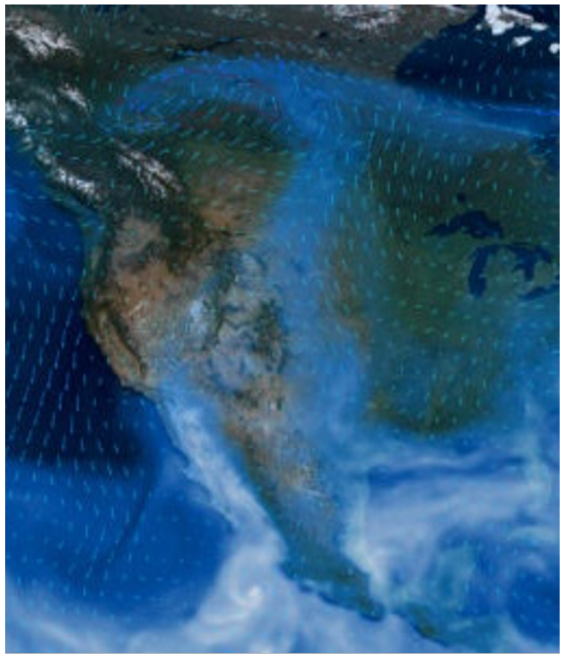
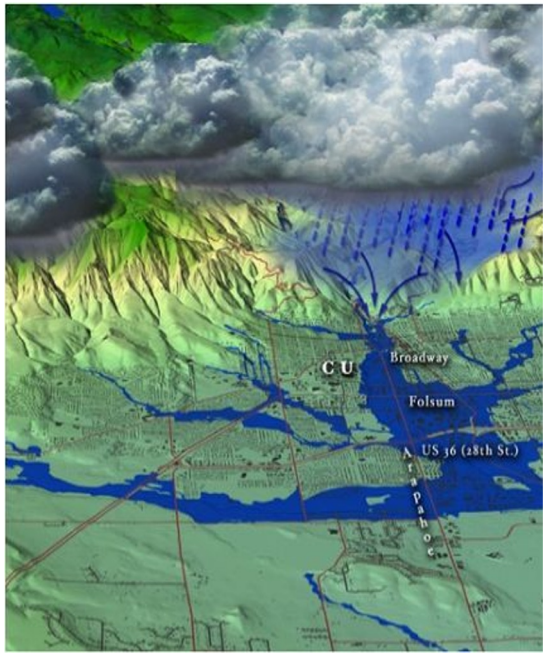
SAIL Field Campaign Overview

Dr. Dan Feldman,
LBNL Staff Scientist and PI of SAIL
drfeldman@lbl.gov and https://sail.lbl.gov
With contributions from many, many others



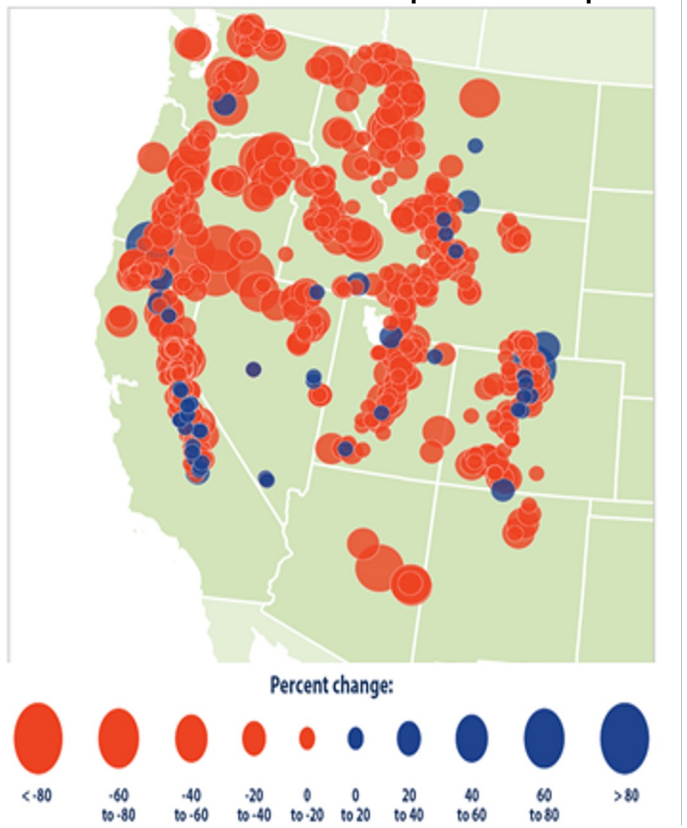


BERKELEY LAB

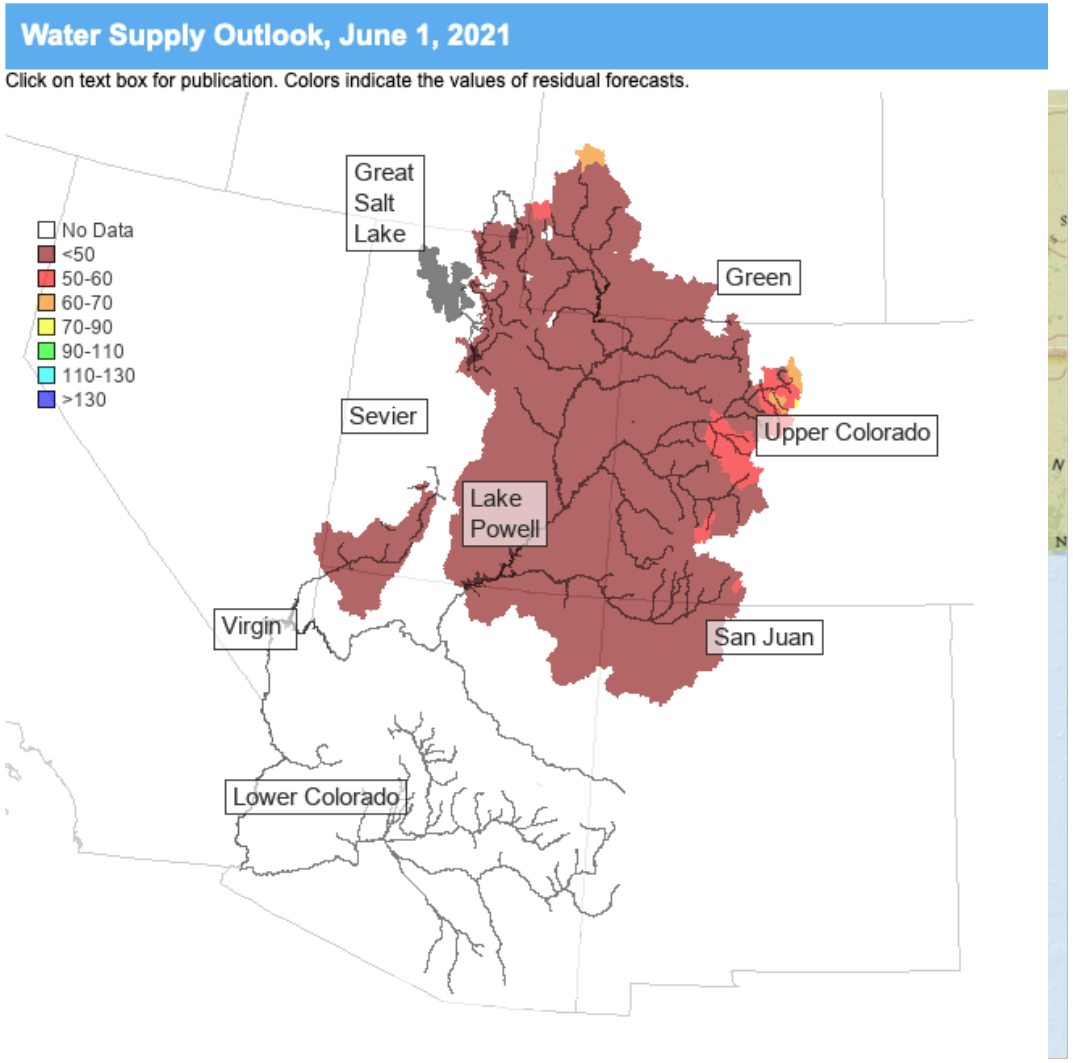
U.S. DEPARTMENT OF ENERGY
Office of Science

The Colorado River Watershed is Changing

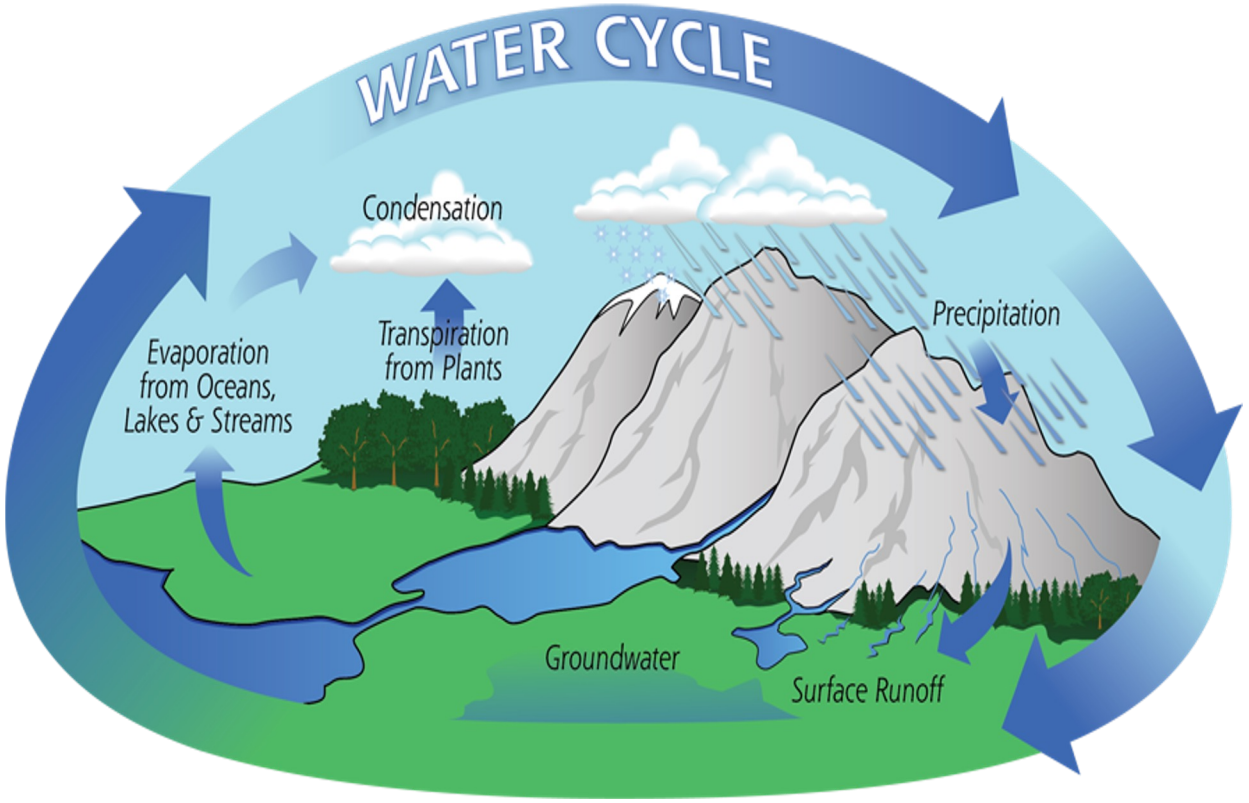
1955-2016 trends in April Snowpack



Mote and Sharp, 2016



Where did the water go?!?!



Potential Explanations:

1. Low precip after winter
2. Precip overestimated
3. Dry soils
4. Large ET losses
5. Snow sublimation

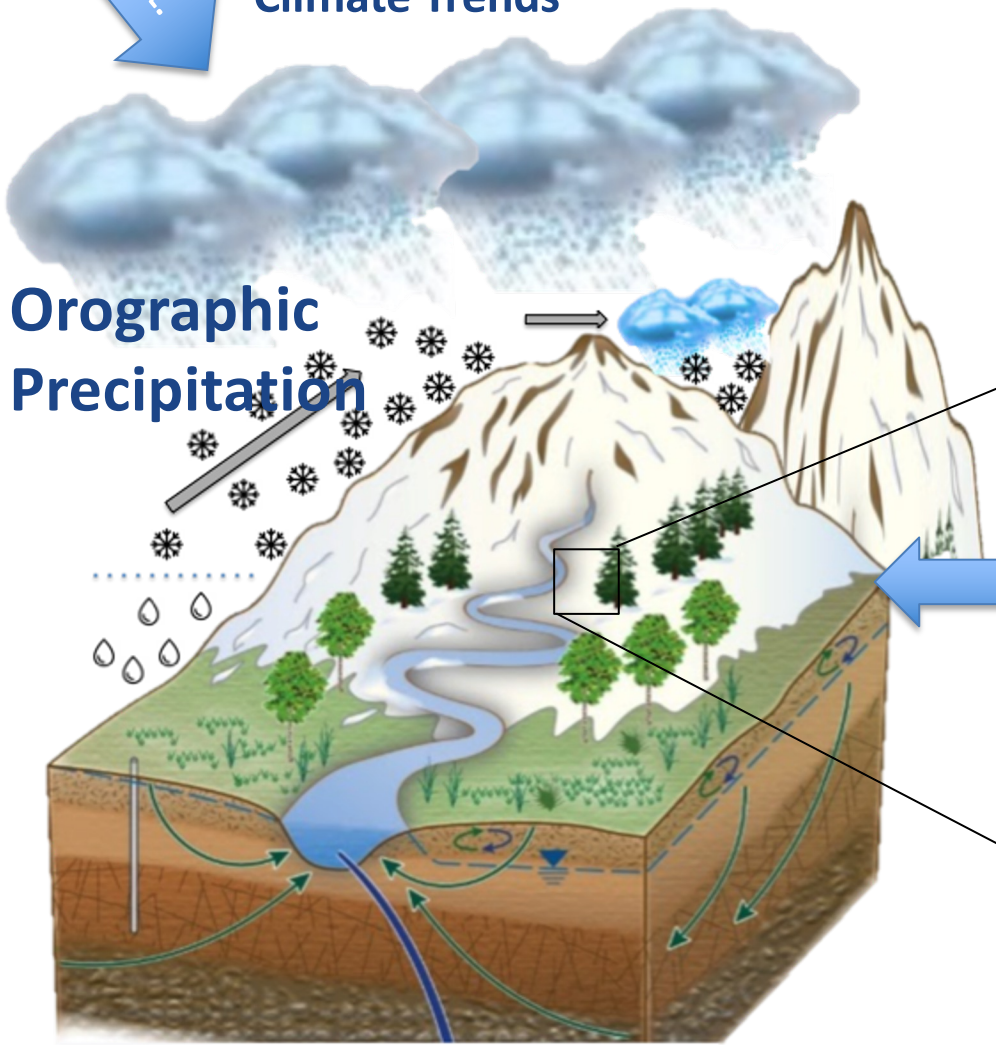
$$P = ET + R + I + \triangle S$$

Precipitation | Evapotranspiration (Sublimation) | Runoff | Infiltration | Storage

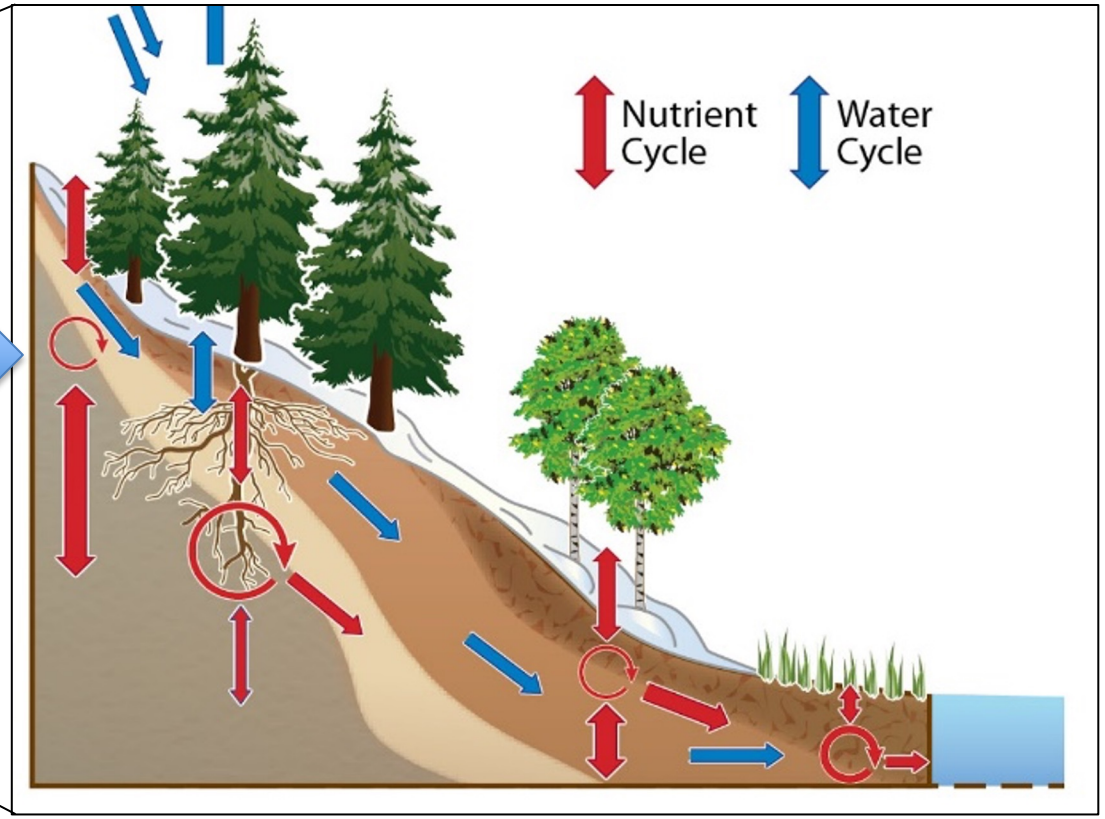
Predicting where the water will go is complex

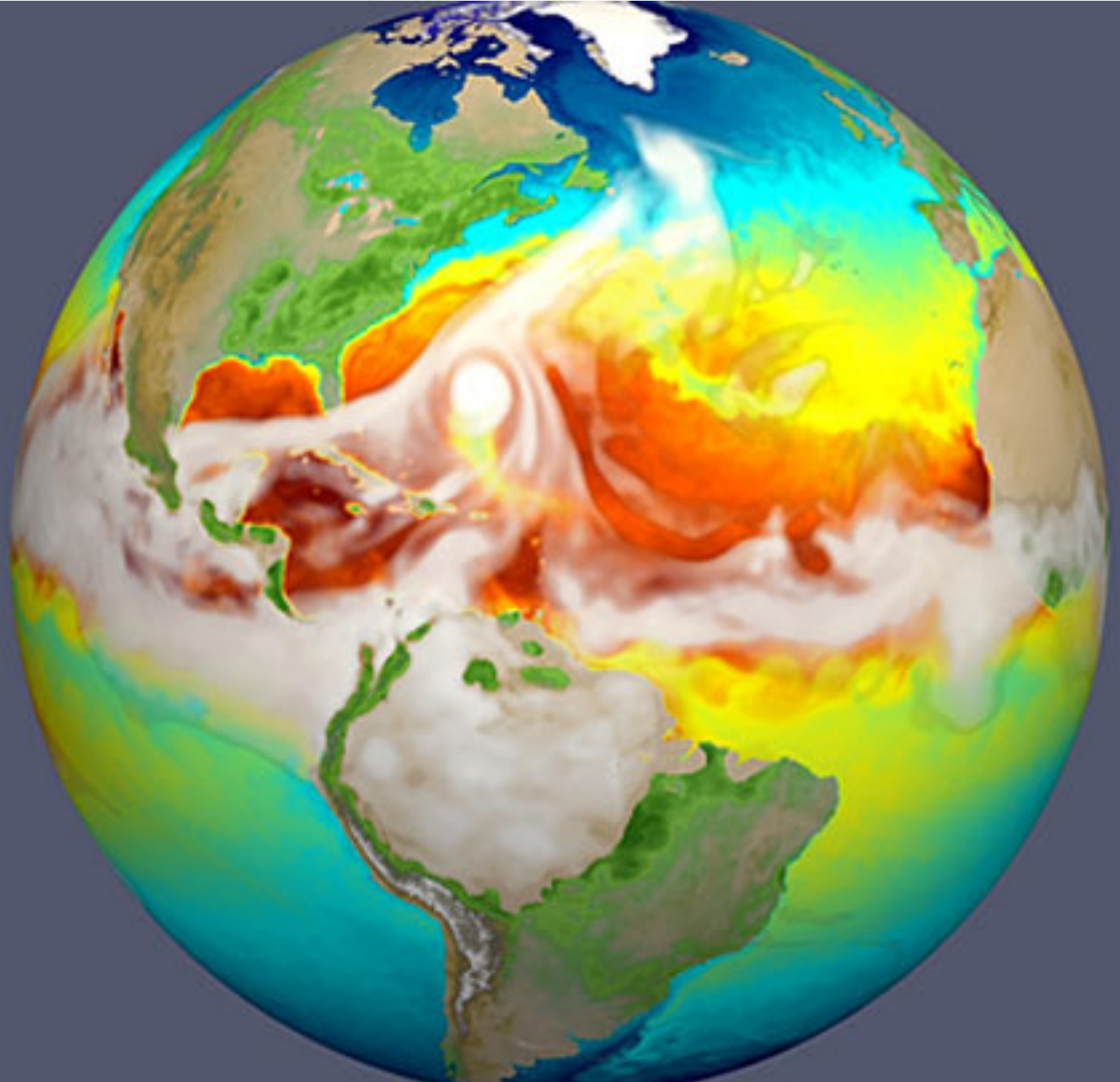
Climate Trends

Orographic Precipitation

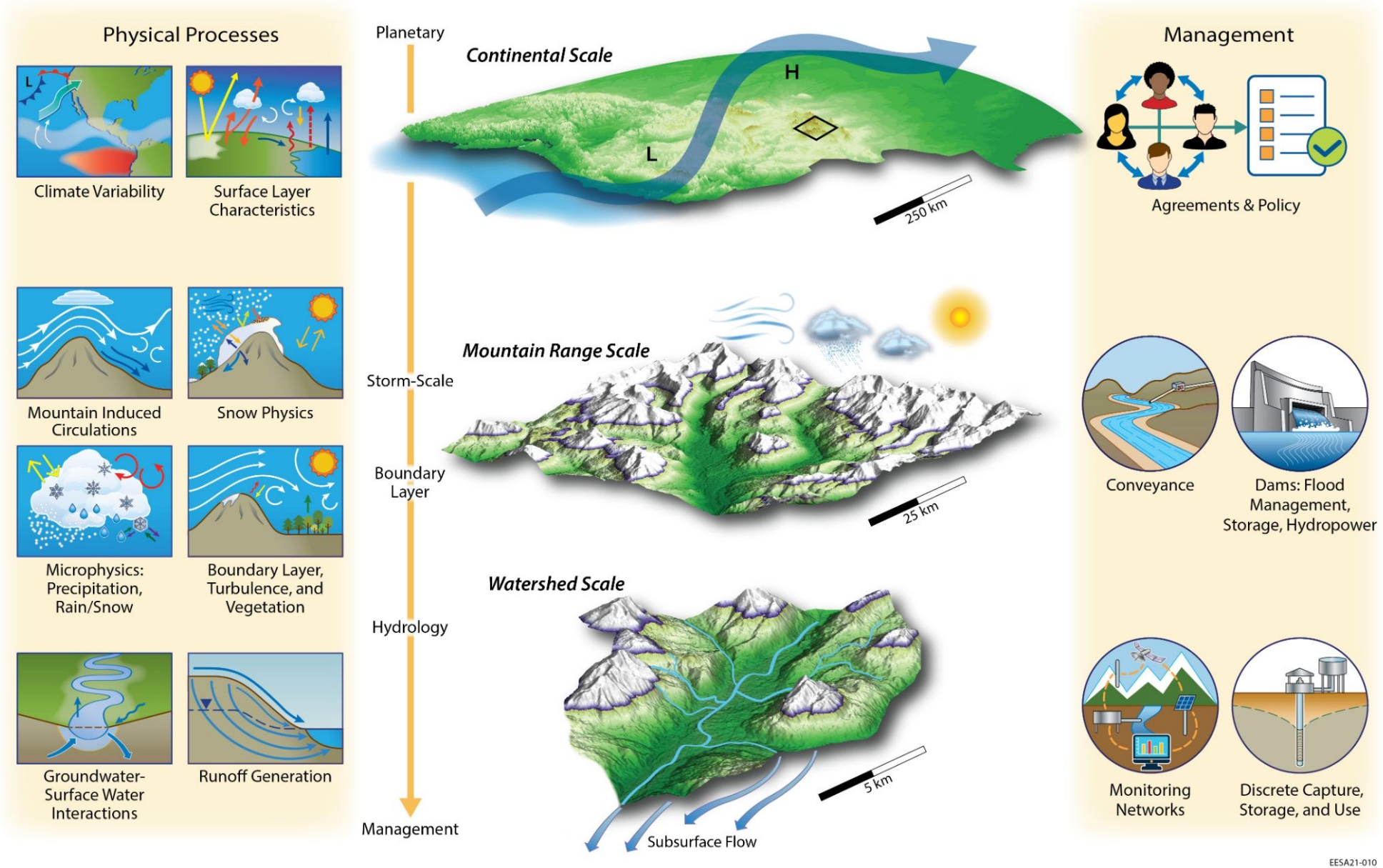


Land Through Subsurface Processes





How do we narrow that range?



Woodburn et al, 2021

Observational Gaps Lead to Understanding and Prediction Gaps

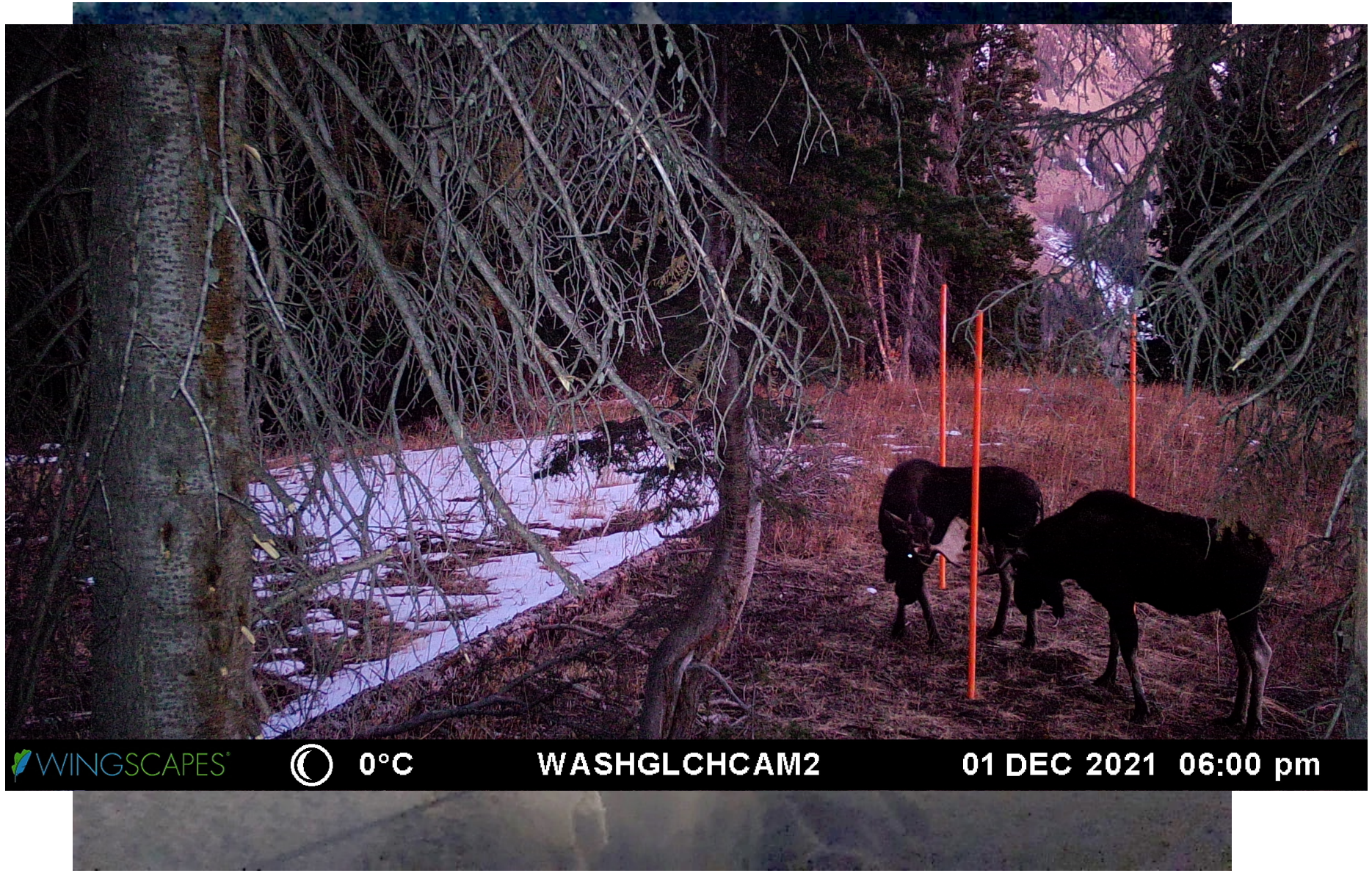


Photo Credit: Ryan Carr (2021)

SAIL: Surface Atmosphere Integrated Field Laboratory

Multi-Million $ Infrastructure Investment by DOE ARM near Crested Butte, Colorado. Started 9/21.

Deploying dozens of instruments. Partnering closely with NOAA to improve weather forecasts

El Paso

SAIL in the News!

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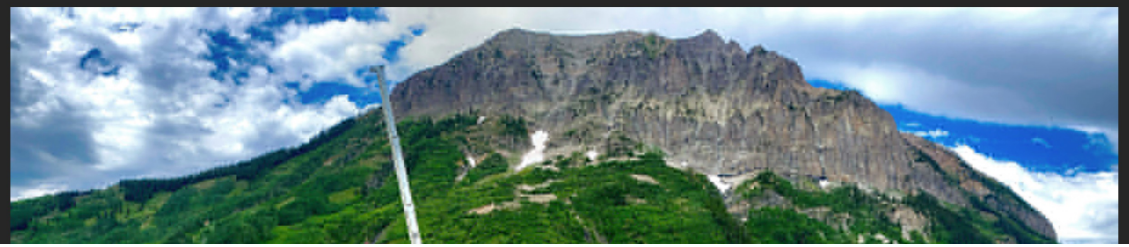
HOME > NEWS > ALL NEWS > HIGH IN THE COLORADO ROCKIES, SCIENTISTS LAUNCH SEARCH FOR CAUSES OF WESTERN WATER WOES

NEWS | EARTH

High in the Colorado Rockies, scientists launch search for causes of western water woes

New study of snow, ice, and rain aims to improve Colorado River flow forecasts

24 AUG 2021 · 5:00 PM · BY ERIK STOKSTAD



DISPATCHES 489

Atmospheric research seeks to inform water policy

Tom Oates

At a time of critical concern about climate change and federally declared water shortages, a Surface Atmosphere Integrated Field Laboratory (SAIL) site began operations on September 1, close to the headwaters of the Colorado River, near Crested Butte, Colorado. Called the first-ever "bedrock-to-atmosphere" observation system, the SAIL project's primary objective is to monitor and predict rain, snowfall, and water availability in the Col-

precipitation occurs to eventual flows of water", says Ken Williams, SAIL co-investigator and LBNL's water resources program lead (Crested Butte, CO). "When should we release water from a dam? How much should we release and how much should we hold? We believe the data we gather will be very useful for those policy-making decisions."

"The threats are multidimensional; it's not just temperature", says Alejandro Flores, an eco-hydrologist with SAIL and associate professor at Boise State University (Boise, ID). For example, "dark aerosols influence how quickly snow melts and are linked back to human activity.

Also, "plants
mountain hillslo
moves from the
sky to ground. Th
of the climate
instrumentation
our ability to unc
the pumps, which
Steltzer, co-princ
LBNL's US DOI
SFA and professo
(Durango, CO).

"As scientists
resources policie
place where wate
I think they will

Eos Science News by AGU

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ABOUT SPECIAL REPORTS TOPICS PROJECTS NEWSLETTER SUBMIT TO *EOS*

Collaboration in the Rockies Aims to Model Mountain Watersheds Worldwide

As Earth's climate changes at an unprecedented rate, the Surface Atmosphere Integrated Field Laboratory is studying precipitation on an unprecedented scale.

By Saima Sidik 21 September 2021

Sign up for AGUniverse, featuring news events and

The Washington Post
Democracy Dies in Darkness

He spent almost 50 years alone at 10,000 feet. His hobby helped shape climate research in the Rockies.

An amateur scientist began logging snowfall to keep busy. Along the way, he became an unwitting chronicler of climate change in a region known as the water tower for the drying American West.

By Karin Brulliard

November 27, 2021 at 7:00 a.m. EST

Who is behind SAIL? The Atmospheric Radiation Measurement (ARM) Program.

The ARM Climate Research Facility is a **DOE scientific user facility** and key contributor to atmospheric research efforts, providing the climate research community with **strategically located in situ and remote sensing atmospheric observatories** designed to improve the understanding and representation in climate models

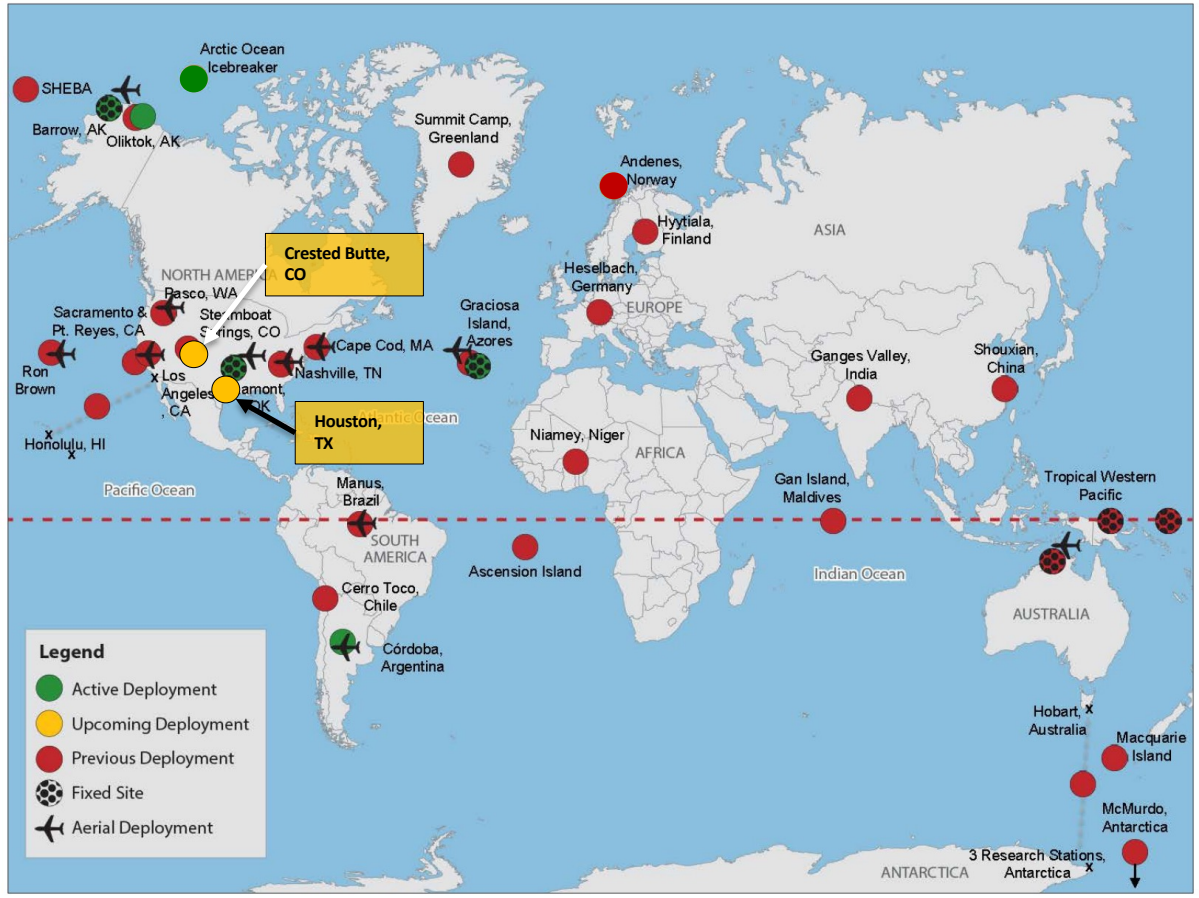
ARM is a U.S. DEPARTMENT OF ENERGY | Office of Science

Biological and Environmental Research Office Program

Nine US D.O.E. National Laboratories are involved in supporting the ARM User Facility

Global Climate Measurements with a Local Focus

maintains **the world's largest global infrastructure for obtaining observations of the natural atmosphere**: Clouds, Aerosol, Precipitation, and Energy



3 Fixed Sites:
Southern Great Plains (SGP)
North Slope Alaska (NSA)
Eastern North Atlantic (ENA)

3 Mobile Facilities:
ARM Mobile Facility 1 (AMF1)
ARM Mobile Facility 2 (AMF2)
ARM Mobile Facility 3 (AMF3)

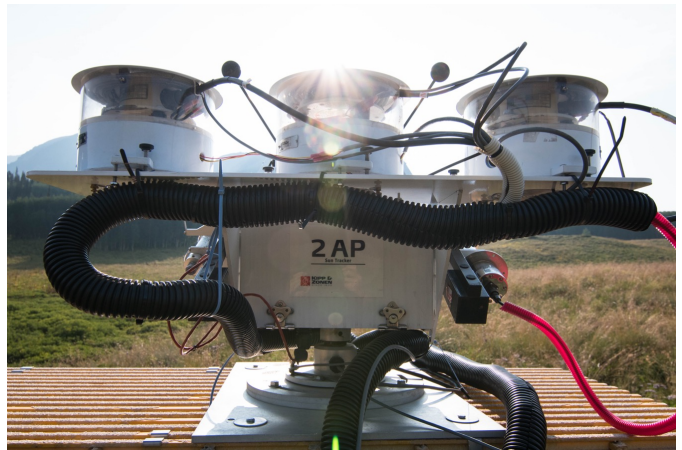
1 Aerial Facility:
ARM Aerial Facility (AAF)

Precipitation, Clouds, Winds, Aerosols, Radiation, Temperature, Humidity …

- Numerous datastreams being collected.
- https://sail.lbl.gov/what-we-measure





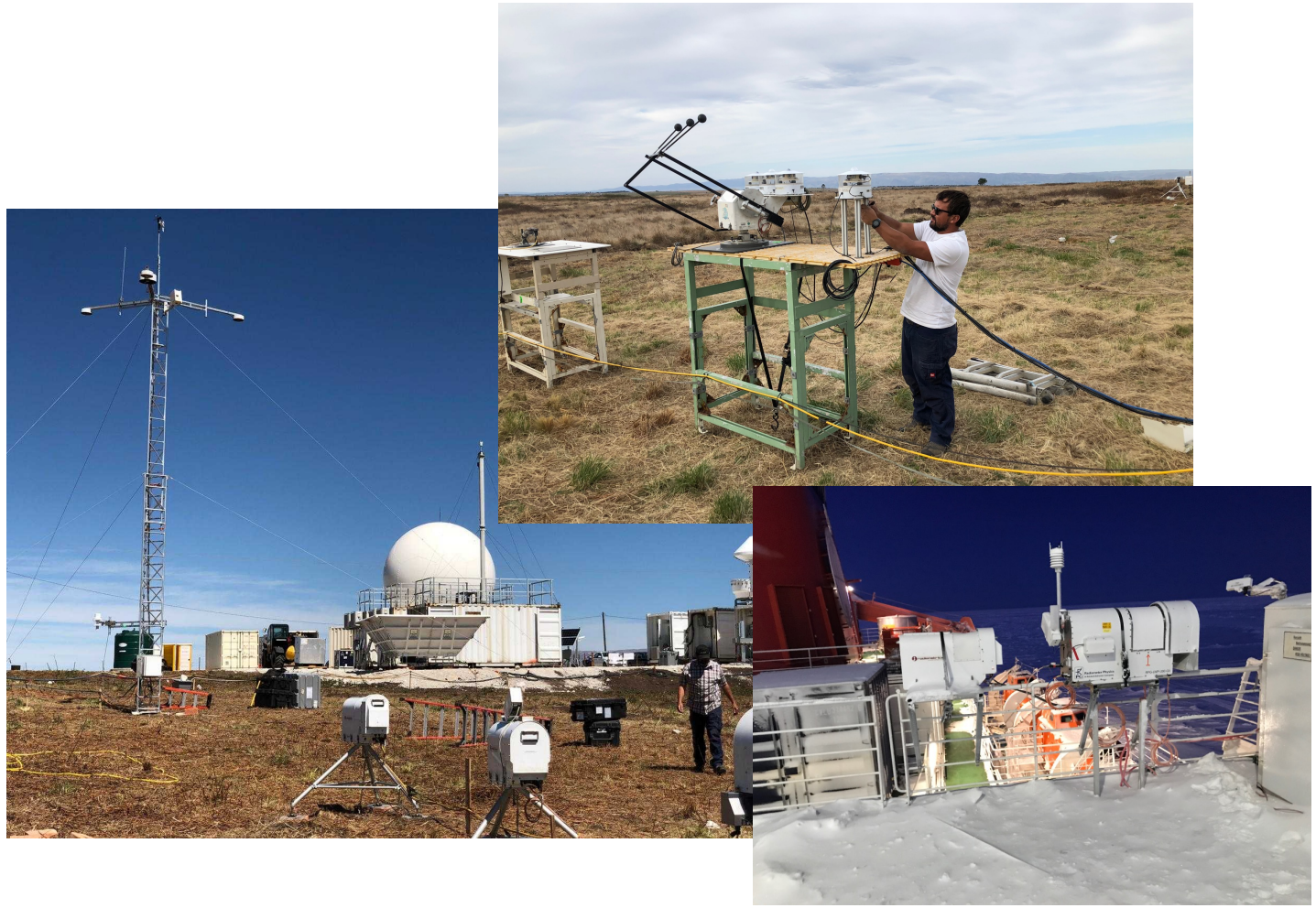
Images courtesy of ARM Flickr Account

SAIL Measurements: Surface Meteorology

- Anemometer
- Barometer
- Ceilometer
- Balloon Borne Sounding System (BBSS)
- Laser Disdrometer
- Present Weather Detector
- Optical Rain Gauge
- Surface Energy Balance System (SEBS)
- Temperature/Relative Humidity
- Total Sky Imager
- Weighing Bucket Rain Gauge

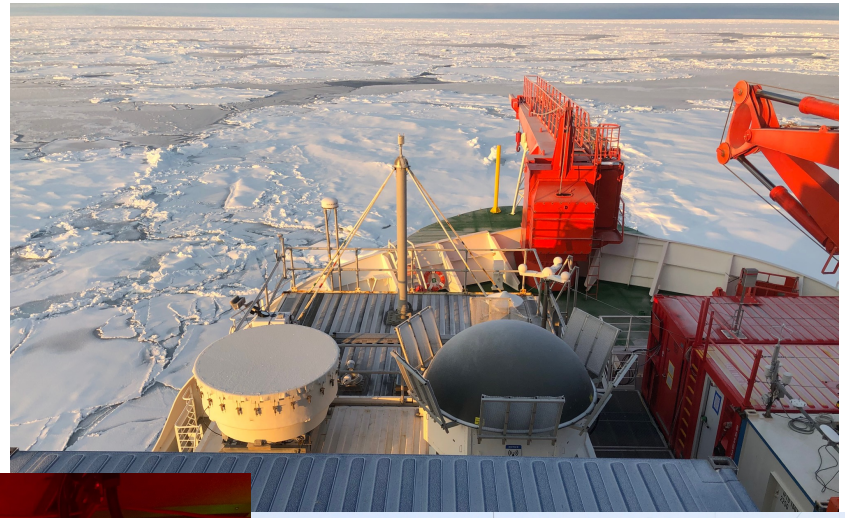
SAIL Measurements: Radiometry

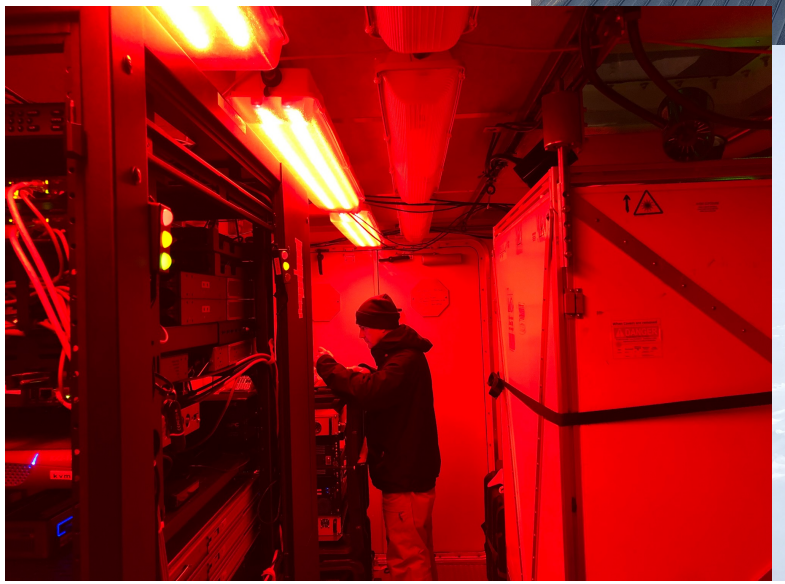
- Cimel Sunphotometer
- SKYRAD
  - Downwelling Shortwave Radiometry
  - Downwelling Longwave Radiometry
- GNDRAD
  - Upwelling Shortwave Radiometry
  - Upwelling Longwave Radiometry
- Infrared Thermometer
  - Upwelling
  - Downwelling
- Multifilter Radiometer
- Microwave Radiometer
  - 2-channel
  - 3-channel



SAIL Measurements: Cloud Properties

- Atmospheric Emitted Radiance Interferometer (AERI)
- Doppler Lidar
- High Spectral Resolution Lidar
- Radar Wind Profiler (RWP)
- Ka-Band ARM Zenith Pointing Radar (KAZR)
- Micropulse Lidar

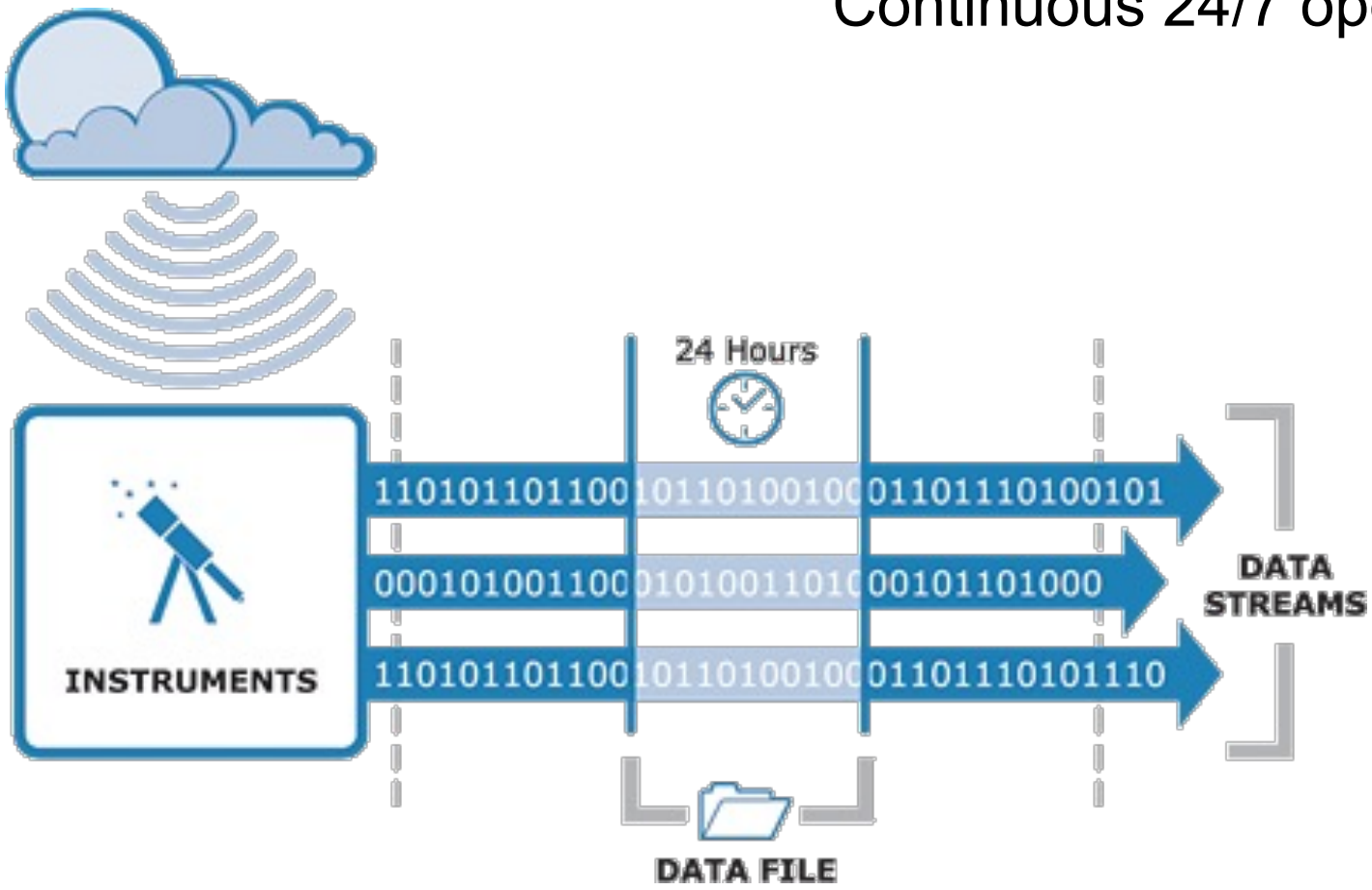




SAIL Measurements: Aerosols

- Aerosol Chemical Speciation Monitor
- Ambient Nephelometer
- CO Analyzer
- Ozone Analyzer
- Cloud Condensation Nuclei Counter
- Condensation Particle Counter (Fine/Ultra Fine)
- Humidified Tandem Differential Mobility Analyzer
- Particle Soot/Absorption Photometer
- Scanning Mobility Particle Sizer
- Single Particle Soot Photometer
- Ultra-High Sensitivity Aerosol Spectrometer

SAIL Data at the ARM Data Center



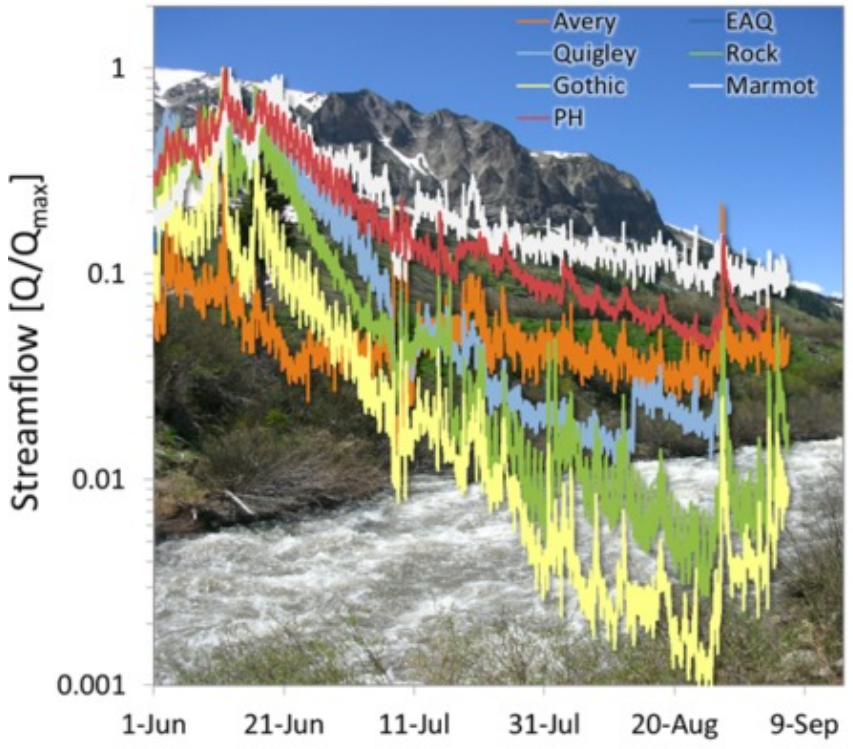
Continuous 24/7 operations deliver quality assured data to the

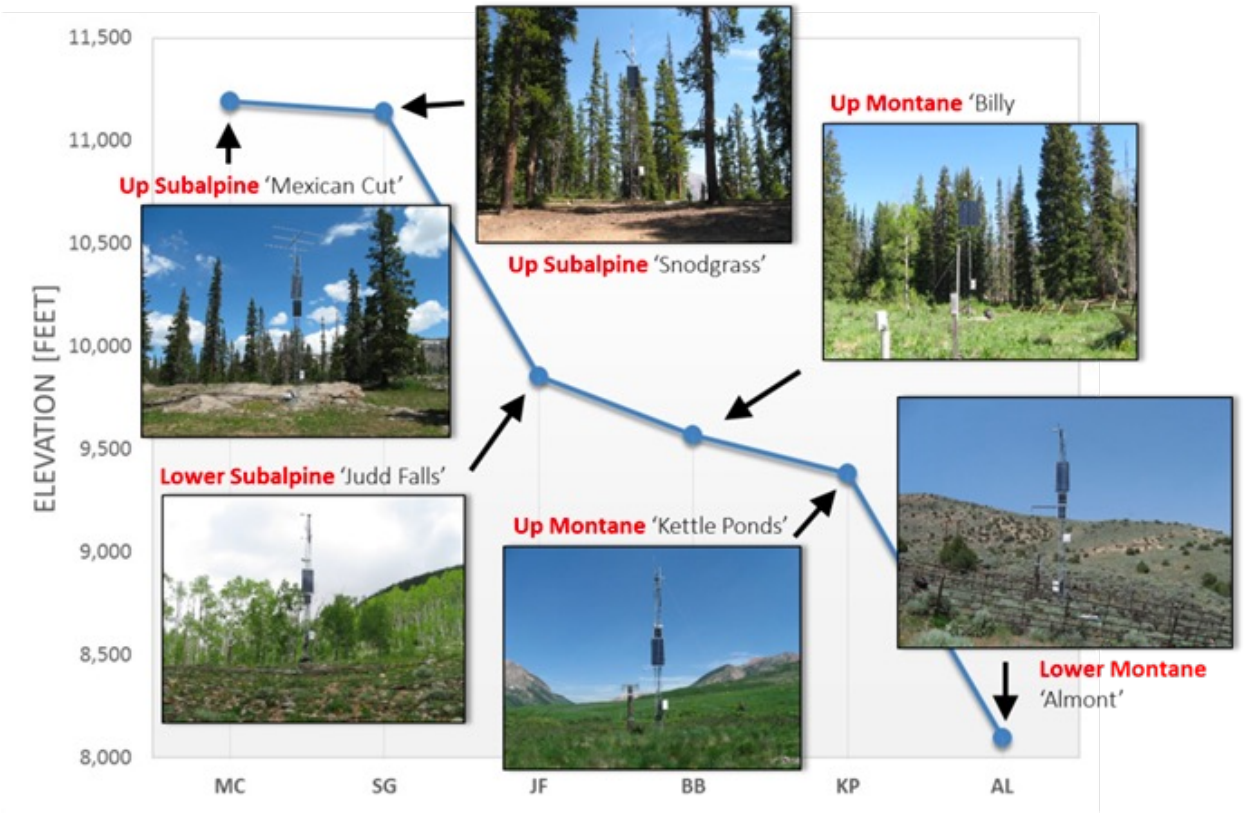
ARM Data Center

and is **distributed freely worldwide** within 24-48 hours of collection and processing

Collaborative Resources: Watershed Function SFA

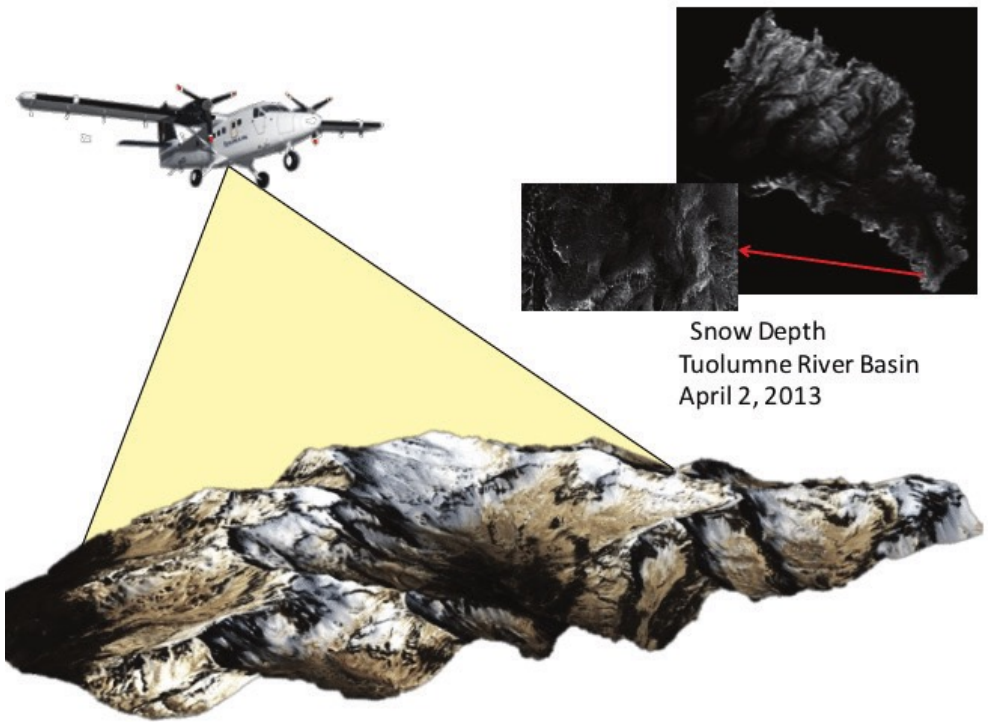
SAIL is leveraging will leverage resources and expertise from the Watershed Function SFA, which is an SBR-funded research program to characterize surface and sub-surface processes in mountainous watersheds.

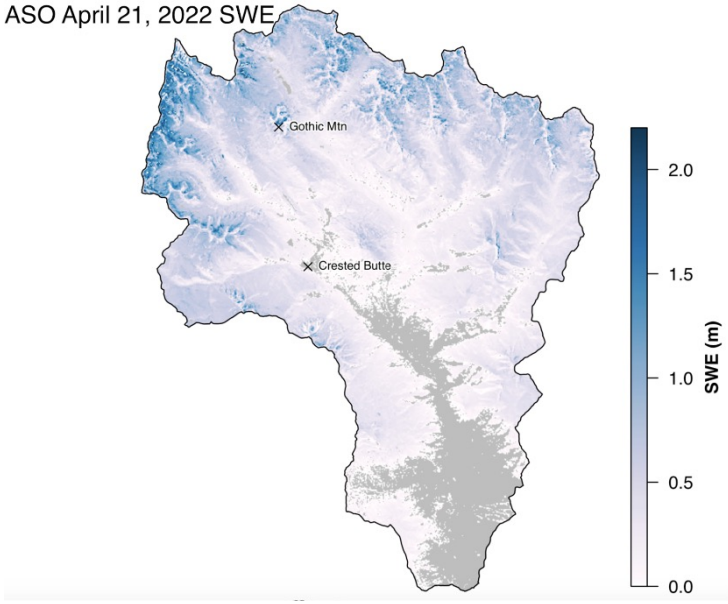


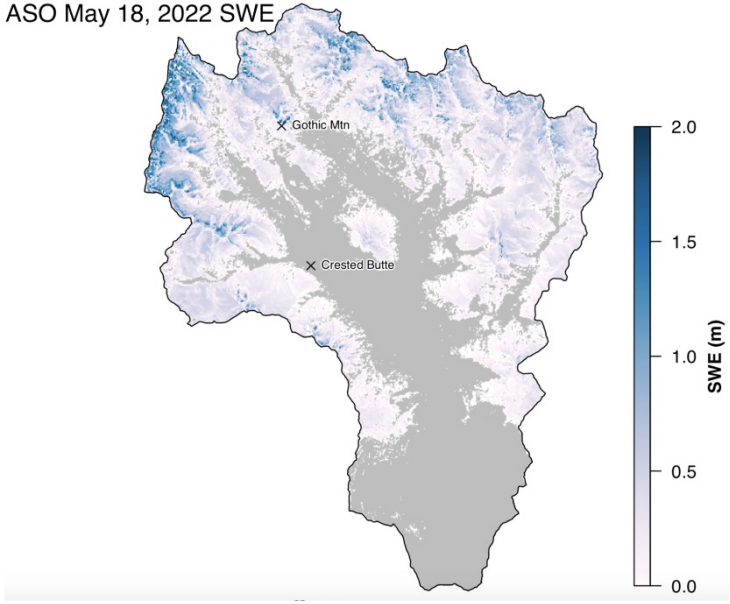


Collaborative Resources: Snow Surveys

SAIL has catalyzed the collection of remote-sensing snow surveys from the Airborne Snow Observatory.

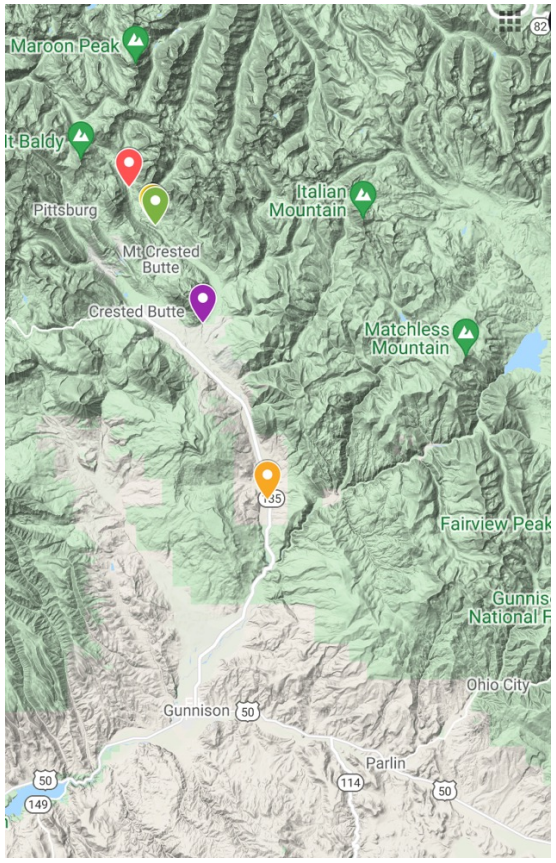






Collaborative Resources: NOAA SPLASH

NOAA Physical Sciences Laboratory is leading the Study of Precipitation, the Lower Atmosphere, and Surface for Hydrometeorology (SPLASH).

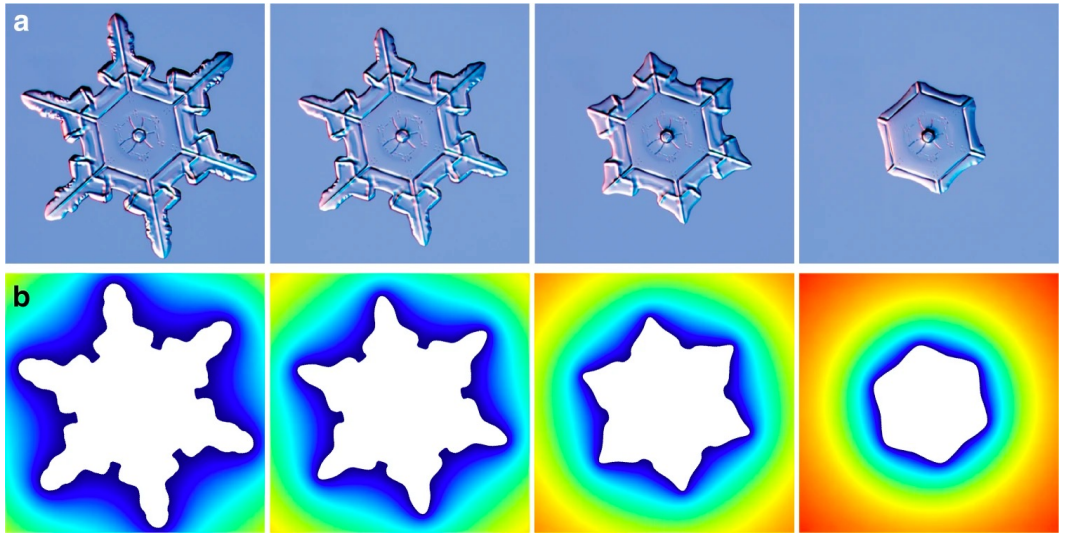


Measured quantities	Avery Picnic	Kettle Ponds	Brush Creek	Roaring Judy
Surface Meteorology (2m T, p, q, winds)	X	X	X	X
Soil Moisture	X	X	X	
Snow depth	X	X	X	
Snow temperature and density		X		
Thermodynamic profiling			X*	X*
Wind profiling			X*	
Cloud base height		X	X	X*
Surface precipitation rate and droplet size distribution		X	X	
Snow/Rain level		X	X	
Precipitation profiling		X	X	X
Sky/Surface broadband surface radiation	X	X	X	
Surface Spectral radiation		X	X	
Surface turbulent fluxes	X	X	X	
Turbulence at 10 m		X		
Cloud optical depth			X	
Aerosol optical depth		X	X	
Cloud fraction		X	X	X
Surface albedo, snow cover and soil moisture surveys	X	X	X	
In-situ thermodynamic, wind and turbulence profiling	X	X		
Normalized Difference Vegetation Index	X	X	X	

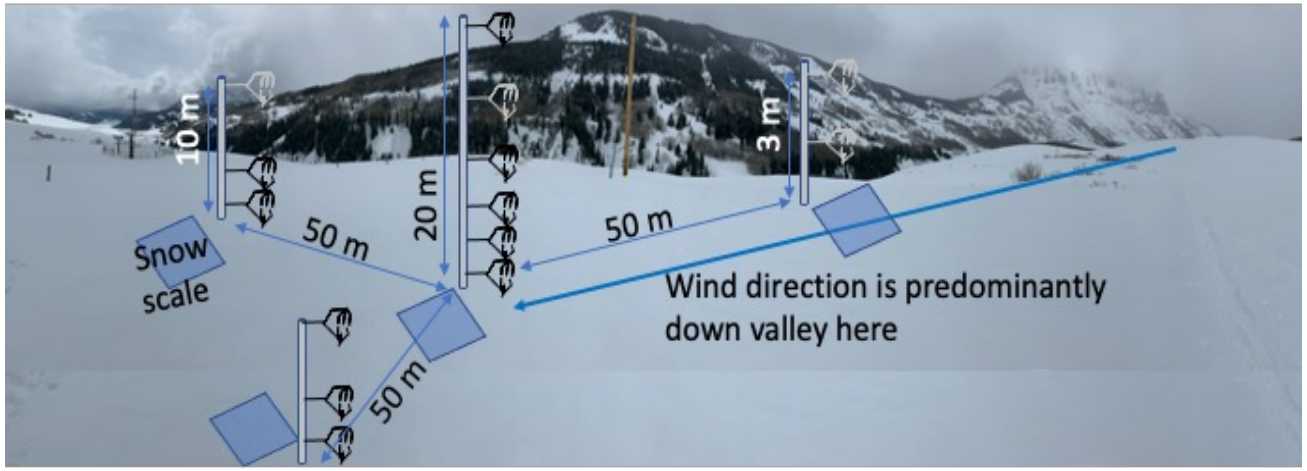
Collaborative Resources: SOS

The Sublimation of Snow (SOS) project will deploy a network of eddy covariance towers near SAIL, supported by NSF EO.

These are measuring water vapor fluxes 2 km away from SAIL in a valley location to characterize boundary layer dynamics and develop sublimation estimates as a function of meteorological conditions.



Source: Jambon-Puillet et al, Nature Comm. 2018



SAIL Science Objectives

SAIL is characterizing processes across seasons.

1. Precipitation: determine spatial distribution on sub-seasonal time-scales & influence of large-scale circulation

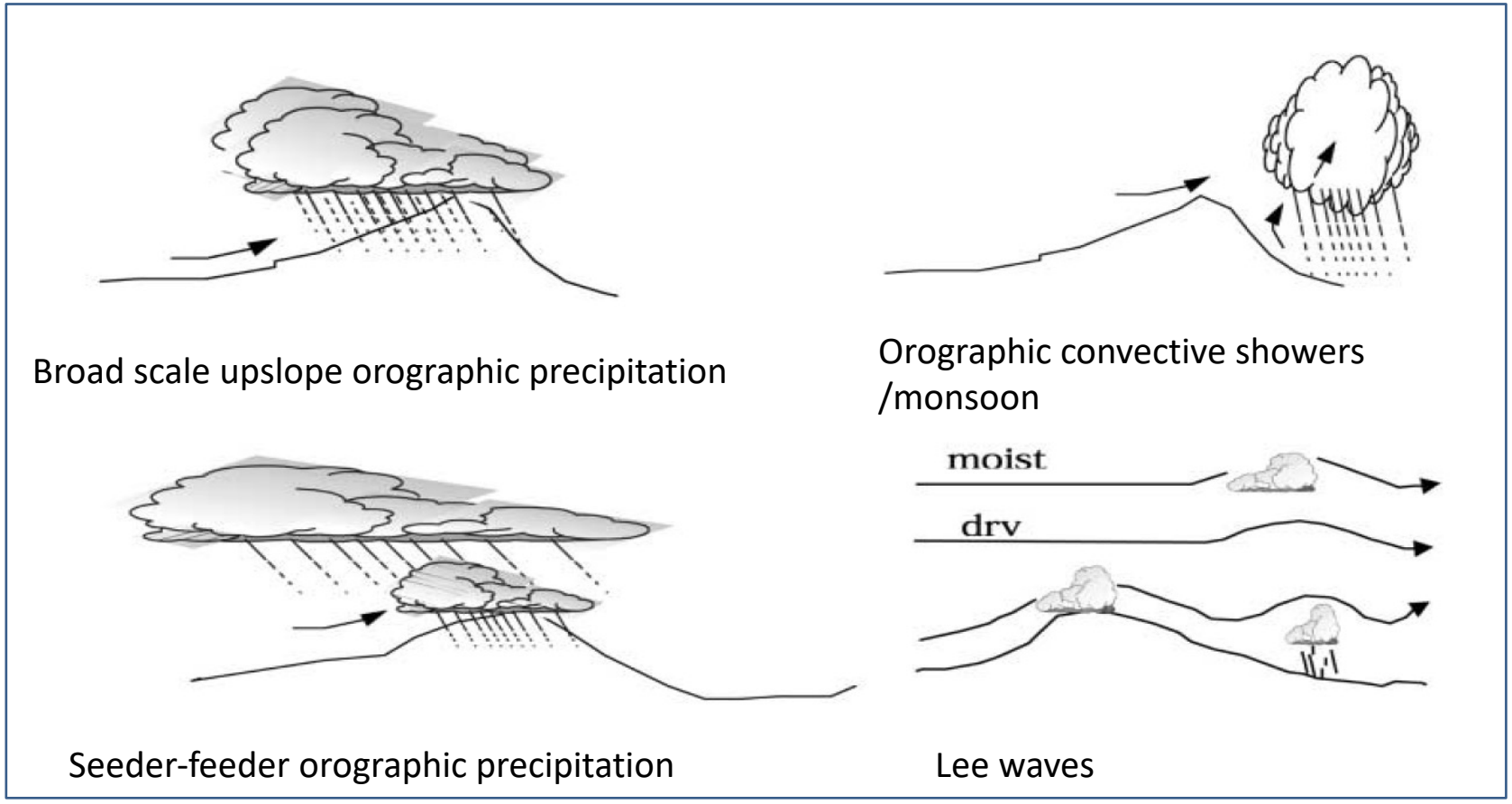
2. Winds: quantify impact on snow sublimation and redistribution

3. Aerosols: determine simultaneously their surface and atmosphere radiative impacts

4. Aerosols: quantify cloud-phase and precipitation sensitivity to CCN and INP.

5. Surface energy balance: quantify factors in the land and atmosphere that control its spatial variability on seasonal time-scales

Precipitation Processes in Complex Terrain



From Lee et al. 200

Precipitation in complex terrain forms as a result of four principal ways:
Orographic upslope flow, convection, seeder-feeder, and lee waves.

Today, we will learn about how to analyze precipitation and wind information to look at these dynamics

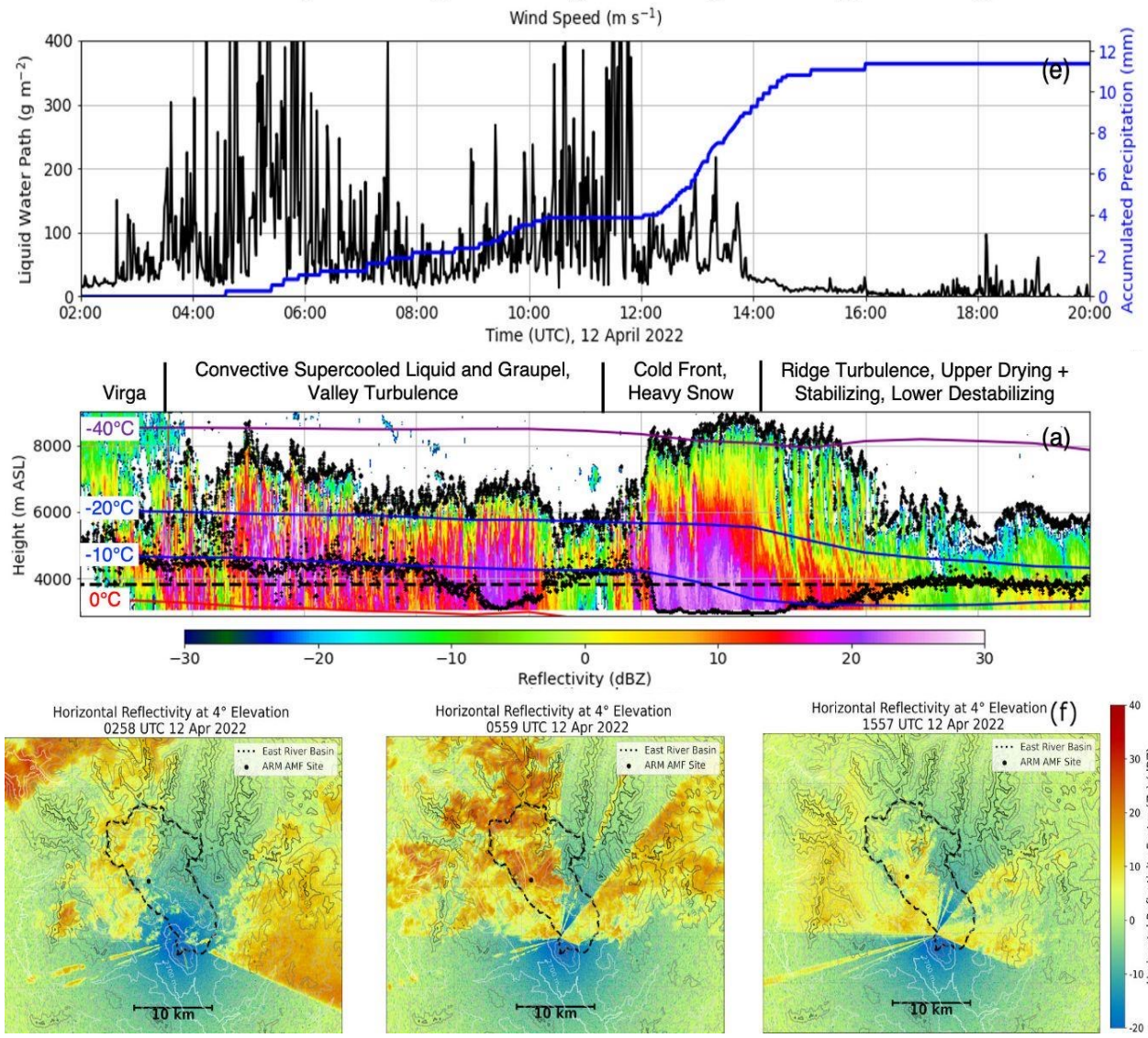
Precipitation Example

SAIL has numerous datastreams that measure what exactly happened with each storm that blows through the Upper Colorado River Basin.

Let's start with a look at April 12, 2022. The weather was unsettled, with lots of winds at the surface before snow fell for a few hours, took a break, and then fell strongly in the afternoon before subsiding in the evening.

However, there were a lot of atmospheric dynamics: virga followed by supercooled liquid and graupel, then a break, then heavy snow from a cold front, and ridge turbulence.

These details allow understanding to improve models!

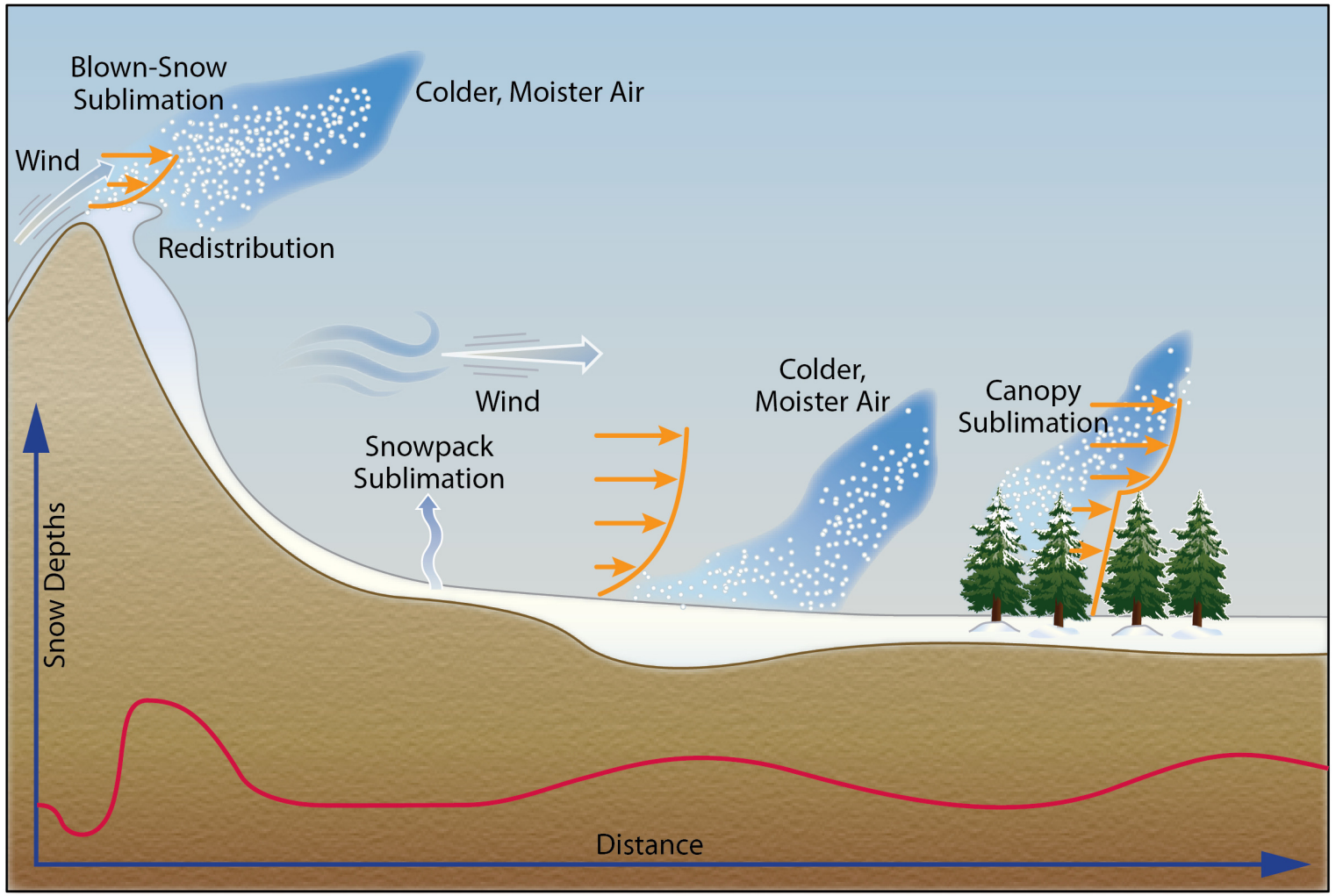


From Feldman et al, 2022, Submitted

Sublimation and Wind-Redistribution Process Studies

Snow can be redistributed during and after precipitation events, and snowpack can be vaporized through sublimation on blowing particles.

Models predict 0.1 – 26% of seasonal snowpack loss from sublimation. We can narrow this range.

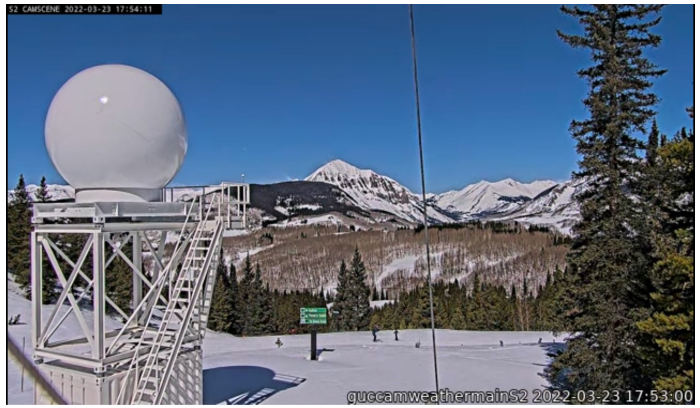


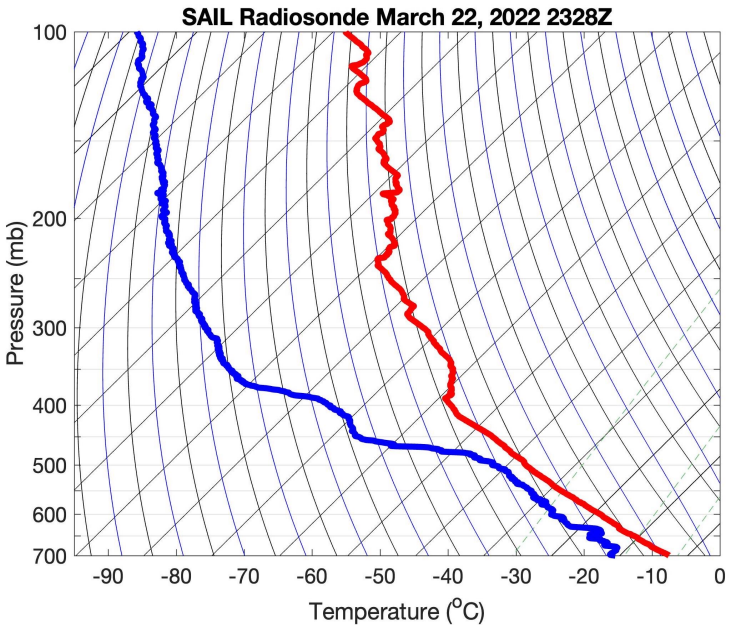
Sublimation Example

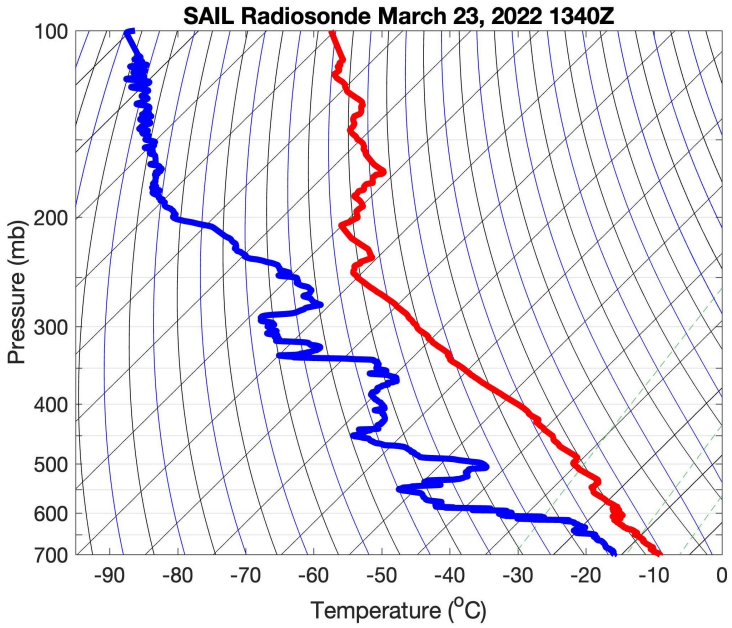
From Feldman et al, 2022, Submitted

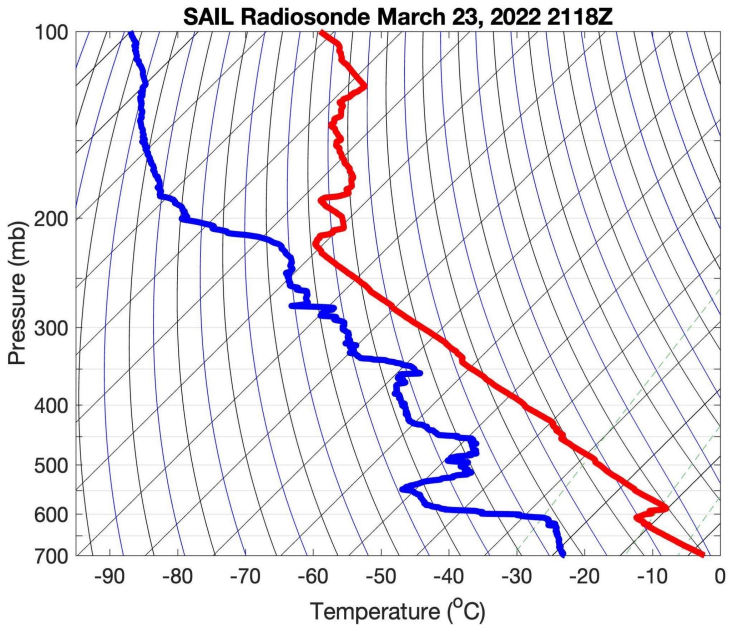
SAIL has numerous datastreams that measure blowing snow and its effects on the atmosphere.

We can see the evolution of boundary layer temperature and humidity when the snow is blowing.









Vision

Unite advanced models, observation and data systems to meet the challenge of regional climate prediction and provide actionable information for resource managers

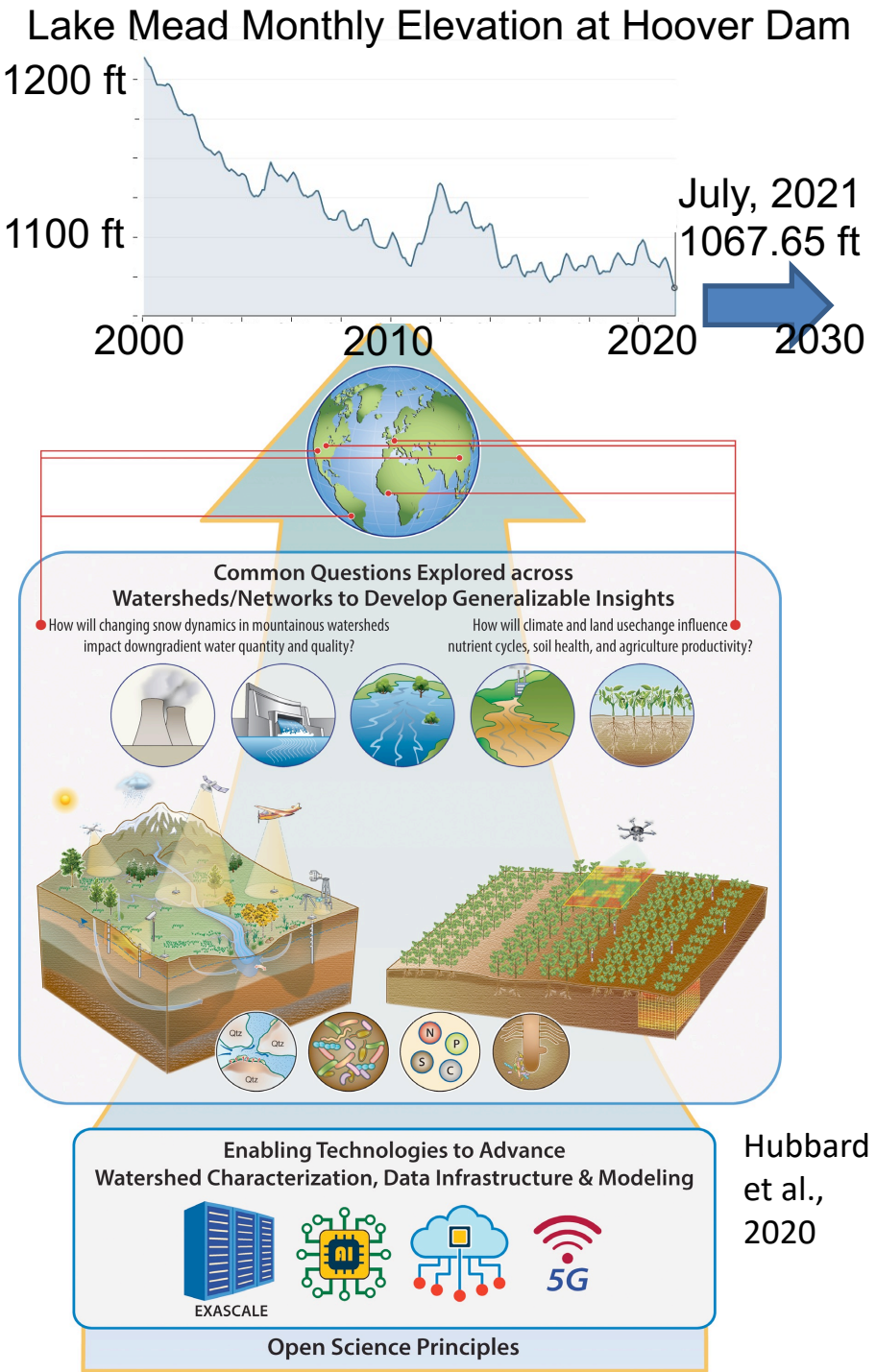
Opportunity

Emerging Technologies allow us to advance and transform Prediction

Convergence of Projects and Extreme Collaborations provide Opportunity for Sum>Parts

Let's follow up!

drfeldman@lbl.gov



Hubbard et al., 2020