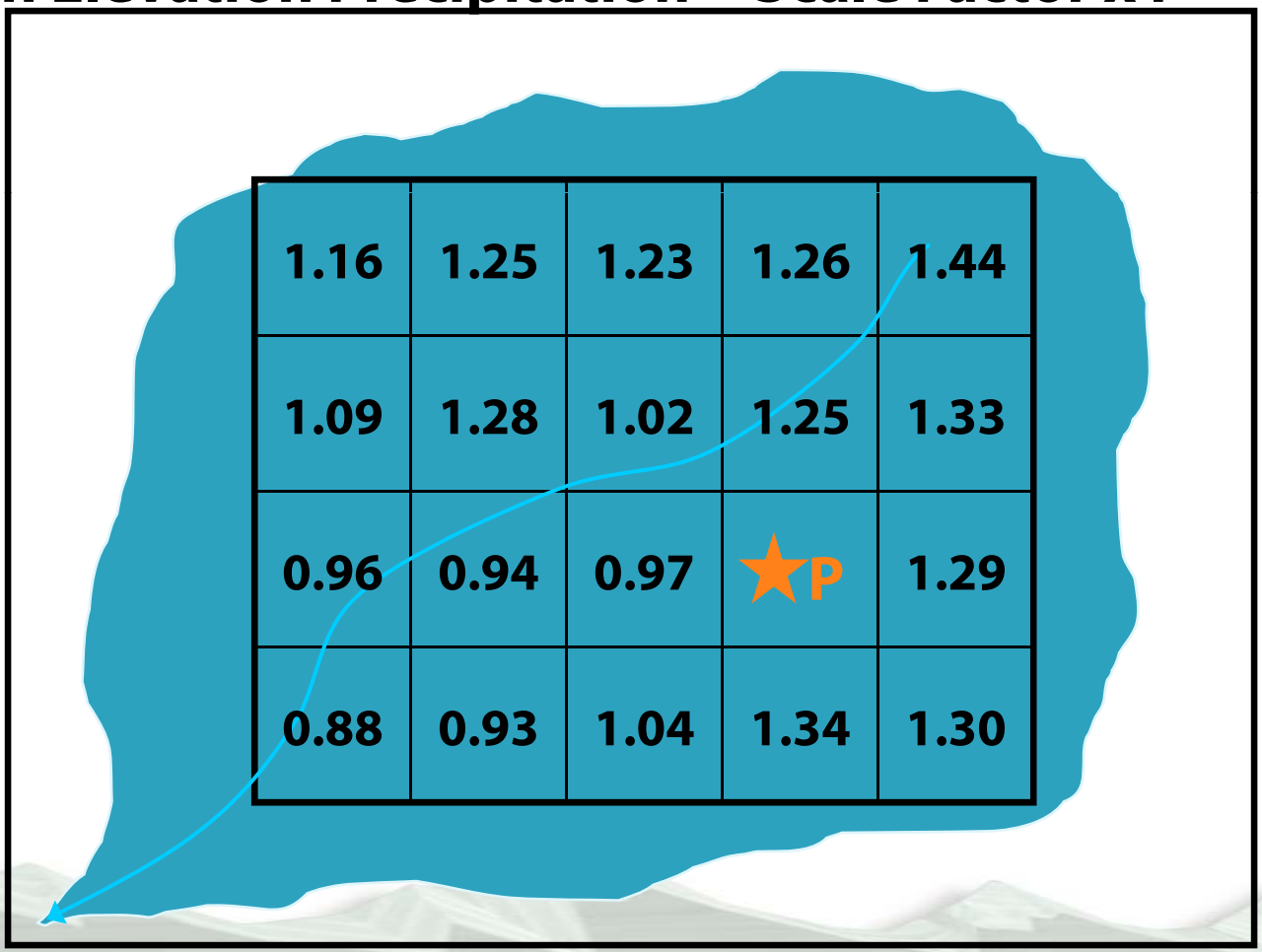
Take the climatological average value at each grid cell and divide by the value where P is measured



This gives us a weighting factor for each grid cell, which we assume is fixed through time

High Elevation Precipitation = Scale Factor x P