Snowpack Monitoring in the Rocky Mountain West: A User Guide

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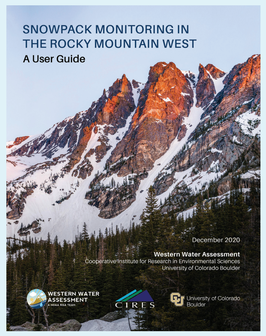
ABSTRACT

In the Rocky Mountain West, snow is a dominant player in the hydrologic cycle. Since variation in the size of the snowpack from year to year strongly controls the magnitudes of seasonal, annual, and peak streamflows, monitoring the evolution of the snowpack over the course of the winter and spring is critical to forecasting streamflow and managing water supply.

Western Water Assessment developed the Snowpack Monitoring in the Rocky Mountain West: A User Guide for those who use, collect, and produce snow information.



GUIDE OBJECTIVES

- Outline the fundamental characteristics of the snowpack, the processes that drive its variability over time and space, and the challenges of sampling such a dynamic resource.
- Highlight the key role of snowpack in seasonal water supply forecasting.
- Describe the SNOwpack TELemetry (SNOTEL), snow course, and other networks of point observations.
- Summarize the several products providing spatial estimates of snowpack derived from point observations, snow models, and remote sensing.
- Provide practical guidance on accessing, interpreting, and applying snow data.

UNDERSTANDING SNOWPACK

How do we know how much water is in the snowpack? The depth, density, and areal extent of the snowpack changes over time, making answering this question particularly challenging. The metric most commonly used to express the amount of water contained in the snowpack is snow water equivalent, or SWE. SWE can be thought of as the depth of water that would result if you melted a column of the snowpack. Point observations of SWE are often used as proxies or predictors for water volume in an area or basin.

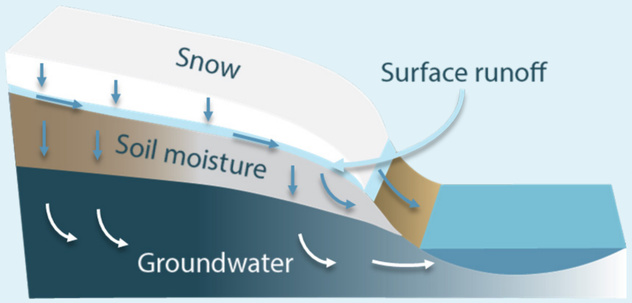


Figure 1: Schematic representation of the route of snowmelt from snowpack to streamflow. Only a portion of snowmelt runs off directly to streams and rivers, while much of the snowmelt becomes new groundwater, which then pushes older groundwater to the stream channel.

MONITORING SNOWPACK

In situ:

- **Snow courses:** A network of in situ, point measurements managed and maintained by the NRCS, with state and local cooperators, for over 80 years. Critical for validation and continuing long-term records.
- **SNOTEL:** Automated SNOwpack TELemetry (SNOTEL) stations have augmented and/or replaced the snow courses since the late 1970s. They carry the vast majority of the load for operational monitoring, and are used to construct, calibrate, and validate other snow data products.
- **Volunteer Observers:** COOP (Cooperative Observer Program) and CoCoRaHS (Community Collaborative Rain, Hail, and Snow) programs provide useful supplemental snow data collected by volunteer observers.

Remote:

Remote sensing from satellite platforms provides spatially continuous data that complements in situ observations. Examples include MODIS (Moderate Resolution Imaging Spectroradiometer) and airborne platforms, such as ASO (Airborne Snow Observatory). They have inherent uncertainties not shared by in situ measurements but cover larger areas. In the Colorado River Basin, remotely sensed snow data are being increasingly deployed and integrated into snowpack monitoring and runoff forecasting systems.

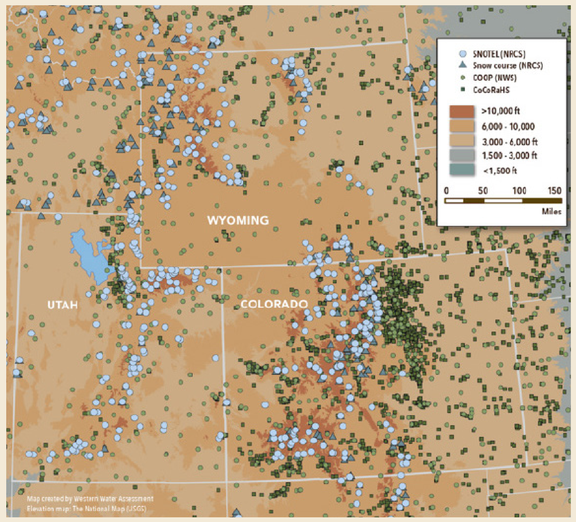


Figure 2: Locations of in-situ snow observing sites in the Rocky Mountain West (CO, UT, WY). The NRCS SNOTEL and snow course sites are focused on snow observations at higher elevations, and under normal operations, SWE measurements are available from all of the sites shown. The vast majority of COOP and CoCoRaHS sites are at elevations below the SNOTEL/snow course network.

APPLYING SNOWPACK DATA

NRCS forecast methods: The characteristics of the snow course and SNOTEL networks have influenced the NRCS water supply forecasting approach. Statistical regression modeling is used to relate several predictors– typically water-year-to-date precipitation and current SWE from SNOTEL sites–to the target predicted value: spring-summer streamflow at a given forecast point. Point-based measurements are well suited for this statistical approach–it requires a limited number of predictors to represent the basin snowpack above the stream gage being forecasted.

NOAA RFC forecast methods: Seasonal water supply forecasts for the Great Basin and the Colorado River Basin are provided by NOAA's Colorado Basin River Forecast Center, or CBRFC. This and other RFCs use the same forecast tools for seasonal water supply, but they produce and distribute their operational forecasts differently. The two tools are (1) a statistical forecast method very similar to that used by the NRCS, and (2) a physically based conceptual hydrologic modeling system that produces an ensemble of equally likely streamflow sequences (Ensemble Streamflow Prediction, or ESP).

Accessing Snowpack Data: There are a wide range of tools available for accessing snowpack data. Table 1 indicates the variables and snow products available in each tool.

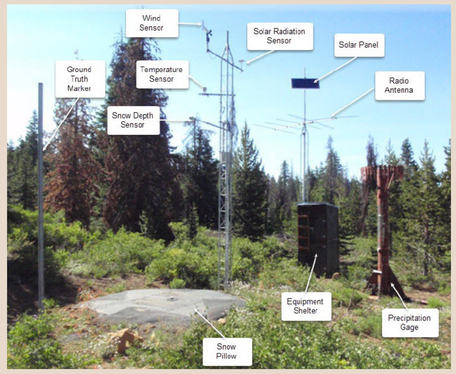


Figure 3: SNOTEL automated collection site. Source: NRCS (https://www.wcc.nrcs.usda.gov/about/mon_automate.html).

Tool or resource	Variable: SWE	Snowfall	Snow depth	Snow density	Snow temperature	Air temperature	Precipitation	Precipitation as snow	Snow products / networks displayed in tool
NRCS Interactive Map	Yes		Yes	Yes		Yes	Yes		SNOTEL Snow course
NRCS Snow Survey Interactive Charts	Yes (CO, UT only)					Yes (UT only)	Yes (CO, UT only)		SNOTEL Snow course
CBRFC snow groups	Yes (CBRFC domain only)								SNOTEL
NOAA snowfall and snow depth map		Yes	Yes						COOP CoCoRaHS
CoCoRaHS maps	Yes	Yes	Yes				Yes		CoCoRaHS
NOAA SNODAS map	Yes		Yes	Yes	Yes		Yes	Yes	SNODAS SNOTEL COOP CoCoRaHS
CWCB CDSS SNODAS tools	Yes (CO only)								SNODAS
U. Arizona SnowView map	Yes						Yes		SWANN SNODAS SNOTEL
CBRFC modeled snowpack map	Yes								SNOW-17

Table 1: Tools for accessing snowpack data and the available variables per tool.

In 2021, WWA hosted a two-part webinar series about the Snowpack User Guide. In Part 1, Karl Wetlaufer and Jeff Deems discussed the details of snowpack observations, both in situ and remotely sensed. In Part 2, Gus Goodbody and Patrick Kormos covered applications of snowpack information. **View webinars: wwa.colorado.edu/outreach/webinars**

LEARN MORE

You can download the Snowpack User Guide at wwa.colorado.edu

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