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

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Lower Rio Grande Valley
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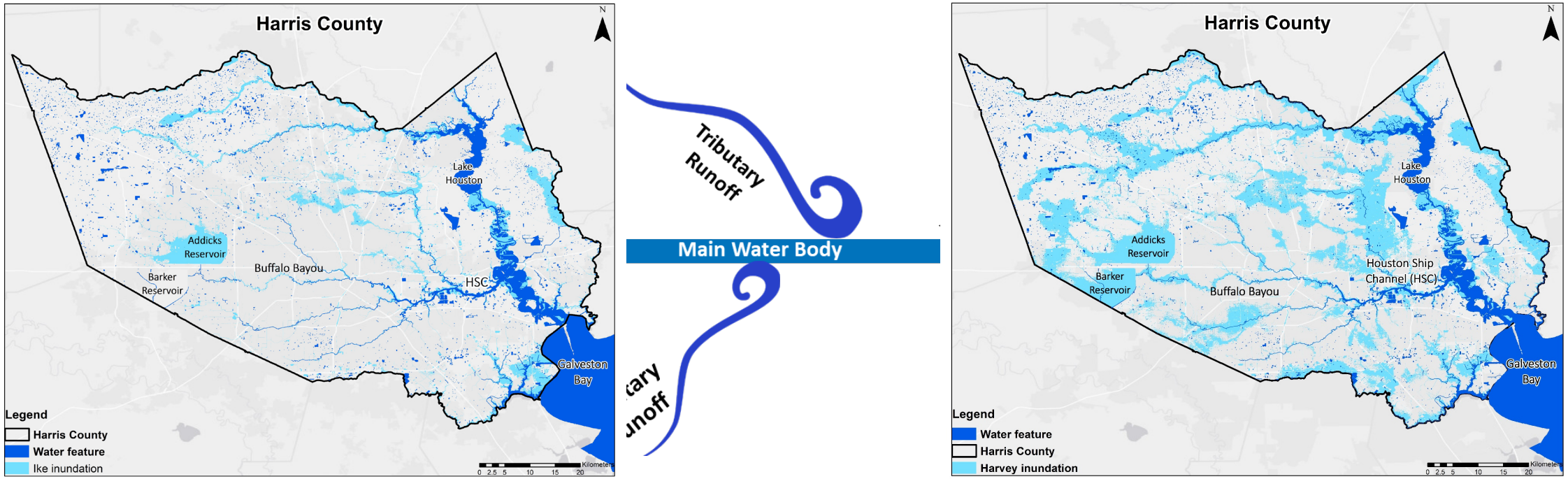
Storm surge and rainfall

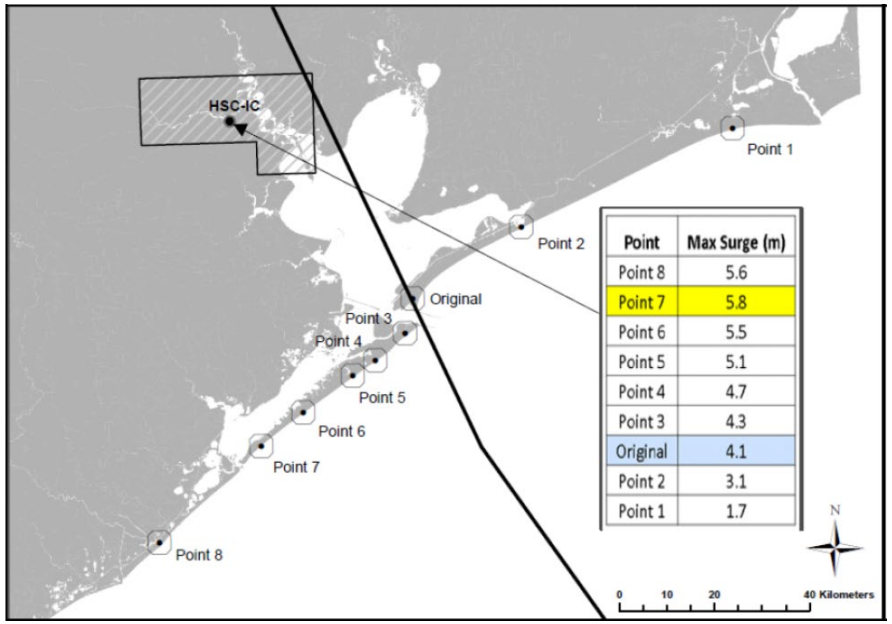
It is commonly believed that storm surge is the costliest aspect of a hurricane.

- 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

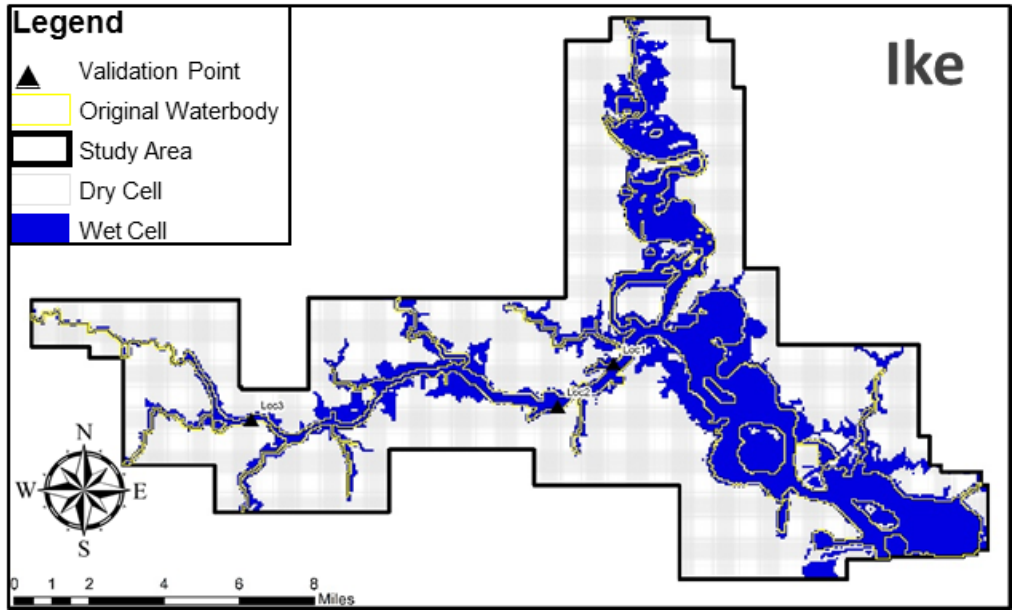


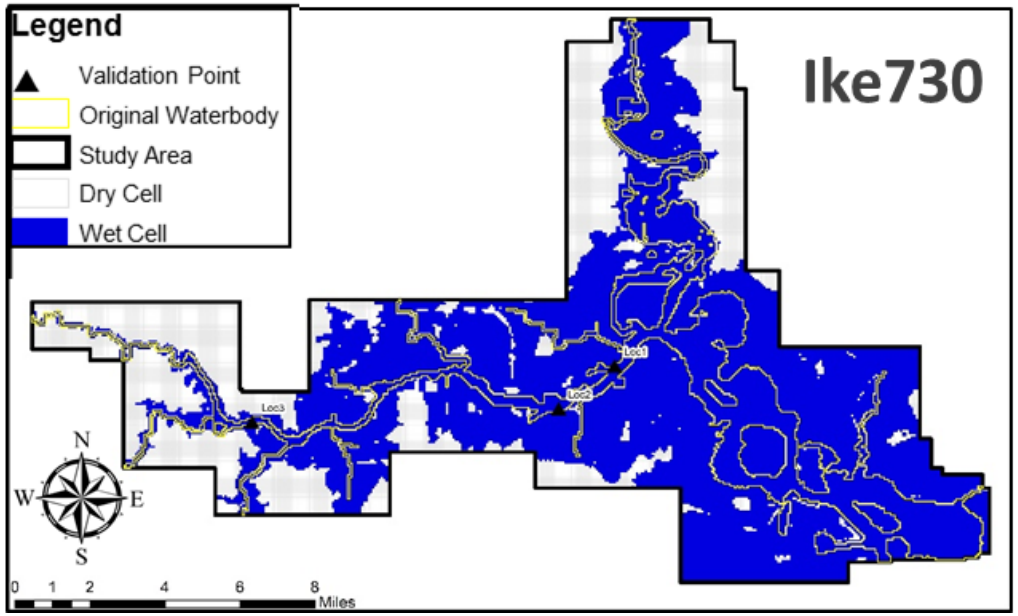
Hurricane Ike (2008) **Hurricane Harvey (2017)**

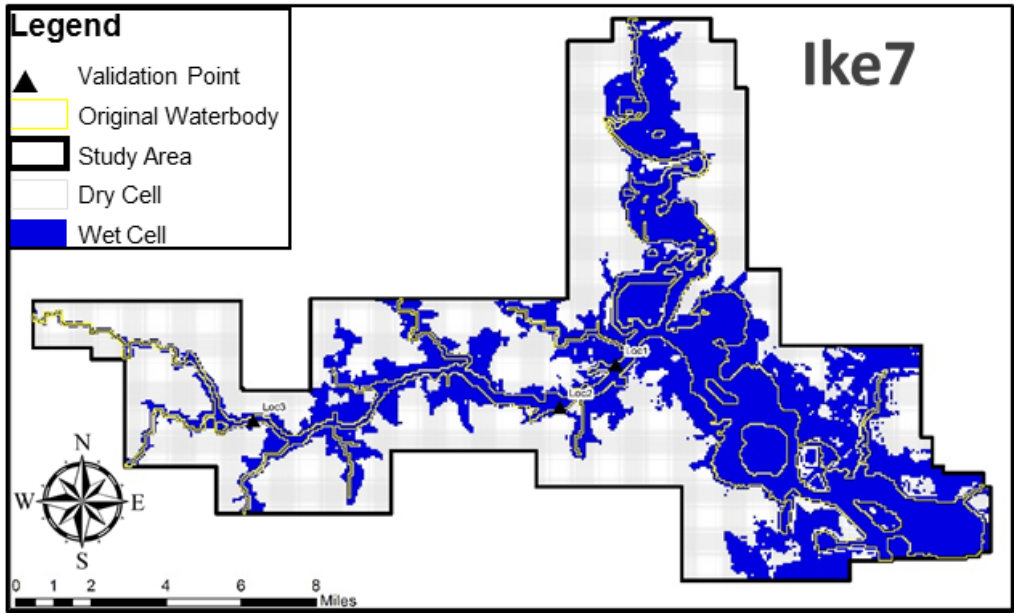
How could it get worse?



Point	Max Surge (m)
Point 8	5.6
Point 7	5.8
Point 6	5.5
Point 5	5.1
Point 4	4.7
Point 3	4.3
Original	4.1
Point 2	3.1
Point 1	1.7







Compound events

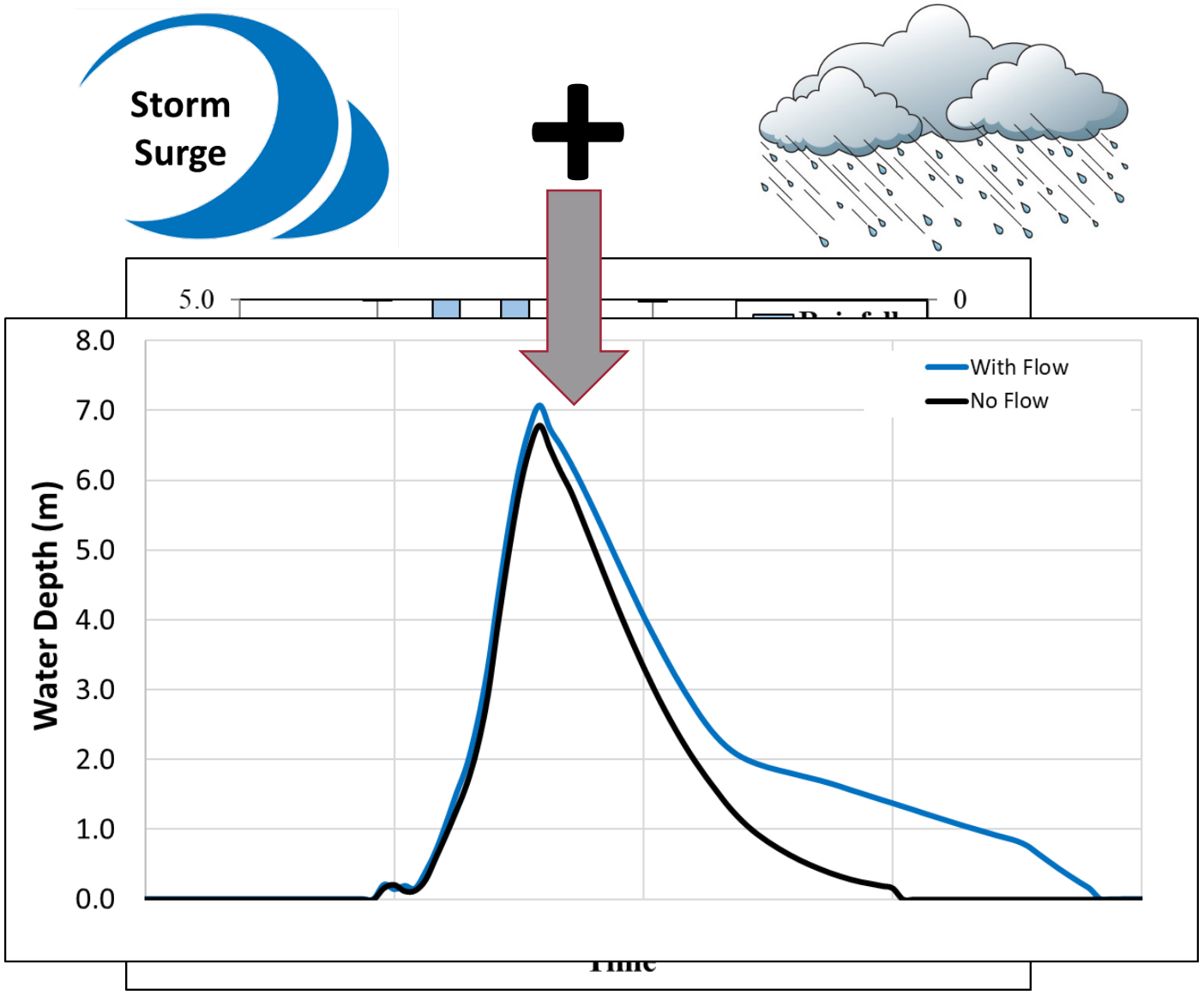
Intergovernmental Panel on Climate Change (IPCC), 2012:

(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).

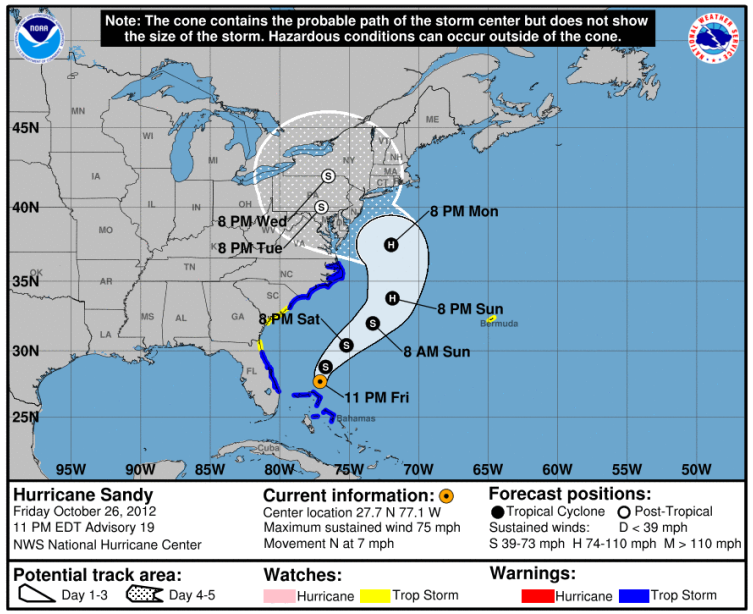
Compound flooding: Storm surge and rainfall



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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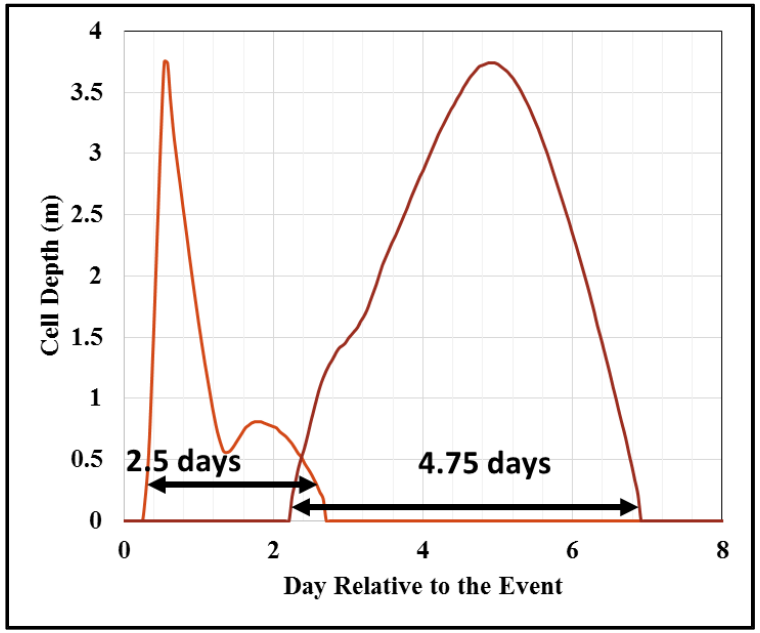


- Understanding the complexities associated with the hydrodynamics of surge and/or significant rainfall can be best achieved via models developed specifically for this purpose.

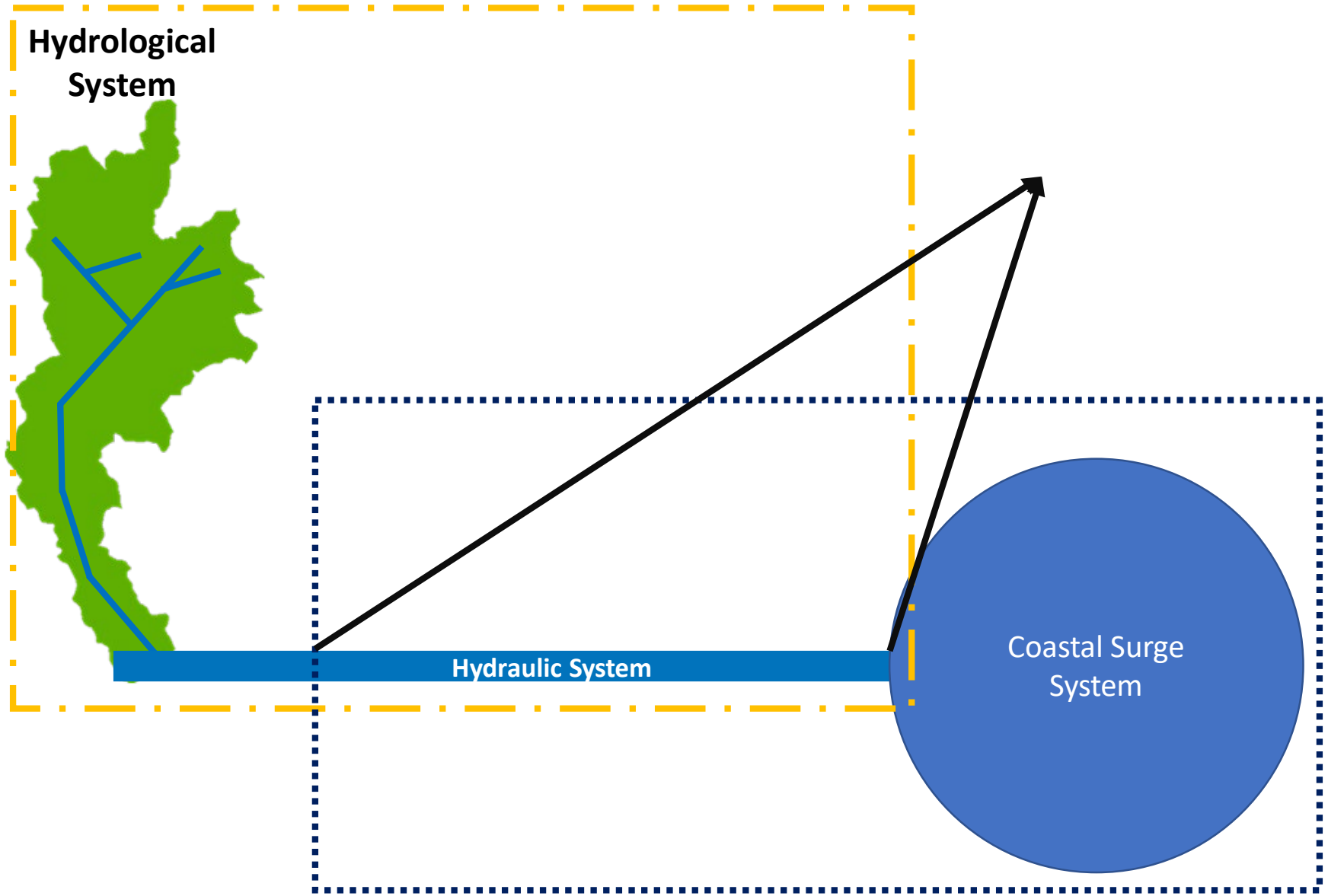
What types of models are available?

Whatever you need!

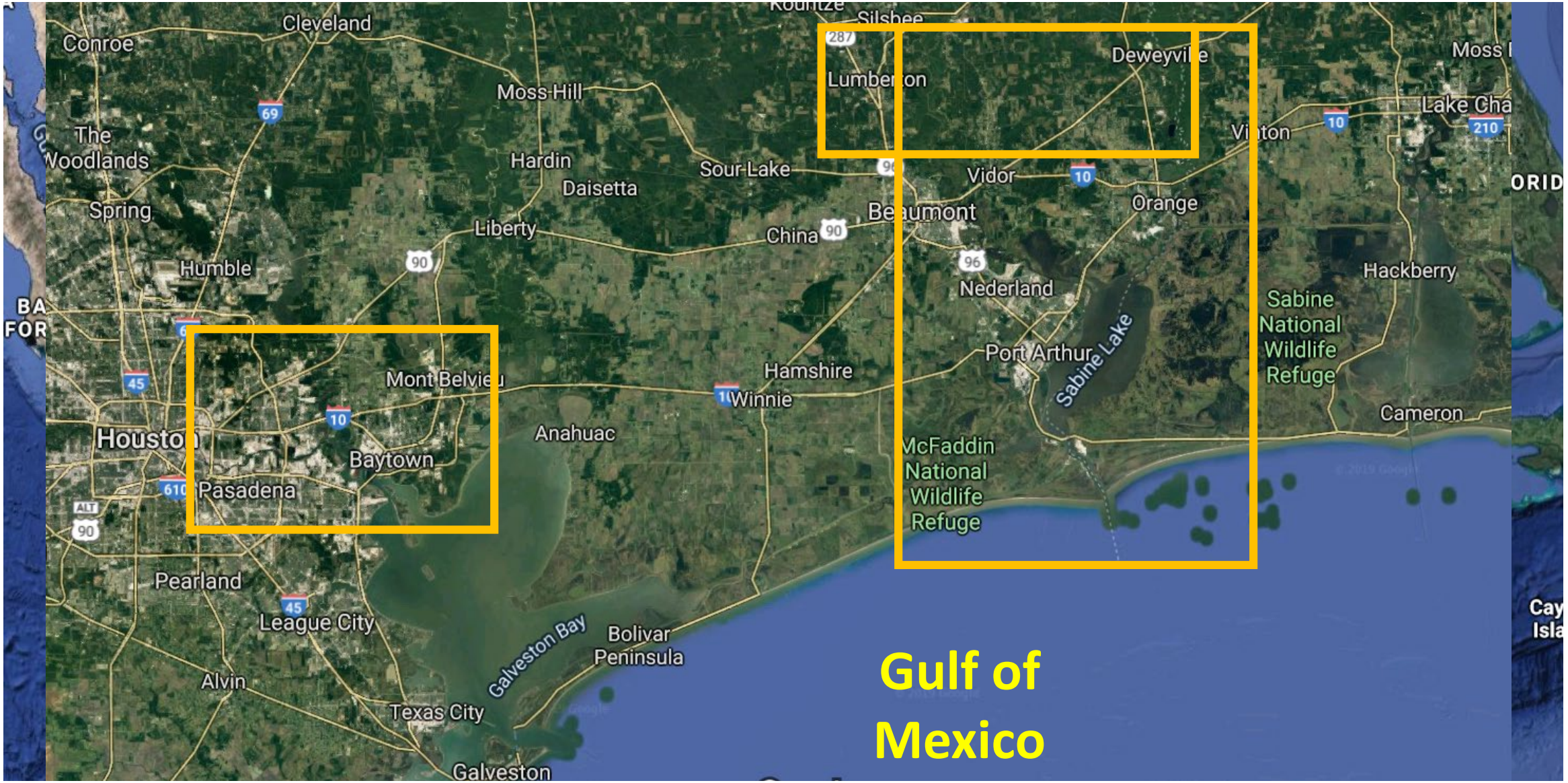
As long as you know the principles, you can use different models

- 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?



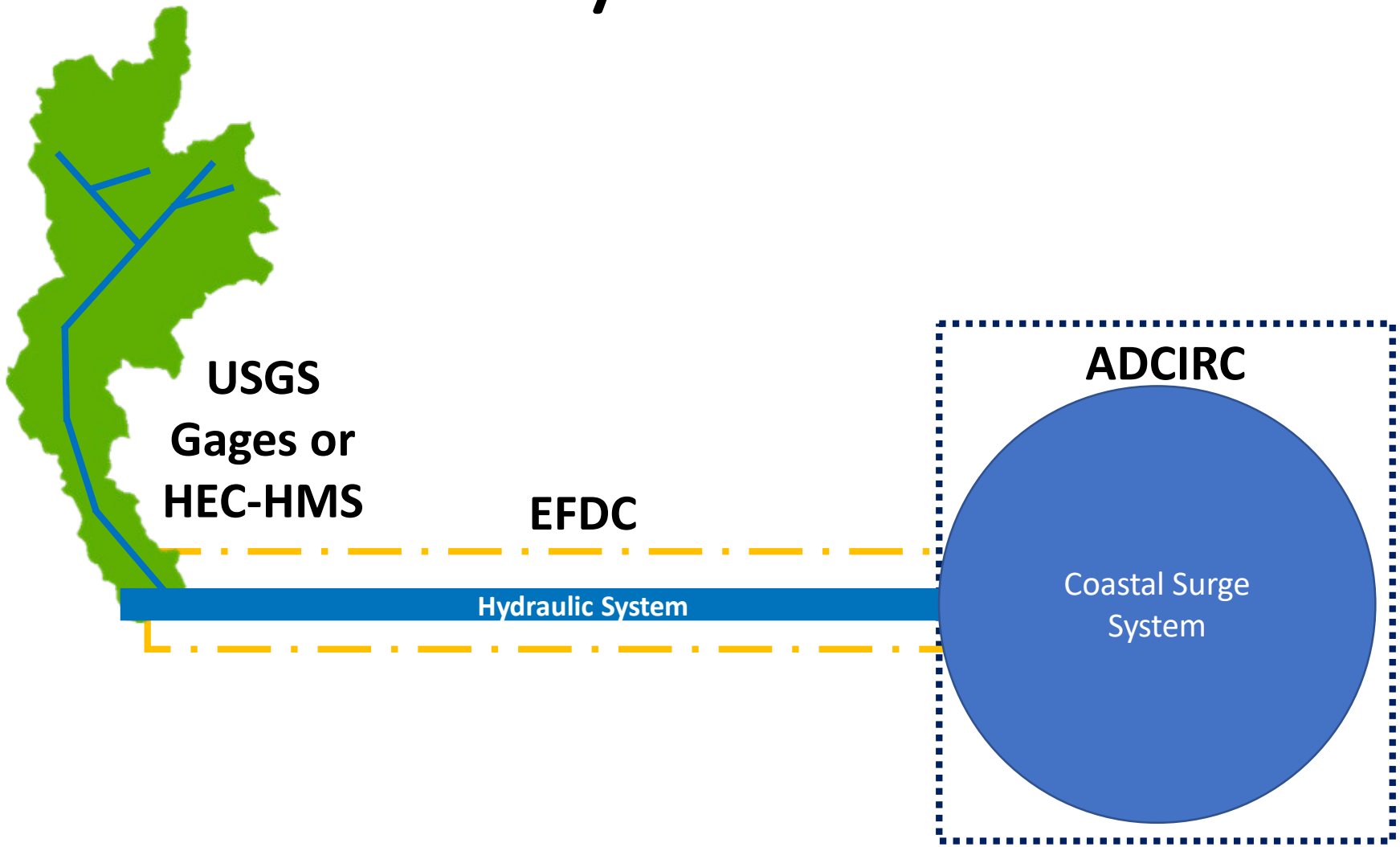
Study areas


Cleveland
Conroe
Moss Hill
The Woodlands
Hardin
Daisetta
Sour Lake
Spring
Liberty
China
Beaumont
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:

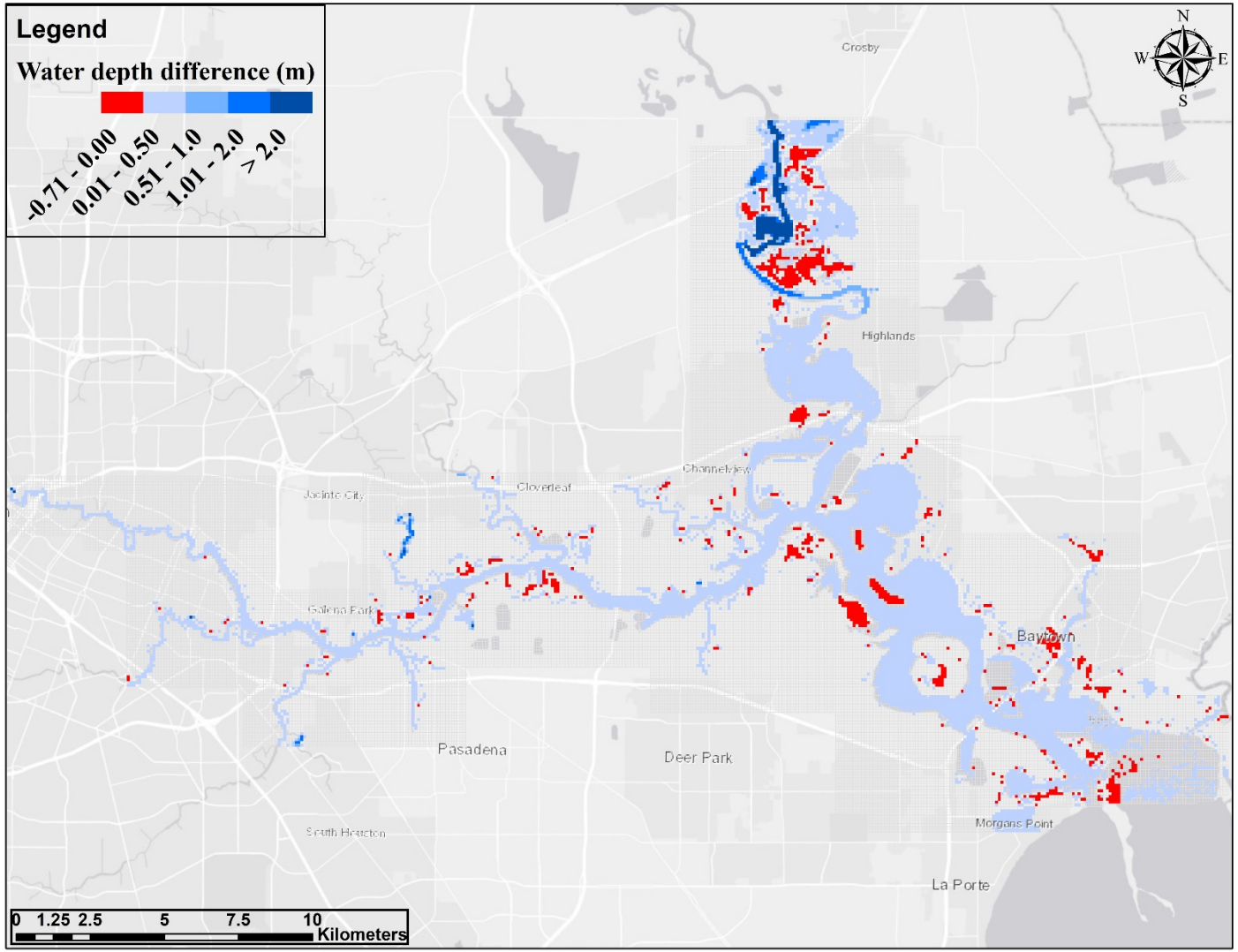
What is the effect of local runoff on inundation levels during a storm surge event?

Estuarine system modeling using EFDC with downstream boundary condition from ADCIRC

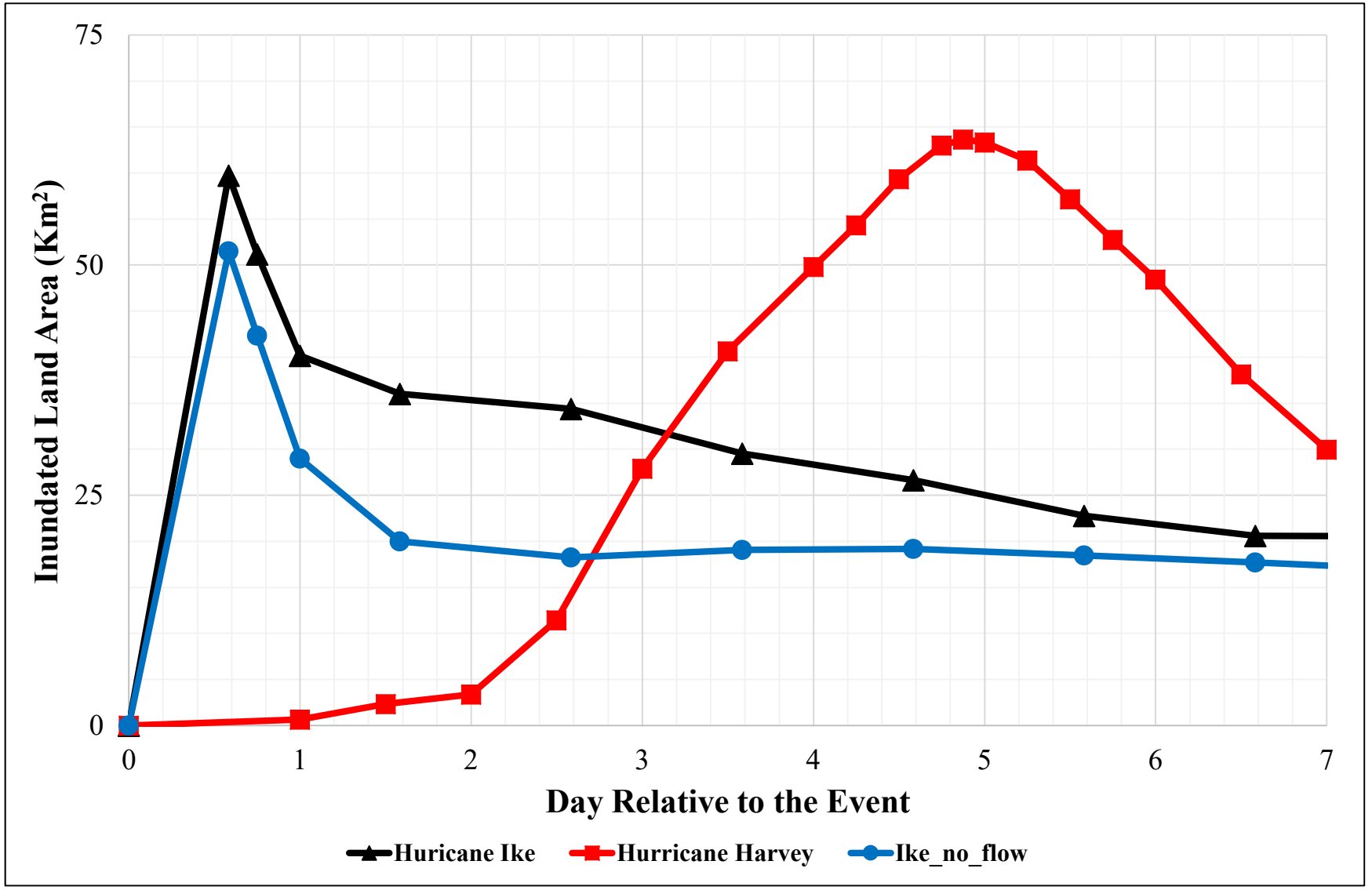


Depth difference due to local runoff during Ike

One week after the surge peak



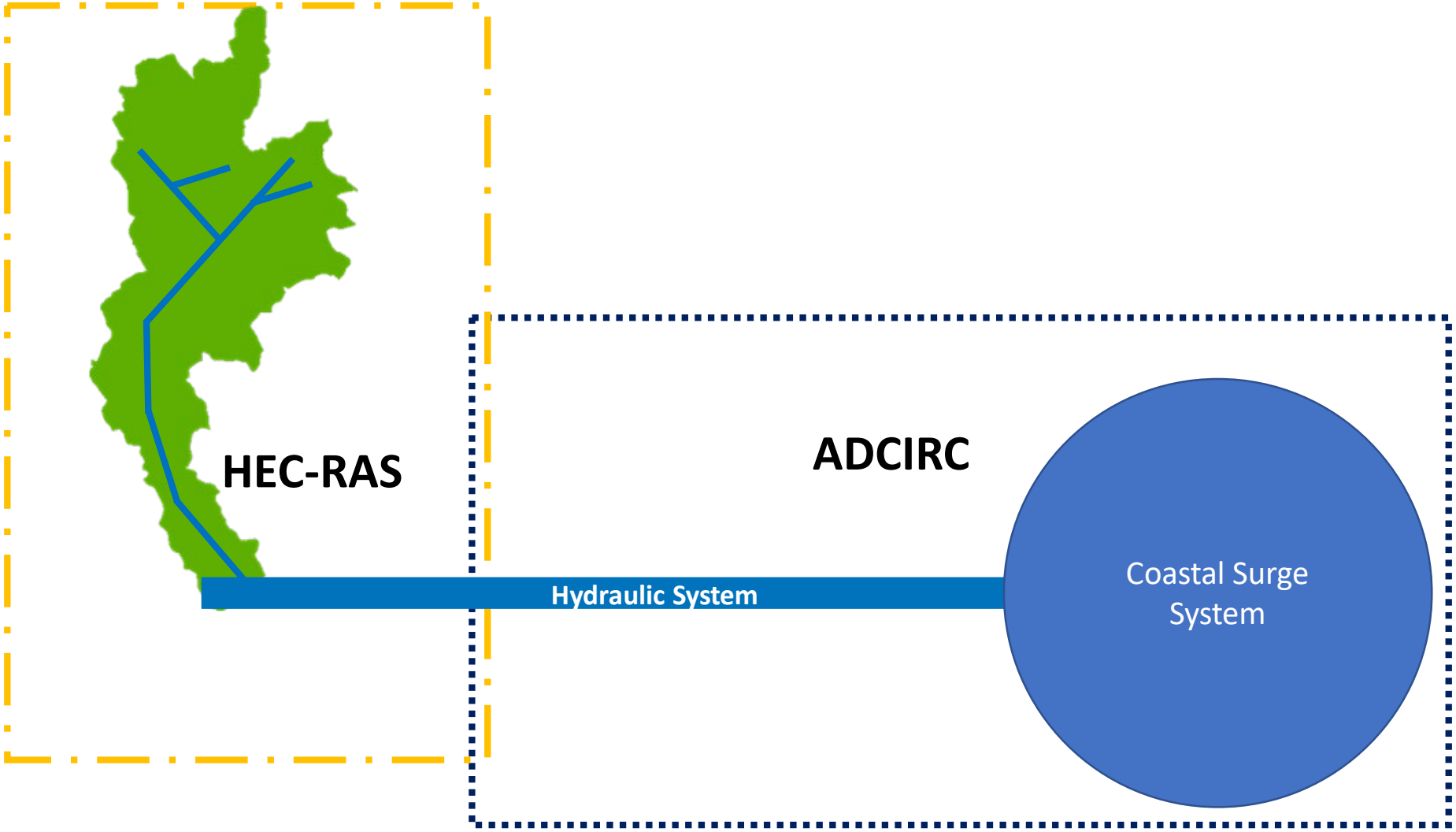
Inundation


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:

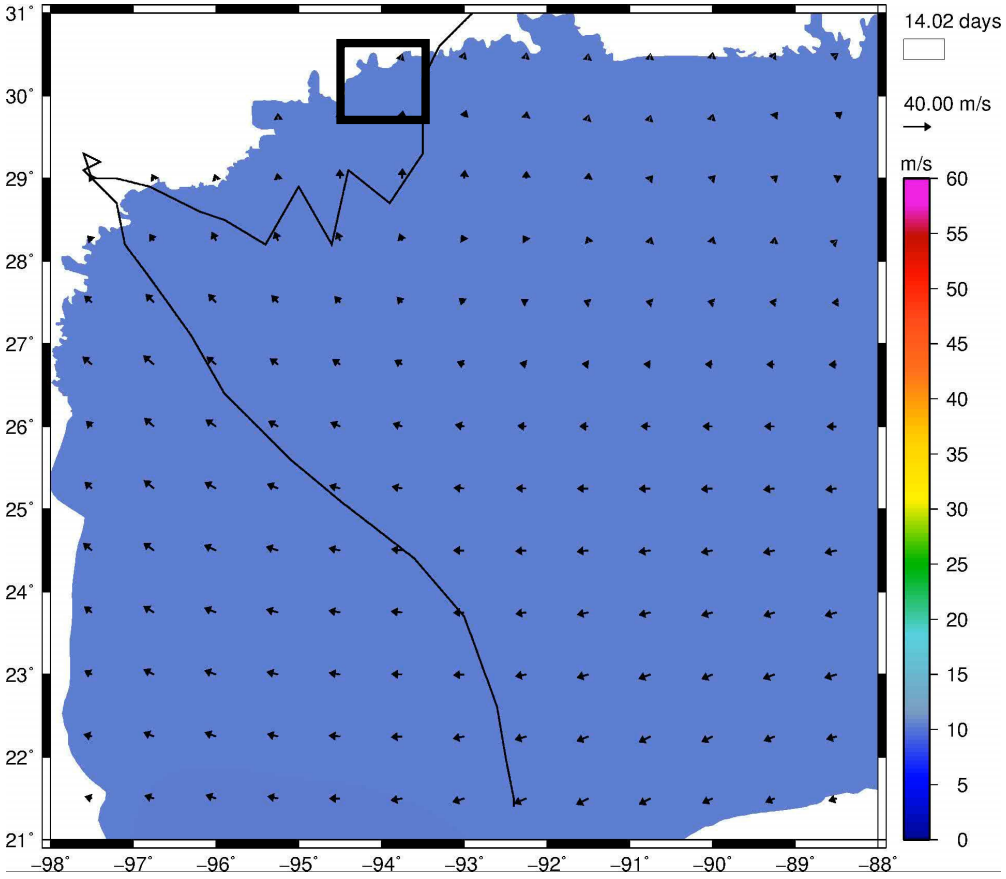
What is the effect of local runoff on inundation levels during a rainfall dominated hurricane?

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

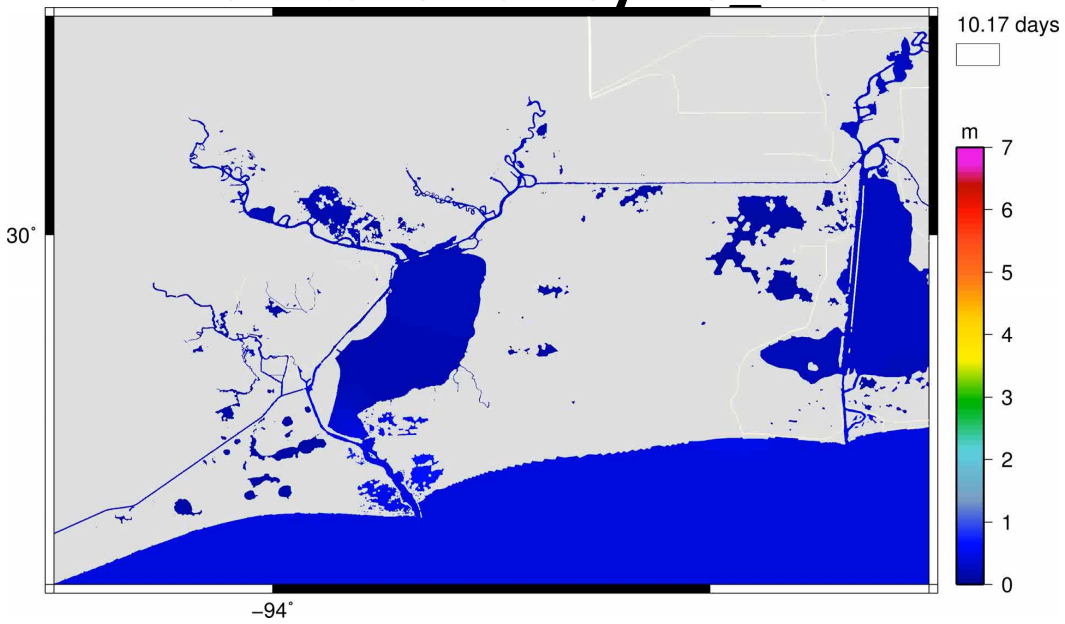


ADCIRC: Hurricane Harvey

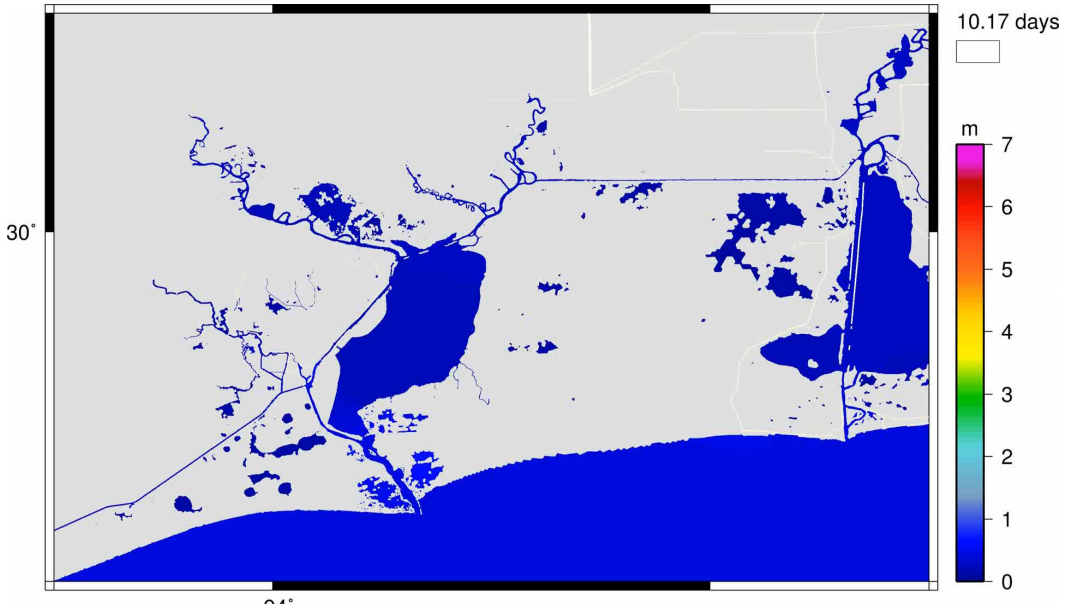
Hurricane Harvey Storm Track



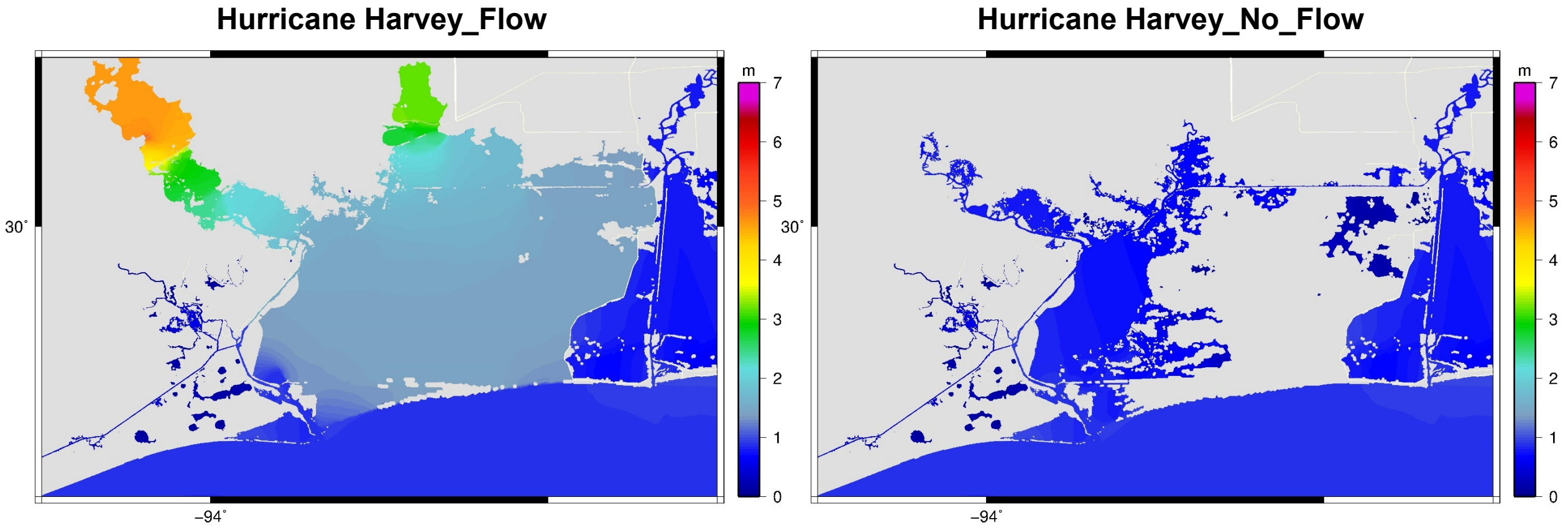
Hurricane Harvey No_Flow



Hurricane Harvey Flow



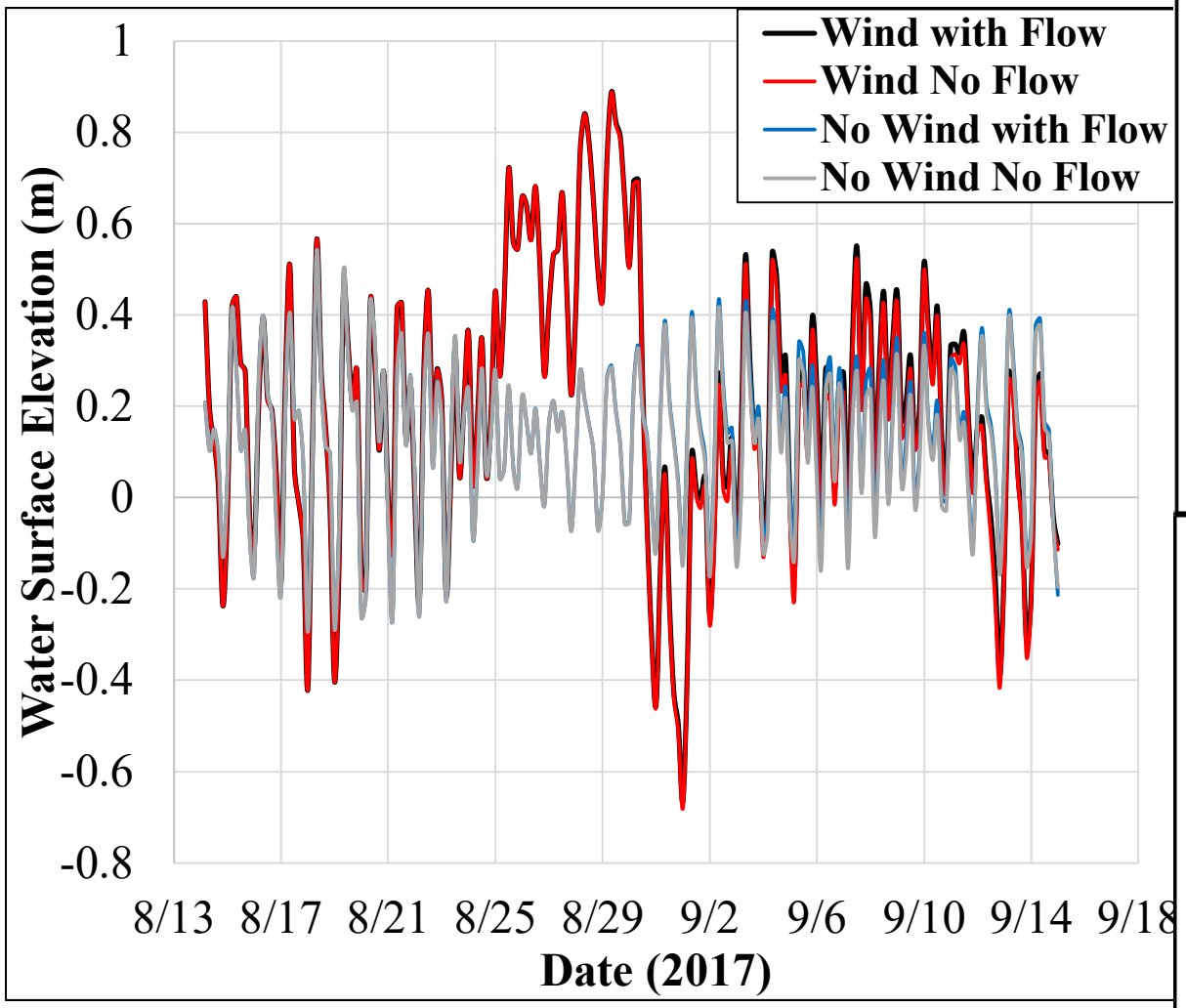
Flow vs. No Flow: Max elevations

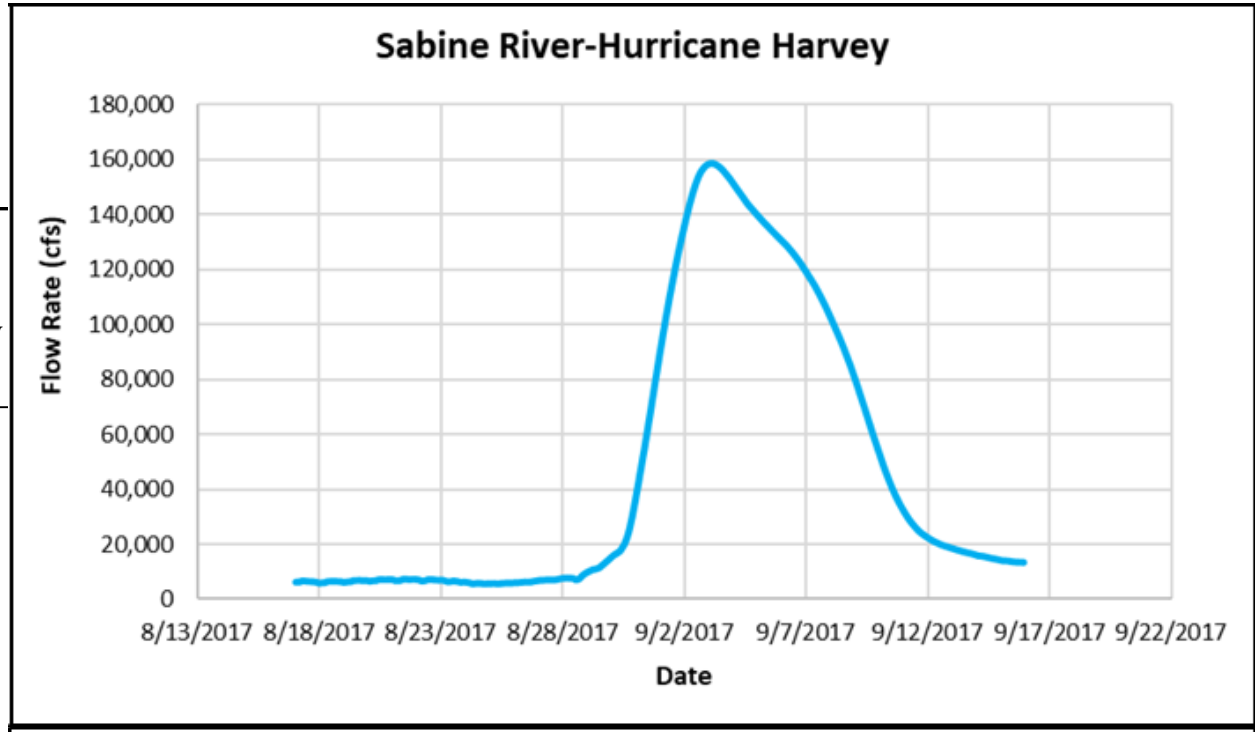


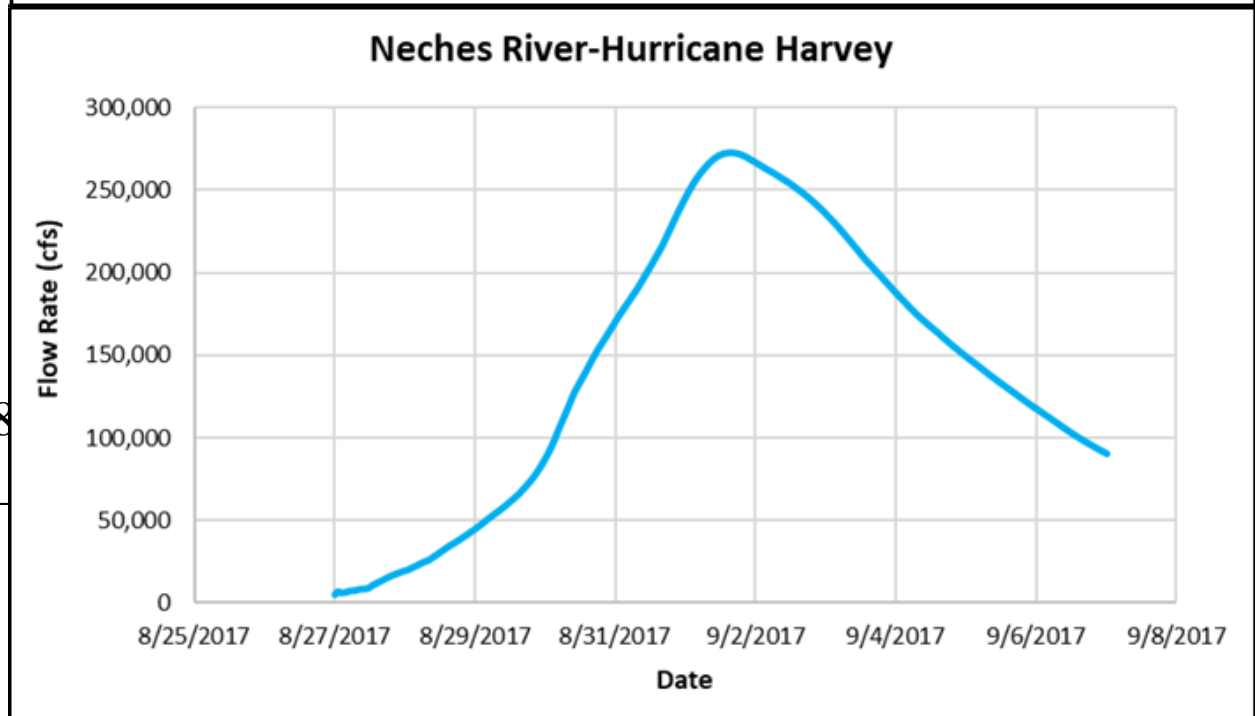
Question 3:

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

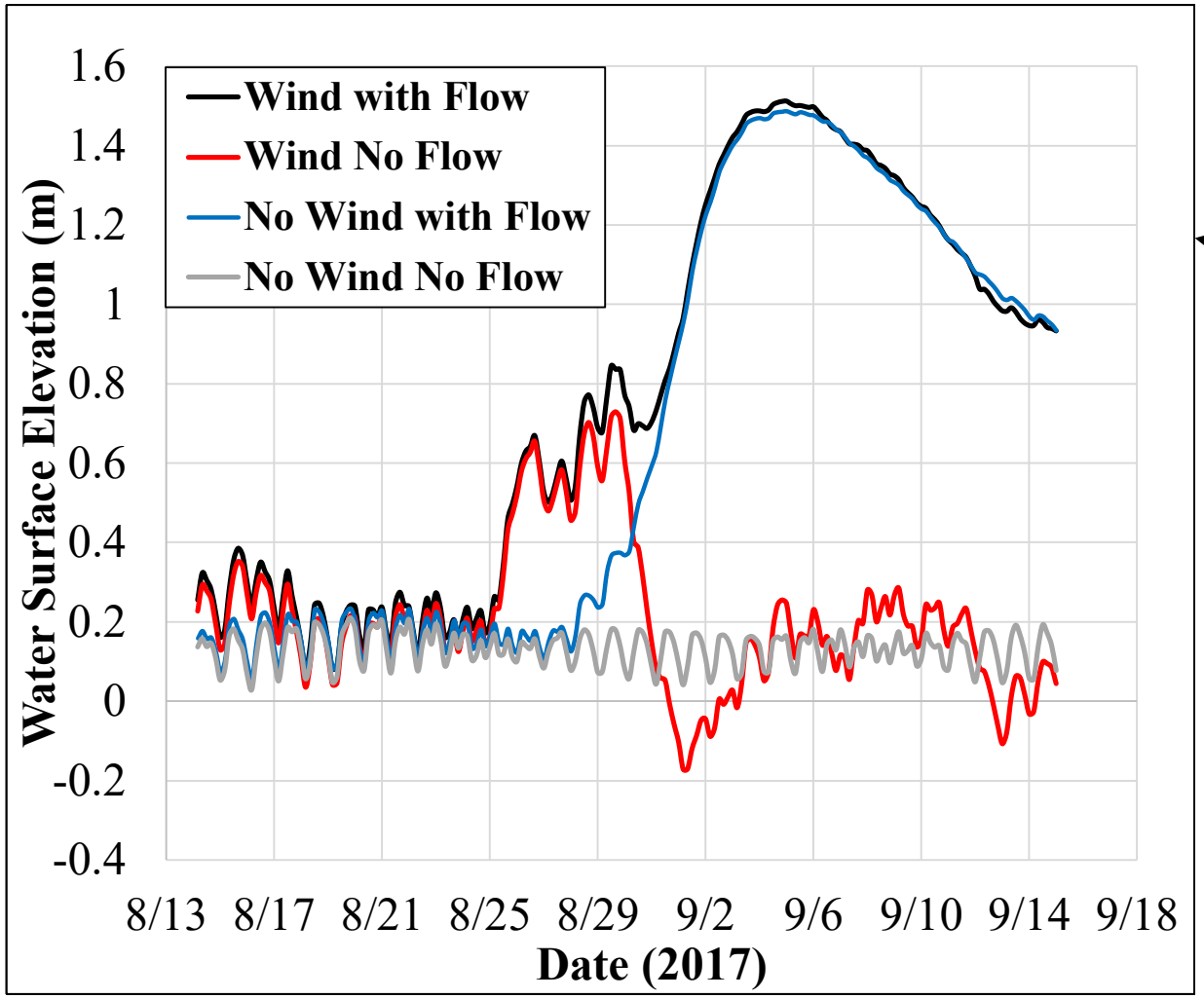
ADCIRC Large Mesh: Gulf Results

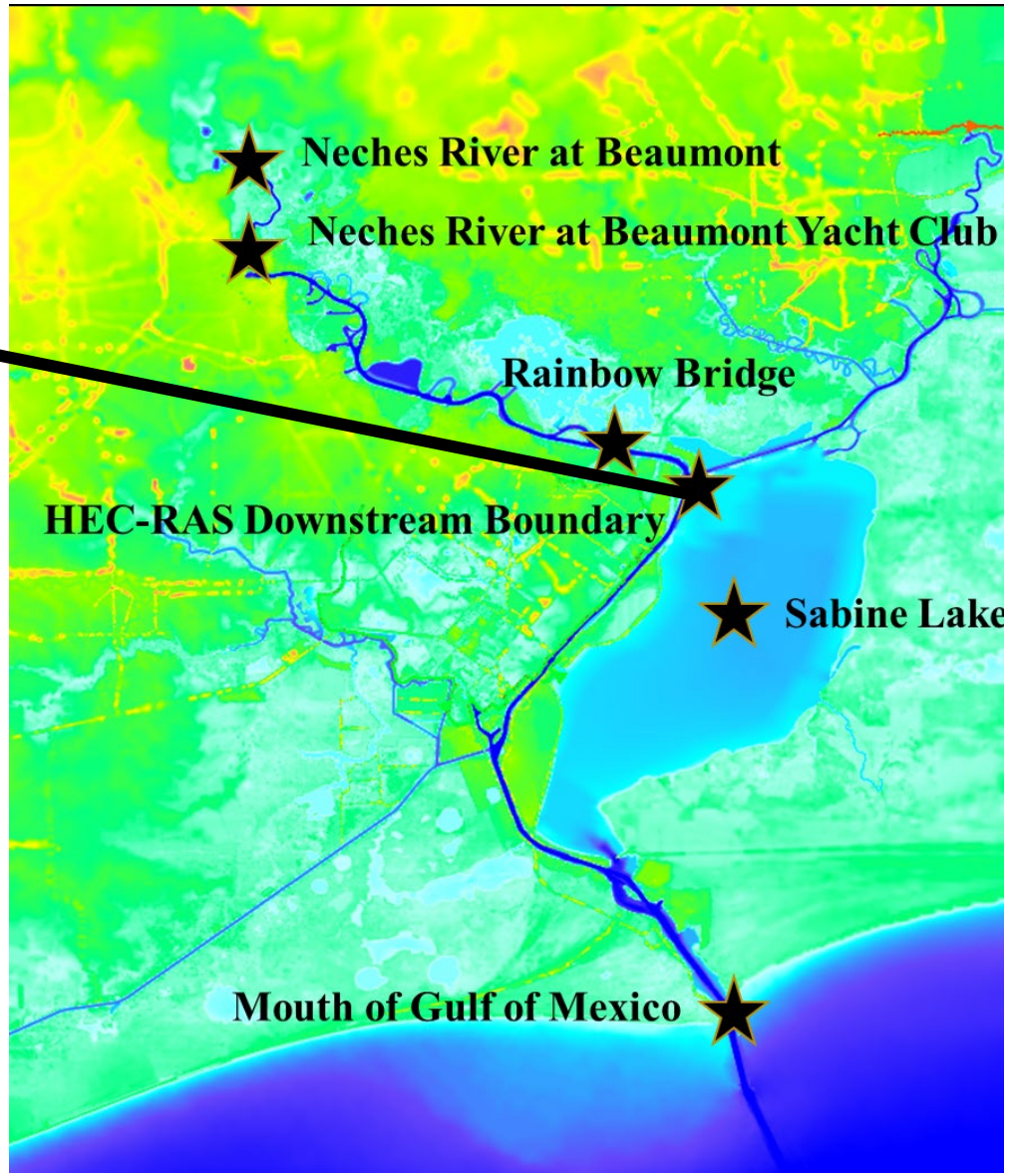






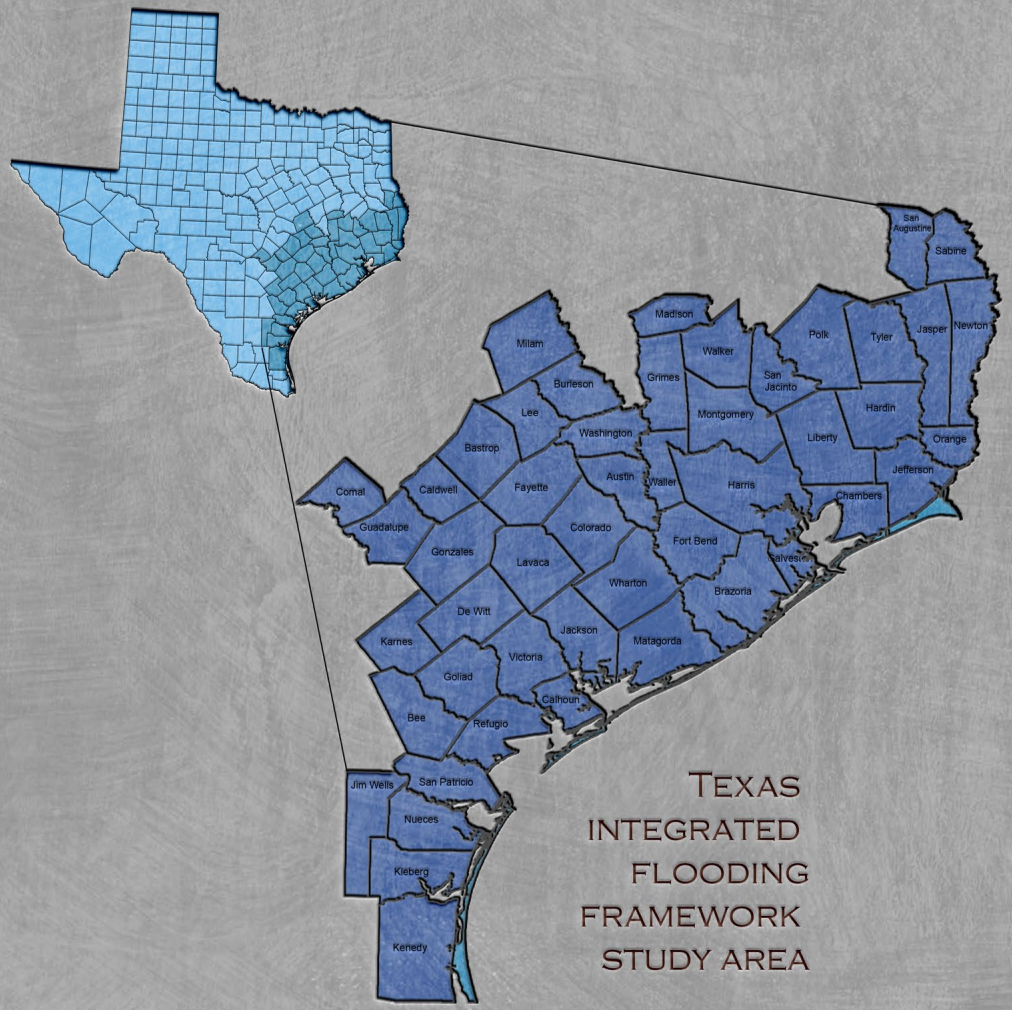
ADCIRC Large Mesh: Confluence of Neches River and Sabine Lake





USGS
science for a changing world

Texas Water Development Board



Texas Integrated Flooding Framework Study Area

TIFF

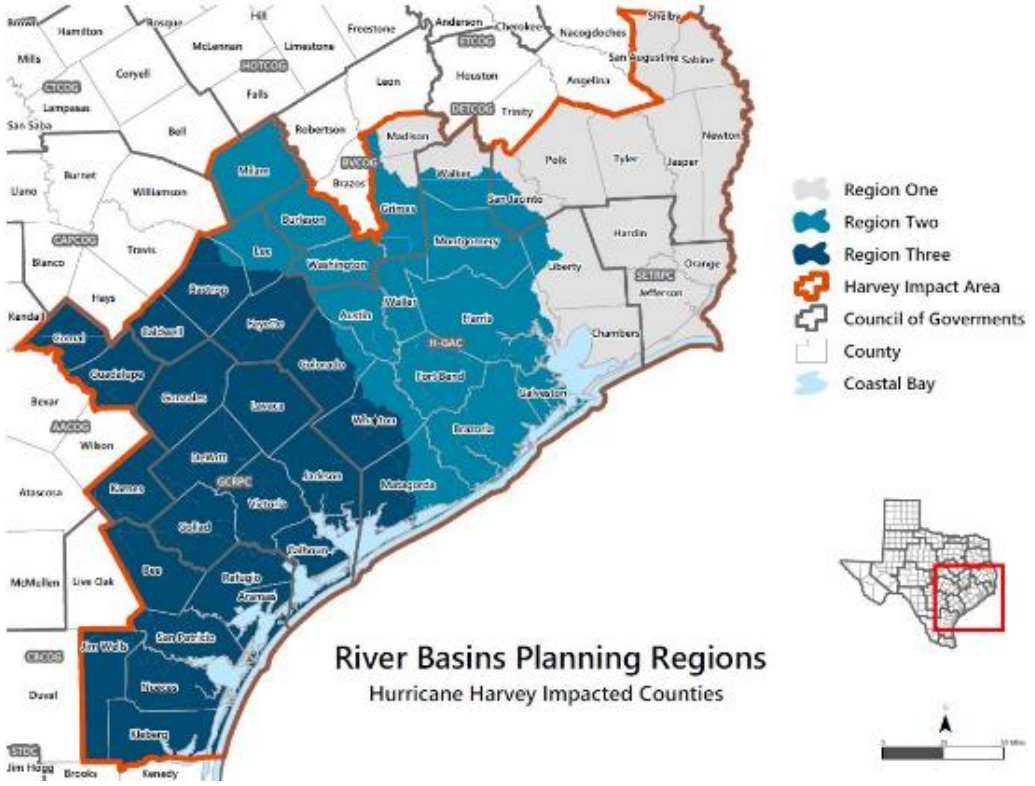
Texas Integrated Flooding Framework

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

TIFF

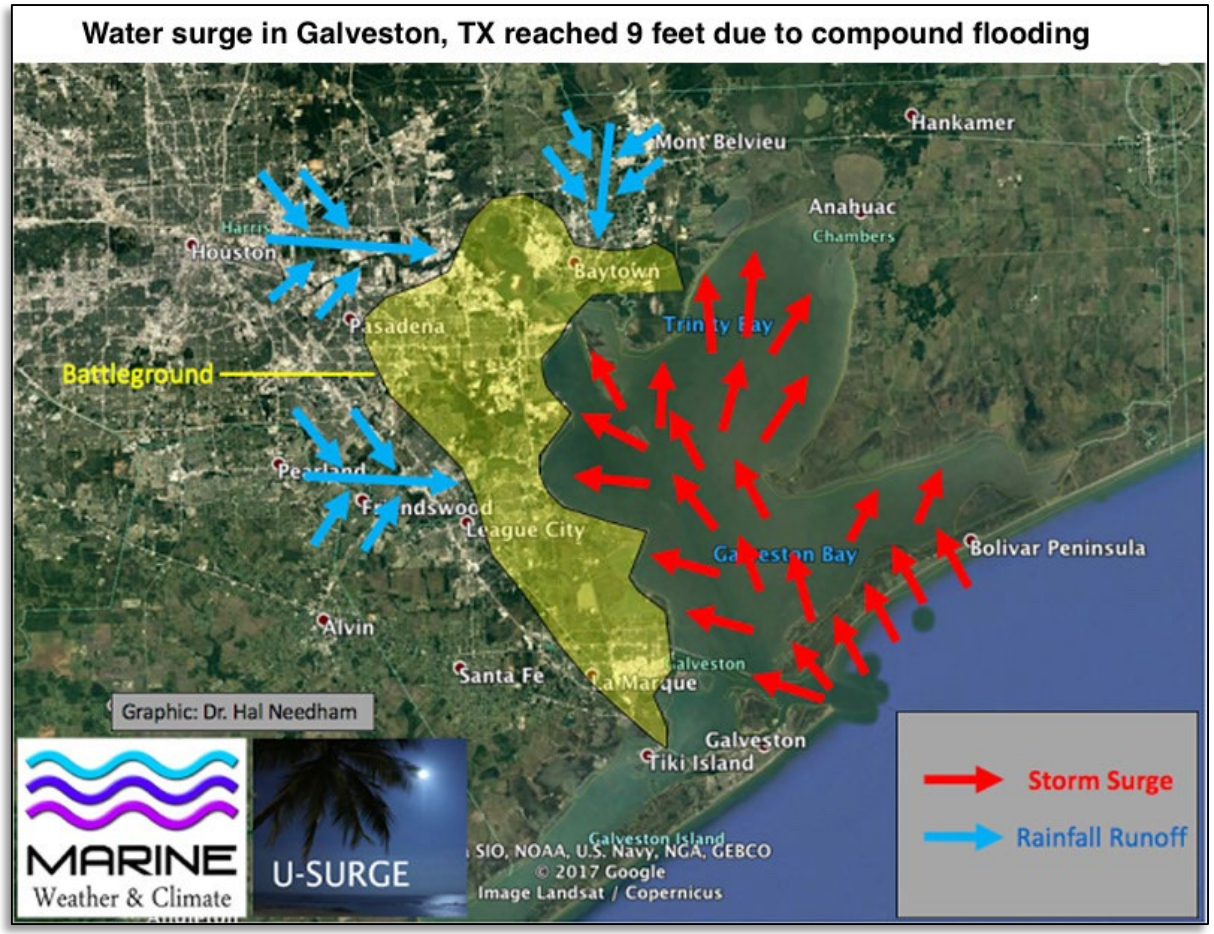
- Create an integrated framework for comprehensive flood planning and mitigation in Hurricane Harvey impacted areas.
- Led by the **TWDB**, **USGS**, and **USACE-Galveston District**
- $3M budget over **3 years**
- Timeframe: November 30, 2020 – **June 30, 2024**
- **Four-component** study
  - Data and Monitoring Gap Analysis
  - Data Management and Visualization
  - Integrated Flood Modeling Framework
  - Planning and Outreach



Each component designed in coordination with *Technical Advisory Teams*

TIFF 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



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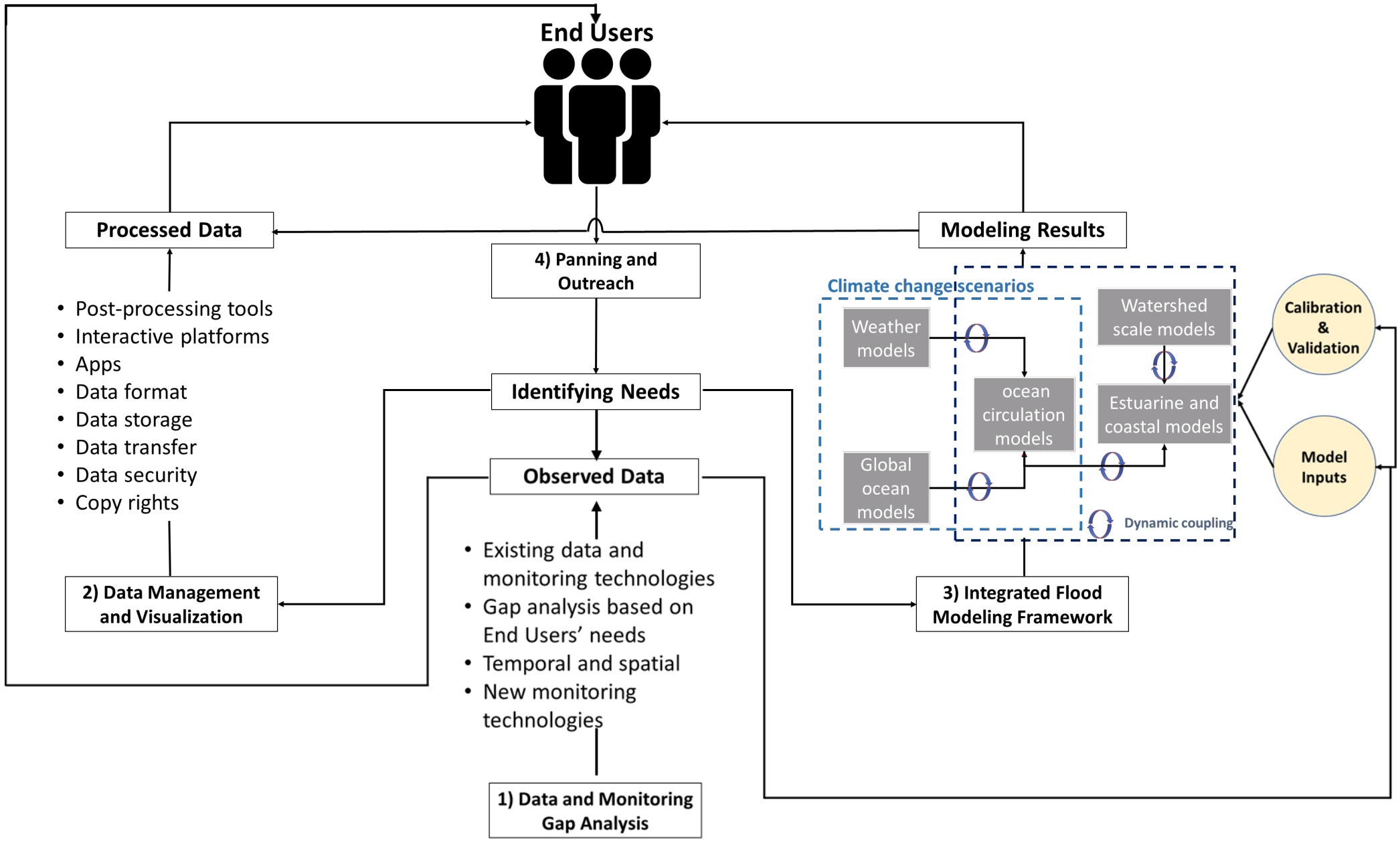
TIFF- How it all comes together



Integrated Flood Modeling Framework

Model coupling framework

- Complexity vs simplicity
- Grid resolutions
- Windows vs Linux

Statistical Methods

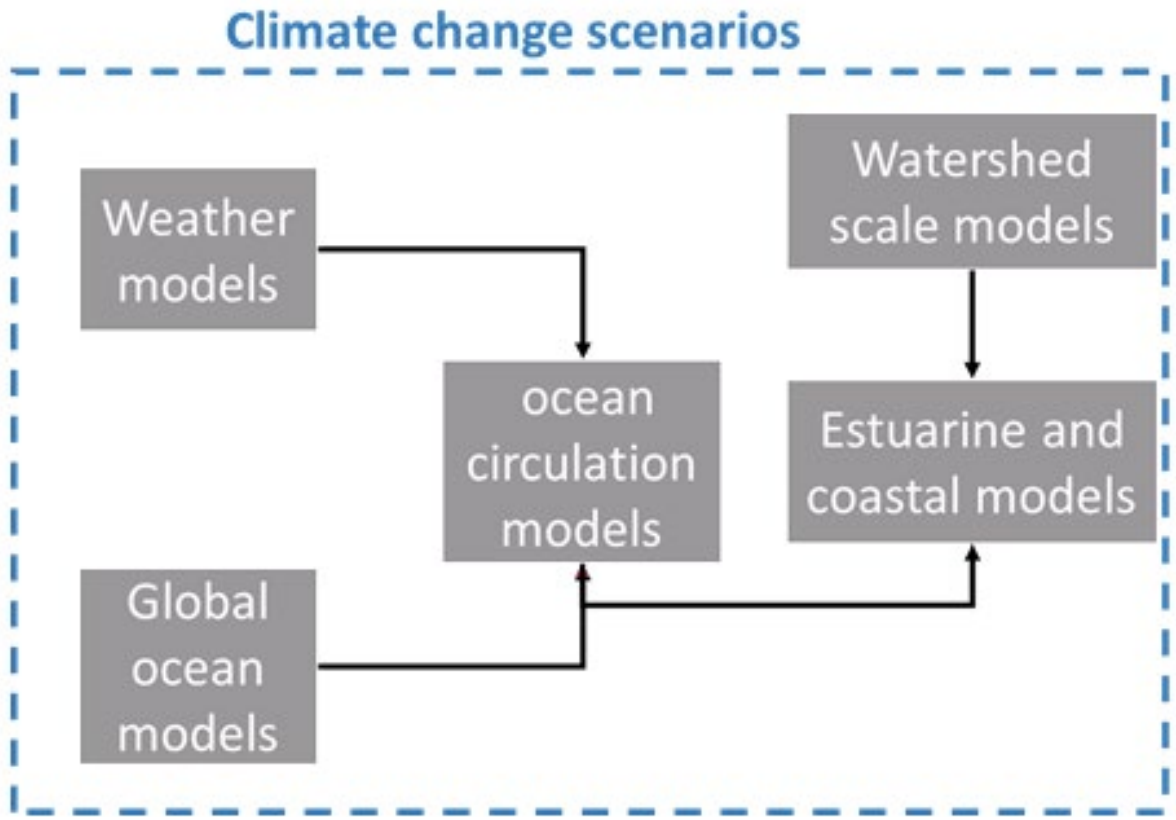
- Joint probability of pluvial, fluvial and surge flooding (e.g., multivariate statistical analysis)
- Improved synthetic precipitation products

Uncertainty quantifications

- Observation Uncertainty: Wind, rainfall, bathymetry, antecedent moisture conditions, land use
- Model uncertainty: Boundary conditions, assumptions

Real-time/ Operational Forecasting

- Time Constraint
- HPC, Cloud-computing, PC



Climate Change

- Sea level rise
- Increase tropical Cyclone intensity

TIFF Steering Committee

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Thank You!

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