Space-borne soil moisture measurements in support of flood hydrology: The NASA SMAP approach

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Soil moisture fields play a critical role in the triggering and evolution of many flooding events. Given the inherent difficulty of either mapping soil moisture using ground-based instrumentation or estimating it using land surface water balance modeling, the availability of reliable soil moisture retrievals from satellite-based sensors is expected to aid in the prediction and/or mitigation of flooding hazards. Slated for launch in 2013, the NASA Soil Moisture Active/Passive (SMAP) mission is a dual L-band active/passive microwave instrument that will substantially increase our ability to estimate surface soil moisture at regional spatial scales (10 to 30 km). These enhancements should be relevant for a range of potential hydrologic applications. In particular, the flood hazard prediction problem requires accurate information about both the ability of a given watershed to infiltrate rainfall and the volume of subsequent rainfall. This paper will discuss the potential impact of SMAP soil moisture measurements on the availability and accuracy of both types of information.

A basin's antecedent infiltration capacity is largely determined by its dynamic soil moisture content. Within the United States, such information is operationally summarized in National Weather Service (NWS) Flash-Flood Guidance (FFG) products which spatially superimpose soil moisture estimates derived from soil water balance modeling with quantitative precipitation estimates from ground-based radar. Using previous studies based on AMSR-E soil moisture retrievals, we will present evidence that remotely-sensed soil moisture observations can enhance the estimation of antecedent soil moisture conditions and provide added flood forecasting skill above and beyond that obtainable from rainfall observations and soil water balance modeling. Such improved skill should translate into improved flash-flood risk assessment. Relative to AMSR-E retrievals, SMAP surface soil moisture products will provide higher resolution soil moisture information at a finer spatial resolution. The potential benefit of integrating new SMAP soil moisture products into NWS flash flood guidance products will be discussed. In particular, the availability of finer-scale SMAP soil moisture retrievals should extend the range of spatial scales (and thus number of individual flooding events) for which remotely-sensed soil moisture retrievals are of value.

For main-stem flooding events within large-scale basins, downstream flood peak predictions can be based on observed precipitation and are not solely reliant on quantitative precipitation forecasts from a NWP model. In such cases, remotely-sensed surface soil moisture retrievals can also be used to improve the accuracy of short-term rainfall accumulations estimates used as input for rainfall-runoff modeling. This potential will be verified using AMSR-E soil moisture retrievals over the continental United States. The ability to correct rainfall offers up the possibility of designing new flood forecasting procedures which leverage the ability of SMAP soil moisture retrievals to simultaneously constrain both antecedent soil moisture conditions and near-past rainfall accumulation estimates. A new Ensemble Kalman Smoothing data assimilation system capable of such simultaneous correction will be presented and demonstrated using AMSR-E observations and data from the Model Parameterization Experiment (MOPEX).