Application of SMAP Soil Moisture data for Flash Flood Forecasting Using HL-RDHM Model

Dugwon Seo, Tarendra Lakhankar, and Reza Khanbilvardi

NOAA-Cooperative Remote Sensing Science and Technology Center, The City College of New York

National Oceanic and Atmospheric Administration
Cooperative Remote Sensing Science and Technology Center

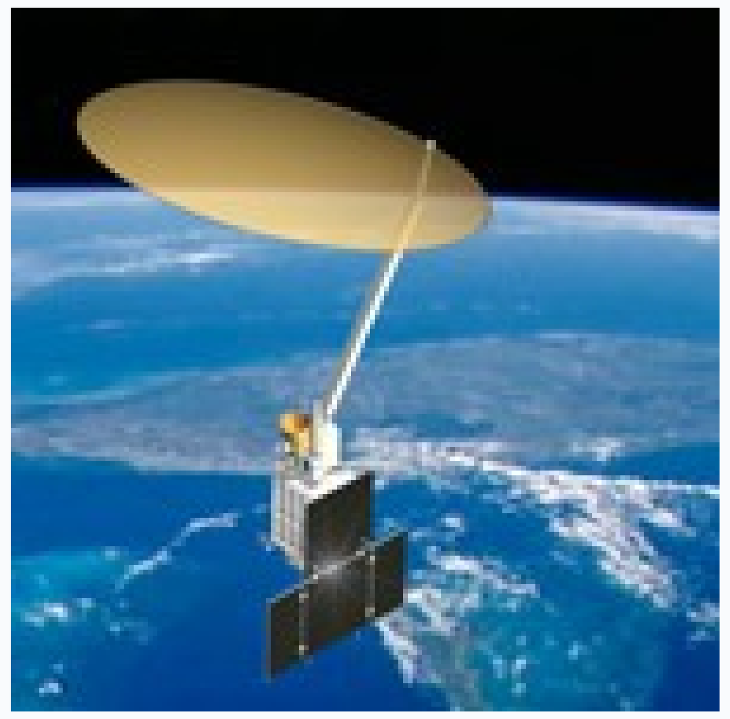
NOAA-CREST

Abstract

The main objective of this research is to evaluate the contribution of remote sensing technology to quantifiable improvements in flash flood applications. The study is focused on adding remote sensing component to hydrological Flash-Flood Guidance (FFG) Algorithm. The current operational FFG algorithm applies precipitation based Antecedent Precipitation Index (API) to counties across the USA and use the Mosaic NEXTRAD to issue Flash Flood Warnings. In order to determine the values of the SMAP data (or Remote Sensing data from AMSR-E) to NWS operations, we will merge SMAP test-bed soil moisture data to FFG algorithm to evaluate how many hits, misses and false alarm generated. The high resolution (1 km) test bed data have space dynamics of soil moisture, temperature from an integration of a distributed (DEM based) hydrological model. The same experiment can be repeated for the main-stem flooding model of the NWS (essentially Sacramento). Both cases will evaluate the value of remote sensing data to constrain the state of the system for main-stem and flash flood forecasting.

SMAP Mission

Soil Moisture Active and Passive (SMAP) is implemented as a directed mission within the NASA Earth Systematic Mission Program. SMAP will use a combined radiometer and high-resolution synthetic aperture radar operating at L-band (1.20-1.41 GHz) to measure surface soil moisture and freeze-thaw state. The instrument is designed to make coincident measurements of surface emission and backscatter, with the ability to sense the soil conditions through moderate vegetation cover. Direct measurements of soil moisture will help understanding of regional and global water cycles, ecosystem productivity and the processes that link the water, energy, and carbon cycles.



Mission	SMAP	
Launch	2015	
Duration	3 years	
Instrument concept	Active microwave - Synthetic Aperture Radar	Passive microwave - Radiometer
Frequency	L-band :1.26 GHz (H) 1.29 GHz (V)	L-band :1.41 GHz
Polarization	HH, VV,HV	H, V, U
Radiometric resolution	1 - 3 km	40 km
Angular range	40 degrees	
Swath width	1000 km	
Temporal resolution	global coverage within 3 days at the equator and 2 days at boreal latitudes (>45°N)	

SMAP Application: Flash Flood Guidance

There is no in situ global soil moisture data since it is difficult to conduct ground-based measurements of soil moisture consistently and regionally. Not only in situ global soil moisture data but also satellite capability to monitor and map soil moisture and freeze/thaw sate is absent. Therefore, as far, soil moisture has been derived from models and agencies such as the National Weather Service hydrologic services proxy estimates of soil moisture at the surface in order support operational flood forecasting. A daily national map of Flash-Flood Guidance (FFG) is produced that is an estimate of soil moisture deficit at the surface.

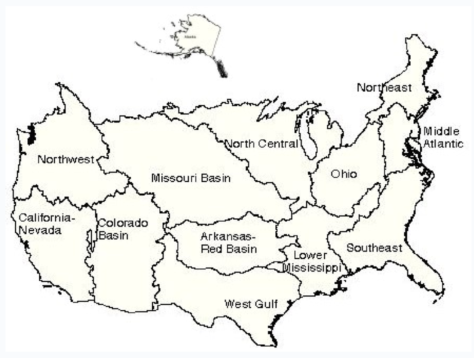
The use of remote sensing to measure soil moisture has been researched over the last twenty years, using both passive and active microwave instruments. Passive microwave remote sensing in low frequency has been optimal to estimate soil moisture since it is very sensitive to the dielectric properties of the surface. Also, low frequency has advantage of longer penetration, therefore, more information on the vegetation optical depth and less atmospheric effect.

SMAP will provide direct observations of soil moisture with an order of magnitude higher resolution. Such data are recognized to be of great value to the development and evaluation of improved FFG and flood warning systems.

Study Area

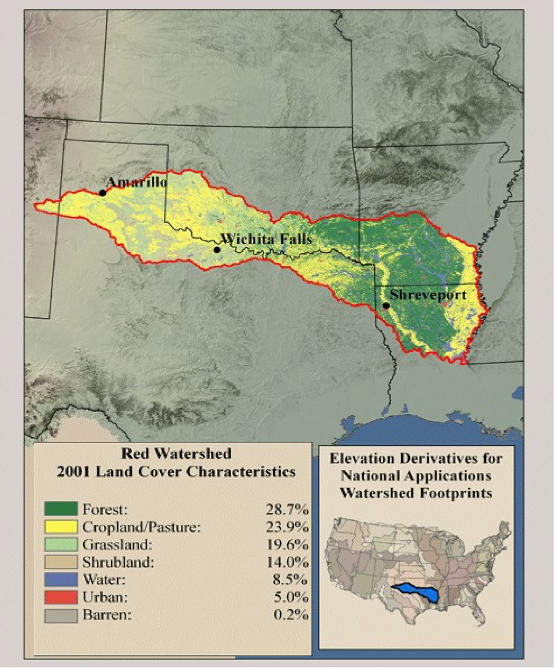
Arkansas Red Basin River Forecast Center(ABRFC)

- Red Watershed



River Forecast Centers

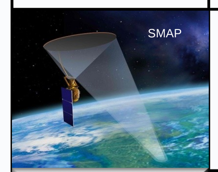
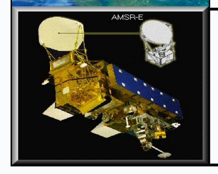
The Red River's watershed covers 65,590 square miles (169,900 km2) and is the southernmost major right tributary of the Mississippi, and the southernmost major river system in the Great Plains. Its drainage basin is mostly in the states of Texas and Oklahoma, but also covers parts of Arkansas and Louisiana.

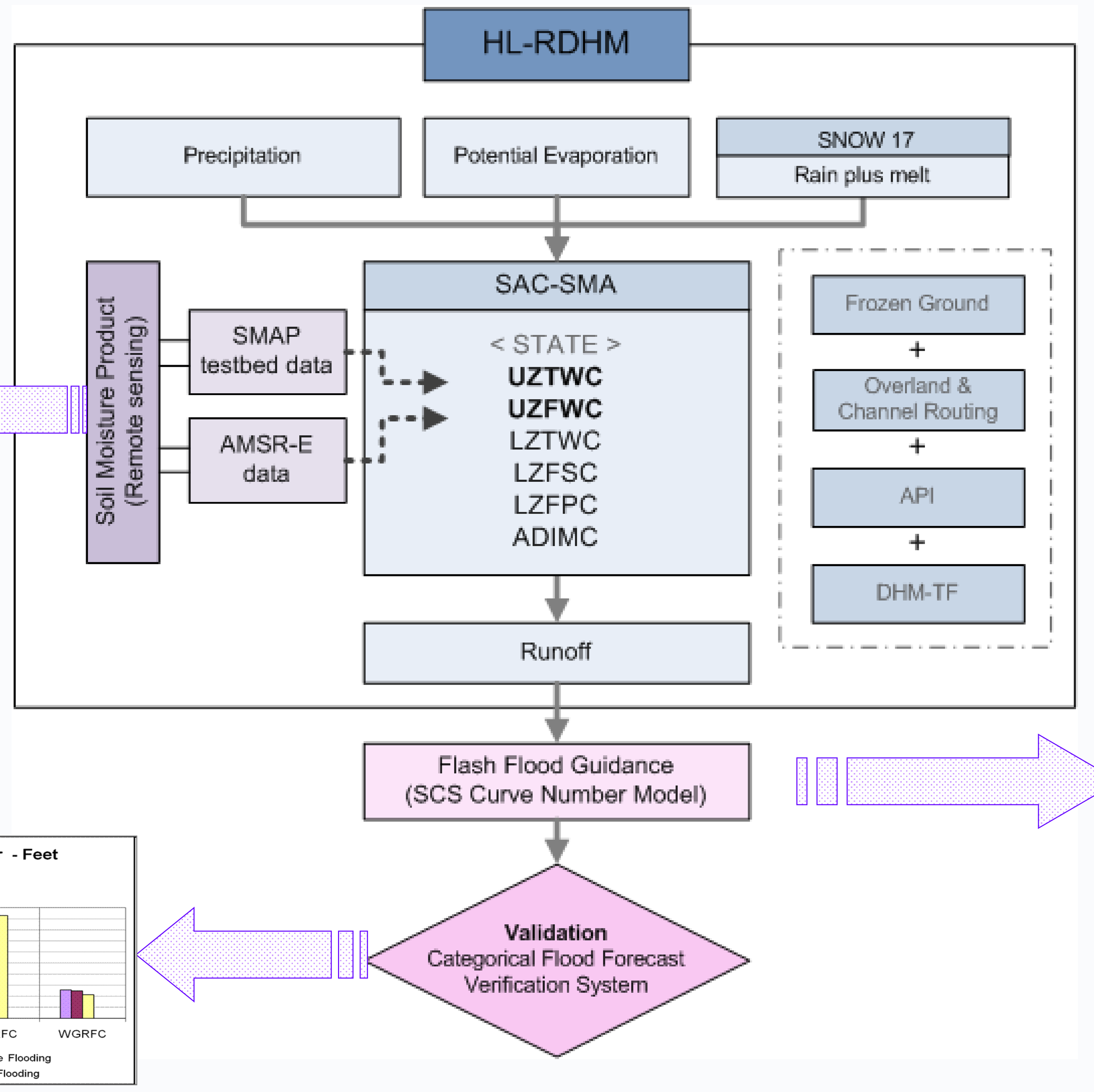


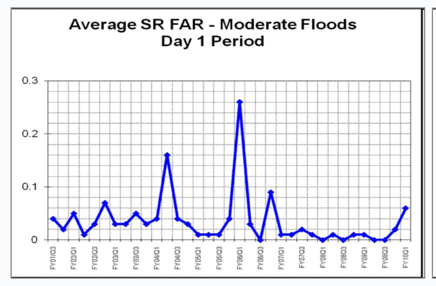
www.edna.usgs.gov/watersheds

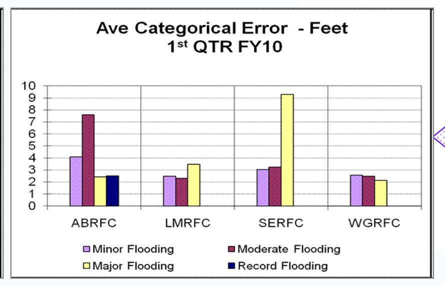
HL-RDHM Model Flow Chart

- Two soil moisture products from the satellite retrieval (SMAP and AMSR-E) will be inserted in the initial state of SAC-SMA for the upper zone and corresponding output runoff will be compared with model estimation.
- Soil moisture retrieval from AMSR-E with C band (6.9 GHz) has the limitation of high attenuation by vegetation, the shallow sensing depth and RFI contamination near large urban areas.
- SMAP has lower frequency than AMSR-E that gives advantage of deeper penetration and less attenuation by vegetation and surface roughness effects.

Instruments	Frequency (Band)	Spatial Resolution	Swath width
	1.2 -1.4 GHz (L band)	10 km (combined product)	1000 km
	6.925GHz (C band)	38 km	1445 km







www.srh.noaa.gov

NRCS Curve-Number Model

$$Q = \frac{(P - 0.2S_{sm})^2}{P + 0.8S_{sm}} \quad (1)$$

Where:

Q = runoff (in)

P = precipitation (in)

S_{sm} = initial abstraction (storage)

FFG represents the precipitation required to produce a given runoff value (threshold runoff). Therefore equation (1) is solved for P, the FFG value.

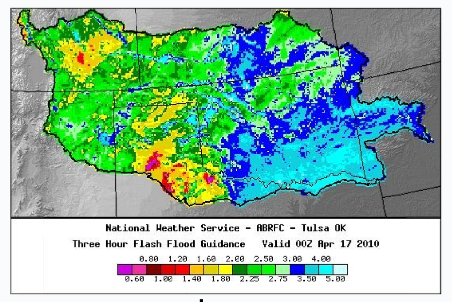
$$P = \frac{0.2S_{sm} + Q_x \pm \sqrt{2Q_x S_{sm} + Q_x^2}}{2} \quad (2)$$

$$P = FFG_X ;$$

Where:

FFG_x = rainfall in x hours required for flash flooding to begin

Q_x = threshold runoff for x hours



www.srh.noaa.gov

Future Work

- A data denial framework will be employed to test the Flash Flood Guidance system using SMAP test-bed soil moisture data.
- SMAP test-bed soil moisture data will be applied to Categorical flood forecast verification system from NWSRFC to evaluate the flash flood guidance.
- A comparative study of flash flood guidance accuracy will be carried out between SMAP, AMSR-E and Sacramento based soil moisture.