2020 In situ snow research in Mammoth Lakes, CA

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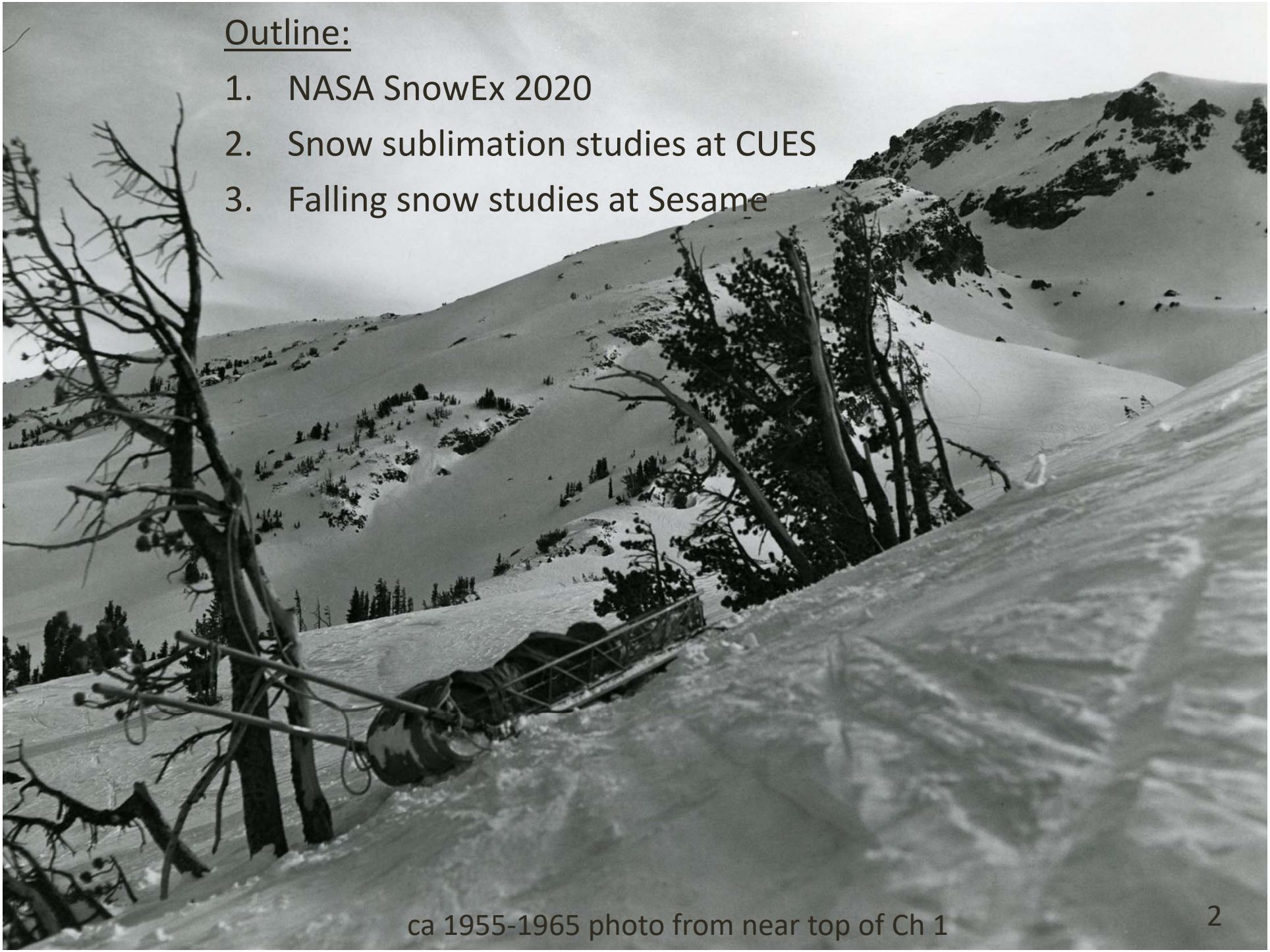
11:20-11:40 AM, Thu November 7, 2019



Outline:

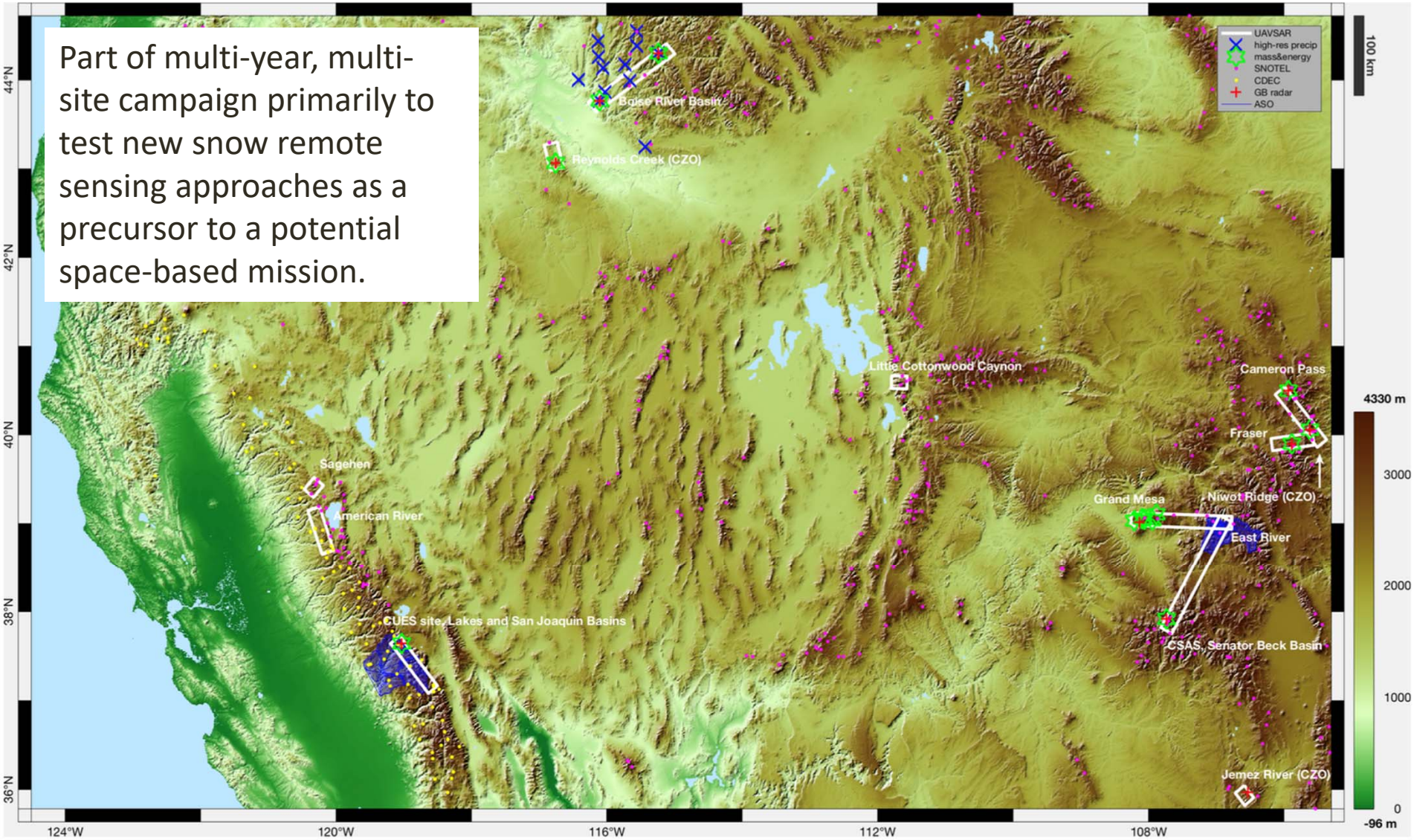
1. NASA SnowEx 2020
2. Snow sublimation studies at CUES
3. Falling snow studies at Sesame

ca 1955-1965 photo from near top of Ch 1

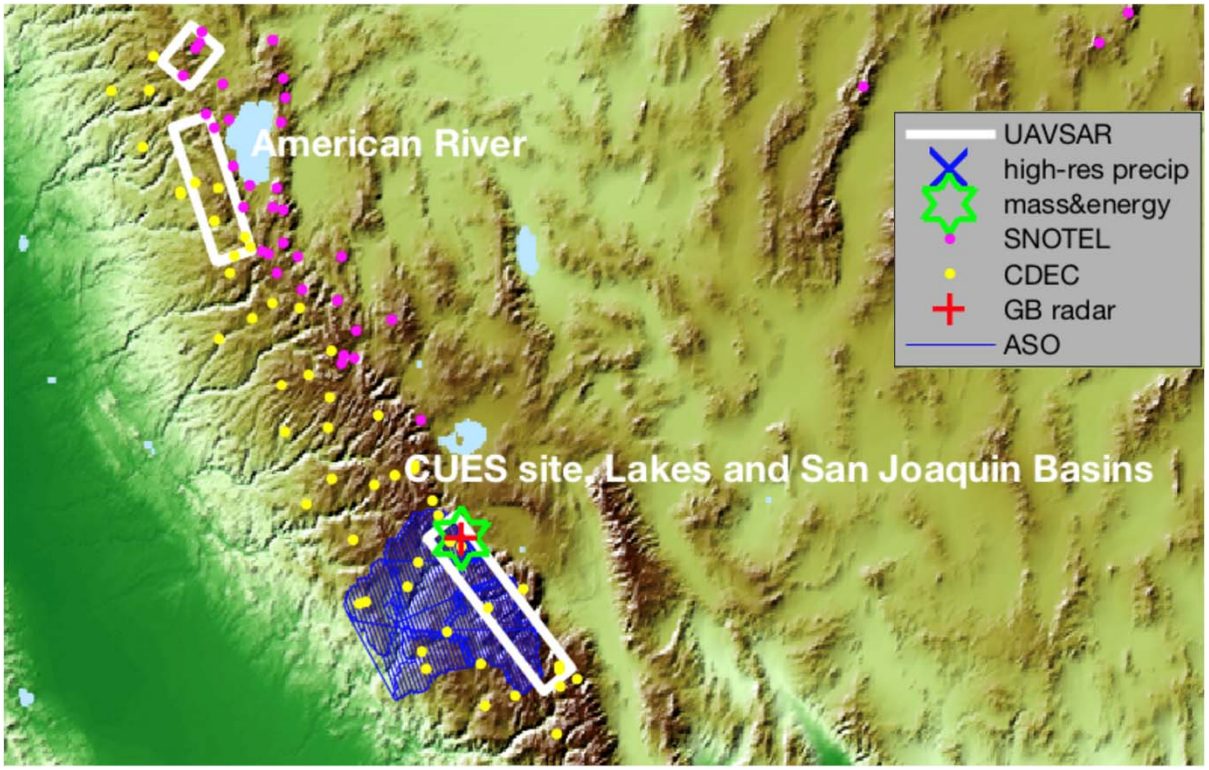
NASA SnowEx 2020

Marshall, H.P. and others, NASA SnowEx 2020 Experiment Plan Draft, 100 pp

Part of multi-year, multi-site campaign primarily to test new snow remote sensing approaches as a precursor to a potential space-based mission.

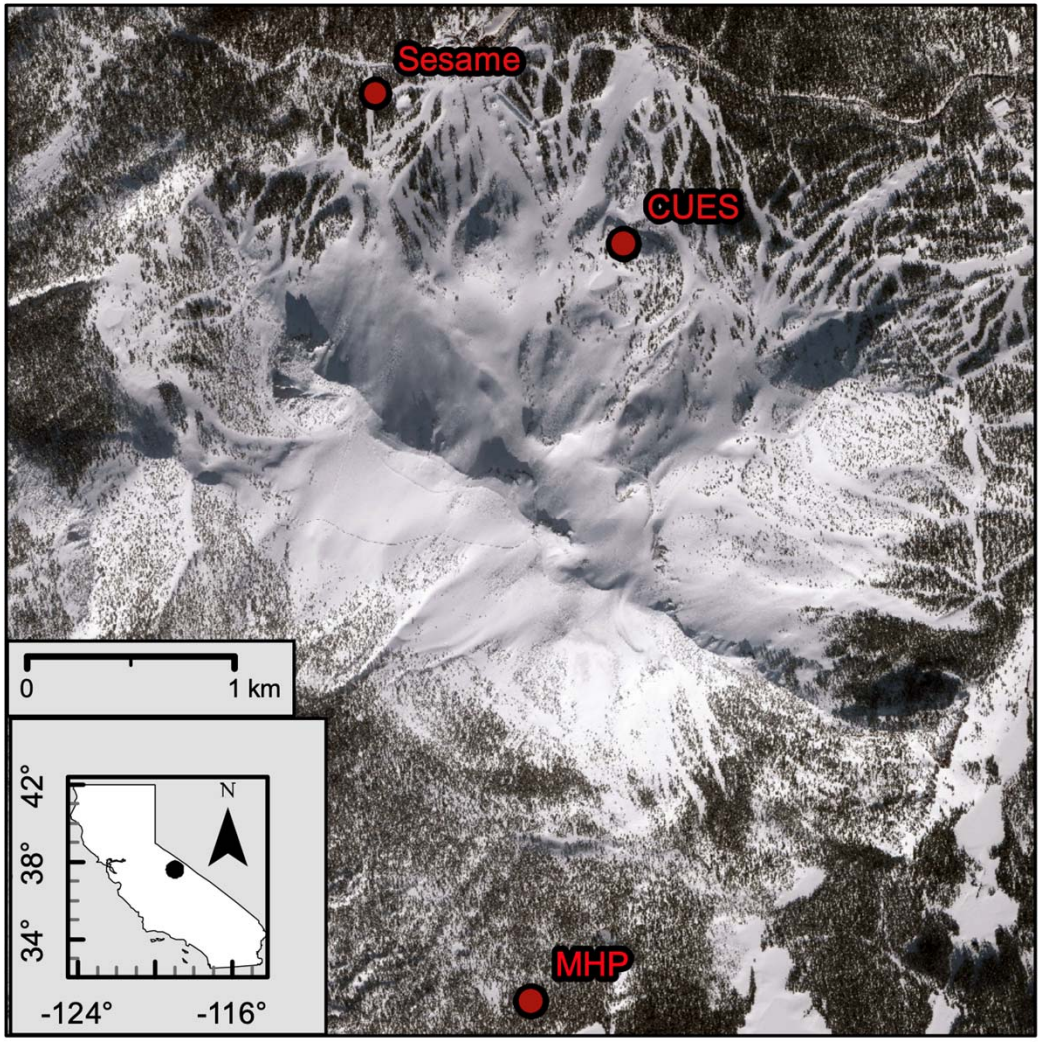


NASA SnowEx 2020 in CA



- Unmanned aerial vehicle synthetic aperature radar (UAVSAR-L)
  - Actually flies on a Gulf Stream III at 40,000 ft, so, impervious to weather
  - L band (20 cm λ) phase change approach
  - Detection of changes in snow depth
  - 14 flights with in situ pits and transects in Mammoth Lakes: Dec 2019 - May 2020
- UAVSAR-Ka
  - Ka band altimetry approach (8 mm λ)
  - Snow on/snow off differencing approach
  - 2 flights, Feb, Mar 2020
- Airborne Snow Observatory (ASO)

Study sites on Mammoth Mountain (covered by SnowEx 2020 flights)



Sesame (patrol.mammothmountain.com)

- Mammoth Mountain Ski Patrol Study Plot since Nov 1982
- Existing:
  - snow depth (HN and HS),
  - pillow SWE
  - manually weighed new snow,
  - precip gauge
- New (2020):
  - 2nd heated tipping bucket
  - Riegl VZ-400 laser scanner
  - OTT Parsivel-2 disdrometer

CUES (snow.ucsb.edu)

- Existing:
  - Over 100 measurements/minute for snow energy and mass balance
- New (2020):
  - 10 Hz water vapor and sonic wind speeds for Eddy Covariance
  - Adjustable snow albedo boom with an automated winch
  - Lufft SHM 31 snow depth (635 nm λ)

MHP (cdec.water.ca.gov)

- LADWP course measurements back to 1926
- Snow depth, SWE, precip

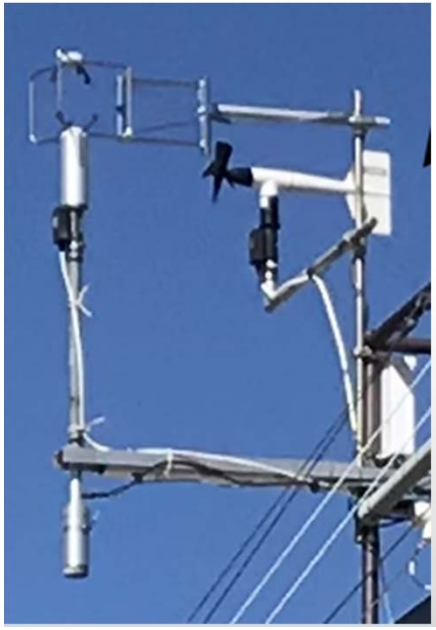
Snow sublimation

Fred Camp photo from Mt Whitney, 1964
Western Snow Conference Collection at UNR

- We know that a lot of water is lost to sublimation throughout the higher elevations of the Sierra, but quantification is poor: 20-60% (Stewart 1982; Kattelmann and Elder, 1991; Hunsaker et al. 2012)
- Beaty (1975) estimates that 50-80% of the snowpack in the White Mountains is lost to sublimation

Snow sublimation

- One estimate for CUES, based on pillow and lysimeter measurements, is 44 %/year (Bair et al. 2015)
- To better quantify at CUES we are taking eddy covariance measurements and experimenting with isotopic tracers (fractionation) in collaboration with researchers at Livermore National Laboratory



RM Young 81000, 5103 and CSI KH20 at CUES

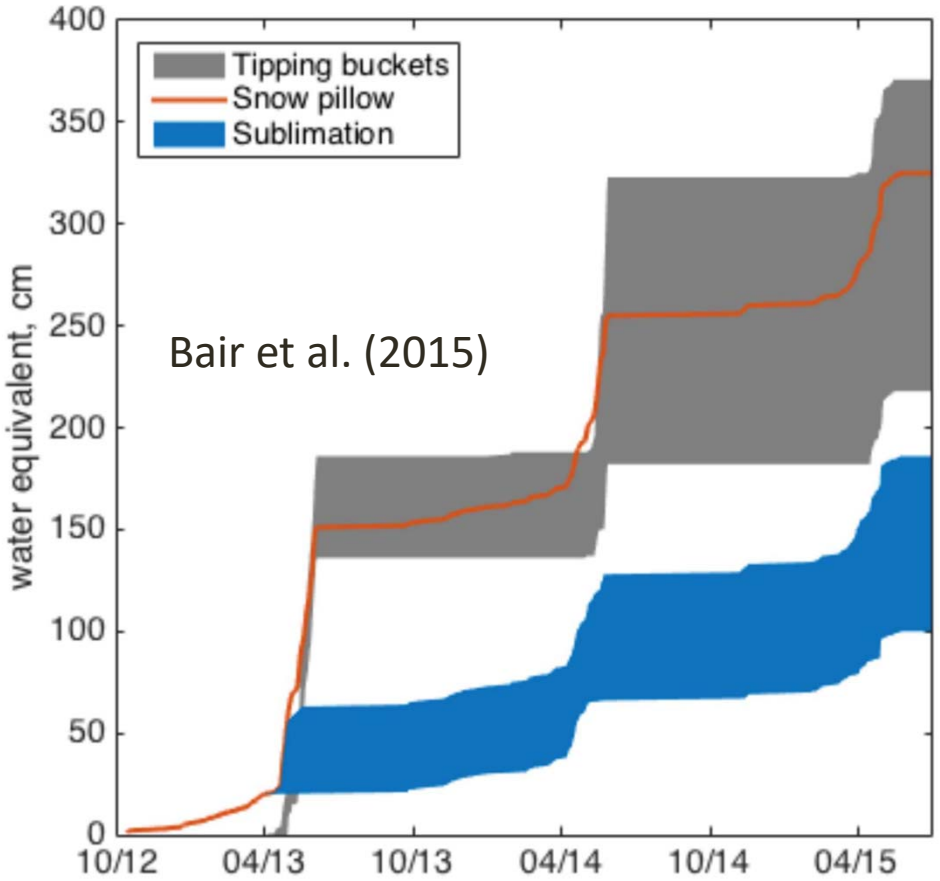
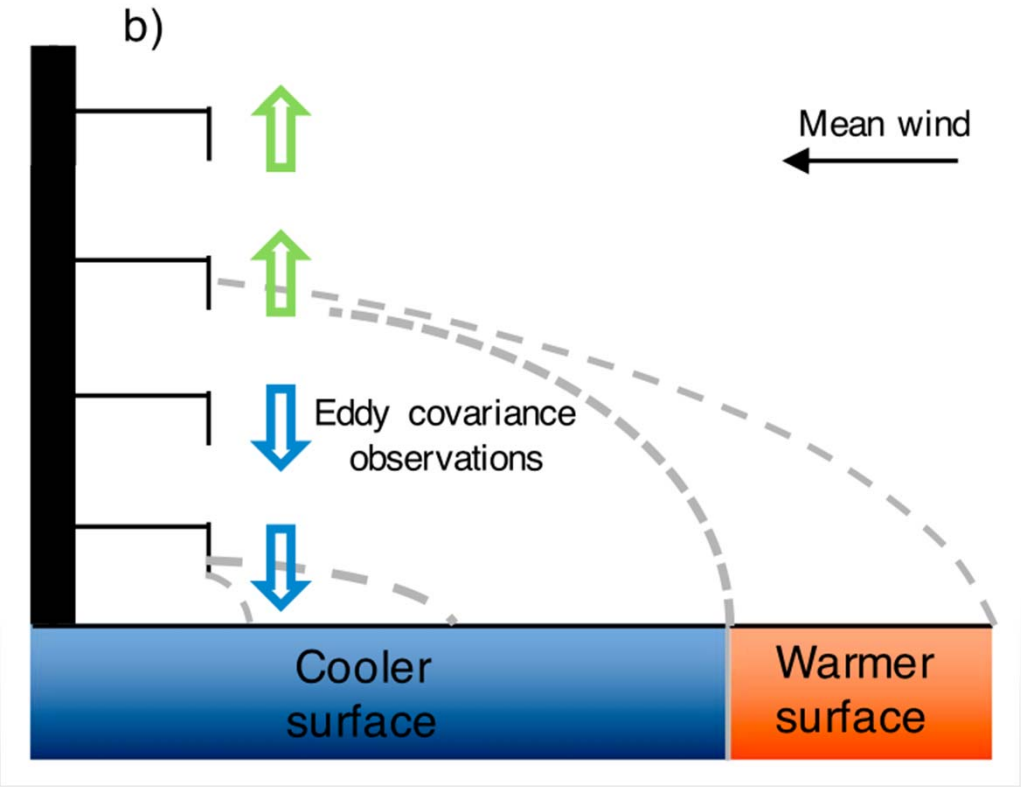


FIGURE 10 | Sublimation measured from lysimeter and snow pillow melt. The range of cumulative tipping bucket melt from three lysimeters is shown in gray. The cumulative snow pillow melt is shown in orange. Sublimation is shown in blue.

Potential pitfalls for eddy covariance measurements

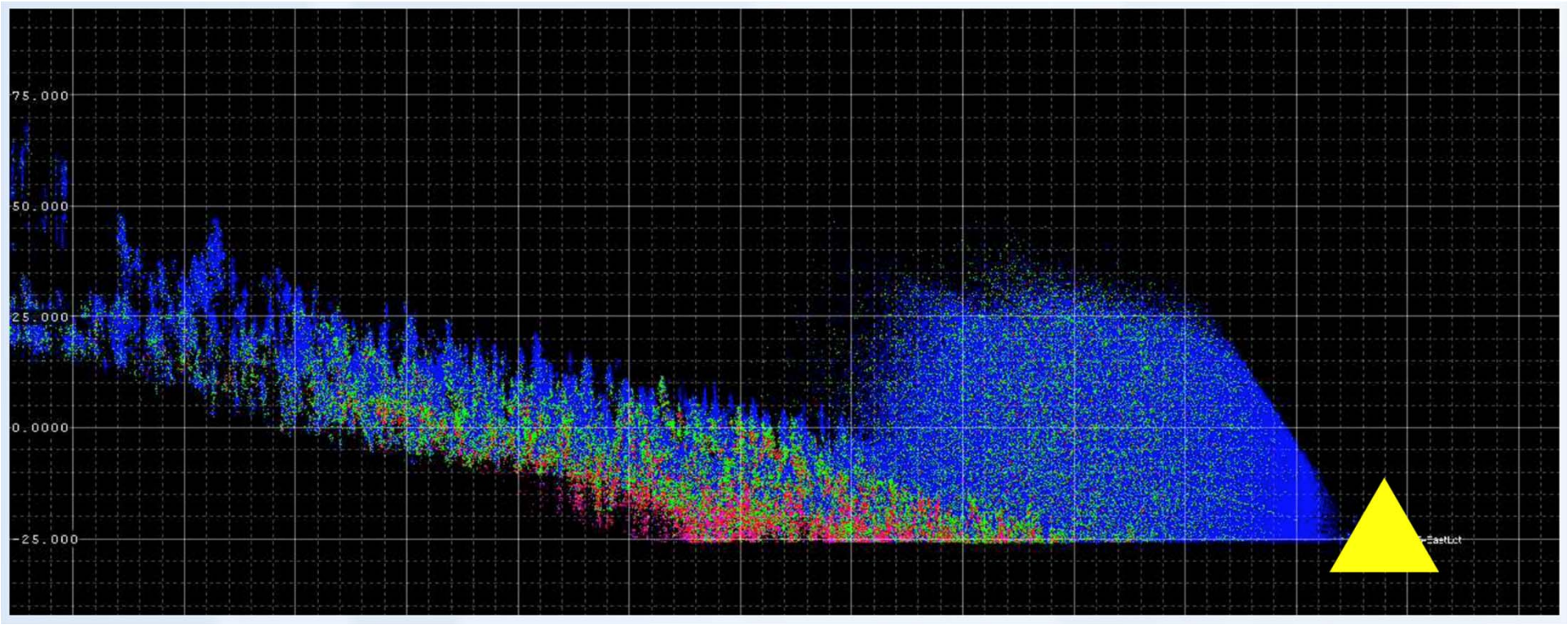


- Counter gradient eddies during bulk stable conditions
- Do we need multiple anemometers?
- Are well-mixed neutral conditions well justified at CUES?

Lapo et al. (2019)

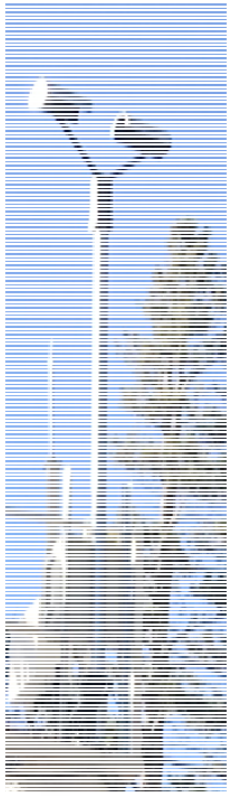
Optical properties of falling & blowing snow

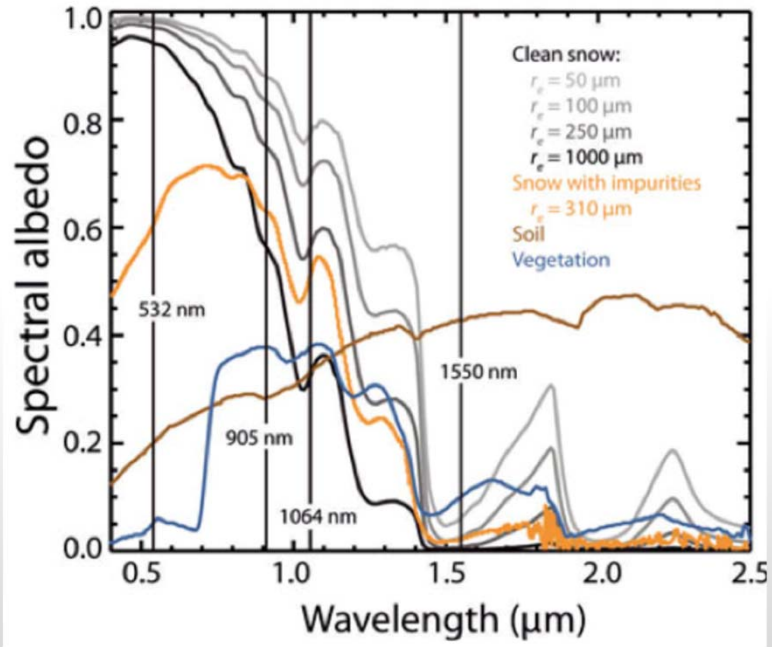
- What is the transmissivity of the snow in the image below?
- What is the particle size distribution?
- Who cares?



Optical properties of falling & blowing snow

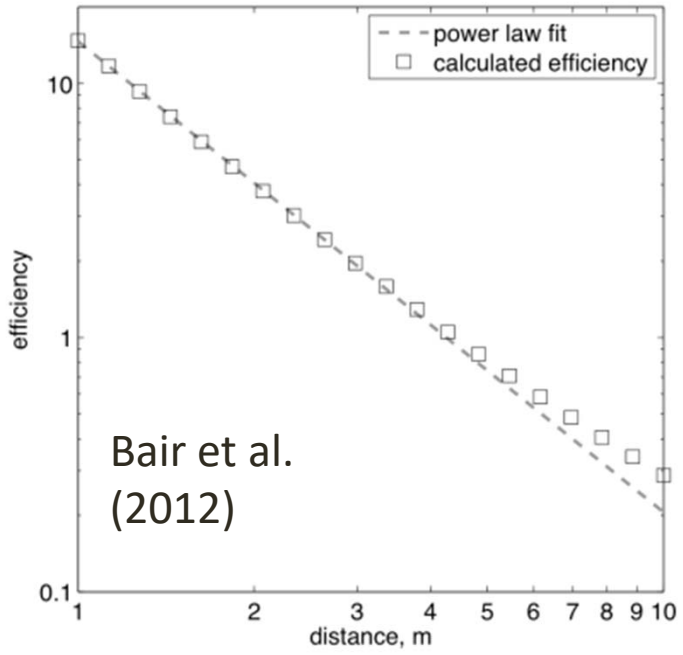
- We now have 2 automated lidars installed on Mammoth Mountain at CUES (Z390i) and Sesame (VZ 400).
- Both are 1550 nm (not good for snow), but VZ400 samples much faster: 300 kHz vs. 11 kHz for the Z390.
- Combined with disdrometer (Parsivel2) and hand/weighed/gauge precipitation, we will take spatially explicit measurements of falling and blowing snow. Think spatial disdrometer measurements, like fall speed.
- Who cares? The Army. Potential for vehicle mounting lidars to estimate things like safe travel speeds in snow storms.

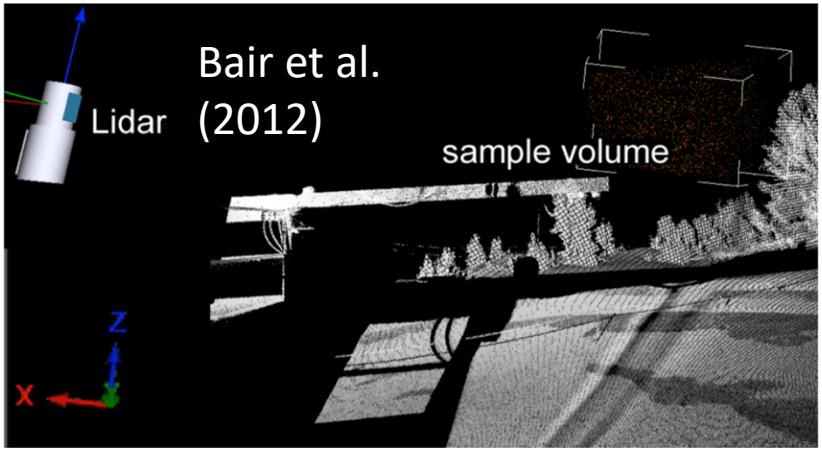




Potential pitfalls for measuring fall & blowing snow

- Sampling theory
  - How far can the lidar get returns??
  - Efficiency: how many hydrometeors are being sampled per pulse?





Phillips et al. (2017)

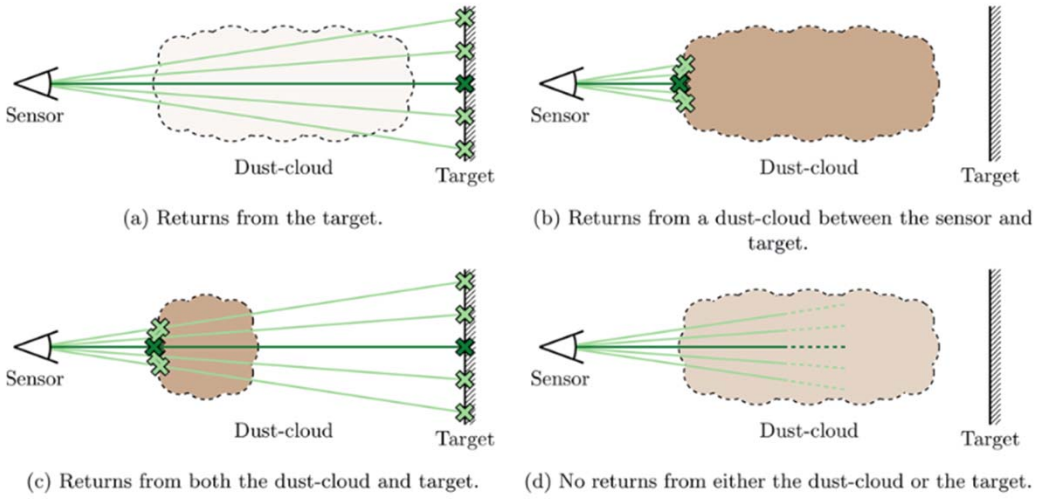


Figure 3. Four range measurement behaviors typically exhibited by LiDAR sensors.

Thanks !