Assimilation of MODIS Snow Cover Data into the SAC-HT/SNOW17 Model over the Western US

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Abstract
As both the model predictions and passive microwave snow water equivalent (SWE) observations contain large errors due to land surface complexities and temporally frequent snowmelt processes in the western United States, the 500m daily MODIS snow cover area (SCA) product has been used in this study as an important constraint on snowpack processes in land surface and hydrological models. The uncertainty in MODIS SCA product has been assessed over the study basin, and quality control will be applied to the MODIS SCA product before assimilated into SNOW17 model.

In this study, we assimilate the MODIS-derived snow cover fraction into the SNOW17 model operating on the HRAP (Hydrologic Research Analysis Project) grid at 4.7625km resolution over DMIP II Carson River basin domains. We update the snow cover fraction values at pixels which feature less than 50% cloud coverage. Because the change of snow cover fraction makes no change to the amount of snow water equivalent in SNOW17, we had to develop a new scheme to account for the effect of change in snow cover fraction to total snow water equivalent. We selected the traditional bias correction method to study this inverse problem. The iterations will depend on the defined error tolerance, which was arbitrarily set to 0.01. Our initial sensitivity experiments show most results converged after 10-15 iterations with this error tolerance, and the computational burden is not large. The assimilation results have been evaluated by SNOTEL SWE (in-situ measurements).

Models
The models used in this study include: SAC-HT version of SAC and SNOW17 under the NASA LIS (Land Information System) framework for land modeling. The study area is in Sierra-Nevada Basin on HRAP grid, and the forcing (temperature and precipitation) is from DMIP II.

MODIS Derived SCF on HRAP Grid
Terra-MODIS Level 3 500m Daily Snow Cover Area Data were aggregated onto HRAP grid at 4.7625km resolution to generate the snow cover fraction data. The HRAP grid is treated as cloud covered when the cloud cover fraction is above 50%.

Data Assimilation
The above figures show the daily snow cover fraction in April 2002 from two simulations: (LEFT) The open loop simulation; (RIGHT) Data assimilation simulation.

LEFT: Comparison of snow cover fraction between the MODIS, the open loop simulation and the assimilation simulation.

RIGHT: Comparison of snow water equivalent between the open loop simulation (green), the assimilation simulation (red) and the in-situ measurement (black) averaged over all SNOTEL sites in the study region.

Summary
This study has investigated remotely-sensed MODIS snow cover estimation uncertainty. For cloud-free pixels, the MODIS SCA retrieval errors can be quantitatively predicted by temperature with regional calibrated parameters.

The preliminary experiments show that the snow cover fraction after assimilation shows close agreement with the MODIS SCA values. Comparison at an individual grid between open loop and assimilation simulations shows that the snow water equivalent is also improved through assimilation of MODIS SCA.

Future Plan
- We will apply the statistical equation to depict the uncertainty in MODIS snow cover fraction, and further to apply the ensemble Kalman Filter (EnKF) in our data assimilation scheme.
- We will couple SAC-HT/SNOW17 to a stream flow model in order to use station stream flow measurements as additional method to verify the performance of our assimilation.