Geophysical Research Abstracts
Vol. 15, EGU2013-4861, 2013
EGU General Assembly 2013

Estimating mountainous snow water equivalent via ensemble Kalman filtering with improved AMSR-E observation and model representation

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Snowpack in the Sierra Nevada mountain ranges serves as a critical water resource and an important climate indicator. Accurately estimating snow water equivalent (SWE) and melt timing in the Sierra has both civil and scientific merits. Passive microwave remote sensing (PM) contains spatial-continuous SWE information, however its coarse resolution makes it difficult or impossible for direct SWE retrieval in mountainous regions. Physical process based land surface model (LSM) could be set up at high spatial resolution to simulate SWE, nevertheless biased meteorological forcing usually lead to significant biased and uncertain modeling results. Assimilating PM into LSM could combine the advantages of both sides, offering a path to a better SWE characterization in mountainous area.

In this study, downscaled PM measurements are assimilated into a high-resolution model through Ensemble Kalman Filter (EnKF) to estimate SWE in the Sierra. The study is carried out at Kern Basin where SWE are highly variable as a result of complex terrain. SSiB3 and MEMLS are coupled to provide priori prediction. NLDAS2 data are used to force the coupled model, bias in NLDAS2 has been pre-removed via Bayesian reconstruction. AMSR-E brightness temperature (Tb) is assimilated into the model to reduce the model error and uncertainty. The novelty of this study is that both modeling and PM measurements, which are two SWE information resources in EnKF, have been enhanced to contribute more signals. As there is more information in both model prediction and measurement, it is reasonable to expect an even better posterior SWE than previous EnKF PM assimilations. In this study, rather than using EASE-Grid Tb, the Tb data is obtained by processing raw AMSR-E 37GHz V-pol observed Tb at its native footprint resolution (L2A) of 14 km x 8 km, which is 1/6 of the size of an EASE-Grid cell. Preliminary results show this effective rise in data resolution makes L2A Tb contains three times more information about SWE and melt-onset than EASE-Grid Tb. From the modeling aspect, several dominant parameters in Tb simulation have been identified and calibrated, some snow processes that have considerable effects on Tb simulation but are missing in previous modeling are added. Experiments demonstrate the modeled Tb could be highly correlated with the AMSR-E measurements (r2=0.93) during accumulation season at point scale. At basin scale, modeled Tb at the Upper Kern is aggregated to AMSR-E 37GHz resolution to compare with the raw observed AMSR-E Tb, the RMSE across the Upper Kern Basin (∼1200km2) is ∼6.7K. Besides these preliminary experiments, in this study the coupled model is also run at 90m-resolution across the entire Kern Basin to evaluate the model's accuracy in Tb and SWE prediction as well as its ability to capture the variability of SWE and Tb. EnKF assimilation is carried out at five gages where well-controlled in-situ data are available, posterior EnKF SWE estimates are compared with in-situ measurements for validating and calibrating the EnKF scheme for the basin-scale assimilation in the next step.