

Large-scale Snow Water Equivalent Estimation: Optimal Use of Remote Sensing and Snow Modeling

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Snowpacks are a primary source of water in the western United States, with runoff from snowmelt often supplying over half of the annual water consumption. For this reason, water resource planners invest considerable effort in estimating the water stored in mountain snowpacks in order to predict the spring snowmelt. For instance, planners for the city of Los Angeles conduct annual snow surveys at selected locations, compare the measured snow depth to years of historical measurements, and make predictions based on observed streamflow from past years with similar snow depths. Across the West, important managerial decisions affecting reservoir management, hydroelectricity generation, and irrigation policies rely on such streamflow predictions. Unfortunately, point-scale observations often are not representative of basin-wide snow characteristics, and the empirical relationships used to make predictions are subject to large errors, especially under the prospect of climate change.

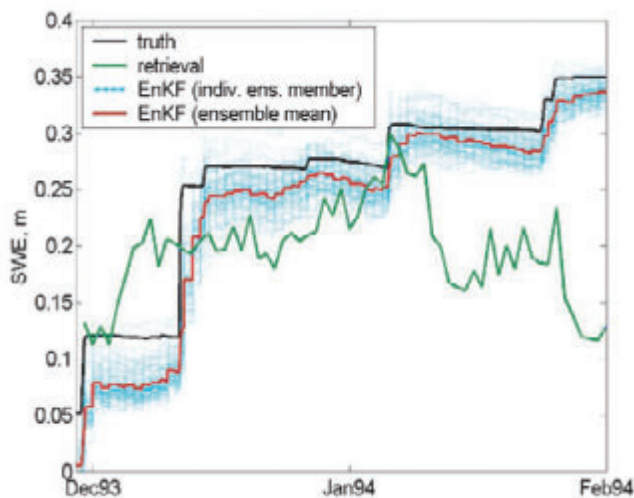
Photo by Noah Molotch – University of Colorado, Boulder.

Measurement and Modeling of Snow

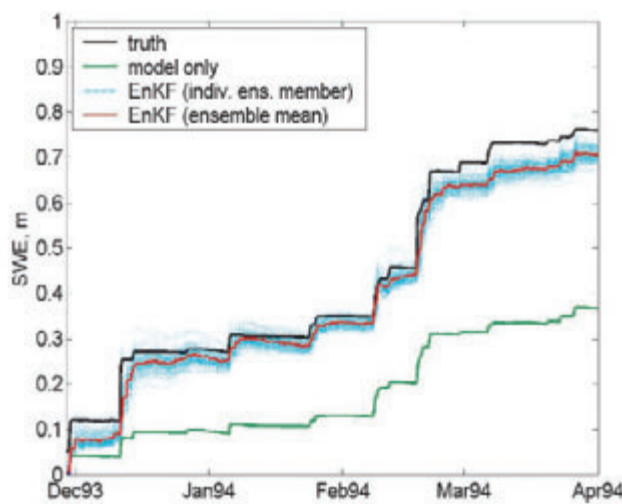
Snow water equivalent (SWE) is the equivalent depth of liquid water stored in a snowpack. The need to obtain more accurate and robust estimates of SWE in mountainous watersheds has motivated research for over fifty years and prompted the development of in-situ measurement techniques, physical and empirical models of snow accumulation and ablation, and the use of remote sensing instruments for retrieval of snow parameters.

In-situ SWE Measurements:

The National Resources Conservation Service maintains a snow telemetry (SNOTEL) network of approximately 600 in-situ sensors that automatically measure SWE. These data provide very accurate observations, but at a very limited number of locations in the United States. While SNOTEL gauges provide a valuable data product used for forecasting and water resources management, the limitations of



Comparison of the EnKF and retrieval SWE estimates to true values early in the accumulation season.



Comparison of the EnKF and model-based SWE estimates to true values over the entire accumulation season.


the method have led researchers to develop other methods for SWE estimation.

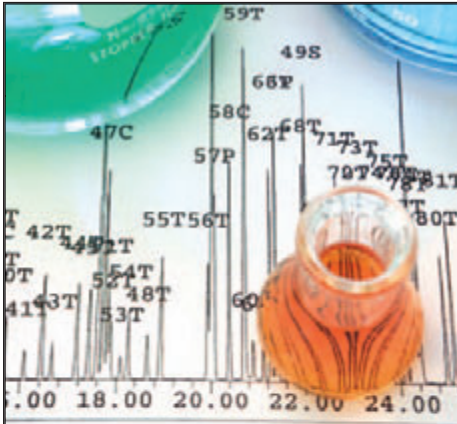
SWE Models: Attempts have been made to model snowpack evolution using numerical models of varying complexity. These models require several meteorological forcing variables as inputs, including precipitation and air temperature. Measurement of input data, especially snowfall in mountainous regions, is notoriously difficult; gauge undercatch of 50 percent is not uncommon. Furthermore, the model structure and parameterizations are subject to uncertainty. While modeled SWE estimates generally are less accurate than in-situ measurements at a point, they are valuable because they can better capture the spatial variability of snow when appropriate ancillary inputs such as topography and meteorological data are available.

SWE Retrieval from Satellite

Observations: Remote sensing data have been used for over thirty years to estimate both snow-covered area (SCA)

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