

A Digital Twin Framework for Coastal Flooding: Field Deployment and Flood Modeling in Hanahan, SC

Presented by: **Ayman Mokhtar Nemnem**

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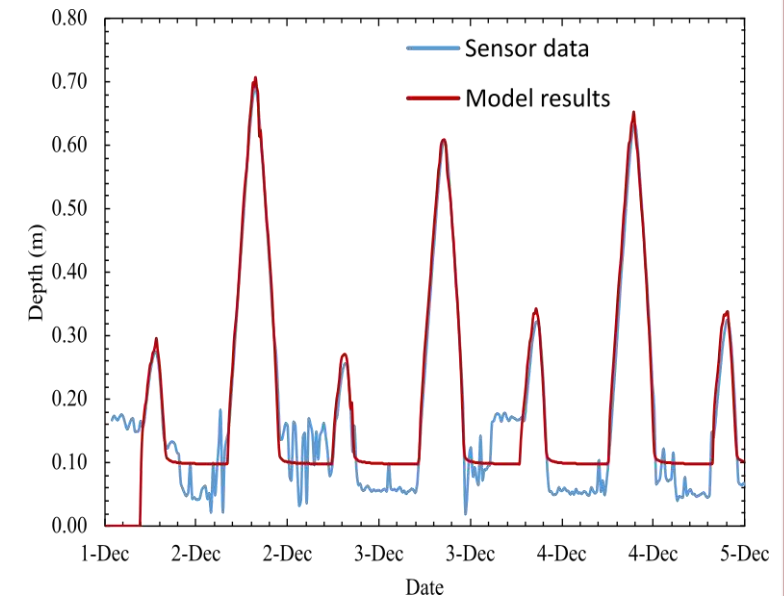
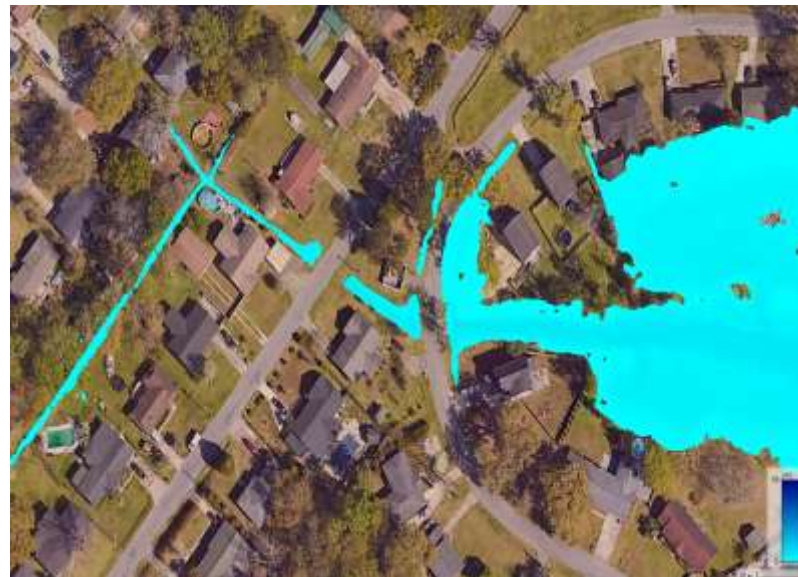


Today's Talk

- Digital twin framework overview
- Field deployment in Hanahan, SC
- Sensor development
- Flood modeling with HEC-RAS and TRITON
- Early warning potential

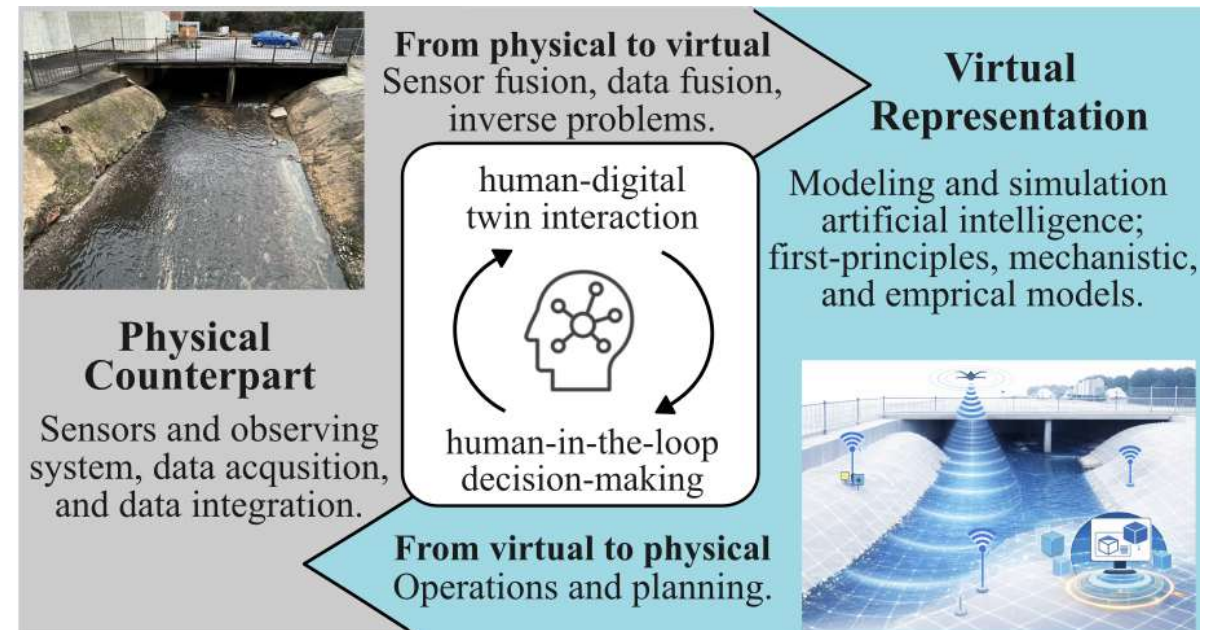


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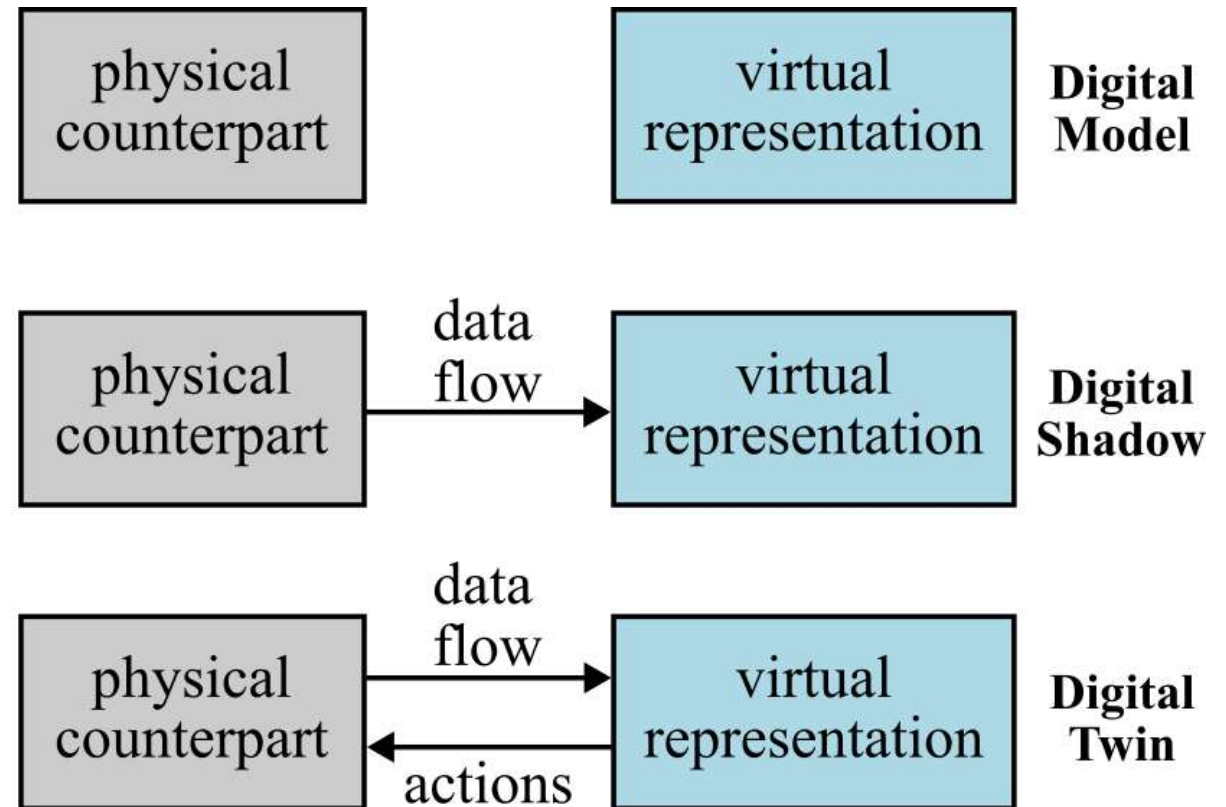
Elements of the Digital Twin Ecosystem

- Information flows bidirectionally between the virtual representation and physical counterpart.
- These information flows may be through automated processes, human-driven processes, or a combination of the two.



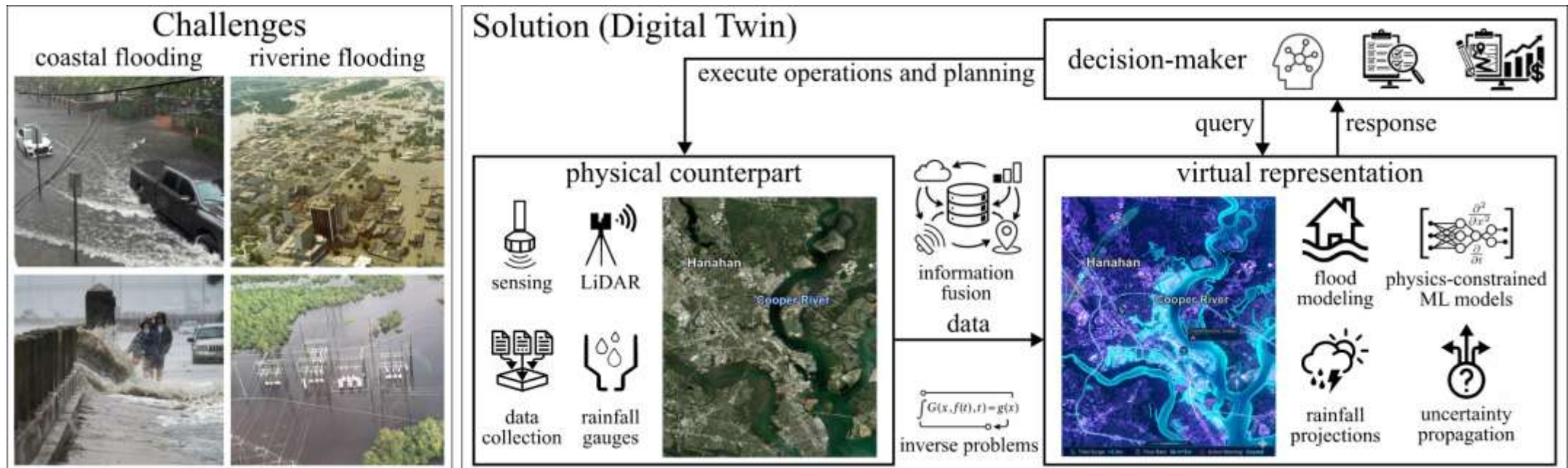
Definitions of Model-centric Approaches

- **Digital Model:** Static virtual representation, no data exchange
- **Digital Shadow:** Online model updating from physical to virtual
- **Digital Twin:** Real-time model updating and actions



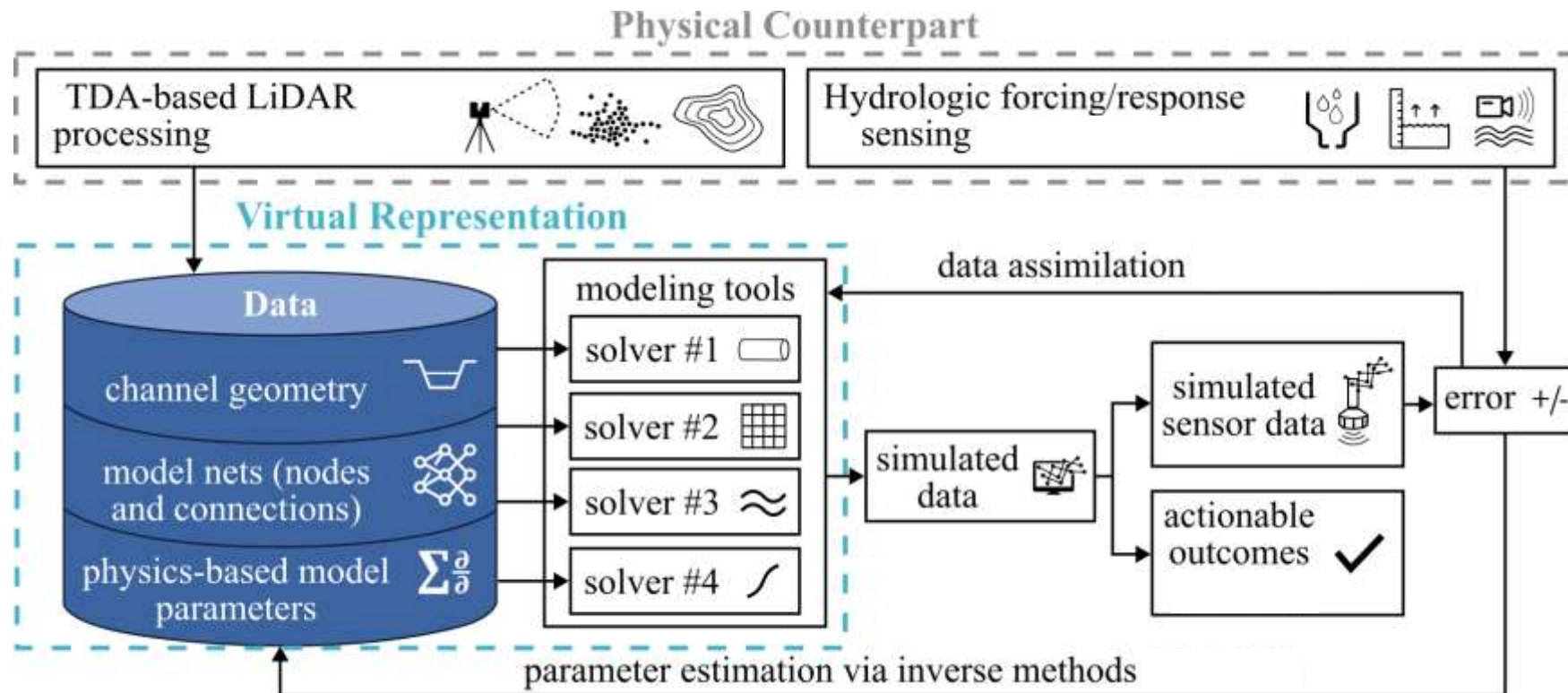
Decision-Maker Layer in the DT

- **Decision Maker:** Uses DT insights to issue controls
 - Actions are directed towards the physical counterpart
 - Queries are directed towards the virtual representation
- **Query/Response Loop:** The virtual representation answers targeted questions and provides predictions for informed decisions



How We Build a Digital Twin

- We combine real-world data with physics-based models, update it continuously, and use it to answer practical questions.



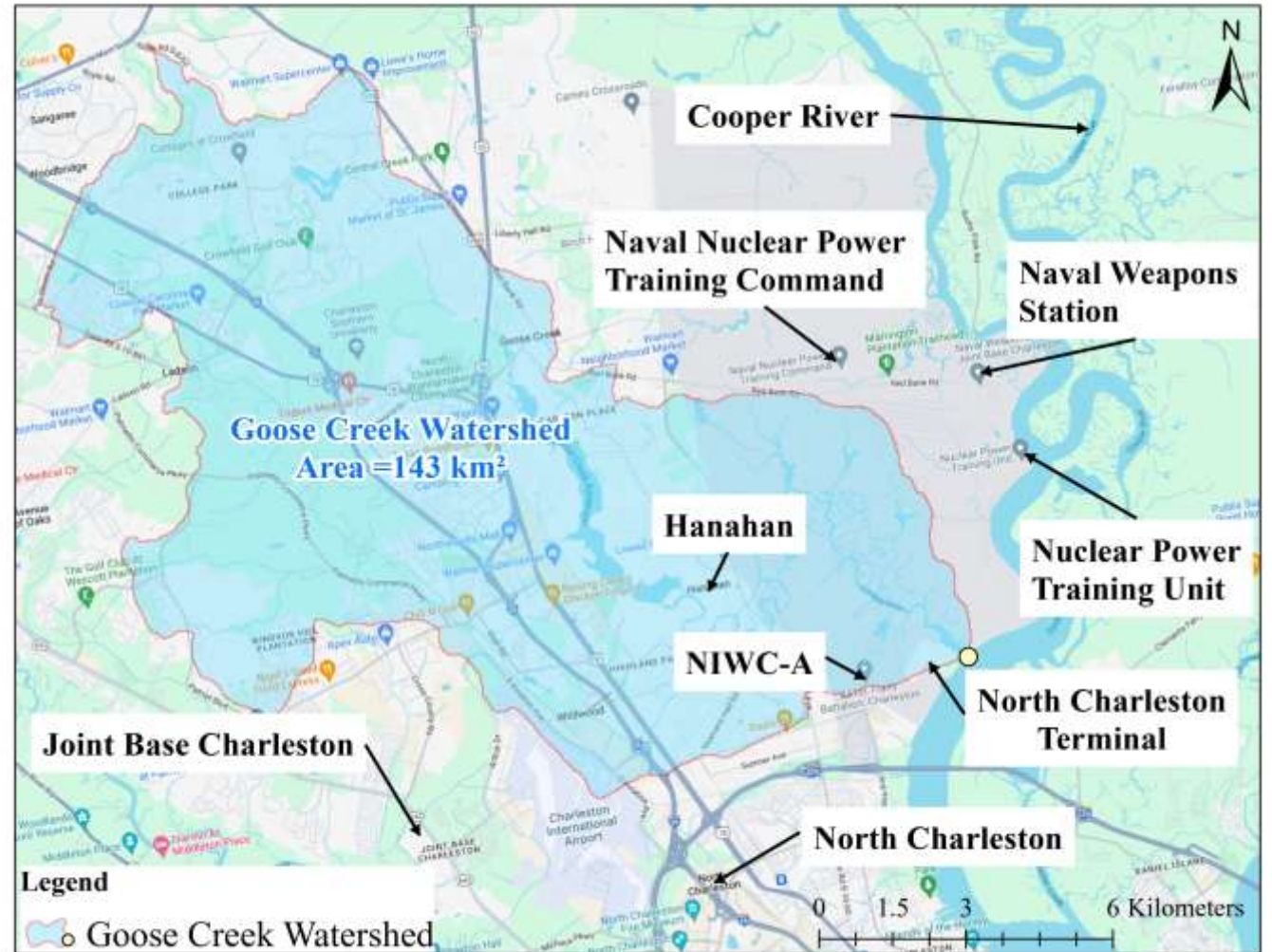
From Data to Action: What the Digital Twin Delivers

- This isn't just a model—it will produce things cities can use immediately: safer routing, better maintenance decisions, and smarter investments.



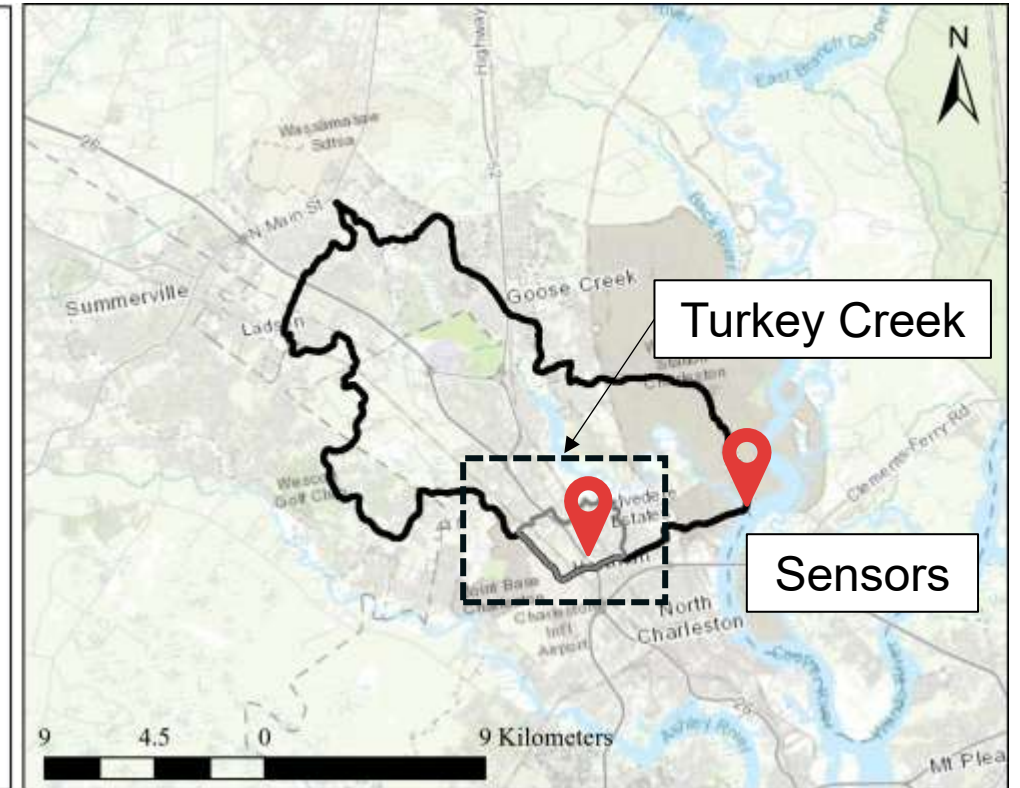
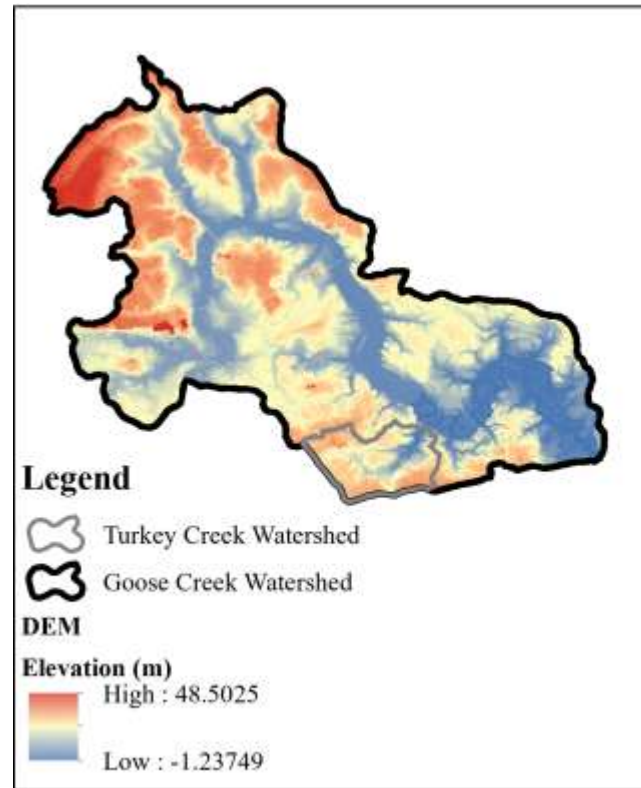
Case Study: **City of Hanahan, SC**

- The City of Hanahan experiences flooding due to a combination of **rainfall-runoff, tidal influence,** and **storm surge.**

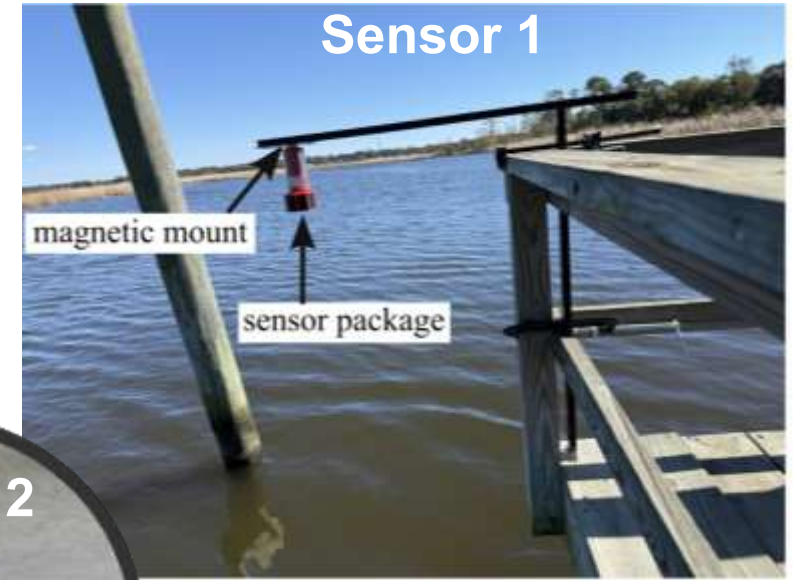
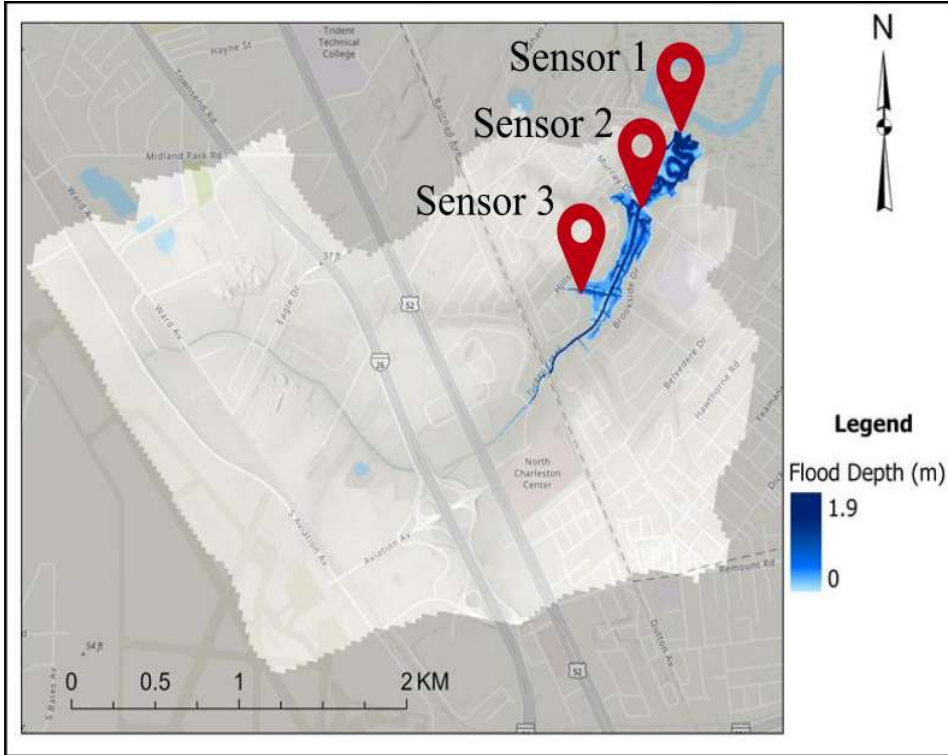


Turkey Creek Watershed

- Goose Creek watershed Area =143 km²
- USGS Digital Elevation Model(DEM) 10 M resolution.
- Focus on the Turkey Creek watershed = 9 km²
- Lidar 2 ft resolution
- Total of 4 sensors deployed



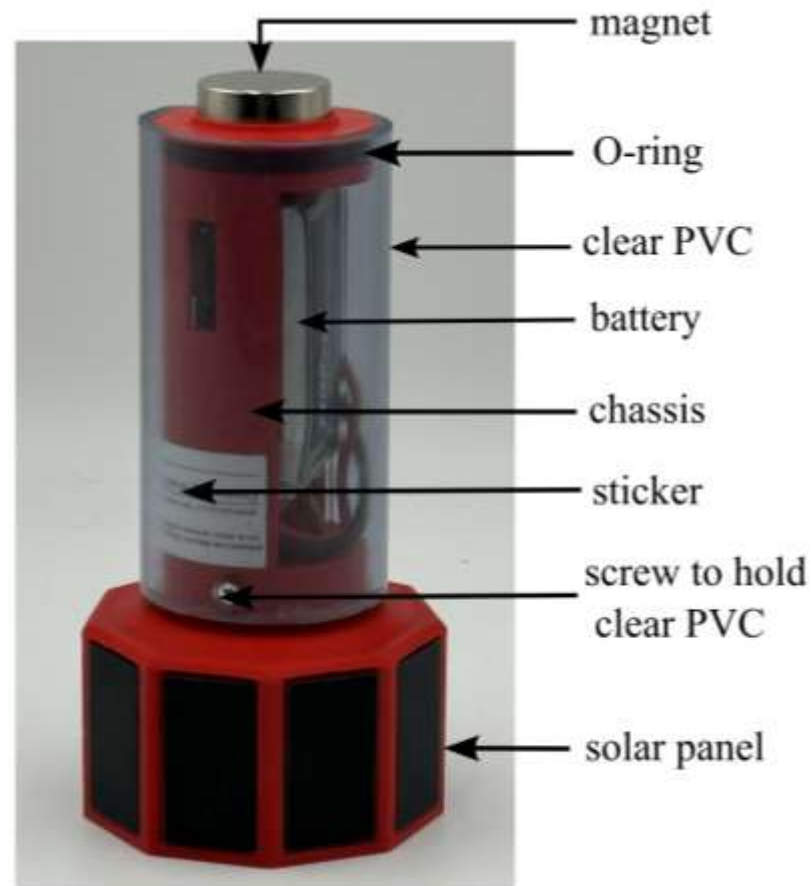
Field deployment Turkey Creek, SC



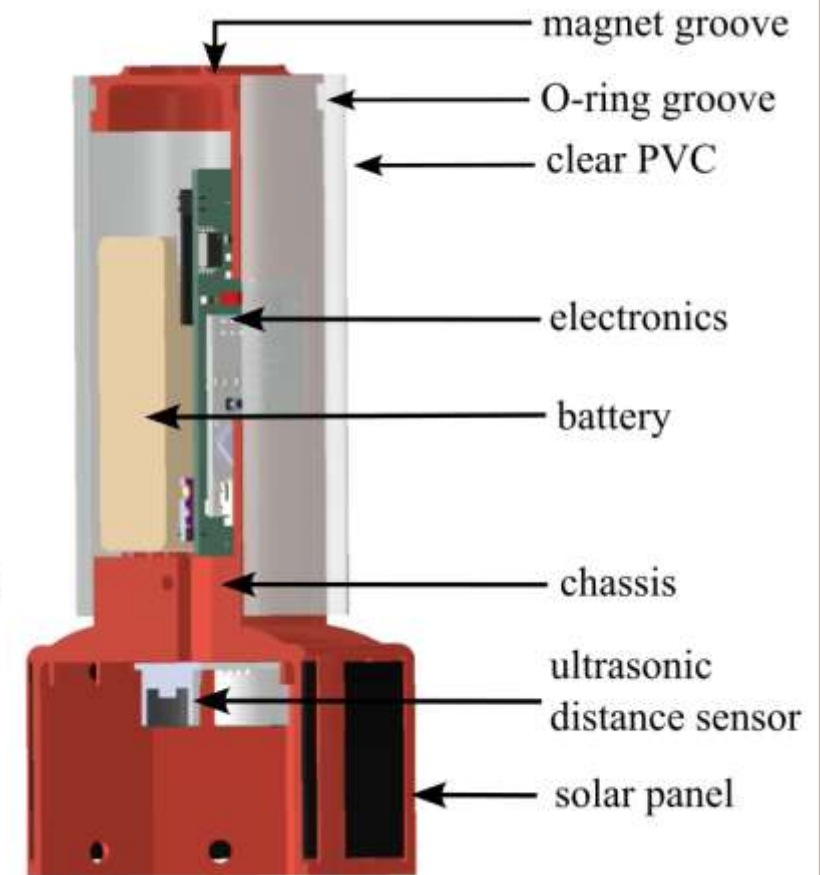
Sensor design

- Based on open-source hardware and software
- 3D printed parts
- Size, Weight and Power constrained package
- All contained in one package
- Easy to deploy
- Focused towards citizen science

Repository link to the sensor package design



Full body view



Cross section view

SWaP-Constrained UAV-deployable Water-Level Sensor (SCUWLS)

Slide borrowed with permission from Grad. student Asif Khan.

The UAV deployable version

- An electro-permanent magnet (EPM) combines a permanent magnet with an electrically switchable magnetic field.



OpenGrab
EPM V3



Long extended operation

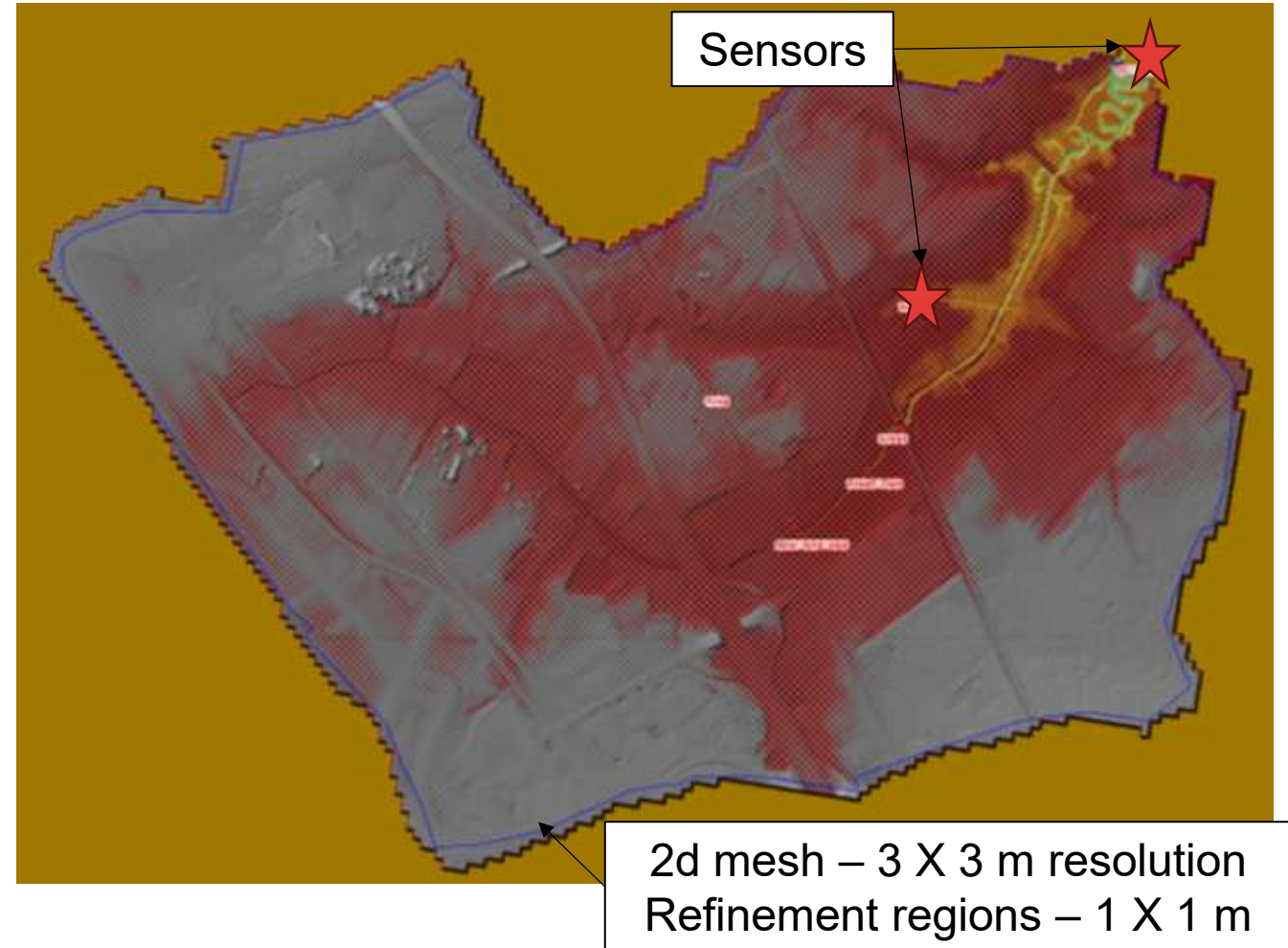
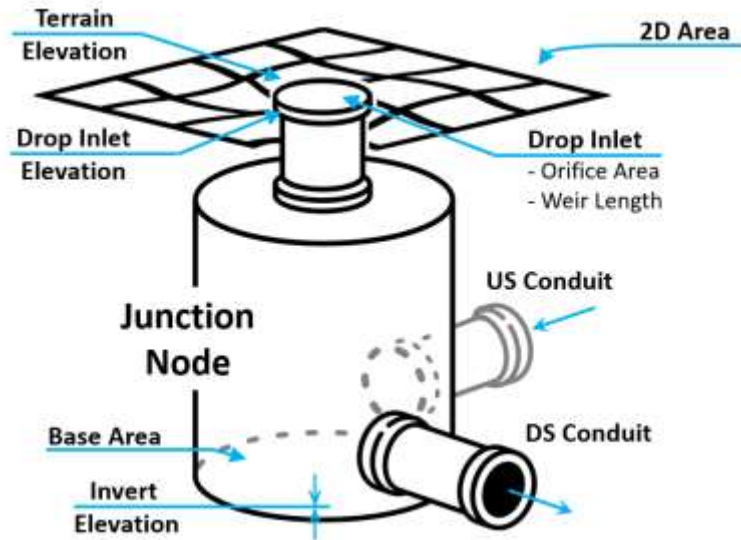


- Externally wired large solar panel
- Temporary solution for long extended data logging

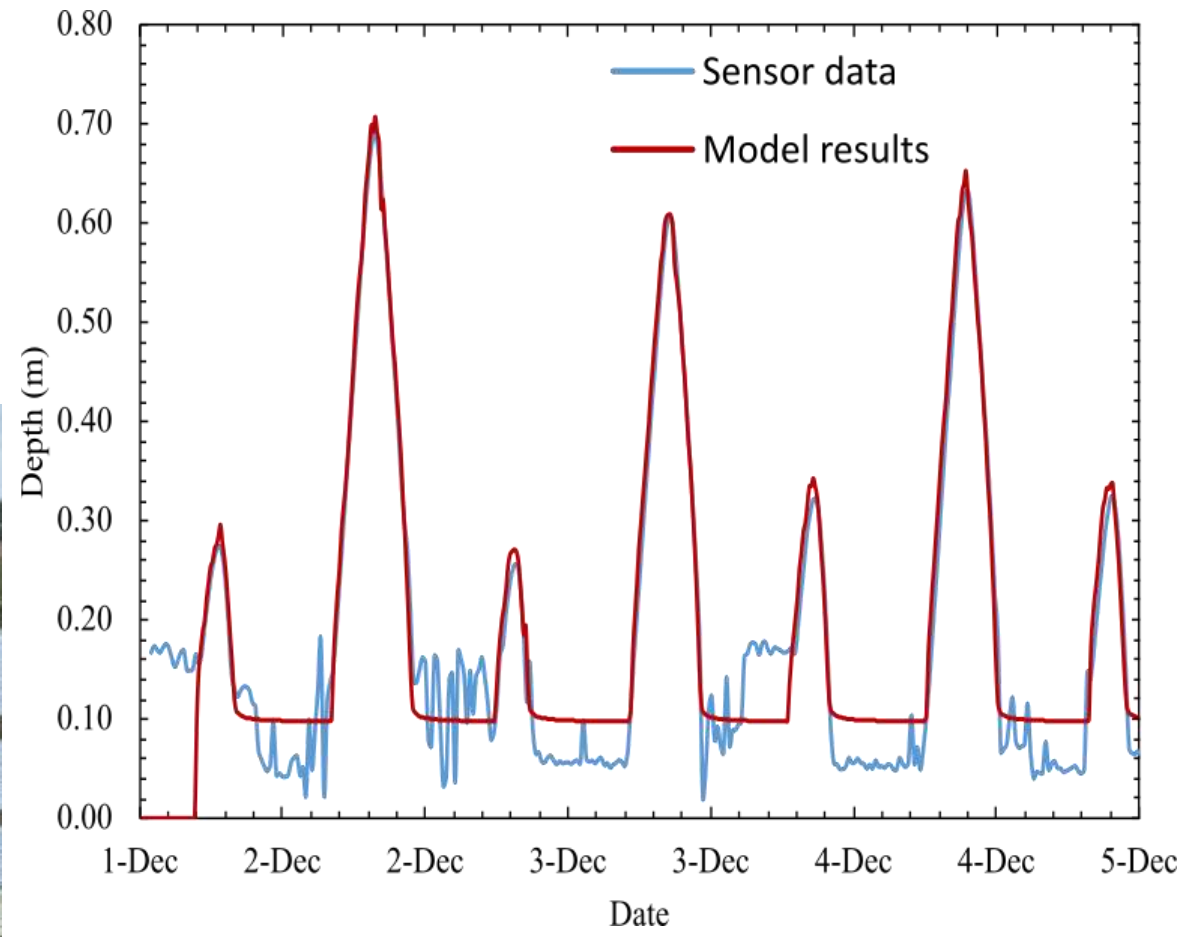


HEC-RAS Model Domain

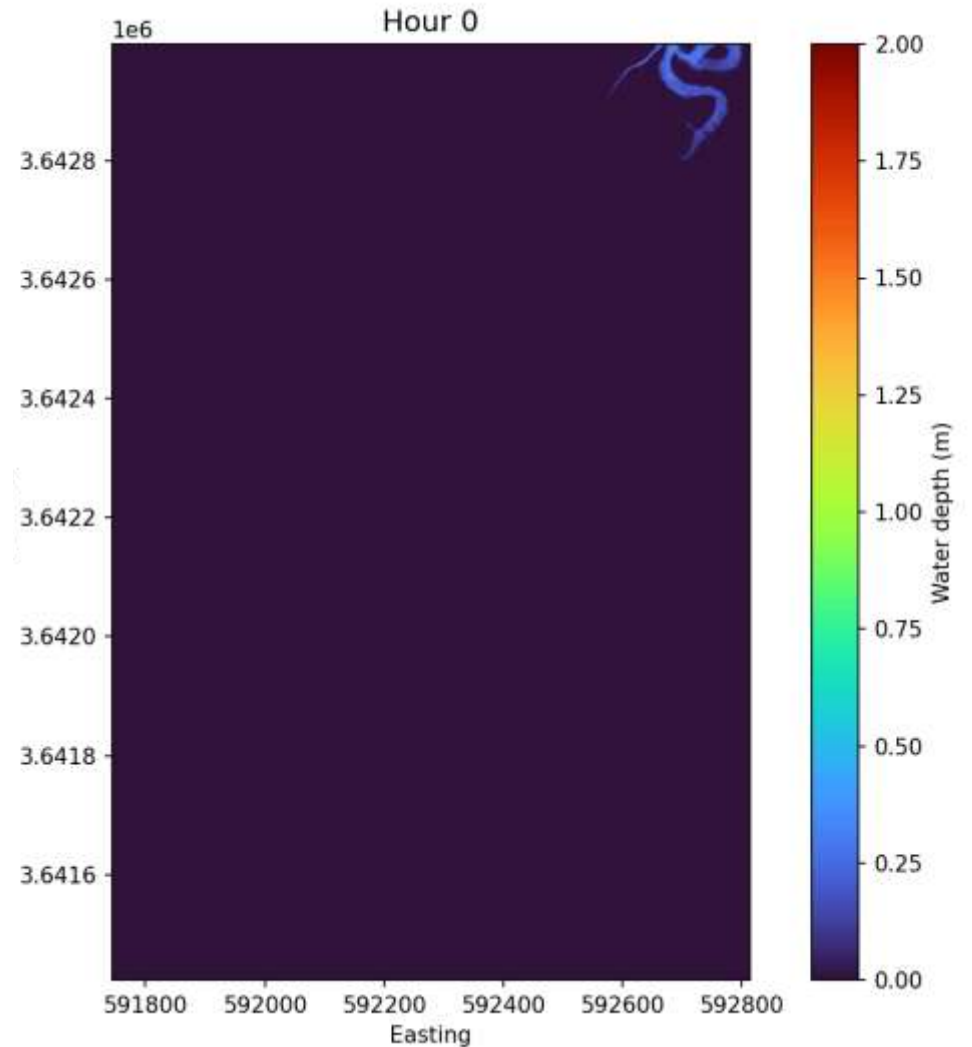
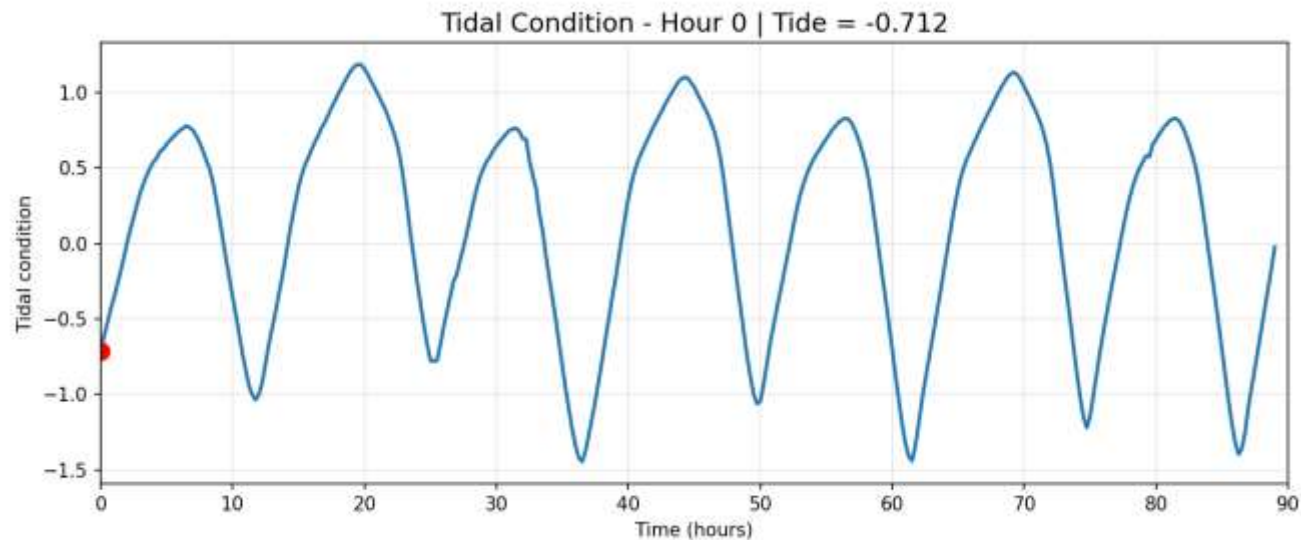
- USACE - HECRAS 2D model.
- Covers the Turkey Creek watershed.
- No. of cells is 900k.
- LiDAR 2ft.
- Tidal boundary + excess rainfall over grid
- Next steps: incorporate storm networks



Flood Modeling Error

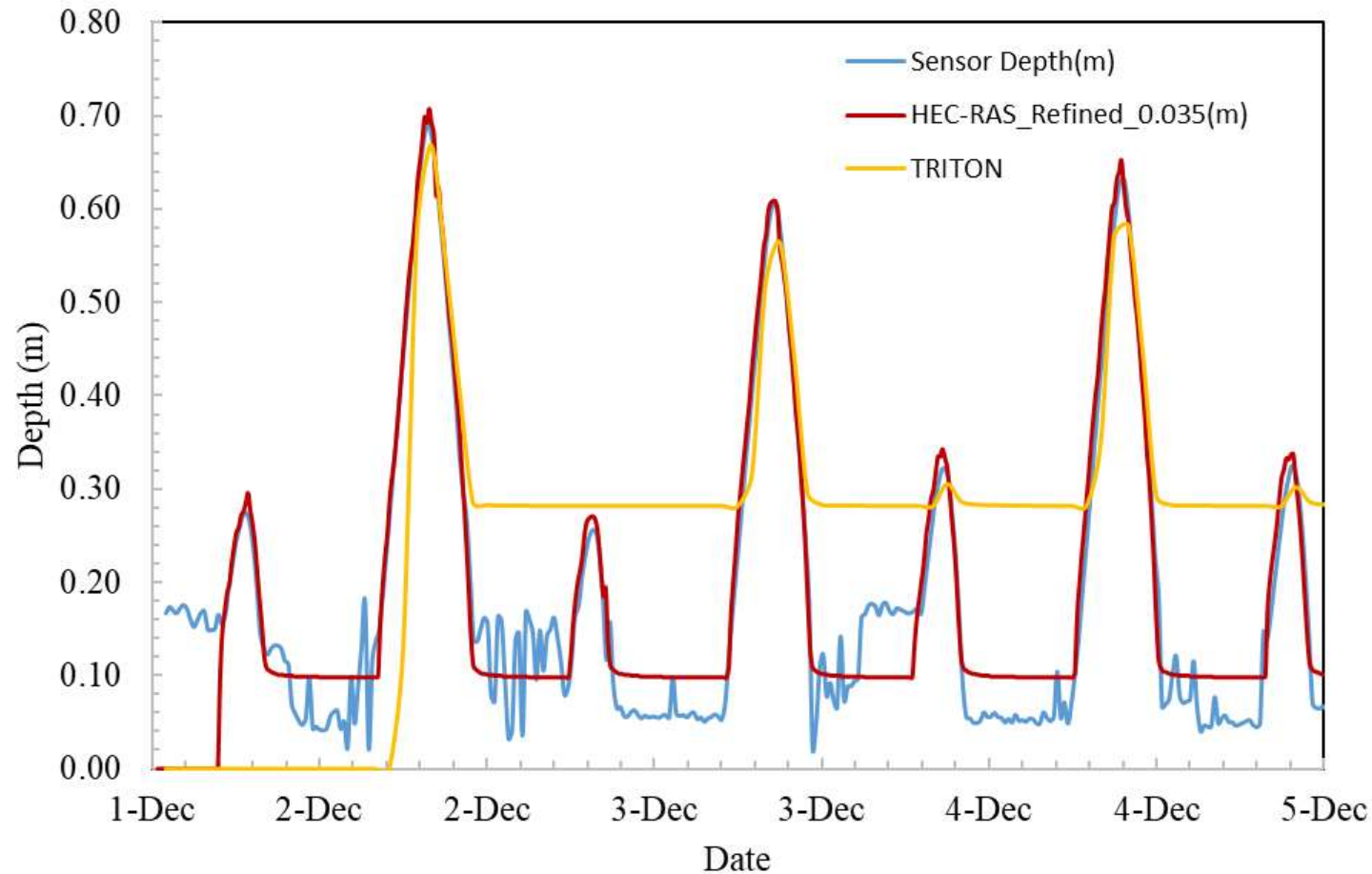


TRITON Tidal Boundary Condition and Flood Propagation



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Comparison of TRITON and HEC-RAS



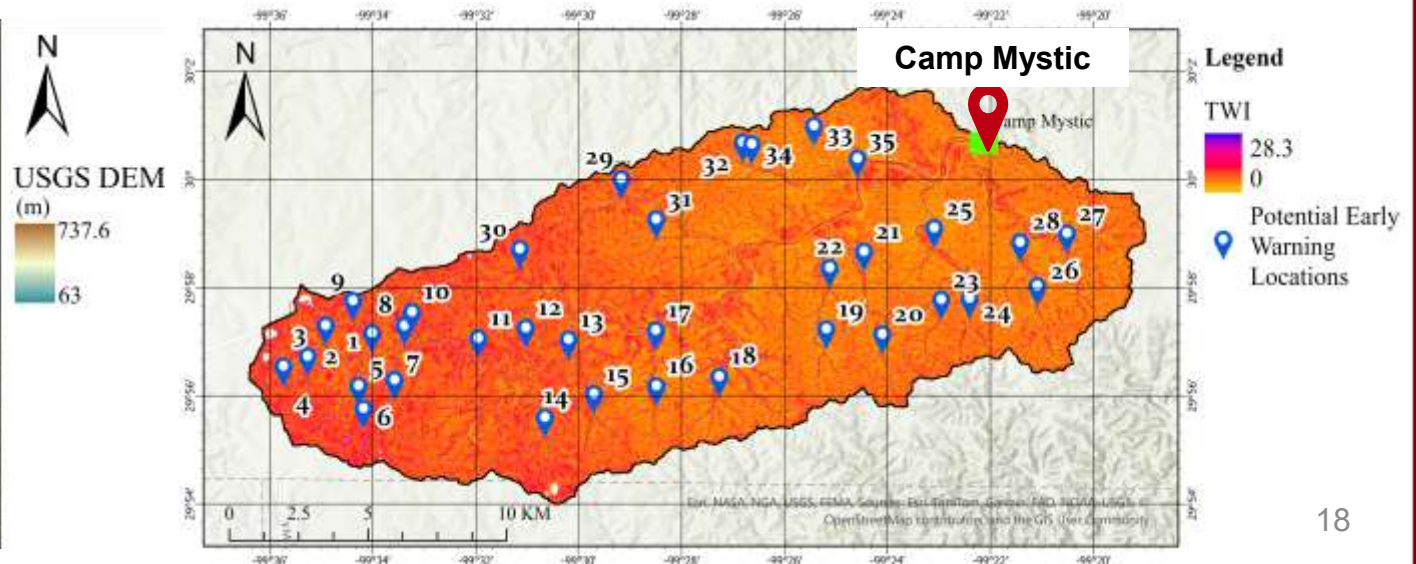
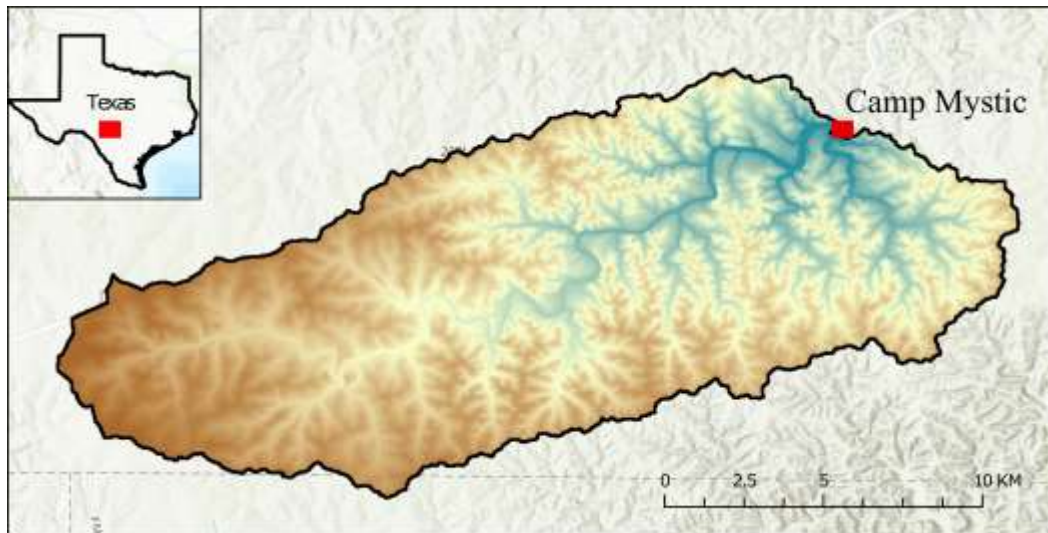
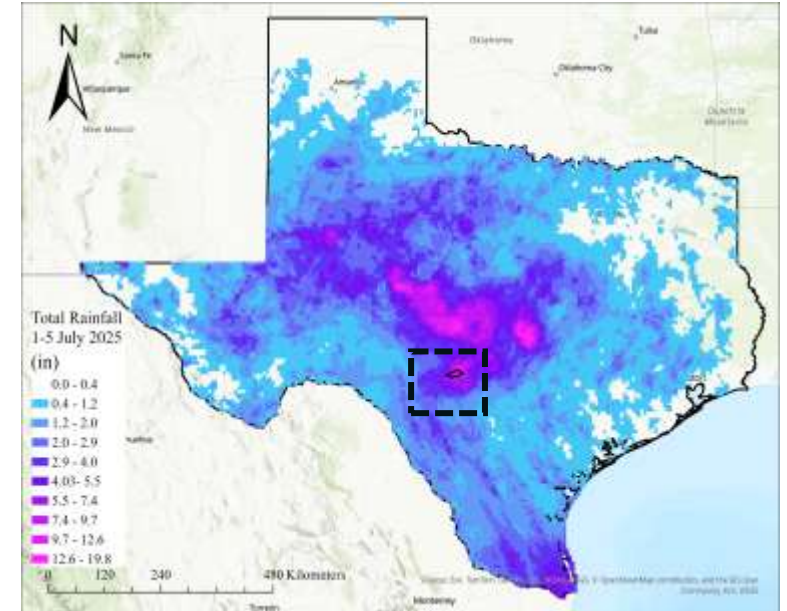
TRITON	HECRAS
The peak with less than 3.5 cm difference.	Both the high tide peaks are effectively captured.
Run time: ~30 mins	HECRAS: ~5.5 hours

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Texas Camp Mystic flash flood

July 2025

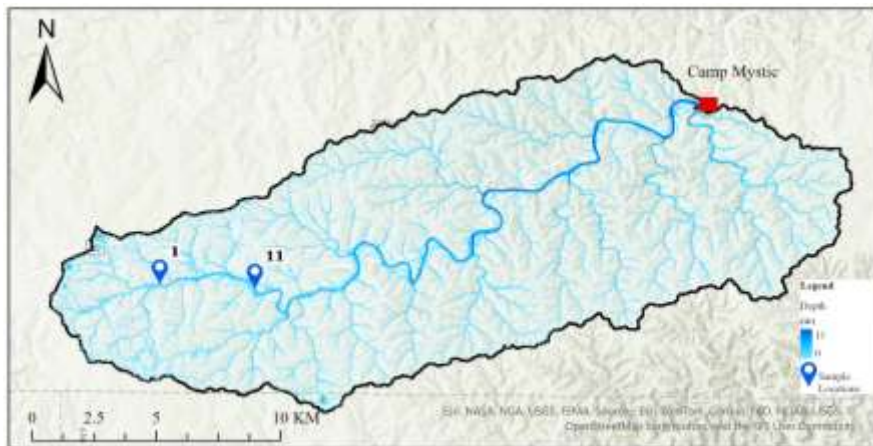
- **>200 mm** rainfall in 12 hours
- **130 fatalities** (27 at Camp Mystic)
- **no upstream monitoring**



Early signs of flash flood

Time Since Onset	Ref. Pt 1 (mm/hr)	Ref. Pt 11 (mm/hr)	Camp Mystic (mm/hr)
1st hour	634	267	230
2nd hour	864	1,212	657
3rd hour	1,773	1,706	2,317
4th hour	-142*	1,601	3,711

*Negative value indicates stage drawdown after peak stage.



(Mokhtar et al., 2026)
Read the paper here



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Thank You for Your Time

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