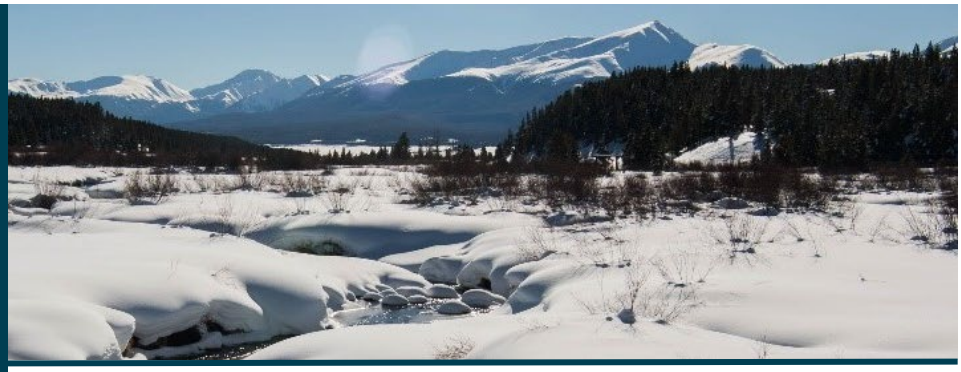
BUREAU OF RECLAMATION

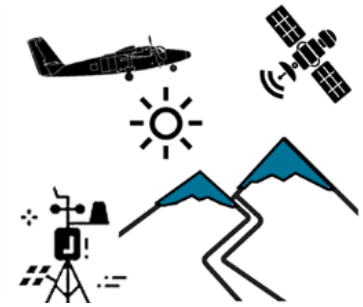


Emerging Technologies in Snow Monitoring

Report to Congress

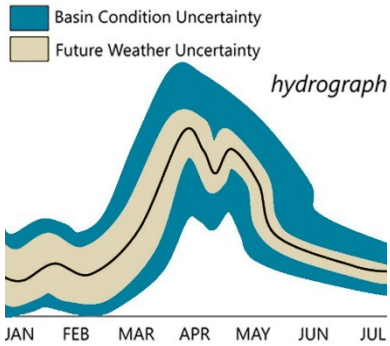
The Bureau of Reclamation, on behalf of the Secretary of the Interior, is implementing the recently authorized Snow Water Supply Forecasting Program (Program). Snow is a critical component of our Nation's water supply, particularly in the Western United States where over half of streamflow is derived from snowmelt. The Program aims to improve snowpack measurement to the benefit of water supply forecasts and water management. As part of Program framework development, a report to Congress on emerging snow measurement technologies was developed. The Report to Congress summarizes technologies and program implementation, finding that:

- Ground-based snow measurements are critical to developing and evaluating new snow monitoring technologies; maintaining and enhancing these networks is a high priority.
- While snow characterization is critical for water supply forecasts, weather forecasting and other variables (e.g., soil moisture) play major roles in being able to predict runoff and overall water availability. Improving weather and seasonal climate forecasts for temperature and precipitation will provide the complementary information needed for a more complete picture of future water conditions.
- No single snow monitoring technology provides complete snow condition information throughout the West with the desired frequency, precision, and efficiency. There is unlikely to be such a technology for some time. Accordingly, a "portfolio" approach to snow monitoring that uses a blend of complementary technologies is and will continue to be important to advance emerging technologies to enhance snow monitoring and subsequent water supply forecasts.
- Several snow monitoring technologies were reviewed but did not meet the emerging technology criteria as they are not yet sufficiently mature. Many of these have the potential to produce substantial future benefits. Continued development of these promising technologies and research on new concepts is valuable.
- Emerging technologies would benefit from an efficient pipeline to integrate them into widespread water supply forecasting. This will require cooperation amongst agencies and a continuing commitment.
- Partner agencies are engaging in significant efforts related to emerging snow monitoring technologies and their use in water supply forecasts.



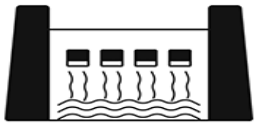
CURRENT BASIN CONDITIONS

Future water supply is a product of current basin conditions, such as snowpack, and future weather.



WATER SUPPLY FORECASTS

Uncertainty from basin observations and weather forecasts result in a range of possible future conditions.



WATER MANAGEMENT

Better observations of snow conditions can reduce basin condition uncertainty and improve forecasts for water managers.

The report reviews snow measurement methods ranging from long-standing practices to approaches still in research or development phases. For this report, an "emerging" technology is mature enough to be usable in water supply forecasts within the next 5 years—but is not being widely used today. Further, for this report, technologies can include sensors, methods, and models. The report found that ten technologies meet these criteria and stand to improve operational water supply forecasts.

Air and Space-Based Technologies

- Aircraft lidar (e.g., Airborne Snow Observatory [ASO]) maps snow depth and when coupled with modeling, provides information on water held as snow.
- Snow Covered Area (SCA) / fractional Snow-Covered Area (fSCA) methods use satellite imagery to map the portion of the land covered by snow.
- Satellite albedo methods use satellite imagery to measure how clean/dirty the snow is, which has implications for how slowly/quickly snow melts.
- Satellite stereo imagery methods use high-resolution pictures from space captured from different perspectives to construct a three-dimensional (3D) model of the Earth's surface providing information on snow depth.

Ground-Based Technologies

- Net radiometers measure energy from the sun and heat from the ground, which informs snow melt timing and can be used to improve snow science.
- Snow temperature sensors measure how cold the snow is at various depths in the snowpack, which can improve predictions of snow melt timing and informs snow science.

Modeling Technologies

- Snow Data Assimilation System (SNODAS) is a National Oceanic and Atmospheric Administration (NOAA) system that blends observations and weather model output to estimate snow conditions across the United States.
- Snow Water Artificial Neural Network (SWANN) estimates snow conditions across the United States using a machine learning system that blends snow observations and estimated precipitation data.
- University of Colorado real-time spatial estimates of snow water equivalents (CU-SWE) uses statistical modeling that blends satellite information with historical snow patterns and landscape characteristics to estimate snow conditions.
- Advanced snow models (e.g., iSnobal) use physics to track finely detailed snow conditions and can produce high resolution maps of basins or regions and can more easily incorporate data from air and space-based technologies.

The Snow Water Supply Forecasting Program Authorization Act, 2020, (PL 260-116, Sec.1111) establishes the Snow Water Supply Forecasting Program within the Department of the Interior. The Bureau of Reclamation, acting on behalf of the Secretary of the Interior, is implementing the Program in coordination with a Program Partner Agency Council.

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