PURDUE UNIVERSITY

Flood inundation modeling from reach to continental scale: challenges and opportunities

Venkatesh Merwade, Lyles School of Civil Engineering, Purdue University

Dr. Venkatesh Merwade

GIS applications in water resources engineering focusing on river channels and surface water hydrology

Siddharth Saksena

Studies floods using topographic maps and 2D modeling techniques

Jessica Eisma

Effect of soil moisture accounting on hydrologic simulation of watersheds

Keighobad Jafarzadegan

Works on remote sensing and machine learning applications in flood extent modeling

Liuying Du

Studies land use and climate change effects on hydrologic processes

Adnan Rajib

Remote sensing; advanced soil moisture accounting and large scale hydrologic modeling

Nikhil Sangwan

Develops alternative flood mapping techniques

Kyungmin Sung

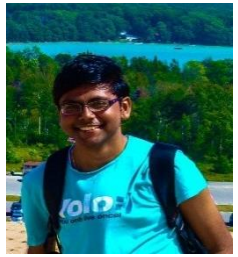
Studies temporal and spatial variances in river channel bed

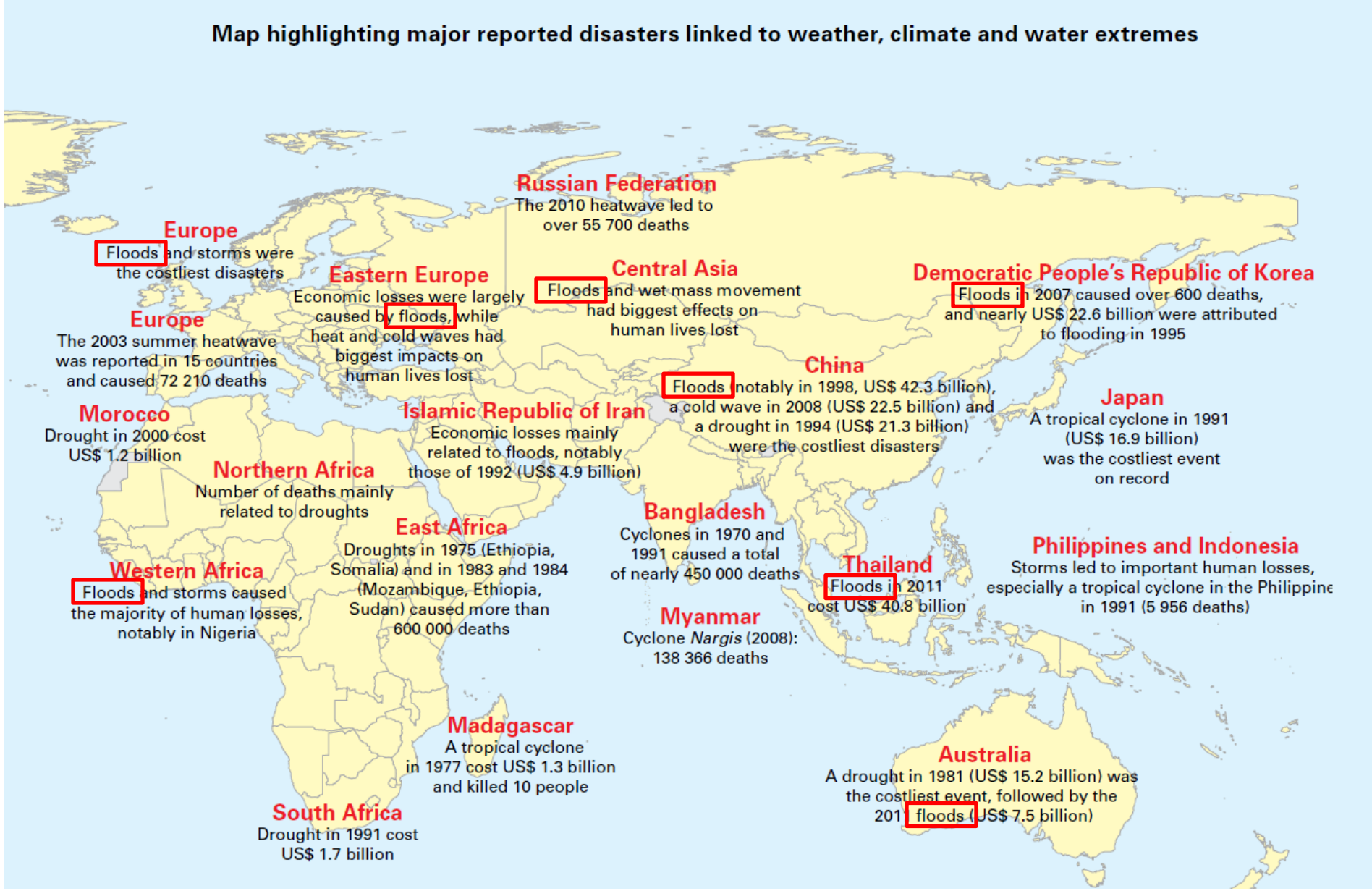
Zhu Liu

Application of 1D and 2D hydraulic models in flood mapping

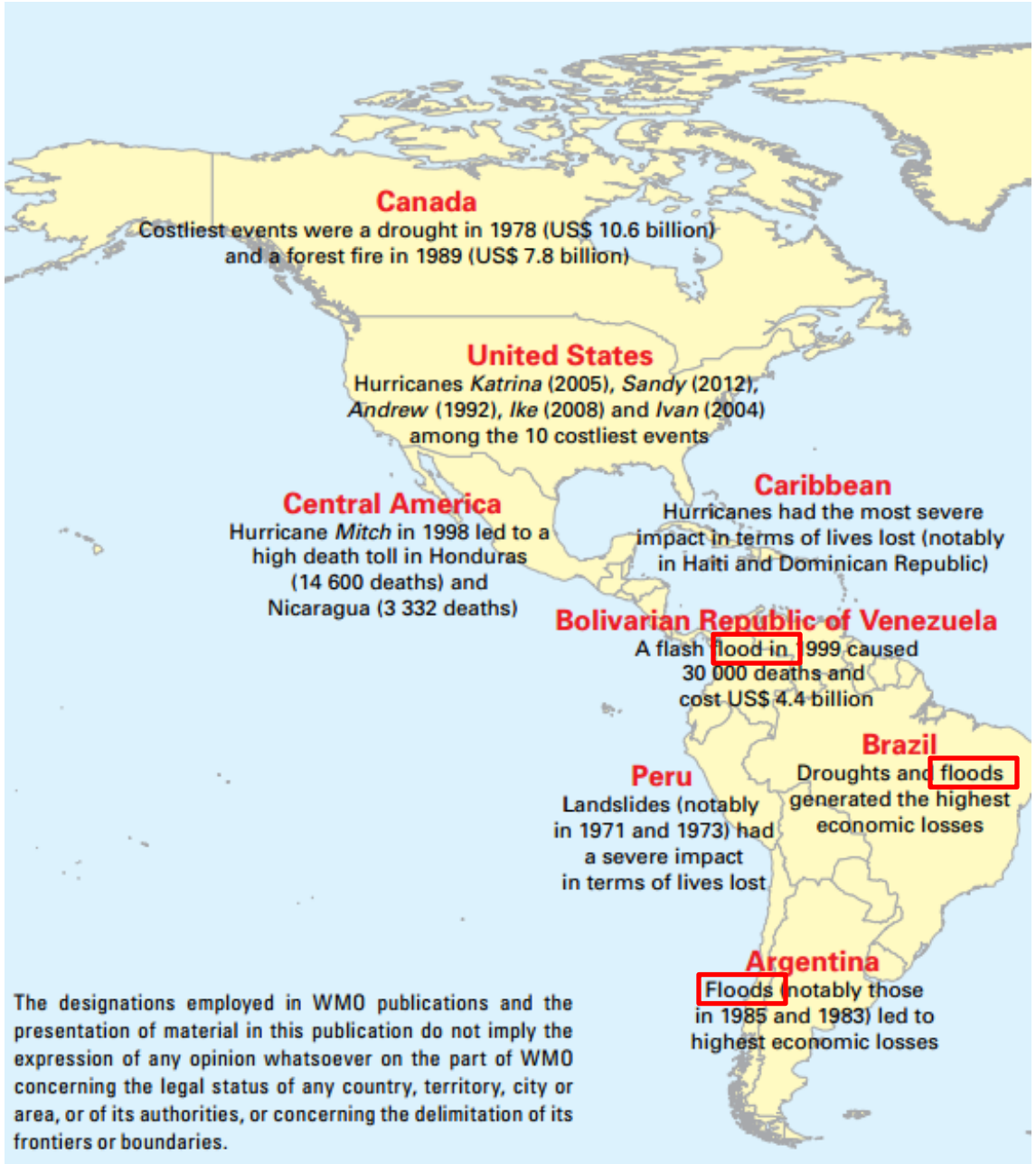
Sayan Dey

Studies the effects of channel bathymetry on hydraulic modeling



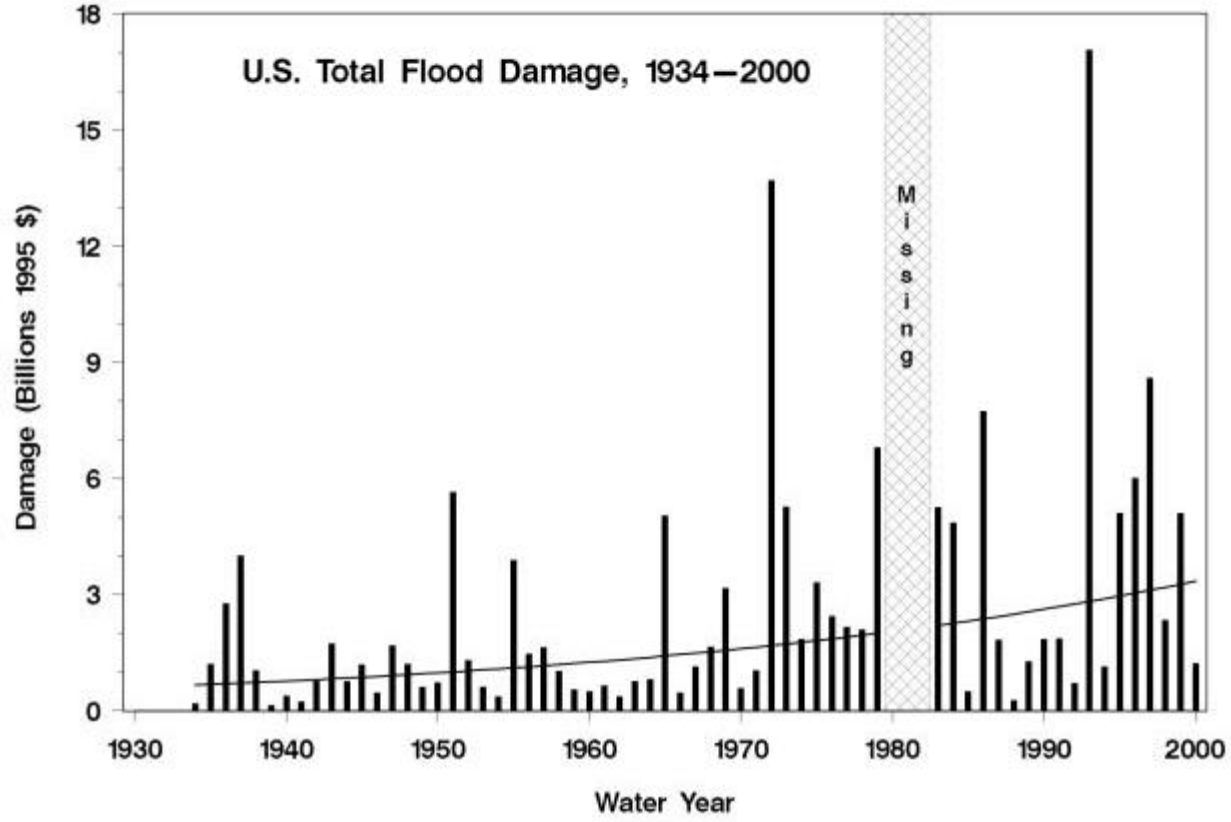


WMO Report: Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970 – 2012)

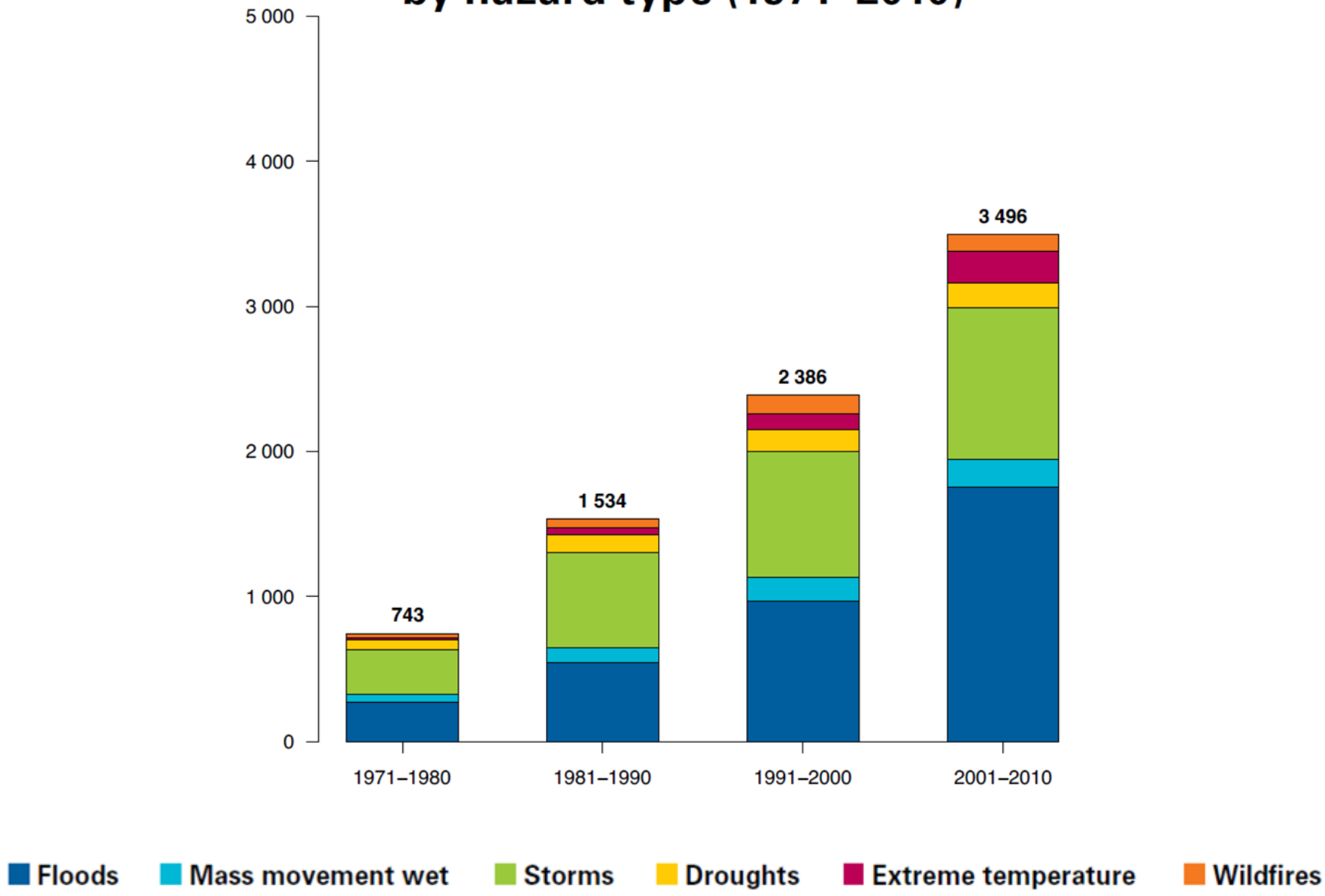

Canada
Costliest events were a drought in 1978 (US$ 10.6 billion) and a forest fire in 1989 (US$ 7.8 billion)
United States
Hurricanes *Katrina* (2005), *Sandy* (2012), *Andrew* (1992), *Ike* (2008) and *Ivan* (2004) among the 10 costliest events
Central America
Hurricane *Mitch* in 1998 led to a high death toll in Honduras (14 600 deaths) and Nicaragua (3 332 deaths)
Caribbean
Hurricanes had the most severe impact in terms of lives lost (notably in Haiti and Dominican Republic)
Bolivarian Republic of Venezuela
A flash flood in 1999 caused 30 000 deaths and cost US$ 4.4 billion
Brazil
Droughts and floods generated the highest economic losses
Peru
Landslides (notably in 1971 and 1973) had a severe impact in terms of lives lost
Argentina
Floods (notably those in 1985 and 1983) led to highest economic losses
The designations employed in WMO publications and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of WMO concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Flood Damages in the U.S.

- Most damaging of all natural disasters
- - Over half of the deaths (US: 140 deaths annually)
- - One-third of economic losses(US: $6 billion annually)



Number of reported disasters by decade by hazard type (1971–2010)




GLENHAVEN

What can we do?

Dealing with floods

OCT 3 2015, 7:47 PM ET: Flash Floods, 'Once in 200 Years Rainfall Event' Loom in South Carolina

OCT 4 2015, 1:22 PM ET: East Coast Flooding: 'Once in 500 Years' Downpour Threatens South Carolina

OCT 5 2015, 2:53 AM ET: 'Stay in Your House': Officials Warn Residents During Unprecedented '1,000-Year' Floods

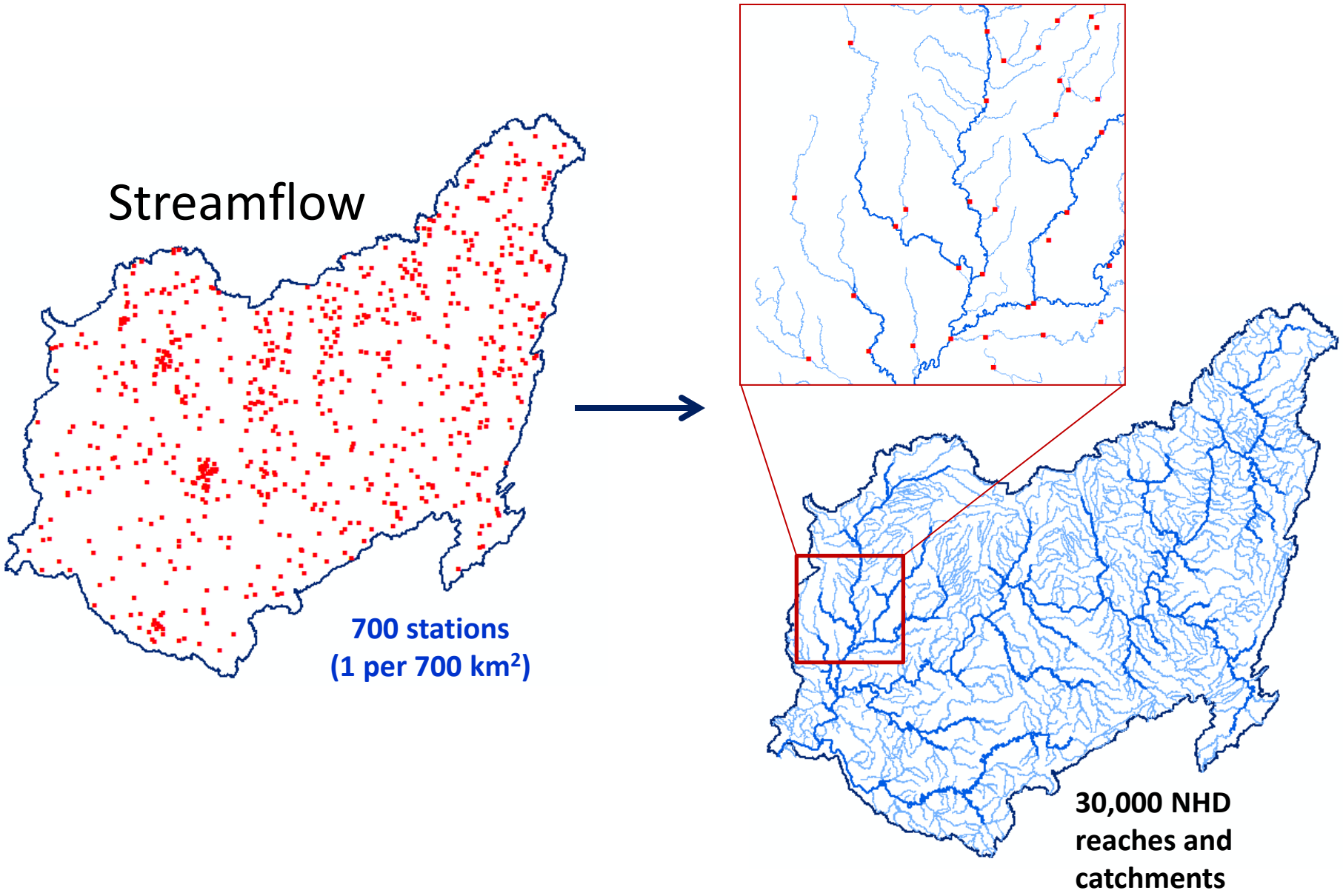
- Better flood prediction - Hydrology
- Better flood inundation maps - Hydraulics
- Better communication of flood risk – everything else

Hydrology

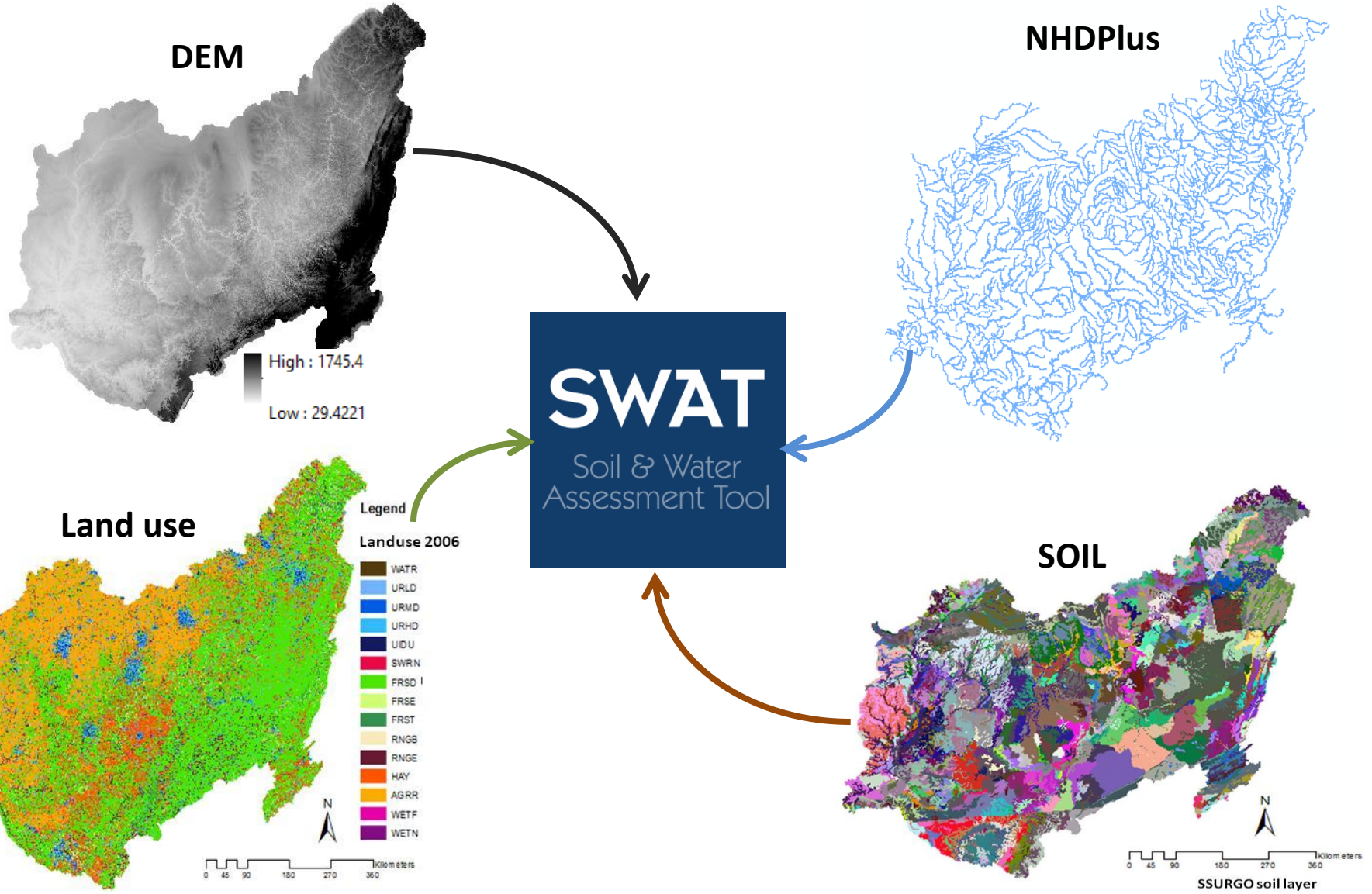
- Data – availability, access, spatial and temporal resolution
- Modeling – spatial and temporal resolution, uncertainty
- Computational Resources - access

Total Drainage Area = 490,000 km^2
Draining through 11 states

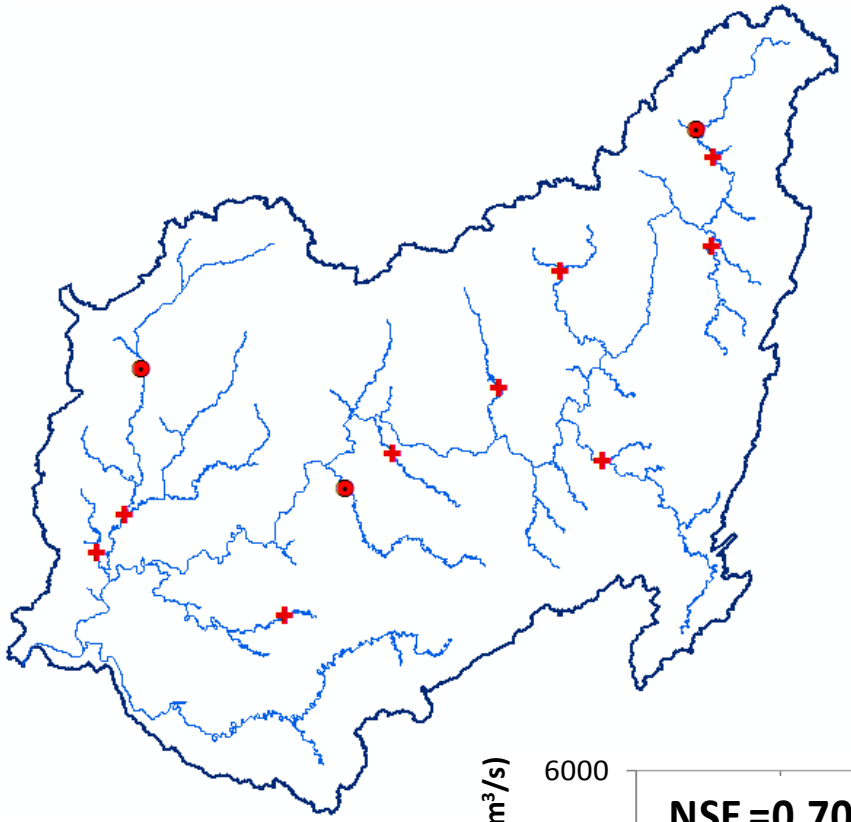
Data availability - Challenge



700 hydrographs to 30,000 hydrographs



Model Uncertainty - Challenge

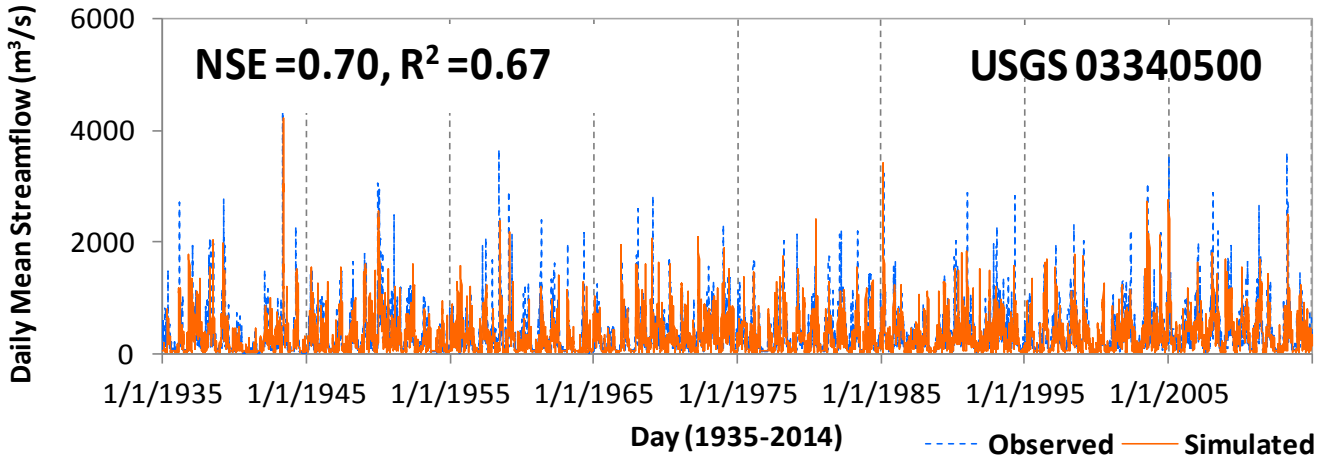


Calibration:
"Simultaneous" multi-gauge calibration: 9 USGS stations

Validation:
3 USGS stations (separate from calibration locations)

Daily time-step
80 year simulation
Average NSE for the entire basin is 0.60

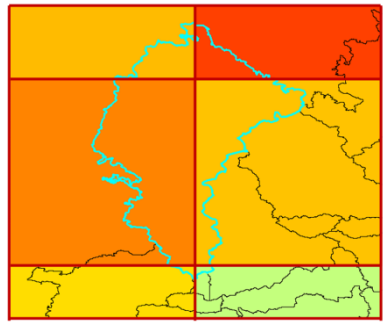
"Moderate" performance considering the daily simulation, large scale and high spatial resolution



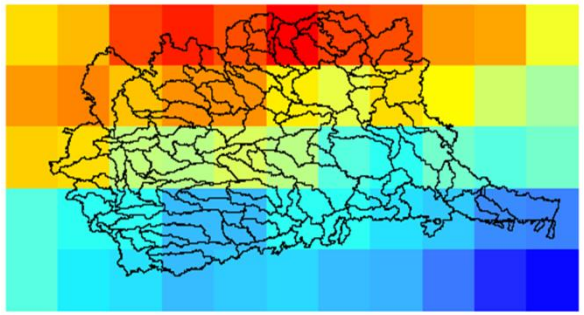
Remote Sensing Products - Opportunity

Improving calibration performance with Remote Sensing applications

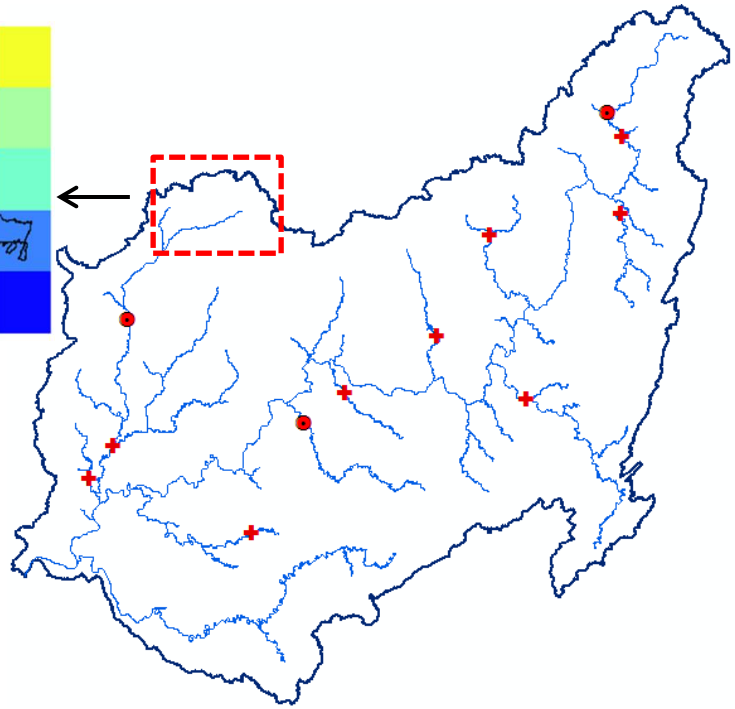
Multi-objective Spatial Calibration: Streamflow (USGS) + AMSR-E surface moisture (NASA)

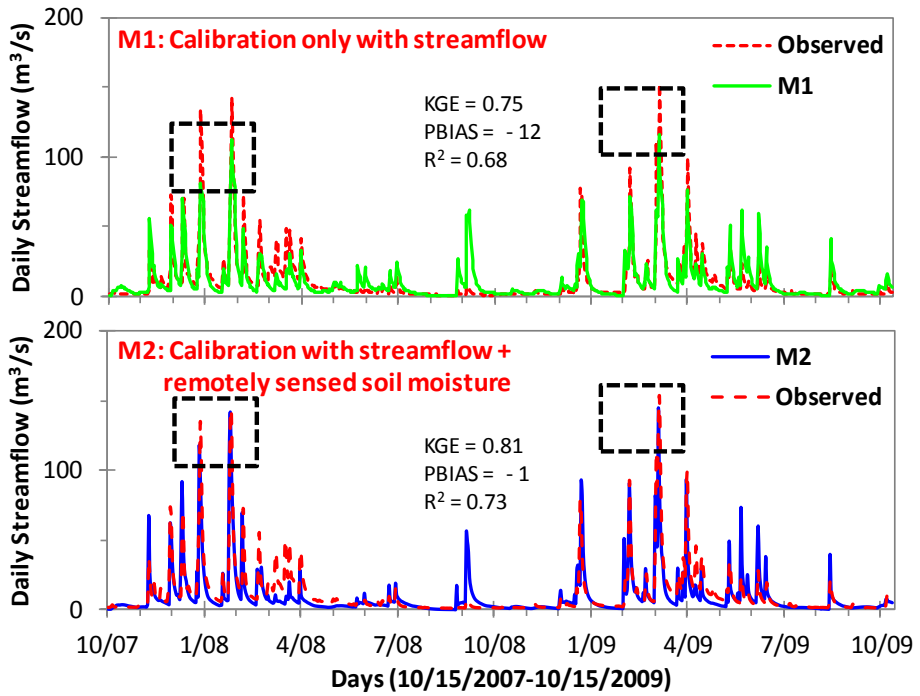


Sub-basin scale aggregation



Auto-extraction of satellite data





Large scale models - opportunity

High resolution gridded rainfall

Land Surface-River Routing models

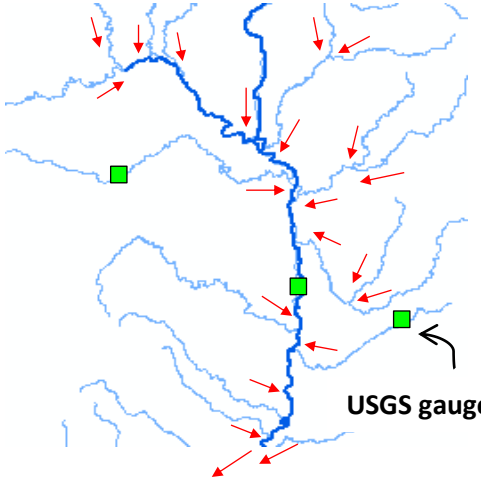
SWAT

VIC-RAPID

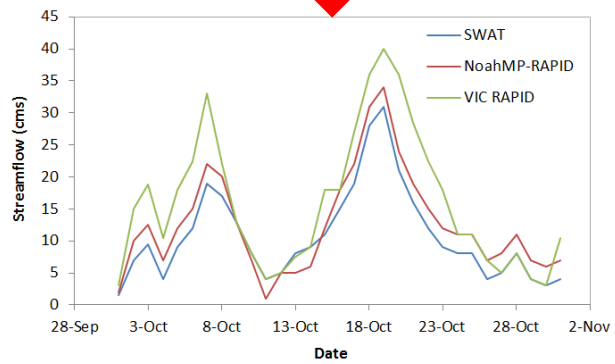
NoahMP-RAPID

- Same weather input
- Same spatial resolution (NHDPlus)
- Simultaneous execution of models

Streamflow output at each reach node



Calibration



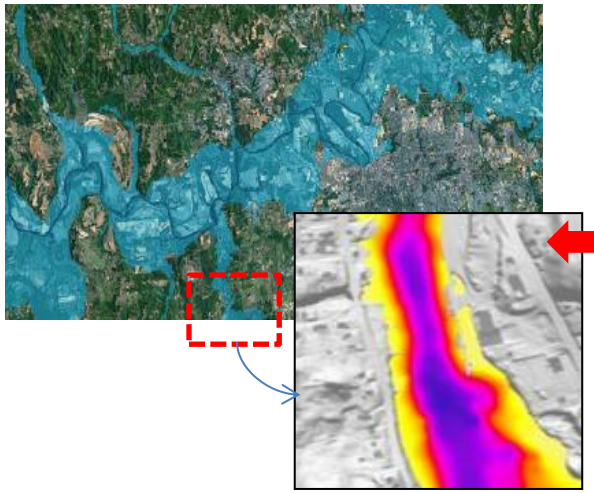
Multi-model ensemble streamflow

LISFLOOD

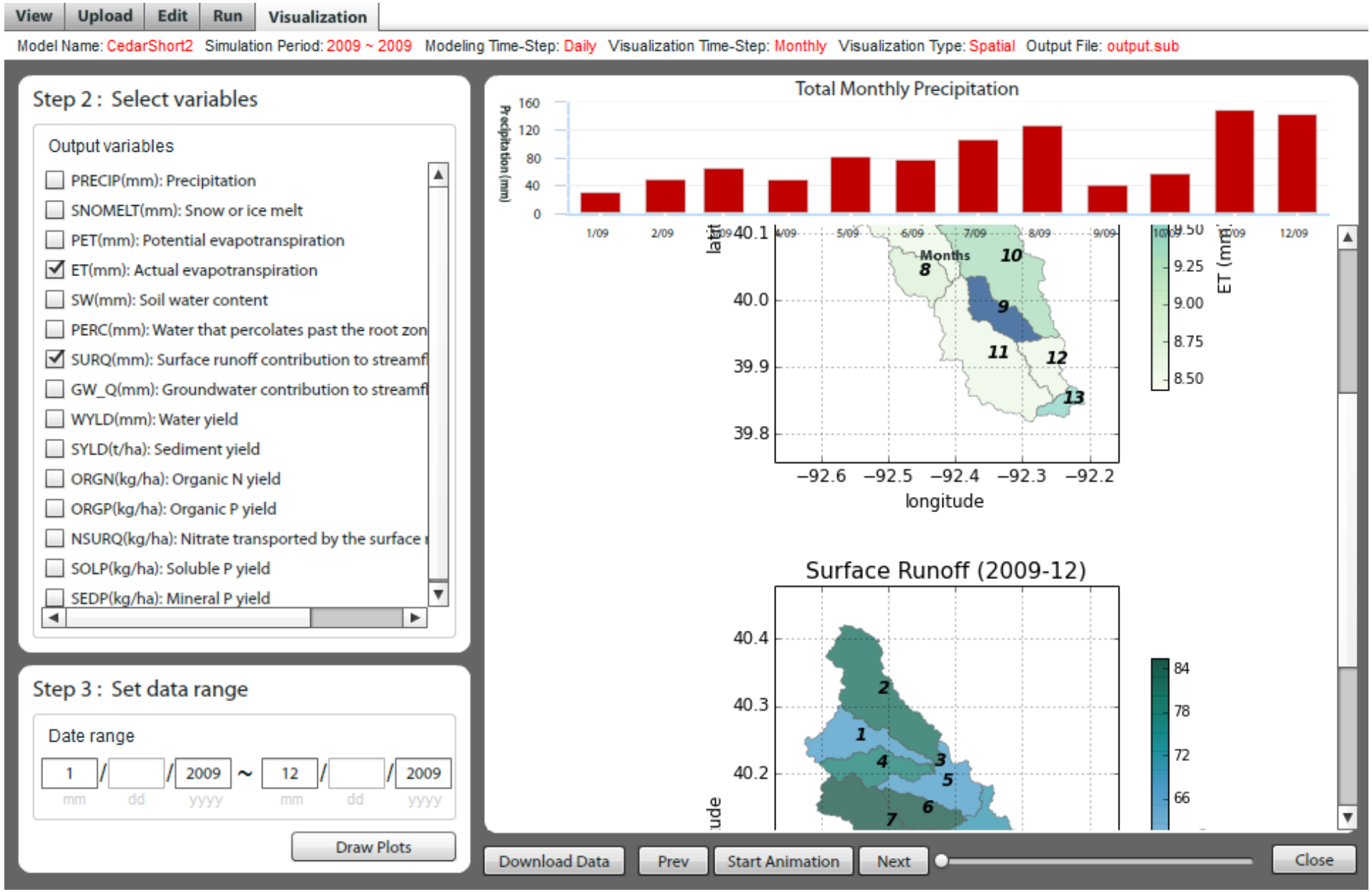
AutoRoute

Hydraulic models

Probabilistic flood map

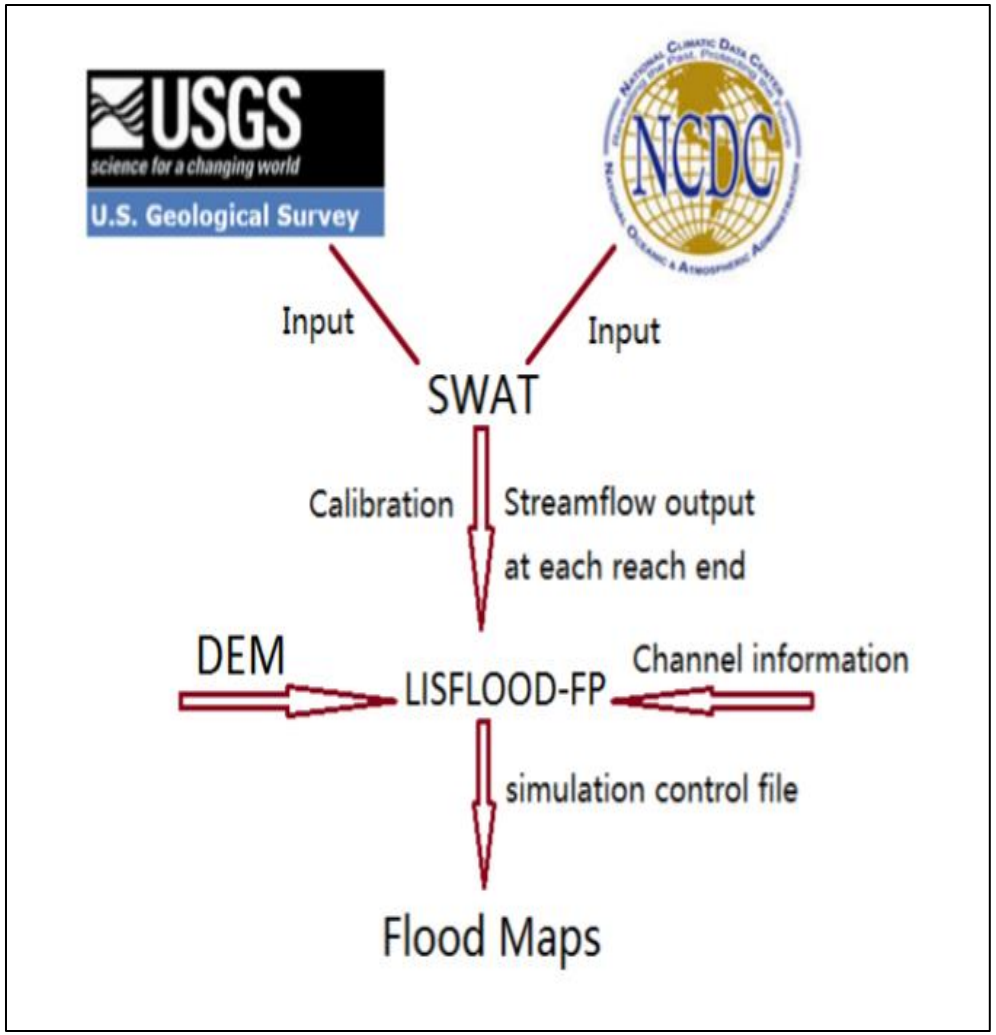


Sharing, running and visualizing models on the web



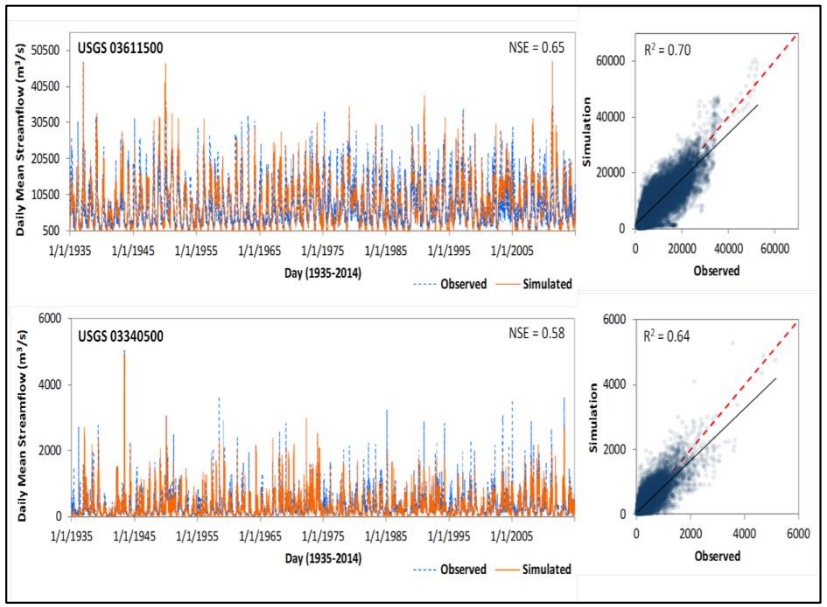
Flood Modeling/Mapping at Reach Scale

- Modeling – uncertainty, type of model and computational resources
- Data – inadequate or poor quality



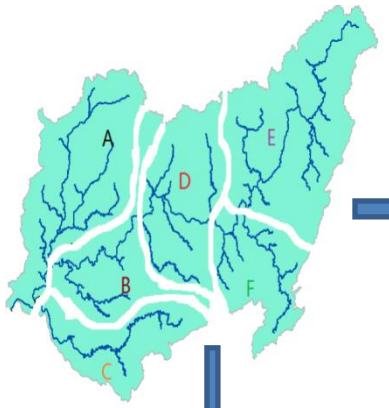
High resolution flood simulation at large scale

Hydrograph output with uncertainty

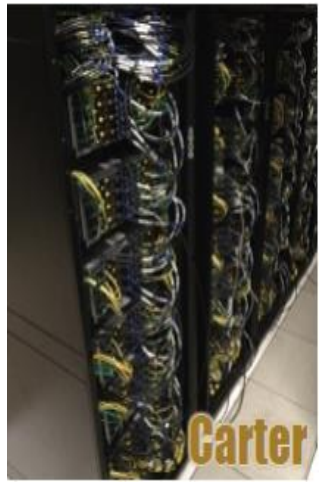


After calibration, the 100 year flow is calculated for each reach based on the LP3 distribution

LISFLOOD-FP Model Setup



The study area is divided into 6 sub regions to distribute the computational load

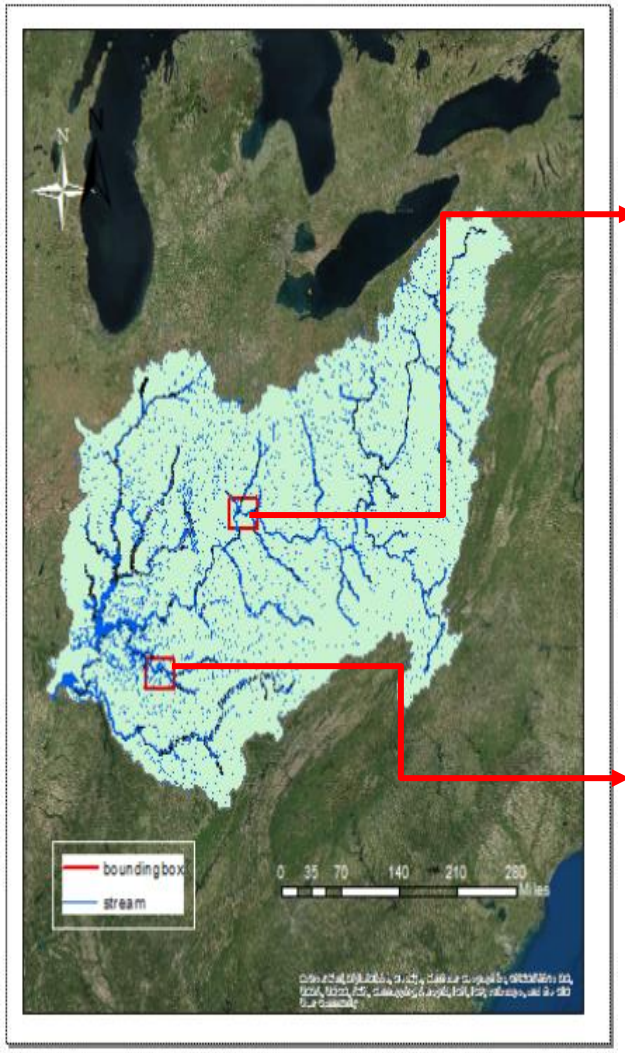


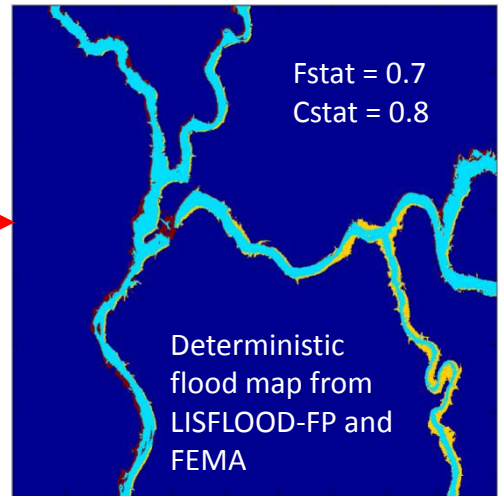
LISFLOOD-FP is run on Linux Cluster

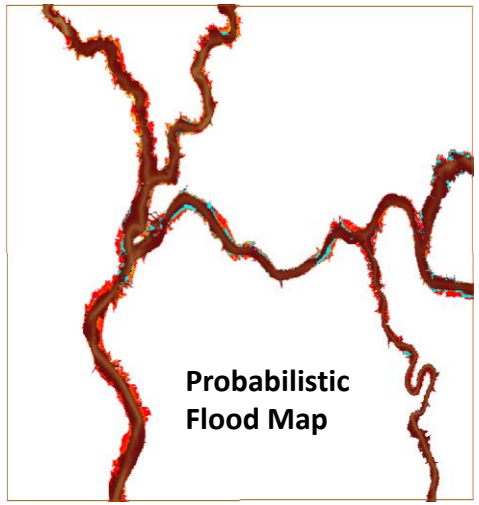
Flood Inundation Maps at reach scale

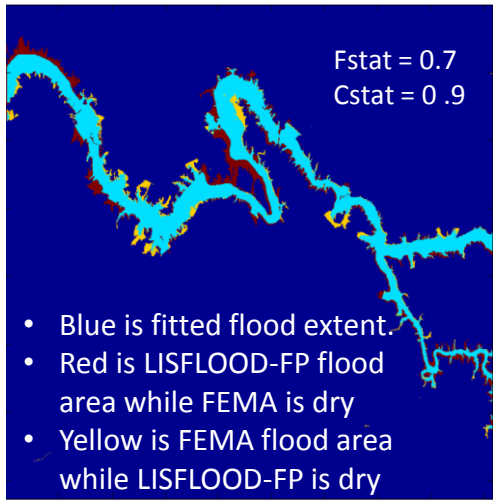
Black color show the flood extent generated by LISFLOOD -FP

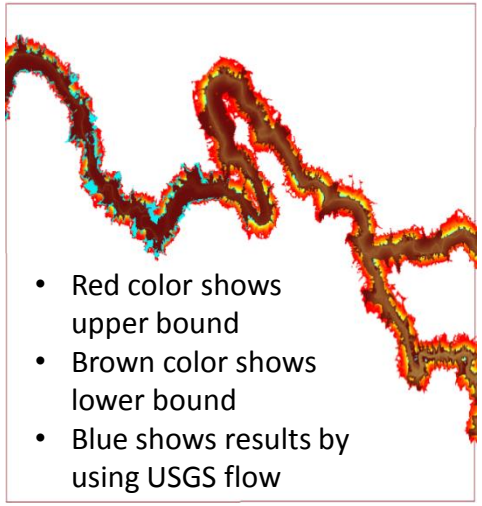
Blue color shows 100 year flood map from FEMA



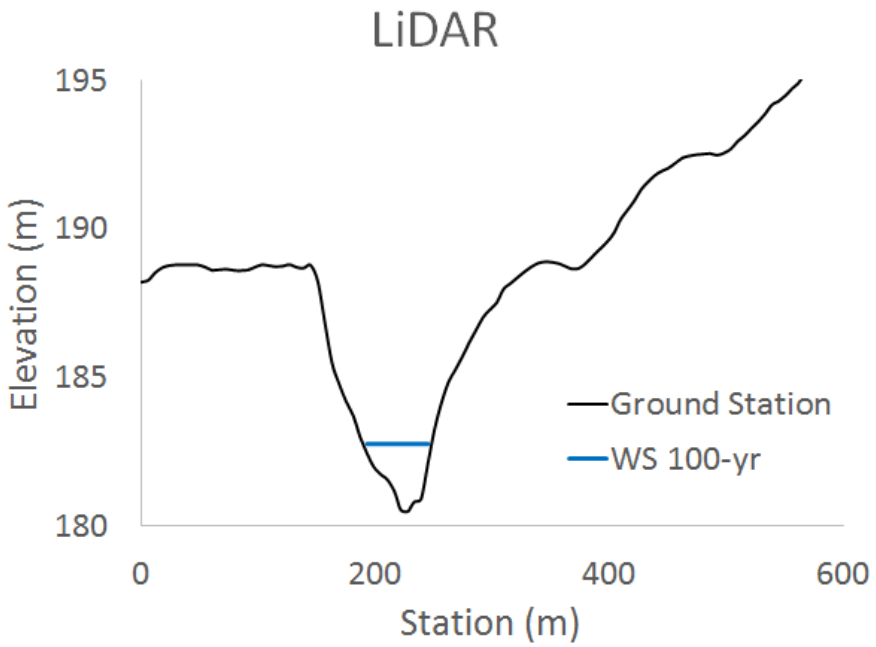


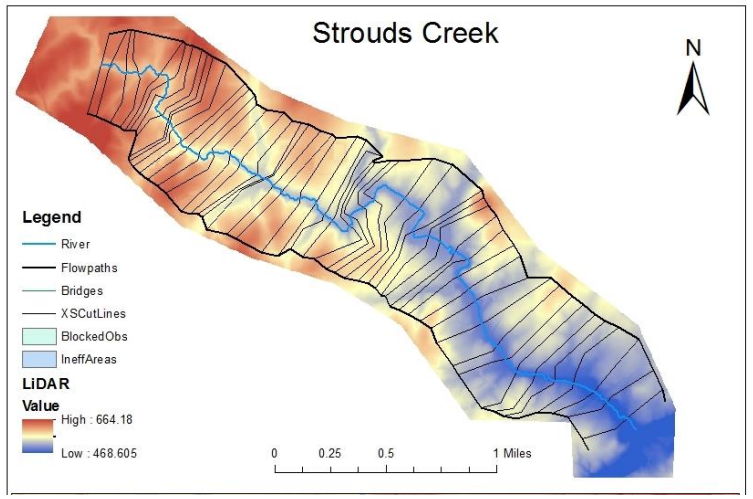




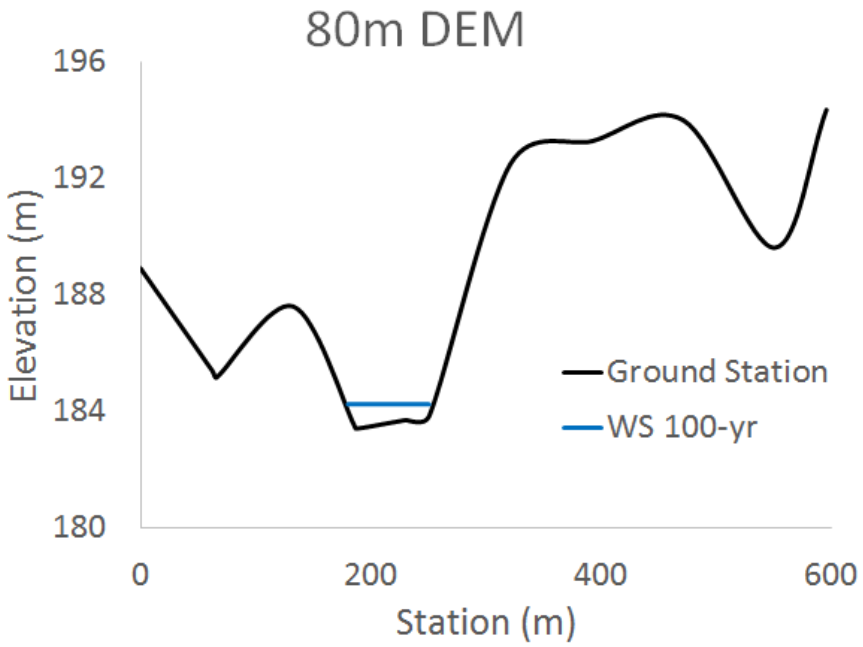


Role of topography



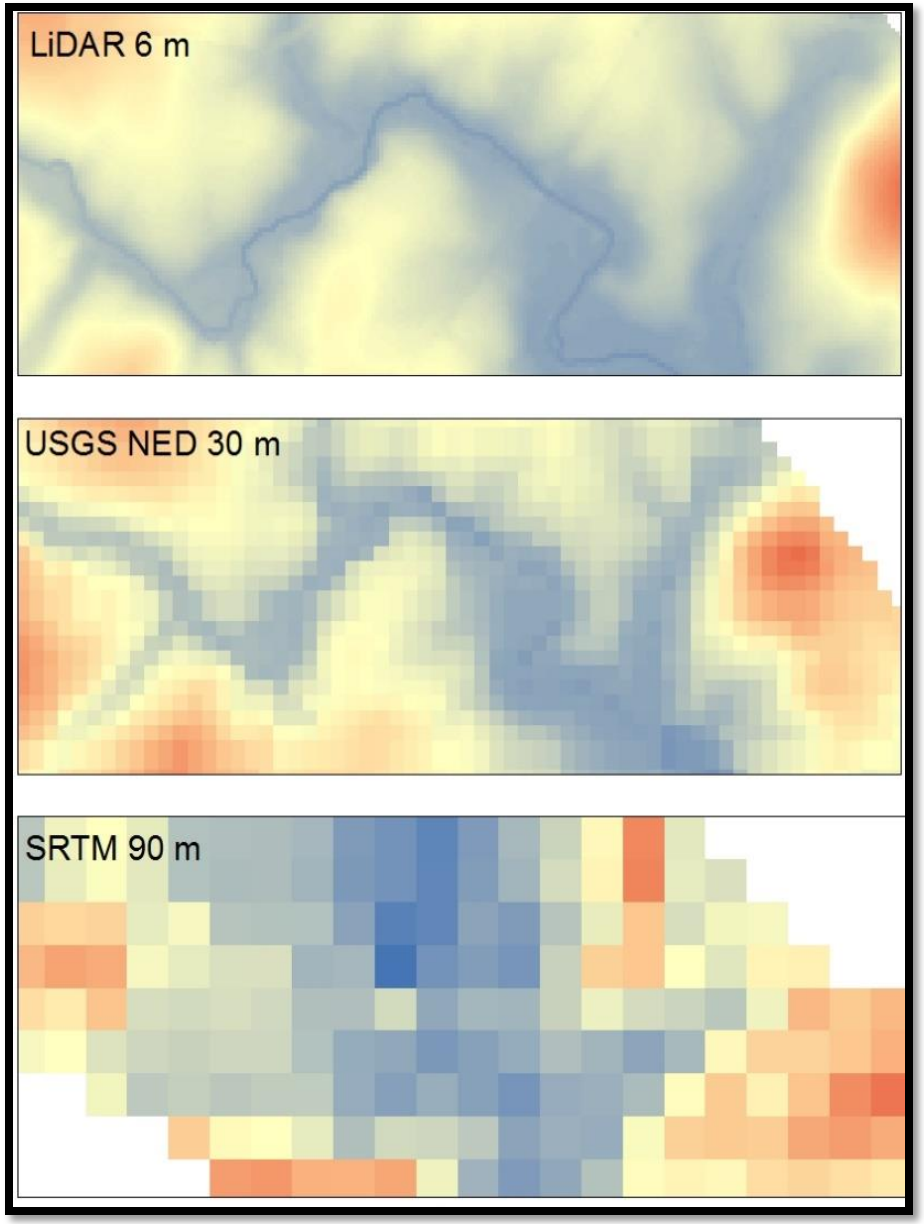


DEM resolution and accuracy both affects the flood inundation modeling and mapping

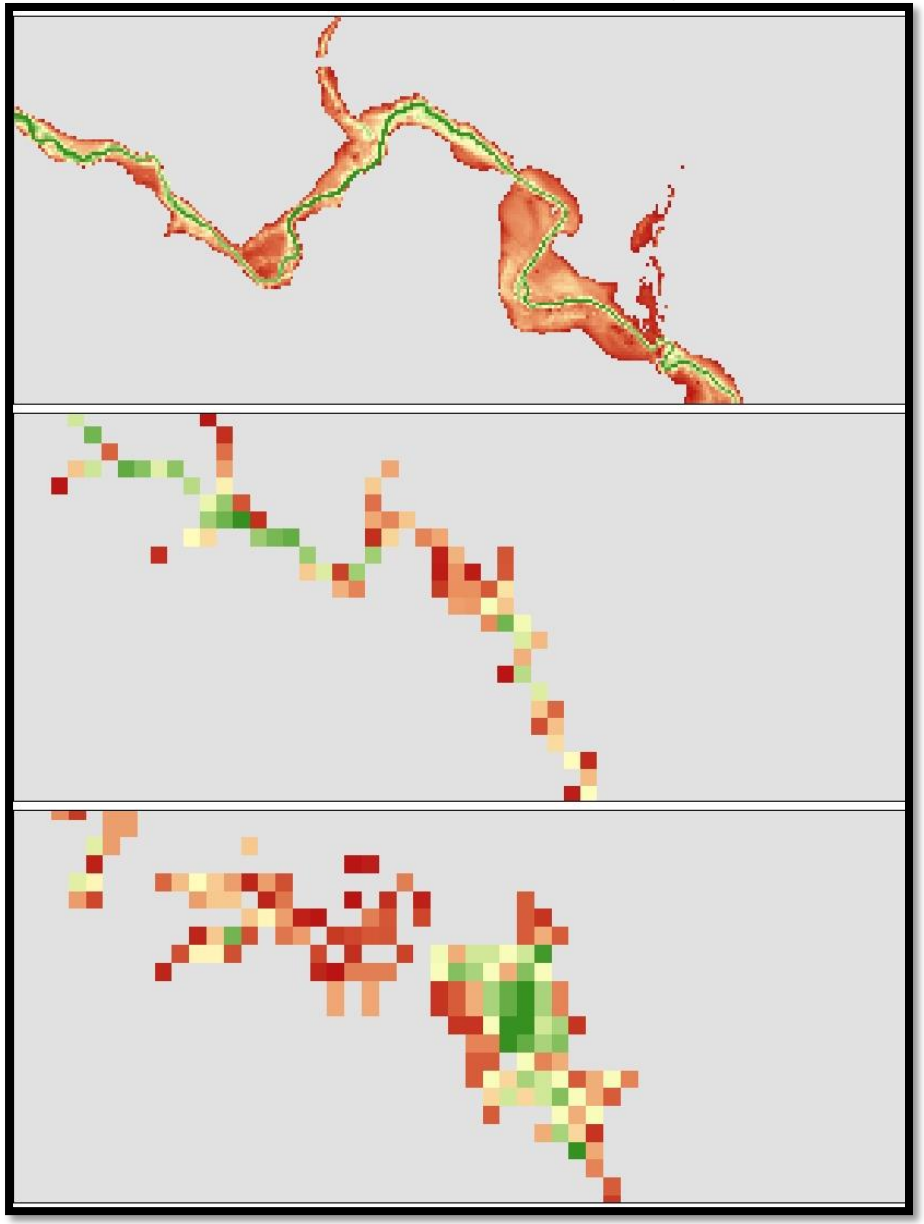


Topography - Challenge

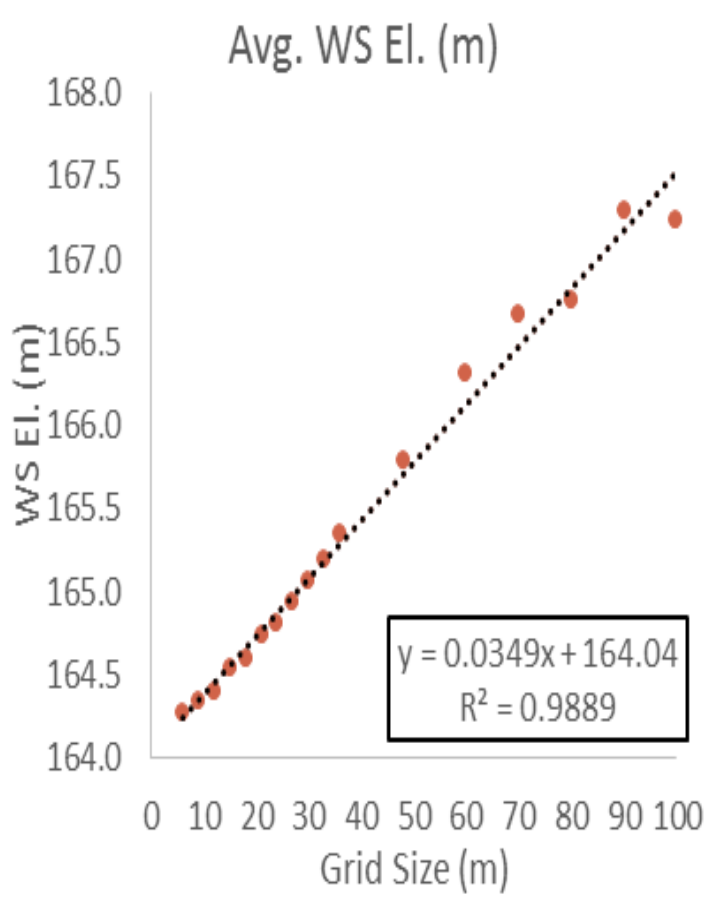
Digital Elevation Model

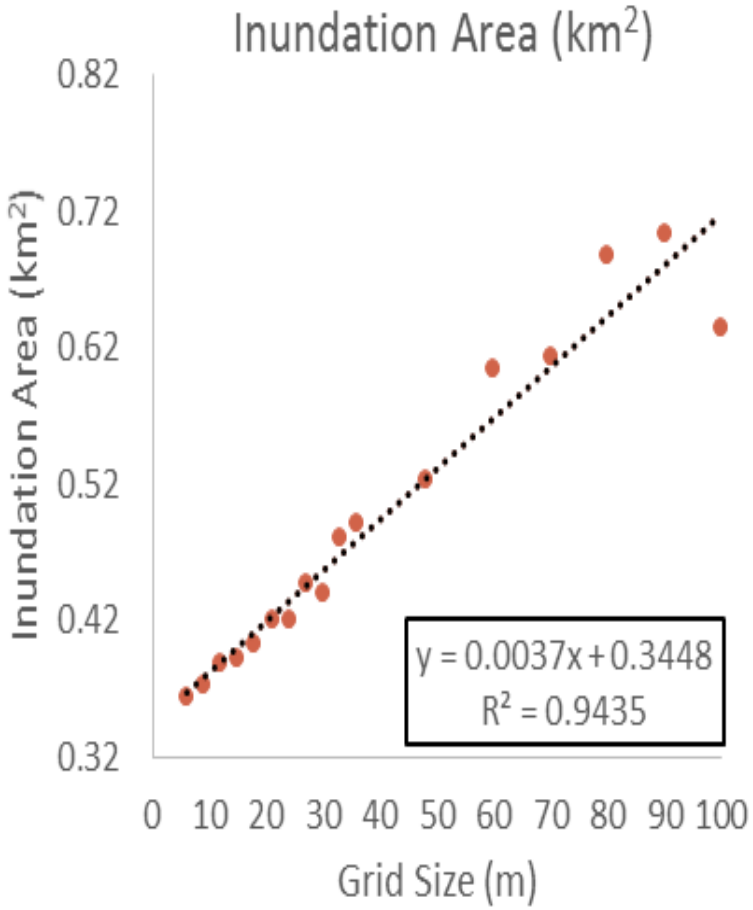


Flood Inundation Map



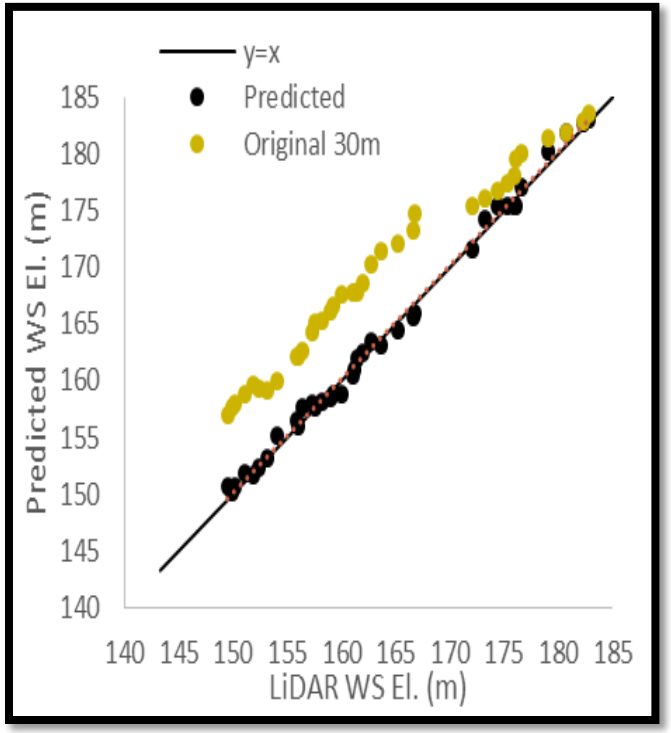
DEM properties and Flood Model Output

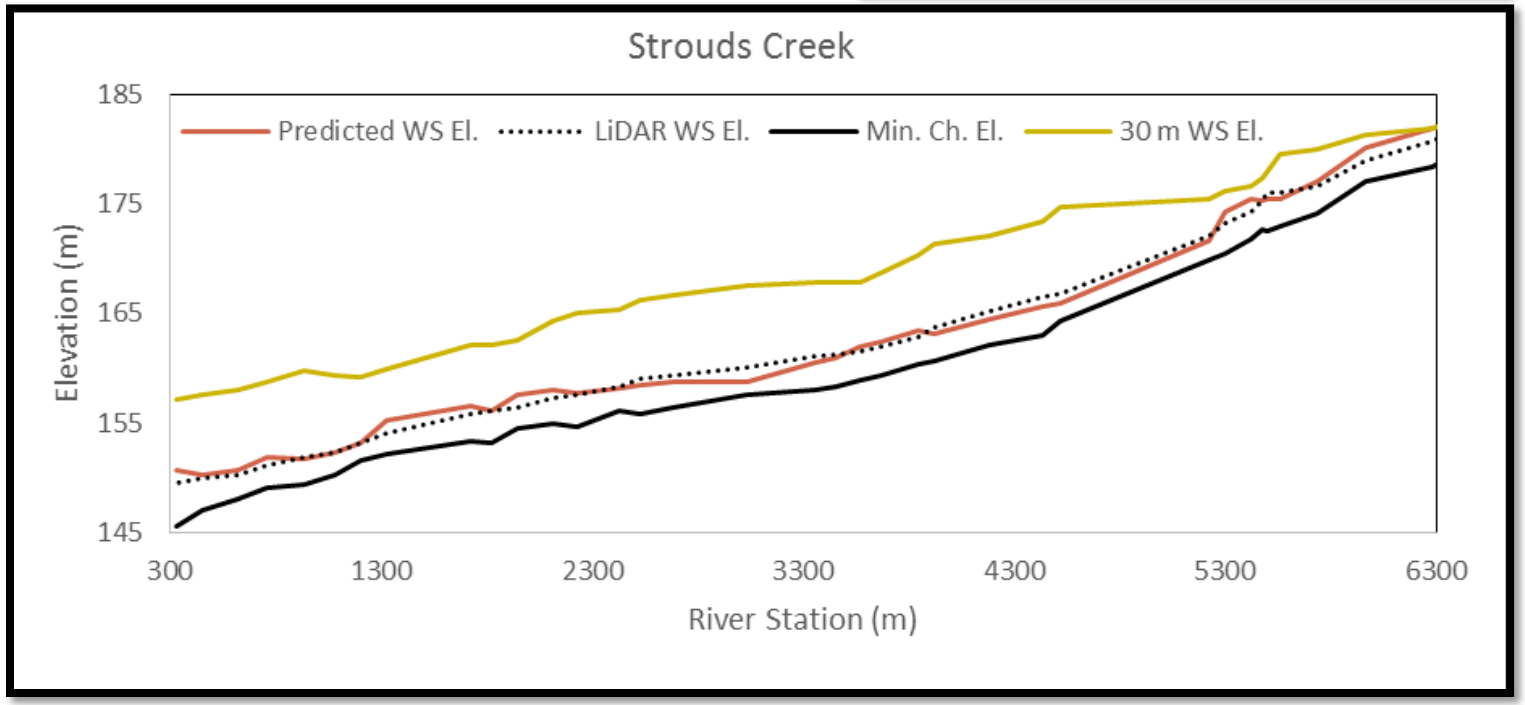




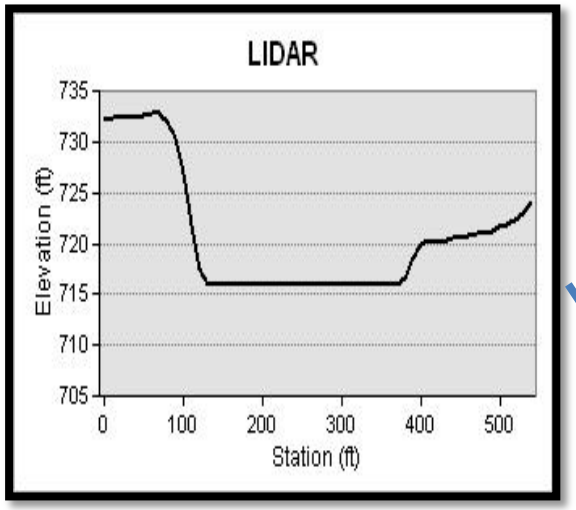
Flood inundation maps (WSE and Area) have linear relationships with DEM resolution and accuracy

Better results coarser DEM

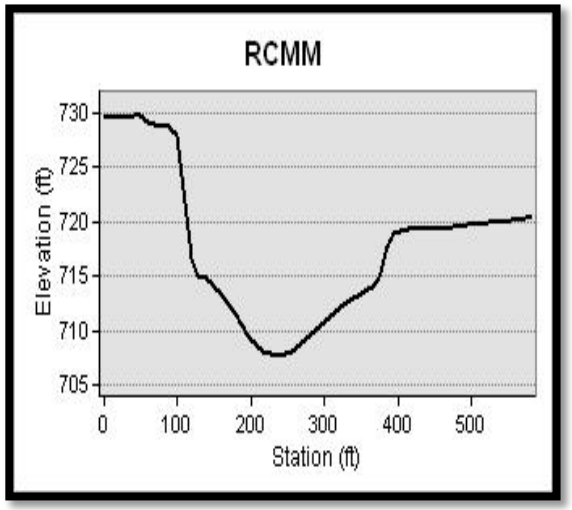




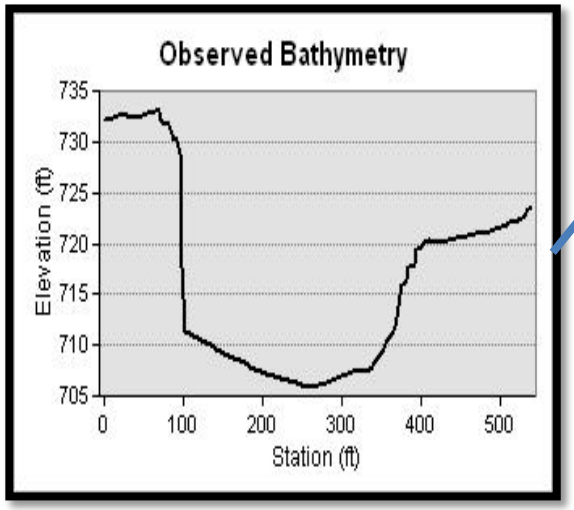
Role of River Bathymetry



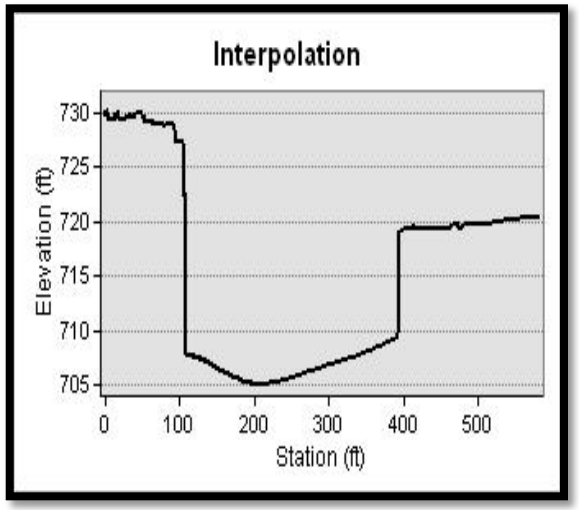
Best data we can get



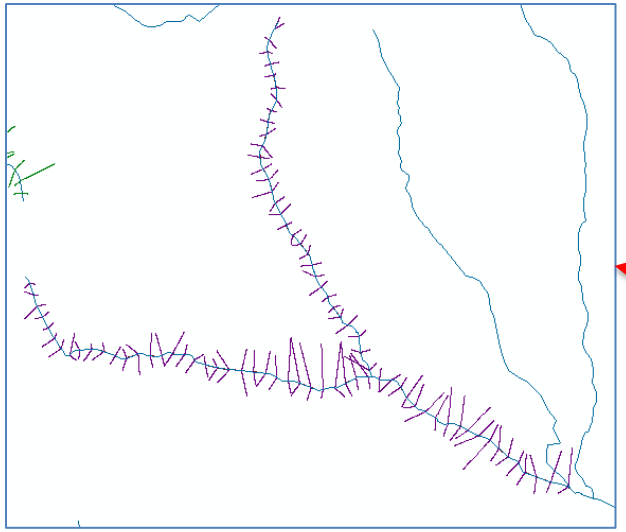
Bathymetry Tools



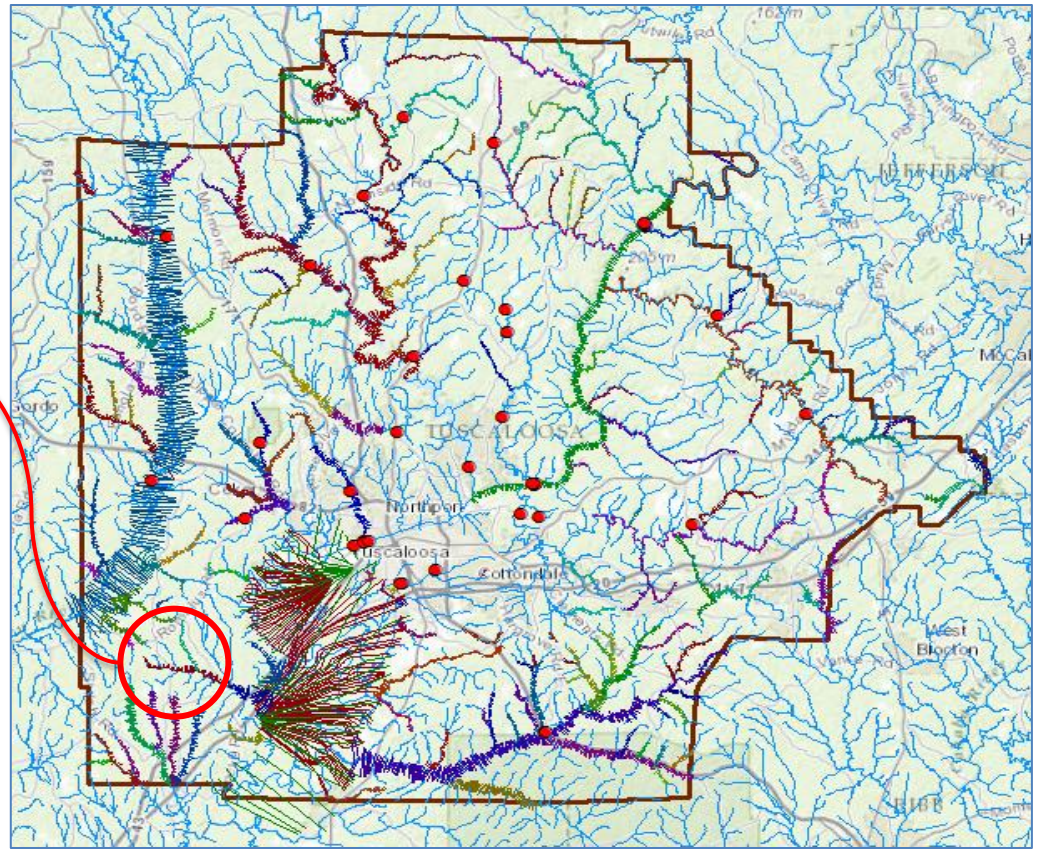
This is what we need



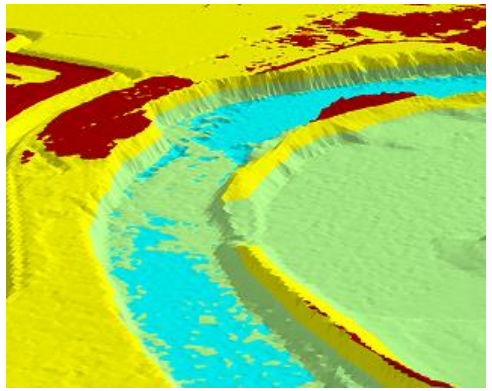
Bathymetry - Opportunity

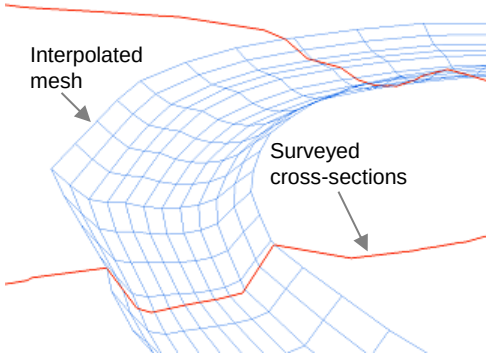


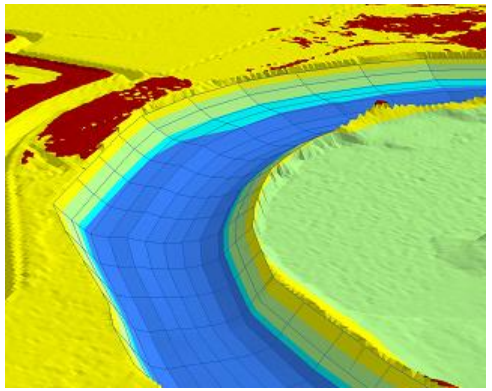
Tuscaloosa, Alabama,USA

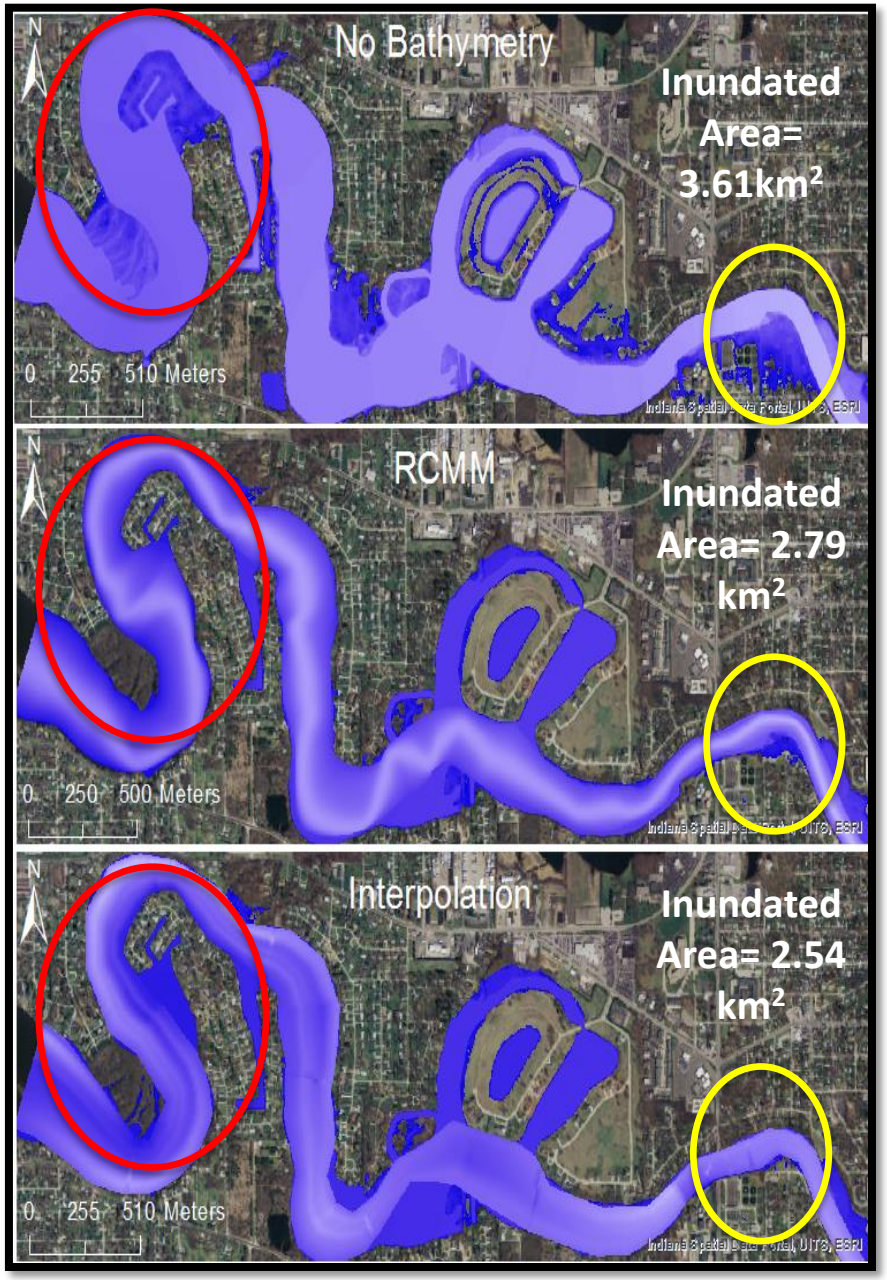


DEM + Bathymetry = Better Results



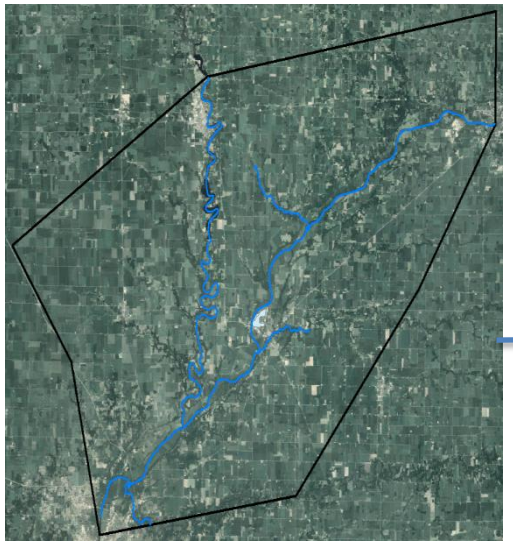




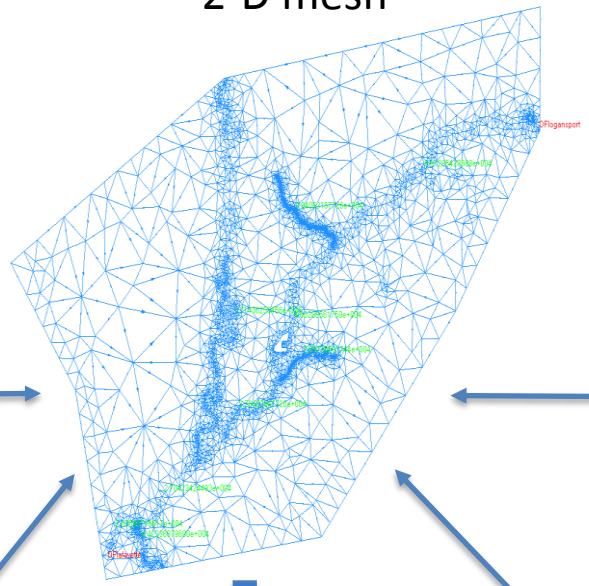


Data + Models → More opportunities

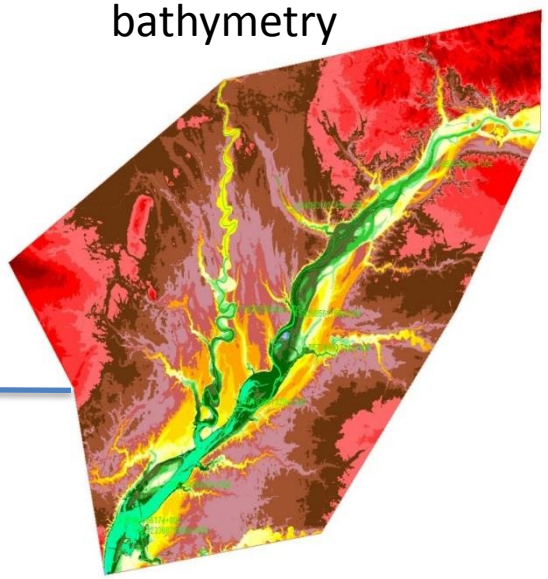
High resolution aerial imagery data

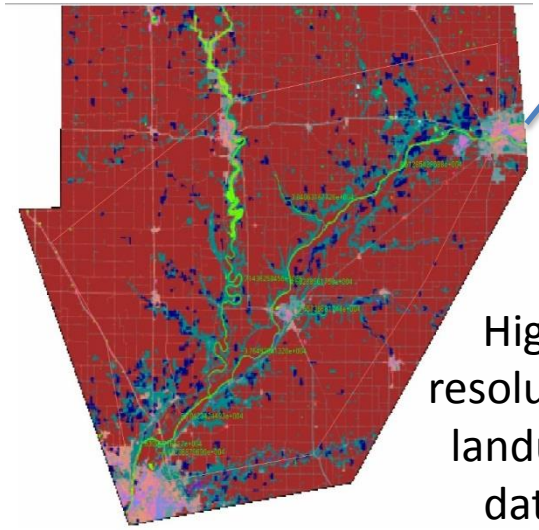


2-D mesh



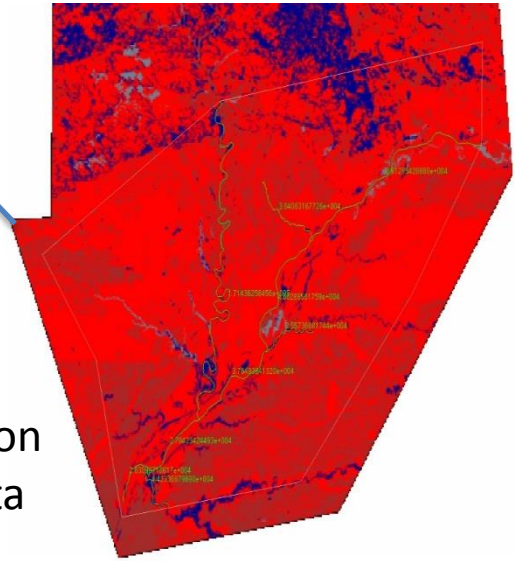
High resolution DEM with bathymetry





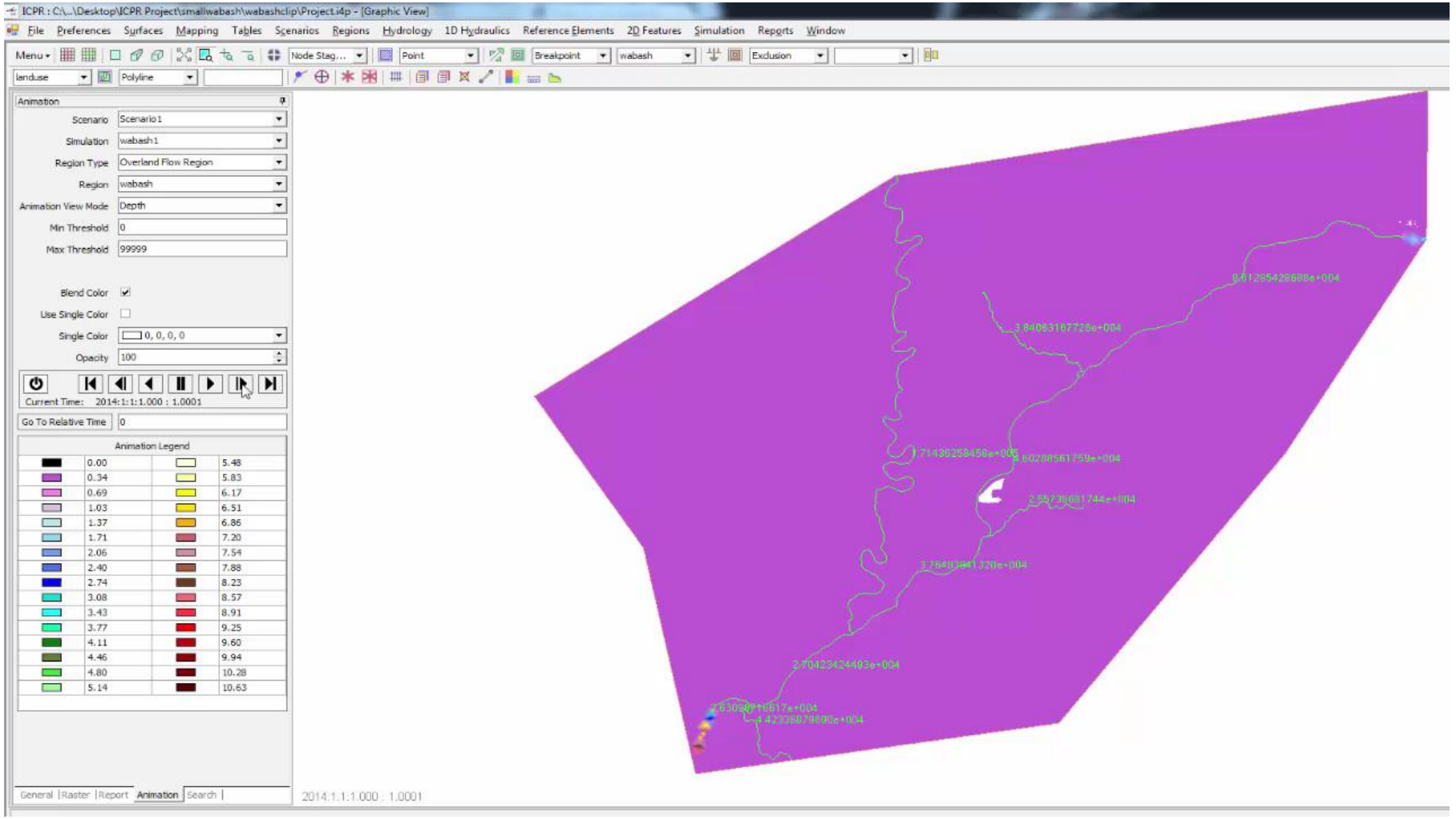
High resolution landuse data

Gridded rainfall data and observed streamflow data



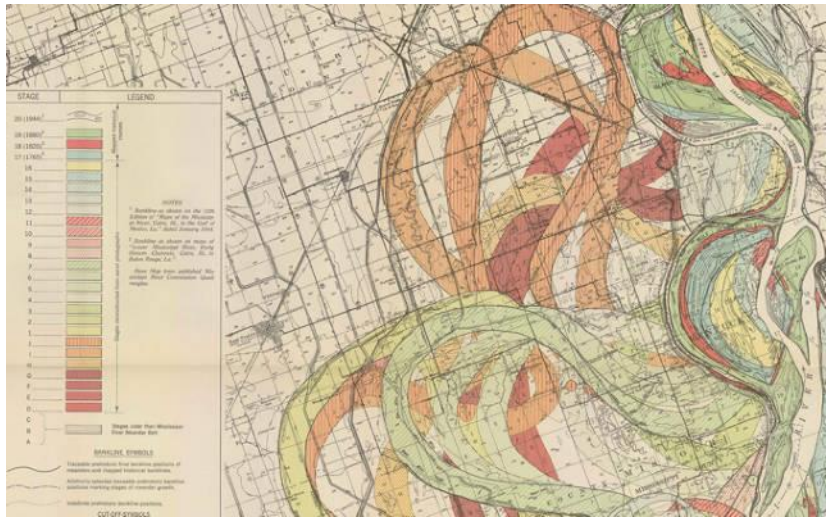
High resolution soil data

Hydrologic + Hydraulic Modeling



Data + historical perspective→ Innovation

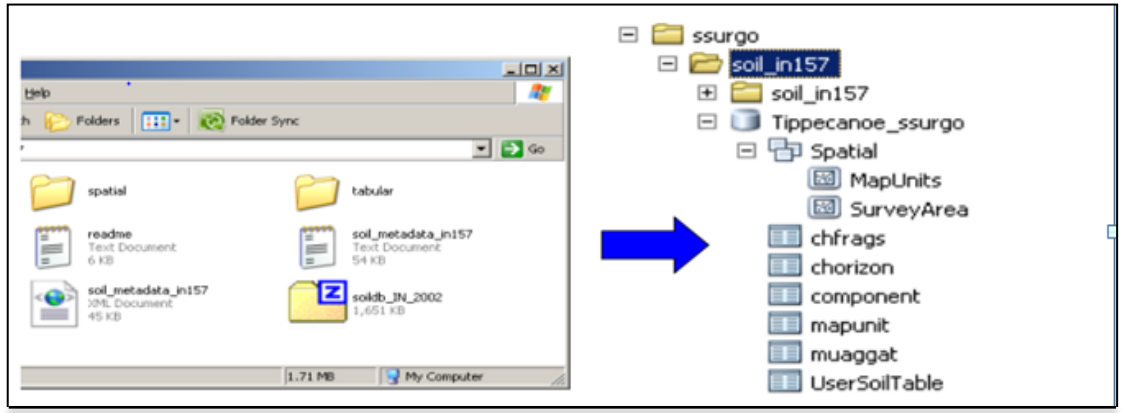
- Non engineering methods
  - Physiography, Soil, Vegetation…
- Cost effective



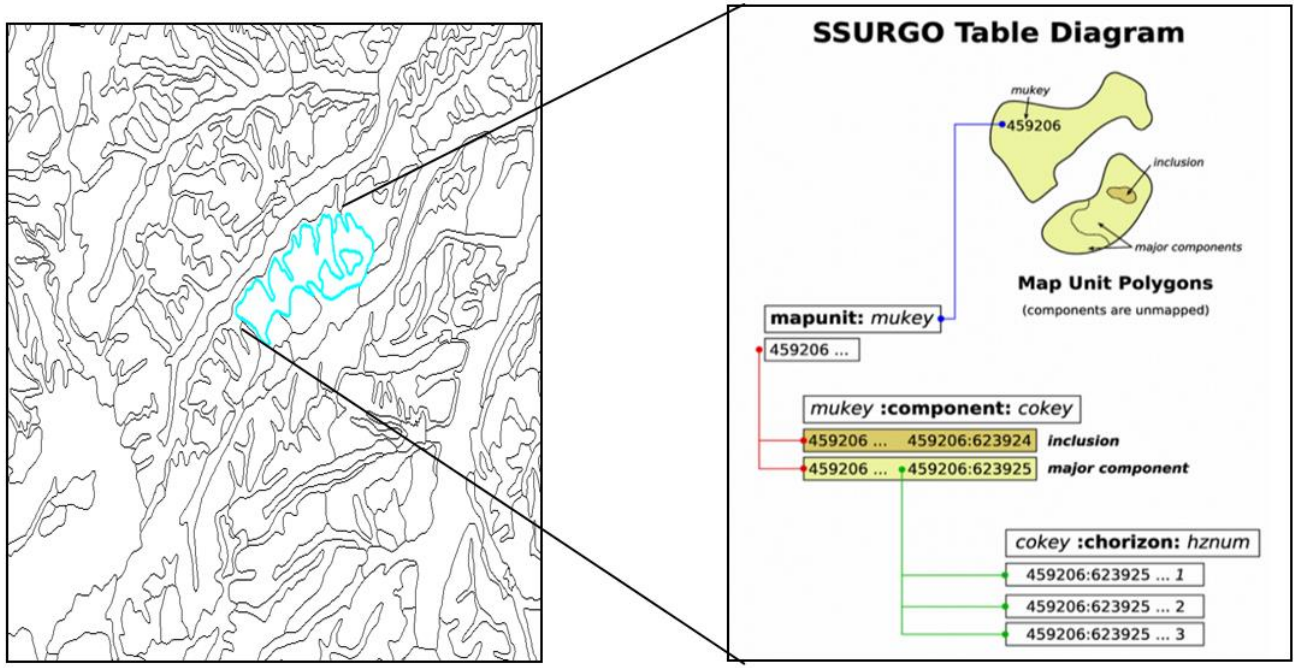
Integration of above approaches facilitated by advancements in technology (GIS) and data collection (SSURGO)

Cain & Beatty (1968), Wolman (1971), Leopold (1978)

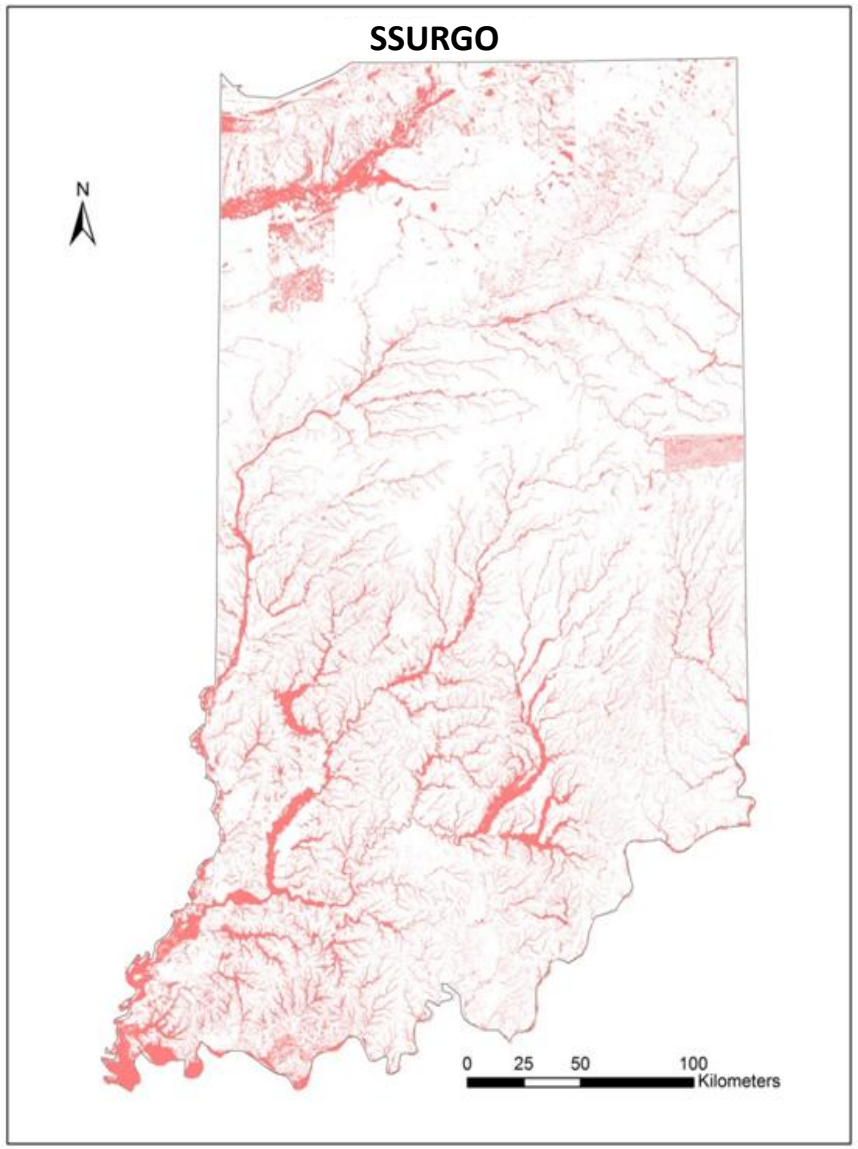
Using SSURGO Soil Data for Floodplain Mapping

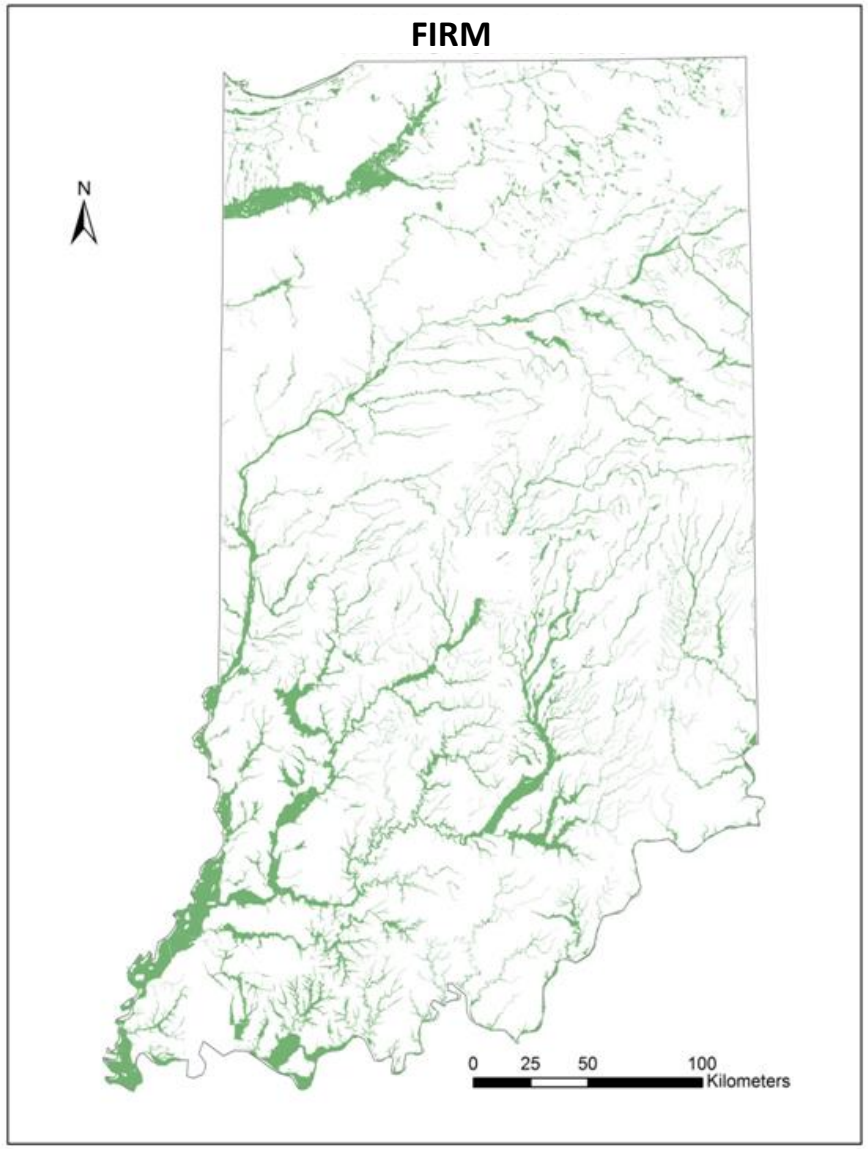


taxsubgrp
geomdesc
floodfreqdc
muname

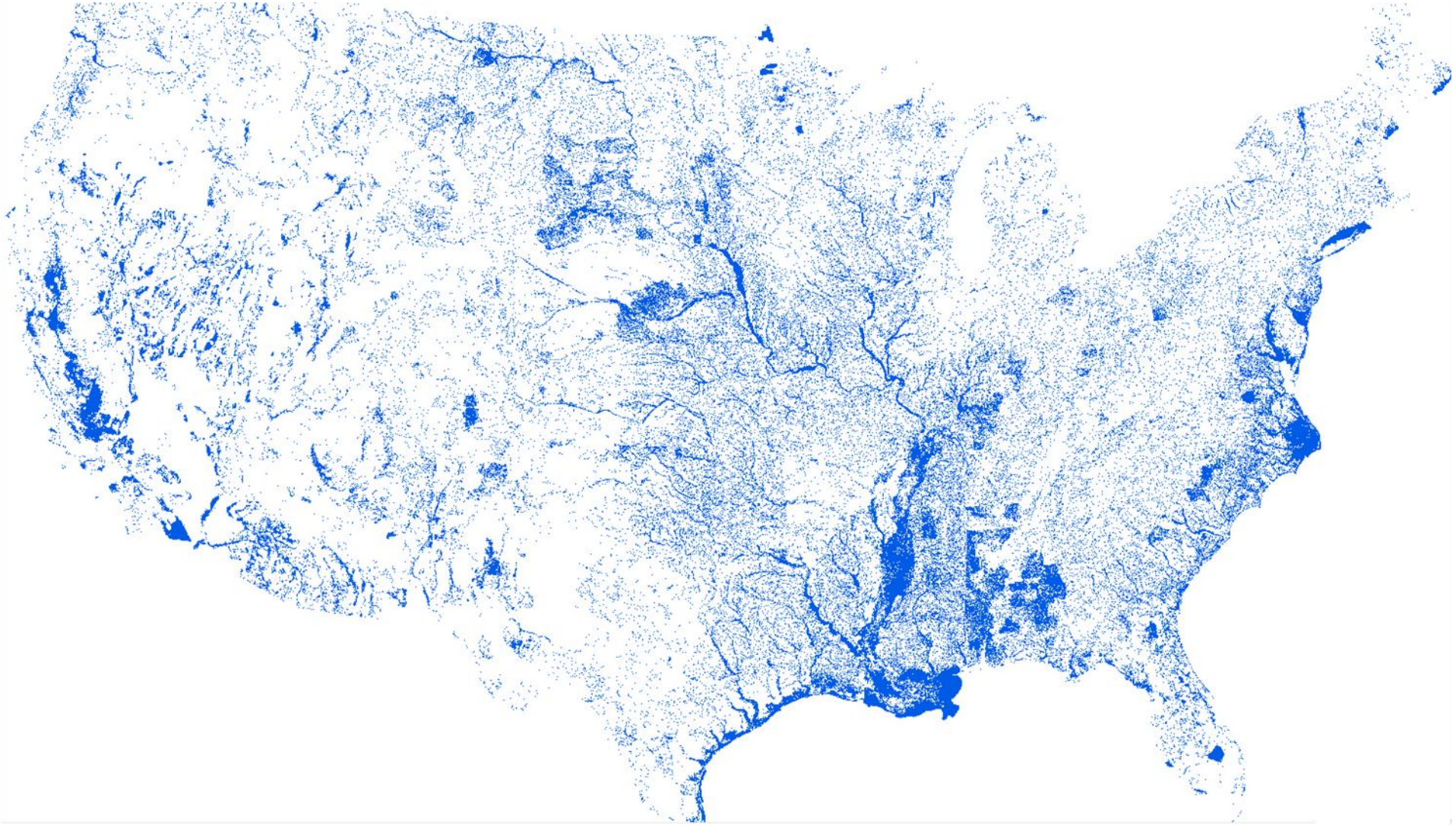


SSURGO based Floodplain Map

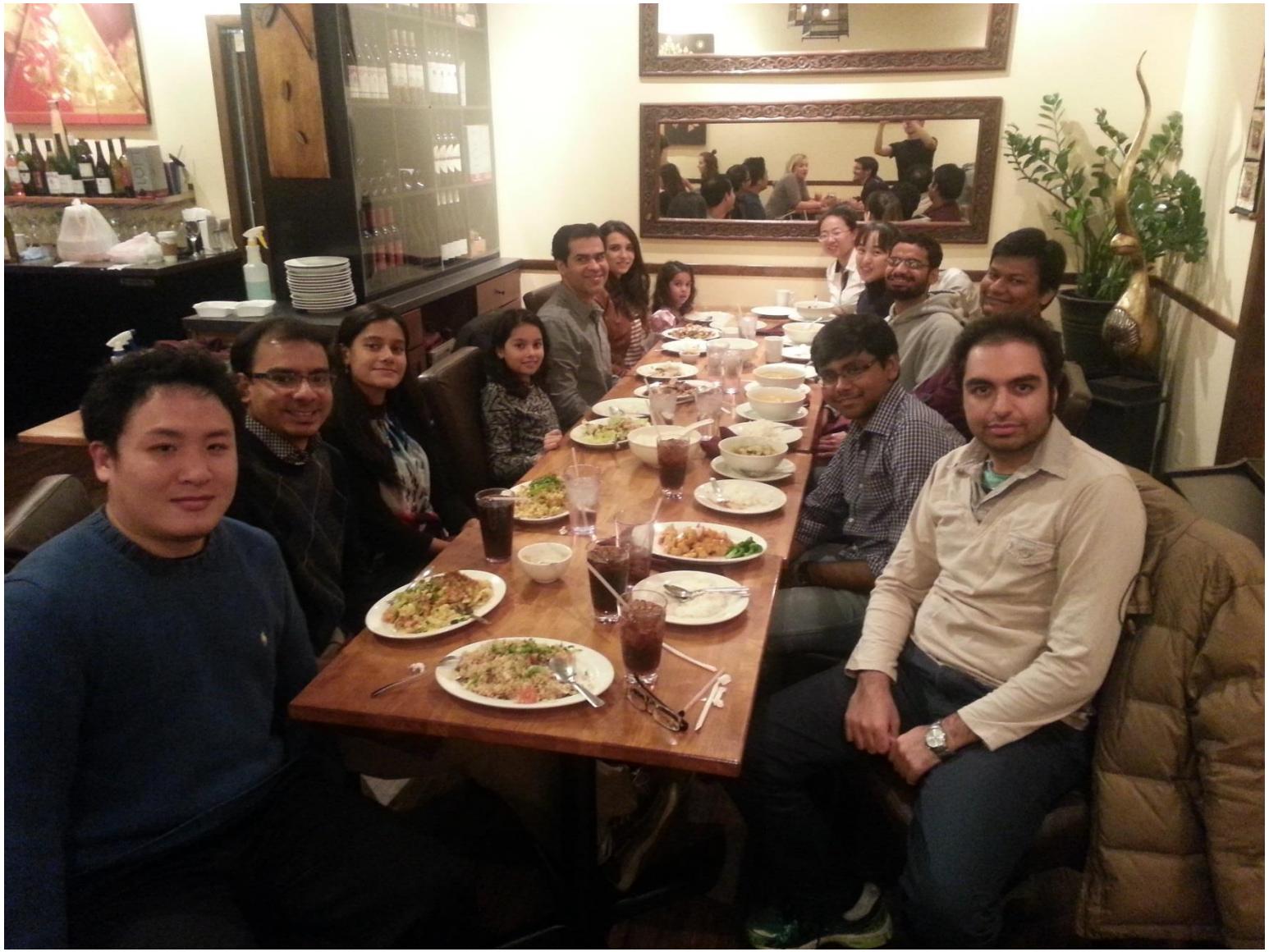




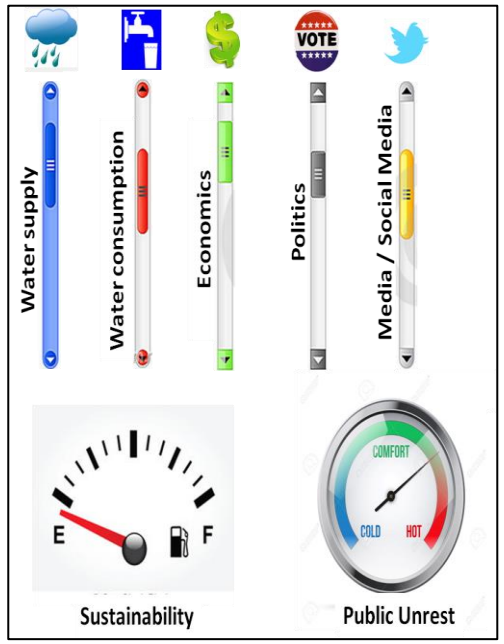
GSSURGO-based floodplain map for the whole US



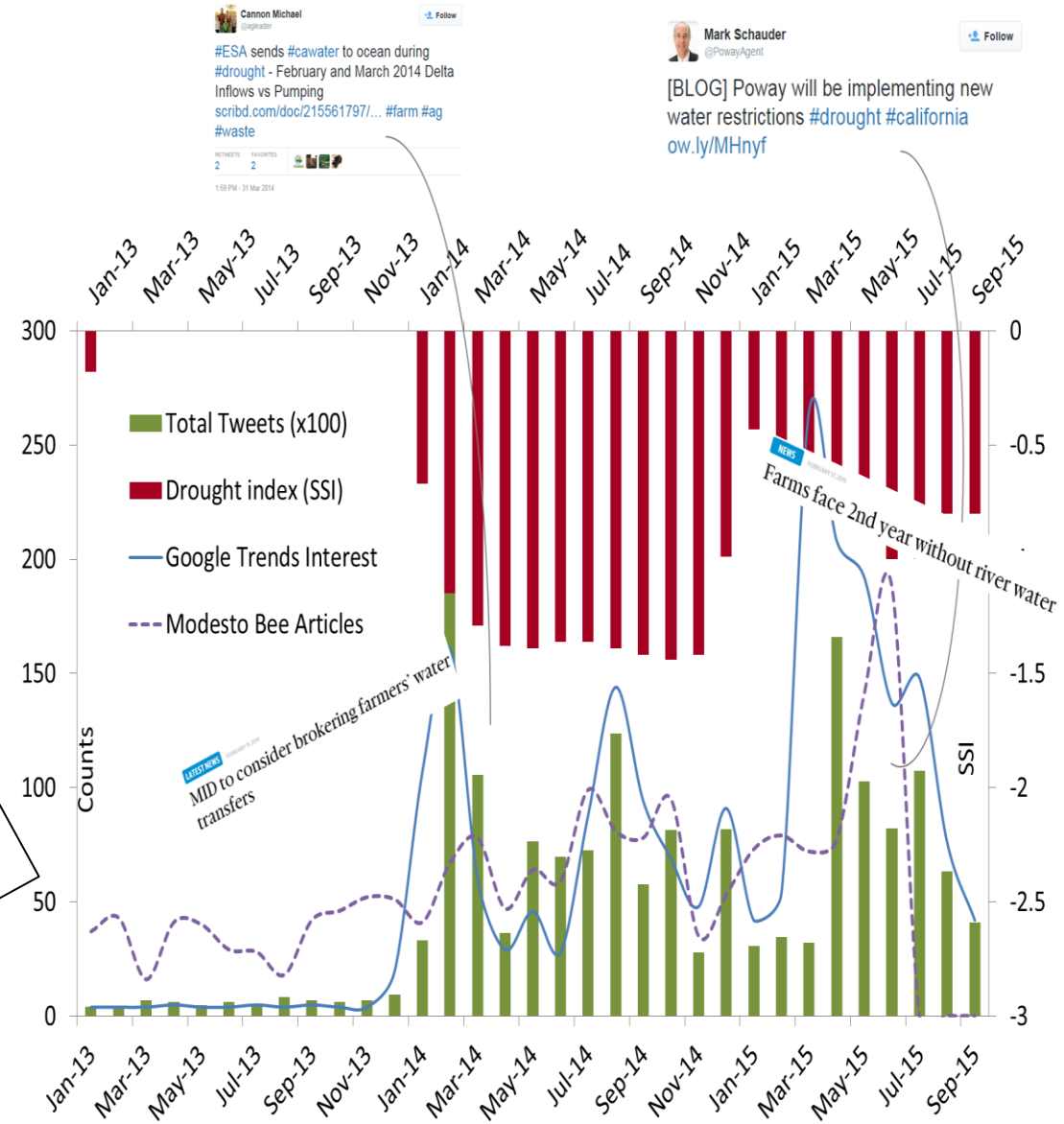
What does it take to create a floodplain map for the entire U.S.?



Data + Modeling + Social Media



Media buzz/Social response created by drought and policies



Summary

- Dealing with floods will require better prediction of hydrographs as well as inundation extents
- There are opportunities to advance the science of hydrology and flood risk information by exploiting big data and computational resources
- Developing low cost scalable technologies to map flood risk is the key to help the most needed communities

Thank you!

Venkatesh Merwade
vmerwade@purdue.edu