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Enhancing Compound Flood Simulation Accuracy and Efficiency in Urbanized Coastal Areas Using Hybrid Meshes and Modified Digital Elevation Model

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Ebrahim Hamidi et al., "Enhancing Compound Flood Simulation Accuracy and Efficiency in Urbanized Coastal Areas Using Hybrid Meshes and Modified Digital Elevation Model," ***Sustainable Cities and Society***, February 2025, 106184, https://doi.org/10.1016/j.scs.2025.106184.

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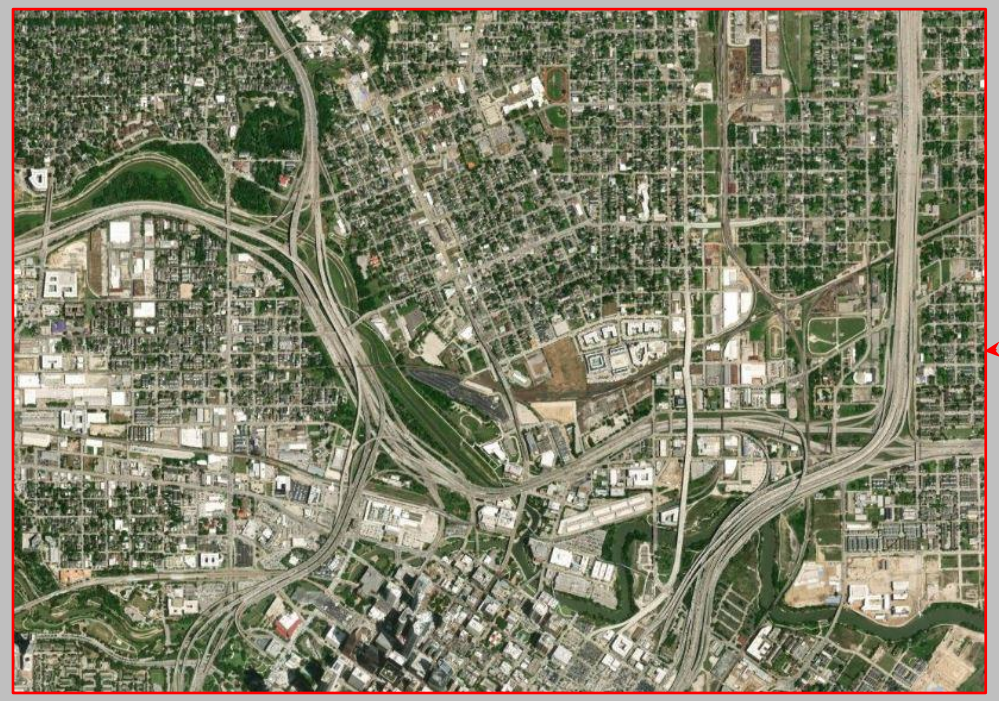
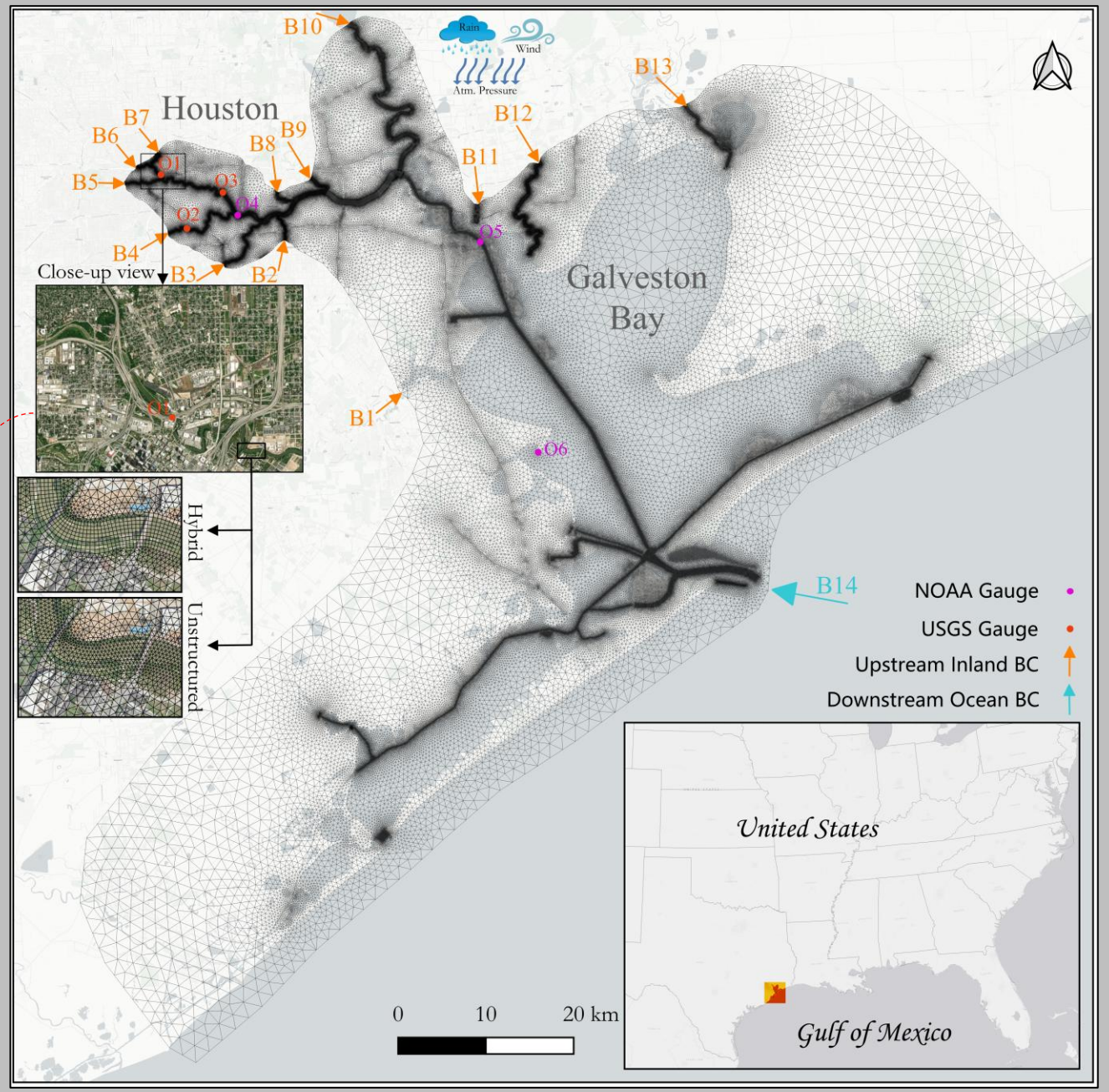
- Flood predictions for Hurricane Harvey Flood in Galveston Bay and Houston City with complex urban infrastructures.





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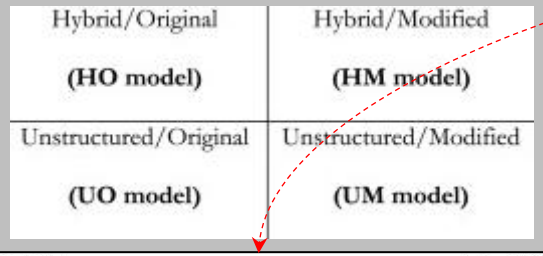
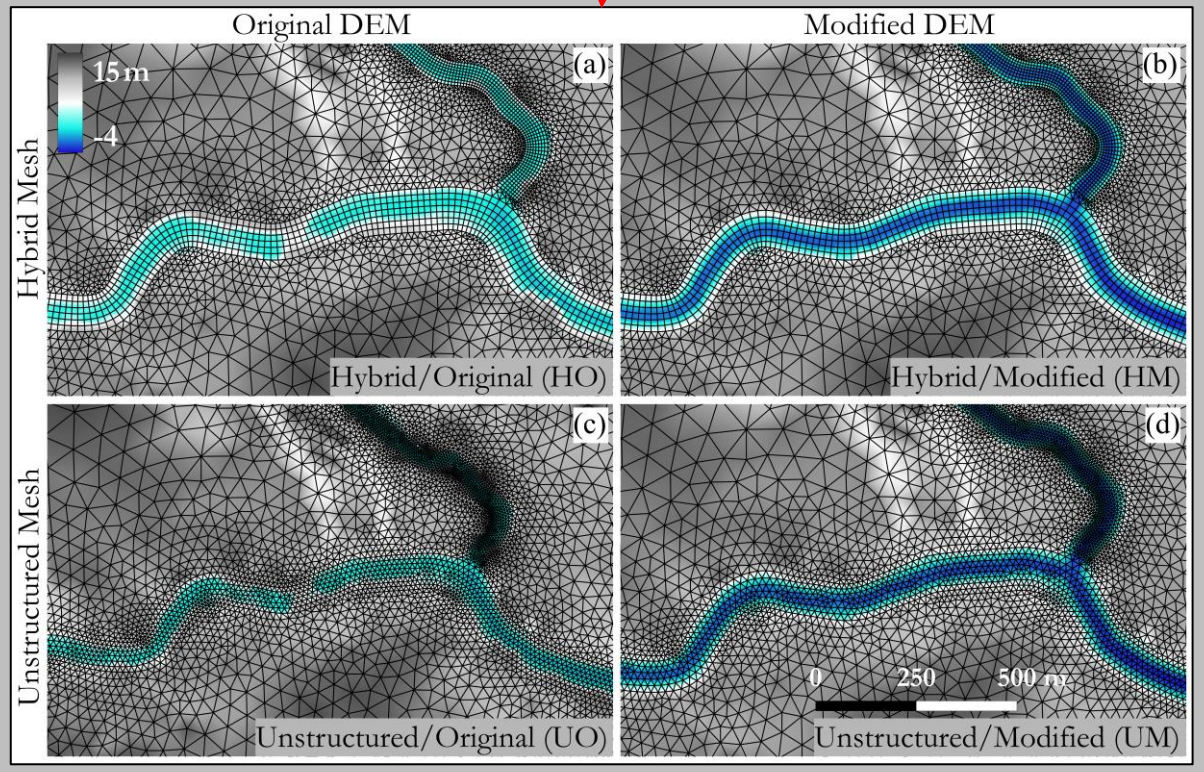
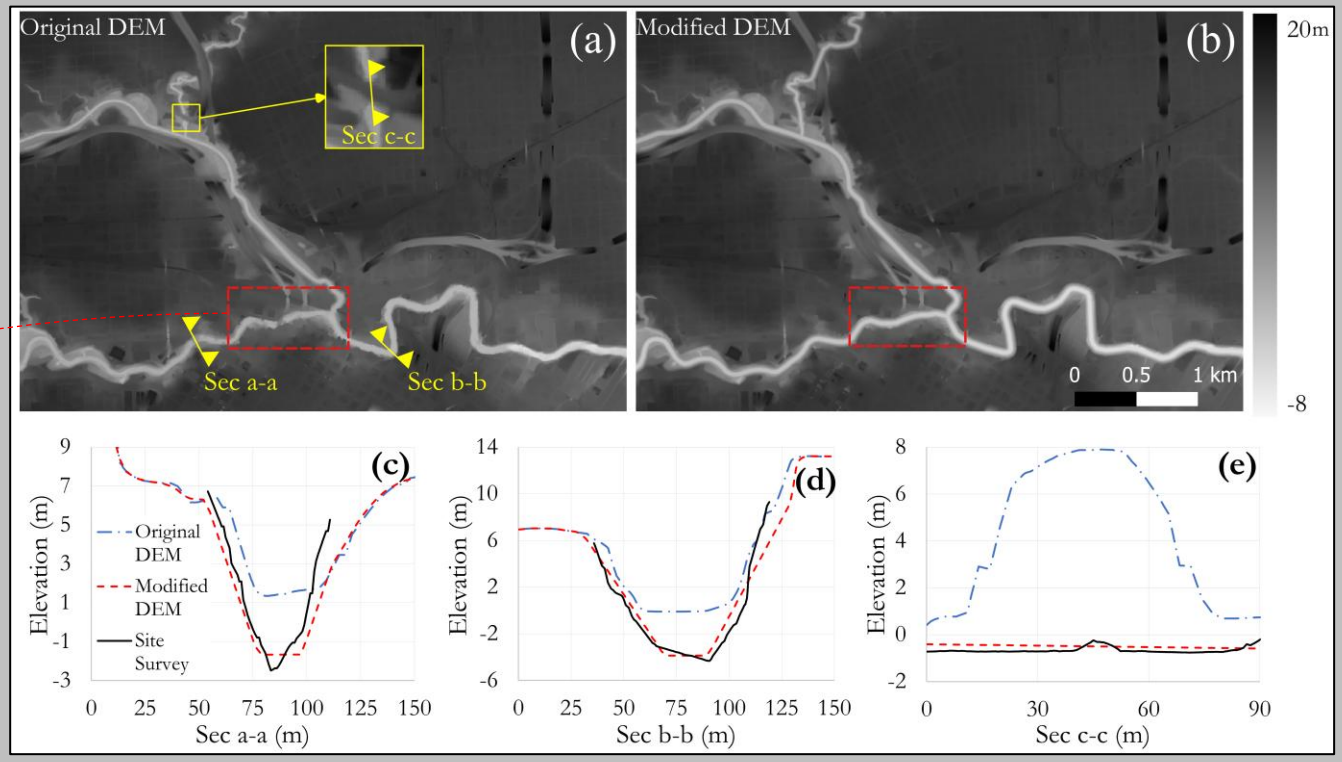
- The Continuously Updated DEM (CUDEM) with a 3m resolution







- DEM modifications using available stie survey from Harris County Flood Control District's Model and Map Management (M3).
- Hybrid and unstructured mesh generation methods are applied to both Original and Modified DEMs.

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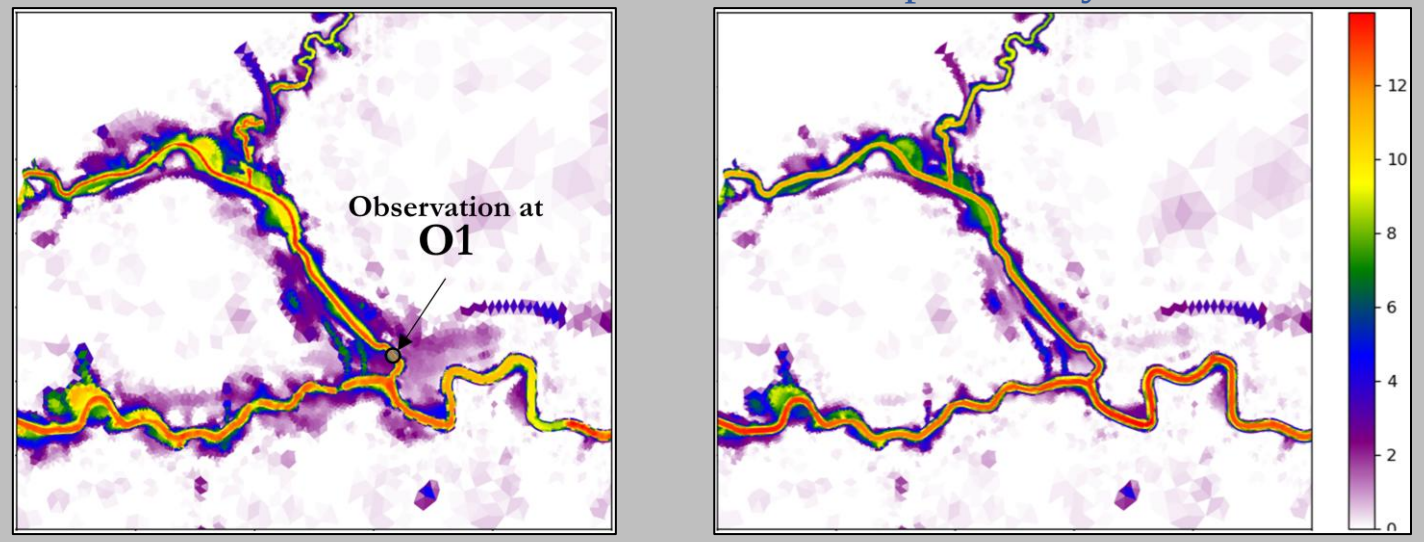
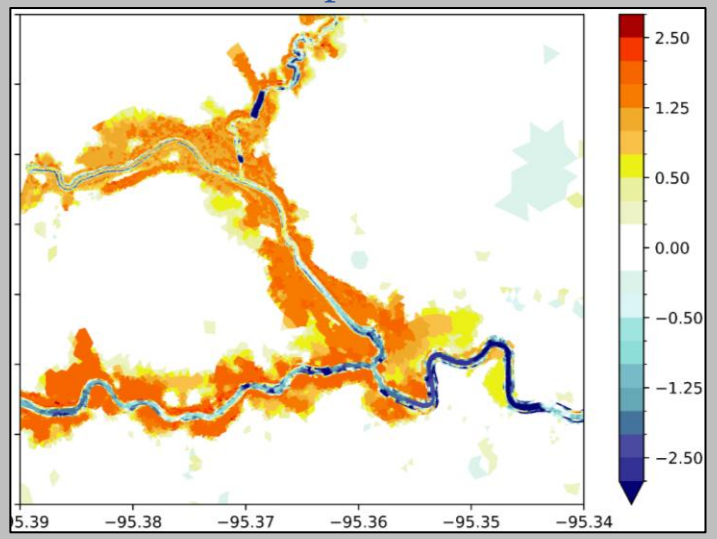
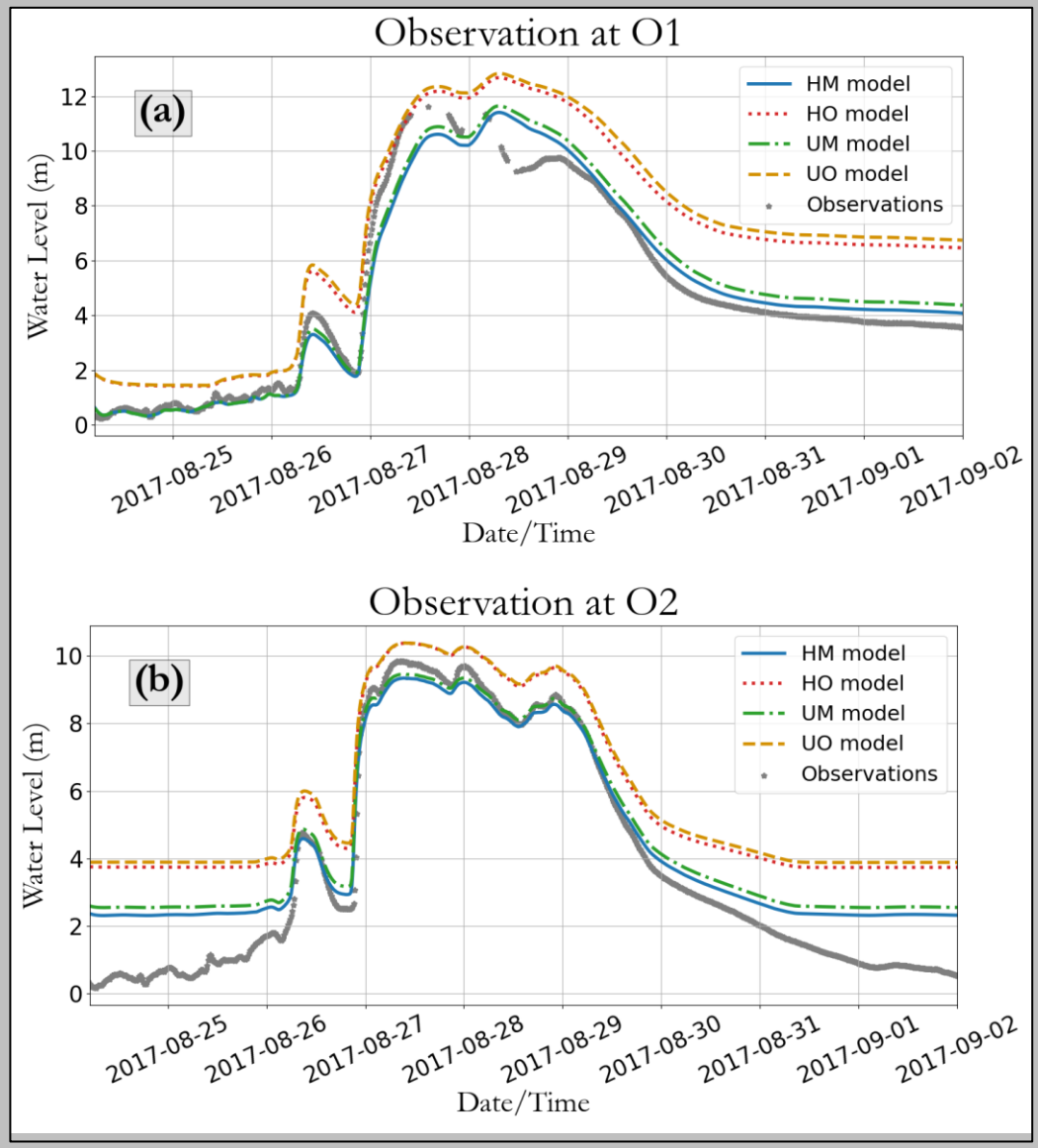
Simulated Water Level vs. Gauge Data

Water Depth for Hyb./Original – Water Depth for Hyb./Modified



= Water Depth Difference





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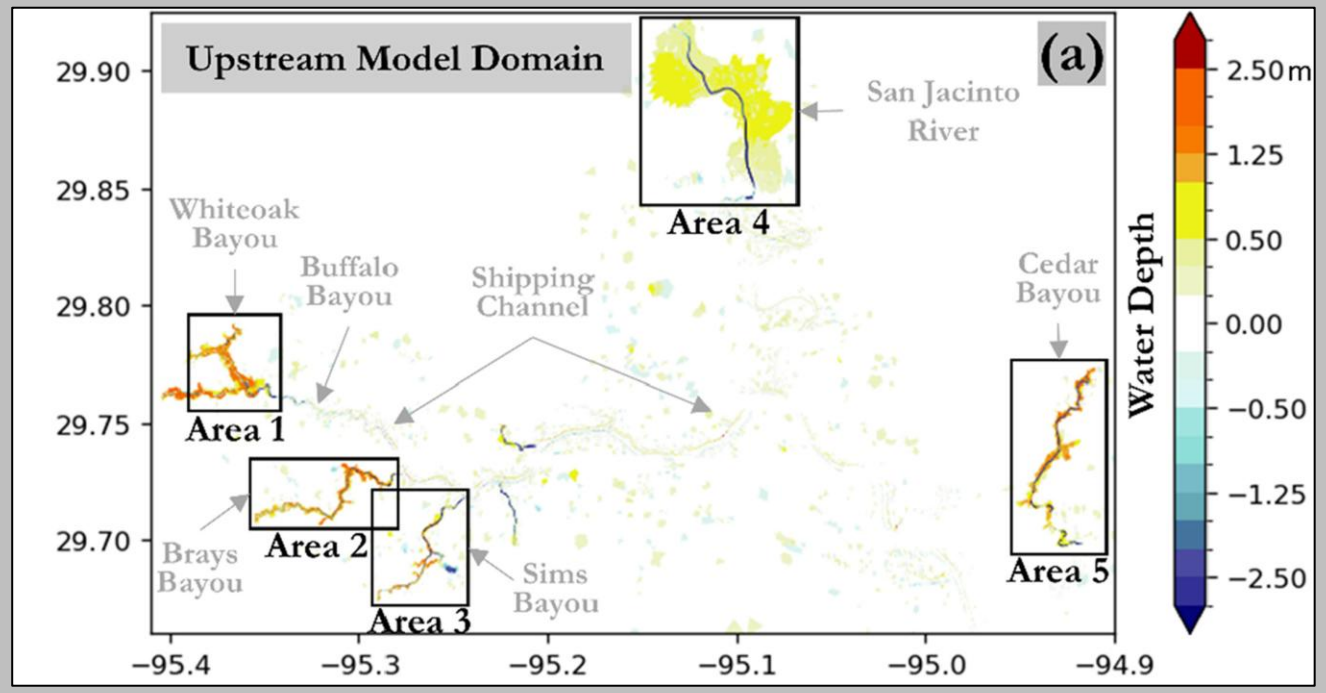
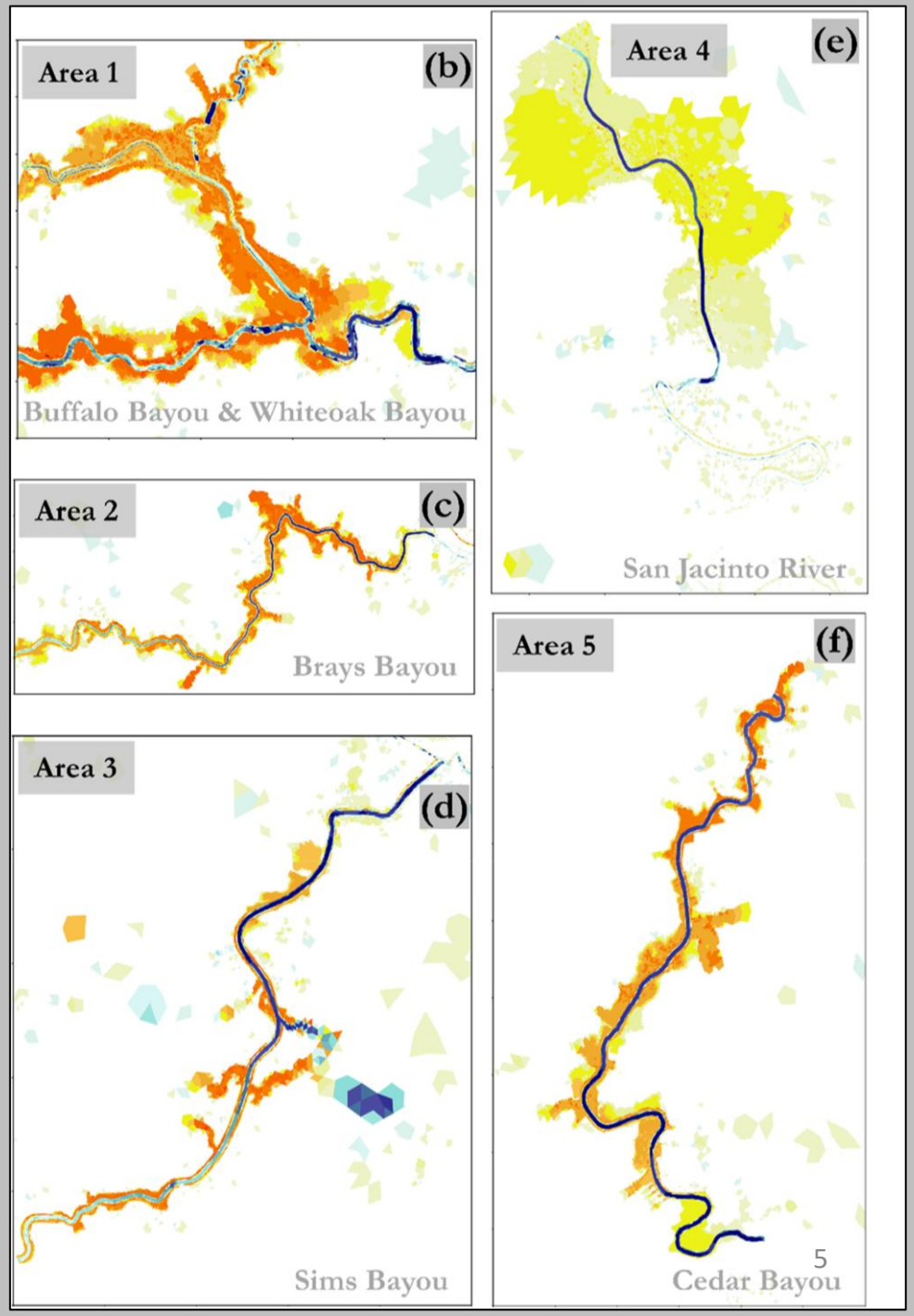
- Difference Maps for Water Depth





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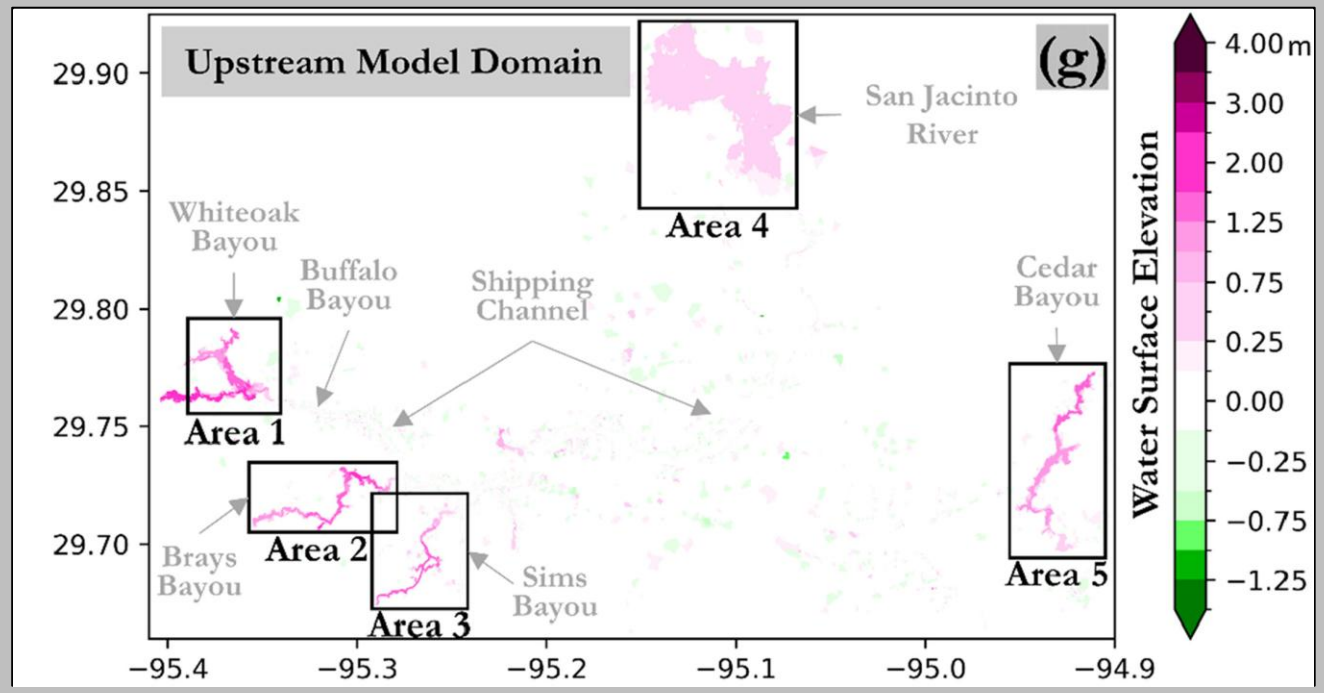
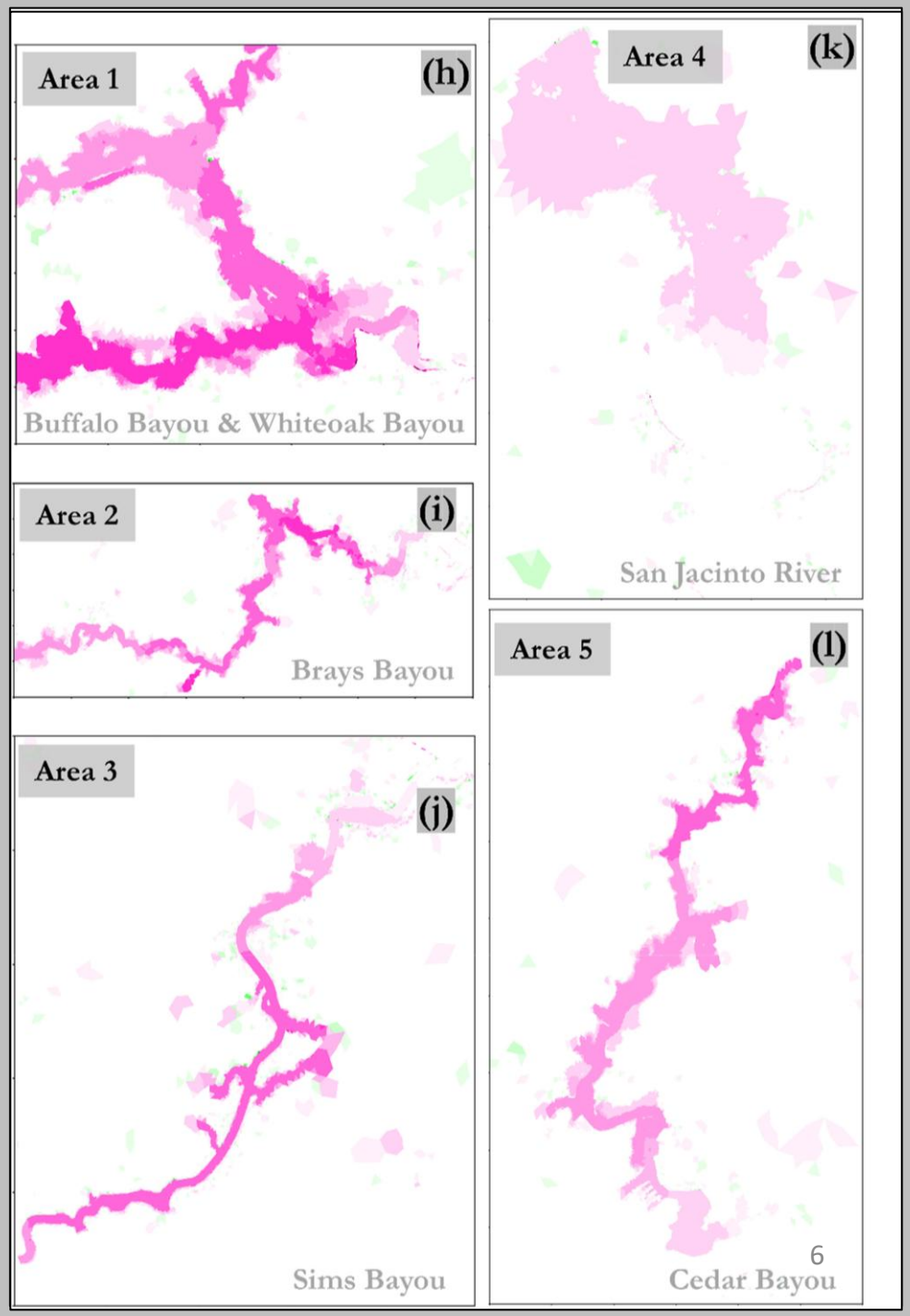
- Difference Maps for Water Surface Elevation





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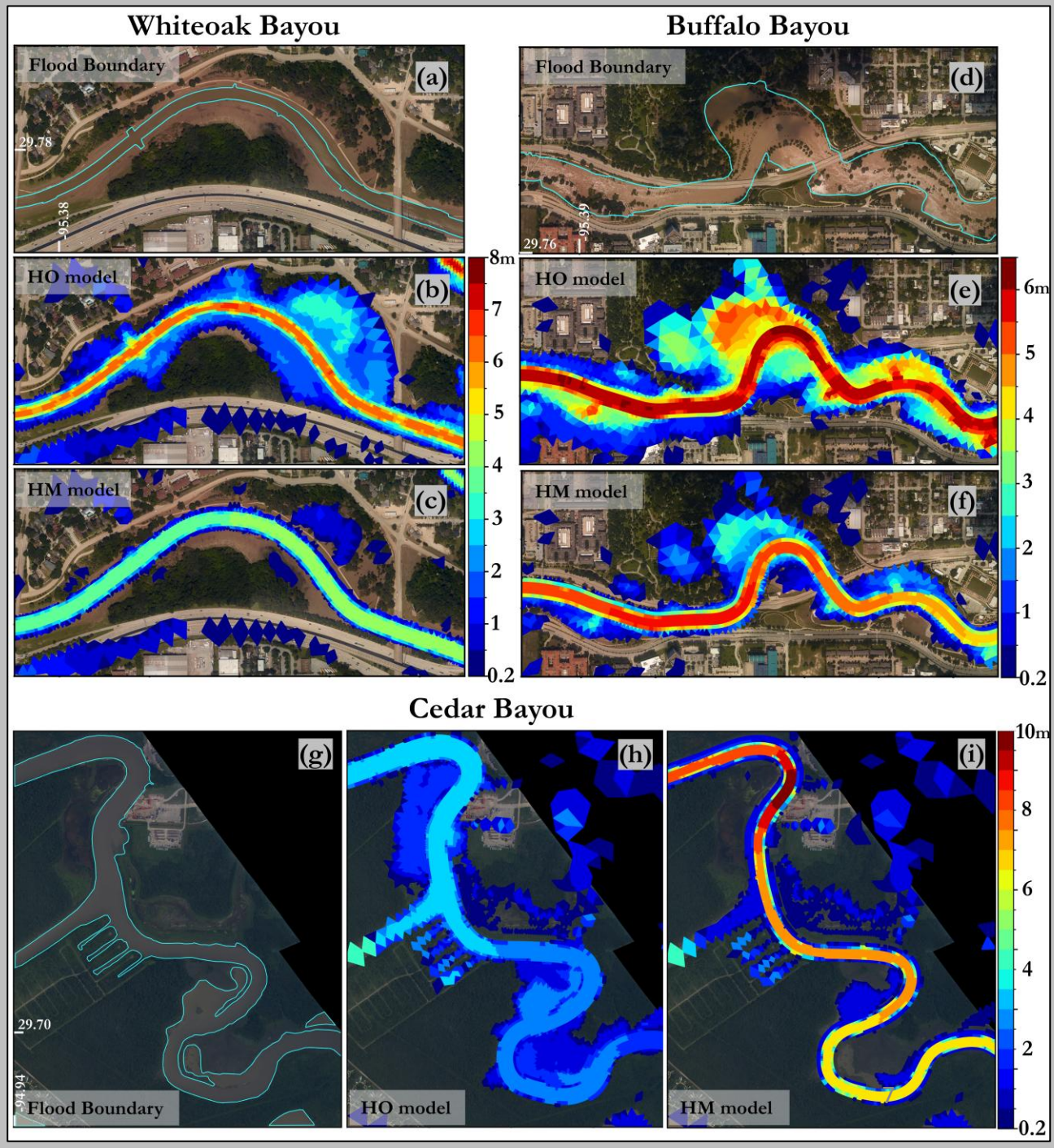
- Flood inundation overestimate in Original DEM model in some parts.
- We assessed computational efficiency between different simulations.

Mesh	DEM	Computation Time (Hours)	Improvement w.r.t Base	Number of Nodes	Number of Edges	Number of Faces
Unstructured	Original	159.56	Base	364,887	1,093,227	728,341
	Modified	148.84	7%			
Hybrid	Original	111.35	30%	356,440	950,060	593,621
	Modified	105.94	34%			



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- The impact of atmospheric forces and storm surge was assessed.

Sustainable Cities and Society 121 (2025) 106184

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Enhancing compound flood simulation accuracy and efficiency in urbanized coastal areas using hybrid meshes and modified digital elevation model

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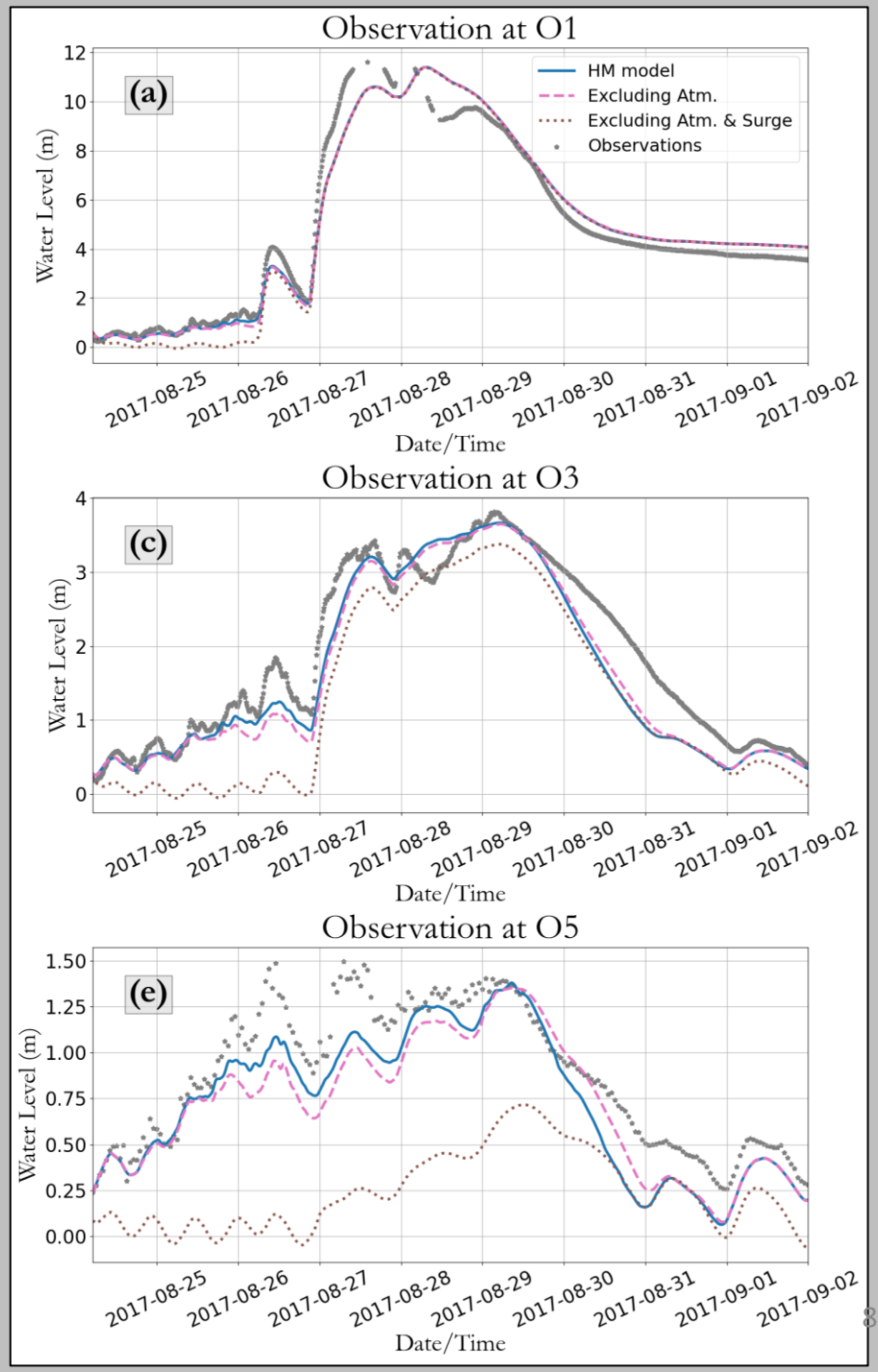
ARTICLE INFO

Keywords:
Coastal compound flood mapping
Appropriate DEM and mesh
Flood modeling accuracy and efficiency
Urban coastal flood mitigation

ABSTRACT

Accurate flood simulation is crucial for comprehending its impacts, especially in urbanized coastal areas. Reliable flood modeling depends on precise input data, as errors can lead to inaccurate severity estimates. This research investigates the impact of Digital Elevation Model (DEM) modifications on hydrodynamic simulation results, particularly in densely populated urban regions where man-made features like roads and bridges significantly affect water movement. Findings reveal that integrating local survey data to modify DEMs not only significantly enhances result accuracy but also reduces computational costs. Additionally, comparing unstructured and hybrid meshes indicates that using hybrid meshes on a Modified DEM significantly improves accuracy and computational efficiency for flood inundation mapping. A case study of Hurricane Harvey in Houston, Texas, shows a 40 % improvement in flood estimate accuracy and a 34 % reduction in computation time with hybrid meshes on a modified DEM. Additionally, the study evaluates the impact of atmospheric forces and surge, revealing a 20 % improvement in results in the Bay area when atmospheric forces are included. This research underscores the importance of employing accurate DEMs, appropriate meshes tailored to domain features and proper boundary forces for precise flood simulations, helping decision-makers and city planners better assess community vulnerability.



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Integrating Multi-Source Remote Sensing and Numerical Simulation Approaches for Enhancing Flood Assessment

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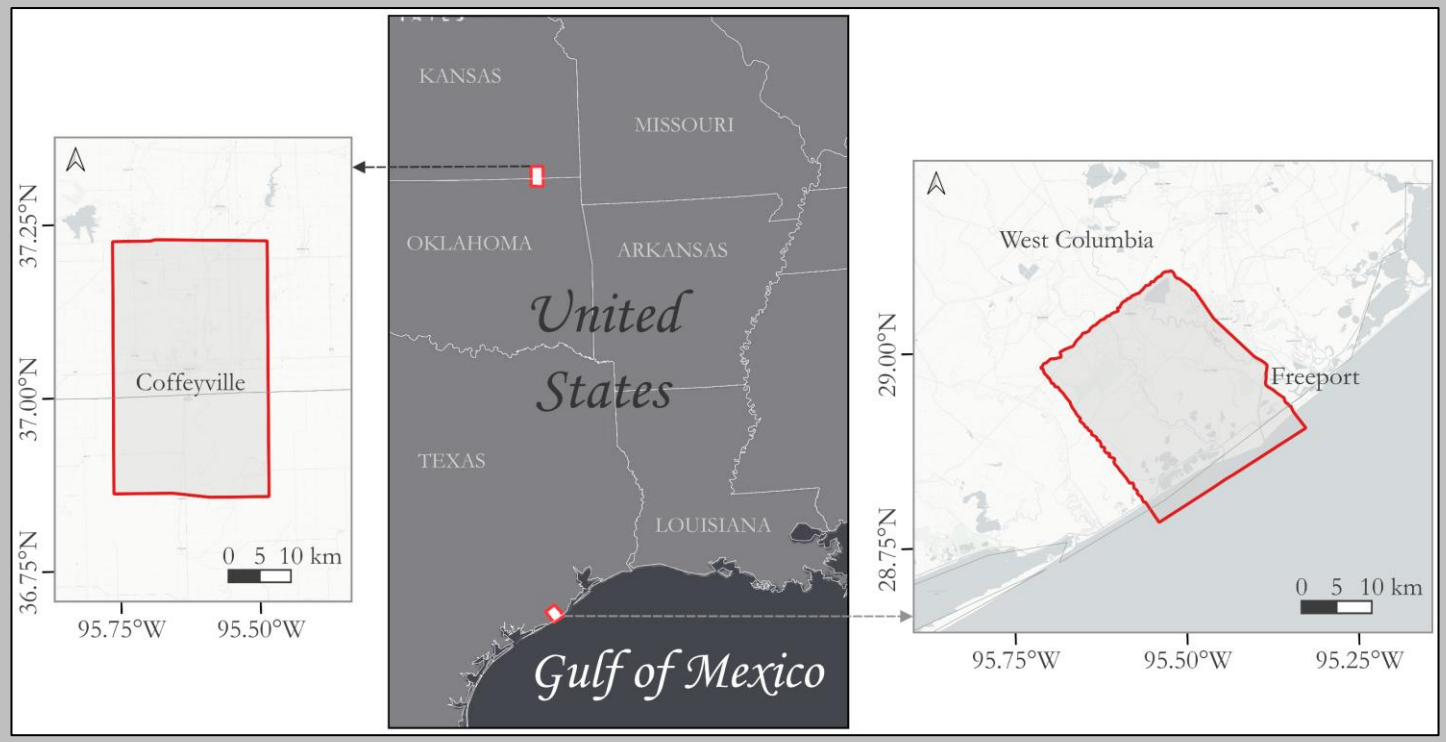
Integration of Remote Sensing and Numerical Simulation

- Extreme flood in Coffeeville, KS, USA on May 2019.
  - Numerical model using HEC-RAS-2D
  - Calibrated using observation gauge
  - Remote sensing data for model verification

- Flood after Harvey in South of Houston, TX, August 2017
  - Numerical simulation using Delft3D-FM
  - No observation gauged for calibration
  - Model calibration and verification using remote sensing flood maps.



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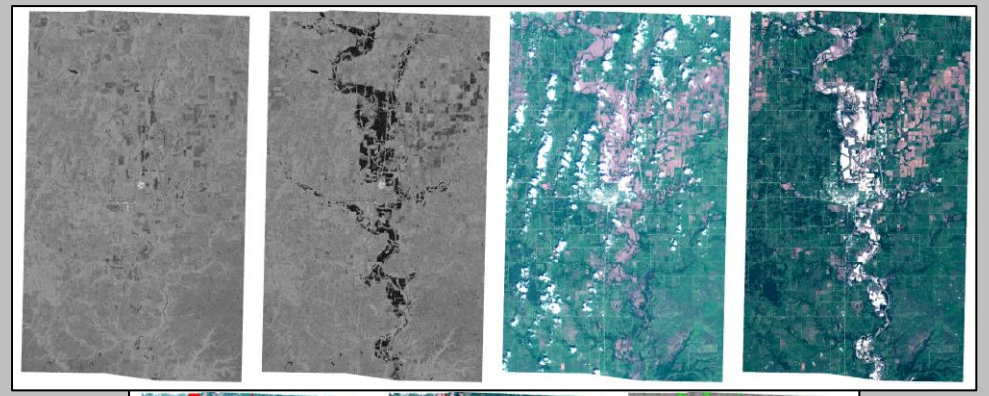
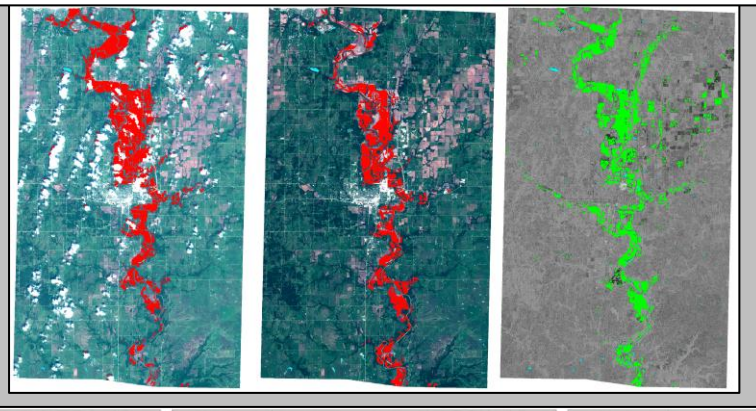
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 61, 2023 4201419

Fast Flood Extent Monitoring With SAR Change Detection Using Google Earth Engine

Ebrahim Hamidi, Brad G. Peter, David F. Muñoz, Hamed Moftakhari, and Hamid Moradkhani

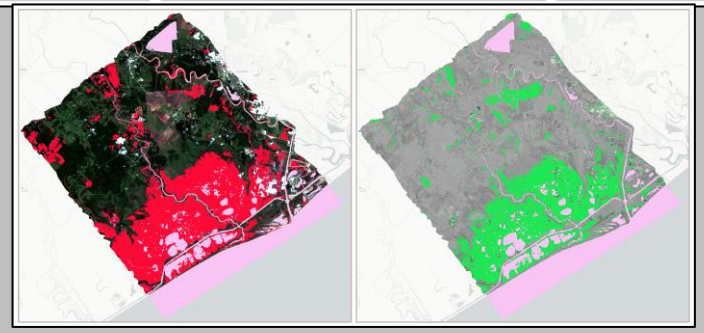


- Three images during Coffeyville Flood
- Two images during Harvey Flood
- Flood map using multi-source remote sensing approach



Sensor	Date	Status	Orbit/Polarization	Spatial Resolution	Study Area
Sentinel-1	1-Jul-18	Before Flood	Ascending / VH	10-m	Coffeyville, KS
	21-May-19	After Flood			
Sentinel-2	27-May-19	After Flood	---	20-m	
	30-May-19				
Sentinel-1	5-Jun-17	Before Flood	Ascending / VH	10-m	Texas coast
	28-Aug-17	After Flood			
Sentinel-2	30-Aug-17	After Flood	---	20-m	

Location	Indices	k_f	*Agr*	*ToAgr*
Coffeeville, KS, USA	NDFI	1.4	70%	50%
	DII	1.2	73%	52%
Texas coast, USA	NDFI	0.4	72%	63%
	DII	0.2	74%	64%



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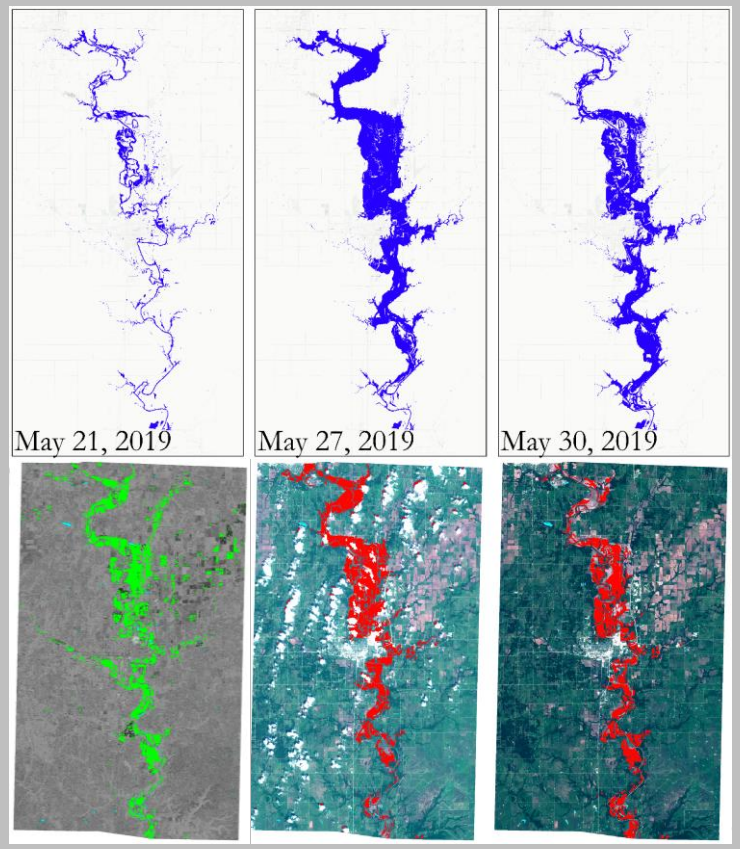
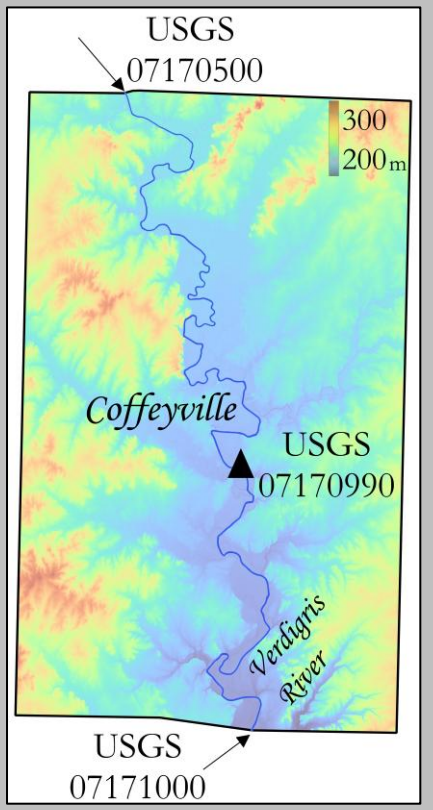
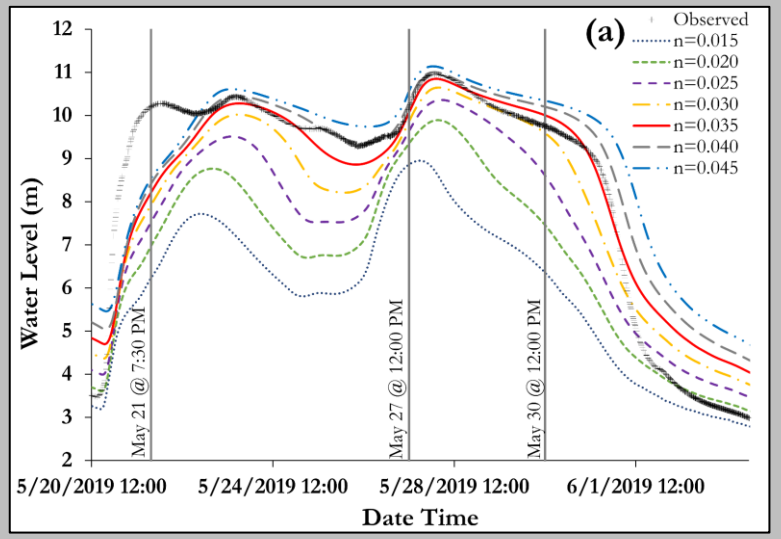
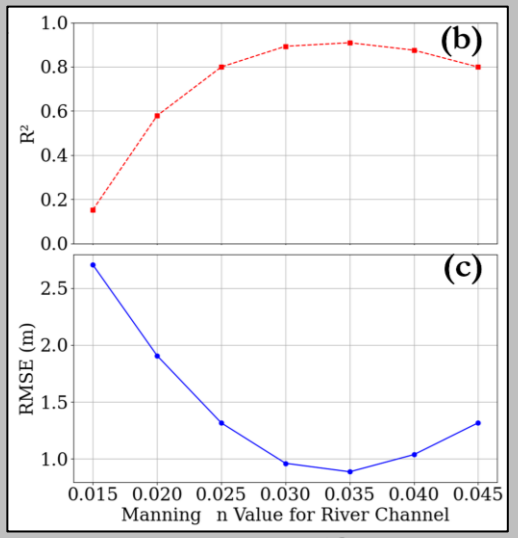
- Model calibration using observed gauge
- Good agreements; however, even a calibrated model has uncertainties.









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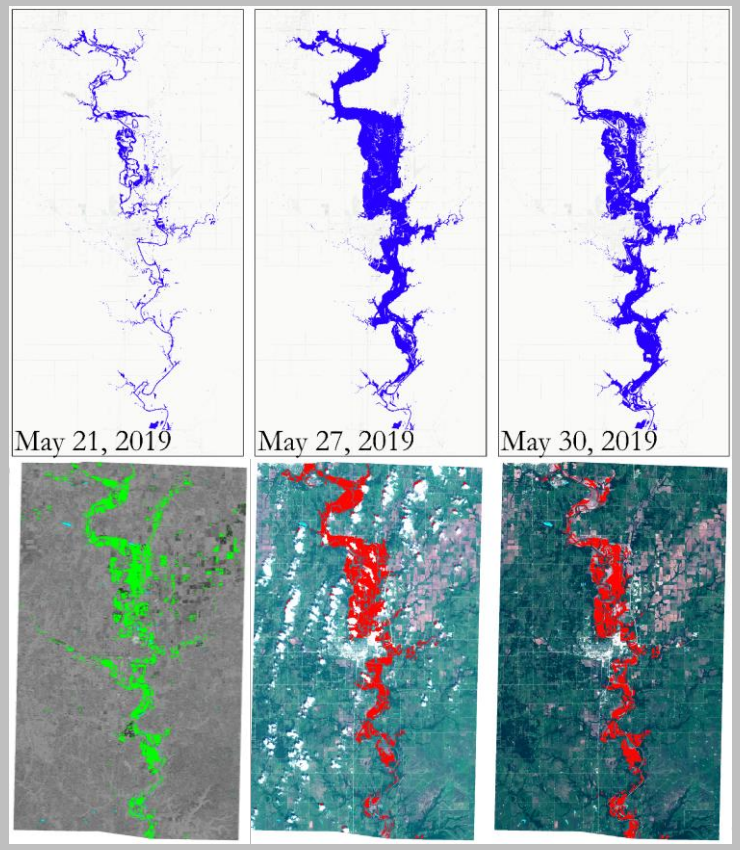

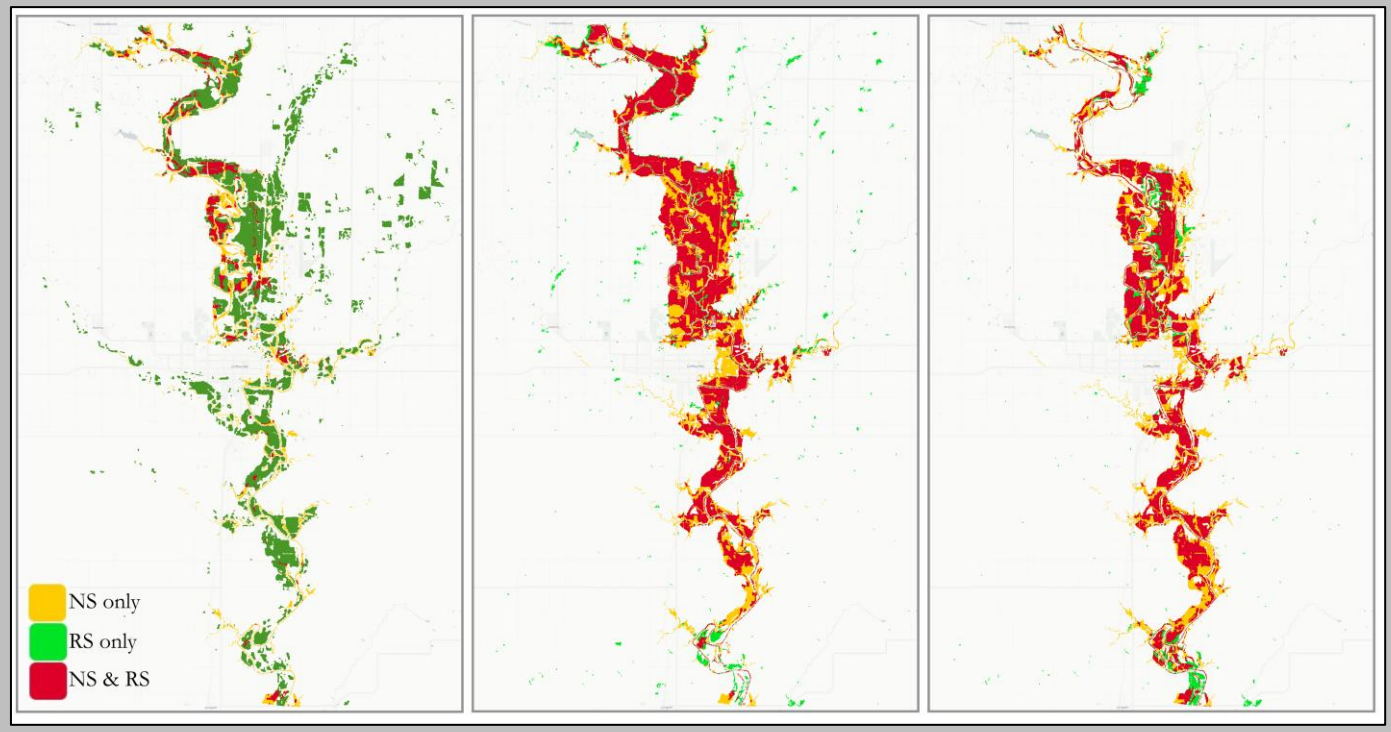

Comparison	Date	*Agr (%)*	*ToAgr (%)*
NS vs. SAR	May 22, 2019	38%	10%
NS vs. Optical	May 27, 2019	98%	65%
NS vs. Optical	May 30, 2019	98%	60%

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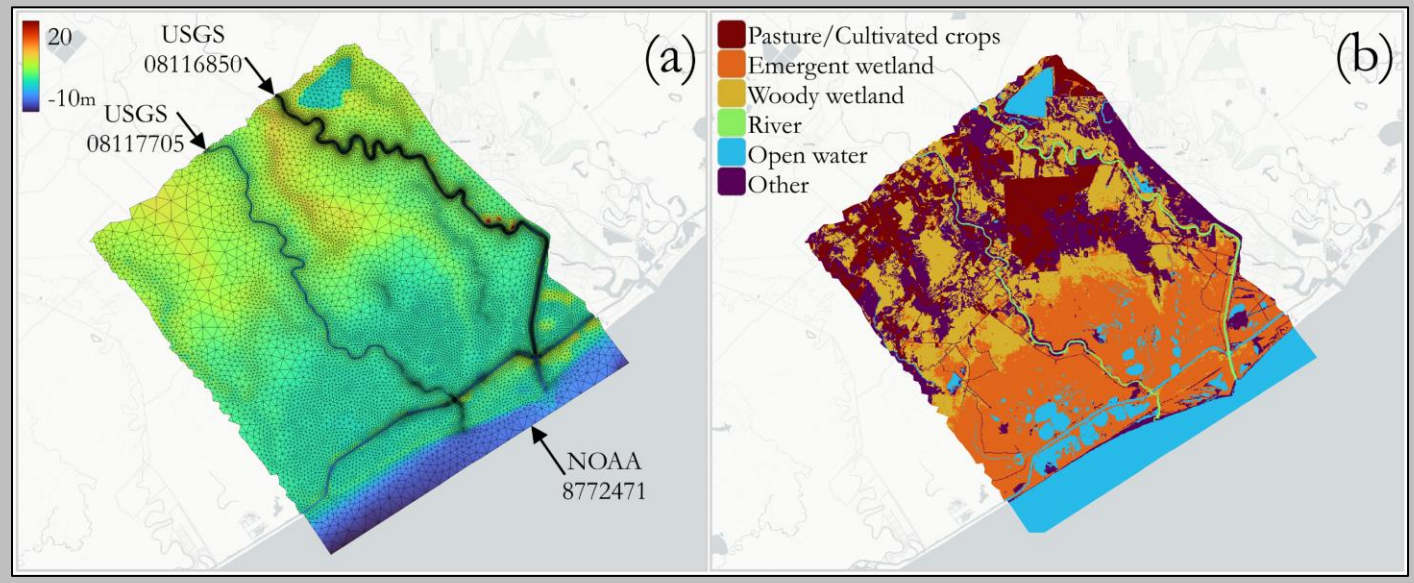
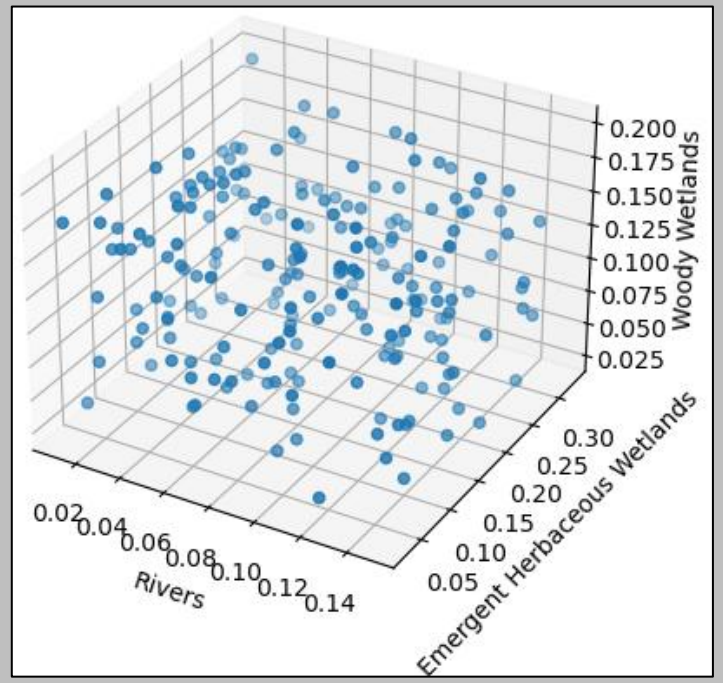
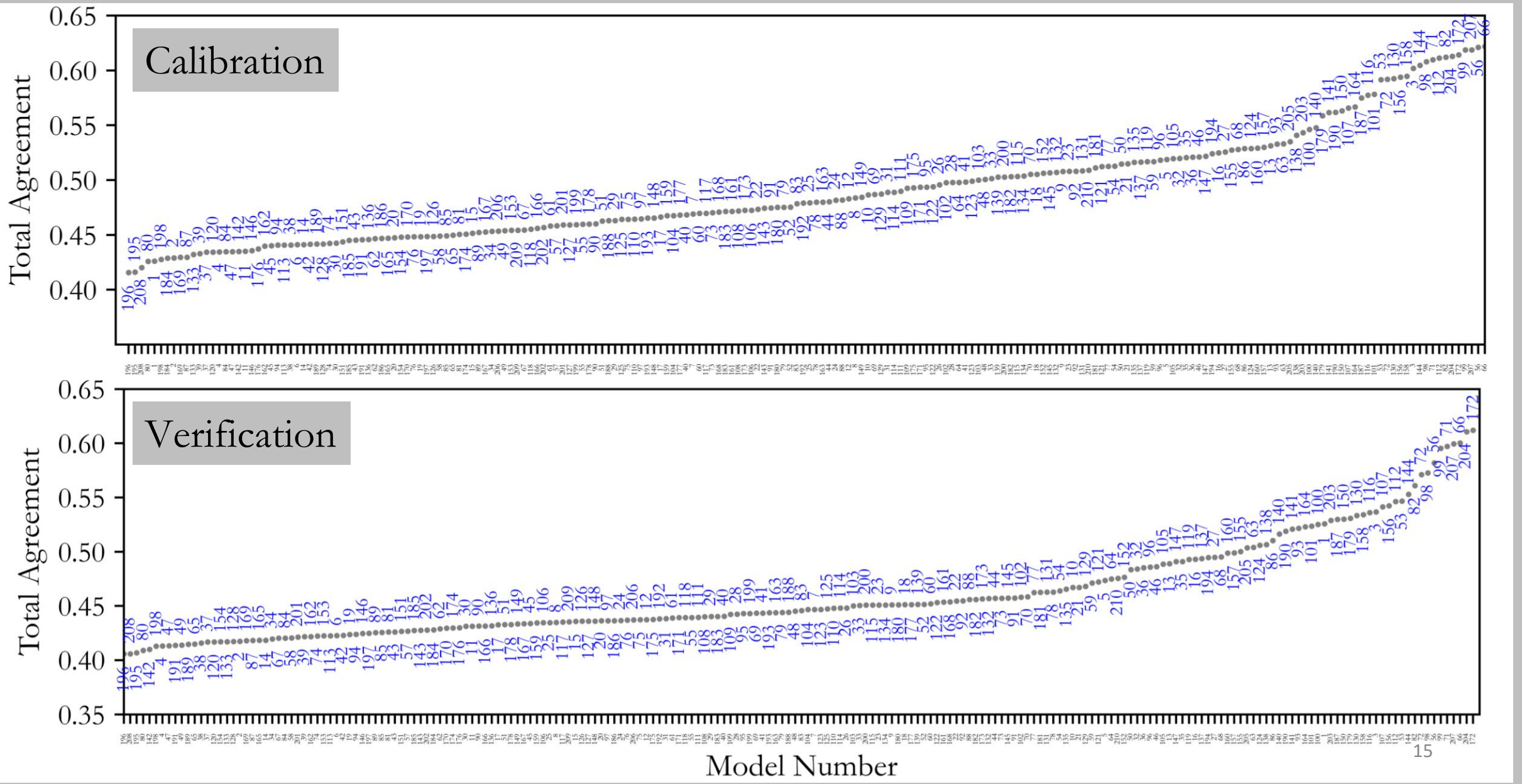
- Model calibration using remotes sensing flood extent map.
- Make well distributed combination of roughness values for 210 simulation using Latin Hyper Cube Sampling.



Event	Land Cover	Manning Value (n) Min	Max	Opt.		Area (km²)	(%)
South Houston, TX, USA	Open water (Ocean)	0.005	0.035	0.008		114	16%
	Open water (Rivers)	0.01	0.15	0.014			
	Pasture/Cultivated crops	0.02	0.3	0.31		93	13%
	Woody wetlands	0.025	0.33	0.04		122	17%
	Emergent wetlands	0.025	0.2	0.163		237	34%
	Other (< 5% each)		---			137	19%
					Total	**703**	**100%**




Calibration
Total Agreement
0.65
0.60
0.55
0.50
0.45
0.40
Verification
Total Agreement
0.65
0.60
0.55
0.50
0.45
0.40
0.35
Model Number

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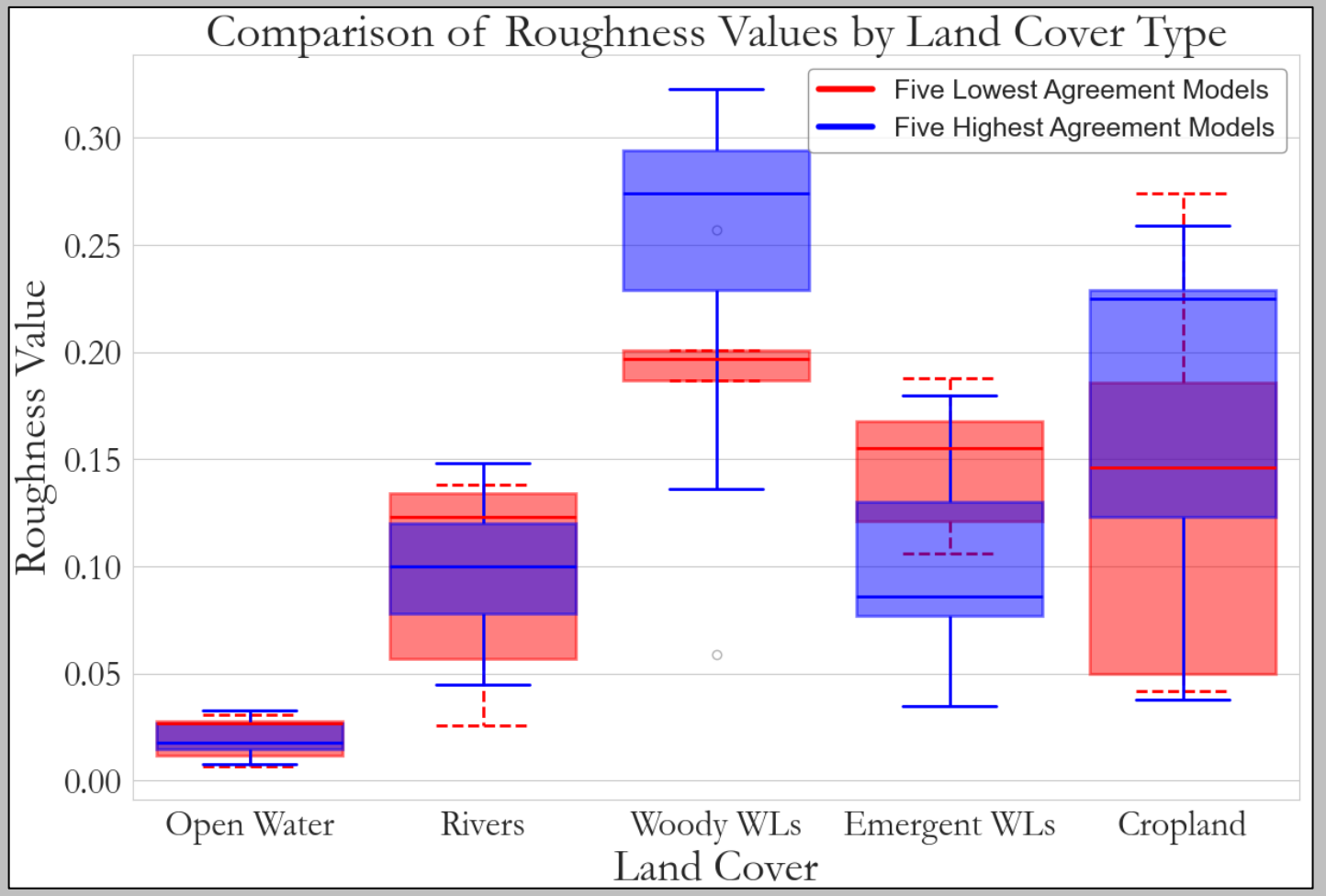
- Higher roughness values for Woody Wetlands and Cropland correspond to better agreement
- Conversely, lower roughness values for Emergent Wetlands enhance agreement



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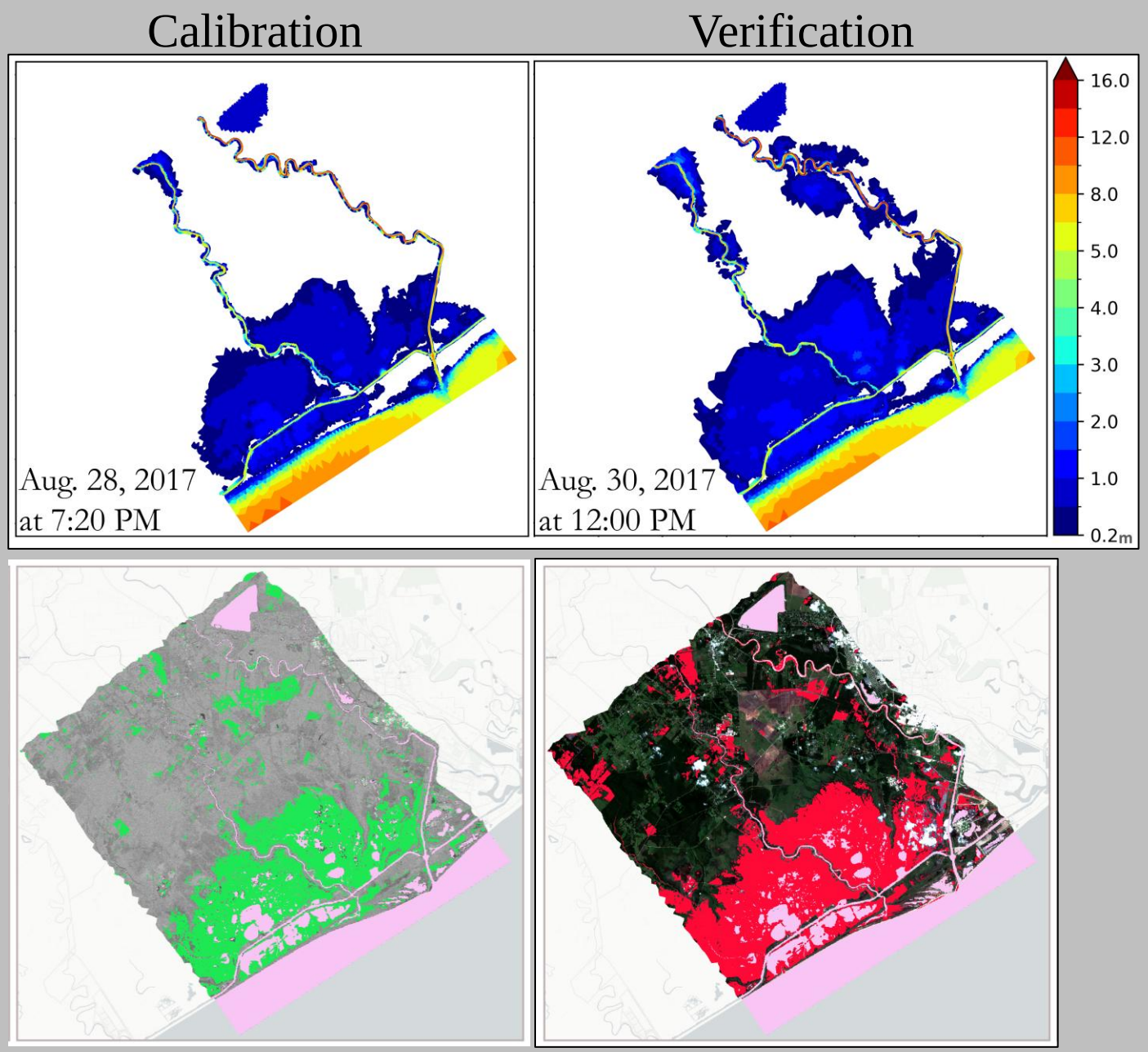
- Model verification shows good agreement with remote sensing flood inundation map.
- Developing countries often lack well-observed data; however, remote sensing data can serve as a valuable resource for calibrating numerical simulations.



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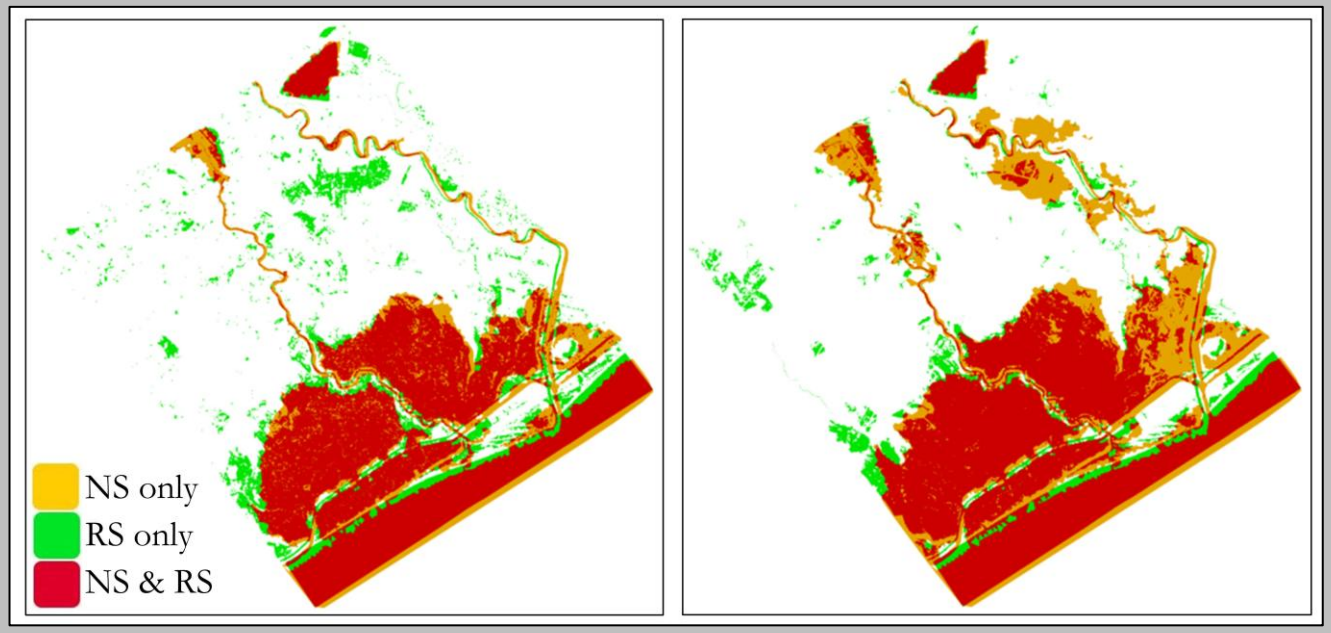
Calibration

Verification



Event	Comparison	Date	*Agr (%)*	*ToAgr (%)*
South Houston, TX, USA	NS vs. SAR	Aug. 28, 2017	75%	61%
	NS vs. Optical	Aug. 30, 2017	84%	60%

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Future work

- Considering flood depth estimation from remote sensing in integration with numerical modeling to enhance flood inundation mapping.
- Developing real-time flood modeling by assimilating remote sensing data into numerical models.
- Physics-informed machine learning methods for improving flood hazard assessments.


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