ASSIMILATION OF MODIS SNOW COVER PRODUCTS INTO OPERATIONAL HYDROLOGIC FORECAST MODELS

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Introduction

The aim of this project is to improve operational streamflow forecast models by assimilating MODIS snow cover products into the hydrologic models used by the National Weather Service and other agencies. In such models, proper initialization is critical for accurate simulation of snowmelt and streamflow at a range of time and space scales.

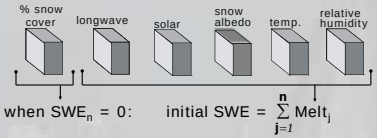
The target region is the Sierra Range but initial efforts are focused on the Kaweah, Merced, and American basins.

Research Questions:

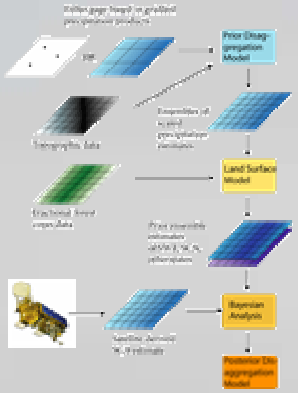
1. How does climate variability influence rates of snow cover depletion and snow albedo decay on intra-seasonal and inter-annual time scales?
2. Does representation of this variability using MODIS snow cover products improve the accuracy of the National Weather Service River Forecast System?
3. Does incorporation of MODIS measurement uncertainty using the Ensemble Kalman Filter reduce the sensitivity of model performance to inter-annual climate variability and ultimately improve forecasts?

MODIS Snow Water Equivalent Reconstruction Model

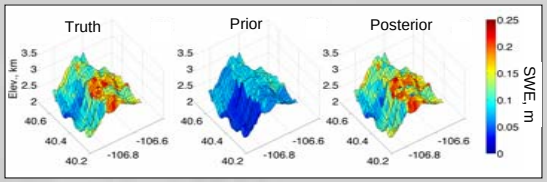
The basis for the SWE reconstruction approach is that satellite observations of snow cover depletion have information about snow accumulation; e.g. snow persists in a given area because initial snow accumulation is greater and/or snowmelt rate is lower. The information in the snow-cover depletion record can be enhanced by modeling spatial variability in the melt rates across the landscape. In this approach, we reconstruct the amount of snow in a grid cell at a previous time based on the cumulative melt flux over the period of observed snow cover.



Snowfall Reconstruction Using Bayesian Analysis of MODIS Snow Cover



1. Develop "Prior" precipitation estimate (e.g. Theissen polygon or an inverse-distance weight).
2. Force a land-surface model coupled to a snow depletion curve model, and obtain a prediction of the SCA at each pixel, and at each time measured via satellite.
3. Use the difference between the predicted and observed SCA in a Bayesian analysis to obtain an interpolator that extends point measurements of snow to a spatial grid.

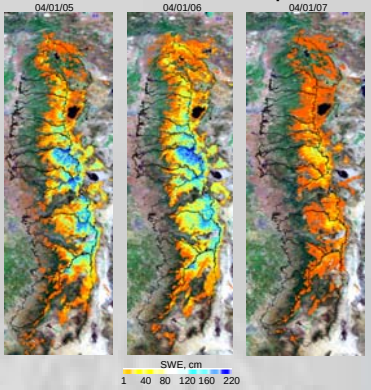


Synthetic tests of the Bayesian reconstruction performed over the NASA Cold Lands Processes Experiment Domain indicate that, at maximum snow accumulation (e.g. 6 March 2003), the posterior and true state variables have similar spatial patterns, while the prior has a significantly different spatial pattern. The incorrect spatial pattern in the prior SWE was thus effectively corrected. (*Durand et al., in press*).

MODSCAG – Dozier et al., in press

Time series of MODIS fractional snow covered area show persistent snow in the higher elevations of the central and southern Sierra Nevada.

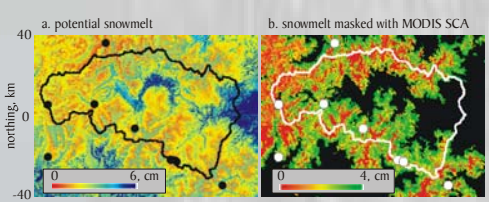
Sierra Nevada Snow Water Equivalent



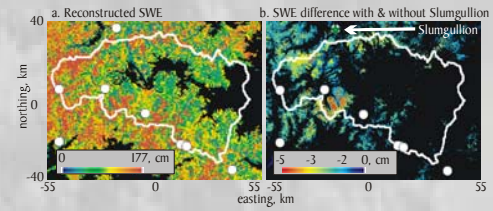
- Reconstructed SWE across the Sierra Nevada reveals inter-annual variability in the magnitude and spatial distribution of snow accumulation.
- Multi-year simulations will be used to derive snowmelt forcings in distributed runoff forecast models. (*Molotch et al., in preparation*).

MODIS SWE Reconstruction VS Point Interpolation

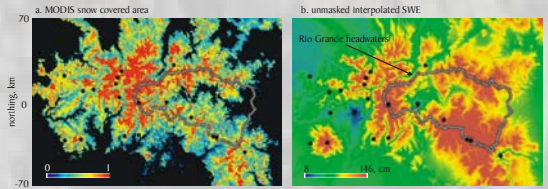
Potential snowmelt flux was calculated assuming snow across the domain; example shown for 10 May 2001 (a). Snowmelt surfaces were masked using the MODIS remotely sensed snow cover data (b).



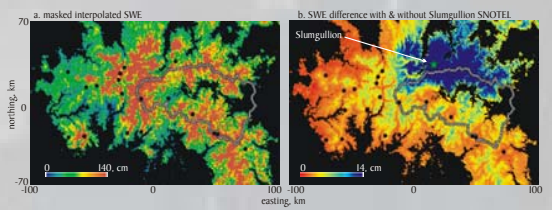
Masked snowmelt surfaces were integrated to estimate SWE (a). Reconstructed SWE estimates on 24 April 2001 generated with and without air temperature data from the Slumgullion SNOTEL site (green star) showed only subtle differences (b).



We illustrate the utility of the reconstruction by comparing SWE estimates with those obtained from an elevation-detrended, inverse disance weighted (IDW) interpolation of 21 snow pillow observations (dots) (b).



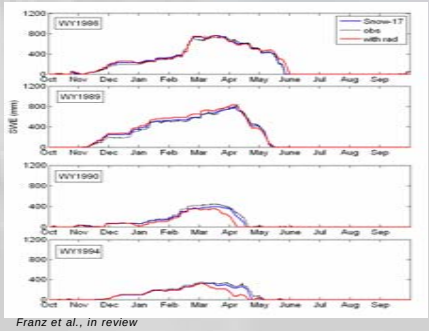
Unlike the reconstructed SWE, IDW-SWE estimates were highly sensitive to point observation locations (a); e.g. dramatic differences in SWE resulted from the removal of the Slumgullion SNOTEL station (green star) (b) (*Molotch, in press*).



Streamflow Forecasts

Simulations of streamflow were performed for WY 1986, '89, '90, '94) using the standard application of the NWS SNOW17 and a version with explicit representation of snow surface albedo and snow cover extent. This addition resulted in improved estimates of snowmelt timing in deeper snowpack years.

The added energy balance component allows MODIS data (i.e. albedo) to be input into the SNOW17, while maintaining much of the original structure of the model.



Franz et al., in review

Future Directions

1. Apply the Bayesian snow water equivalent reconstruction model over the Sierra Nevada for the entire MODIS record (2000 – 2009).
2. Evaluate model performance using leveraged distributed instrument clusters across the Sierra Nevada as part of the Sierra Nevada Hydrologic Observatory.
3. Perform simulations using the modified version of the NWSRFS and compare to the existing NWSRFS at NWS forecast points at the outflow of the Merced, American, and, Kaweah River basins.

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