RISING TO NEW CHALLENGES
FOR CALIFORNIA'S SNOW FORECASTING PROGRAM

California's History of Leadership in Snow Monitoring

In 1929, the State of California initiated a novel water supply forecasting program that relied on measurements of snow in select locations to predict spring and summer runoff into the state's reservoirs. This investment was motivated by the "Tahoe Water War," where the forecasting techniques helped end the long-standing litigation over operation of Lake Tahoe by reducing errors and professional judgment in reservoir operations. Today, this forecasting technique has matured into an indispensable tool for balancing the operations at California's major reservoirs for the benefit of our economy, environment, and public safety. The snow program currently includes 359 monitoring locations that span the watersheds of the Sierra Nevada and Trinity Alps.

The Airborne Snow Observatory (ASO) is an aerial snow monitoring tool that provides precise measurements of depth for every square meter of snow in the watershed. Combined with the conventional surveys, ASO provides a complete and near-perfect picture of snow water content that is robust against climate change.

WHY UPGRADE A WORKING PROGRAM?

Conventional snow surveys have served an indispensable role in California water management for almost a century, but the state has also changed dramatically over the same period. The demand for water has grown along with the population, which has doubled in the past 40 years alone. We have altered our landscape, with urban and suburban growth replacing floodplains. Changes in social values have required that reservoirs be operated not just for people, but also for downstream species and habitat. With the implementation of the Sustainable Groundwater Management Act, highly precise infrastructure operations will be required to maximize groundwater recharge. Finally, the climate appears to be changing in ways that further strain the state's water resources and how we manage them.

As a result of these changes, mistakes in water management have become more expensive than ever. The conventional snow survey and forecast methods rely heavily on professional judgment and extrapolation with a large margin for error because they use a few point locations to estimate water held in tens of thousands of square miles of snow cover. In the past, water managers have hedged imperfections in the surveys by over- or under-estimating water forecasts to avoid flood damage or shorting deliveries. These once-acceptable practices have begun to pose problems for meeting demands of our urban, agricultural, and environmental water users.

Download a PDF of this brochure, here: http://bit.ly/California-ASO

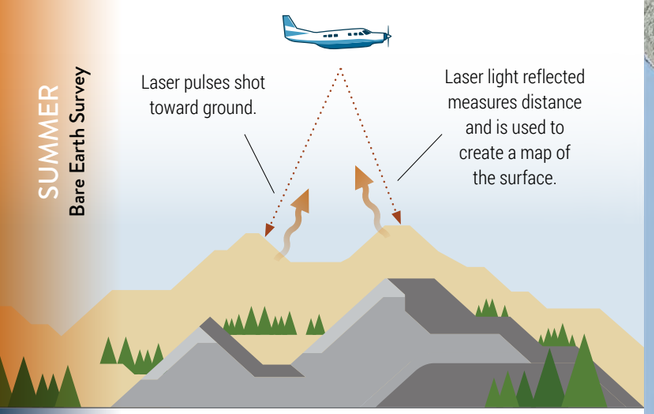
THE AIRBORNE SNOW OBSERVATORY TECHNOLOGY

ASO technology was developed at the NASA Jet Propulsion Laboratory to map the snow water equivalent (i.e. the volume of water stored as snow) and snow albedo (i.e. the reflection of incoming radiation) completely and accurately across mountain basins. ASO measures snow depth and snow reflectivity using plane-mounted light detection and ranging (LiDAR) technology. LiDAR is similar to radar but relies on near-infrared light to measure the distance of objects. Because the measurements are being taken continuously overhead through a wide geographic area, ASO is similar to putting a snow depth sensor in every square meter of snow in the mountains. When data obtained through the ASO surveys are combined with computer-based snowmelt models, they can provide runoff forecasts for up to 10 days in the future for entire seasons for any point on a river.

MEASURING SNOW FROM THE AIR: HOW ASO WORKS

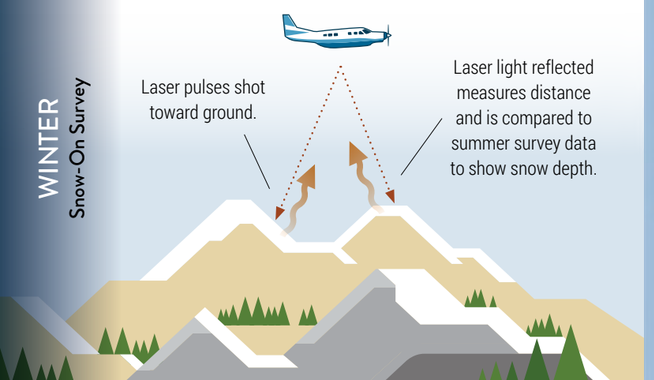
SUMMER Bare Earth Survey

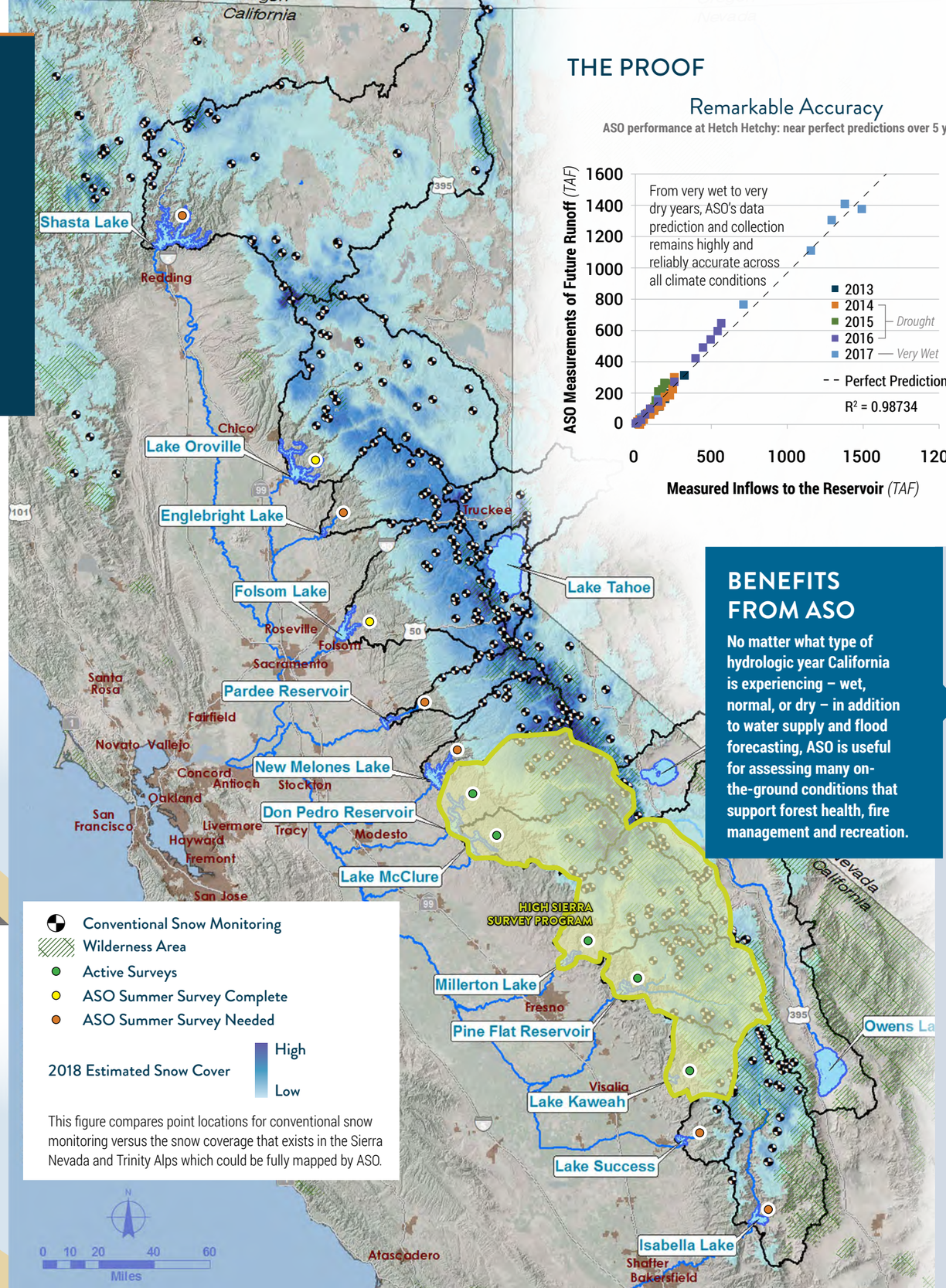
Aircraft flies over **snow-free** mountains and uses laser pulses to measure reflected light bouncing back from the surface.



WINTER Snow-On Survey

Aircraft flies over same area to measure reflected laser light bouncing from **snow on surface**.



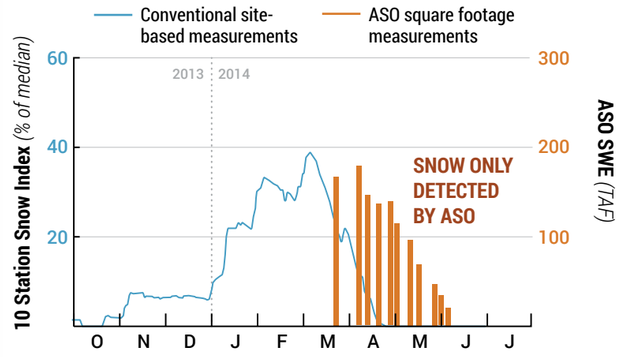


THE PROOF

Remarkable Accuracy

ASO performance at Hetch Hetchy: near perfect predictions over 5 years

Moving from Pixels to a Full Screen



ASO data (orange) reveals significantly more snow remains in the higher elevations much later into the year than conventional data collection methods (blue) were previously able to accurately quantify. ASO's methods give greater confidence in making decisions, such as allocations in drought years such as 2014. The same holds in wet years with flood management.

BENEFITS FROM ASO

No matter what type of hydrologic year California is experiencing – wet, normal, or dry – in addition to water supply and flood forecasting, ASO is useful for assessing many on-the-ground conditions that support forest health, fire management and recreation.

Flood Management

Throughout the year, and especially in the winter and spring, flood managers apply their professional judgment to information about snow and runoff in upper watersheds to determine when and how much flood space will be needed in reservoirs to protect public safety. By providing more precise and accurate data, ASO helps eliminate this "guessing game" and:

- Prevents over-releasing water from reservoirs, impacting water supply storage
- Reduces property loss because large-scale runoff events with potential for flooding will be easier to anticipate
- Avoids false alarms to the downstream public

Water Management

Water supply allocations are frequently delayed as water managers cast dubious eyes on conventional snow pack measurements. Highly precise and accurate ASO data can allow for:

- Earlier and larger groundwater recharge deliveries in wet years
- Avoided losses from overly conservative forecasts in dry years
- More balance among competing demands at reservoirs during the refill season
- Earlier and more confident management decisions for allocating and managing environmental flows

Additional and Indirect Benefits

Data from ASO can also provide value to California through:

- Improved runoff forecasts that can help with detection of hydropower generation opportunities
- Snow assessments that could assist in supporting ski area management, Caltrans efforts, park maintenance, and avalanche risk assessments
- Imagery of forests that can improve forest and fuel management, and surveys of tree mortality and ecosystem health
- Imagery of the terrain, including seismic fault systems, that can help identify and assess landslide risk

PARALLEL MISSIONS: ASO WOULD ADVANCE SEVERAL CALIFORNIA GOALS

Data gathered through ASO can be applied to far more than just runoff forecasts and would complement existing State-led activities or reduce costs of surveys conducted for other reasons, including:

Central Valley Flood Protection Plan

ASO helps achieve the Central Valley Flood Protection Plan's goal to implement flood management solutions that use an Integrated Water Management (IWM) approach before focusing on "harder" engineering solutions. IWM is a proven solution that enhances system understanding by reducing labor costs, avoids implementation of localized solutions, and minimizes unintended consequences to nearby regions.

California's Open and Transparent Water Data Act (AB 1755)

ASO propels California towards achieving the Legislature's vision of AB 1755. This law positions California to lead the nation in fostering public investment to demystify the complexity of water and ecological resources. The terabytes of information collected through ASO will be the underpinning of accessible, discoverable, and usable data that will foster entrepreneurship, innovation and scientific discovery by the public.

Integrated Regional Water Management

ASO is a critical link between Regional Water Management Planning Act of 2002 and the Sustainable Groundwater Management Act of 2014 (SGMA). Development and renewal of Integrated Regional Water Management (IWRM) plans is expected to escalate in response to SGMA. Accurate and timely snowpack data builds relevancy for future IRWM planning efforts.

Efforts to Modernize Advanced Observation Systems

For more than a decade, advanced observation systems have been implemented by DWR to address conventional snowpack measurement systems, particularly in-situ monitoring at high elevations. ASO fills these challenges and supports DWR's evolution in a warming world.

CALIFORNIA'S OPPORTUNITY TO LEAD

Hydrologists and water managers at state, regional, and local levels agree that ASO offers an unparalleled opportunity to improve the management of our shared resources, but California's ability to adopt this technology and harness its benefits on a wide scale is uncertain.

At present, NASA and research funding for ASO surveys has ended. A growing coalition of local and regional water users with a strong belief in the value of the technology has emerged to provide gap funding through the 2019 snow season for ASO surveys of the Tuolumne, San Joaquin, and Kings river basins. This same water-user coalition intends to broadcast the successes experienced by the ASO program and explore opportunities to leverage the range of benefits ASO could provide if implemented statewide.

"ASO provides invaluable information that is not otherwise available, most importantly information about the rate of melt that provides a real opportunity to optimize reservoir operations for water supply, flood control, and instream requirements."

Steve Haugen, Watermaster, Kings River Water Association

"What you've done is created new reservoir space and water supply without any impacts to the current physical or environmental paradigms."

Wes Monier, Chief Hydrologist, Turlock Irrigation District

"Having used this technology, it is hard to imagine a future without it."

Dave Rizzardo, Chief of Snow Surveys and Water Supply Forecasting, Department of Water Resources

"Advanced observing systems are critical elements needed to support integrated water management in the 21st Century."

Mike Anderson, State Climatologist, Department of Water Resources