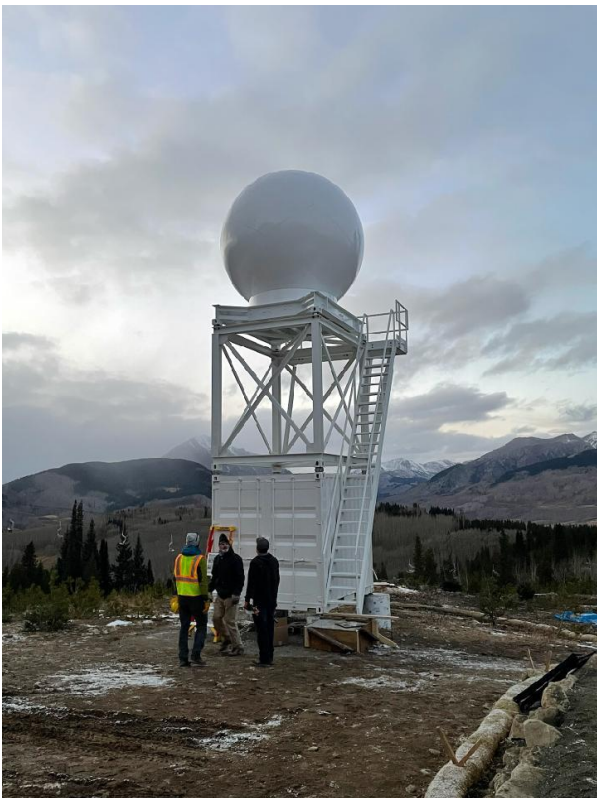
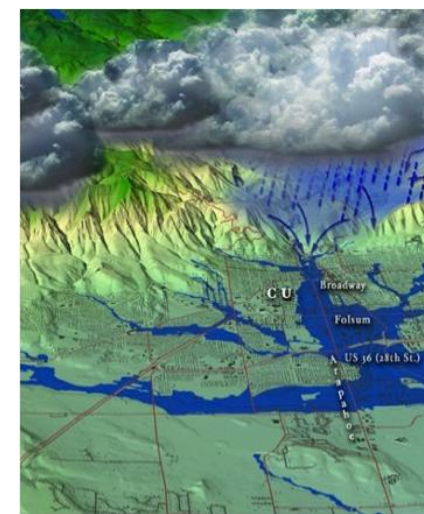
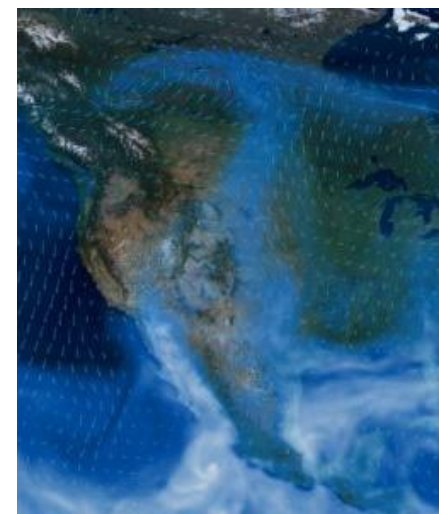


Expanding Water Resources: Snowpack Monitoring



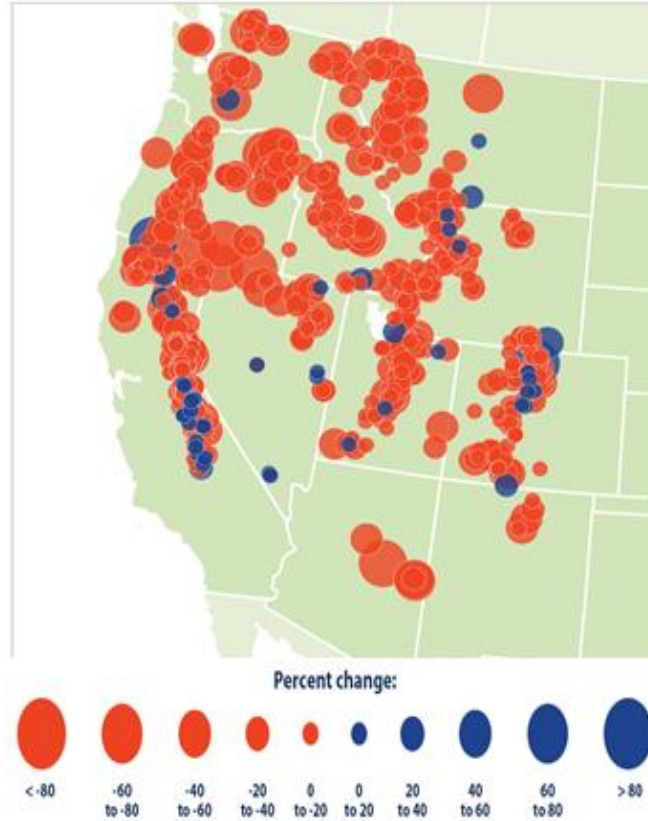
Dr. Dan Feldman,
LBNL Staff Scientist
CSG Colorado River Forum
November 13, 2025



This work was supported by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research and the Atmospheric System Research under U.S. Department of Energy Contract No. DE-AC02-05CH11231.

The Colorado River Watershed is Changing

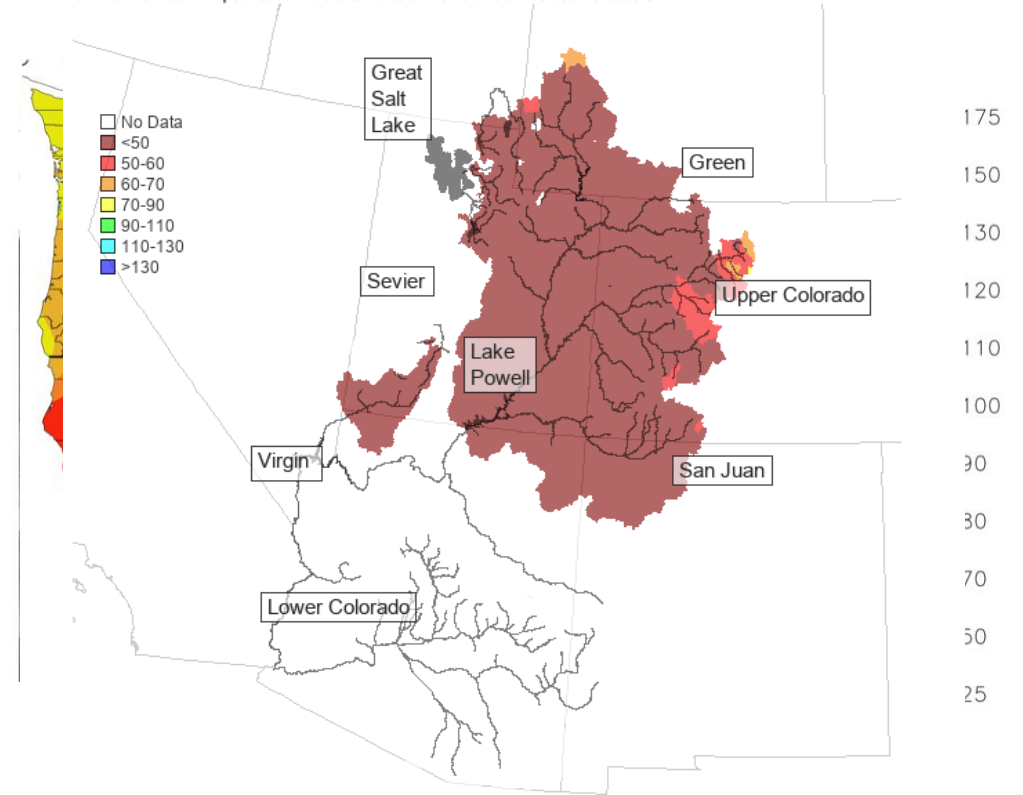
1955-2016 trends in April Snowpack



Mote and Sharp, 2016

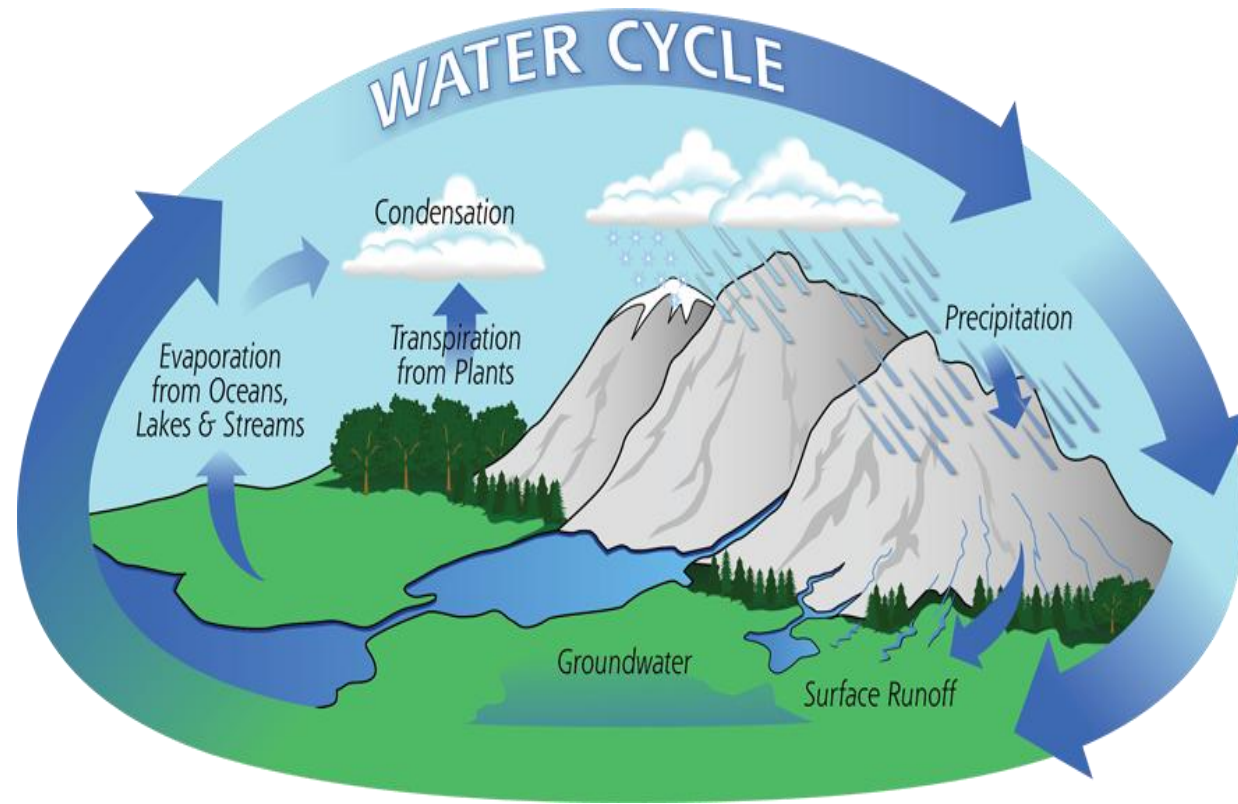
Water Supply Outlook, June 1, 2021

Click on text box for publication. Colors indicate the values of residual forecasts.



Prepared by
NOAA, National Weather Service
Colorado Basin River Forecast Center
Salt Lake City, Utah
www.cbrfc.noaa.gov

Where did the water go?!?!

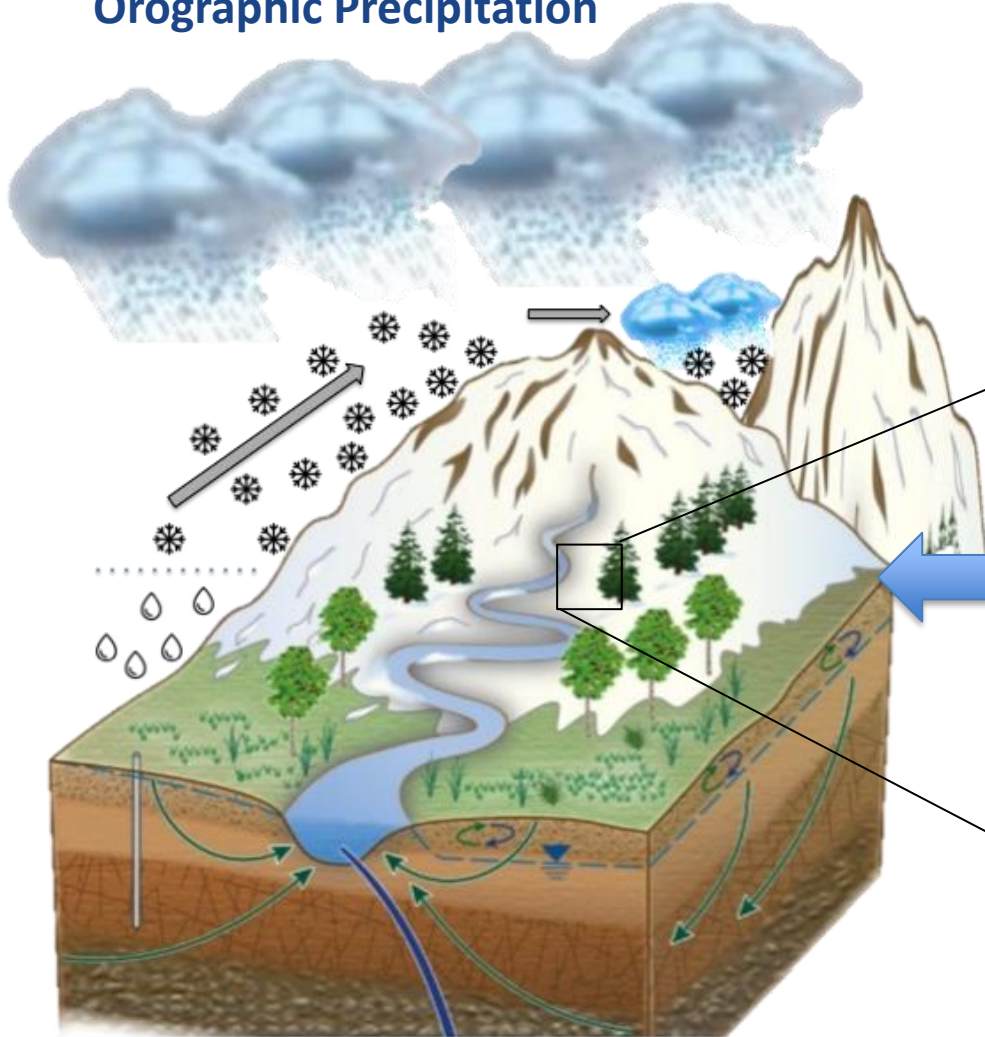


$$P = ET + R + I + \Delta S$$

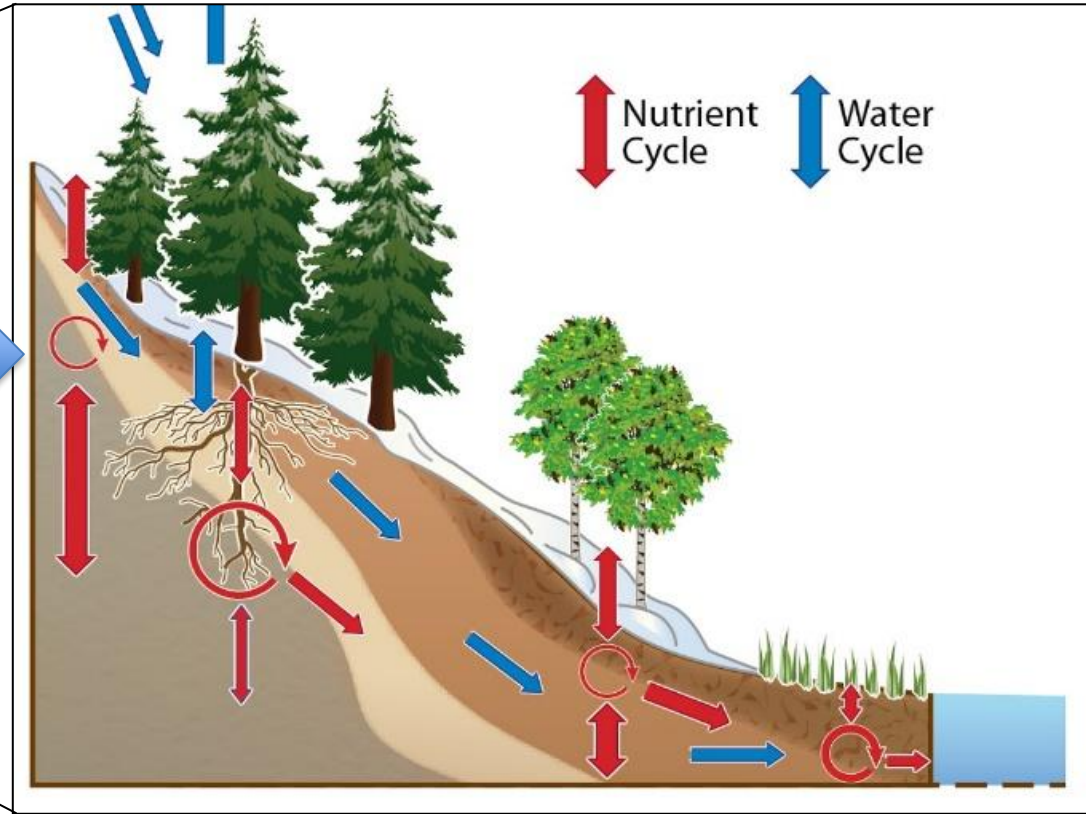
Precipitation Evapotranspiration (Sublimation) Runoff Infiltration Storage

Understanding and predicting where the water goes is complex

Orographic Precipitation

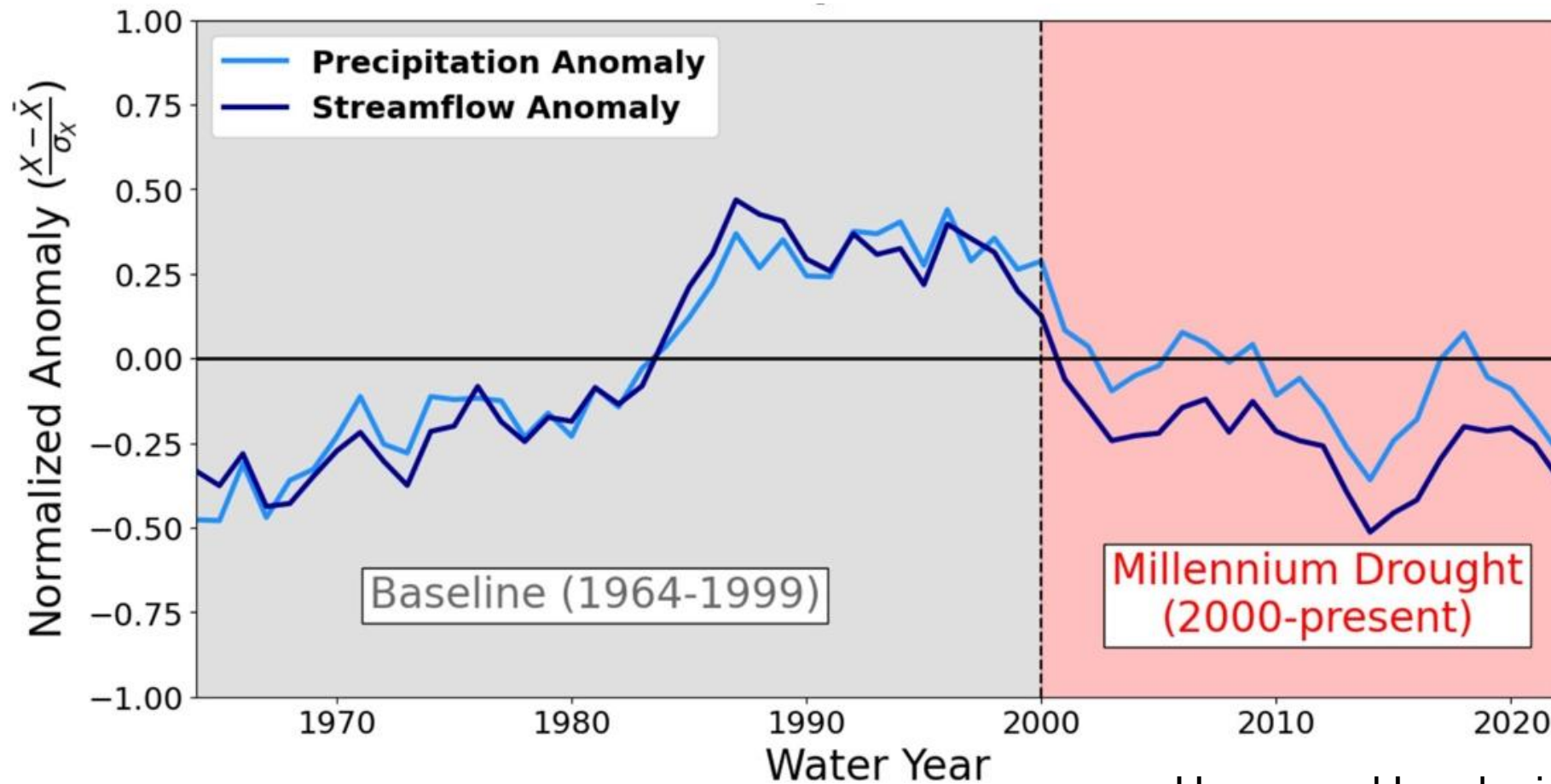


Land Through Subsurface Processes



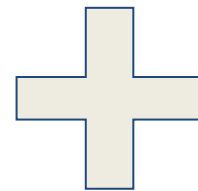
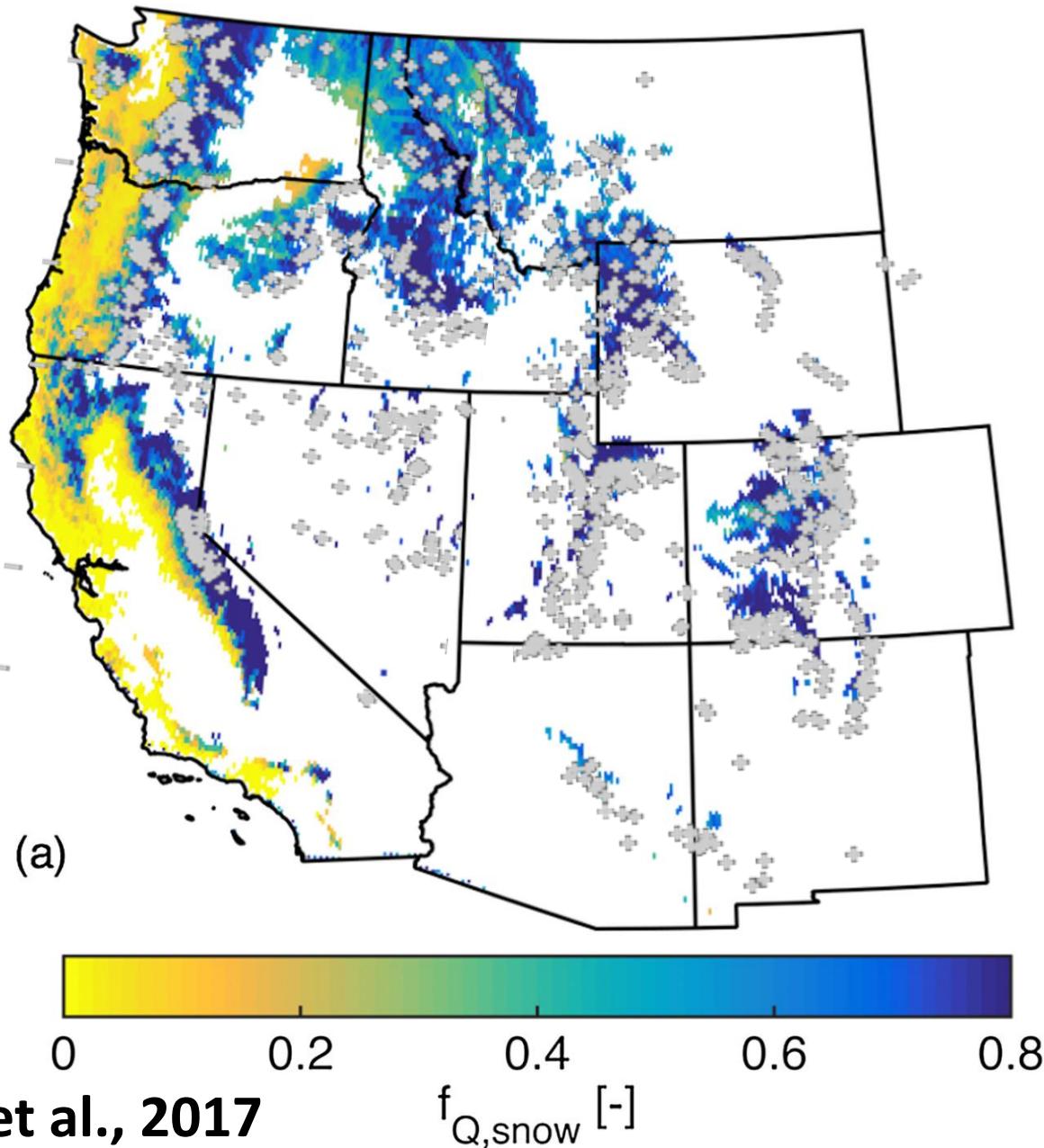
But for now, the Missing Water Mystery is solved

Reduced spring precipitation and evaporative losses in the middle and lower basins created a disconnect between precipitation and streamflow. Other causes are possible in the future.



Hogan and Lundquist, (2024) *GRL*

How did we solve this?
With observations of the
snow, especially SNOTEL.

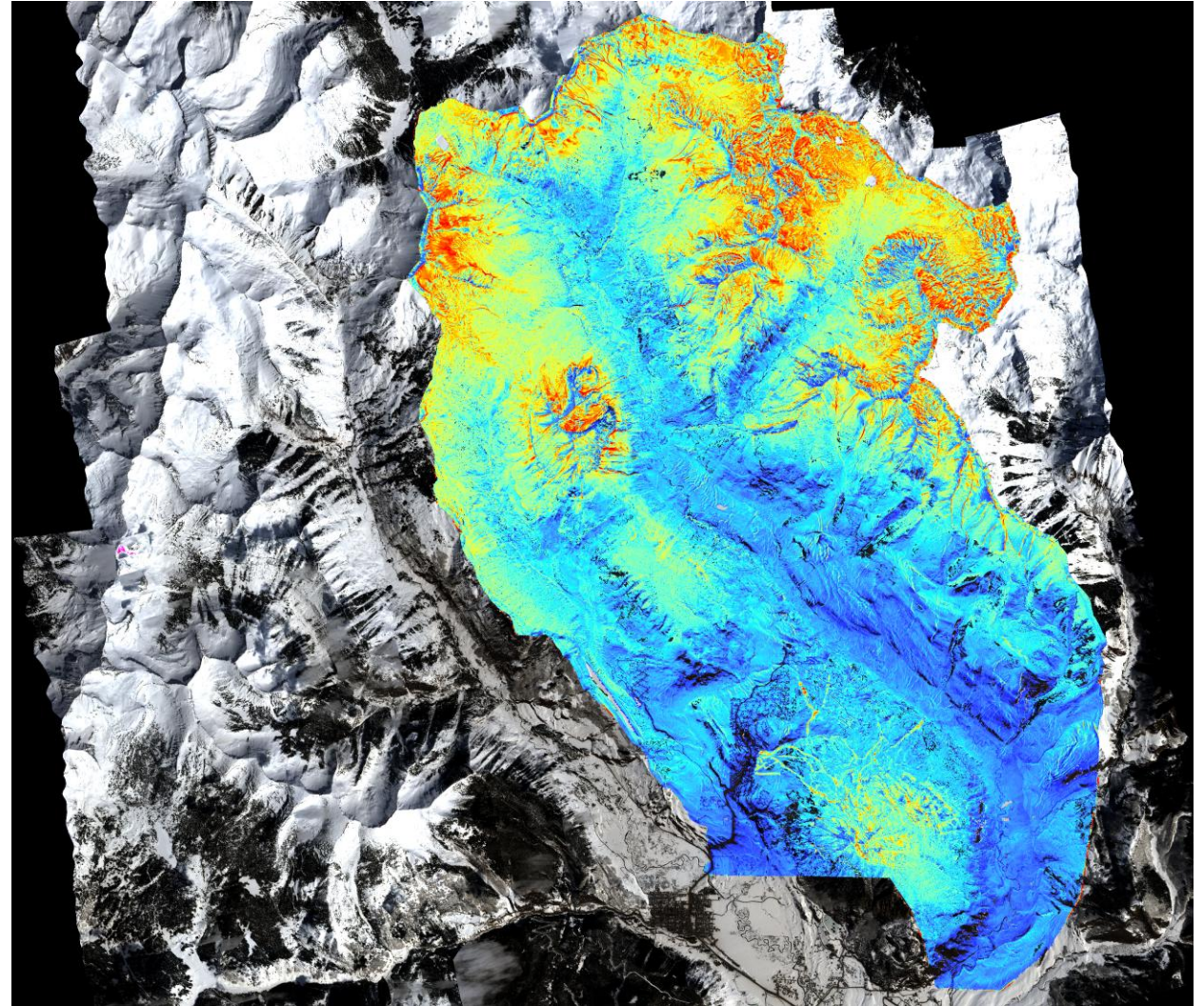
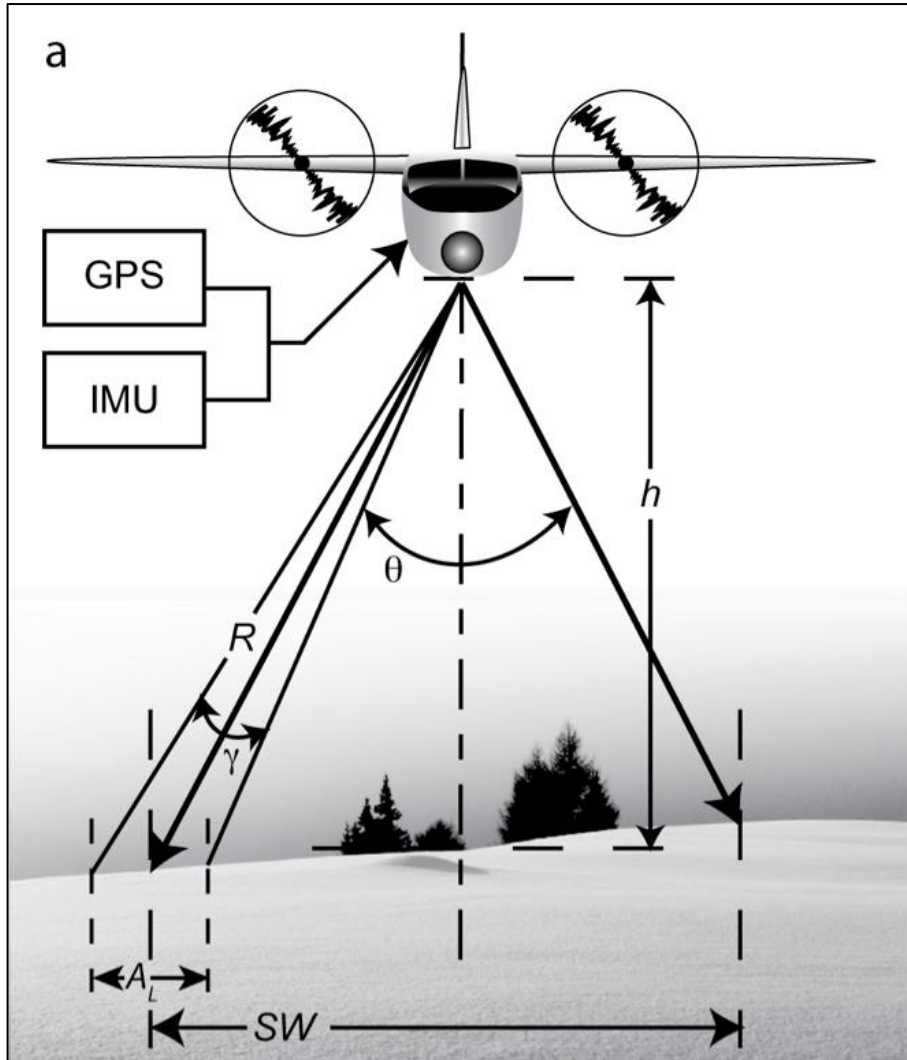


Snow Telemetry (SNOTEL)
network in the Western US

Li et al., 2017

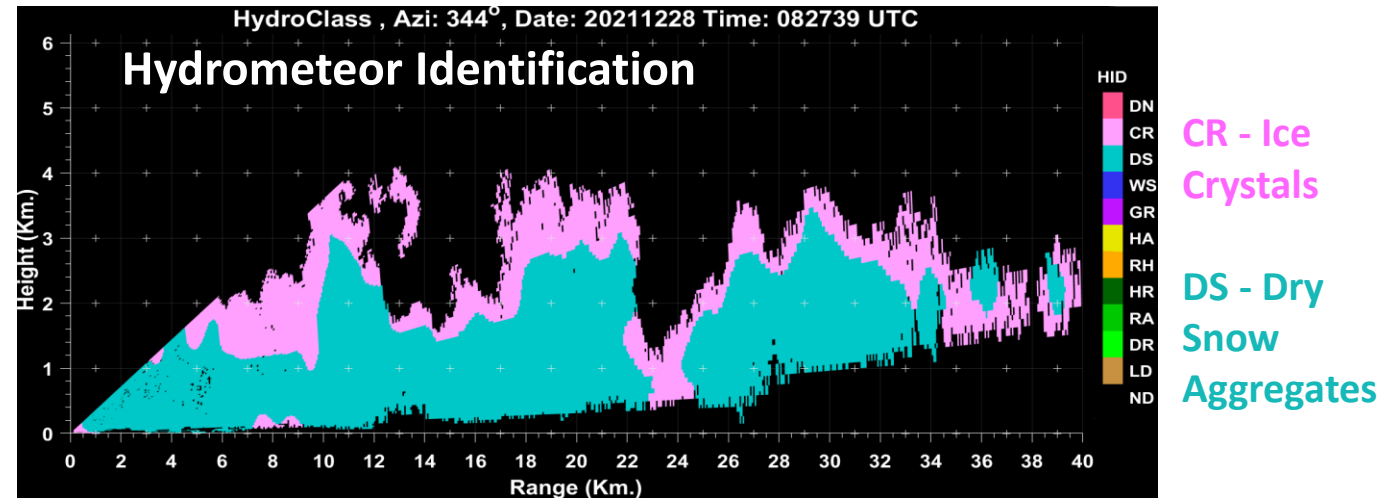
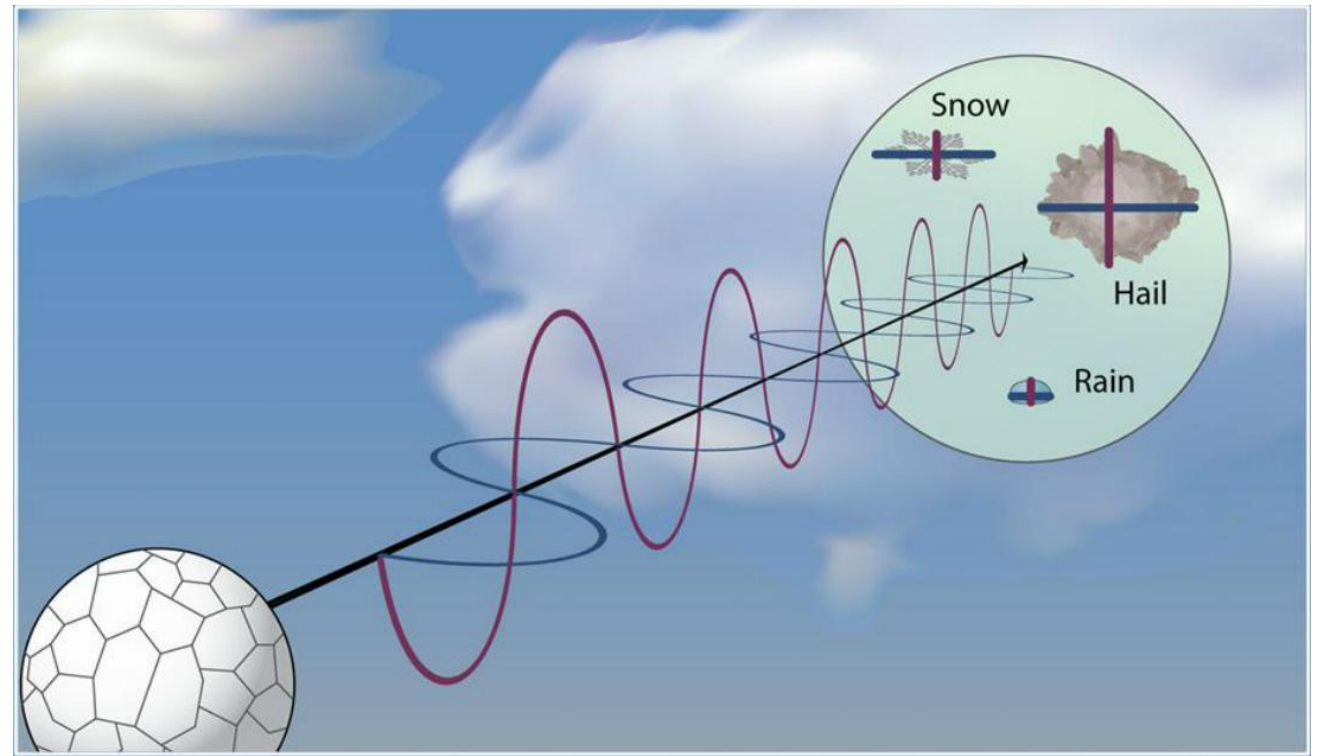
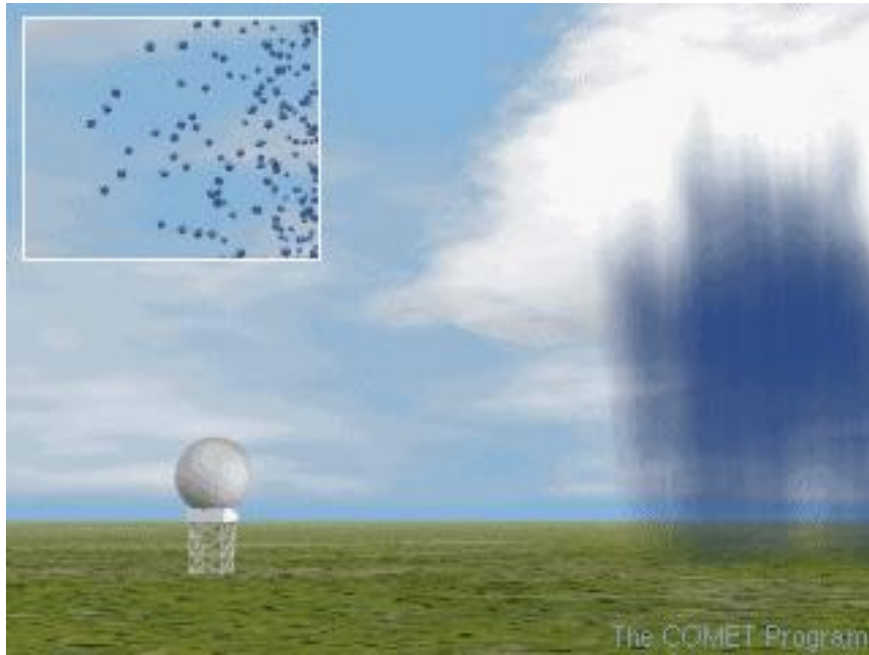
How else do we measure snow?

Airborne snow surveys



How else do we measure snow? Radar

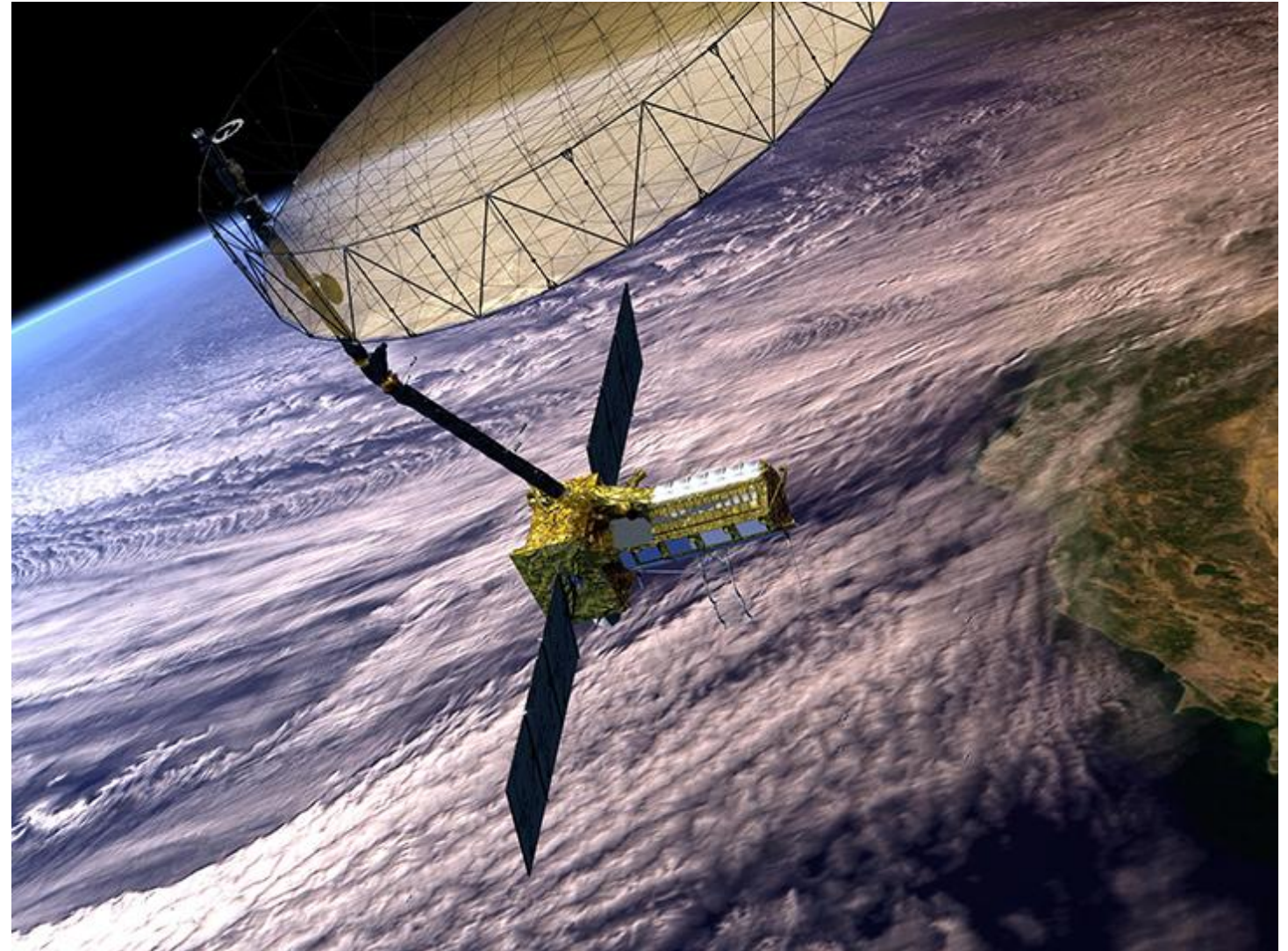
Precipitation radar, where available, show what exactly is falling from the sky.



How else do we measure snow? Sort of with satellites

Satellites can see snow areal extent

Experimental efforts underway to estimate snow depth and water content



How else do we measure snow? Intensive field campaigns

U.S. DOE focuses on intensively studying watersheds in the Upper Basin near Crested Butte, Colorado collecting atmospheric, surface, and subsurface observations.



Observational Challenges Persist

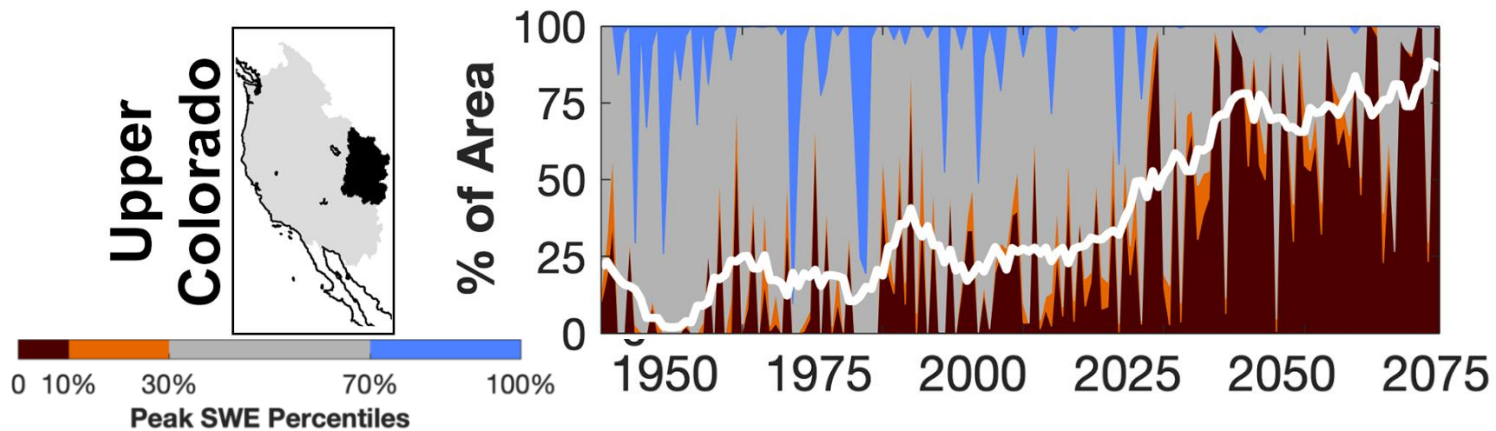
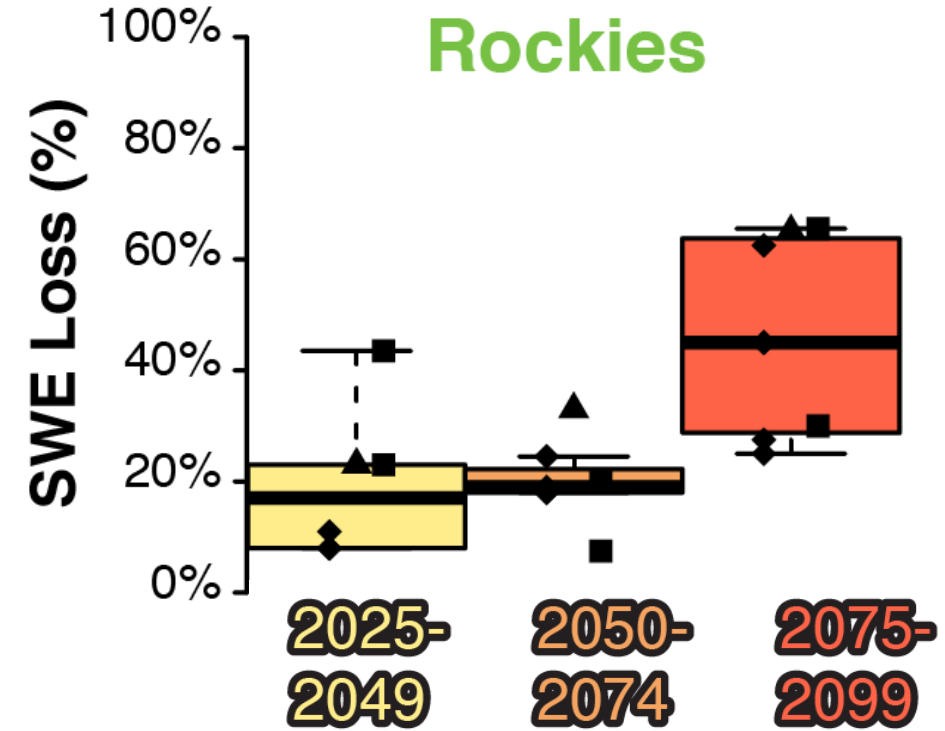
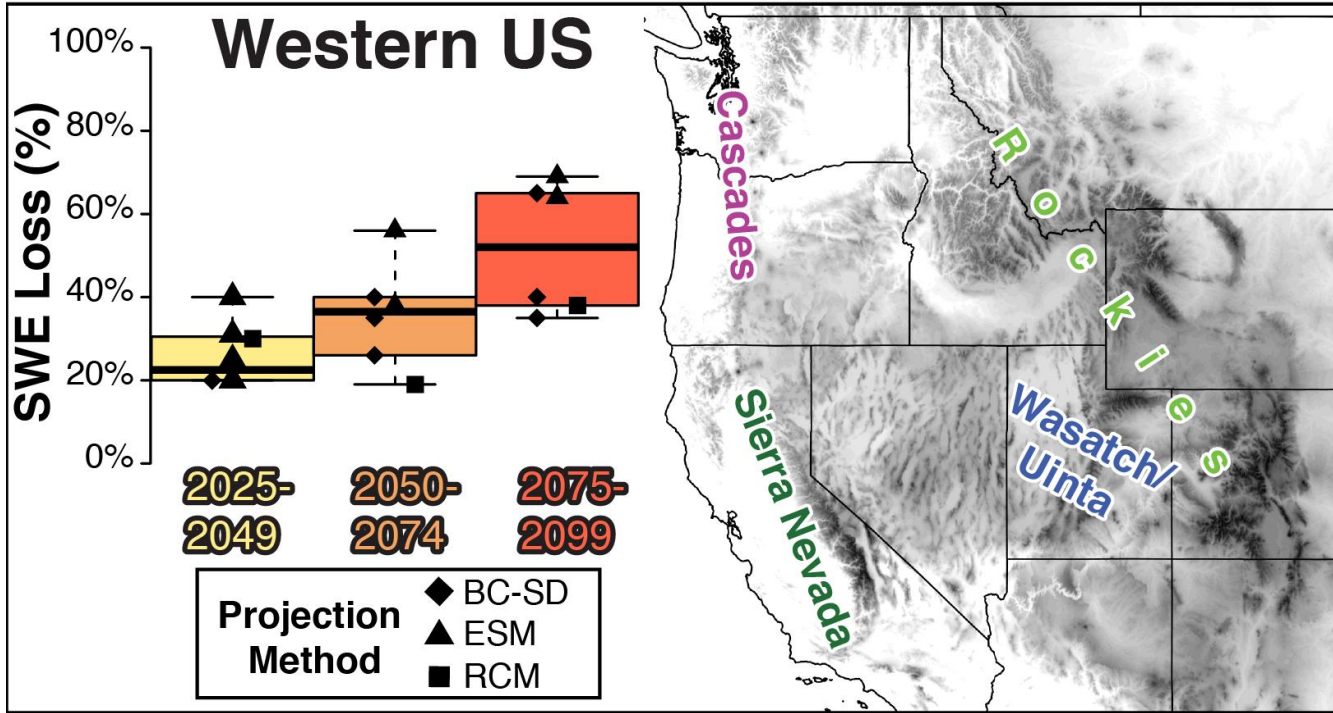


Photo Credit: [Ryan Barr \(2021\)](#)

But we venture out to meet these challenges



Projections of the Snow Water Availability in the West



This is a big range!

Figures from Woodburn, Rhoades, Feldman et al, 2021

This prediction could get harder in the future as SNOTELs go dark

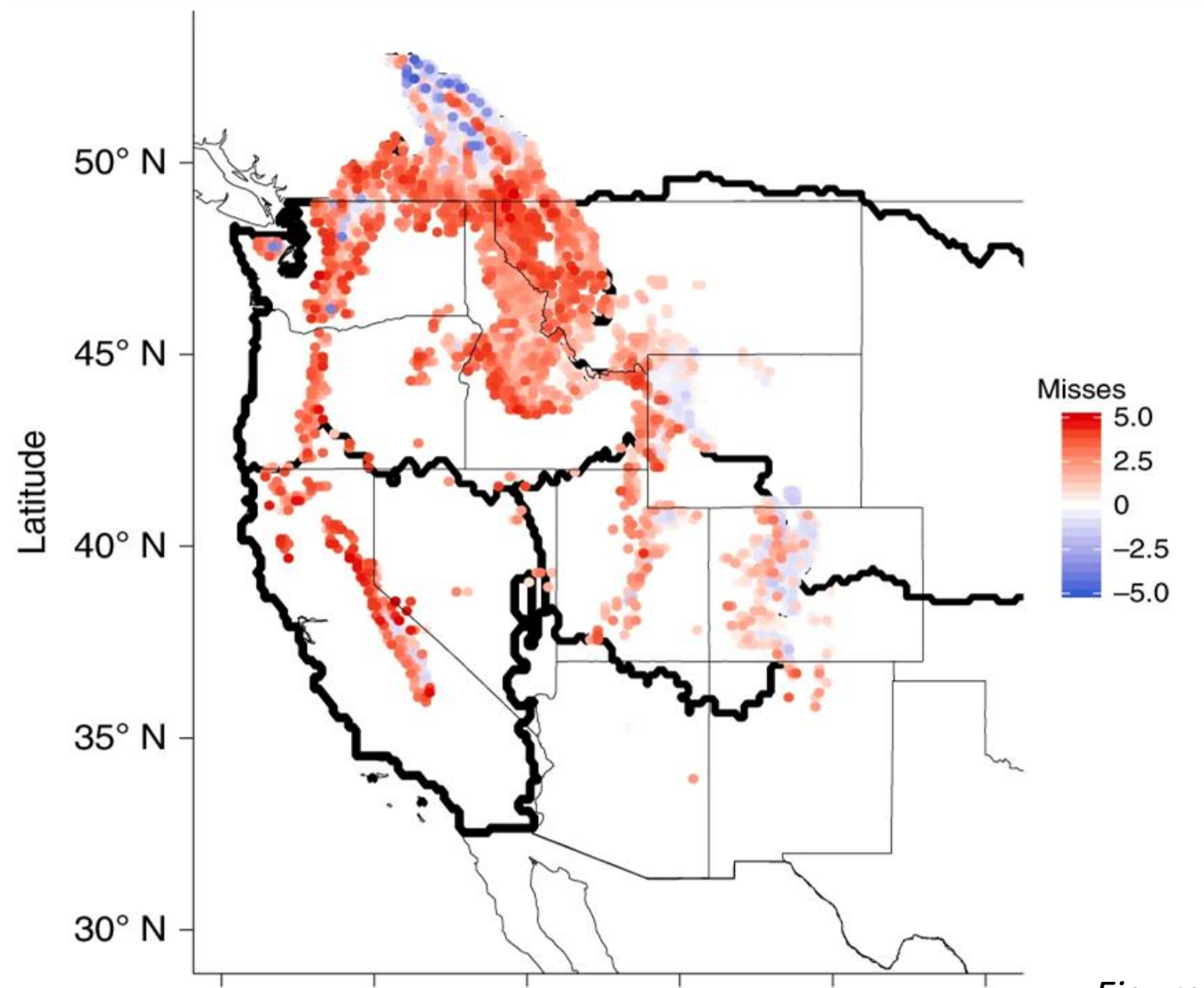
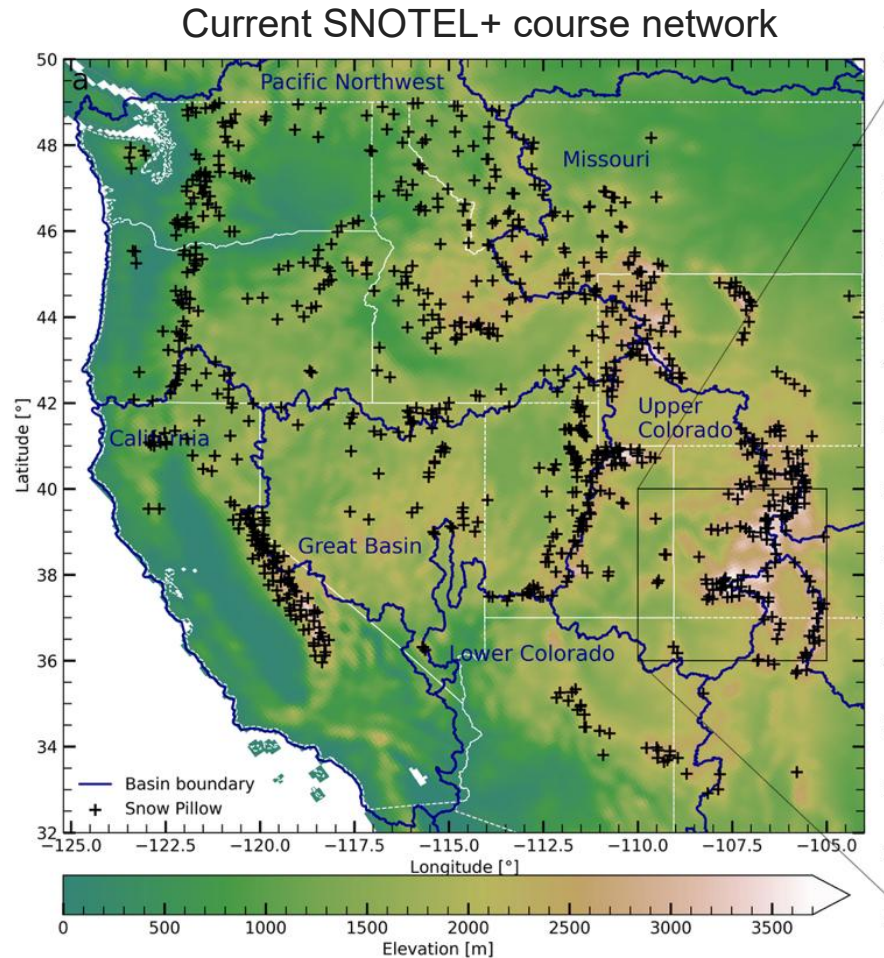


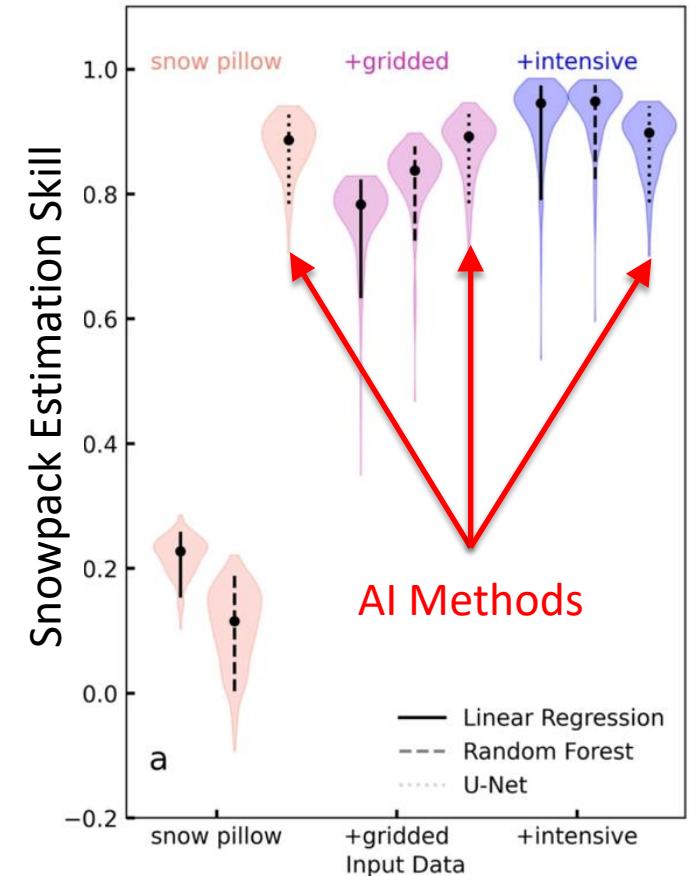
Figure from Livneh and Badger, 2020

We Actually Need AI to Maintain Predictive Skill

- The network for estimating snowpack across the Mountain West is sparse. We can't measure every snowflake everywhere all the time.
- Snowpack estimation skill will degrade. How do we deal with it?
- We can use AI to combine different data sources quickly to estimate snowpack in bad snow years.



Snowpack estimation skill in the 21st Century



Cowherd, Feldman, et al, 2024, Nat Comm Earth Env.

Summary

- Scientists seek to serve the West by measuring, understanding and predicting Western snowpack and water resources now and into the future.
- Integrated observations and modeling of snow enable us to tackle water mysteries and support managers and decision-makers.
- Researchers in the National Lab system, at universities, and with partner federal, state and local agencies are working together, focusing on the Upper Colorado.
- Questions? Want to see science in the field?
 - Email me! drfeldman@lbl.gov

