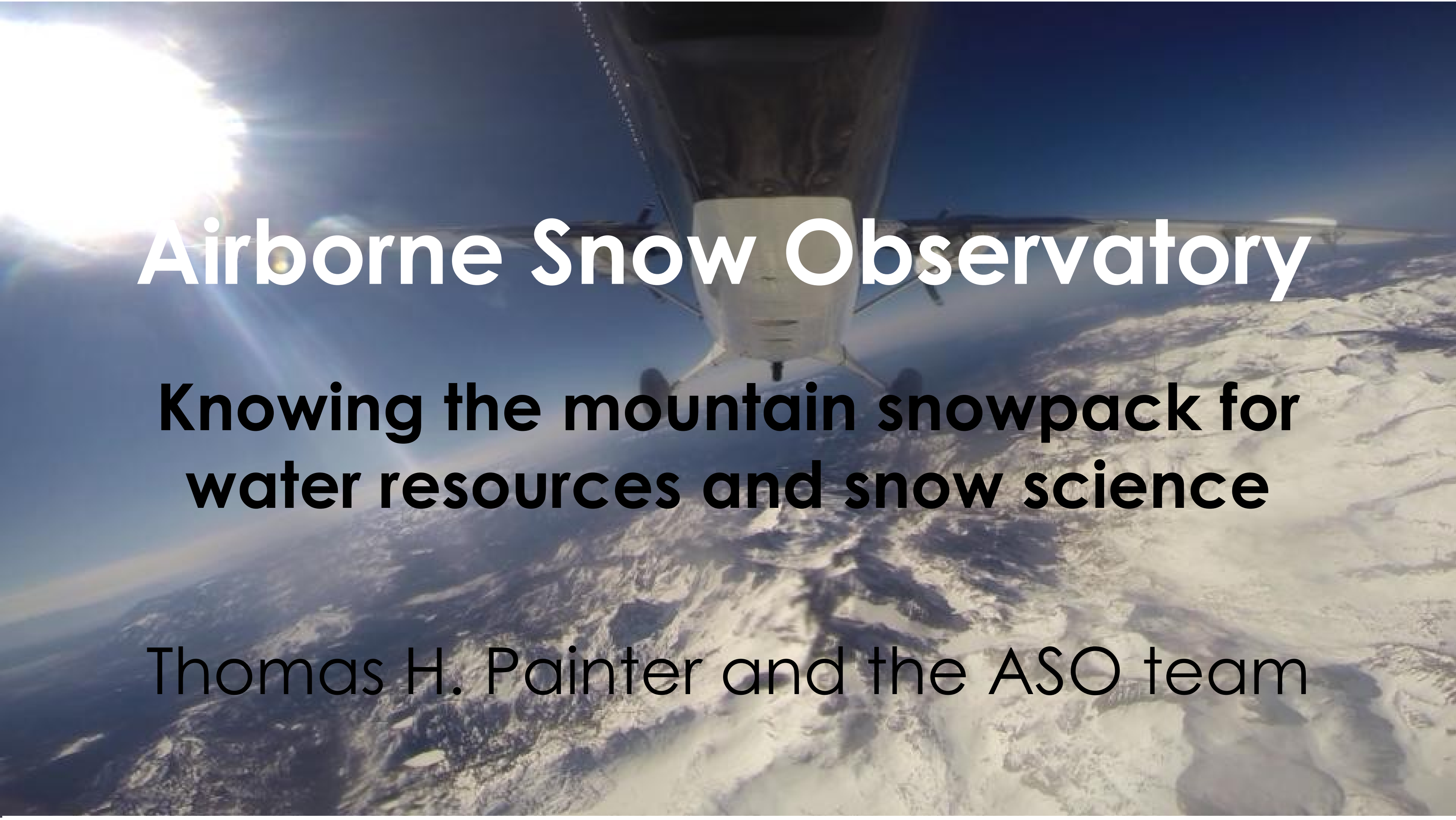


Airborne Snow Observatory

Knowing the mountain snowpack for water resources and snow science

Thomas H. Painter and the ASO team

NASA

Jet Propulsion Laboratory
California Institute of Technology

Department of Water Resources, State of California

California Cooperative Snow Surveys

Western Water Assessment

McGurk Hydrologic

NSIDC
National Snow and Ice Data Center

In California, Reading the Snow to Tell the Future for the Water Supply

Max Whittaker for The New York Times

Frank Gehrke, cen . The state's multibillion-dollar agricultural industry p

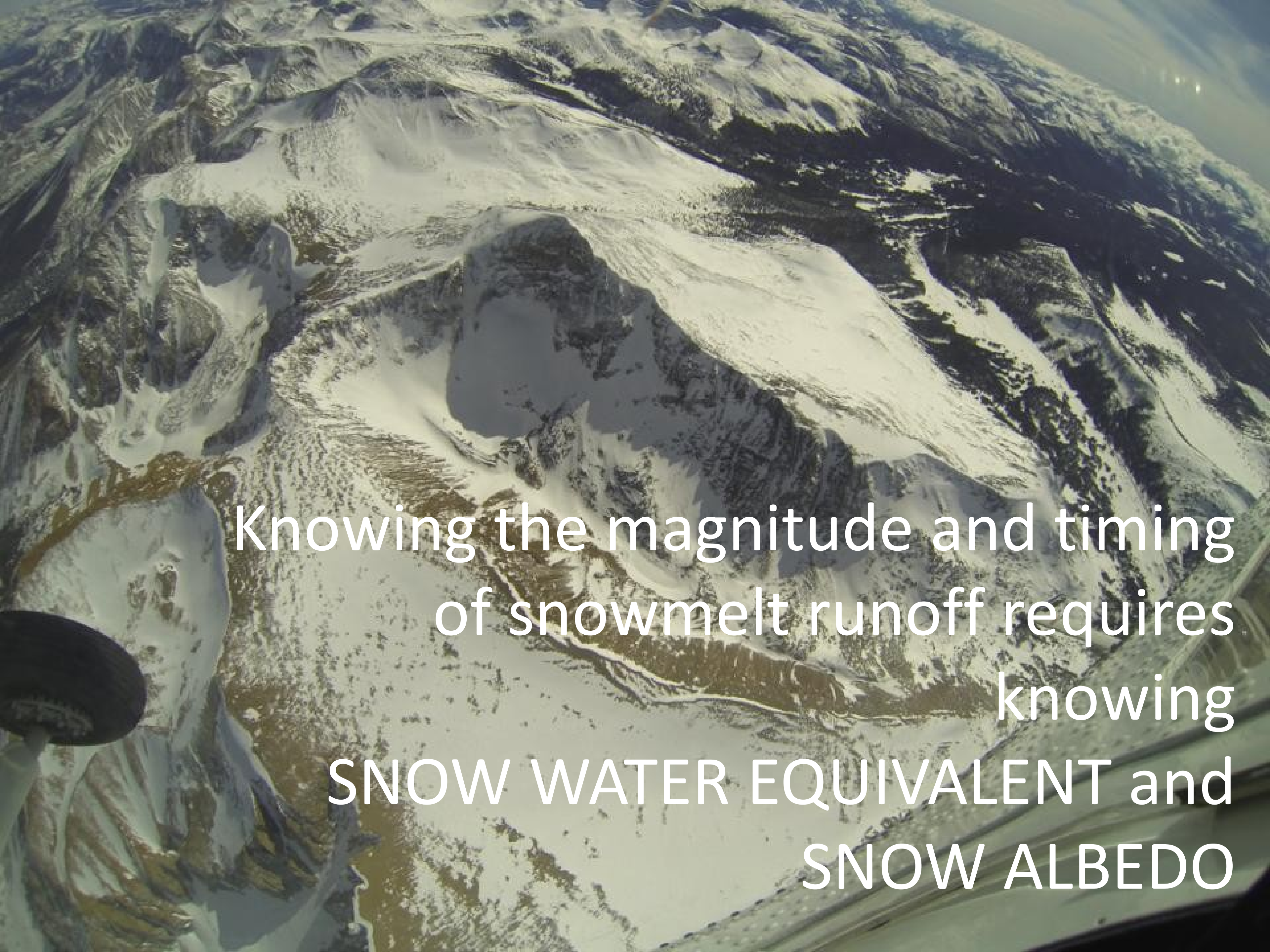
By NORIMITSU ONISHI
Published: February 7, 2013

PHILLIPS, Calif. — Along Highway 50 in the Sierra Nevada,

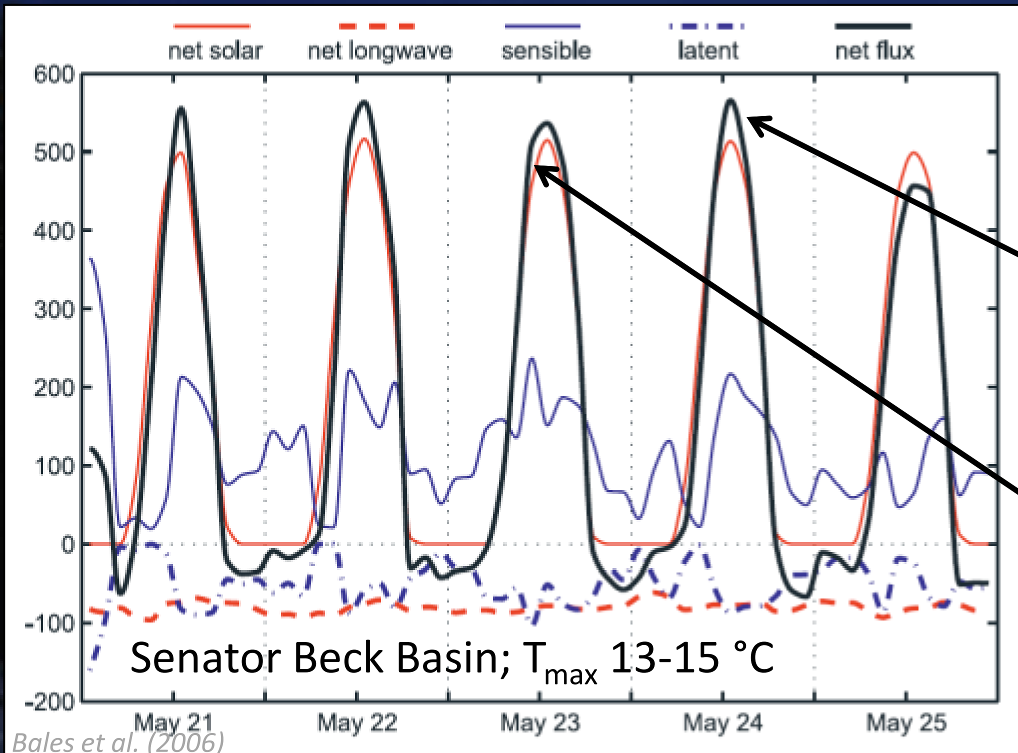
FACEBOOK

NO!

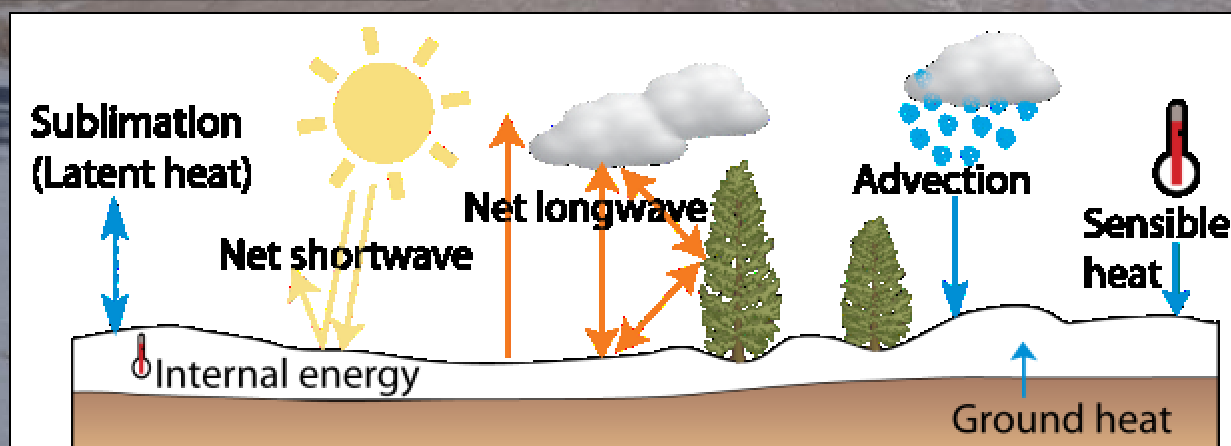
Ground measurements are critical.


Knowing the magnitude and timing
of snowmelt runoff requires
knowing
SNOW WATER EQUIVALENT and
SNOW ALBEDO

Solar radiation controls snowmelt



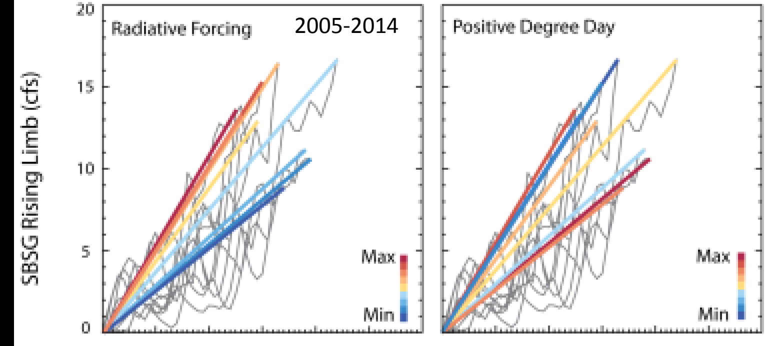
repeat, spatially explicit maps of snow albedo are needed

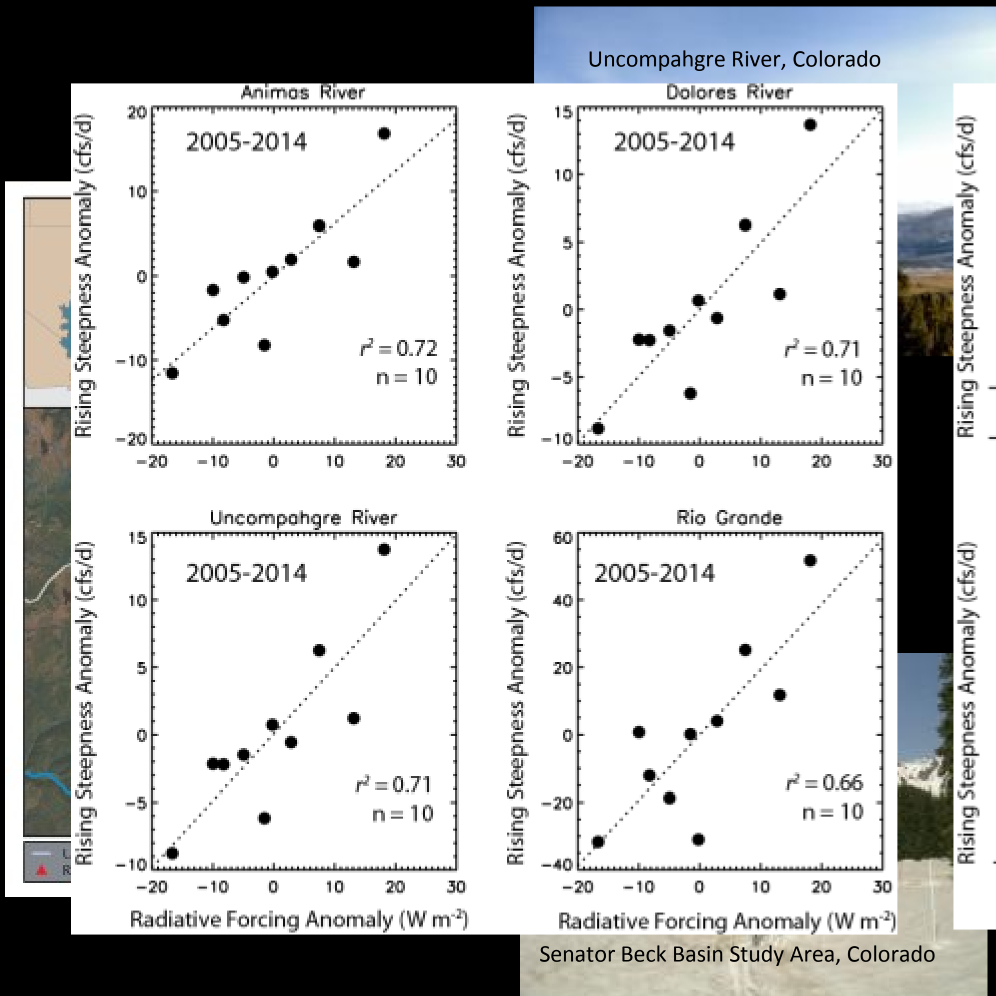


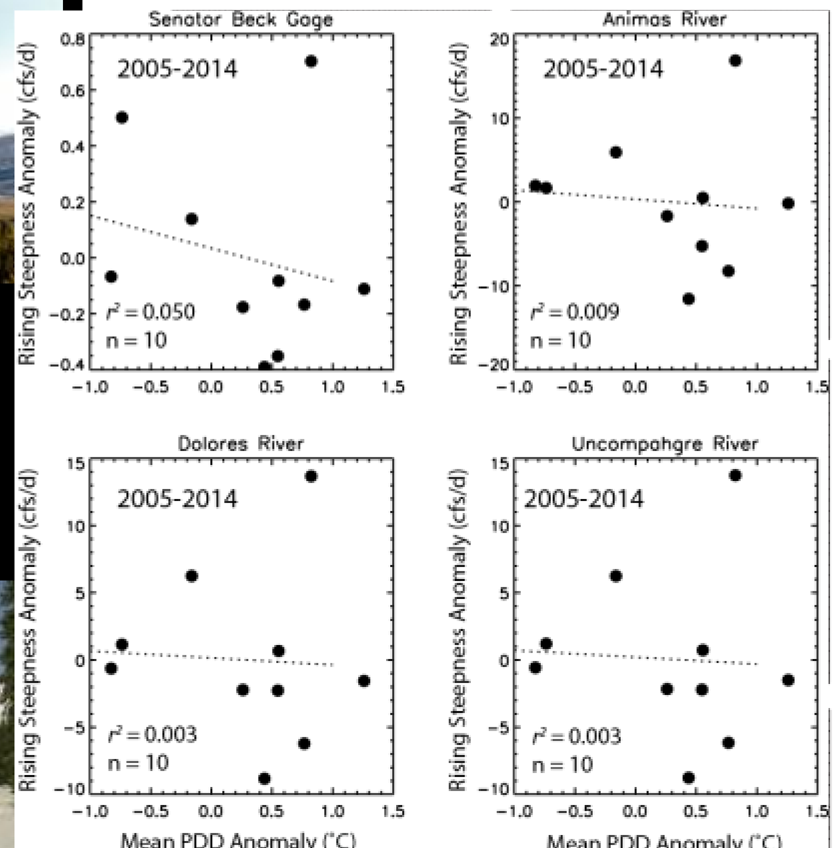
April 2010

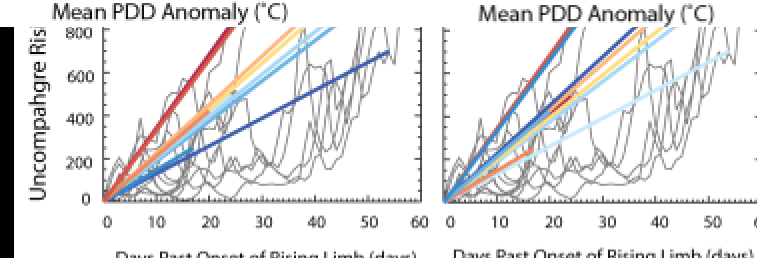
Senator Beck Basin, San Juan Mountains

What controls the steepness of the rising limb of the hydrograph?



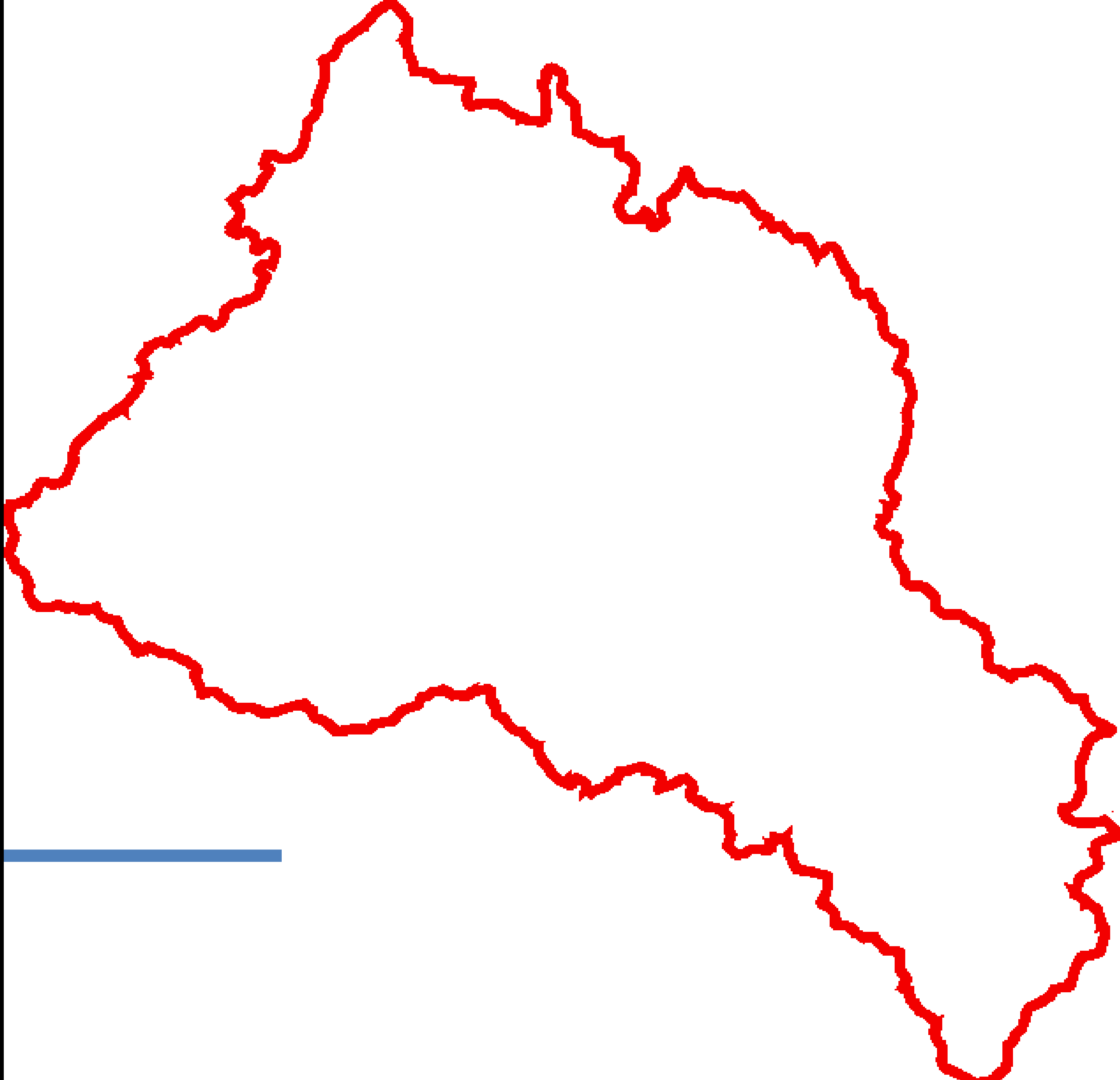






Painter et al (in preparation)

The way we've measured snow in the West since 1910



we
ee it

on times more
verage

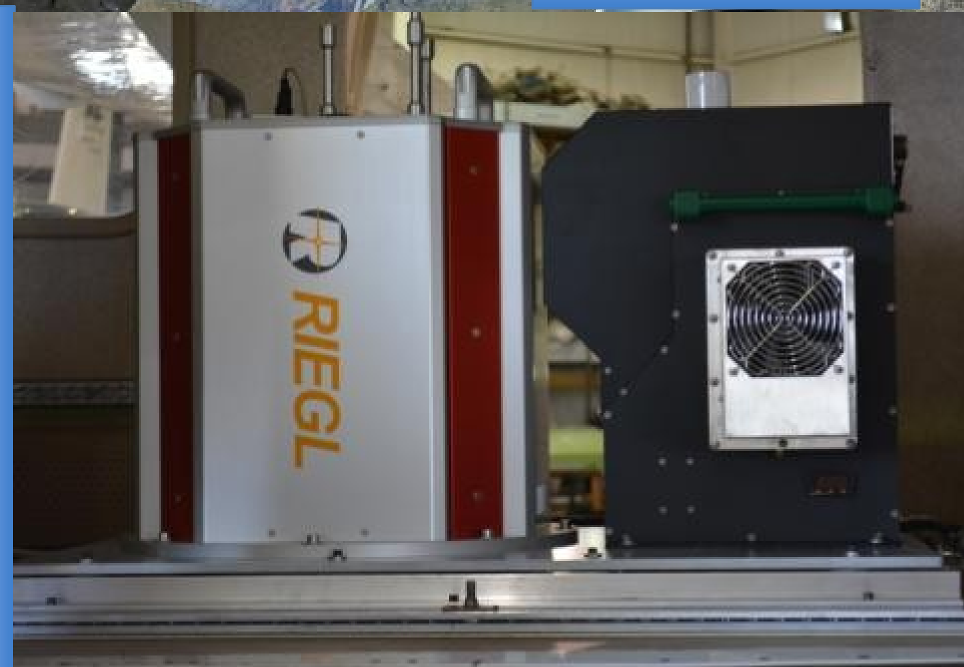
Albedo

CASI-1500 Imaging Spectrometer
0.35-1.05 µm
2 m spatial resolution from 4000 AGL

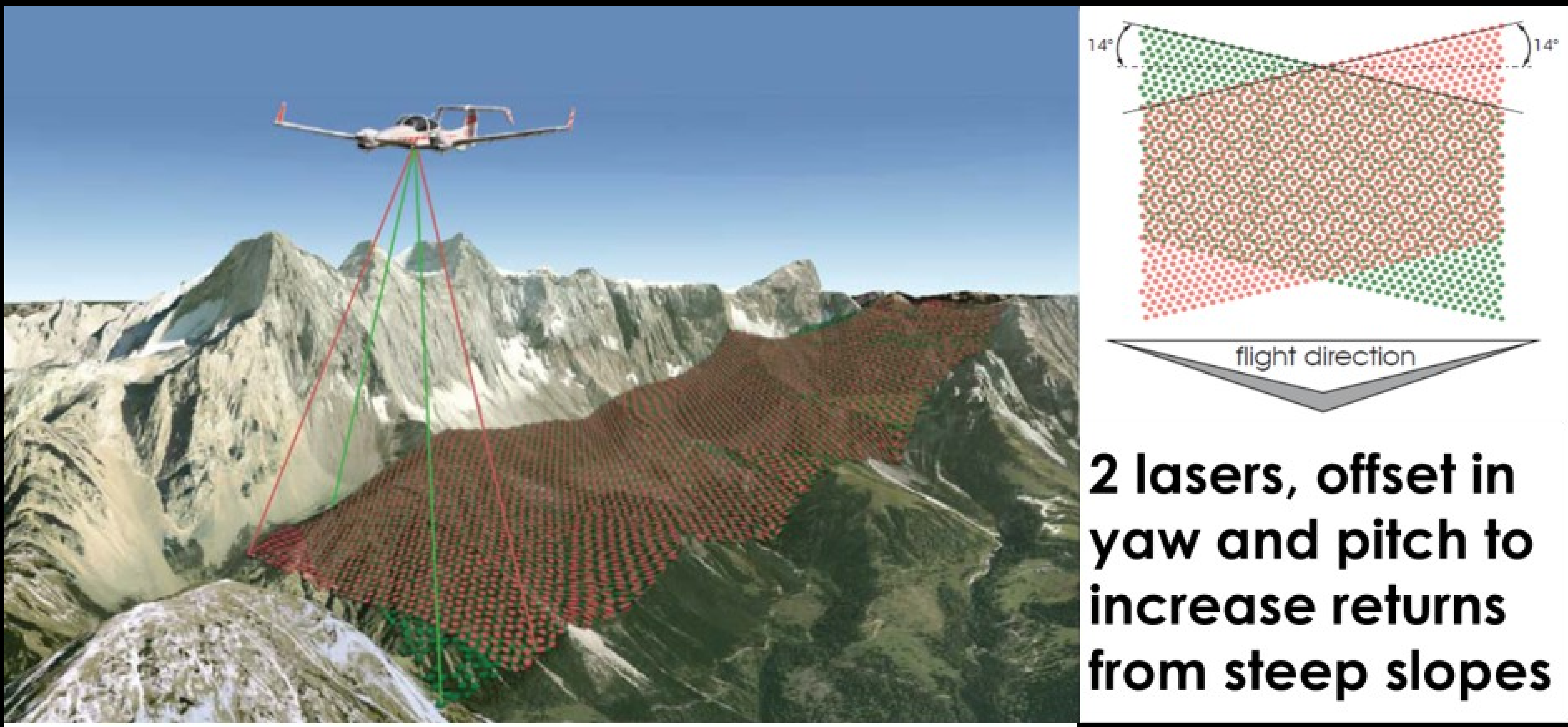
Snow Water Equivalent

Riegl Q1560 3D Scanning lidar
1064 nm, canopy penetration
1 m spatial resolution

- Retrieve topography snow-free and snow-on
- Difference gives snow depth
- SWE comes from assimilation of modeled density field constrained by observations
- SWE variation primarily from depth



ASO scanning lidar

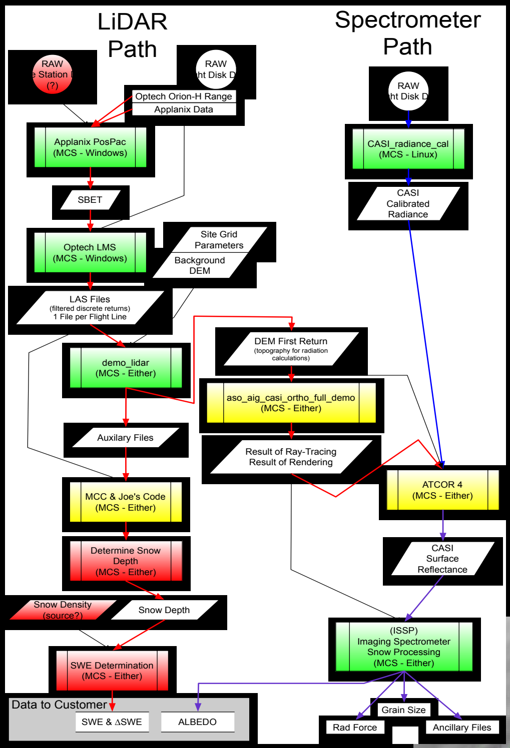


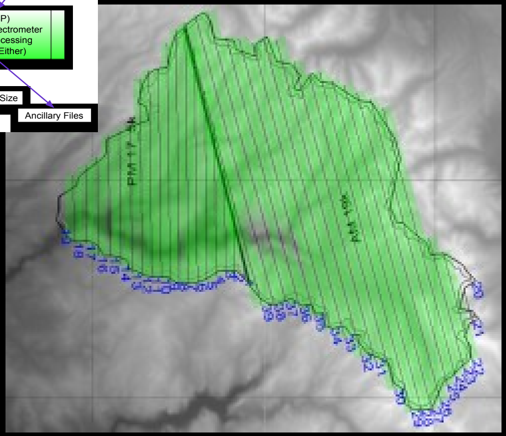
Riegl Q1560, dual-laser


Transit to Merced River

Data processing

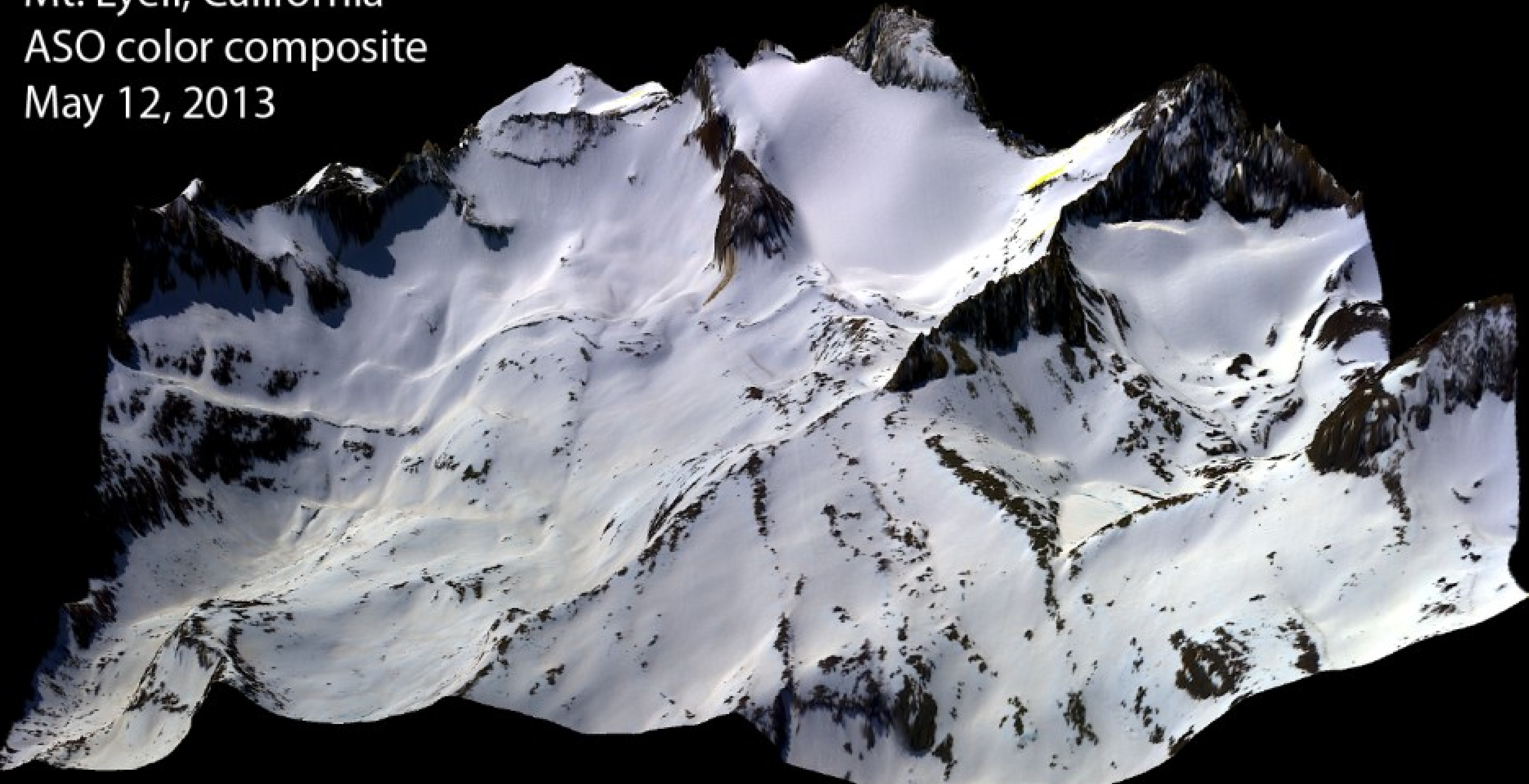
- From flight landing, <u>≤ 24 hr turnaround</u> of SWE and albedo maps at 50 m resolution
- Complex interwoven data chain between spectrometer and lidar
- Coarsening to modeling hydrologic response units



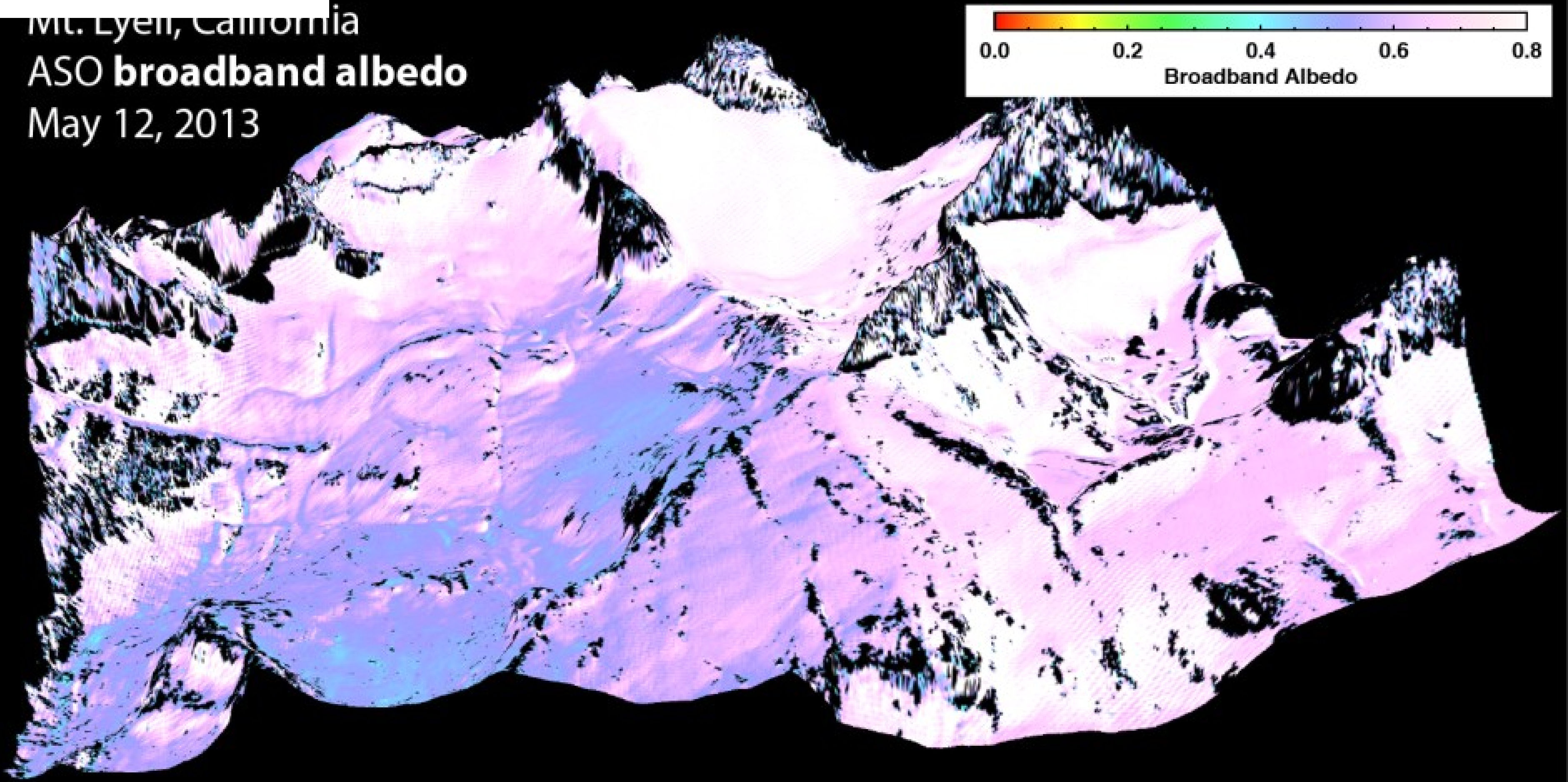


ASO-DM1 Results

Mt. Lyell, California
ASO color composite
May 12, 2013

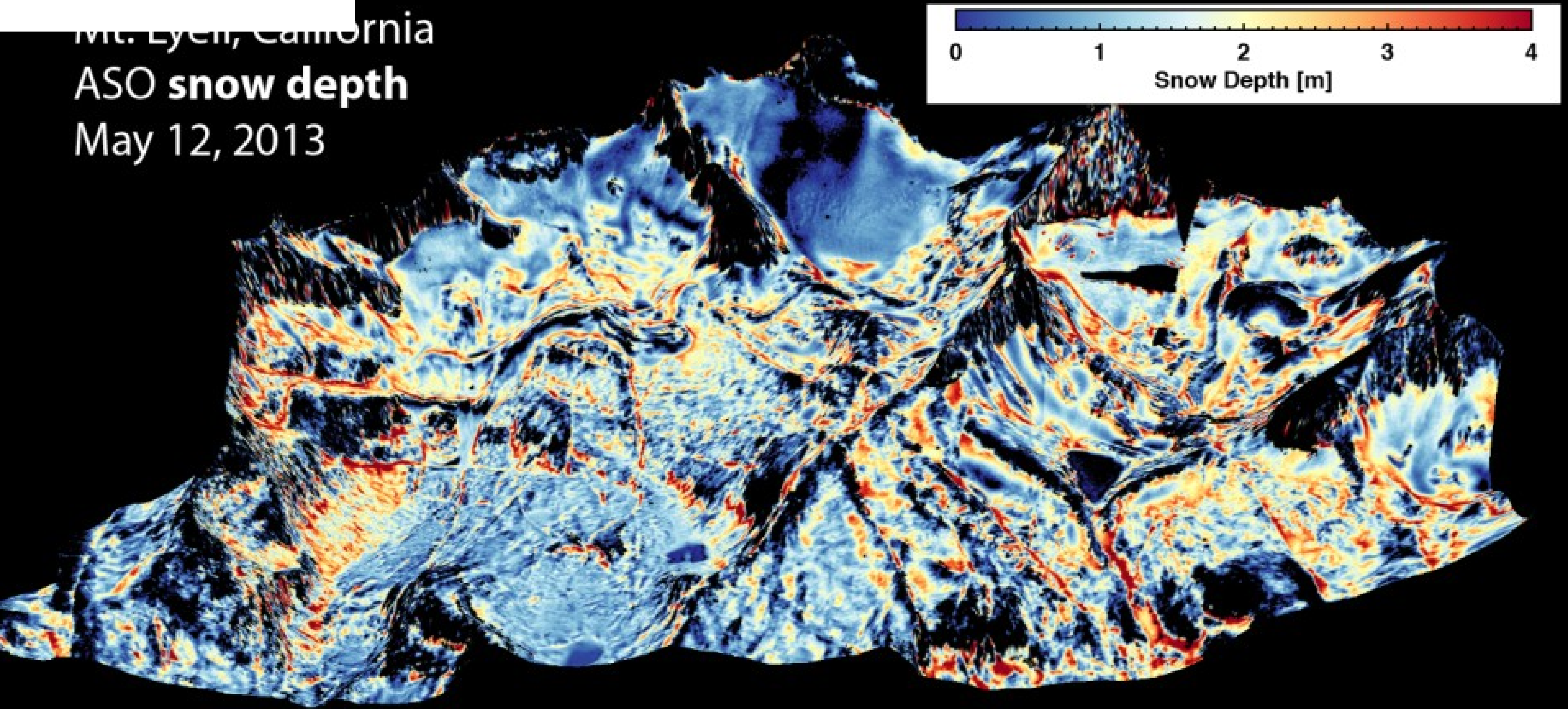


ASO-DM1 Results



ASO-DM1 Results

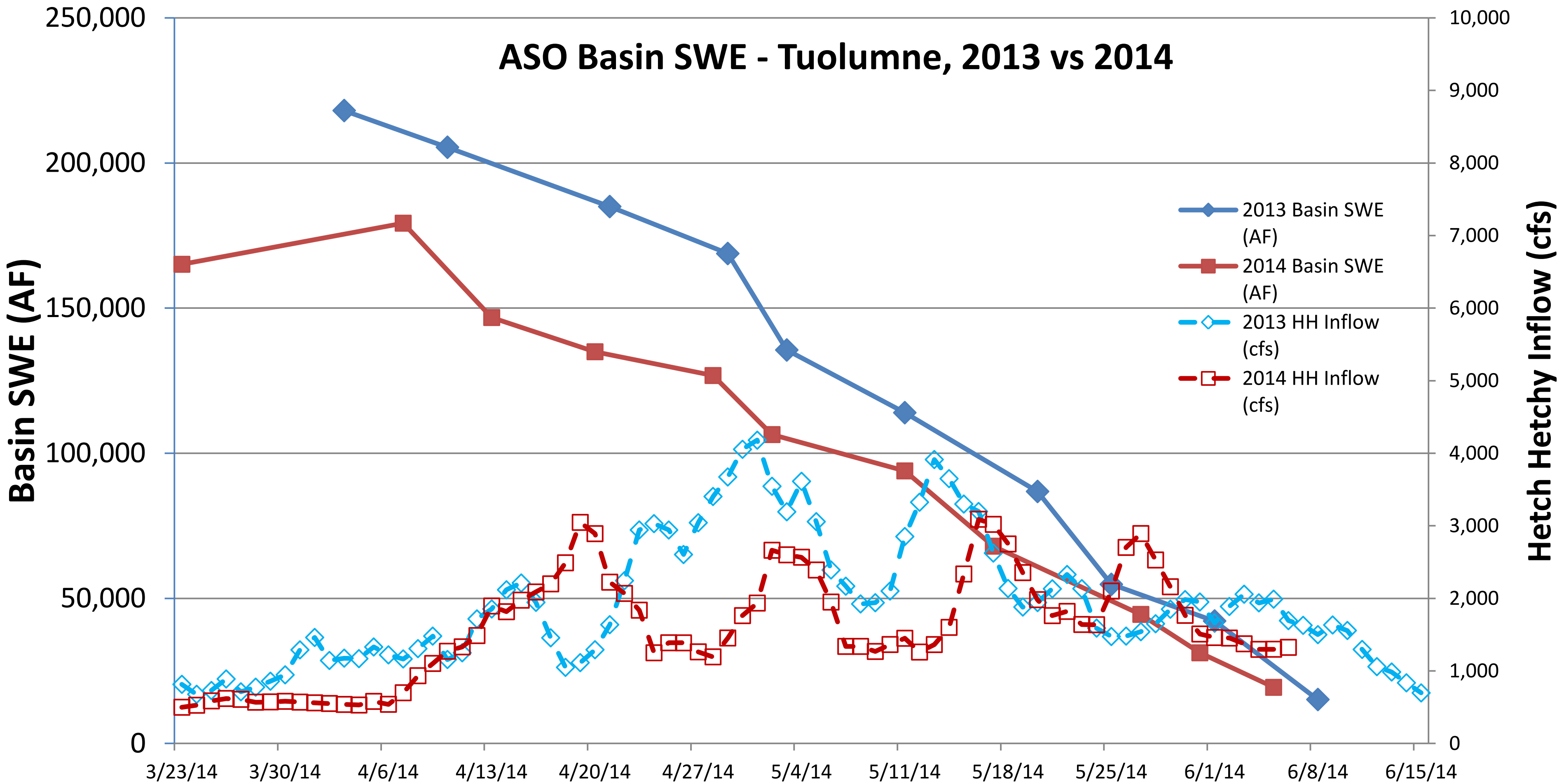
Mt. Lyell, California
ASO **snow depth**
May 12, 2013

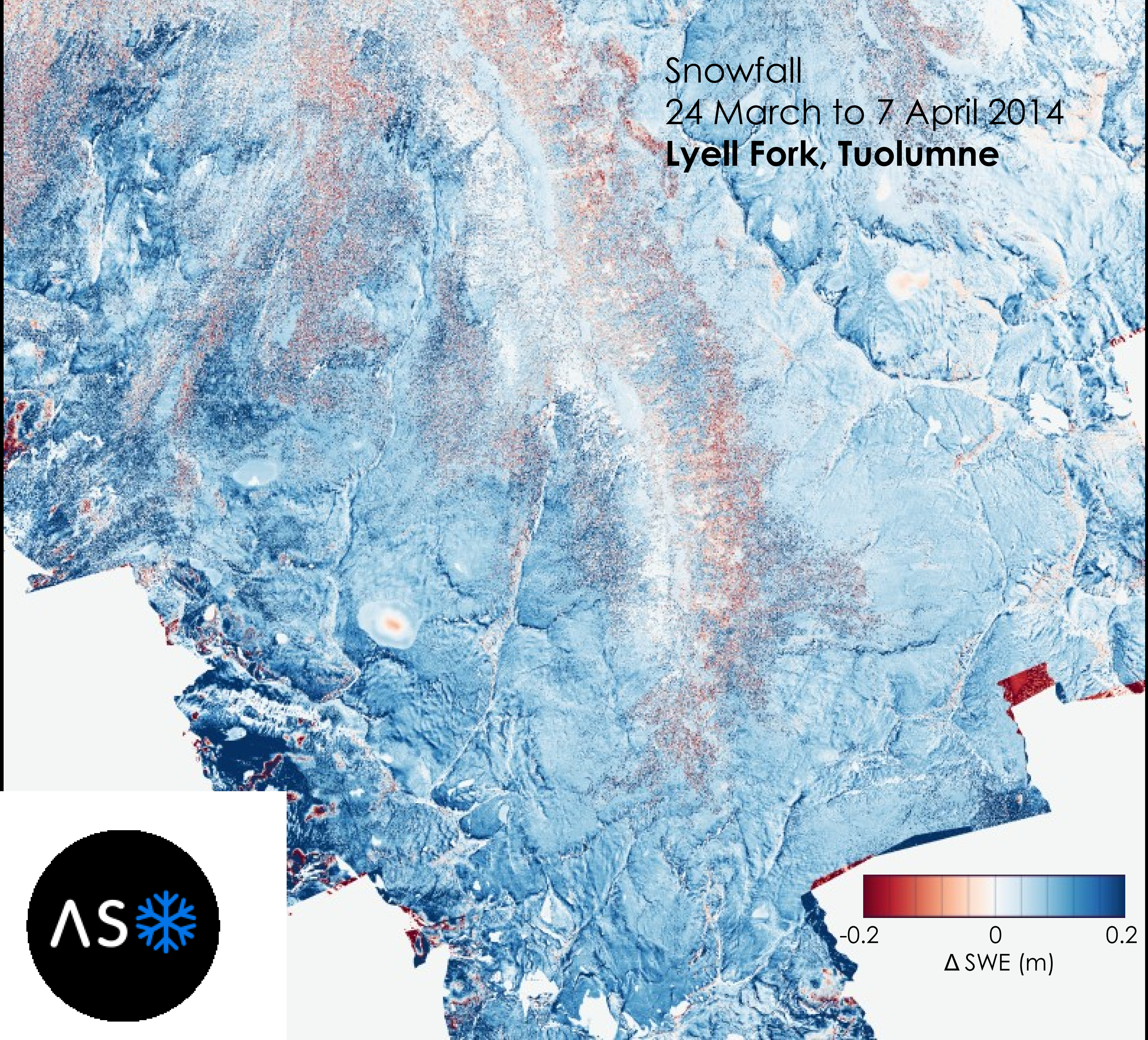


ASO SWE and albedo 2014

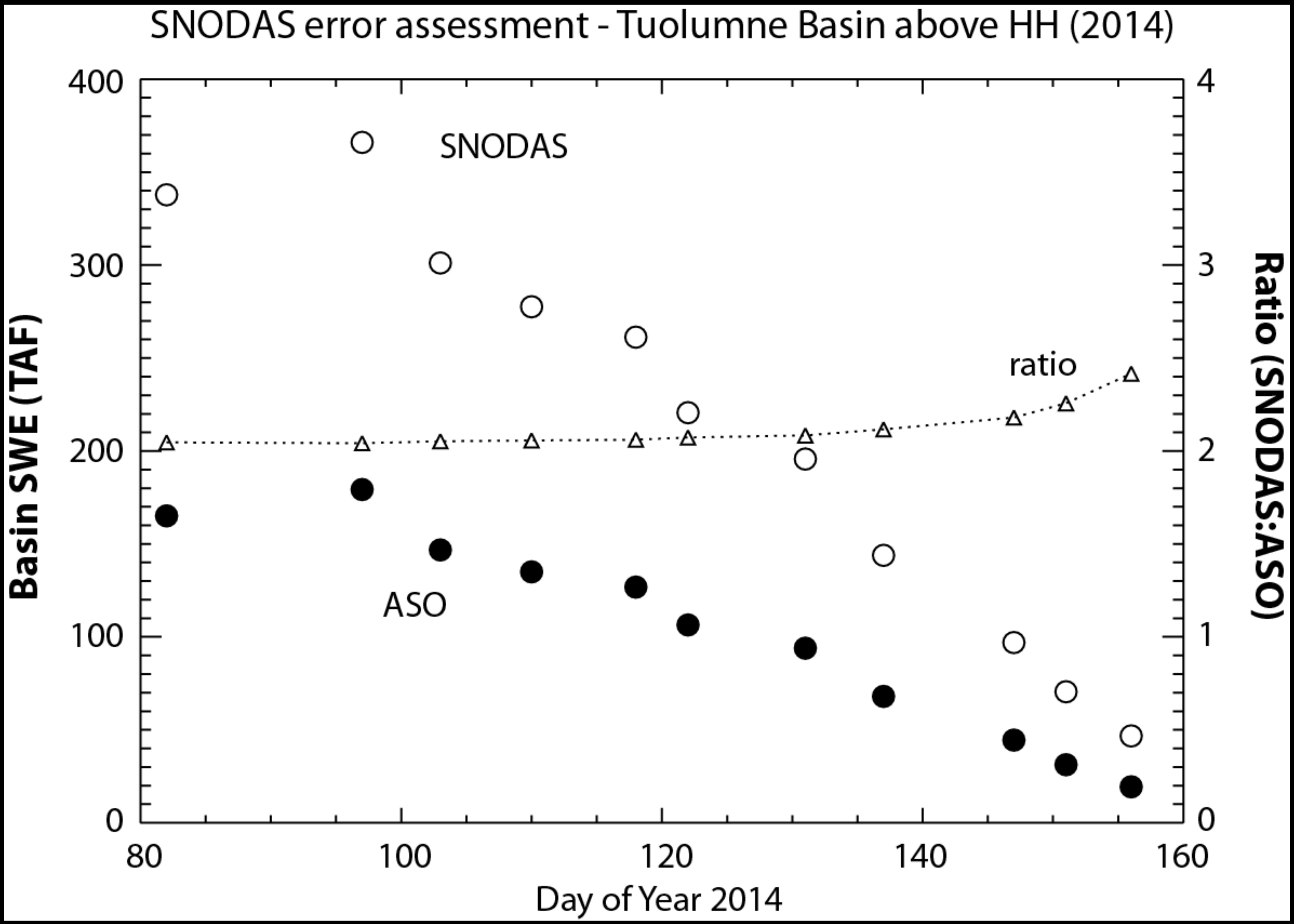
Tuolumne River Basin

Total SWE and inflow




Snowfall
24 March to 7 April 2014
Lyell Fork, Tuolumne
-0.2
0
0.2
Δ SWE (m)

Evaluating what we've thought we've known

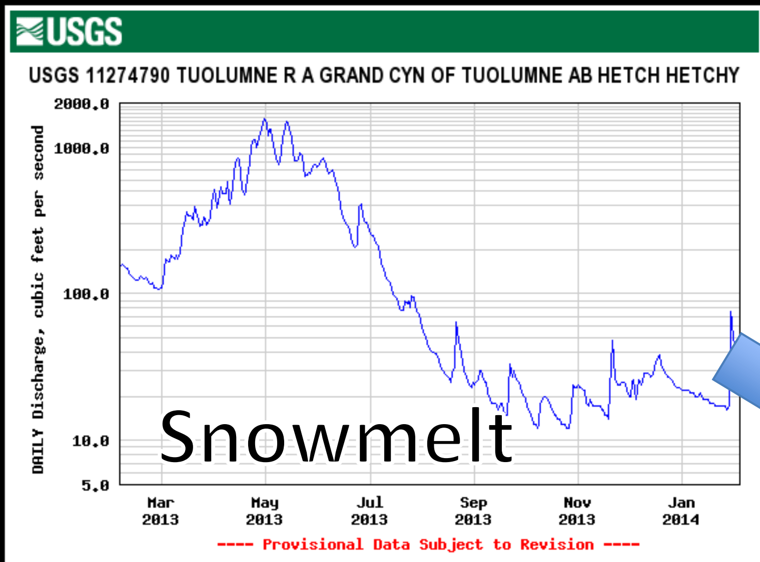


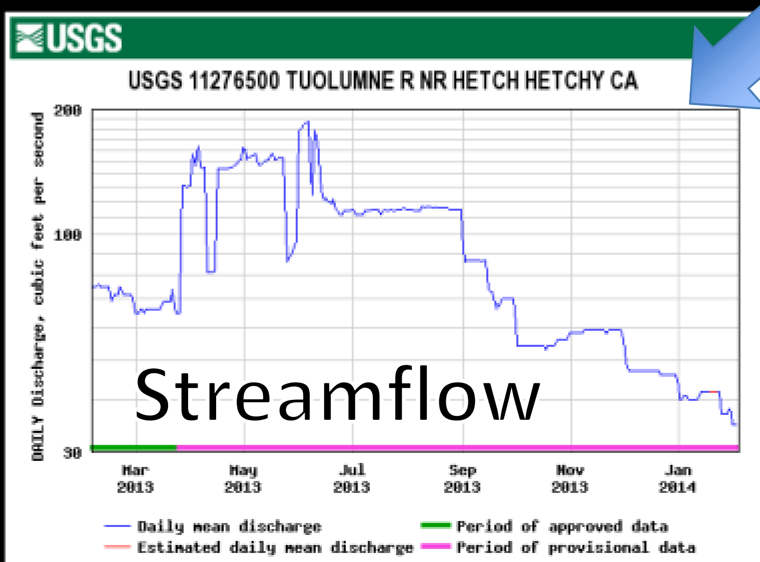
APPLICATIONS:

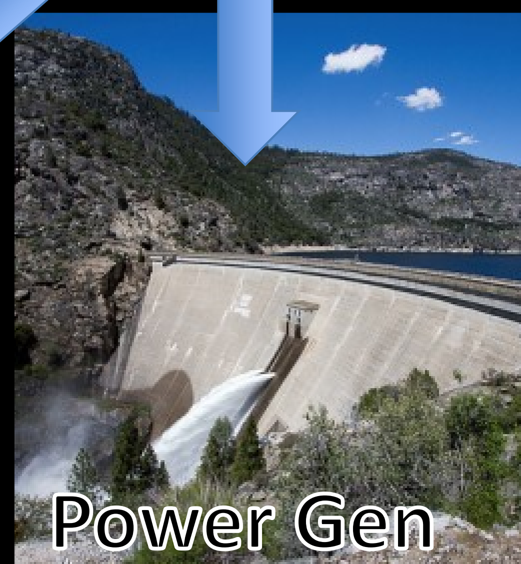
*INTEGRATING **ASO** WITH WATER MANAGEMENT…*

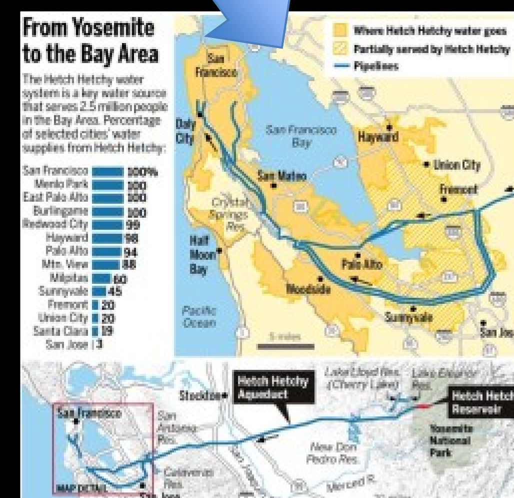
Hetch Hetchy Operations

balancing streamflow, water supply, & hydropower needs







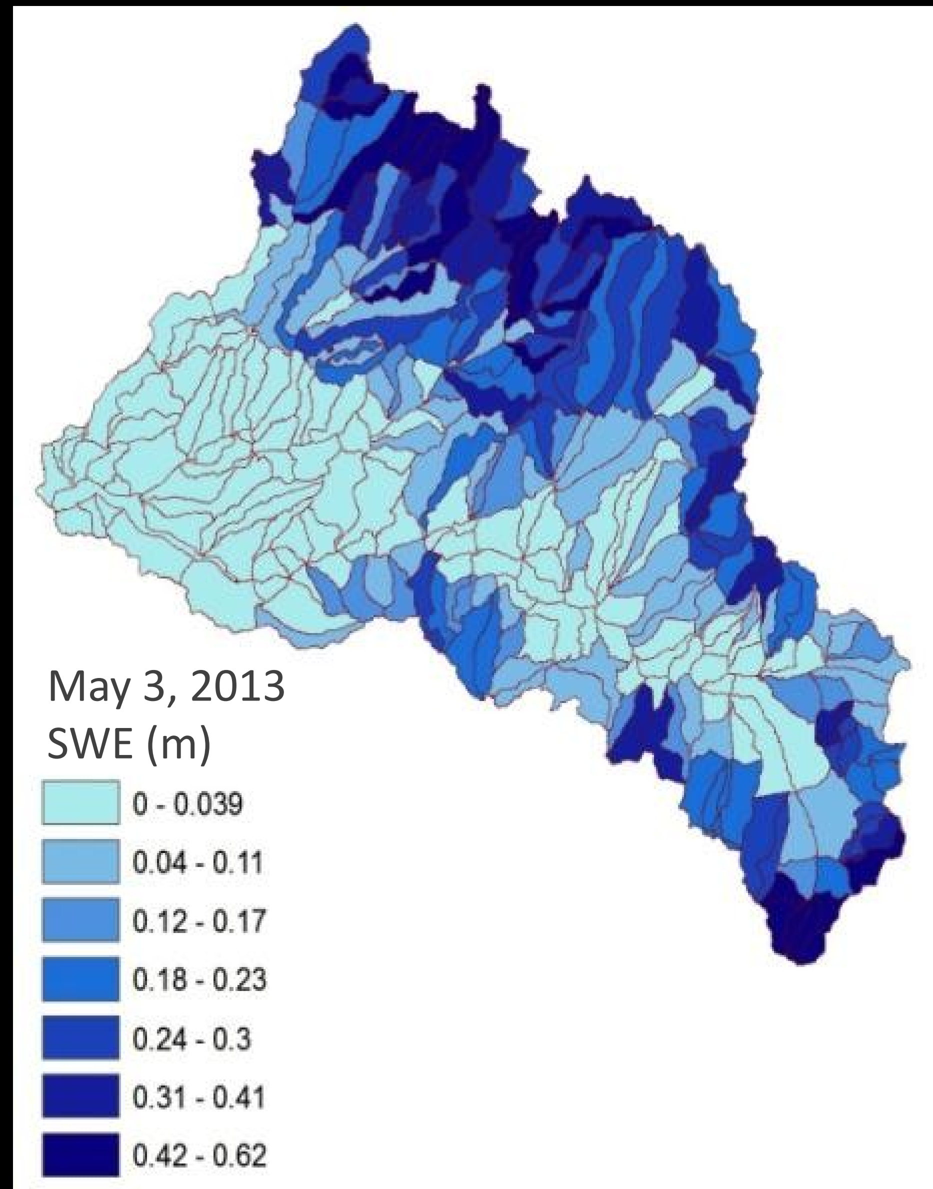


Water Supply

Tuolumne Basin above Hetch Hetchy Reservoir

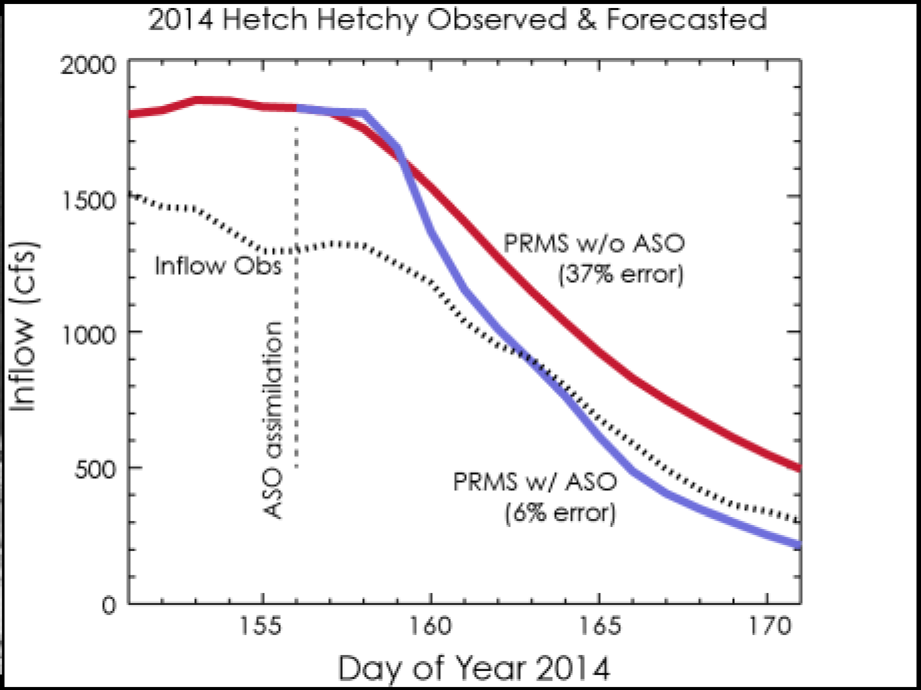
SWE/Met Stations & PRMS Model Units

ASO SWE & Albedo



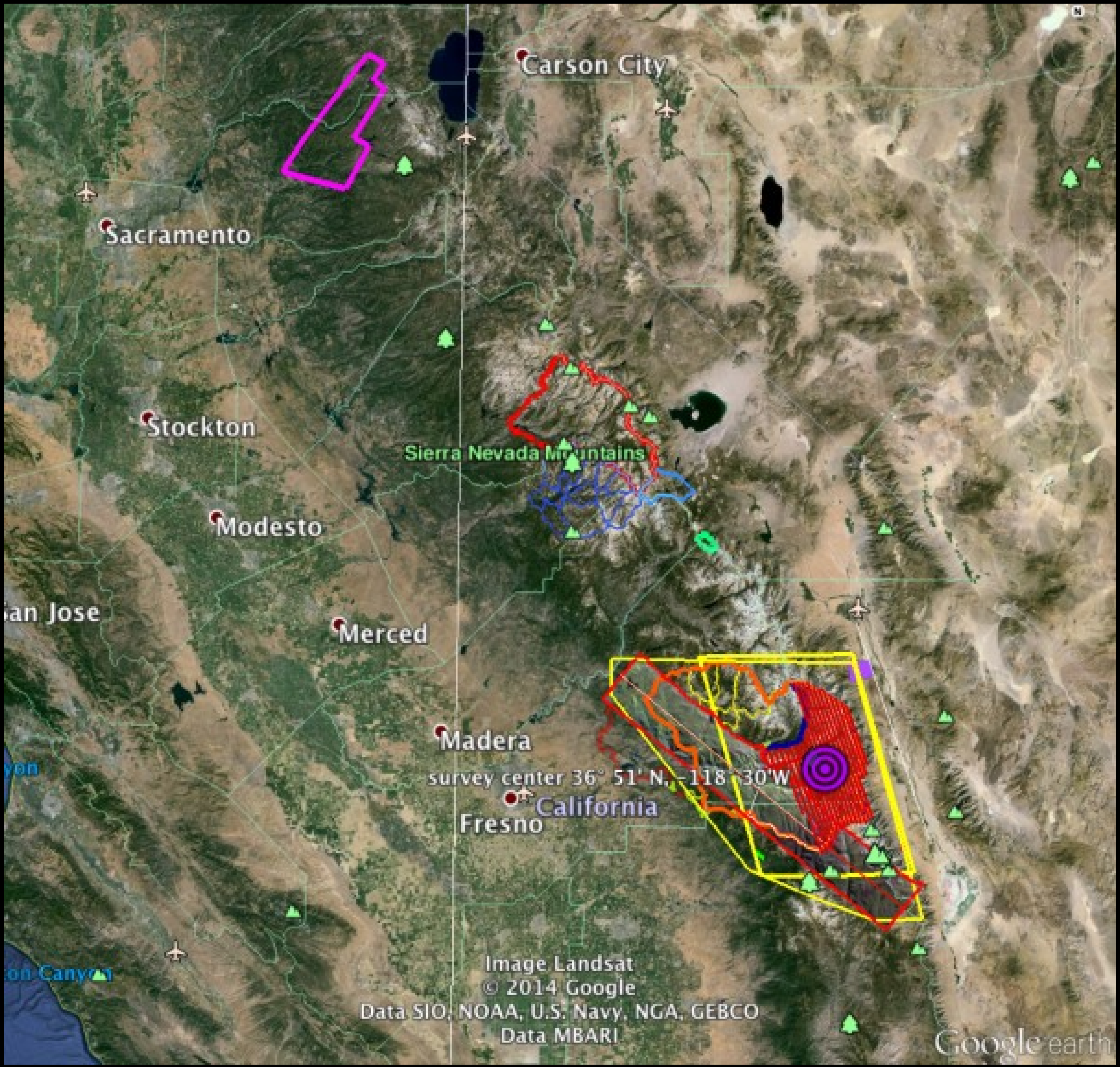
Runoff Forecasting

Hetch Hetchy – Tuolumne River Basin

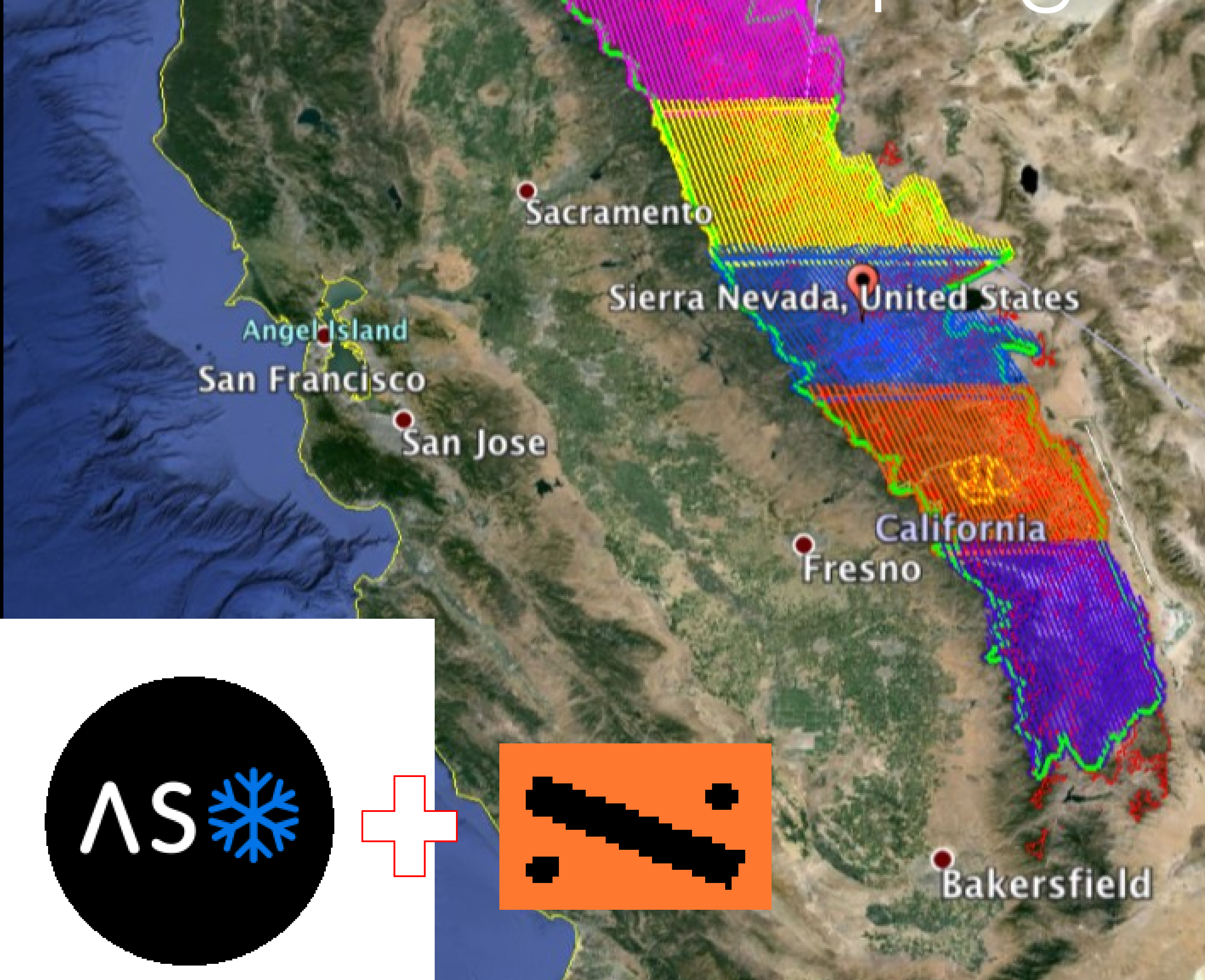


Snowmelt runoff forecasting with USGS Precipitation/Runoff Modeling System (PRMS)

ASO in California Present + Near Future



ASO in California
Envisioned program



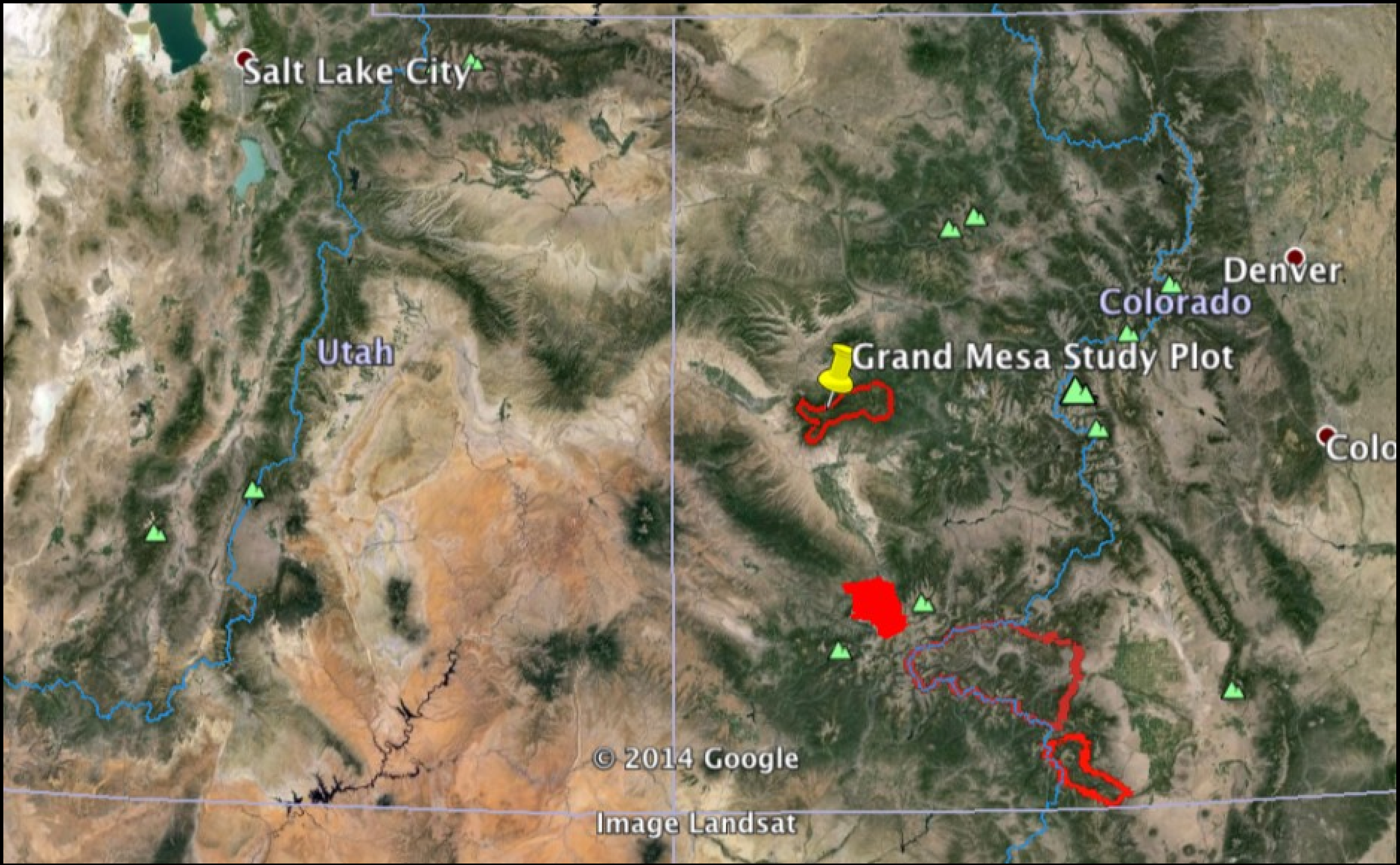
Runoff forecasting

Water allocations (winter and spring updates of AJRO)

Robust assessment of weather modification (cloud-seeding)

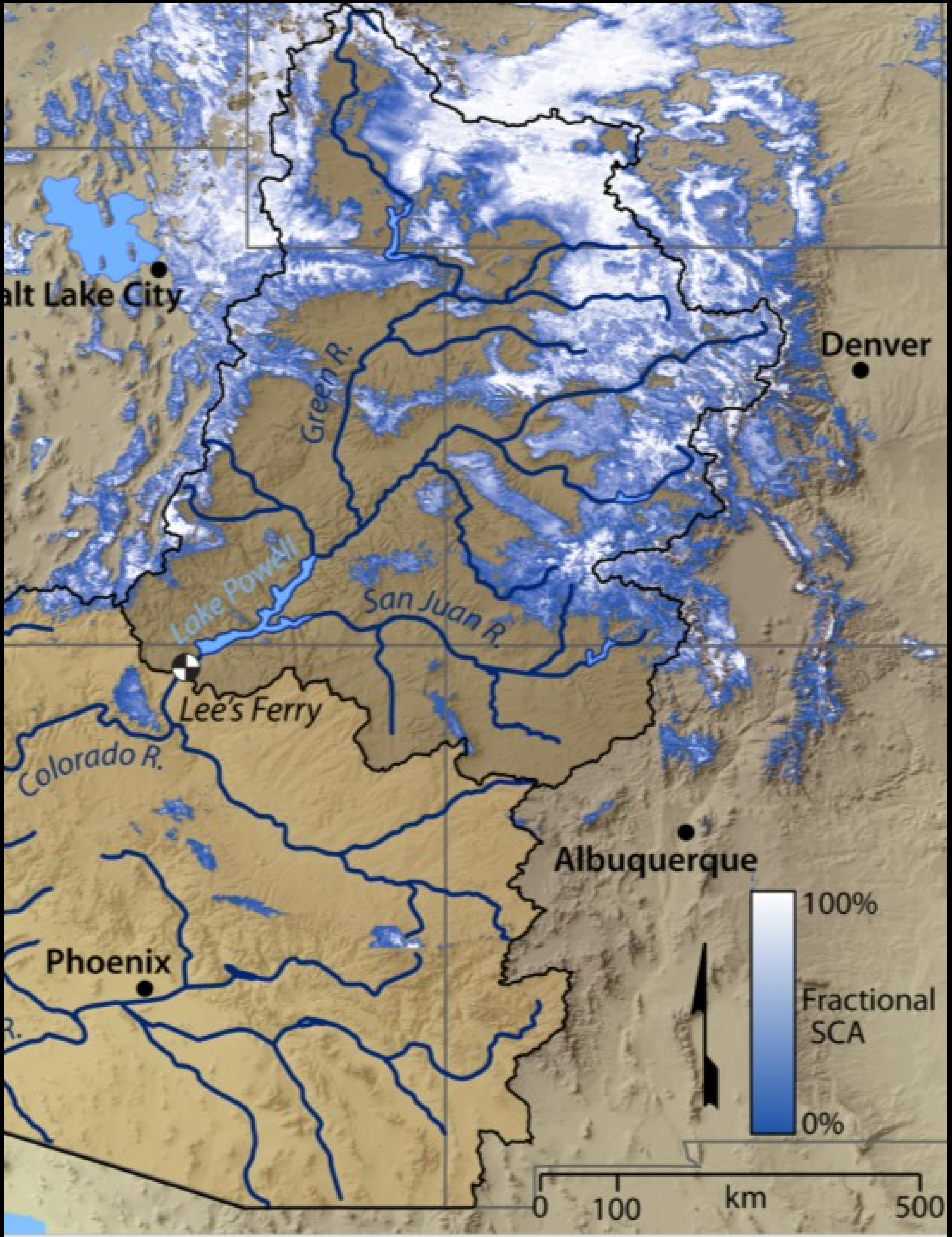
Establishment of modeling boundary and initial conditions

ASO in Colorado River Basin
Present + Near Future - *South*

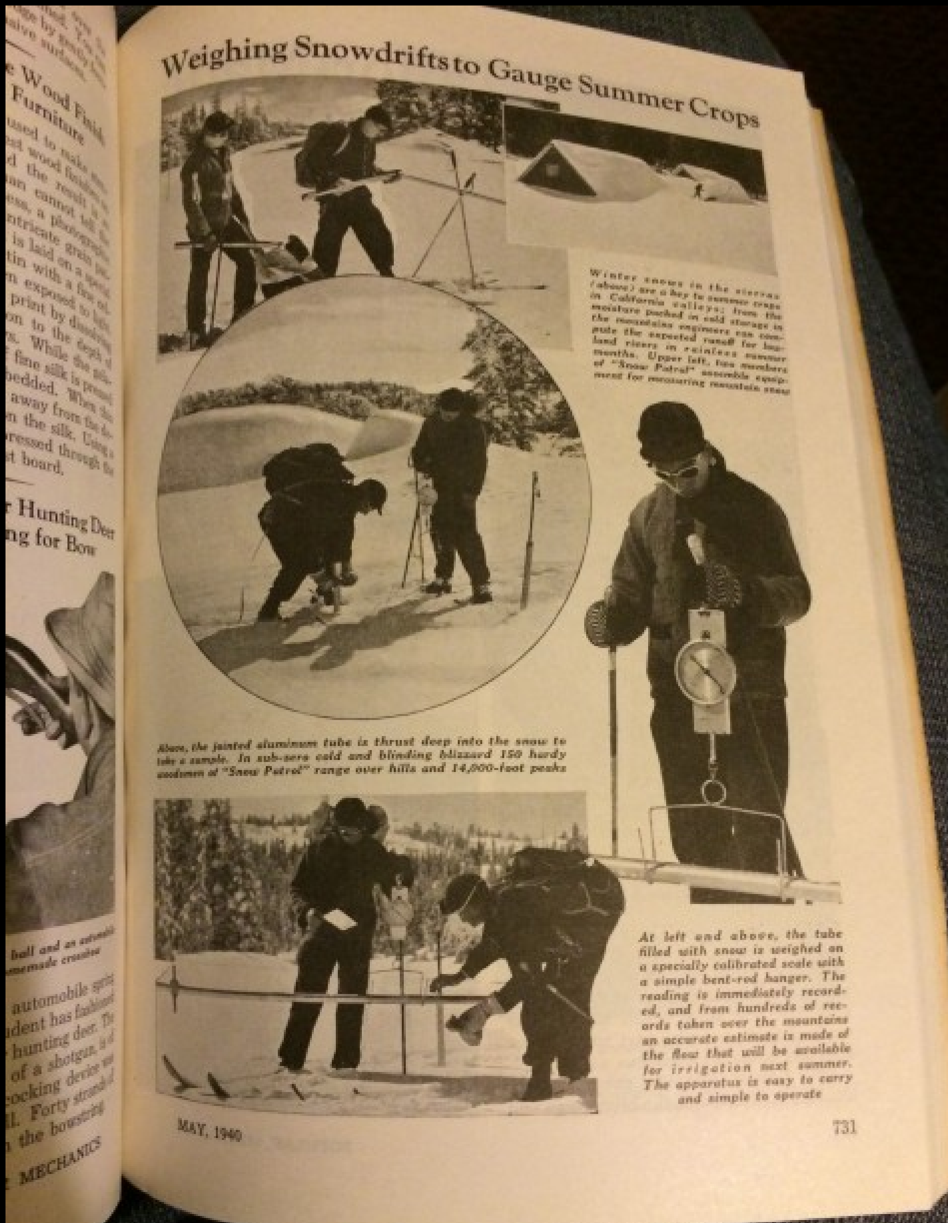


ASO in Colorado River Basin Present + Near Future - *North*

ASO in Colorado: Envisioned program



Popular Mechanics 1940



Weighing Snowdrifts to Gauge Summer Crops

Winter snows in the Sierras (above) are a key to summer crops in California valleys; from the moisture packed in cold storage in the mountains engineers can compute the expected runoff for lowland rivers in rainless summer months. Upper left, two members of "Snow Patrol" assemble equipment for measuring mountain snow

Above, the jointed aluminum tube is thrust deep into the snow to take a sample. In sub-zero cold and blinding blizzard 150 hardy woodsmen of "Snow Patrol" range over hills and 14,000-foot peaks

At left and above, the tube filled with snow is weighed on a specially calibrated scale with a simple bent-rod hanger. The reading is immediately recorded, and from hundreds of records taken over the mountains an accurate estimate is made of the flow that will be available for irrigation next summer. The apparatus is easy to carry and simple to operate

MAY, 1940 731

Popular Mechanics 2014

HOW YOUR WORLD WORKS | WATER

THE SNOW PLANE

How a new way to measure snowpack is changing the drought in California. BY RACHEL STURTZ

ONE HUNDRED AND FIFTY miles outside San Francisco, a reprieve to the city's crippling water crisis could be falling from the sky right now: snow. When it eventually melts in the spring, the snowpack that piles up in the Tuolumne River Basin in the eastern Sierra Nevada Mountains will collect in the Hetch Hetchy reservoir before being doled out in San Francisco, directly determining just how much water will be available for every shower, lawn, and carbon-neutral backyard chicken coop in the city. But all that stored water helps only if city water managers know exactly how much is coming.

Two years ago NASA's Jet Propulsion Lab (JPL) teamed up with the California Department of Water Resources to create the Airborne Snow Observatory (ASO), which allows researchers to predict spring runoff with much greater accuracy—and a lot less walking around in the snow with yardsticks. Led by JPL's Tom Painter, ASO trades manual ground surveys for a plane-mounted, dual-instrument system. The plane is rigged with an imaging spectrometer, which measures snow albedo—the melt rate, based on the amount of sunlight reflected and absorbed by the snow. It also has lidar, a pulsing infrared laser that determines snow depth, allowing researchers to calculate how much snow is there, and thus how much water it will create when melted (called snow-water equivalent, or SWE). Combining the two gives researchers the first-ever 3D model (above) of the snow-covered mountains—and a good idea of just how much water flow city managers can expect in the summer.

ASO's accuracy is unprecedented, predicting snow depth to within 4 inches, and SWE to within 5 percent. And it's highly efficient: Researchers can cover 460 square miles (300,000 acres) in only 4 hours, and maps of basin-wide SWE and snow albedo can be created every 24 hours instead of once a month. As the ASO obtains aircraft that can go faster and higher, its acquisition times will drop even more. Ultimately, the goal is to place ASO instruments on satellites, or even the International Space Station, for global observation. The new technology may not be able to stop droughts, but at least it can help manage them.

And the Snow-Powered Subway

The Hetch Hetchy reservoir—a dammed-off valley in Yosemite National Park—releases 250 million gallons a day, servicing 2.6 million customers on the San Francisco Bay peninsula. The water's 167-mile trek generates enough hydroelectric energy to power local police and fire stations, along with most of the city's subway system.

24 December / January 2015 | POPULAR MECHANICS ILLUSTRATION BY SINELAB