Snow Problem! Improving SWE Estimates Using Bayesian Analysis of Priors

Bayesian Analysis and Computation, Winter 2025

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water in the west:

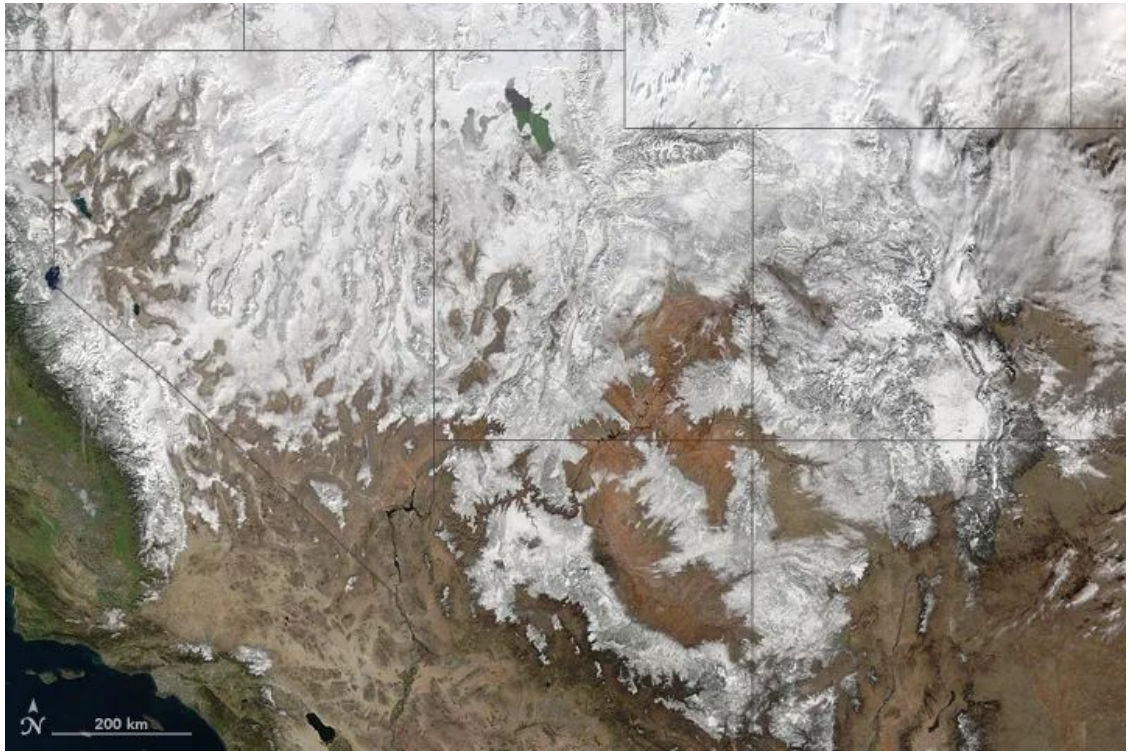


Figure 1: View of snow cover from NASA Modis in January 2017

1. As much as 75% of water supplies in some western states are derived from snowmelt [1]
2. The colorado river supplies water to ~30 million people! [2]

water resource managers want to know **how much water is in the snowpack** for operational decisions.

Figure 2: The Glen Canyon Dam was constructed to harness the power of the Colorado River in order to provide resilience to the water and power needs of millions of people in the west. [3]

characterizing snow cover & SWE

Well, instead of just snow on or off, we need depth and density to understand how much snow & where, on very large spatial scales.

i.e. remote sensing

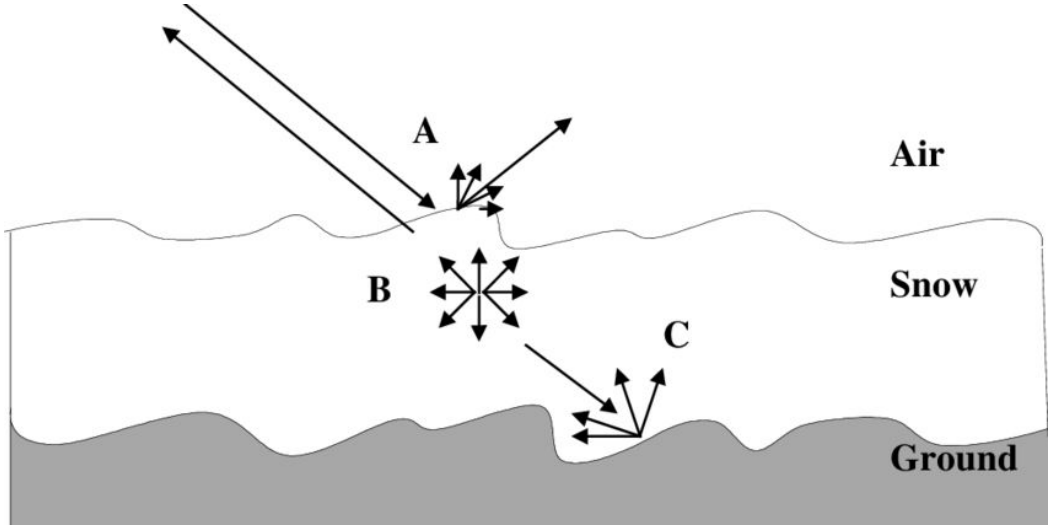
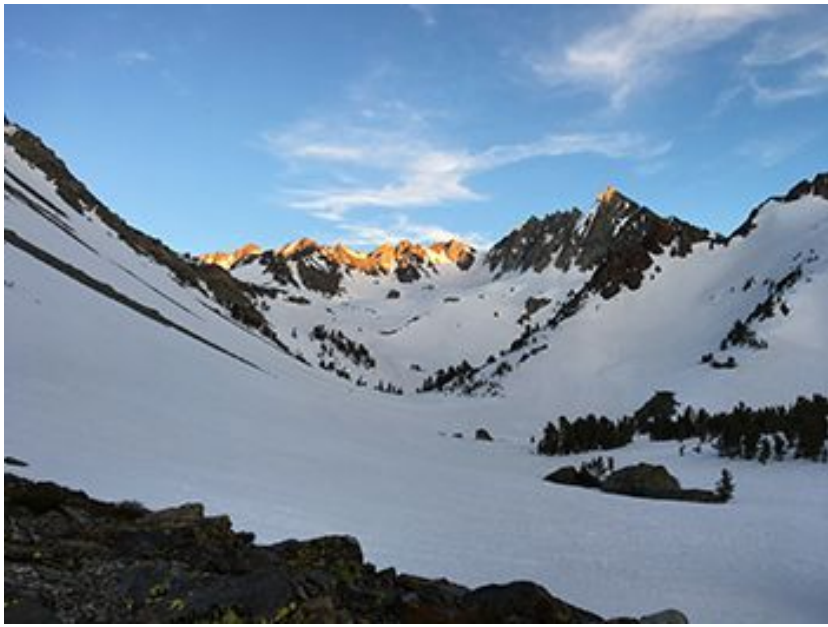


Figure 2: The scattering mechanisms of snow-covered terrain (Koskinen 2001)

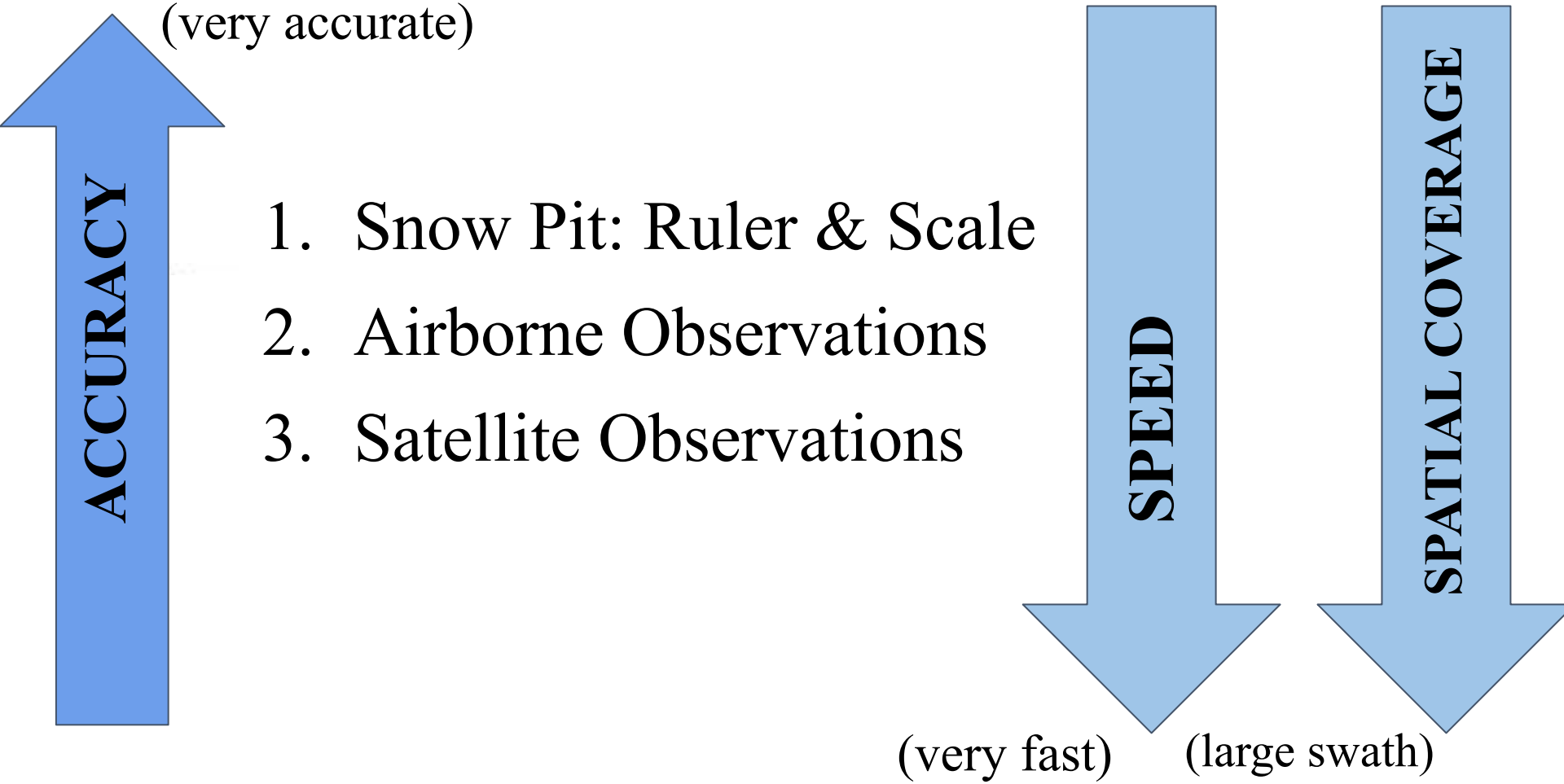


scattering is a complex problem!

digging snow pits is time-intensive:

~30 minutes digging per location

current techniques for SWE obs:



iSnobal: Snowmelt Energy Balance Model

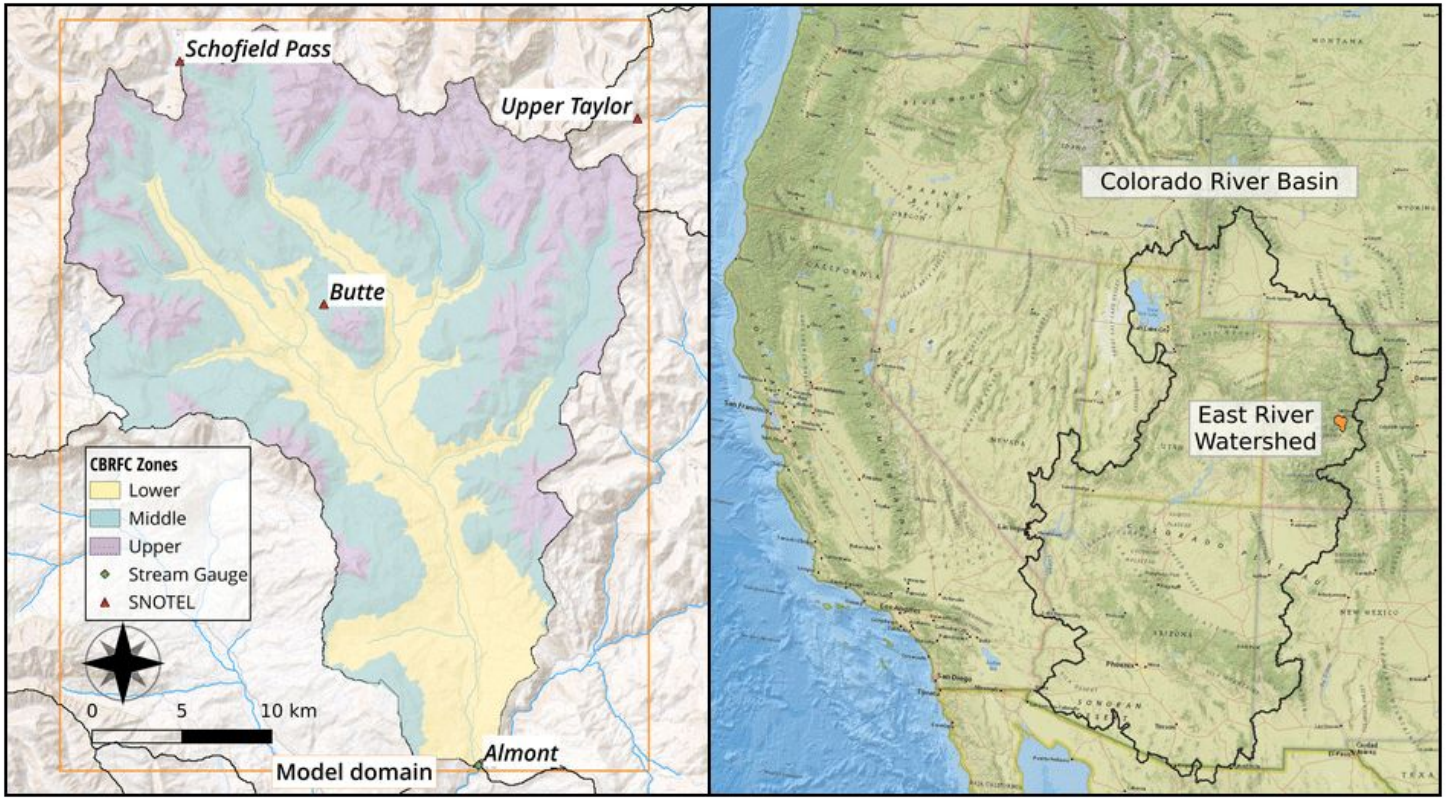
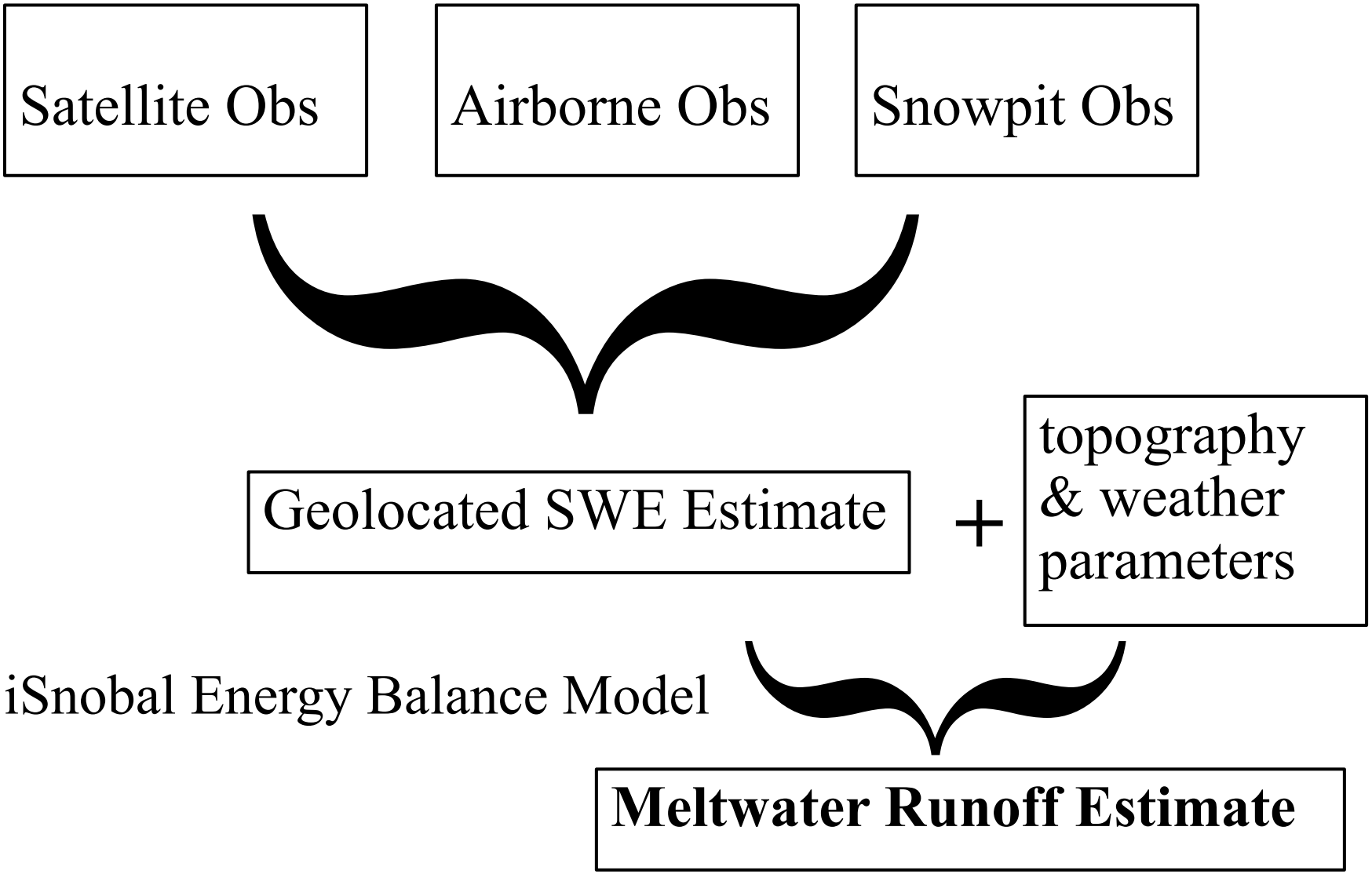


Figure 3: Overview of the iSnobal Model domain. This model allows for large scale hydrological modeling that is required for operational forecasting [4]

data flow:


Satellite Obs
Airborne Obs
Snowpit Obs
Geolocated SWE Estimate
+
topography & weather parameters
iSnobal Energy Balance Model
Meltwater Runoff Estimate

How do **priors** shape SWE-based runoff models, and what data density and uncertainty thresholds ensure reliable predictions?

Methods & Hypothesis

Bayesian Framework: Our SWE observations are our priors, iSnobal Energy Balance Model [4] is our likelihood, and resulting runoff predictions as posterior

Computational Approach: use MCMC to handle the complexity of geospatial data

Dataset: Utilize SnowEx 2023 data, which provides concurrent SWE observations from ground, airborne, and satellite instruments near Fairbanks, AK. [5]

Hypothesis:

Airborne and satellite data, while offering broad coverage, have higher uncertainty in posteriors than required for water management. Combining them with **sparse ground observations** can significantly improve posterior certainty.

Intellectual Merit:

This research advances hydrological modeling by applying Bayesian inference to **new state-of-the-art SWE observations.** Typically, **only one** type of SWE observation is available for modeling.

Informing observational standards for water resource forecasting is an important goal in the face of **exacerbated floods, droughts, and imminent water resource uncertainties** [6].

Conclusions:

1. **New SWE observation techniques** justify research into how their complexities affect runoff models.
2. Water resource management depends on snowmelt runoff models to inform **operational and policy decisions.**
3. **Informed** water management ensures water security for hydropower, agriculture, and public use.

thank you

find slides:
https://github.com/annavalentine/BayesianStats

References:

[1] United States Geological Survey (USGS). *"Snowmelt Runoff and the Water Cycle." Water Science School*, U.S. Department of the Interior, https://www.usgs.gov/special-topics/water-science-school/science/snowmelt-runoff-and-water-cycle. Accessed 16 Feb. 2025.

[2] U.S. Bureau of Reclamation. *Colorado River Basin Water Supply and Demand Study: Executive Summary.* U.S. Department of the Interior, Dec. 2012, https://www.usbr.gov/watersmart/bsp/docs/finalreport/ColoradoRiver/CRBS_Executive_Summary_FINAL.pdf. Accessed 16 Feb. 2025.

[3] U.S. Bureau of Reclamation. *Glen Canyon Dam – Colorado River Storage Project.* U.S. Department of the Interior, https://www.usbr.gov/uc/rm/crsp/gc/. Accessed 16 Feb. 2025.

[4]Meyer, J., et al. *"iSnobal: A Snowpack Energy Balance Model for Hydrological Applications." Geoscientific Model Development*, vol. 16, 2023, pp. 233–256, https://gmd.copernicus.org/articles/16/233/2023/. Accessed 16 Feb. 2025.

[5] National Snow and Ice Data Center (NSIDC). *SnowEx 2023 Data*. National Aeronautics and Space Administration, 2023. Accessed 16 Feb. 2025.

[6]Milly, P.C.D., Betancourt, J., Falkenmark, M., Hirsch, R.M., Kundzewicz, Z.W., Lettenmaier, D.P., & Stouffer, R.J. (2008). *Stationarity is Dead: Whither Water Management?* Science, 319(5863), 573–574. https://doi.org/10.1126/science.1151915