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

NOAA CREST

Incorporation of SMOS Soil Moisture Data on Gridded Flash Flood Guidance for Arkansas Red River Basin

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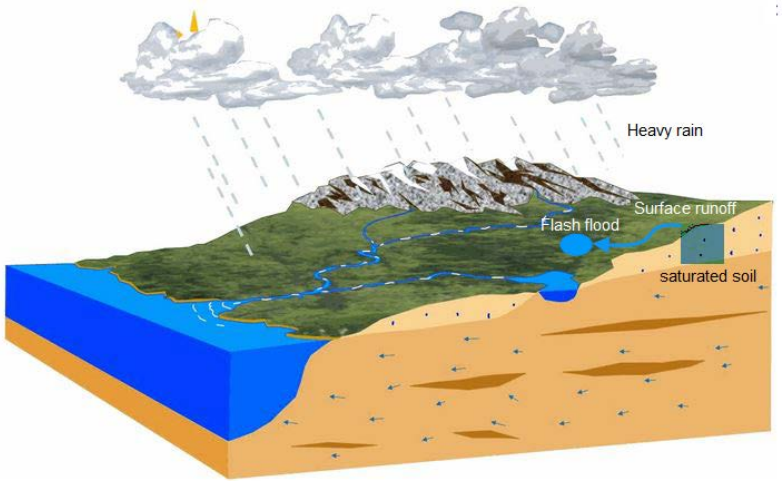
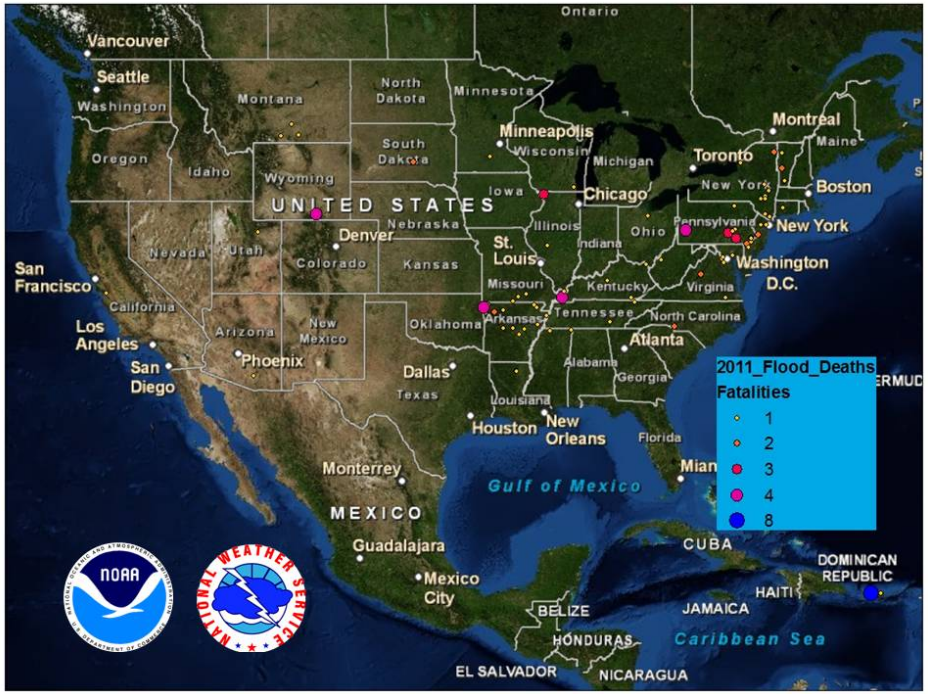
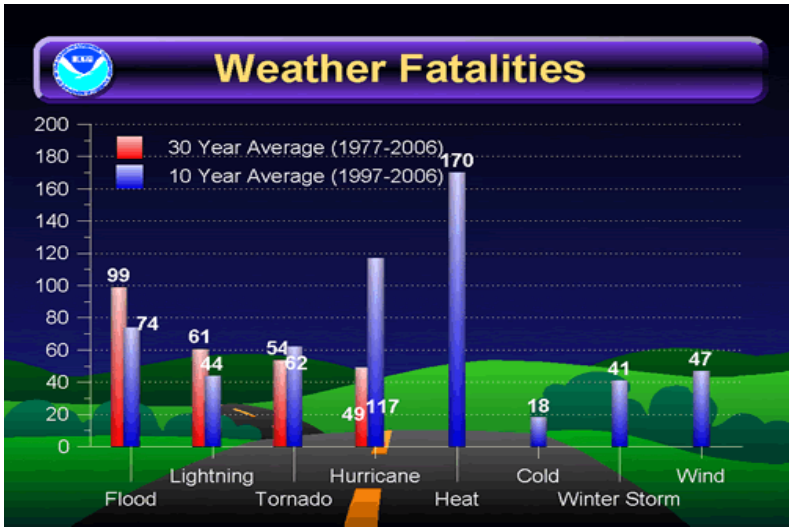
Flash Flood

- Flash flood is “a rapid flooding of water over land caused by heavy rain or a sudden release of impounded water in a short period of time, generally within minutes up to several hours.”
- Flash floods are distinguished from a regular flood by a timescale less than six hours.
- In the US, flash flooding is the number one killer among all weather-related hazards with approximately 140 lives are lost each year (Ashley, 2008).

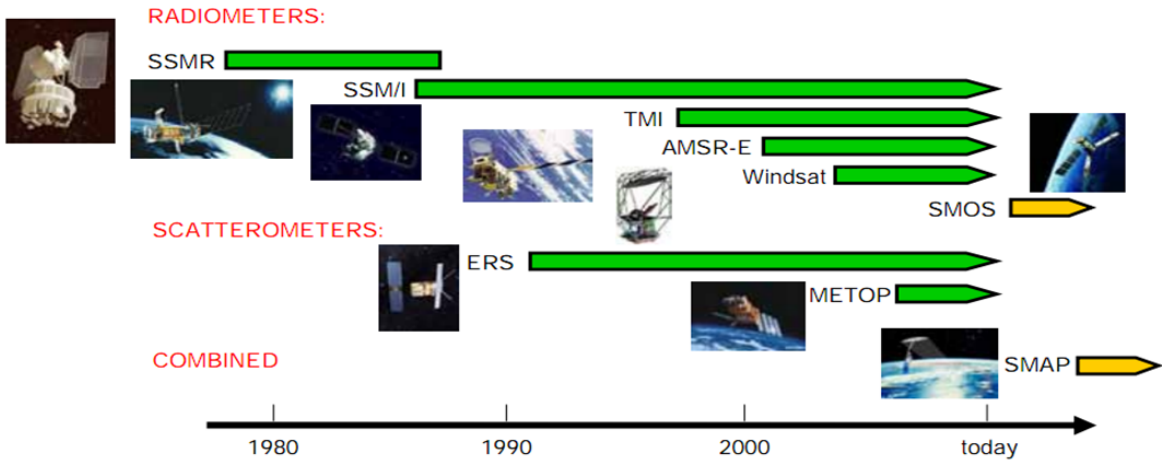






Source – http://www.nws.noa.gov/oh/hic/

Introduction: Soil moisture and remote sensing



- INSTRUMENTS:

1. SMAP(Soil Moisture Active Passive)

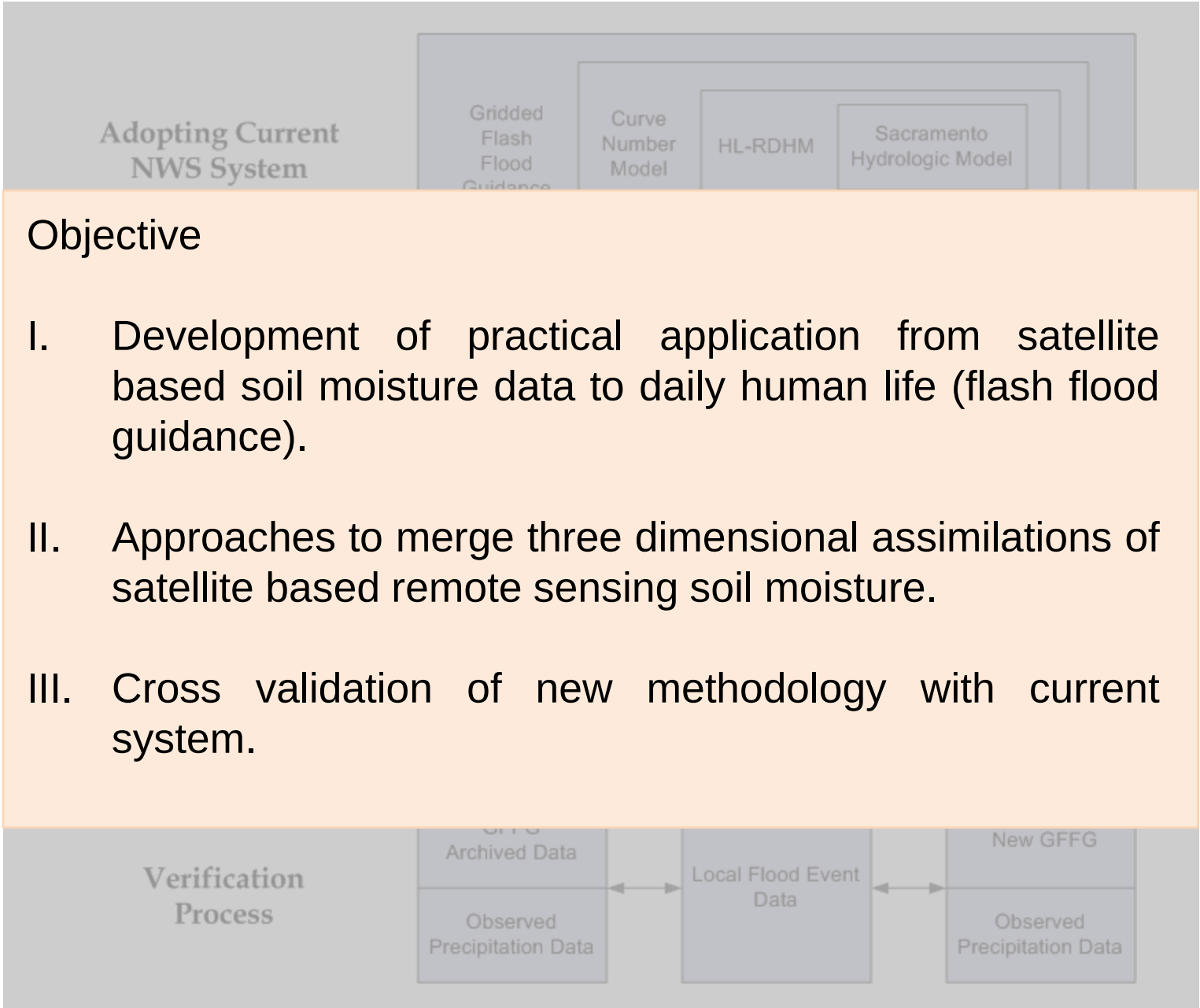
- *NASA JPL*
- *Will be launched in 2015*
- *L-band (1.26 GHz) radar*
  - *High resolution, moderate accuracy soil moisture*
  - *SAR mode: 3 km resolution*
- *L-band (1.4 GHz) radiometer*
  - *Moderate resolution, high accuracy soil moisture*
  - *40 km resolution*

2. SMOS (Soil Moisture and Ocean Salinity)

- ESA (European Space Agency) project
- Launched in November 2009
- L-band (1.4 GHz) MIRAS (Microwave Imaging Radiometer with Aperture Synthesis)
- Spatial resolution: 30-60 km

** SMOS data is selected due to its availability year (2010-current)*

Overview/Objective



Objective

I. Development of practical application from satellite based soil moisture data to daily human life (flash flood guidance).

II. Approaches to merge three dimensional assimilations of satellite based remote sensing soil moisture.

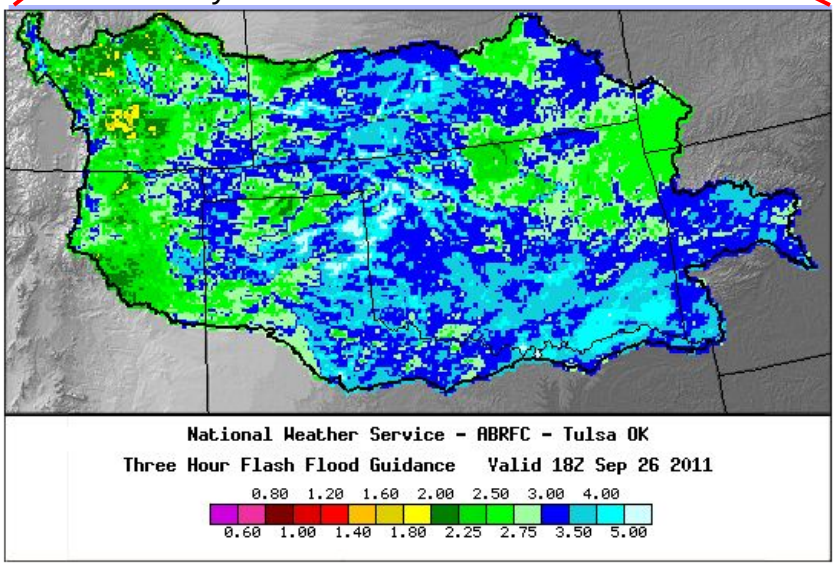
III. Cross validation of new methodology with current system.

Study Area

Gridded Flash Flood Guidance (GFFG)

- Operational spatially-variable, physically-derived Model by Arkansas-Red Basin River Forecast Center, NWS
- Defined as “the threshold rainfall required to initiate flooding on small streams that respond to rainfall within a few hours”. (Sweeney 1992)

Study area - Arkansas Red Basin



Current system: Gridded Flash Flood Guidance (GFFG)

Gridded Flash Flood Guidance (GFFG) is

- Based on Runoff and NRCS Curve Number (CN) model.
- Utilize soil moisture condition for CN adjustment from Distributed Hydrological model (HL-RDHM) developed by Office of Hydrologic Development, NOAA

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

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

S_m = (1000/CN)-10

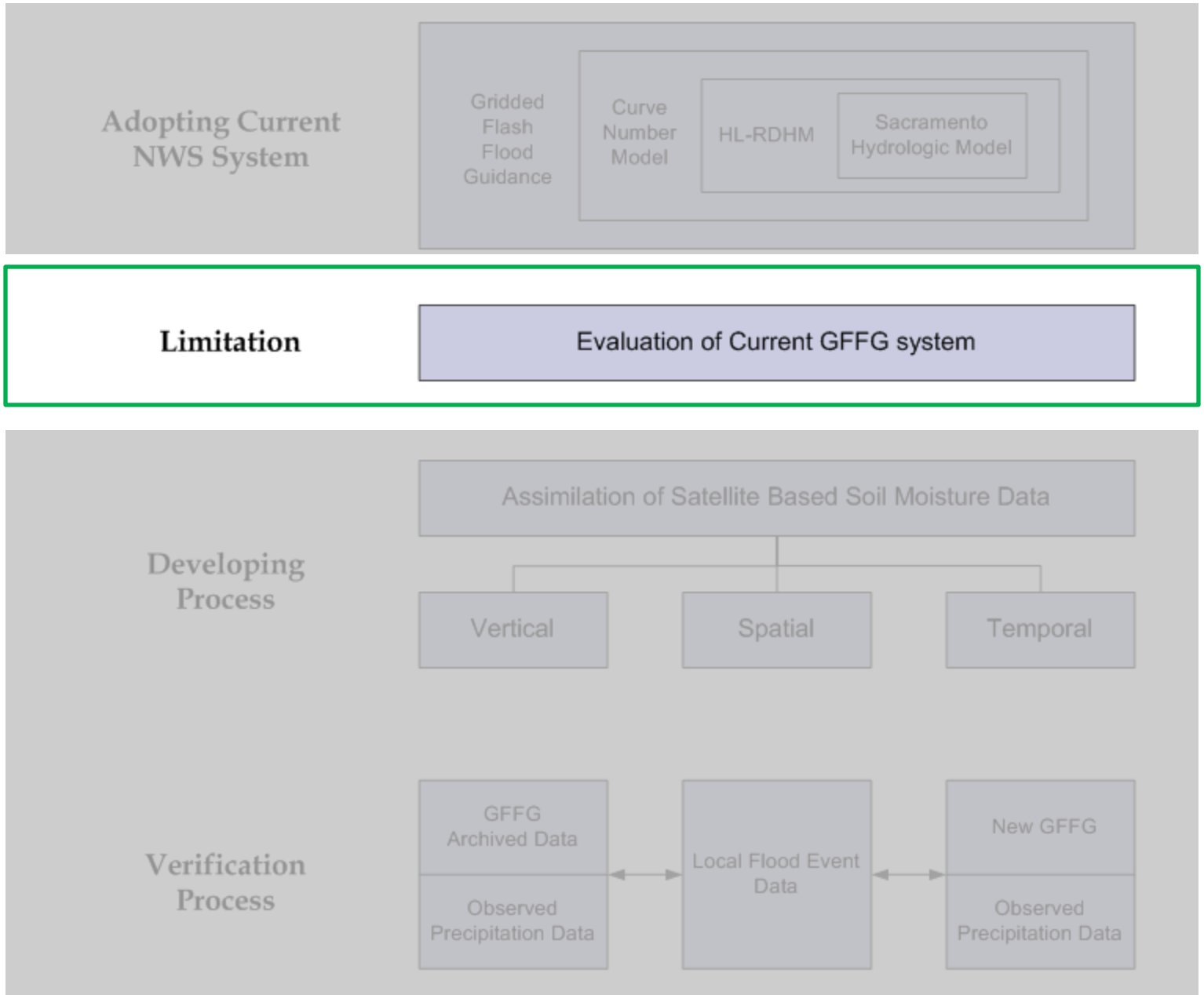
Q_x = ThreshR= $\frac{Estimate\ of\ bankful\ discharge\ (L^3/T)}{Unit\ hydrograph\ peak\ flow\ (L^3/T/L)}$

HL-RDHM
Upper zone saturation= $\frac{uztwc + uzfwc}{uztwm + uzfwm}$

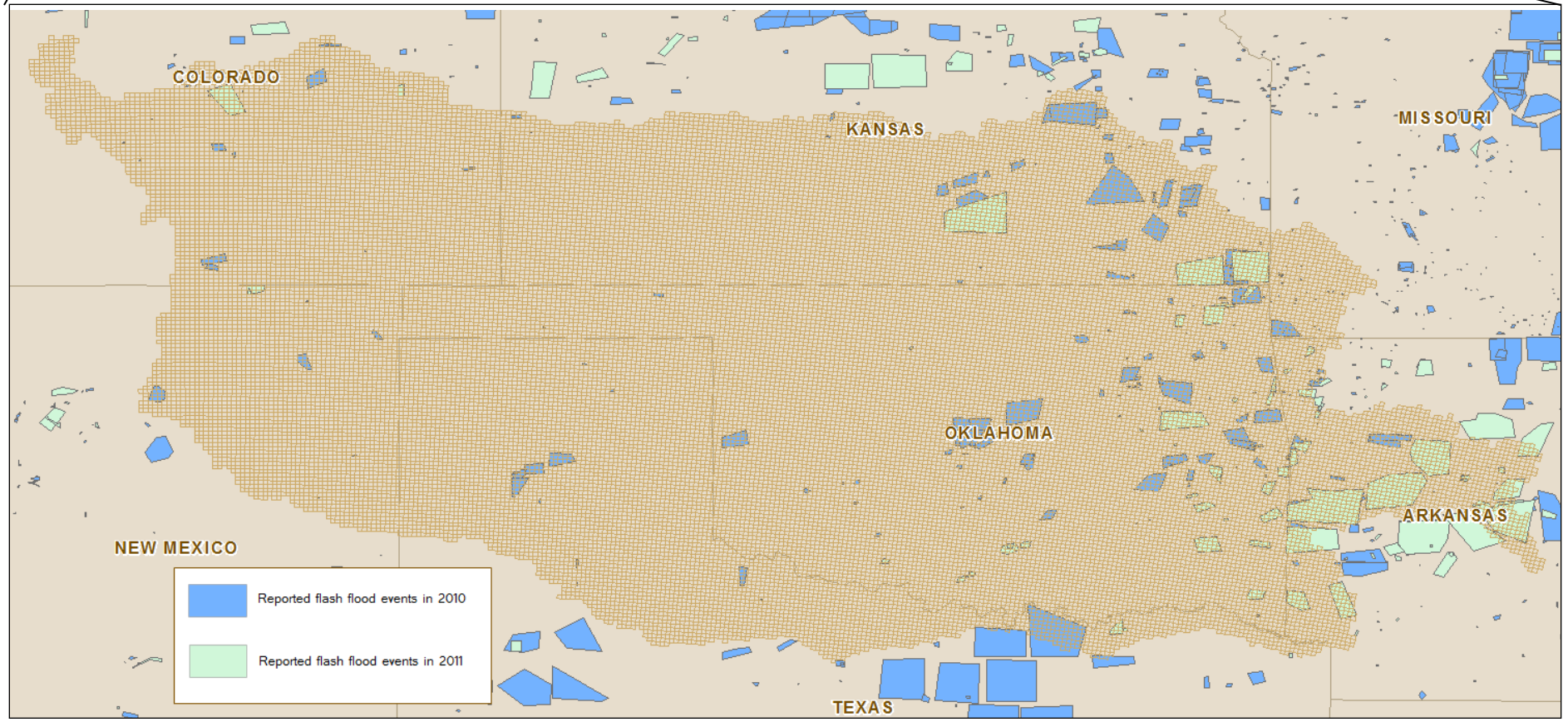
(3) $\mathbf{P = FFG_x^{(inch)}}$

Q_x = Runoff
S_{sm} = Potential maximum soil moisture retention after runoff begins
P = Precipitation (rainfall in x hours required for flash flooding to begin)

High-Level Summary

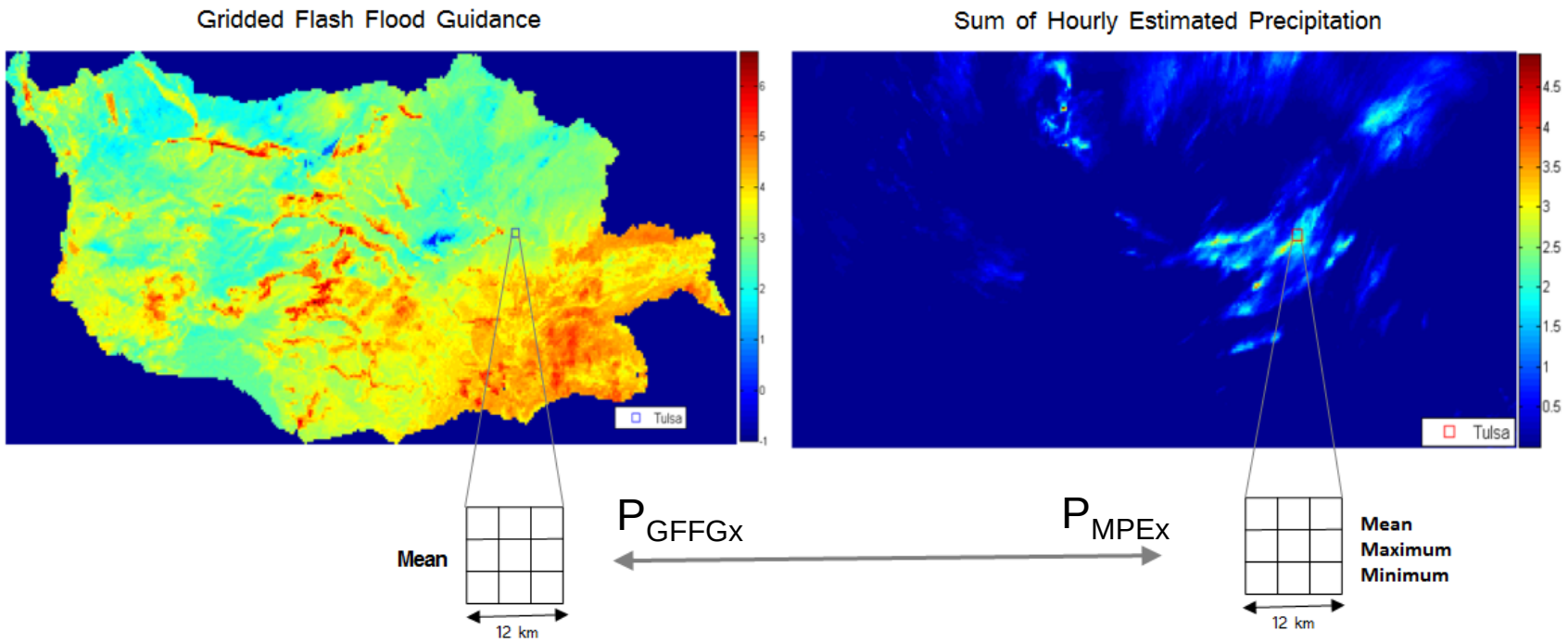


Flash flood observation –*NWS storm data*



NWS Storm Event Data (Reported)

Procedure of Evaluation

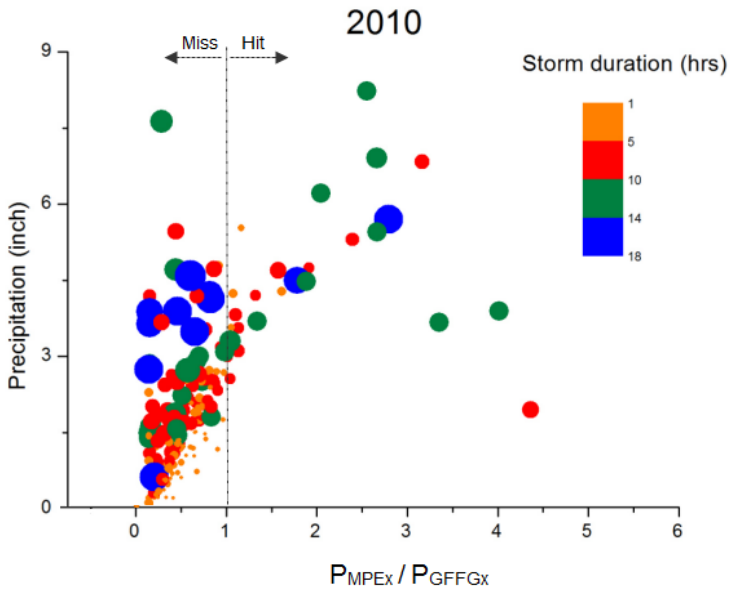


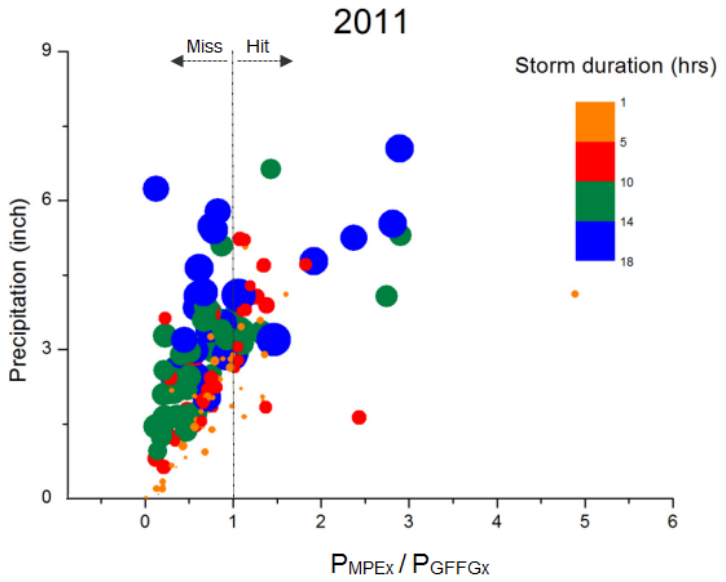
GFFG (inch)	MPE (inch)	Comparison	Analysis	Event	Define
P_{GFFGx}	P_{MPEx}	$P_{GFFGx} \leq P_{MPEx}$	$P_{MPEx} / P_{GFFGx} \geq 1$	Flood	Hit
P_{GFFGx}	P_{MPEx}	$P_{GFFGx} > P_{MPEx}$	$P_{MPEx} / P_{GFFGx} < 1$	Flood	Miss
P_{GFFGx}	P_{MPEx}	$P_{GFFGx} < P_{MPEx}$	$P_{MPEx} / P_{GFFGx} > 1$	No Flood	False Alarm
P_{GFFGx}	P_{MPEx}	$P_{GFFGx} \geq P_{MPEx}$	$P_{MPEx} / P_{GFFGx} \leq 1$	No Flood	Hit

Preliminary Result-POD

Verification statistics: Probability of Detection $POD = \frac{hits}{hits + misses}$

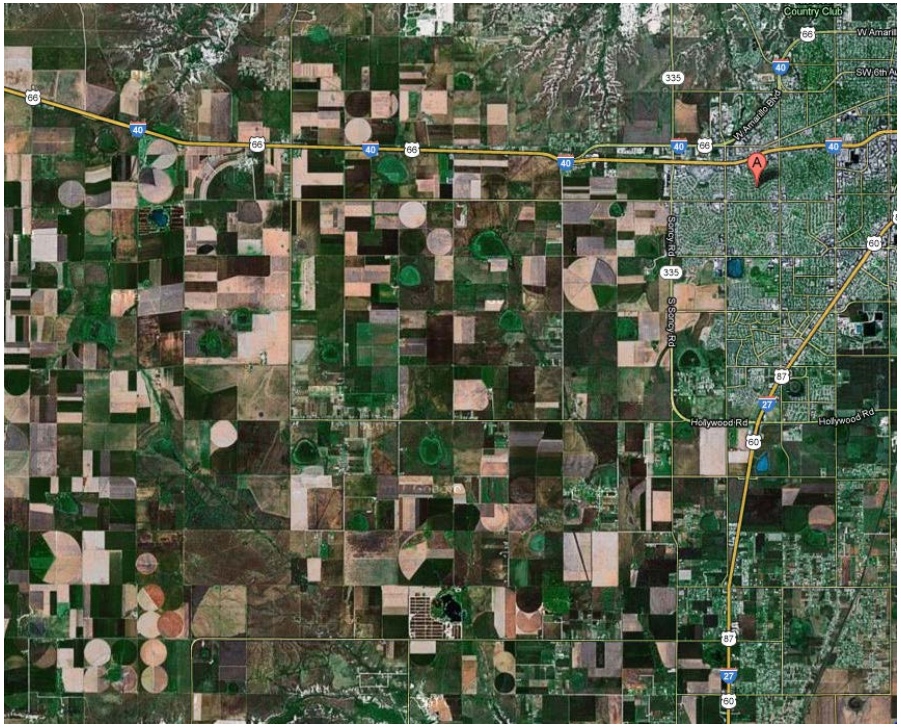
Year	QPE	Statistics	3-hr GFFG	6-hr GFFG	Total
	MEAN	Number of hits	7	14	21
		POD	0.08	0.14	0.11
2010	MAX	Number of hits	23	30	53
		POD	0.23	0.33	0.28
	MIN	Number of hits	5	5	10
		POD	0.06	0.06	0.06
	MEAN	Number of hits	15	19	34
		POD	0.21	0.22	0.22
2011	MAX	Number of hits	31	36	68
		POD	0.34	0.54	0.43
	MIN	Number of hits	9	2	11



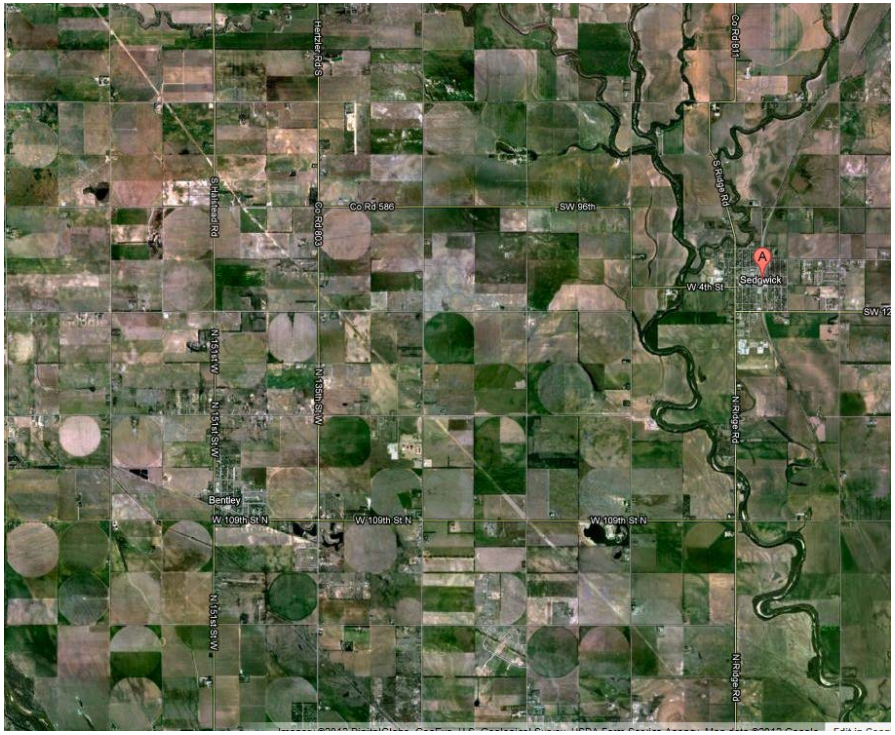


Case study Analysis – Artificial irrigation areas

Google Earth image close-up view of the flash flooded location in near of the agricultural farm areas. Google Earth imagery © Google Inc.



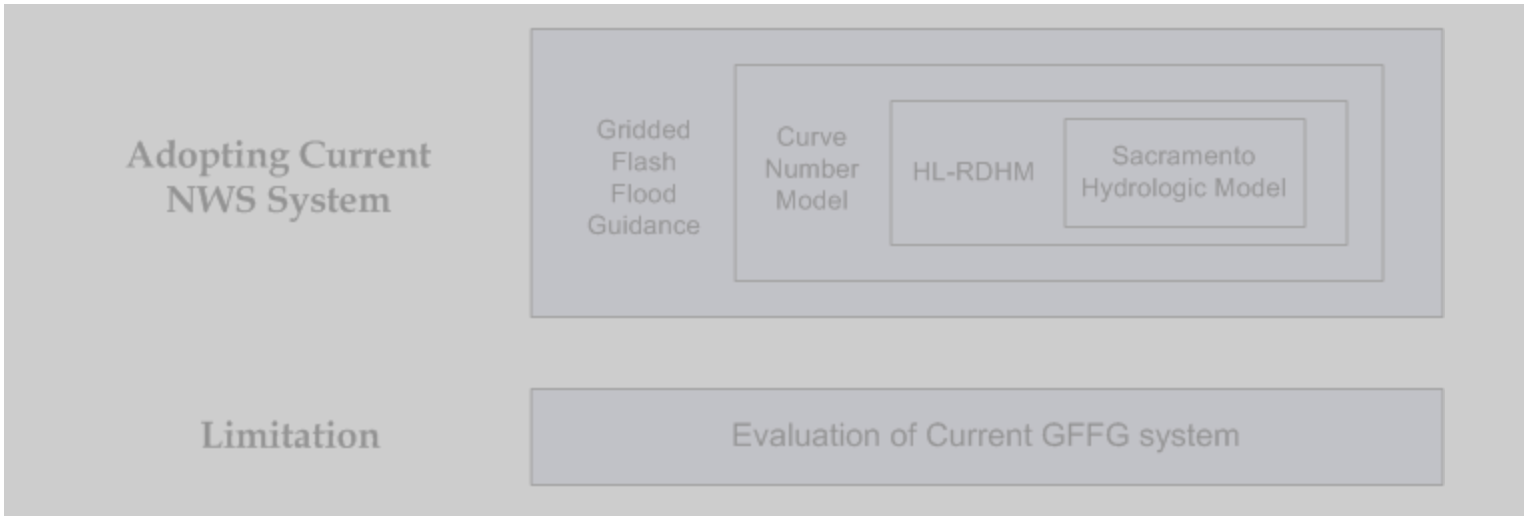
Potter, TX: flash flood on September 16th, 2010 at 15:15 UTC

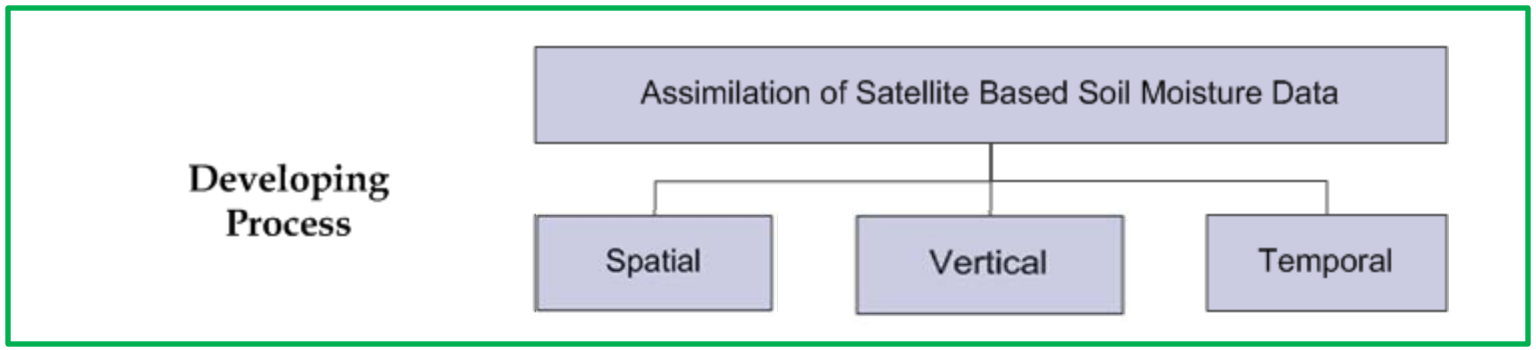


Sedgwick, KS: flash flood on June 9th, 2011 at 19:40 UTC

*Seo et al 2012 ‘Evaluation of Operational National Weather Service Gridded Flash Flood Guidance over the Arkansas Red River Basin’, submitted to Journal of the American Water Resources Association.

High-Level Summary



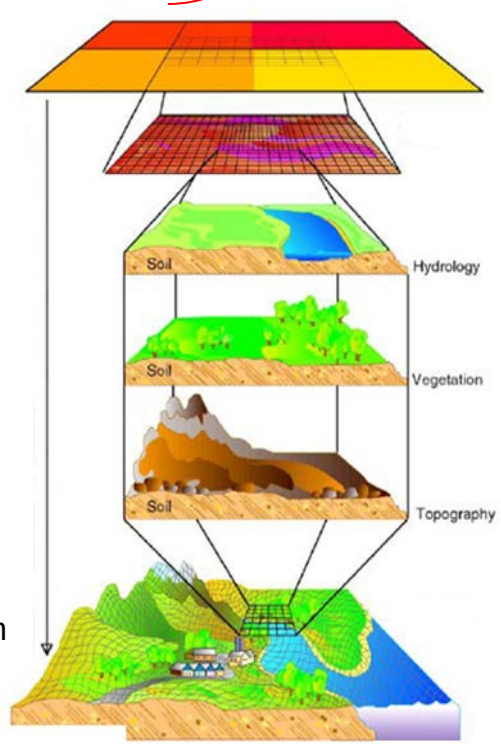


	SMOS	Assimilated soil moisture
Spatial	40 km x 40 km	4 km
Vertical	Top ~ 5cm	Upper zone soil profile (root zone = 50 - 100 cm)
Temporal	2 – 3 days	6 hours

1. Spatial assimilation method

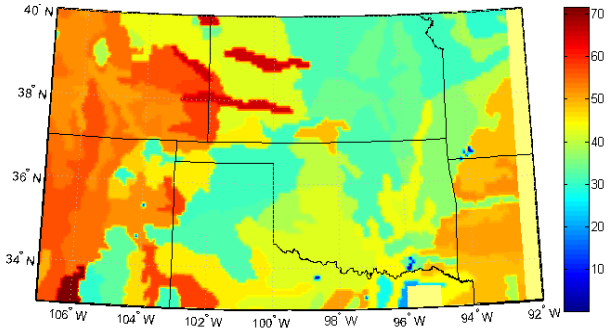
$$\theta_F(i,t) = \theta_C(j,t) * f[SF_F(i), EL_F(i), NDVI_F(i,t)]$$

*Acknowledgement: Narendra Das



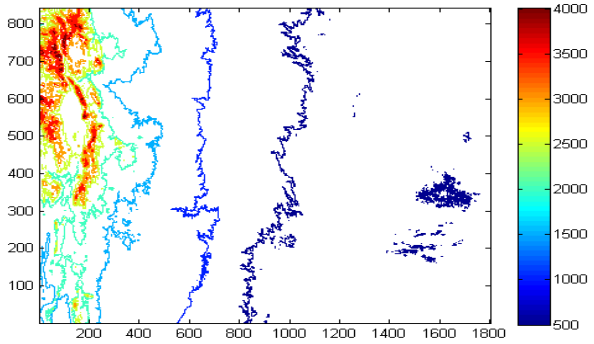
Average Sand Fraction: ISRIC-WISE derived soil properties (5 arc minute)

Static



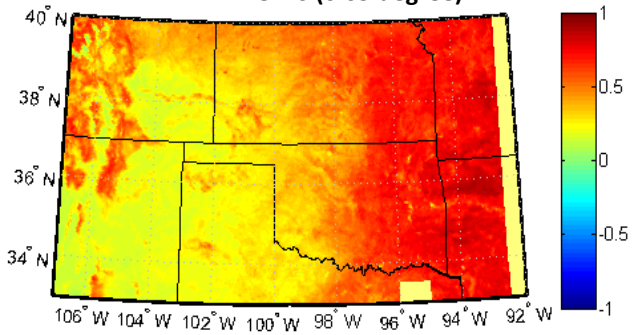
Elevation: Global Topographic Data (GTOPO30 – 30 arc second)

Static



NDVI : MODIS (0.05 degree)

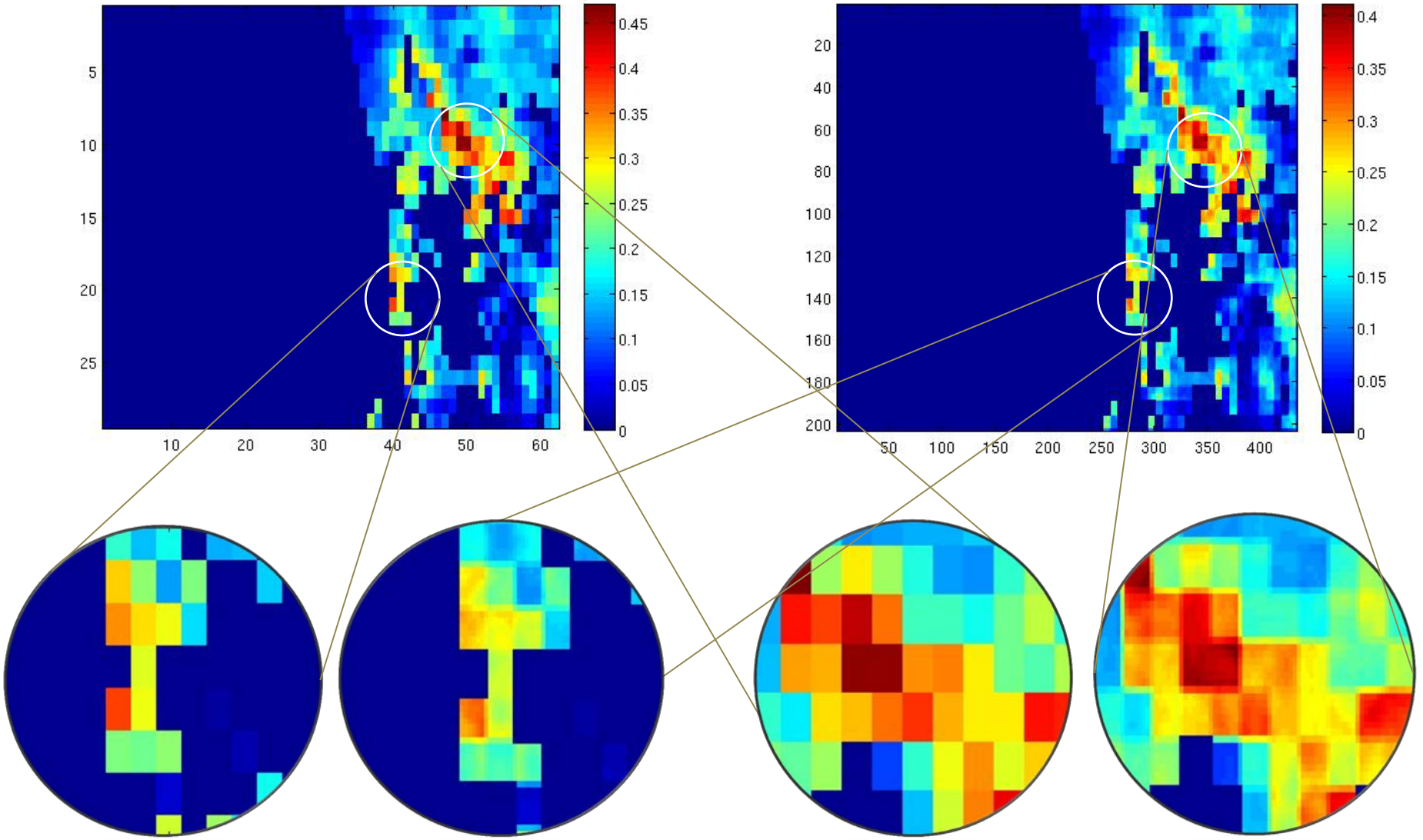
Dynamic
(Monthly 12 data set)



1. Spatial assimilation preliminary

SMOS at Coarse resolution (0.25 degree)

Spatially assimilated SMOS at Fine resolution (4 km)



2. Vertical assimilation method

HL-RDHM Model

- Forcing input: Precipitation, Potential Evaporation, Physical parameters
- Outputs States: Soil profile total moisture states, Layer depth

SMOS incorporation

smc0 :surface retention ~3 cm

smc1: depth ~ 5- 16 cm

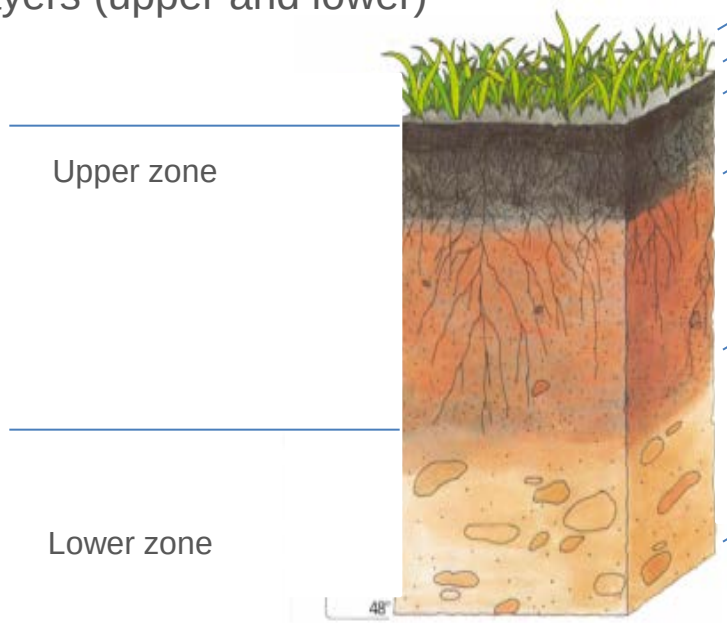
smc2: depth ~ 16- 63 cm

smc3

smc4

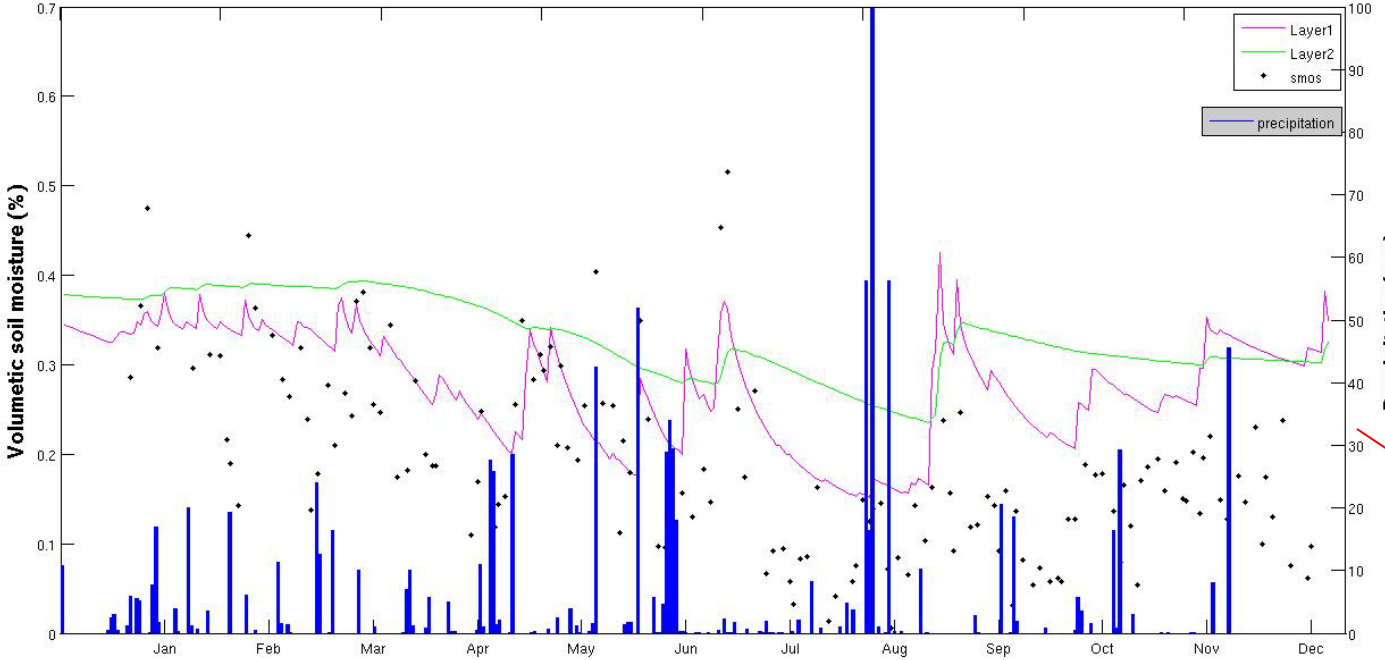
smc5

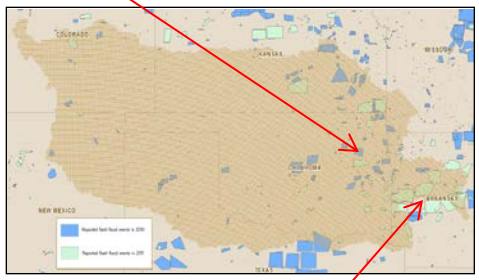
1. SAC-SMA function :
Two layers (upper and lower)



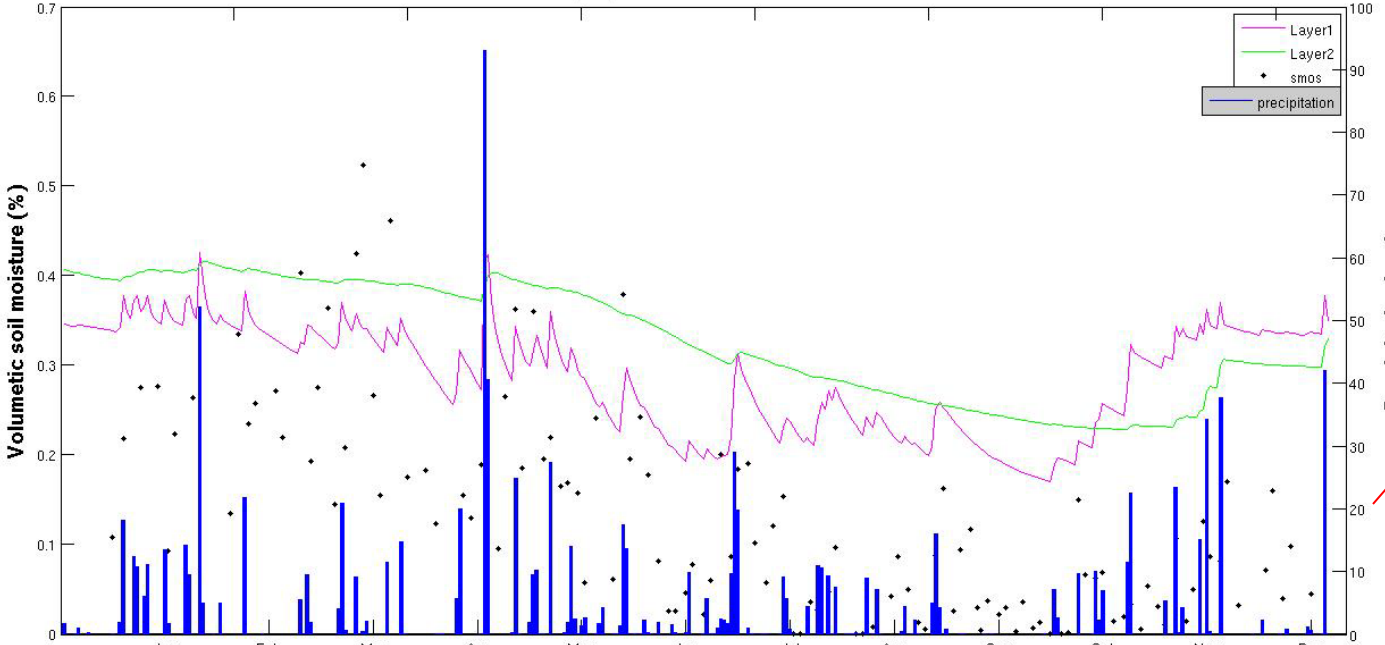
2. Frozen ground (frz) function :
outputs soil moisture contents and depth (varies in cells) in multi-layers

Location1(OK) soil moisture variation 2010



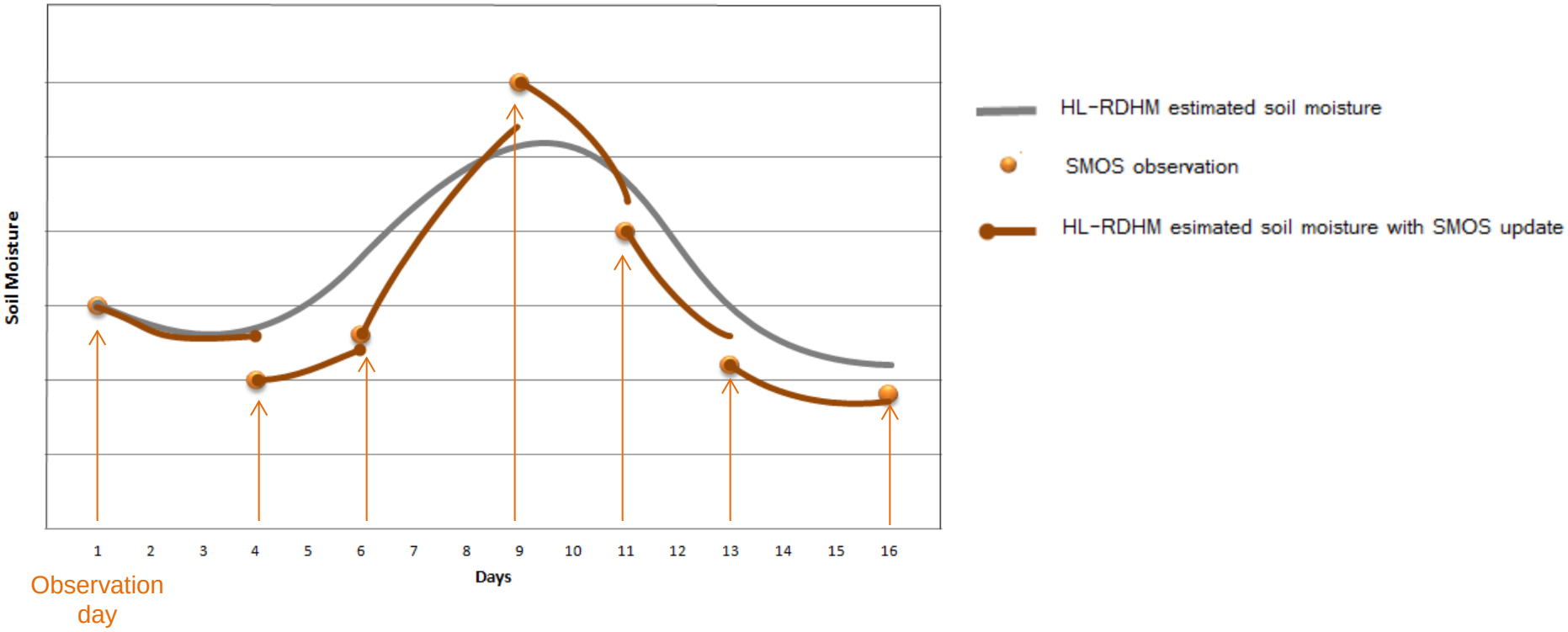


Location 2(AR) soil moisture variation 2010

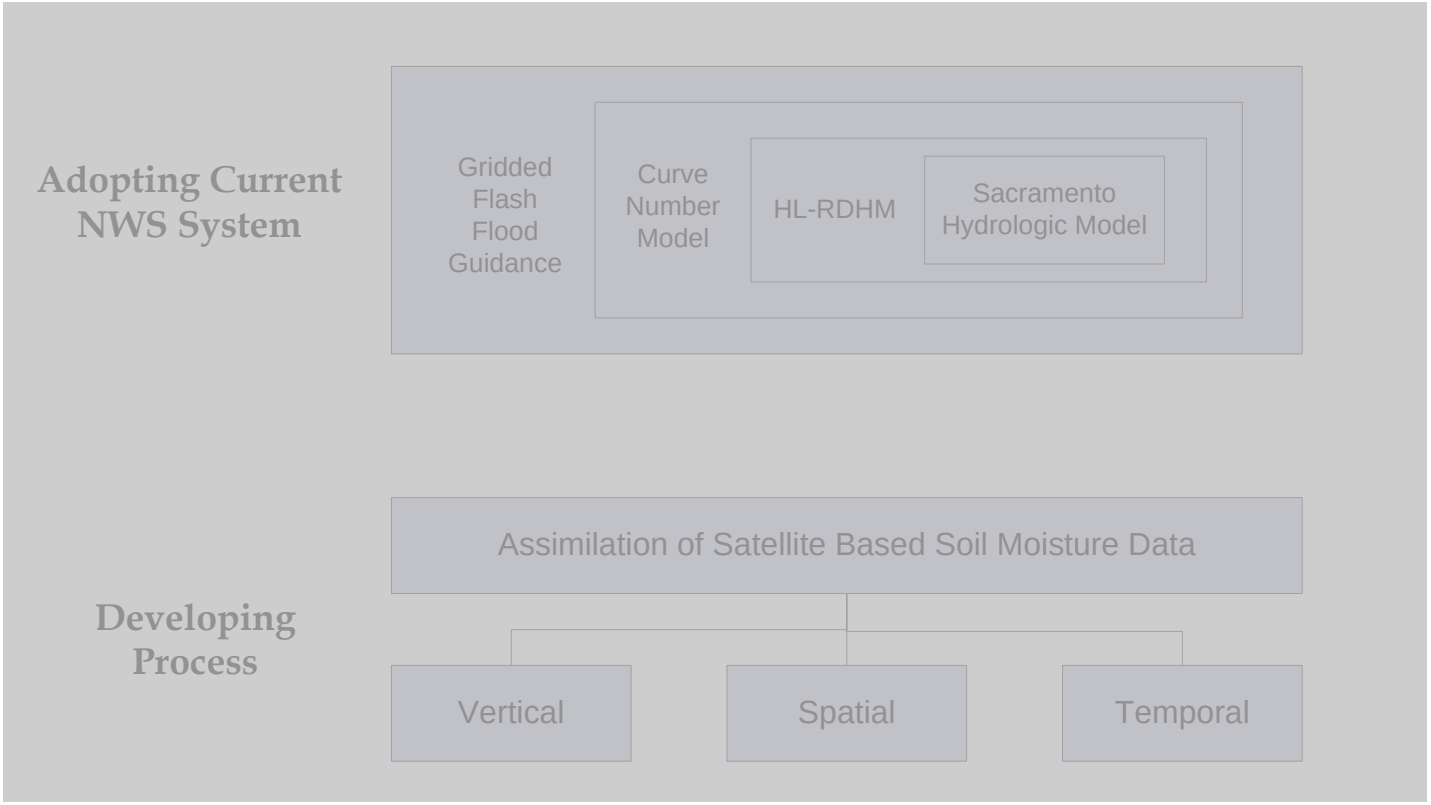


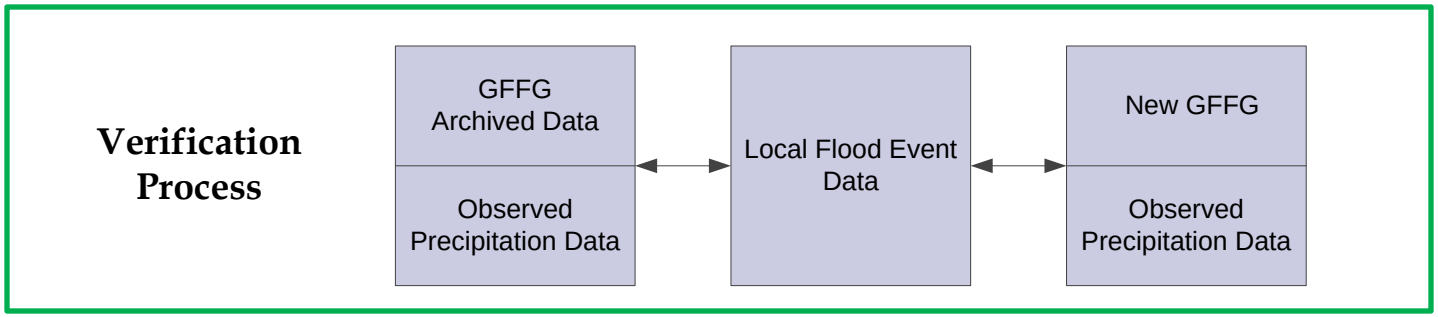
3. Temporal Assimilation

- Proxy hourly satellite data
  - Assimilation of satellite data to the current time

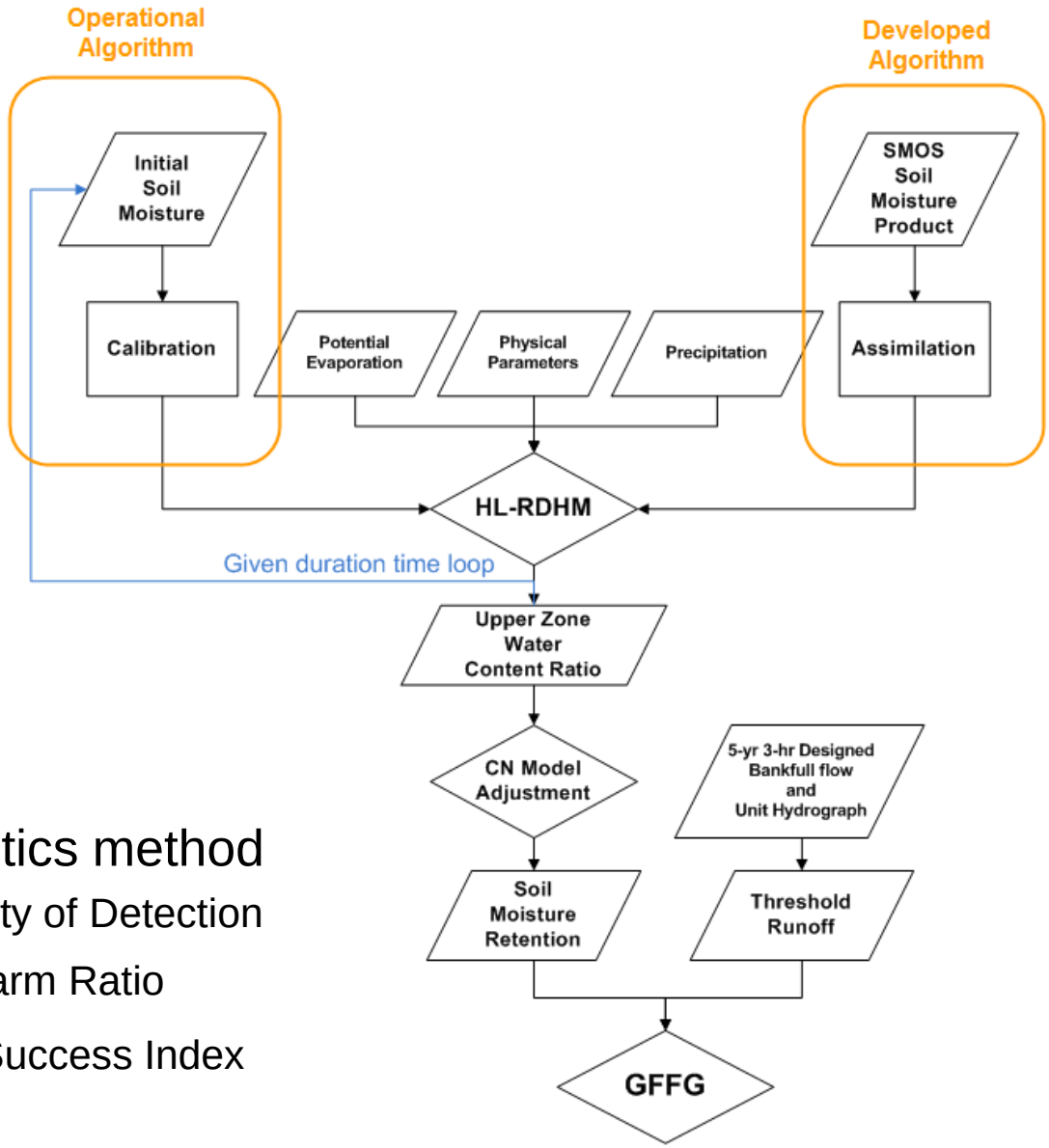


High-Level Summary





4. Verification of Flash Flood Guidance



Verification Statistics method

1) Probability of Detection
2) False Alarm Ratio
3) Critical Success Index