Characterization and Modeling of Compound Flooding: Introducing the Texas Integrated Flooding Framework (TIFF) Planning Project

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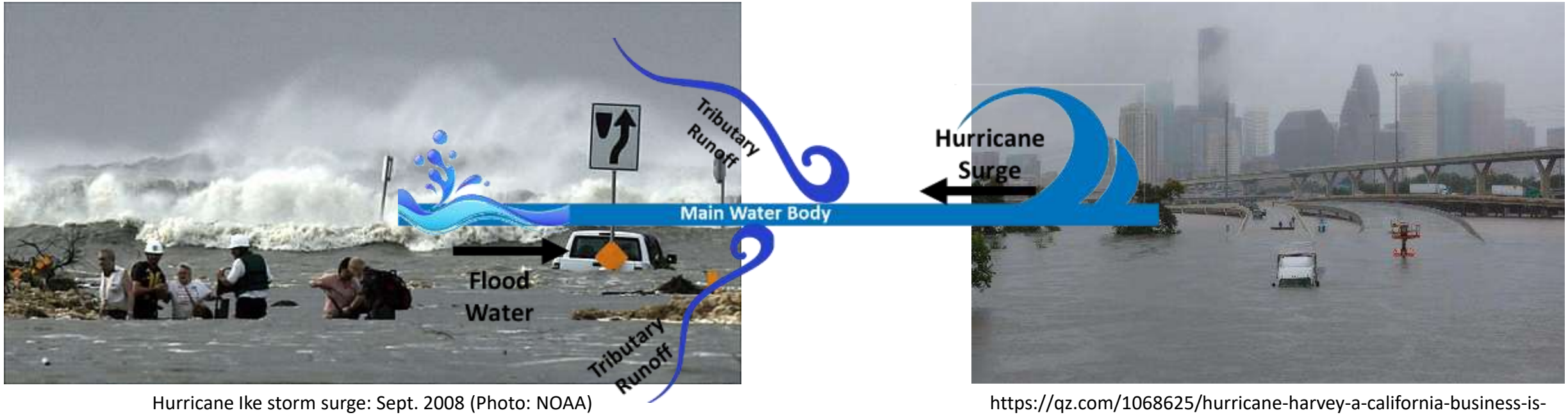
July 21, 2021

GALVESTON BAY COUNCIL (GBC) QUARTERLY MEETING

Storm surge and rainfall

It is commonly believed that storm surge is the most costly aspect of a hurricane.

- Hurricane Ike (2008) with 17.4 ft. storm surge in Galveston Bay ➔ $36.6 billion in damage
- Hurricane Harvey (2017) with a 6 ft. storm surge in Corpus Christi and ~50 inches of rainfall in Houston➔ $130 billion

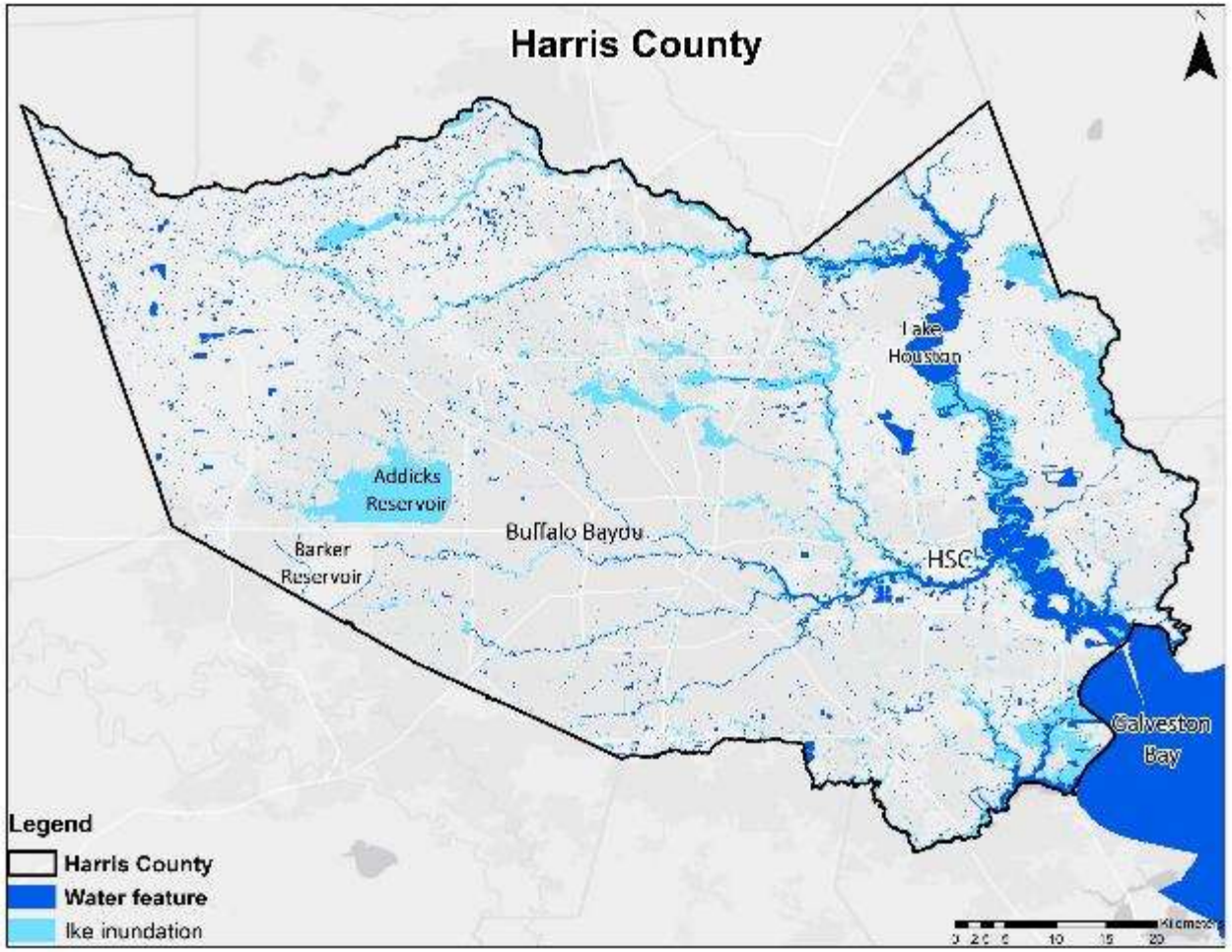


Hurricane Ike storm surge: Sept. 2008 (Photo: NOAA)

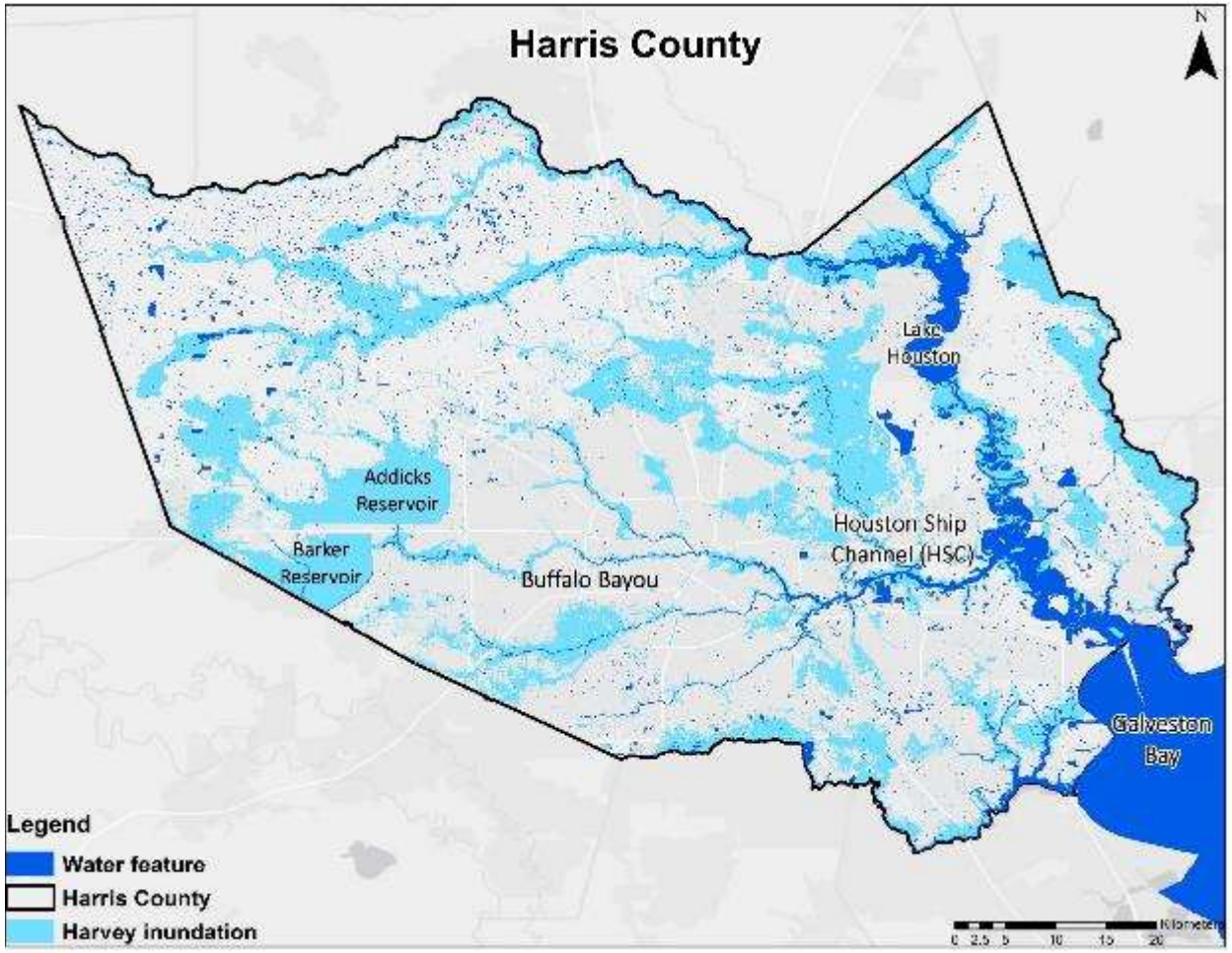
https://qz.com/1068625/hurricane-harvey-a-california-business-is-offering-free-data-recovery-for-wet-and-damaged-phones/

Surge-based vs. rain-based inundation

Maximum inundation



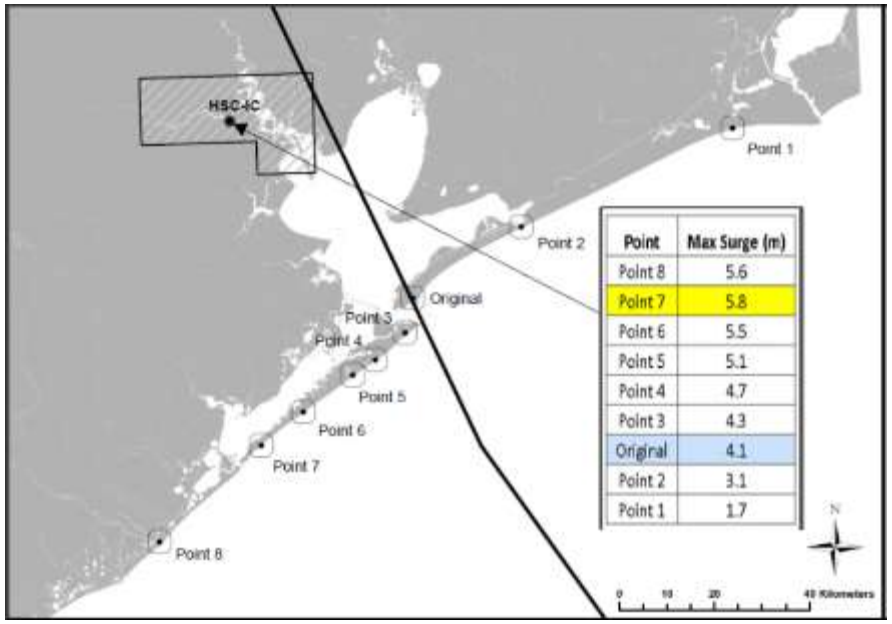
Hurricane Ike (2008)

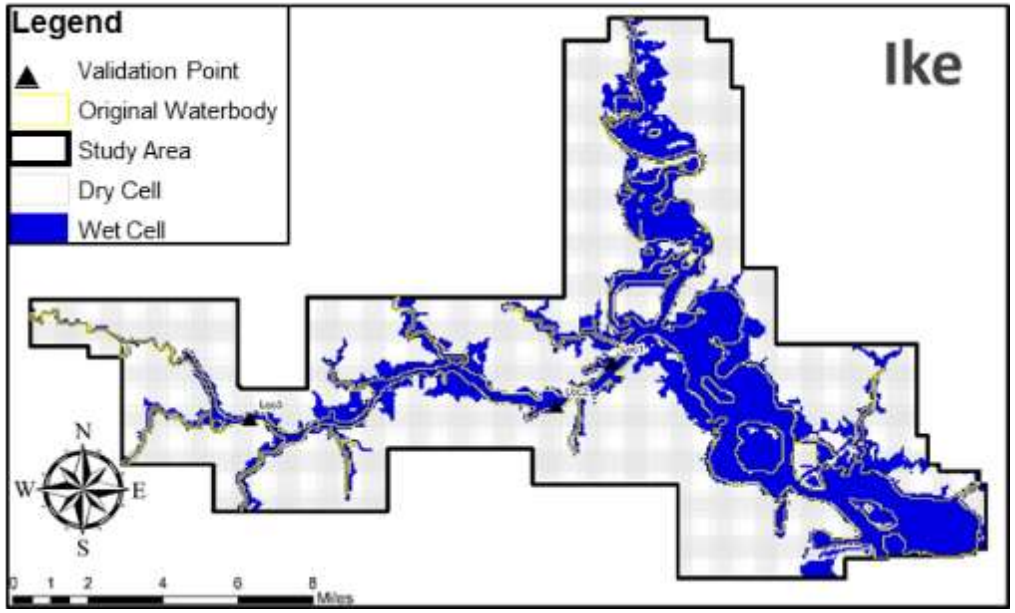


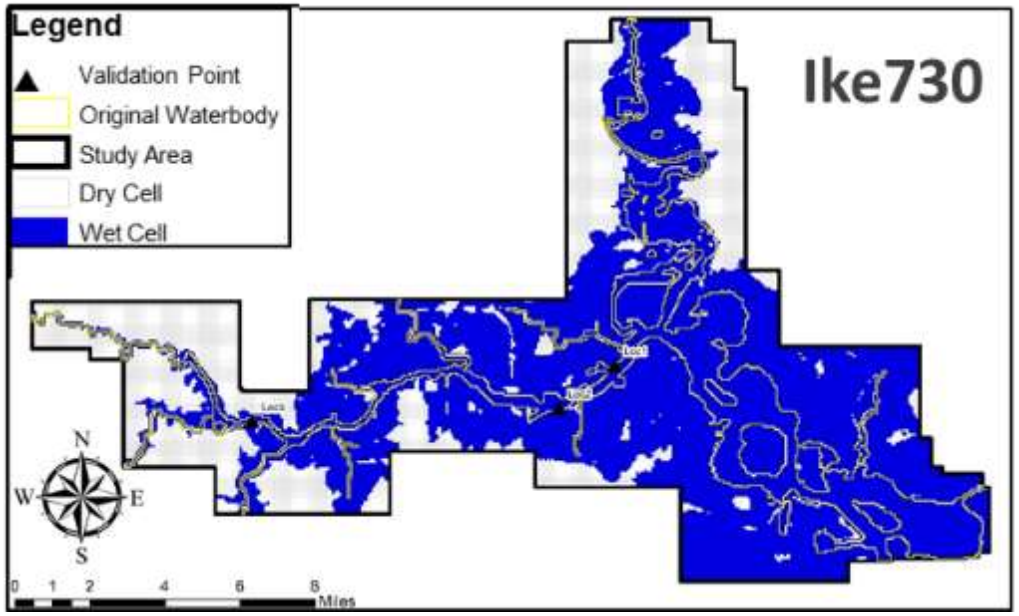
Hurricane Harvey (2017)

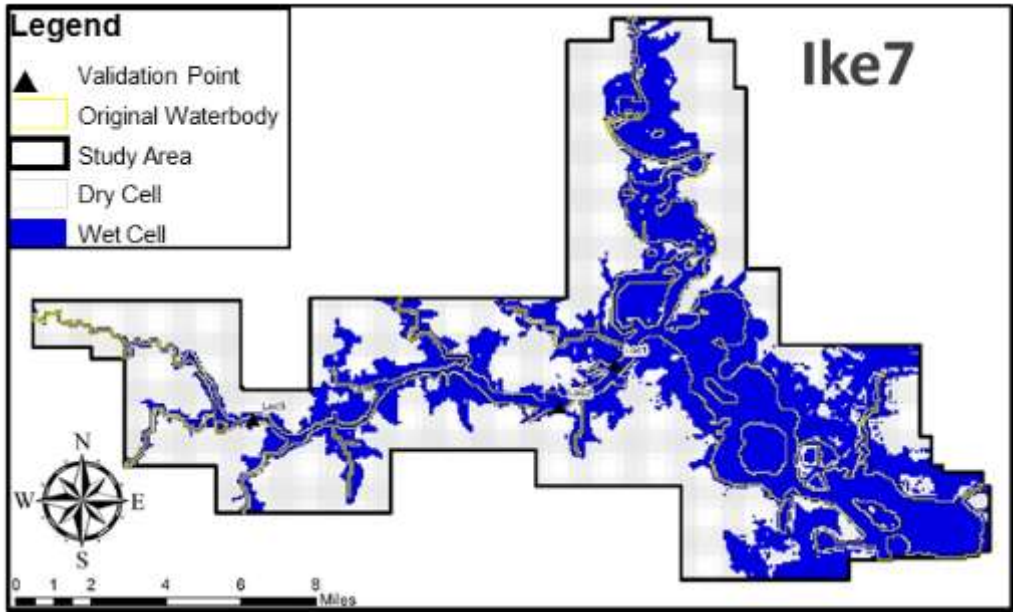
Kiaghadi, A., Govindarajan, A., Sobel, R.S. *et al.* Environmental damage associated with severe hydrologic events: a LiDAR-based geospatial modeling approach. *Nat Hazards* **103,** 2711–2729 (2020). https://doi.org/10.1007/s11069-020-04099-1

How could it get worse?









Kiaghadi, A., Rifai, H. S. & Burleson, D. W. Development of a storm surge driven water quality model to simulate spills during hurricanes. Mar. Pollut. Bull. 129, 714–728 (2017).

Compound events

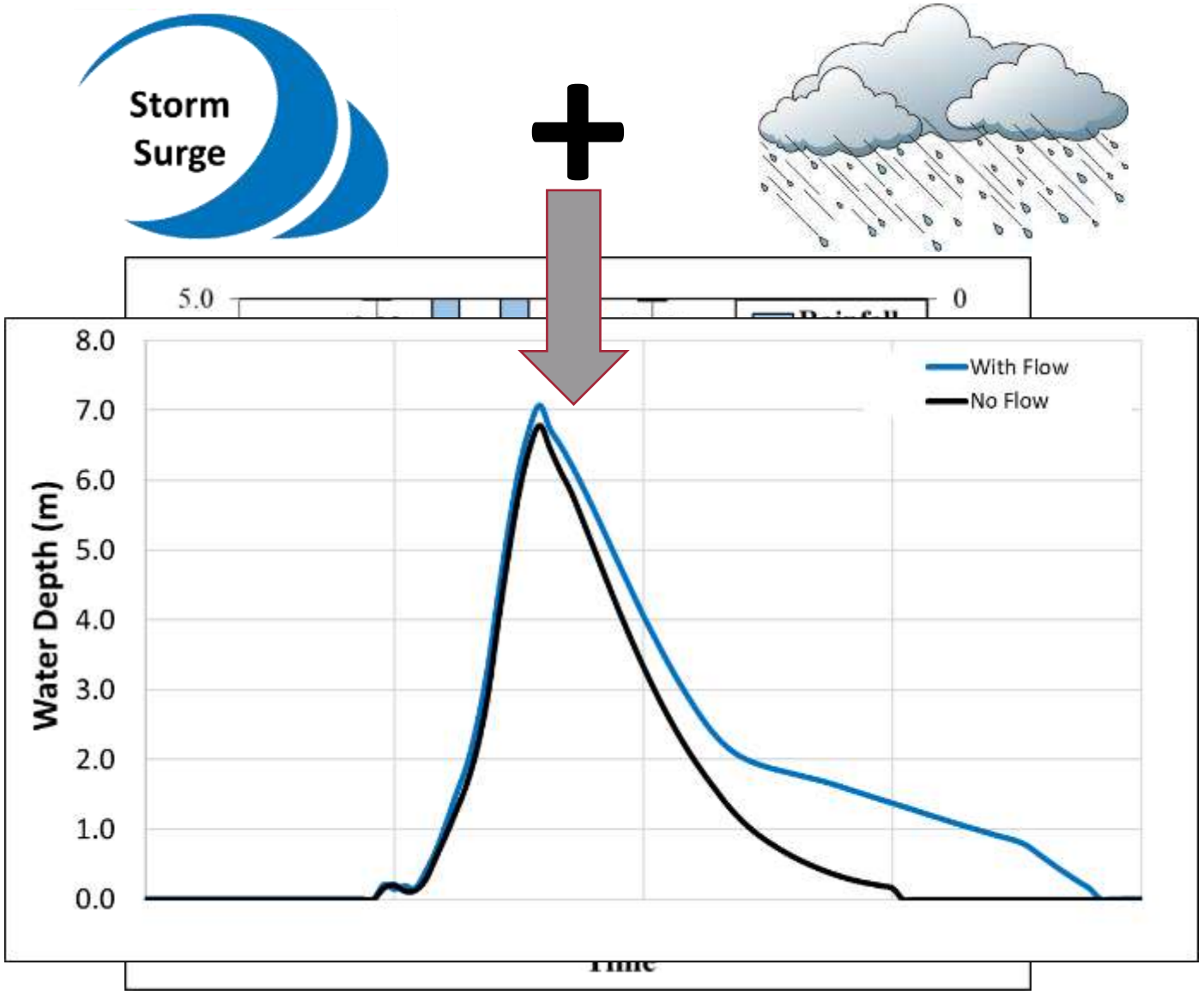
Intergovernmental Panel on Climate Change (IPCC), 2012:

(1) Two or more extreme events occurring simultaneously or successively

(2) Combinations of extreme events with underlying conditions that amplify the impact of the events

(3) Combinations of events that are not themselves extremes but lead to an extreme event or impact when combined. The contributing events can be of similar (clustered multiple events) or different type(s).

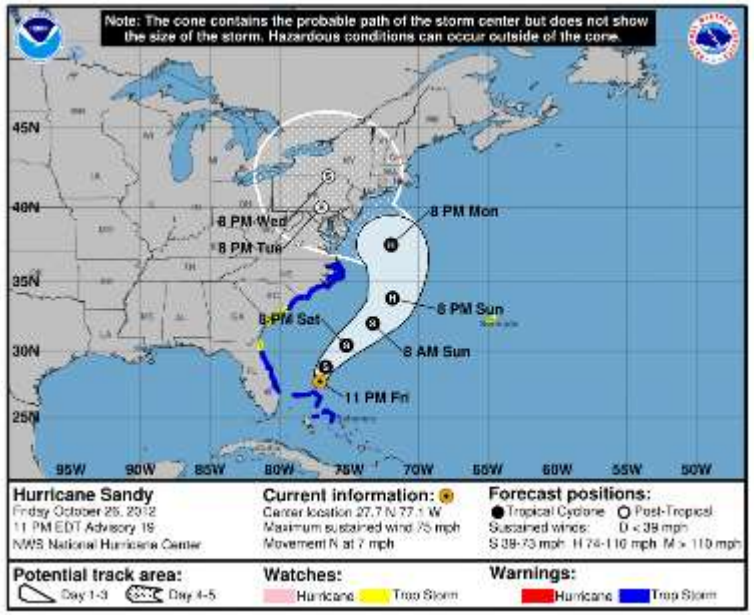
Compound flooding: Storm surge and rainfall



WSE at Morgan's Point (Houston, TX), Rainfall recorded at a HCFCD rainfall gauge near Green's Bayou

Why do we need models?

- Predicting land inundation and water behavior prior to the event is key in damage mitigation and rapid response determination



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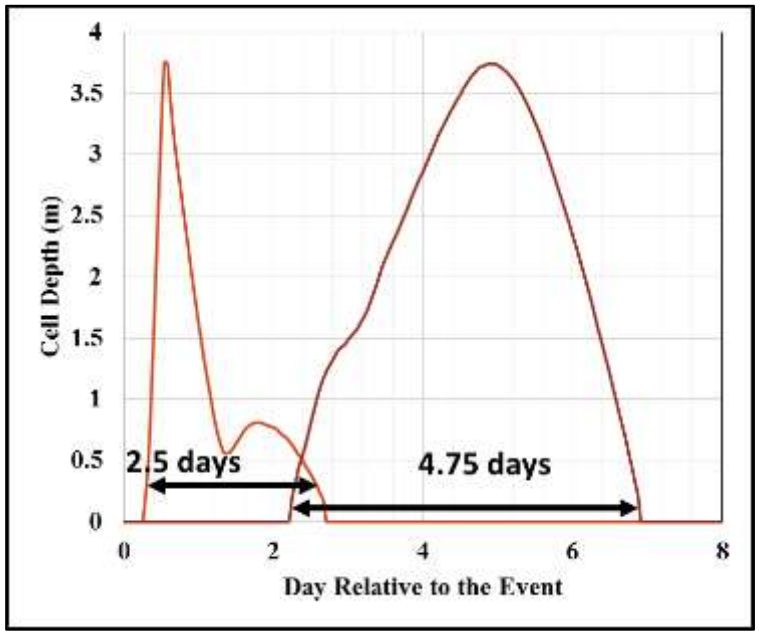


- Understanding the complexities associated with the hydrodynamics of surge and/or significant rainfall can be best achieved via models developed specifically for this purpose.

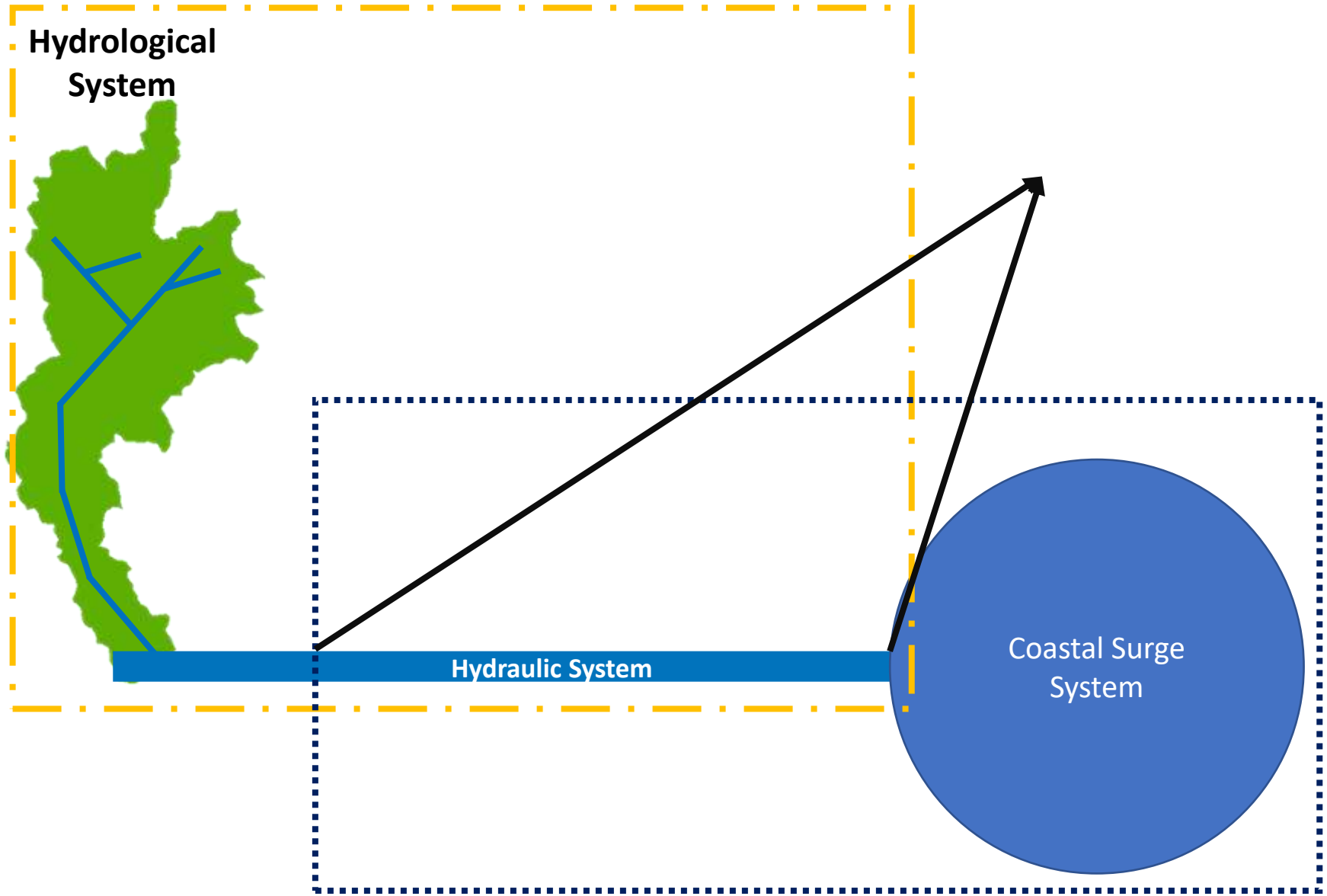
What types of models are available?

Whatever you need!

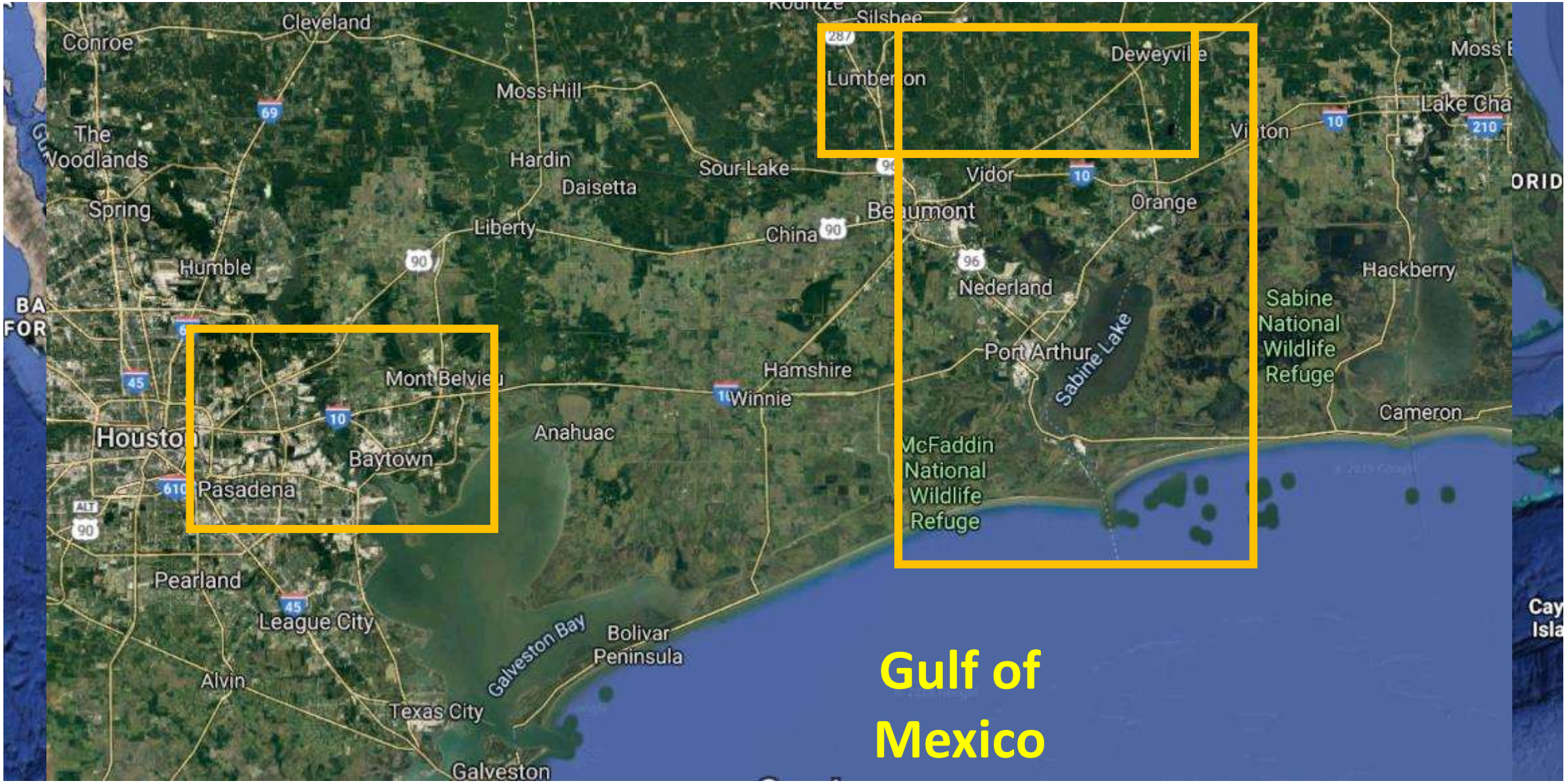
As long as you know the principles, you can use different models

- Examples of rainfall-runoff and hydraulic models
  - Gridded Surface Subsurface Hydrologic Analysis (GSSHA)
  - Hydrologic Engineering Center River Analysis System (HEC-RAS)
  - Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS)
  - Hydrological Simulation Program - FORTRAN (HSPF)
  - Environmental Fluid Dynamics Code (EFDC)
- Examples of storm surge models
  - ADvanced CIRCulation (ADCIRC)
  - Sea, Lake, and Overland Surges from Hurricanes (SLOSH)
  - Delft3D
  - Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM)

Compound flooding: Is one model enough?



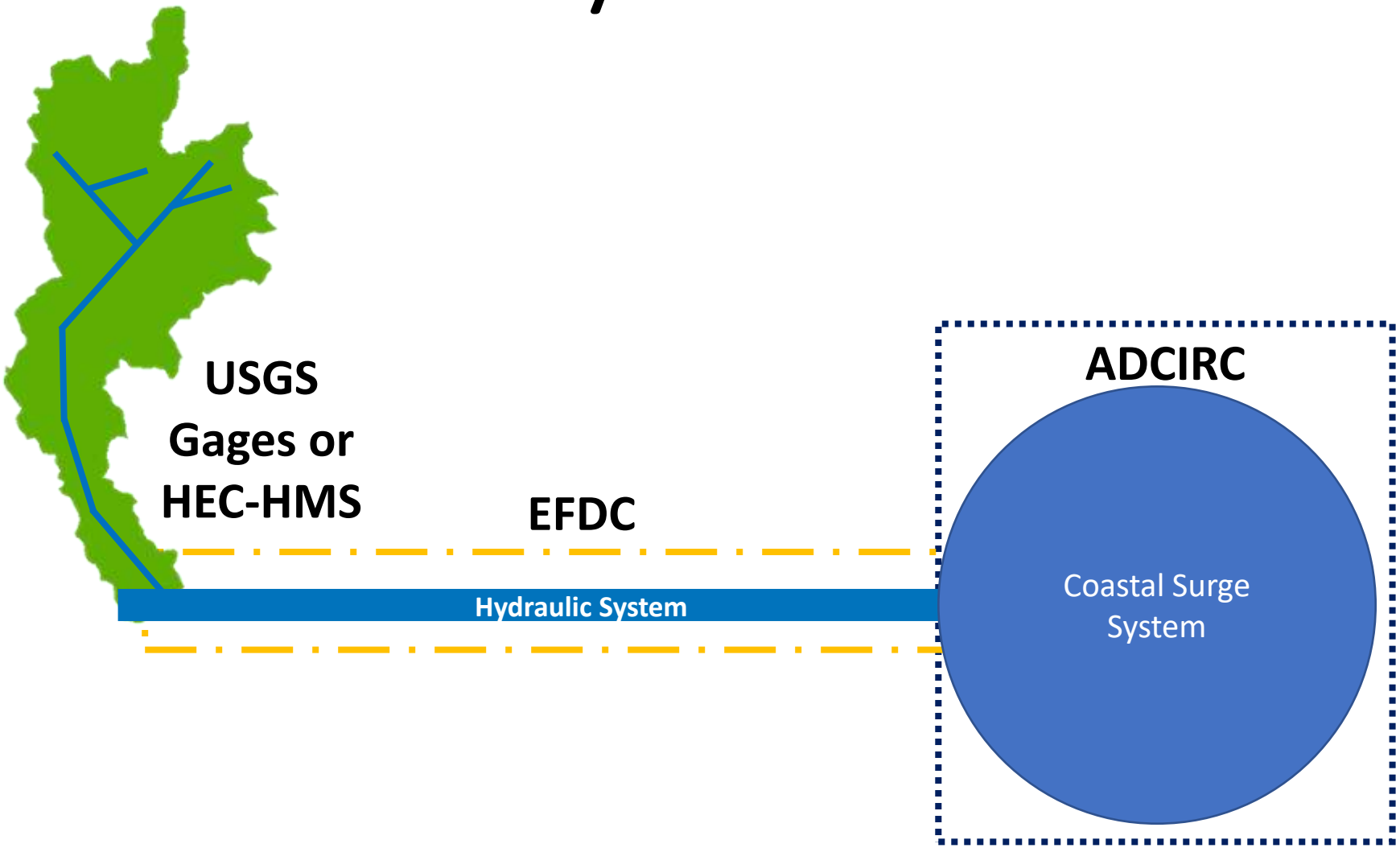
Study areas


Cleveland
Conroe
Moss Hill
The Woodlands
Hardin
Daisetta
Sour Lake
Spring
Liberty
China
Vidor
Orange
Humble
Nederland
Hackberry
Sabine National Wildlife Refuge
Port Arthur
Sabine Lake
Hamshire
Winnie
Mont Belvieu
Houston
Anahuac
Baytown
Pasadena
McFaddin National Wildlife Refuge
Cameron
Pearland
League City
Galveston Bay
Bolivar Peninsula
Alvin
Texas City
Galveston
Gulf of Mexico

Question 1:

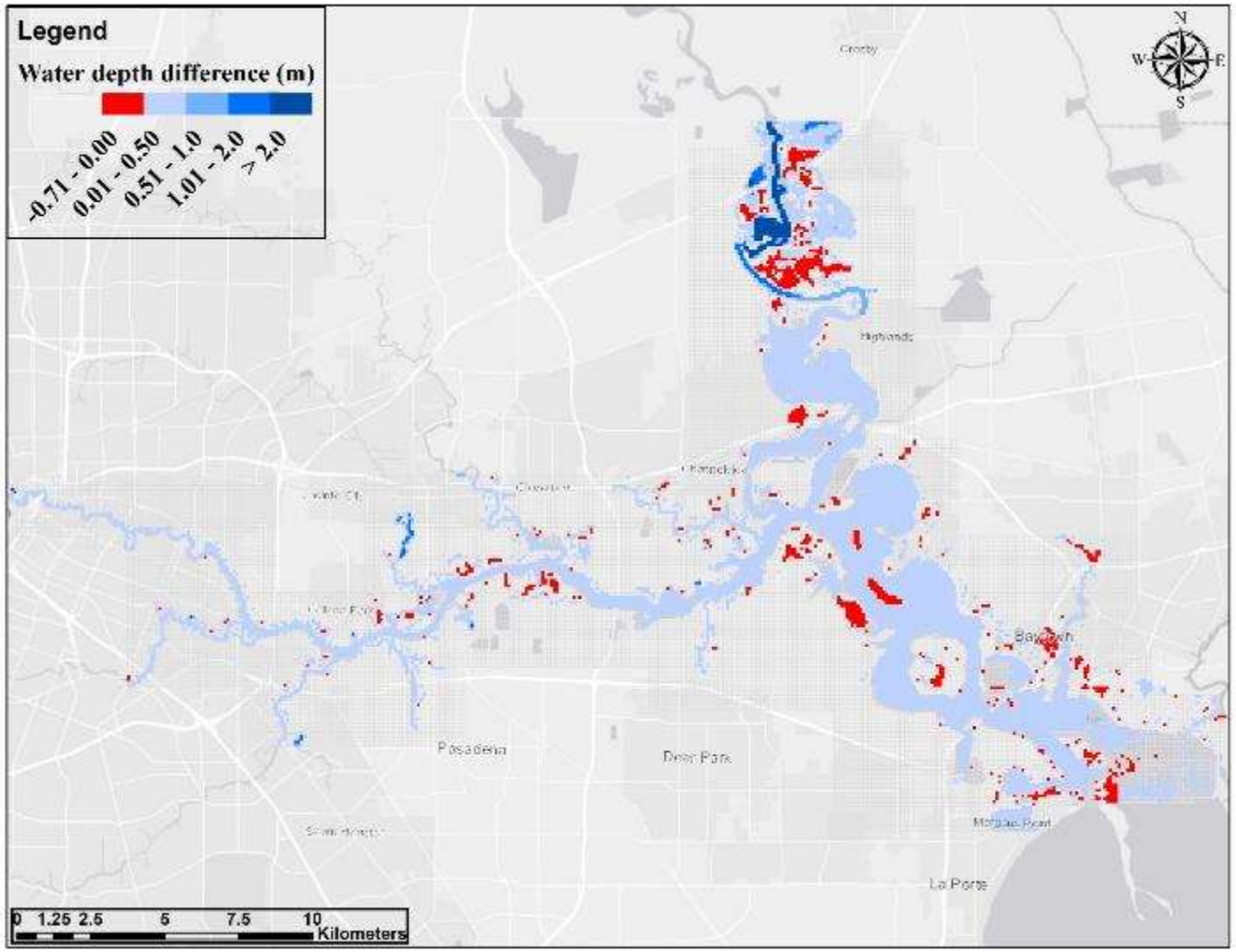
What is the effect of local runoff on inundation levels during a storm surge event?

Estuarine system modeling using EFDC with downstream boundary condition from ADCIRC



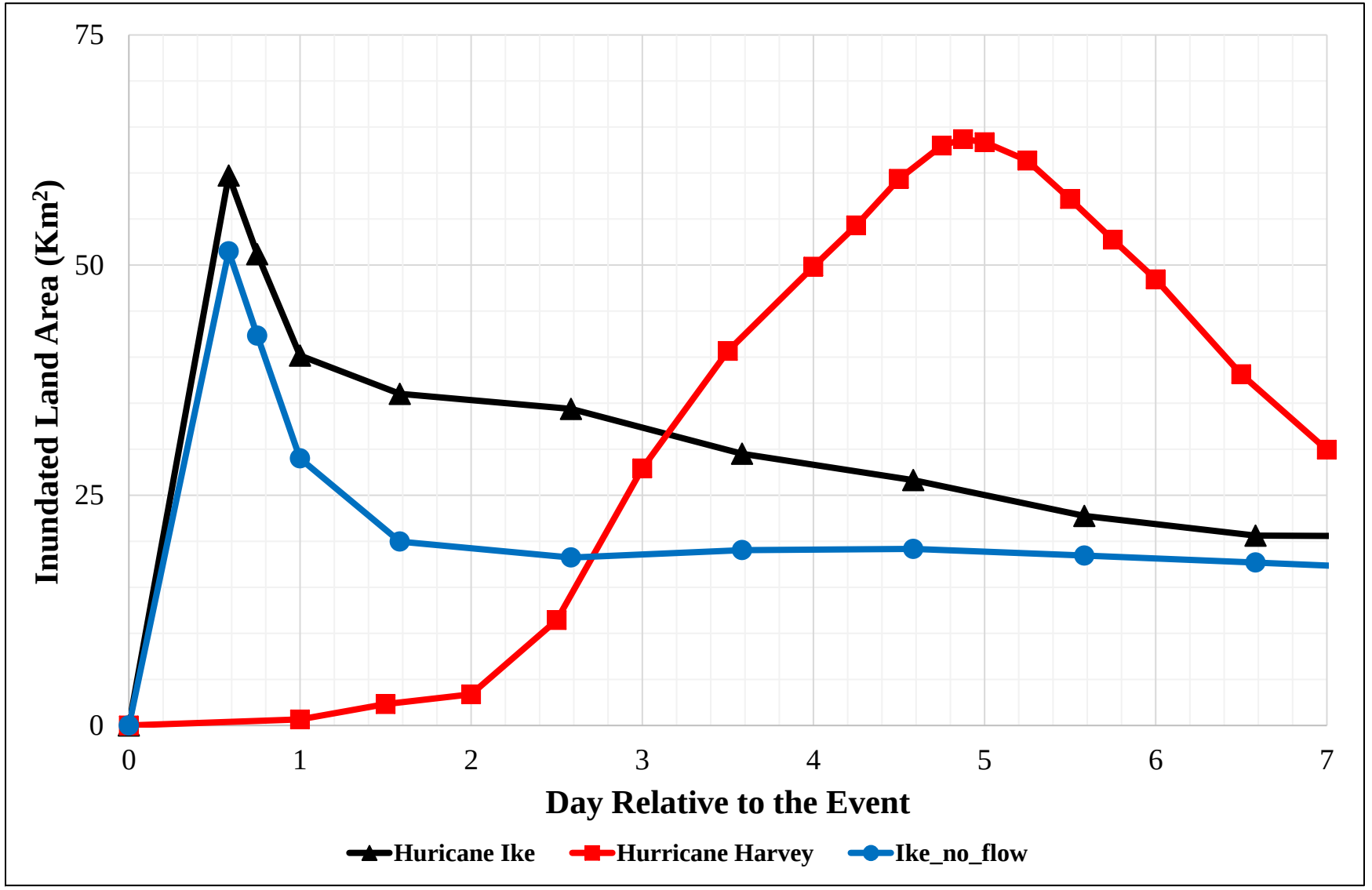
Depth difference due to local runoff during Ike

One week after the surge peak



Kiaghadi, A., Rifai, H. S. & Burleson, D. W. Development of a storm surge driven water quality model to simulate spills during hurricanes. Mar. Pollut. Bull. 129, 714–728 (2017).

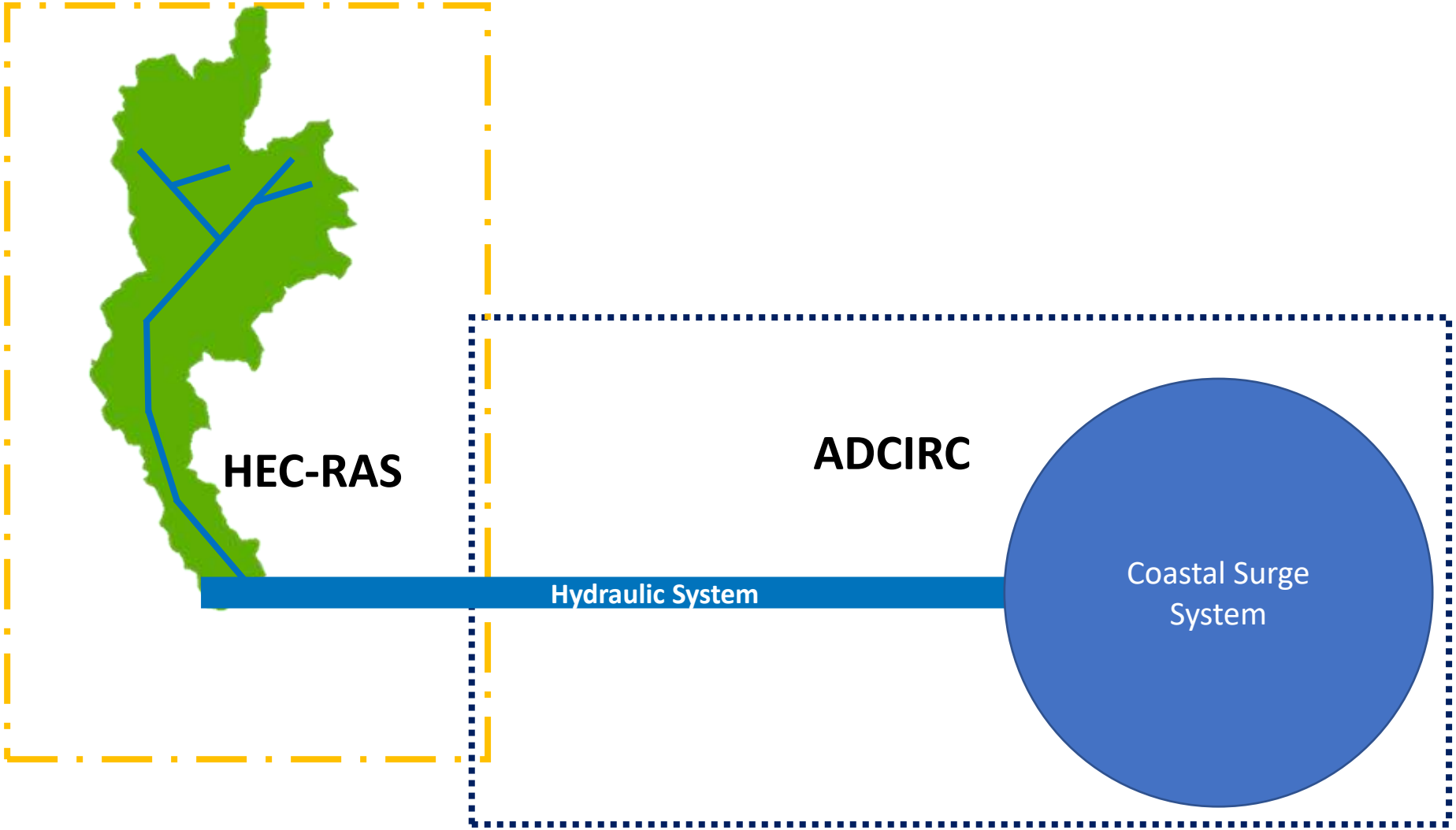
Inundation


75
50
25
0
Inundated Land Area (Km²)
0
1
2
3
4
5
6
7
Day Relative to the Event
Huricane Ike
Hurricane Harvey
Ike_no_flow

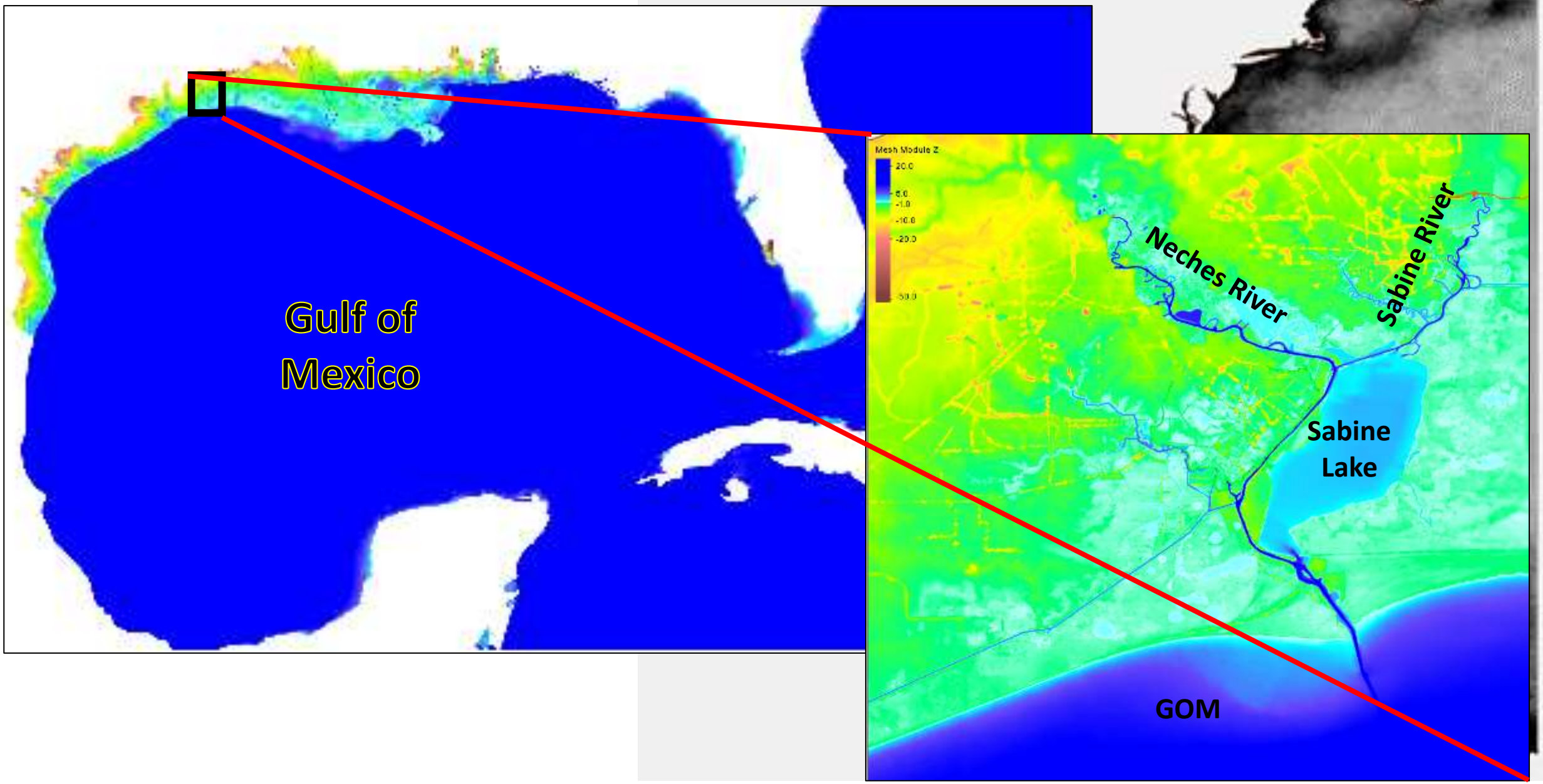
Question 2:

What are the effects of different components of a compound flooding?

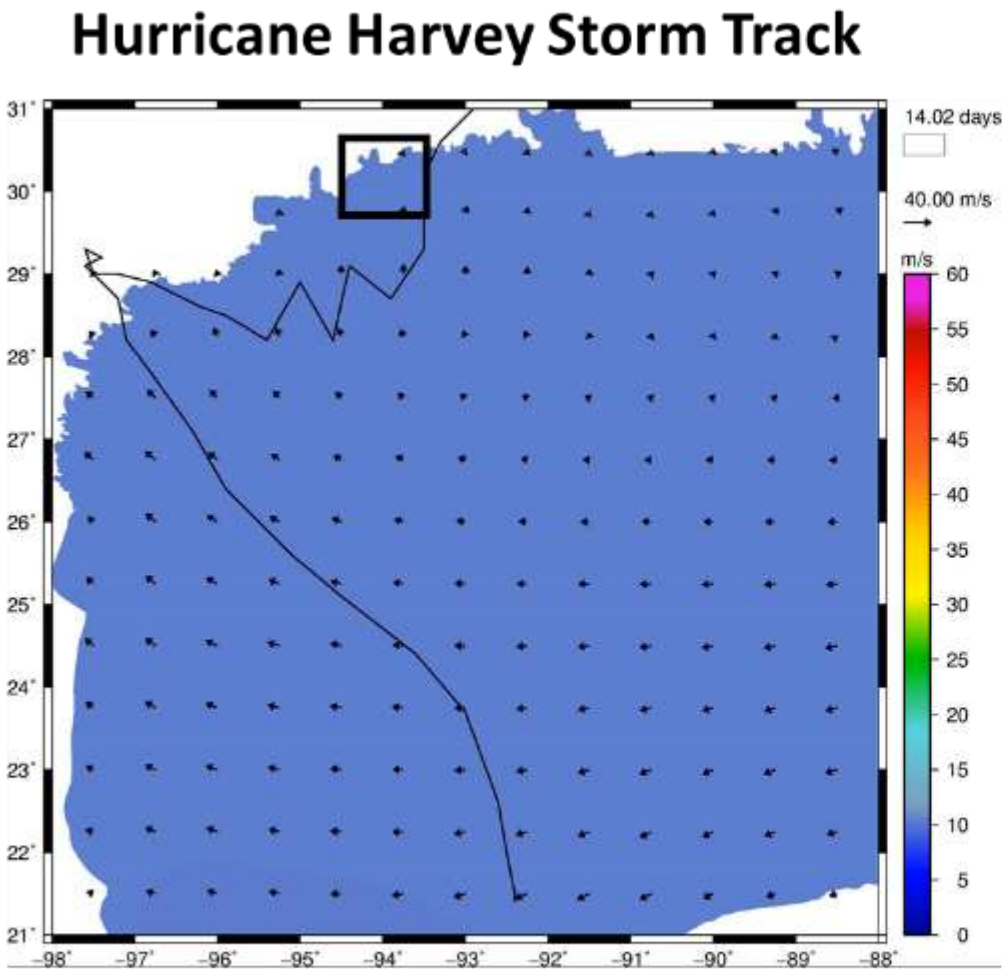
Storm surge modeling using ADCIRC with flow boundary condition from HEC-RAS

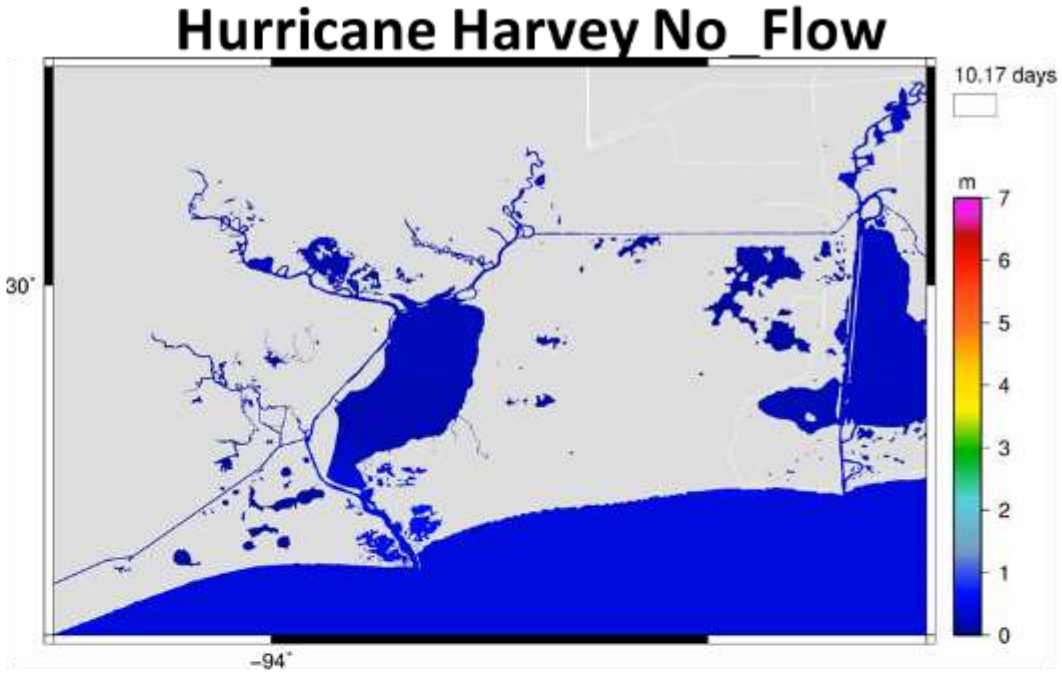


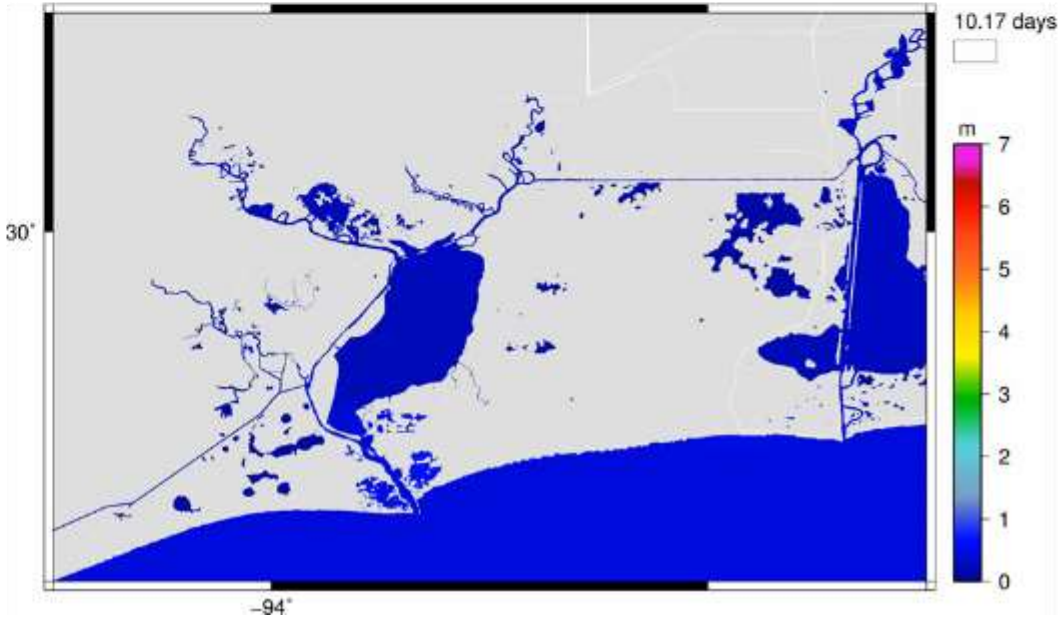
ADCIRC Large Mesh



ADCIRC: Hurricane Harvey







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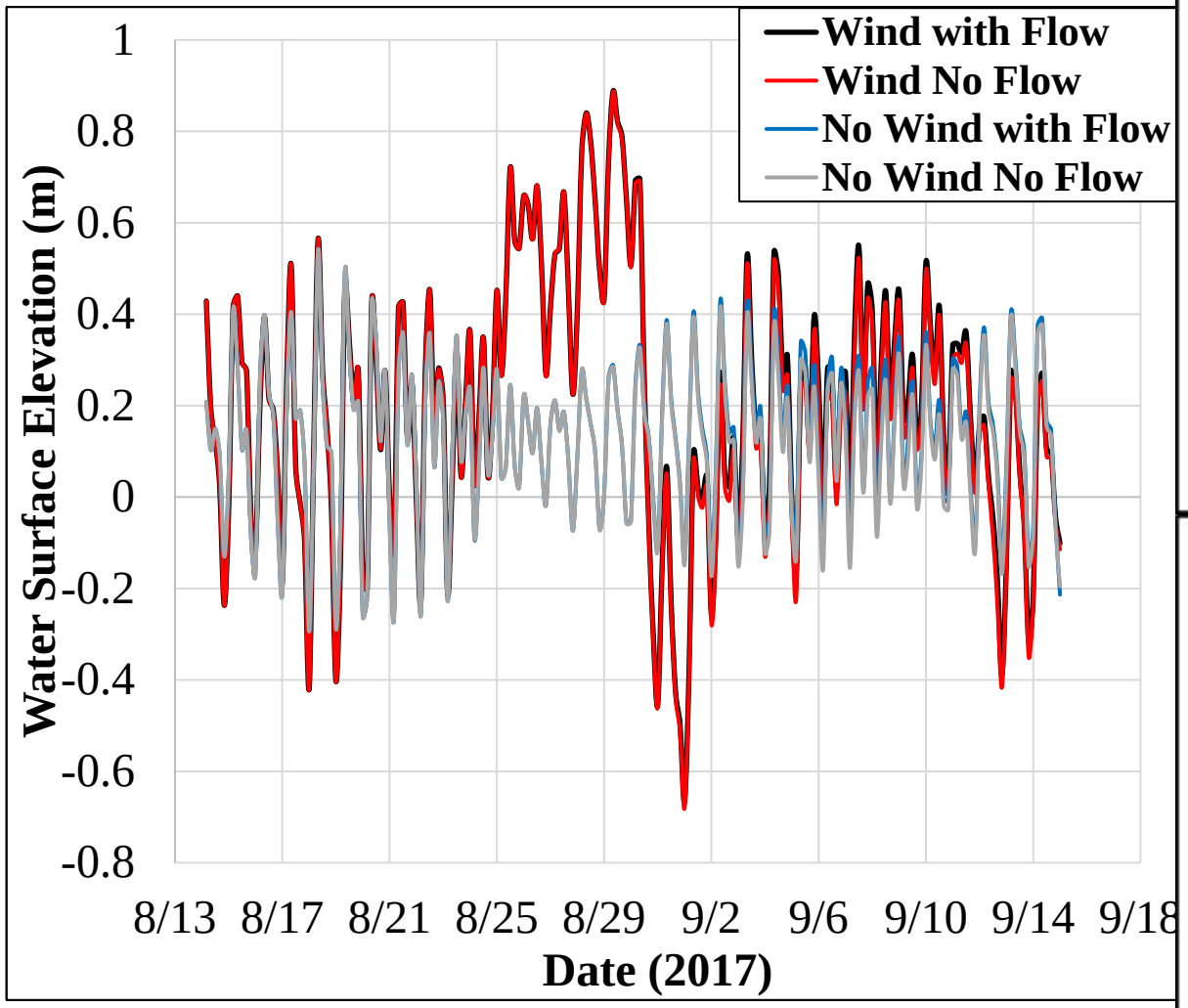
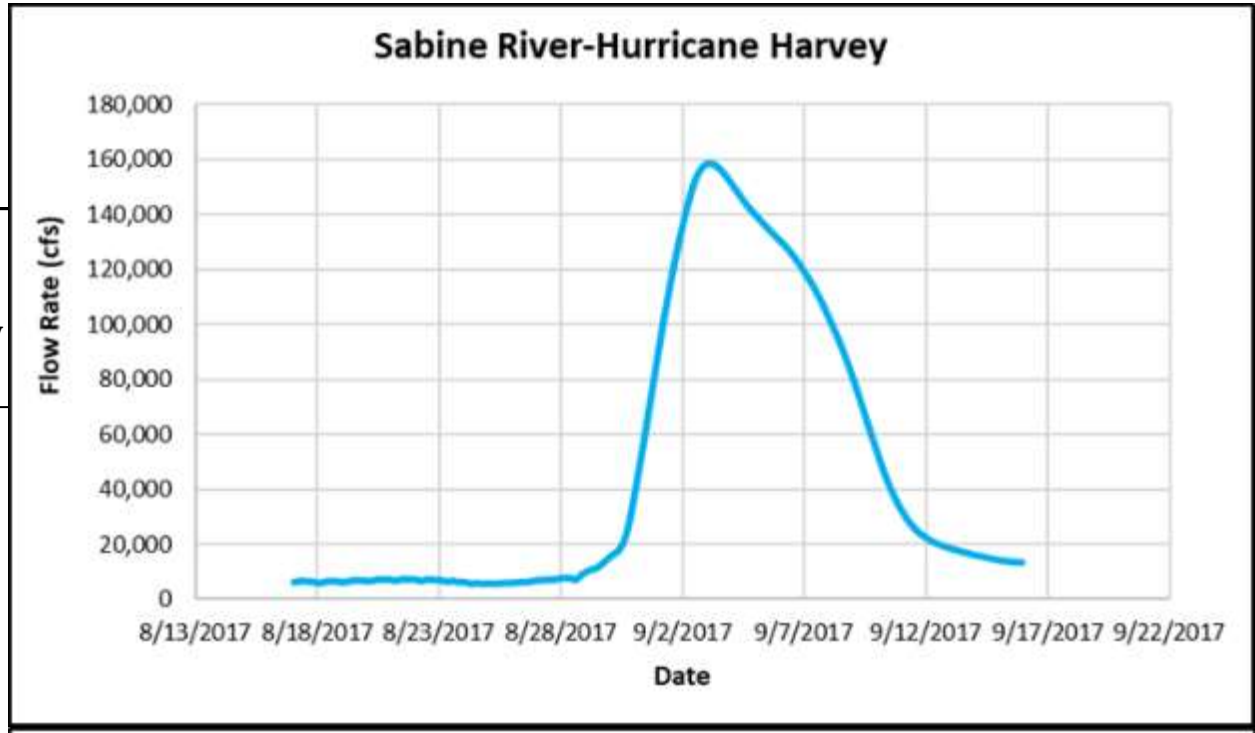
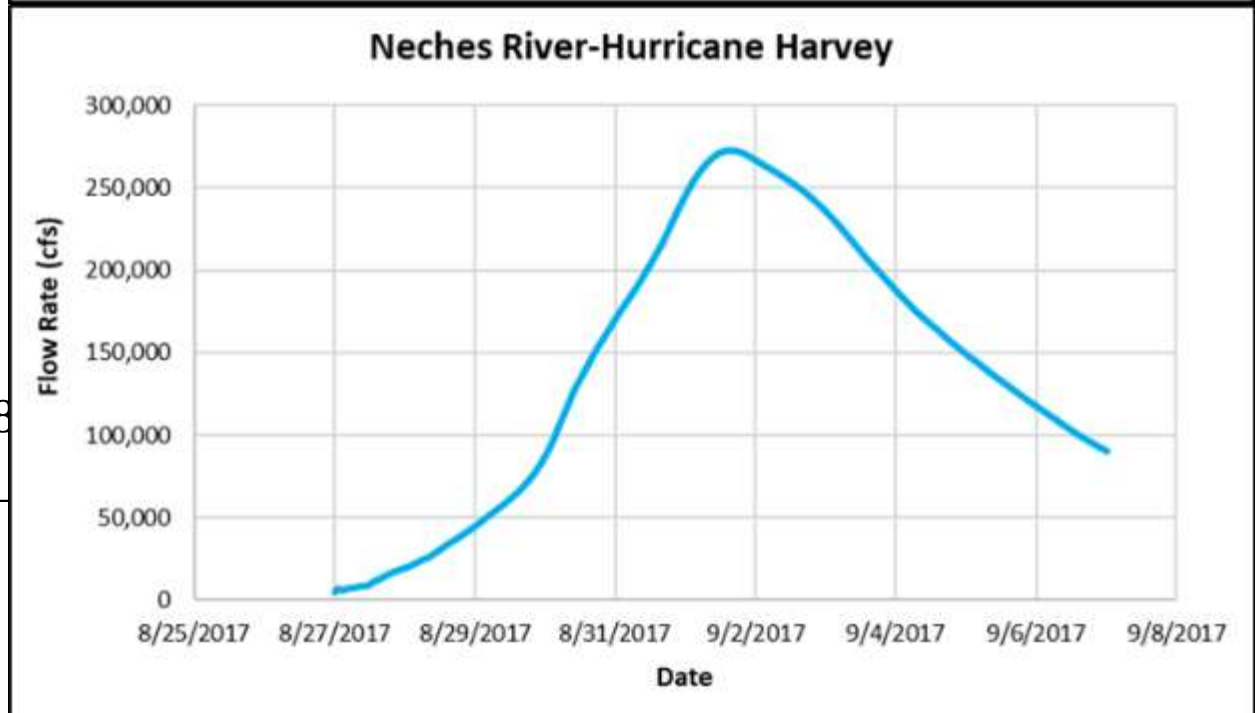
ADCIRC Large Mesh: Gulf Results

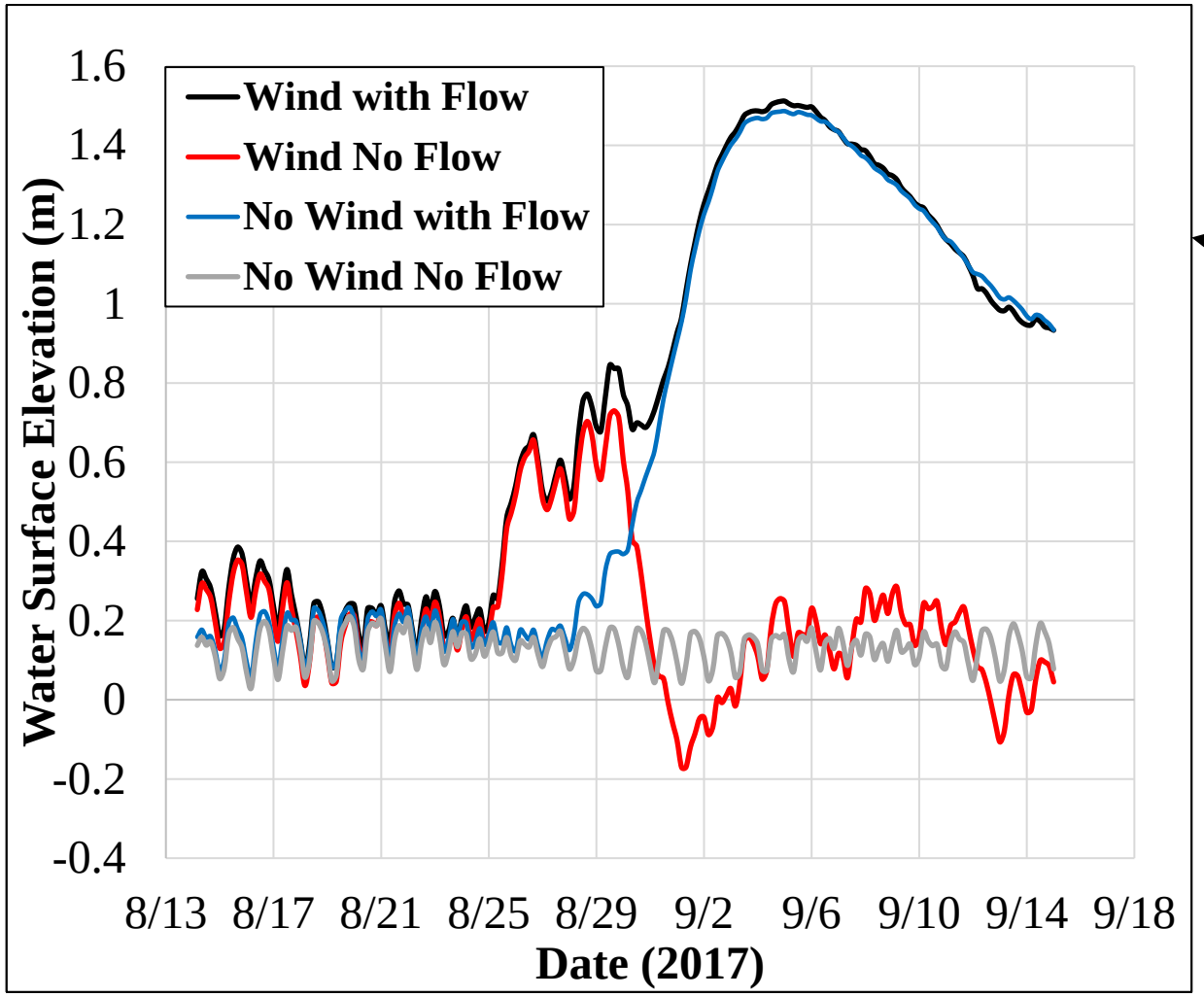


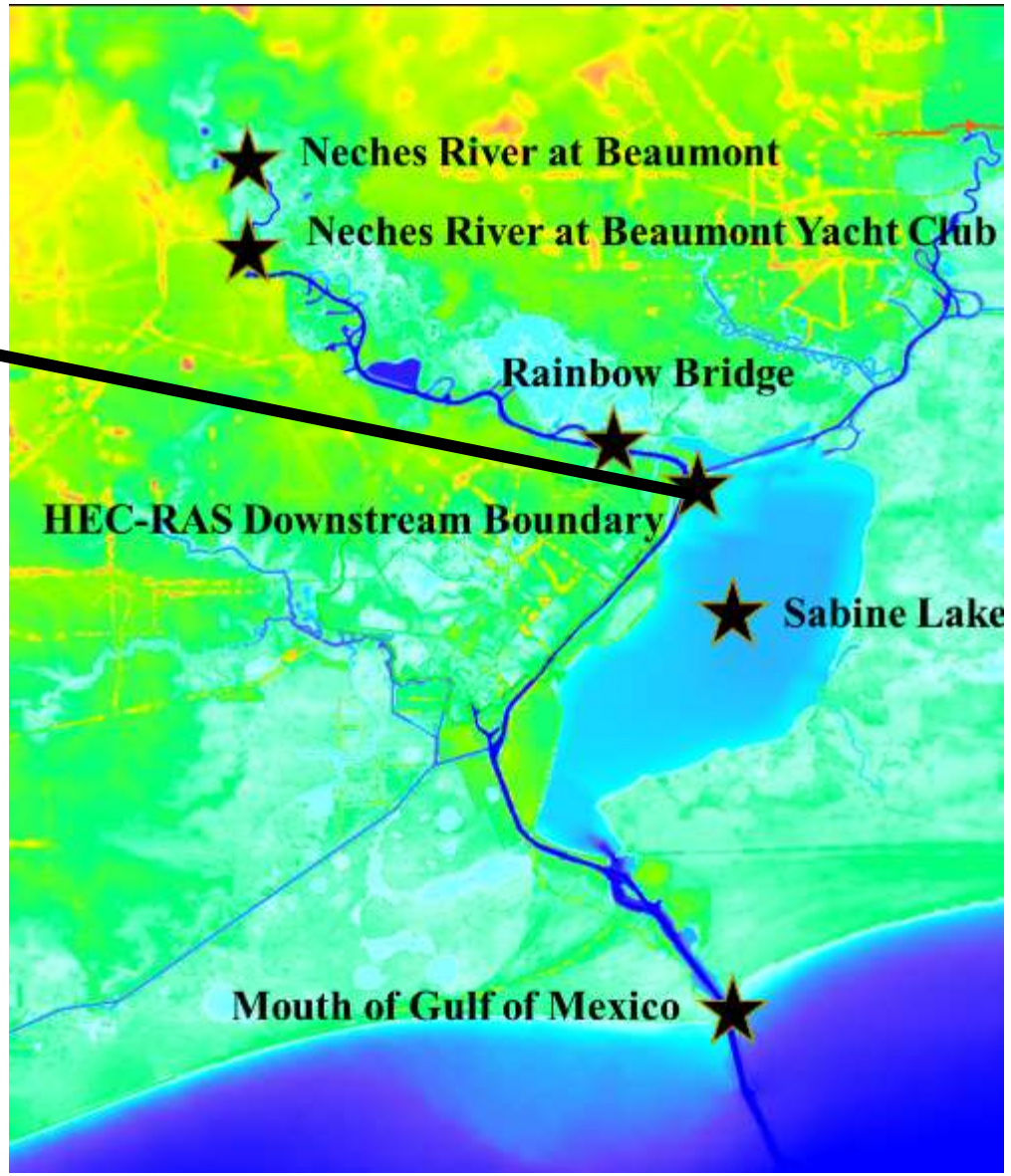




Loveland M, Kiaghadi A, Dawson CN, Rifai HS, Misra S, Mosser H and Parola A (2021) Developing a Modeling Framework to Simulate Compound Flooding: When Storm Surge Interacts With Riverine Flow. Front. Clim. 2:609610. doi: 10.3389/fclim.2020.609610

ADCIRC Large Mesh: Confluence of Neches River and Sabine Lake





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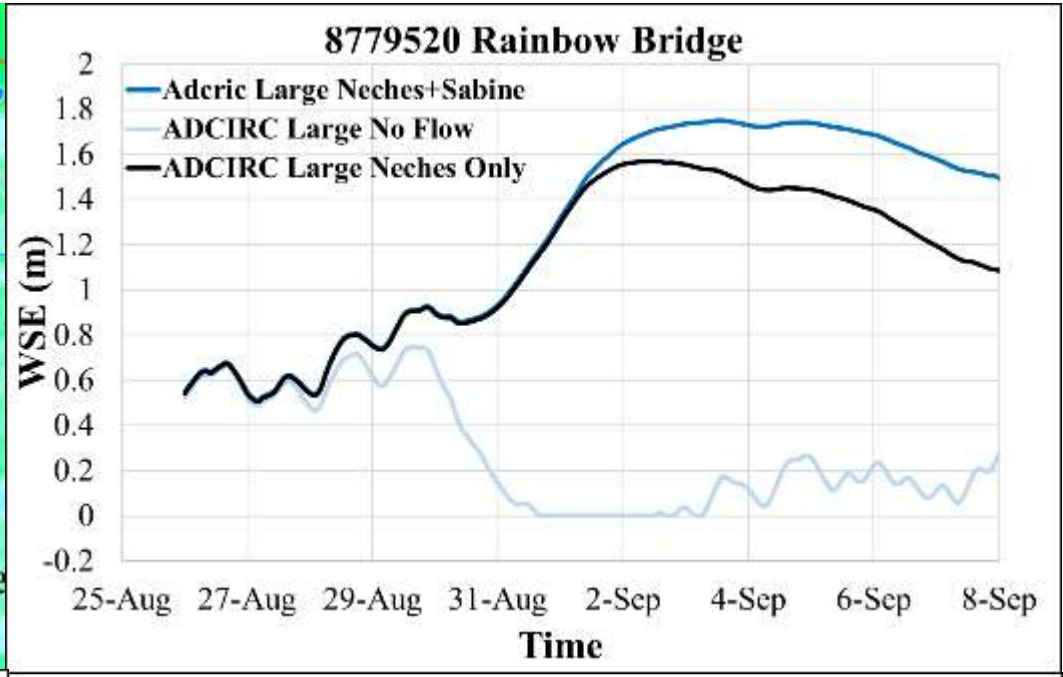
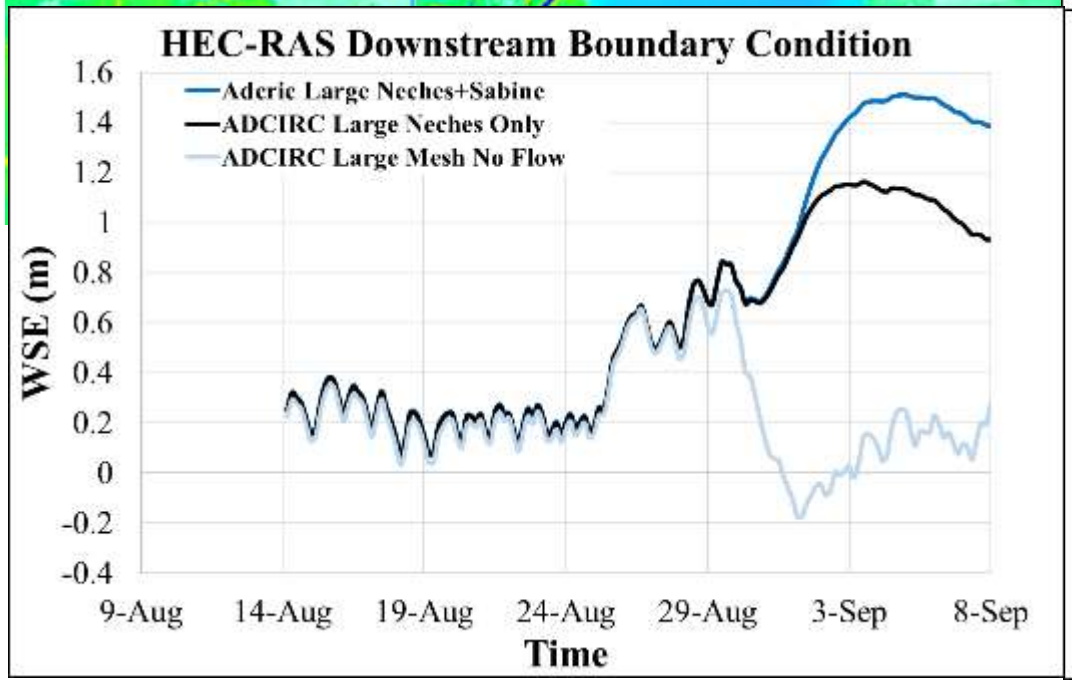
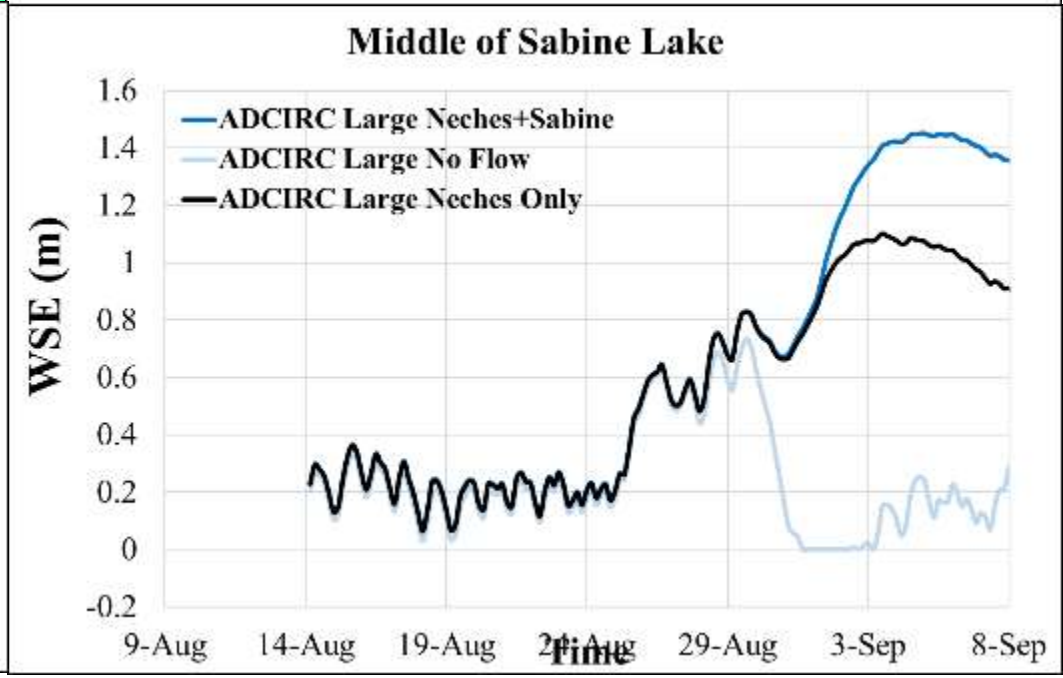
Question 3:

How could the discharge from one watershed affect the WSEs in another watershed?

Watershed Interactions







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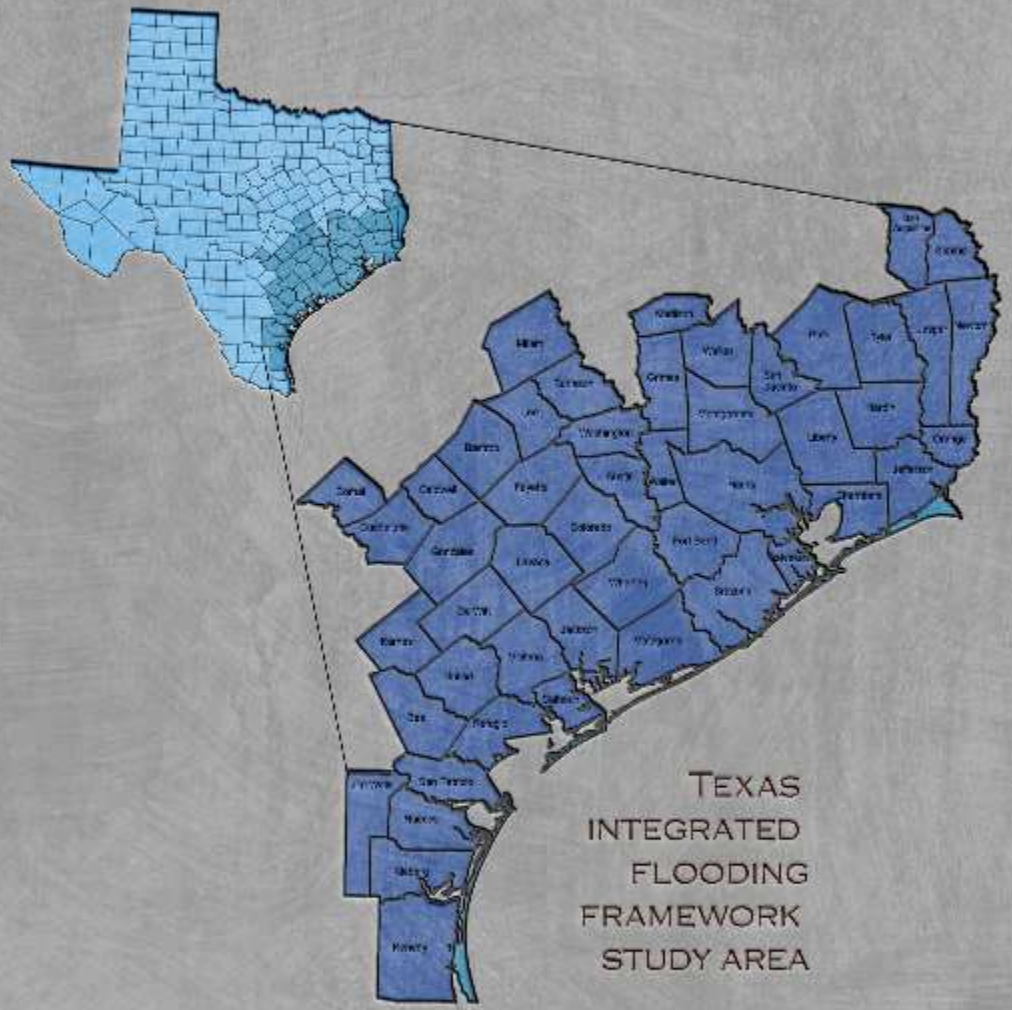


TEXAS INTEGRATED FLOODING FRAMEWORK STUDY AREA

TIFF

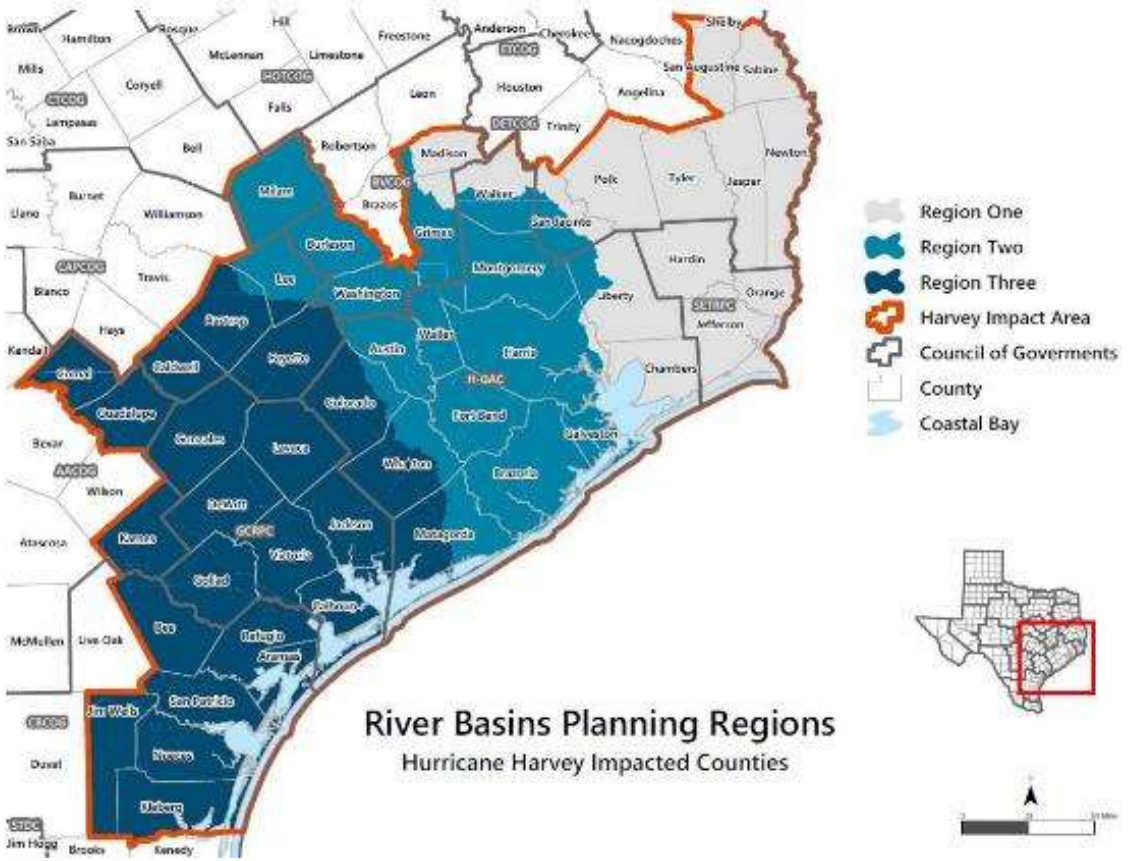
Texas Integrated Flooding Framework

Data collection • Visualization • Modeling • Planning

A COLLABORATION BETWEEN THE TEXAS WATER DEVELOPMENT BOARD, THE U.S. GEOLOGICAL SURVEY, THE ARMY CORPS OF ENGINEERS, AND THE TEXAS GENERAL LAND OFFICE

Texas Integrated Flooding Framework (TIFF)

- Goal: Support comprehensive flood planning and mitigation in Hurricane Harvey impacted areas.
- Team: TWDB, USGS, and USACE-Galveston
- Budget: $3M
- Timeframe: November 30, 2020 – June 30, 2024
- Four-component study
  - Data and Monitoring Gap Analysis
  - Data Management and Visualization
  - Integrated Flood Modeling Framework
  - Planning and Outreach



Each component designed in coordination with *Technical Advisory Teams*

TIFF Steering Committee

TEXAS WATER DEVELOPMENT BOARD

Caimee Schoenbaechler
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TIFF Project Manager

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Texas Integrated Flooding Framework

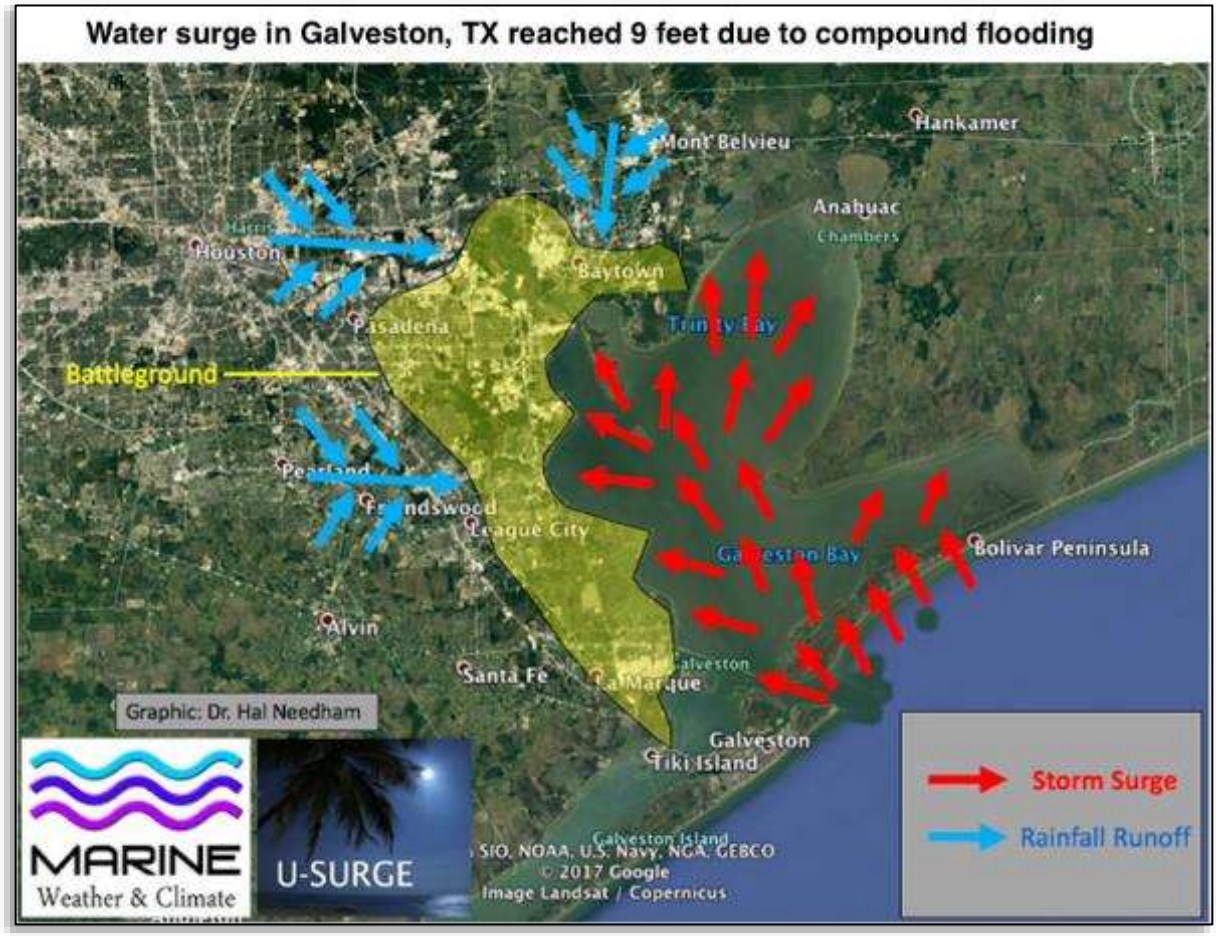
Texas Water Development Board

USGS science for a changing world

TXGLO

The TIFF Vision

- Focus on compound flooding
- Facilitate access to compound flood-related information for decision makers at all levels
- Utilize quality data, robust models, and sound science
- Collaborative planning approach
- Develop trusted relationships among agencies
- Enable reliable coastal compound flood risk planning
- Minimize duplicative effort



Texas Integrated Flooding Framework

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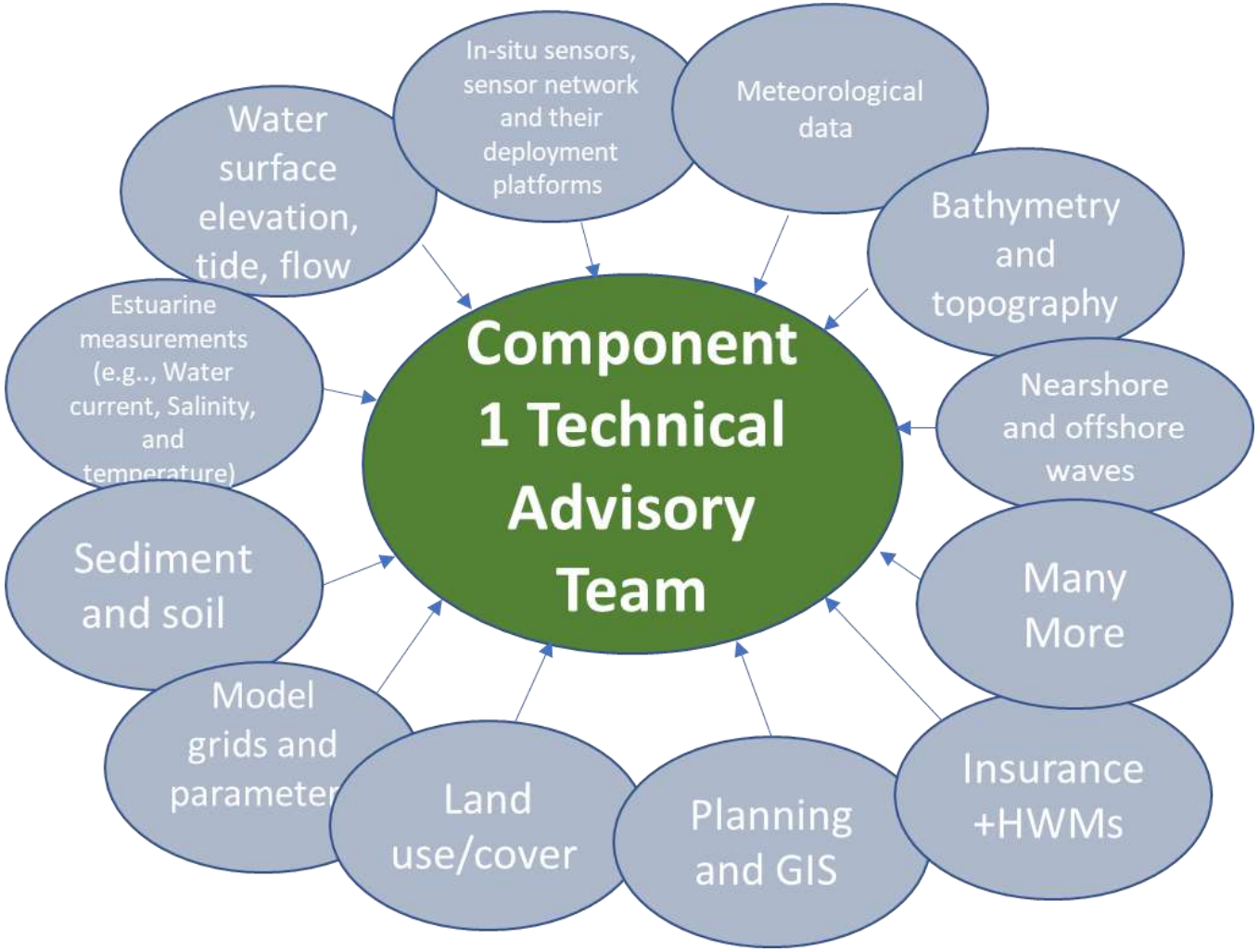
Component 1

Data and Monitoring Gap Analysis

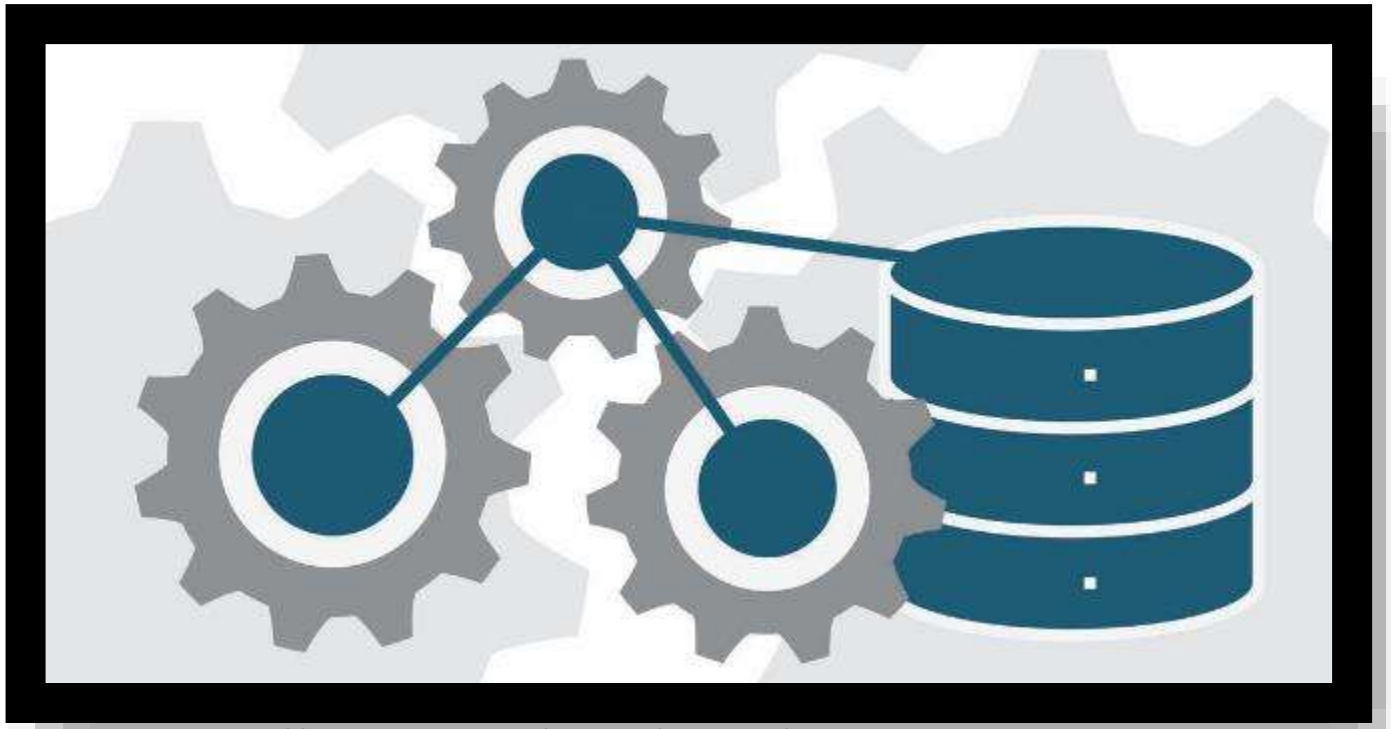
- Inventory all hydrologic, hydrodynamic, meteorological, and planning data currently available, including data necessary for model calibration and verification.
- Perform gap analysis using geospatial and analytical tools to identify and prioritize data needs for planning.
- Evaluate new monitoring technologies



Component 2

Data Management and Visualization

- Identify uniform data standards and methods for interoperability
- Integrate these into the systems maintained by agency partners
  - Texas Disaster Information System (TDIS)
  - Interagency Flood Risk Management (InFRM)
  - TWDB Data Hub
  - Flood Decision Support Toolbox (FDST)



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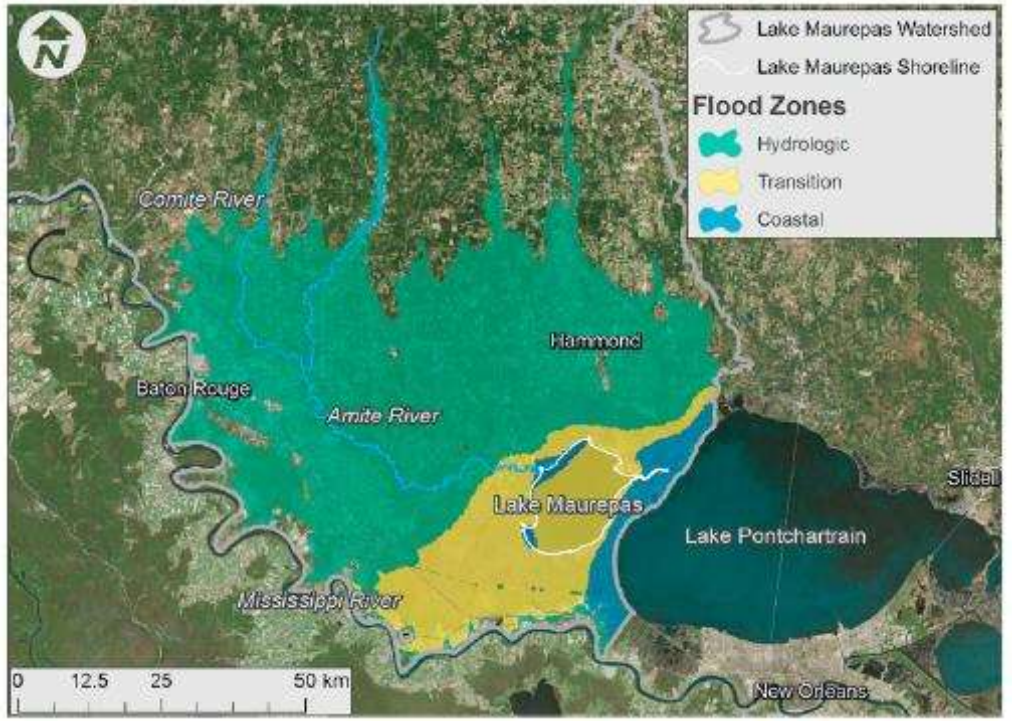
Component 3

Integrated Flood Modeling Framework

- Inventory existing and proposed models for planning, real-time, and forecasting.
- Assess and vet potential meteorological, hydrologic, hydraulic, and hydrodynamic models for evaluating and mitigating flood risk for Texas.
- Develop a conceptual model-coupling strategy, including coupling of hydrologic-hydraulic and estuarine-surge models.
- Develop scenarios and an evaluation matrix to test effectiveness of the conceptual model integration strategy.

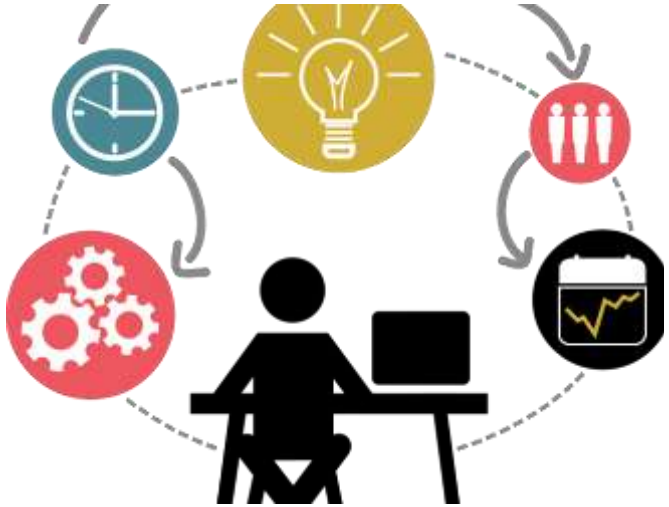


- ❑ **Hydrologic flooding zone**
- ❑ **Transition flooding zone**
- ❑ **Coastal flooding zone**

Component 4

Outreach and Planning

- Conduct and coordinate outreach with Regional Flood Planning Groups and other stakeholders to ensure that resiliency and mitigation planning needs are incorporated into the integrated framework.



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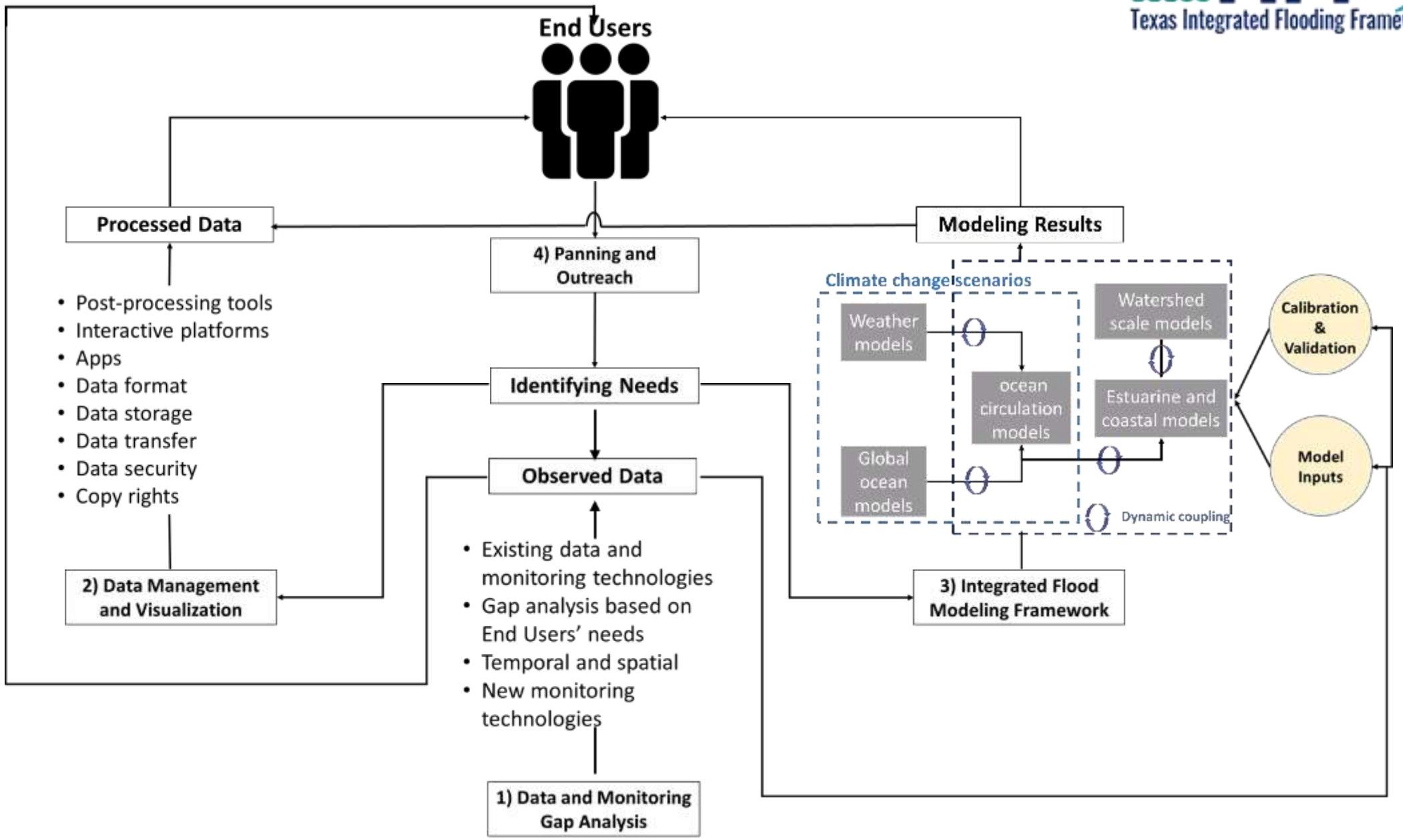
How it all comes together



Recent progress

- Agency contracts are executed!
- The Meadows Center for Water and the Environment has been selected as the Facilitation Team
- Four Technical Advisory Teams were formed
- Kickoff meeting was held on April 5, 2021
- TIFF website:

https://webapps.usgs.gov/tiff/

Thank You!

Contact Info:

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