

# SIMULATING COASTAL FLOODING DUE TO EXTREME STORMS: LESSONS LEARNED FROM HURRICANE IAN

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COASTAL  
PROTECTION  
ENGINEERING

# STORM SURGE & STORM FLOODING

- **Storm Induced flooding in Florida = storm surge + rainfall**
- **Storm surge:** Abnormal rise of water during a storm, mostly caused by onshore wind (~95%) and pressure

## Storm Surge Magnitude is Affected by:

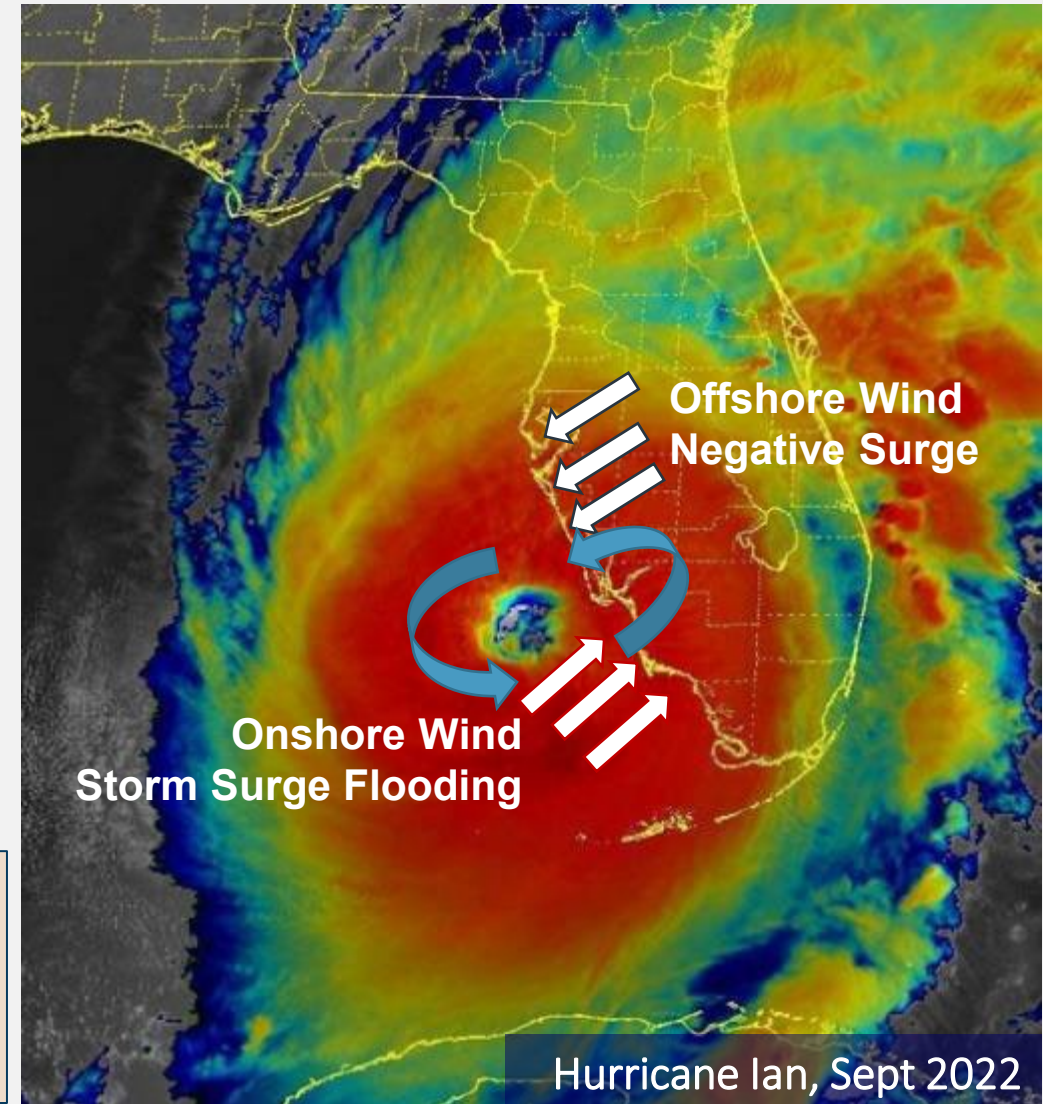
- Wind Speed
- Storm Forward Speed - duration and location
- Size of storm - larger wind fields widespread surge
- Angle of approach - think Irma vs Ian
- Width of continental shelf: - SE FL vs SW FL conditions.

Where is the Surge???

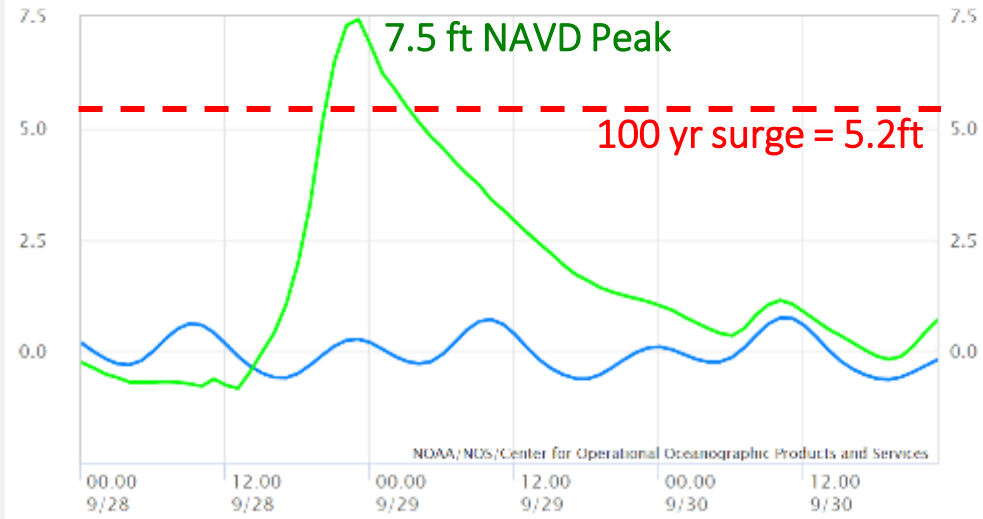
SW Coast of FL: South of eyewall

East Coast of FL: North of eyewall

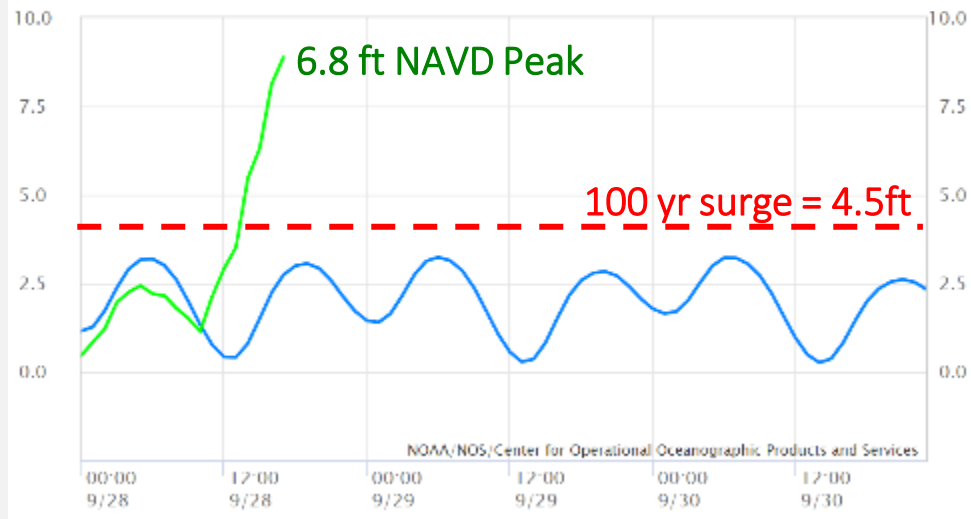
FL Panhandle: East of eyewall



NOAA Gauge - Fort Myers, Downtown



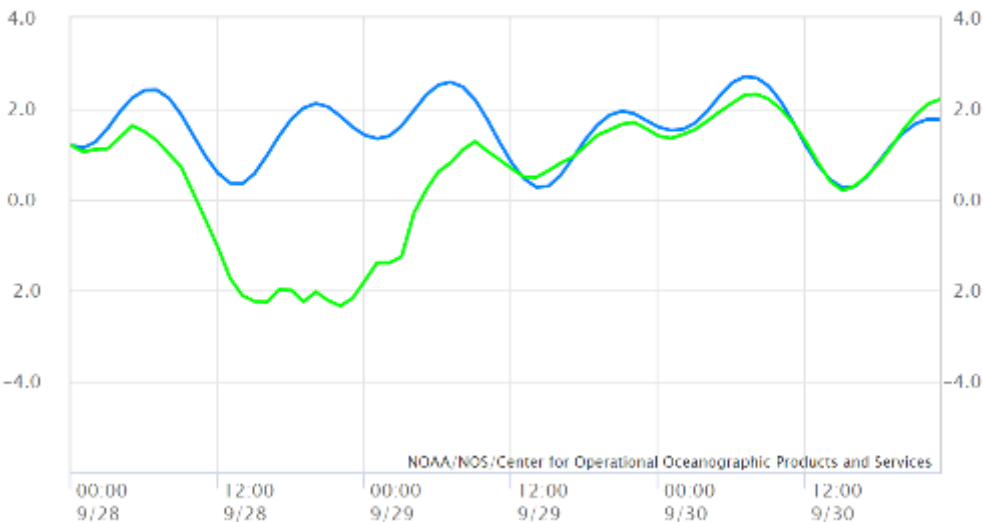
NOAA Gauge - Naples Pier



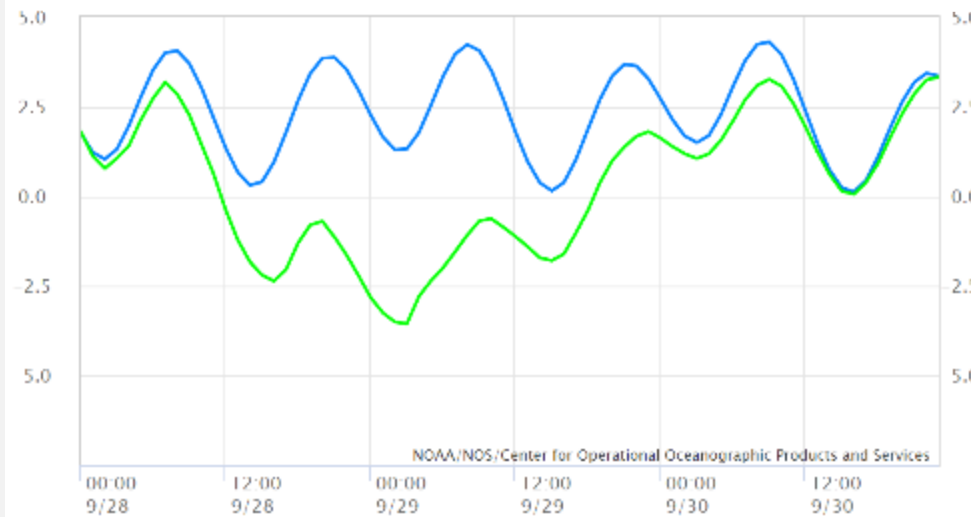
South of H. Ian  
Eyewall

Onshore Winds &  
Storm Surge

NOAA Gauge - Port Manatee



NOAA Gauge - Cedar Key

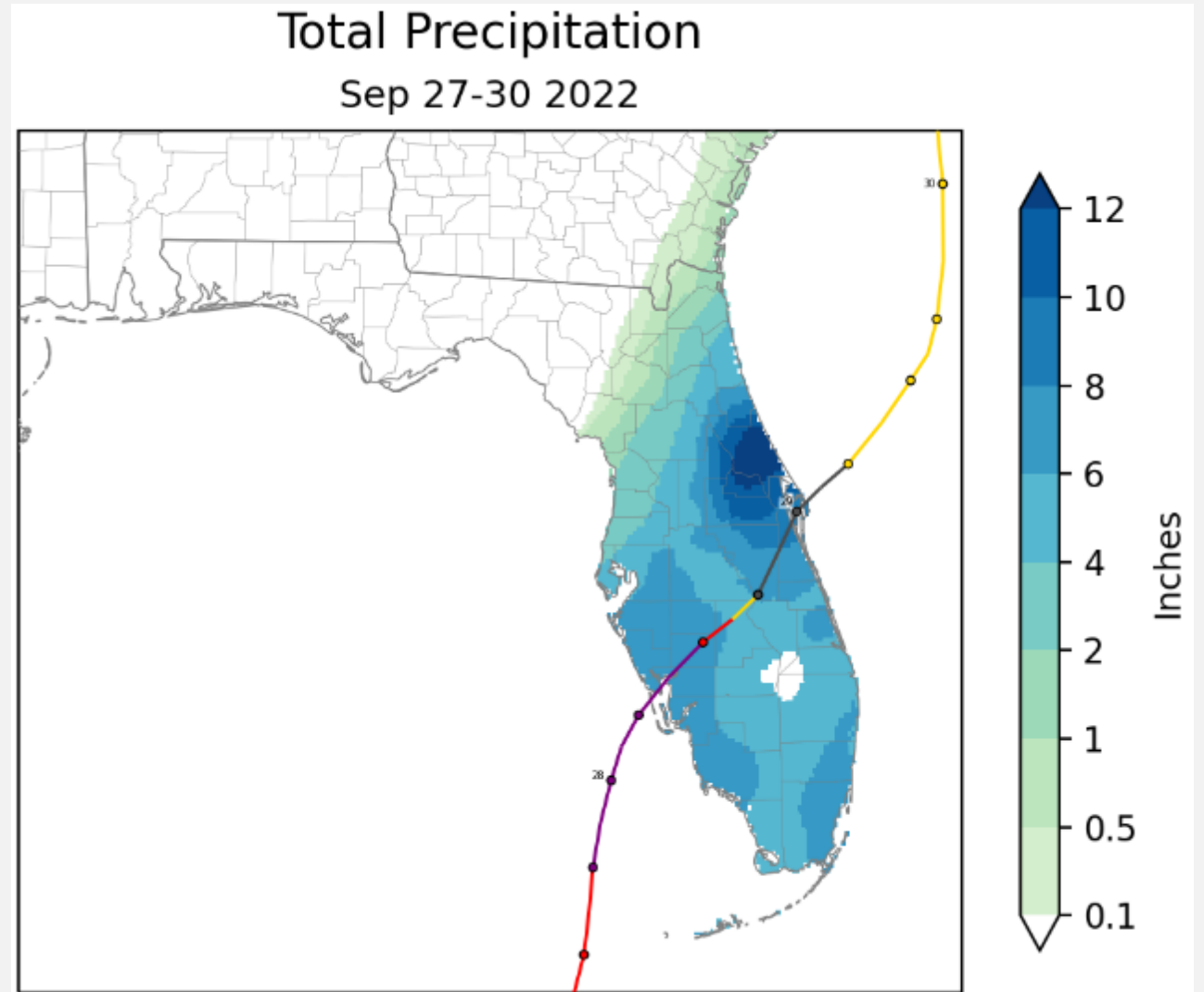


North of H. Ian  
Eyewall

Offshore Winds &  
Negative Storm Surge

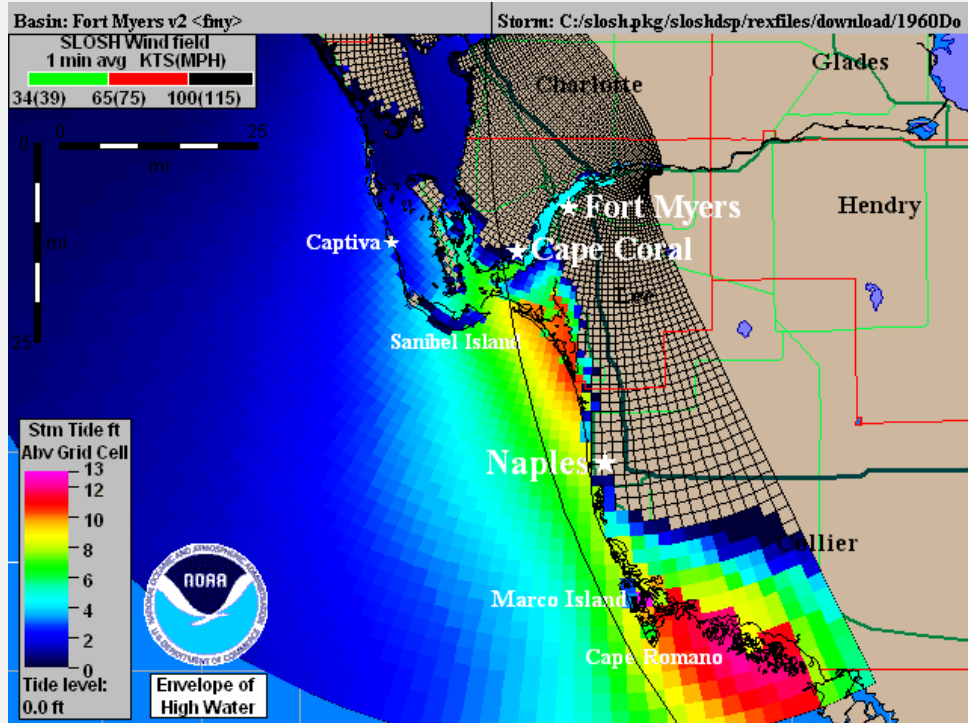
# STORM INDUCED FLOODING

- During Ian it rained more than an average month of Sept. in 3 days.
- Rainfall waters cannot drain when there is a surge, especially with passive gravity systems.
- The SFWMD struggled for a long time after the storm passed to drain inland waters.

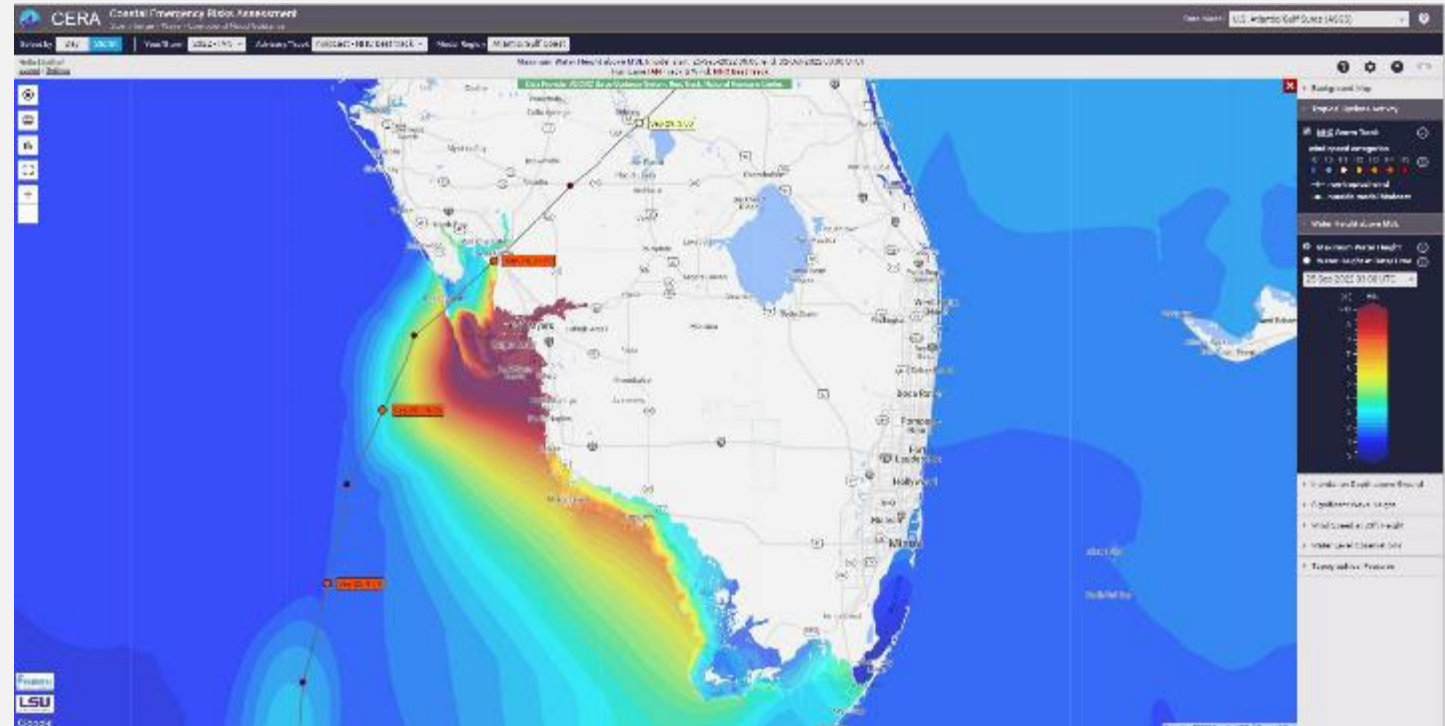




# MODELING STORM INDUCED FLOODING

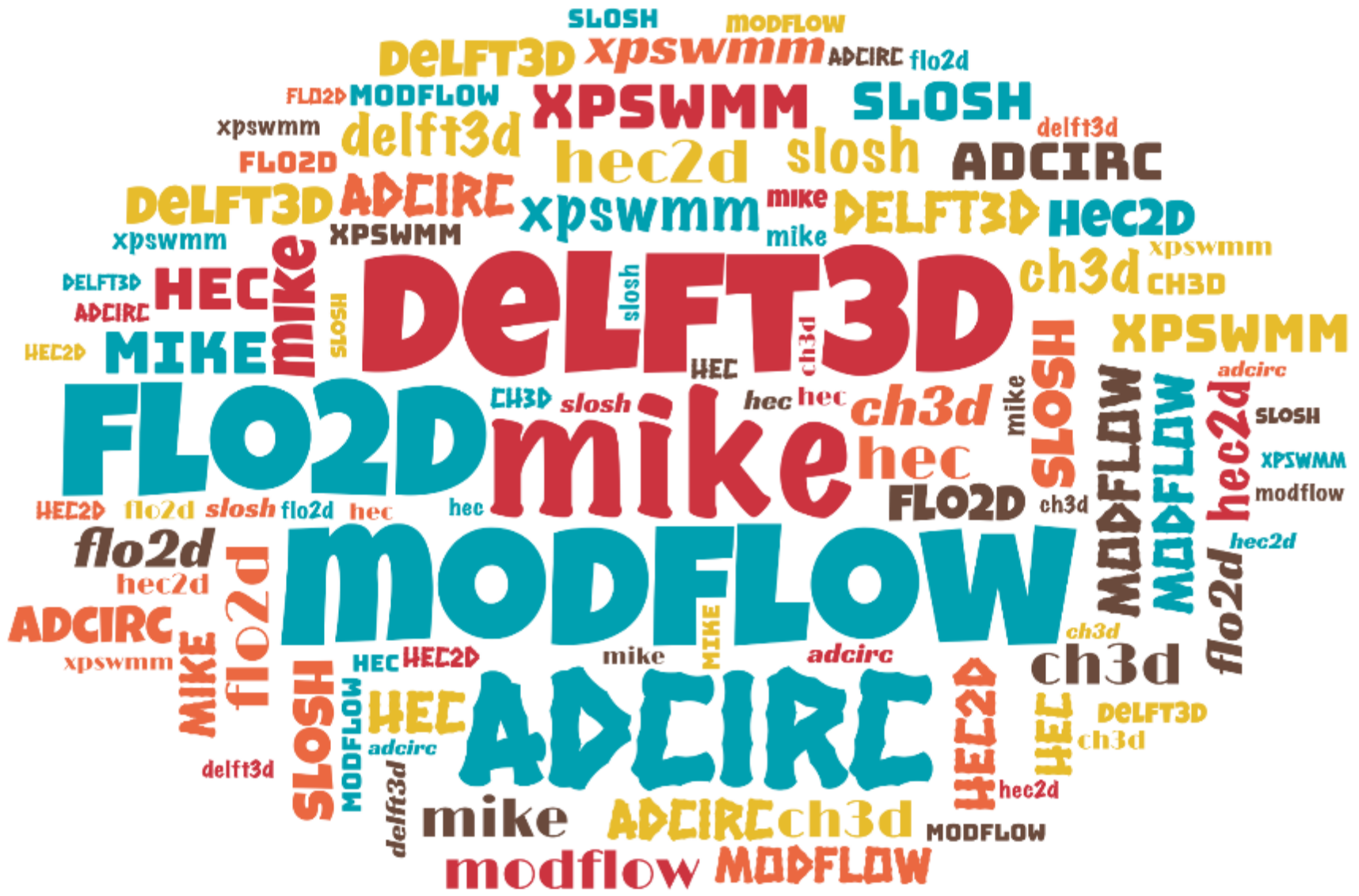


NOAA SLOSH



CERA – ADCIRC <https://cera.coastalrisk.live>

- Storm Surge Operational forecasts are available (NOAA SLOSH, CERA-ADCIRC).
- **These are NOT flooding models. There are no operational forecast of storm induced flooding with high resolution grids over land and a combination of surge, hydrological processes and hydraulic structures in Florida.**



Different numerical models and modeling approaches are used to simulate coastal flooding

**BUT WHICH MODEL SHOULD I USE?**

# MODEL SELECTION

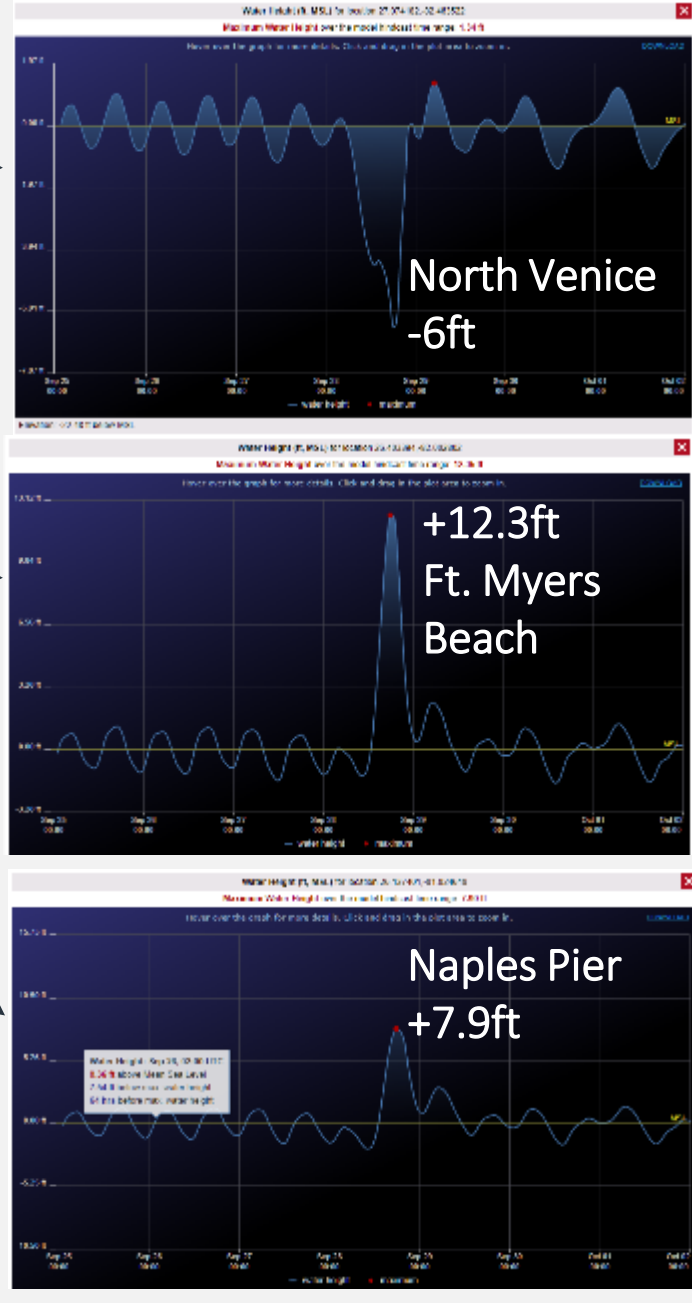
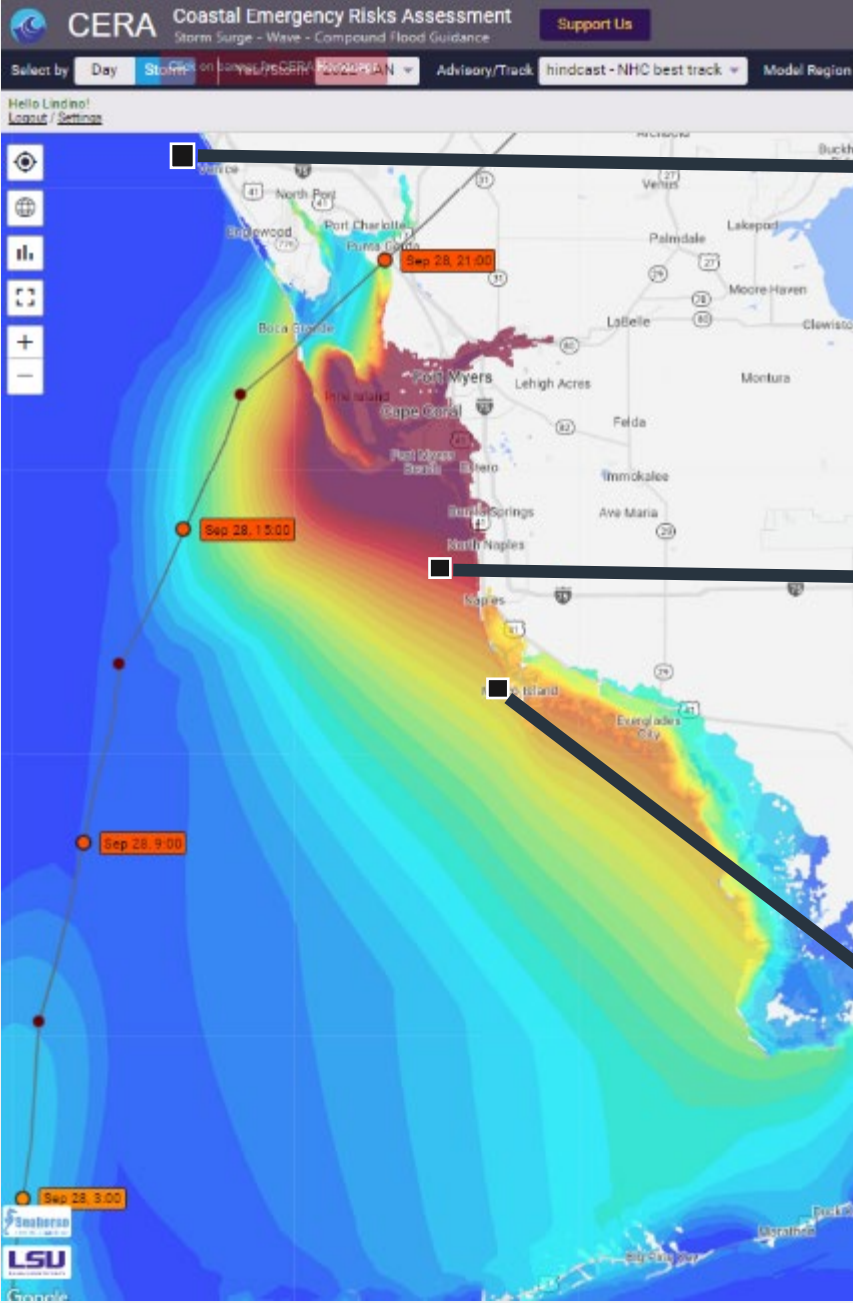
- What questions do we want to answer?
- Which physical processes are important?
- Hydrology-Hydraulic (H&H) modeler vs Hydrodynamic modeler perspective



# MODEL SELECTION – COASTAL STORM FLOODING

- Including hydrological processes and hydraulic structures in large scale coastal hydrodynamic models is difficult, but essential for coastal flood modeling in Florida.
- Operational forecasts of storm surge do exist, better models are now readily available, these can help improve forecast guidance from agencies.
- Different coastal flooding modeling approaches will be presented here.



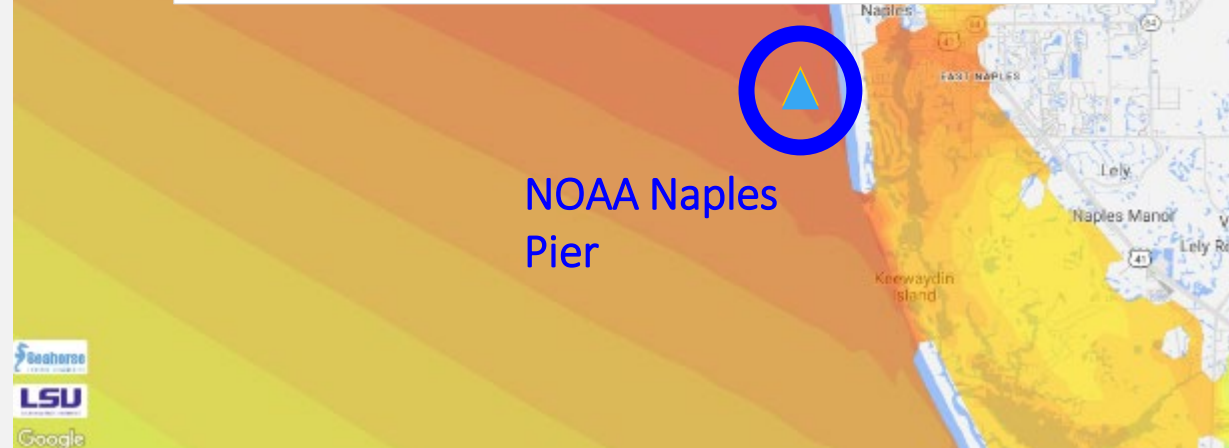
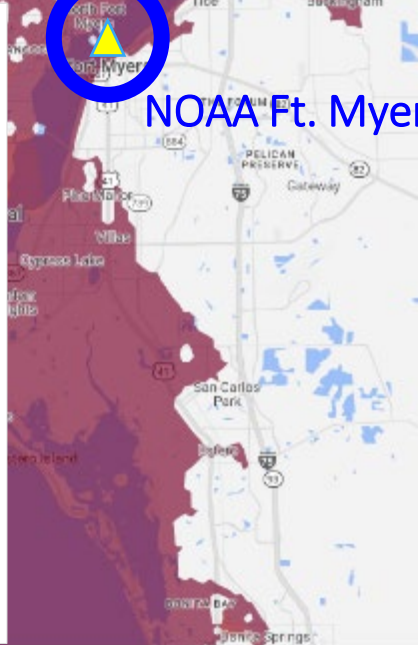
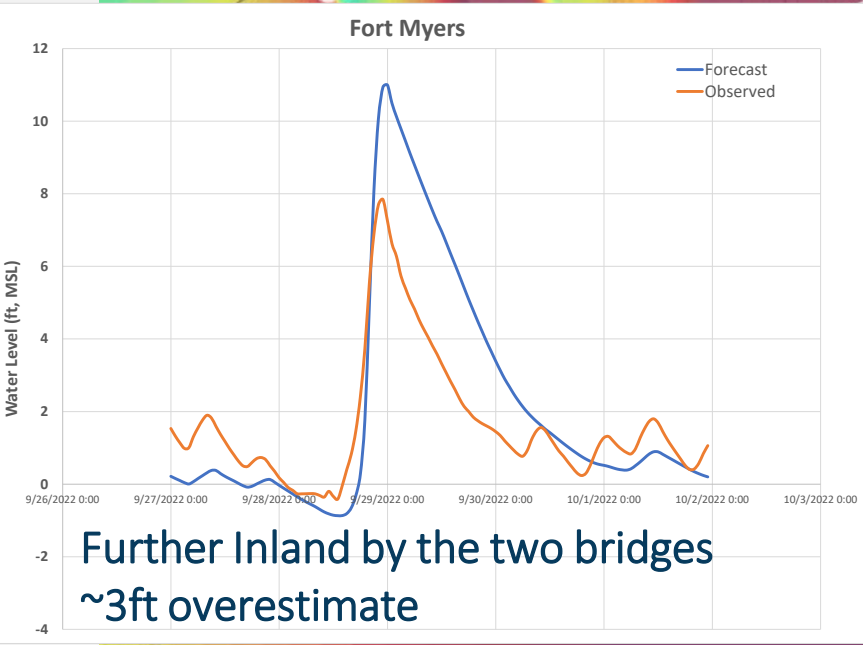
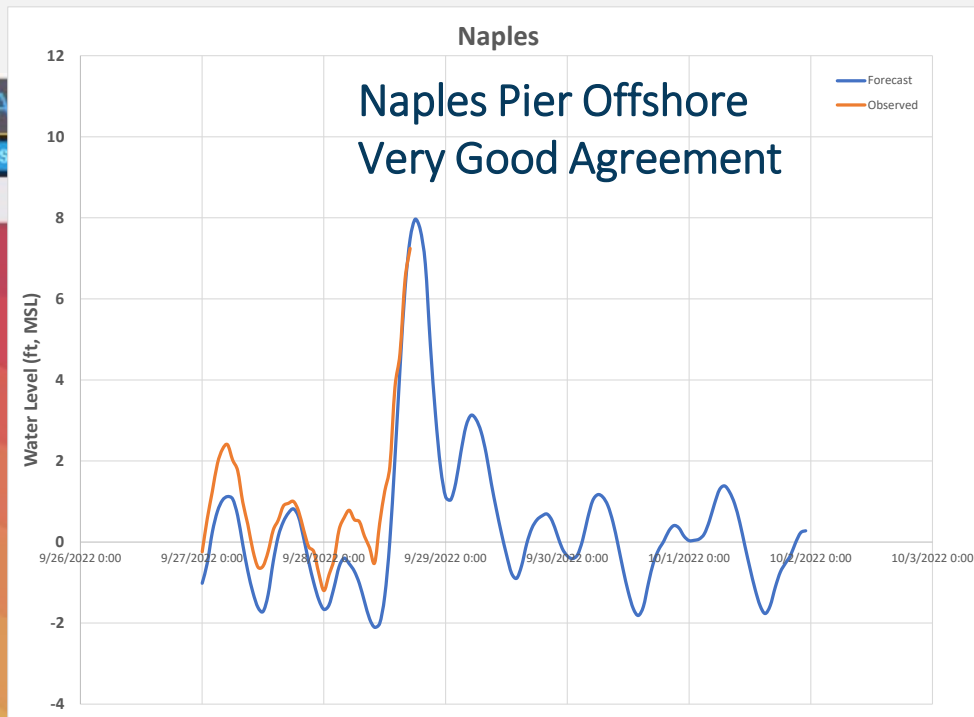
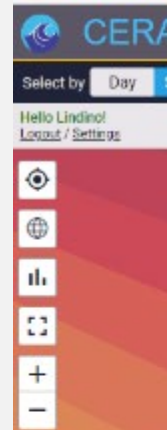
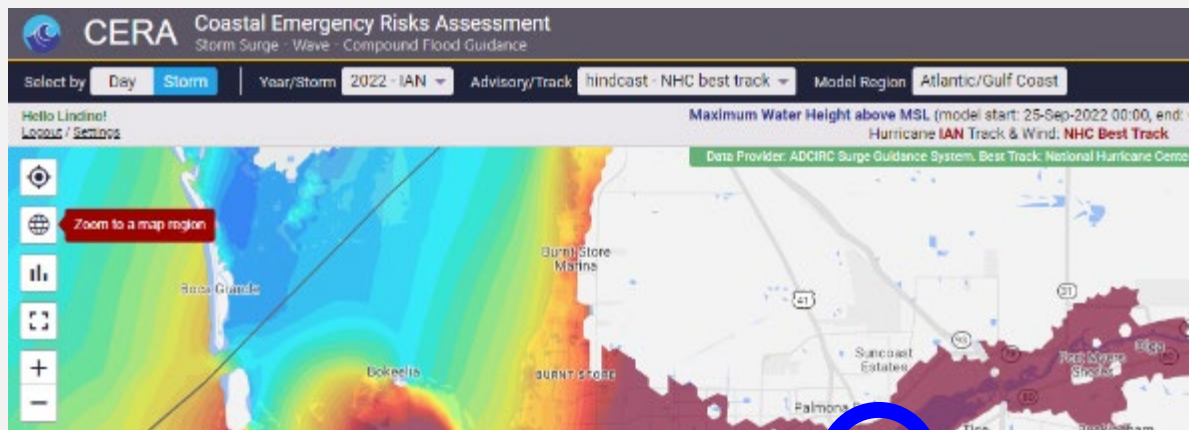


# CERA – ADCIRC

- High resolution ADCIRC + Interactive Web map interface
- One new model run at every NHC new track forecasts
- Database of past storms, possible to extract time series at selected locations
- Free for authorized users
- <https://coastalrisk.live/>

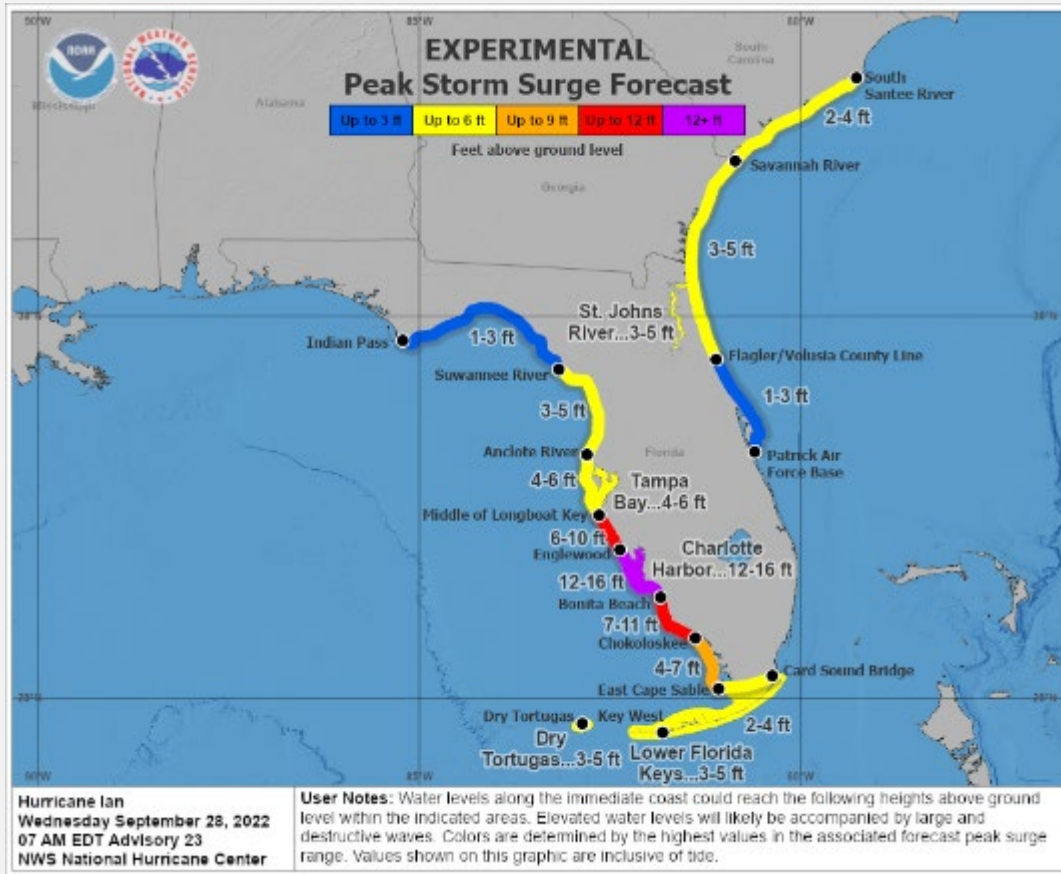


# CERA – ADCIRC

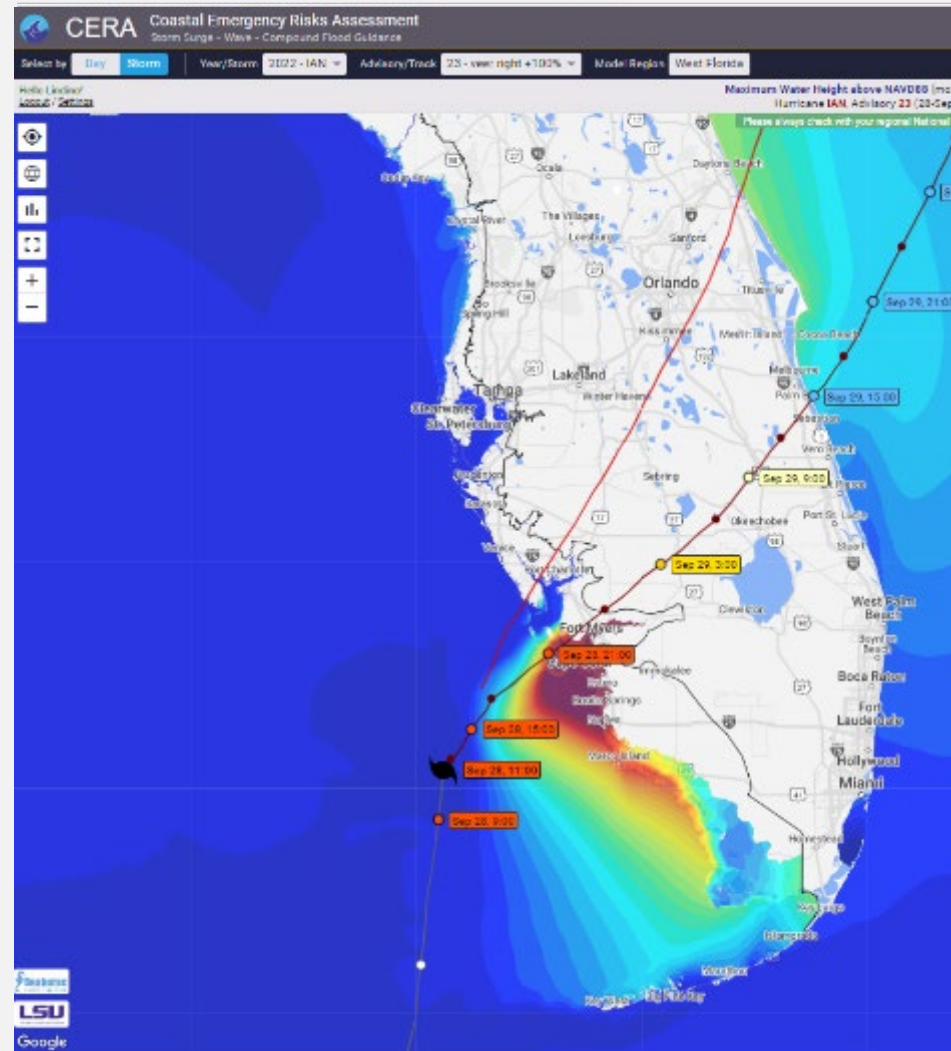




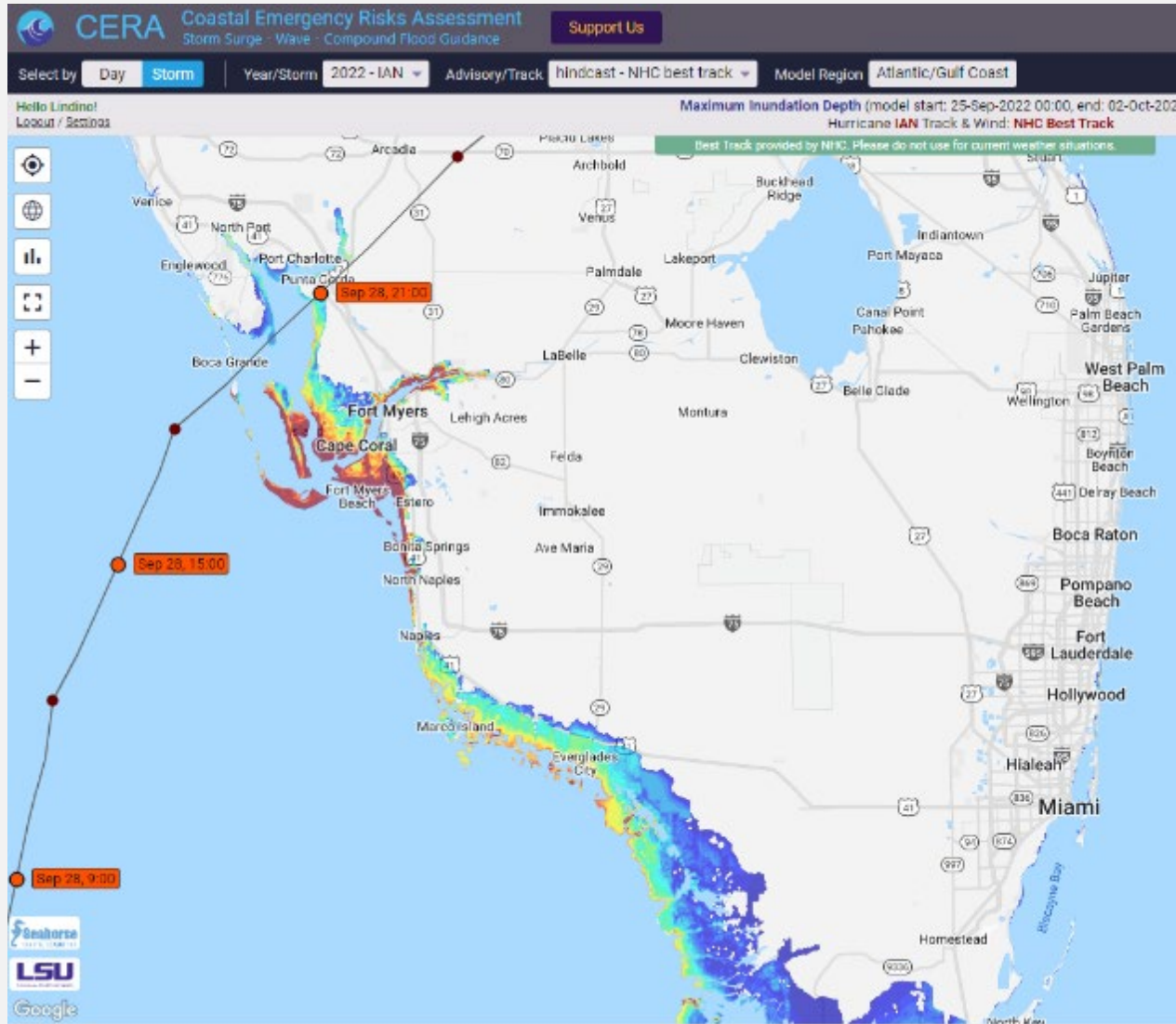
# HURRICANE IAN SURGE FORECASTS AND NHC GUIDANCE



Wednesday 7am, 8 hours before landfall



# HURRICANE IAN – MAXIMUM INUNDATION



## ▼ Inundation Depth above Ground

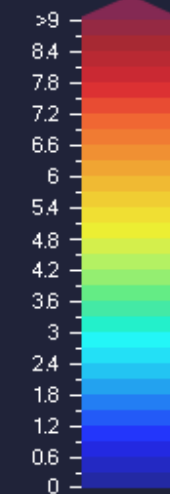
Colors over land mean water height above ground. Colors over water mean water height above Mean Sea Level.

- Maximum Inundation i
- Inundation at Date/Time i

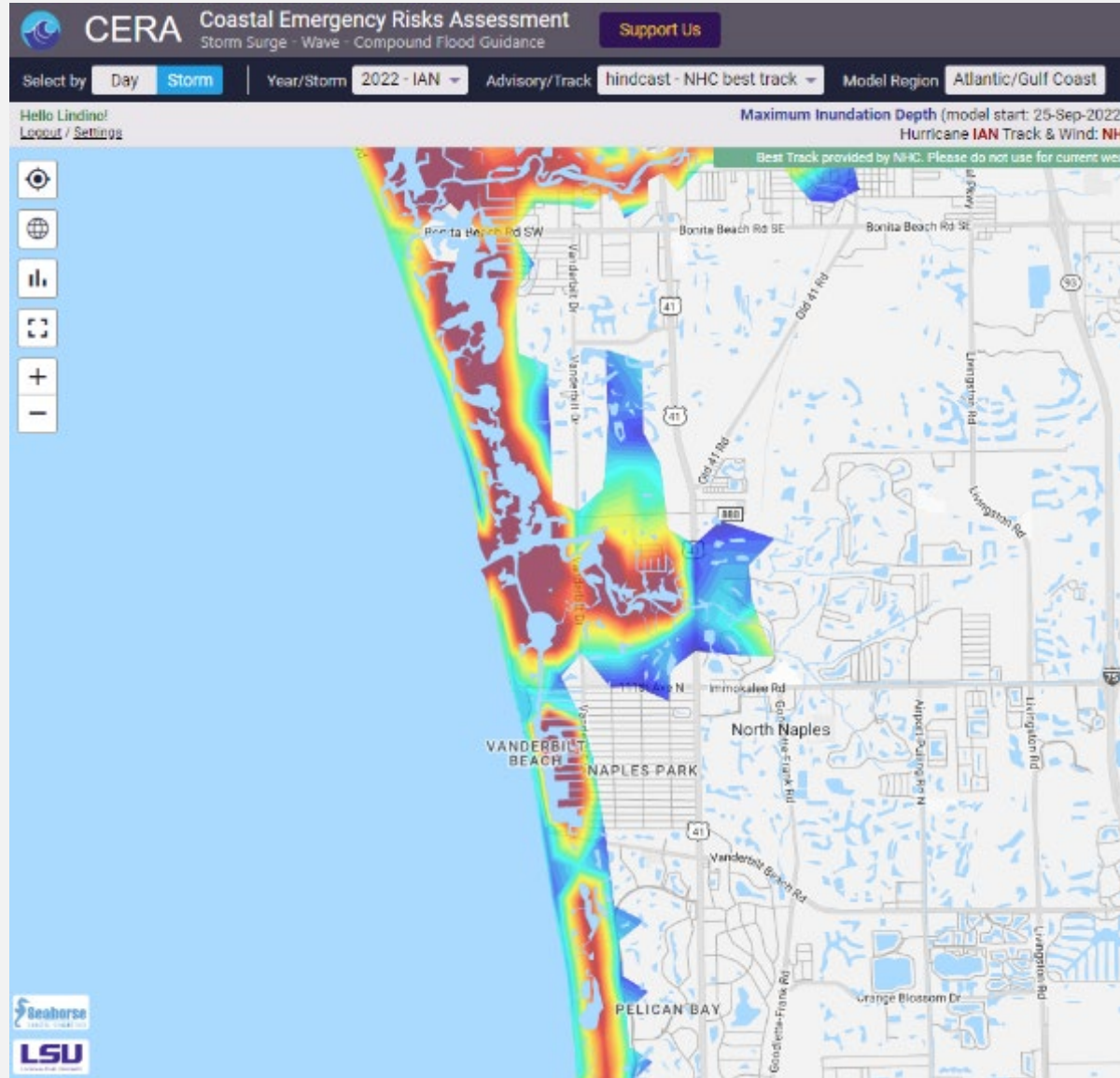
25-Sep-2022 03:00 UTC ▼

▶ Start Animation

[ ft ]



# HURRICANE IAN SURGE FORECASTS



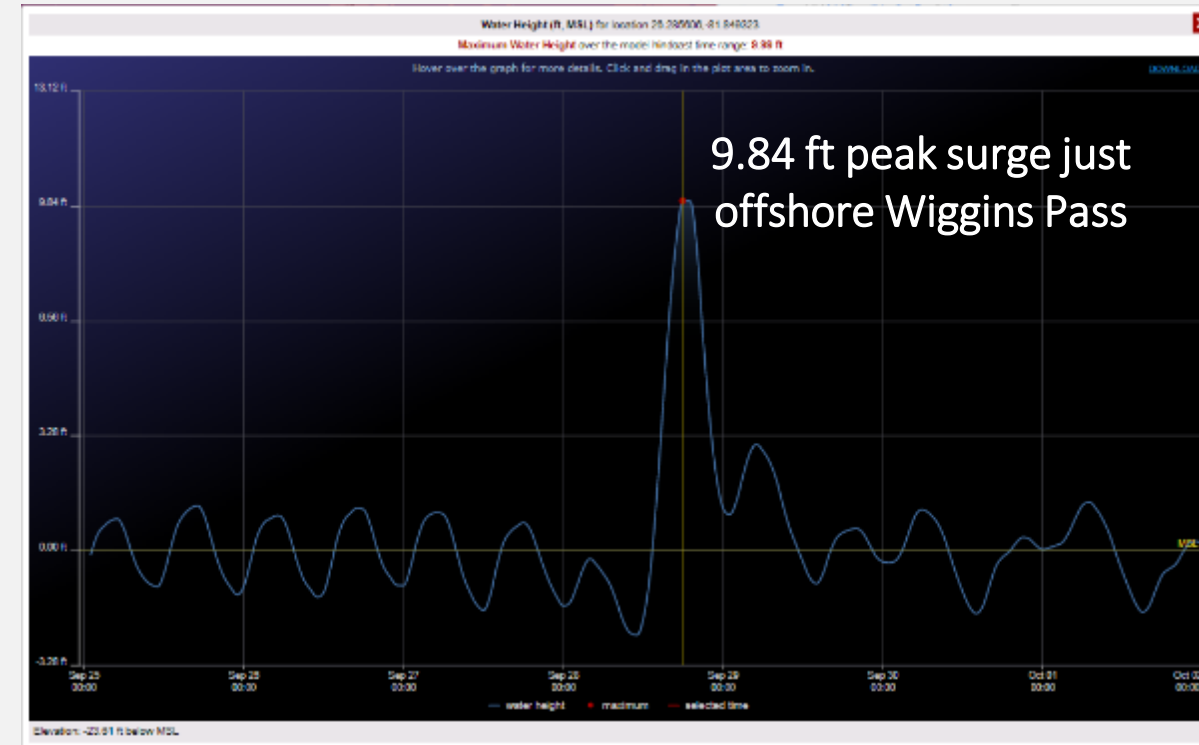
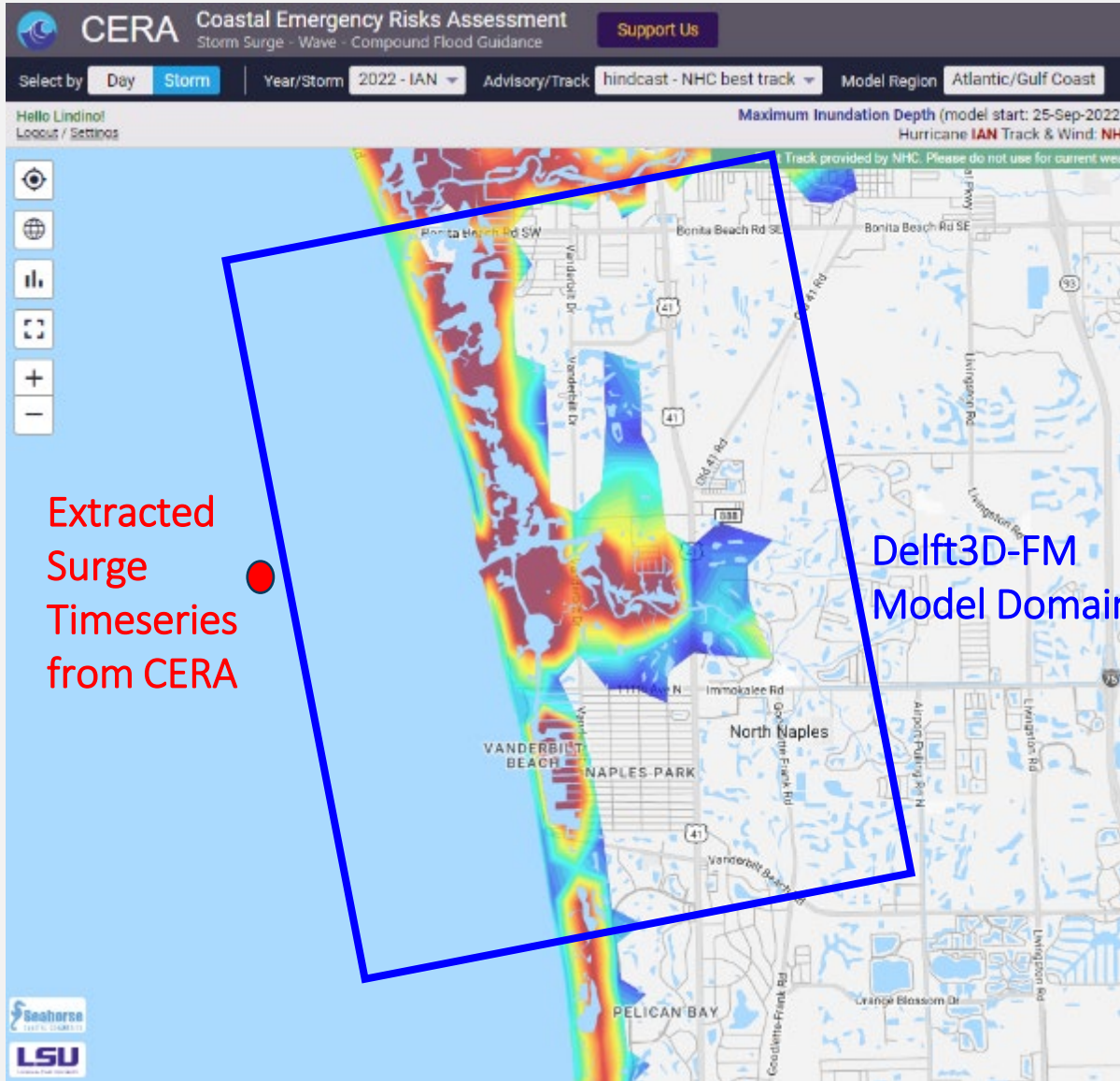
“Great let me see how it did in North Collier County around Wiggins to compare with Tom’s site visit Pictures!”



Although the modelling system is great for open water surge forecast, it was not designed to simulate overland flooding. Not enough grid resolution and ADCIRC does not have hydrological processes.

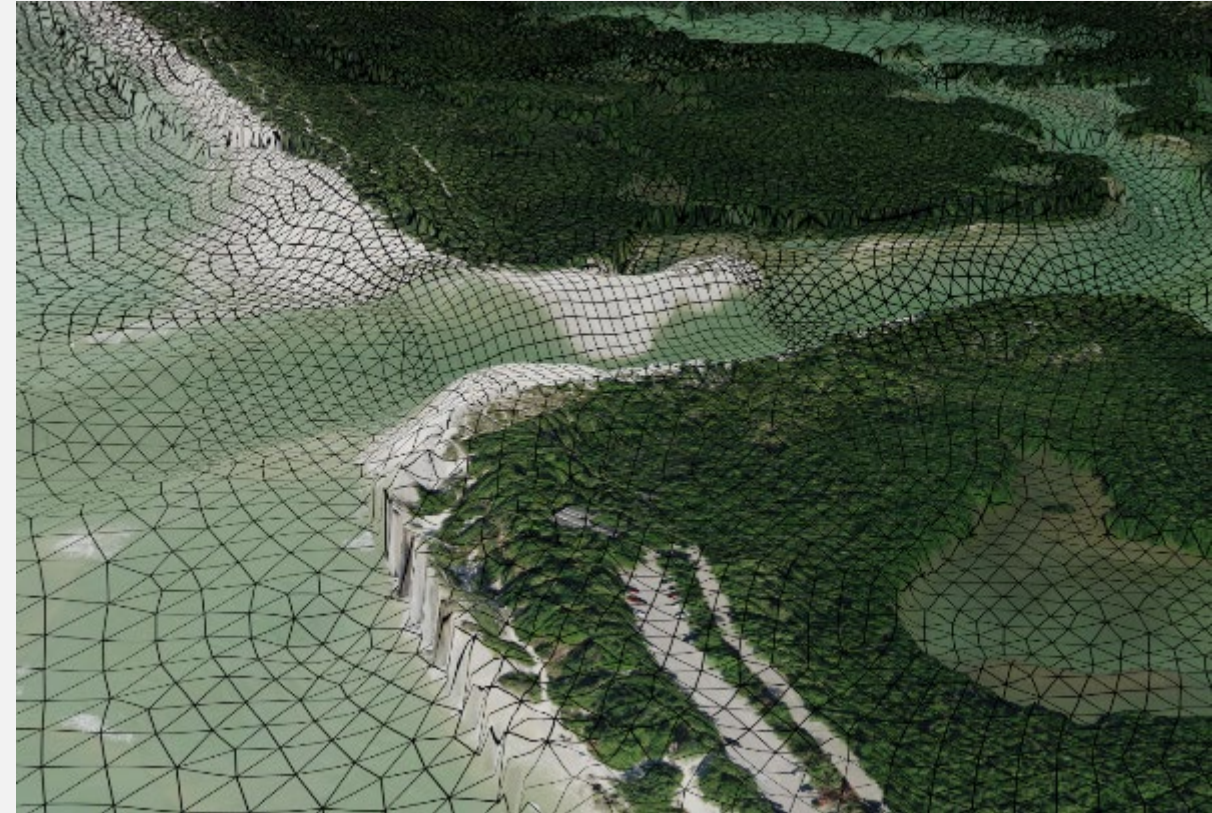


# HURRICANE IAN SURGE – CPE DELFT3D FM



# DELFT 3D FLEXIBLE MESH

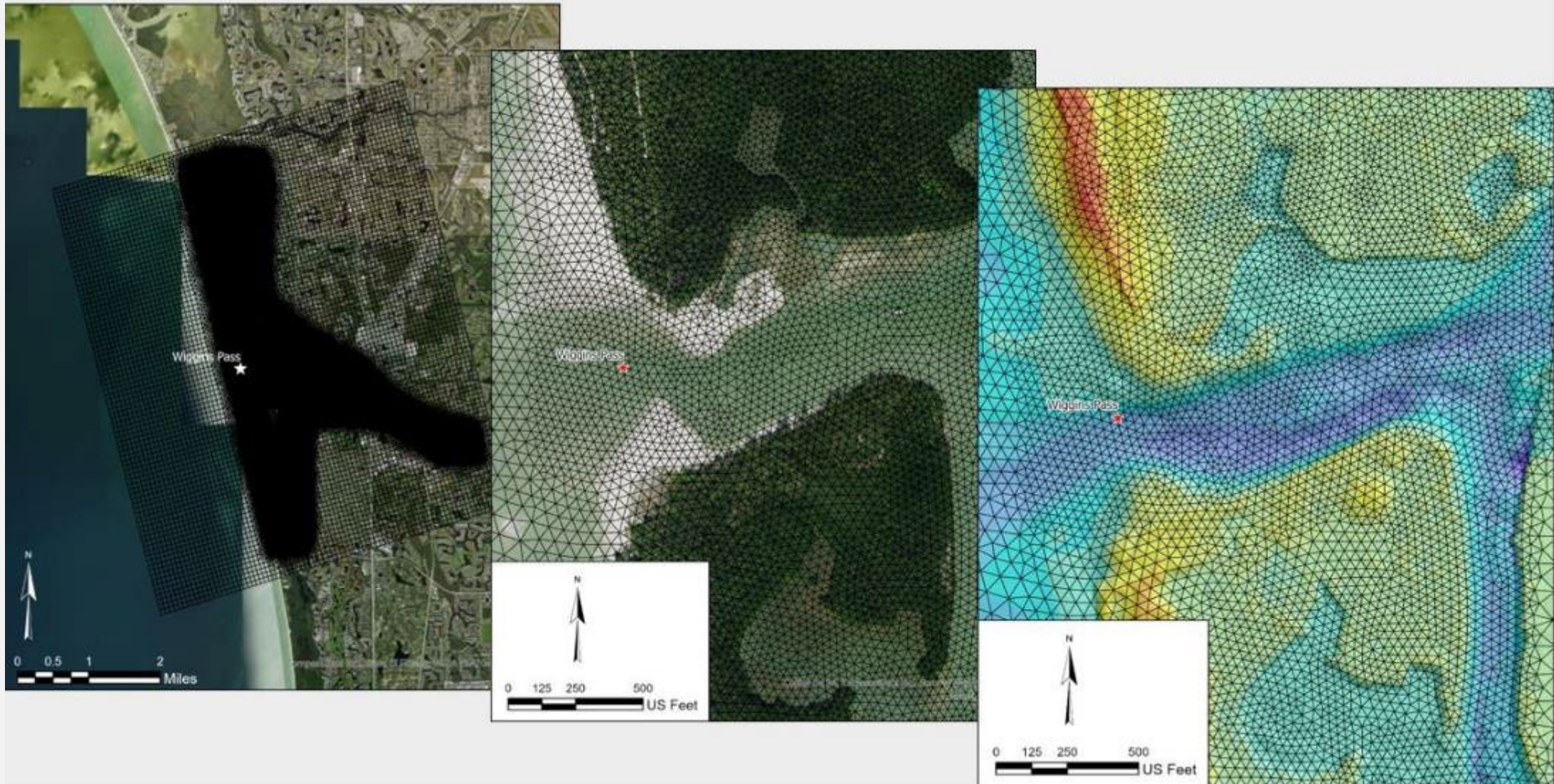
- Successor of Delft3D structured and SOBEK from TU Delft/Deltares.
- Unstructured 2D-3D grids, widely used on the coast, lakes and rivers.
- Coastal hydrodynamics plus hydrological processes and a few hydraulic structures.
- Allows for implementation of hydrological structures such as weirs, gates, pumps and flow obstacles such as dams.
- Improvement compared to other coastal hydrodynamic models used for flooding simulations, but still not an urban flood routing model - lack of stormwater infrastructure, small scale structures hard to model.



Wiggins Pass Grid, Collier County, FL



# NORTH COLLIER DELFT3D FLEXIBLE MESH

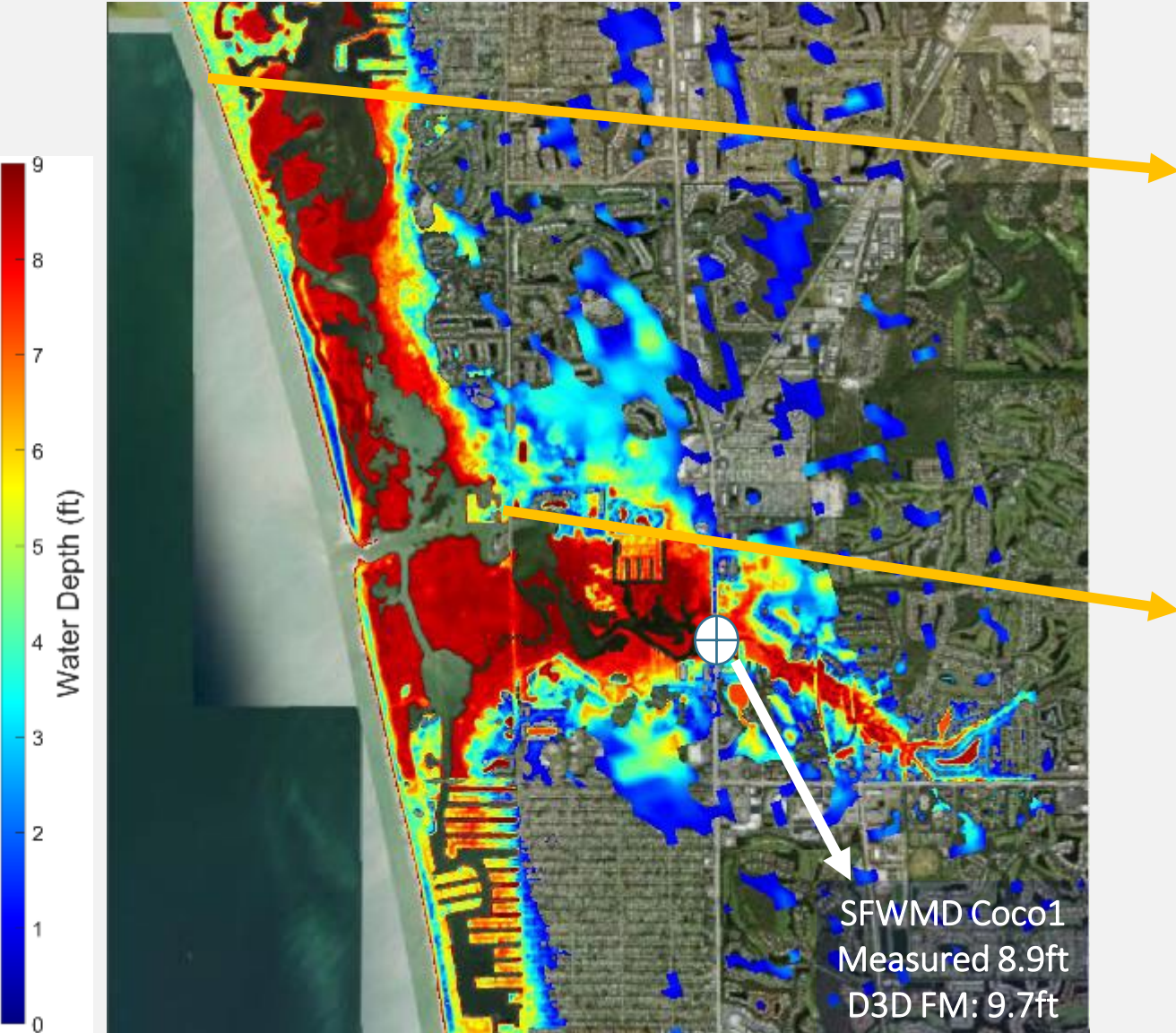








# DELFT 3D FLEXIBLE MESH PEAK WATER DEPTH



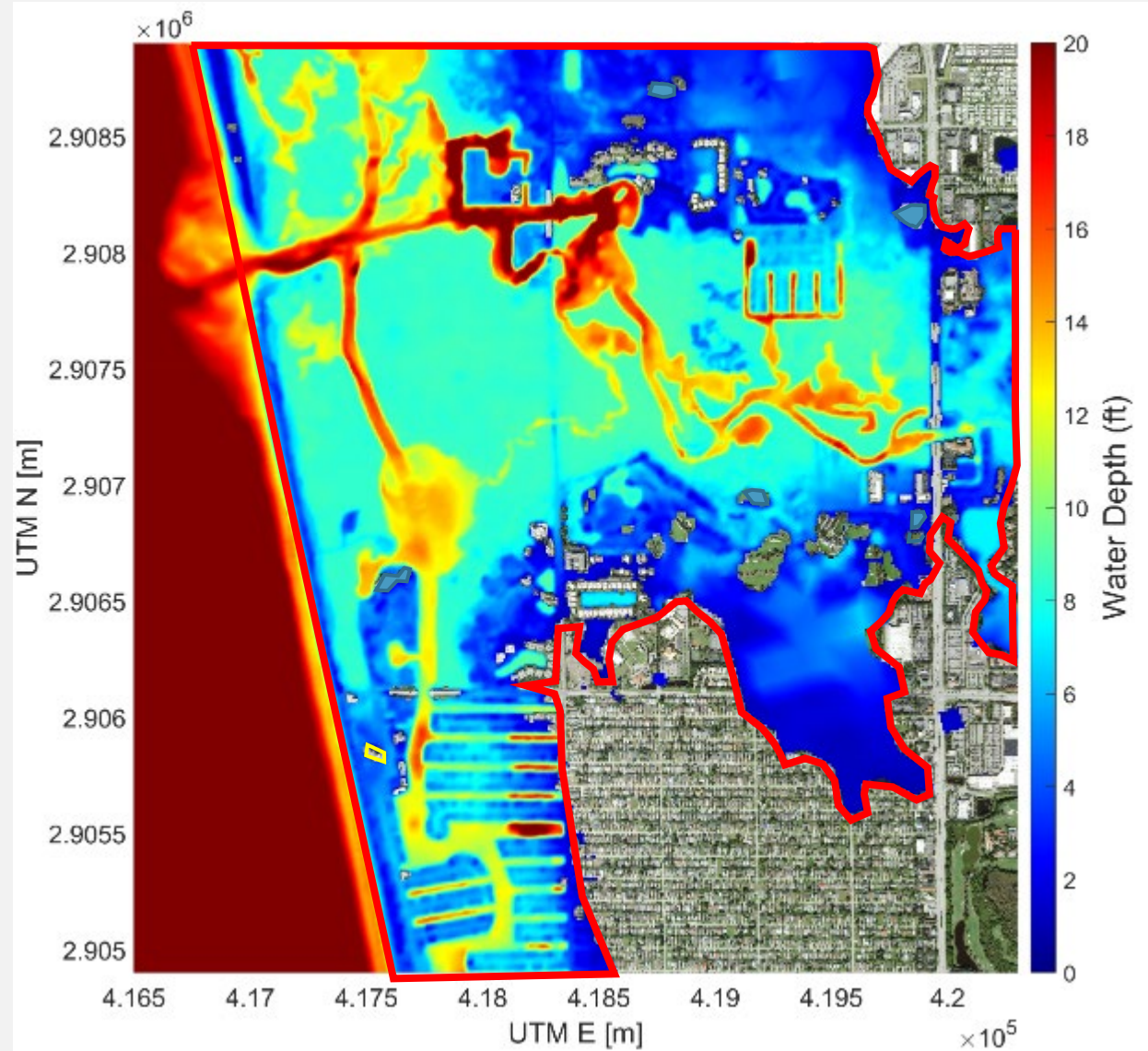
Barefoot Beach



Pelican Isle Yatch Club

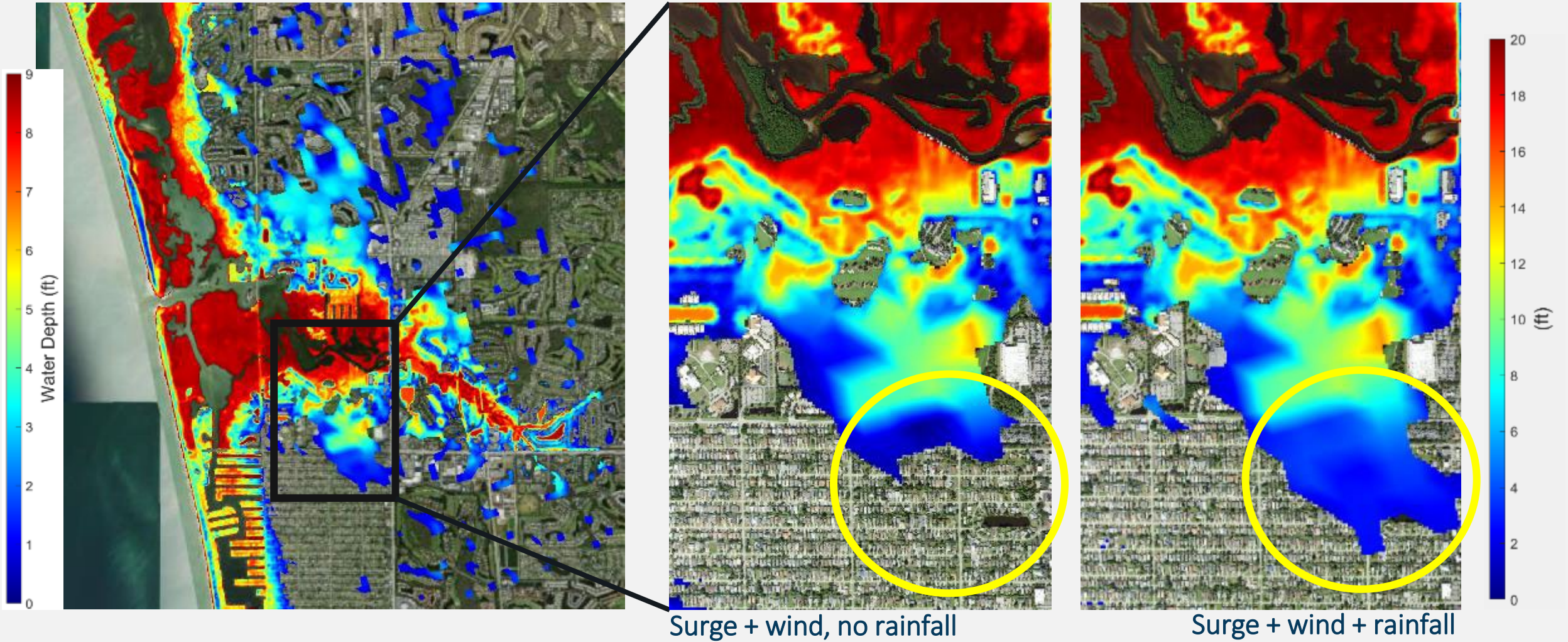


# DELFT 3D FLEXIBLE MESH PEAK WATER DEPTH





# DELFT 3D FLEXIBLE MESH PEAK WATER DEPTH





# COUPLED D3D & FLO2D H&H

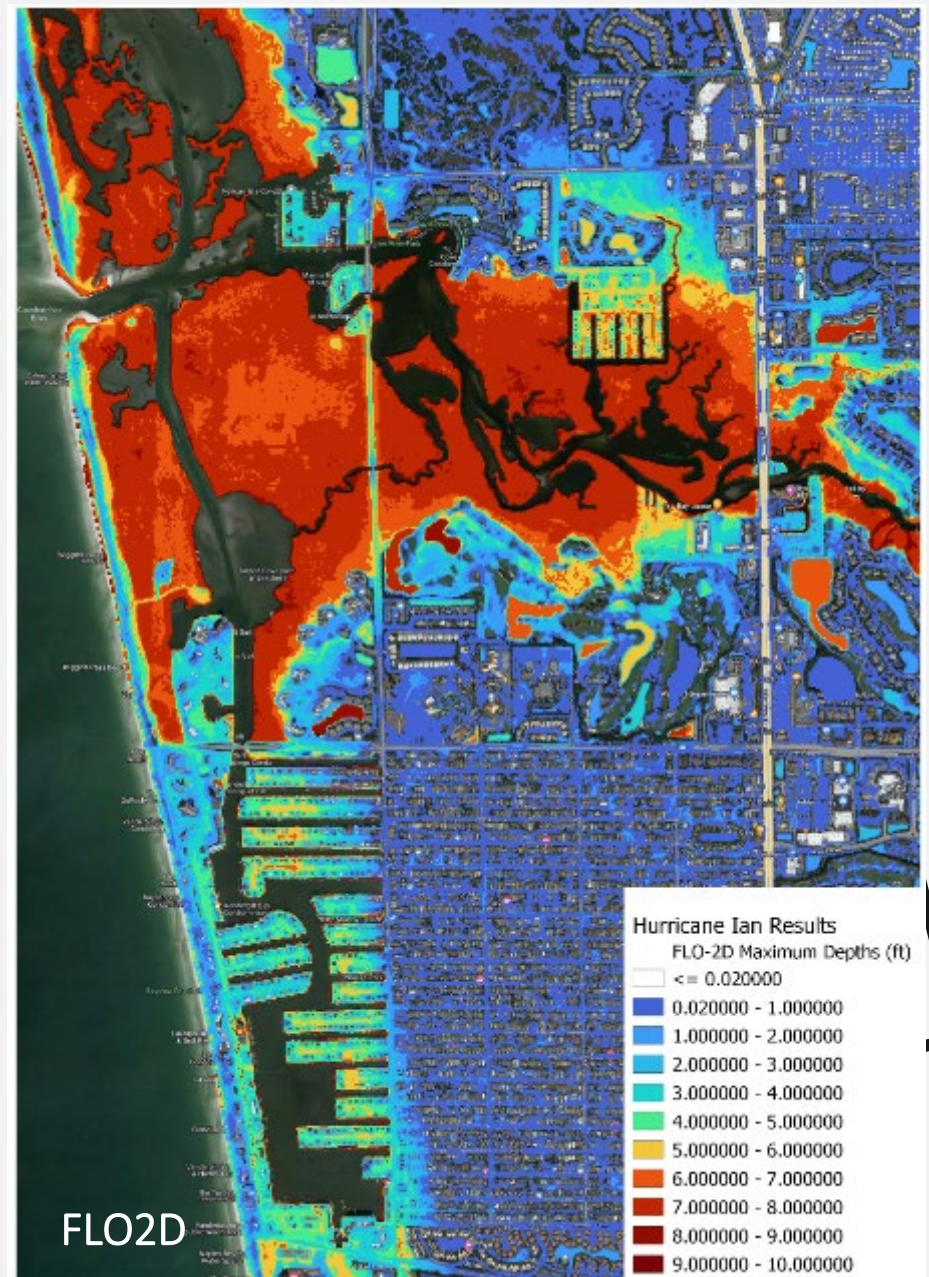
Collier County Flo2D H&H Model

Subdomain #1 – North Naples

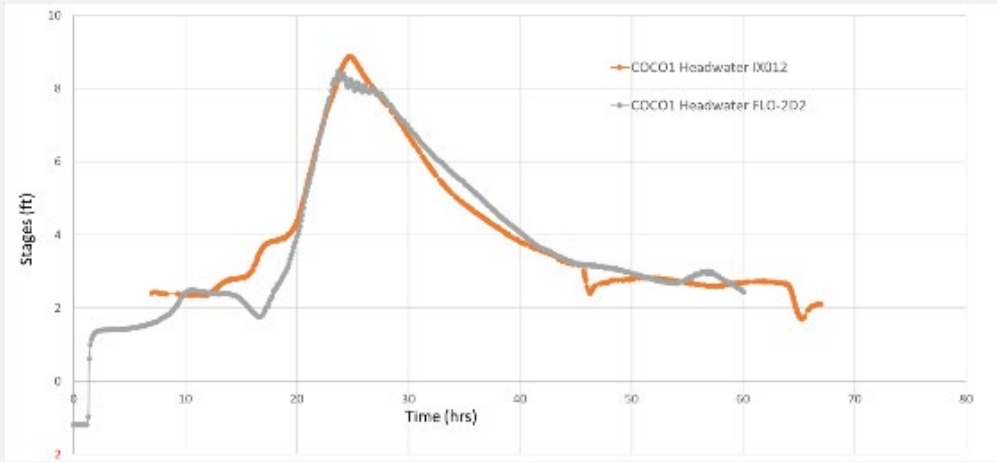
Feed with Delft3D surge boundary conditions at Wiggins Pass

- 2D/1D H&H Model
- 1.5M grid cells
- 2281 water intake features
- 2341 Conduits
- 420 manholes
- 29 junctions
- 221 outfalls
- Curbs, building polygons
- Space varying rainfall, infiltration, roughness

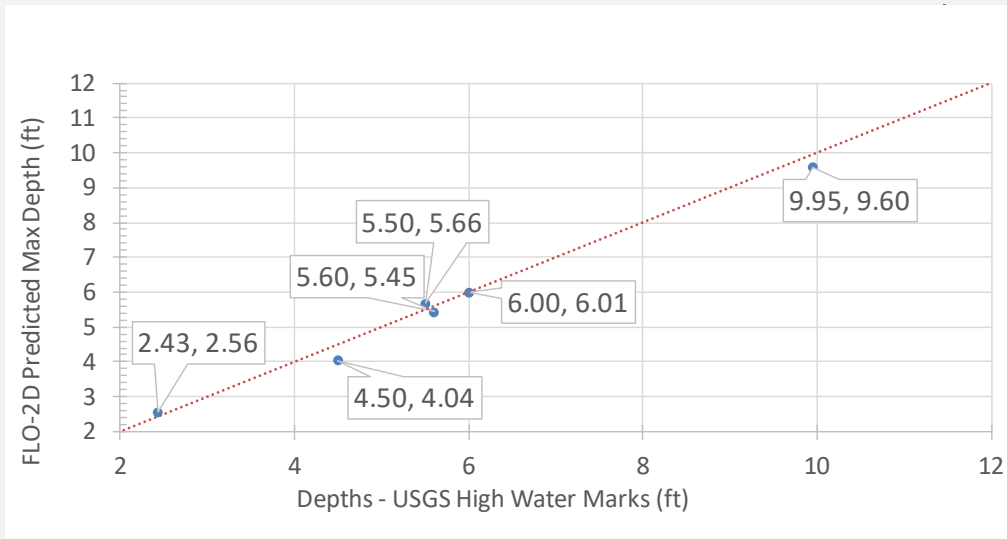
- No waves
- No wind effects on water flows
- Water bodies hydro flattened



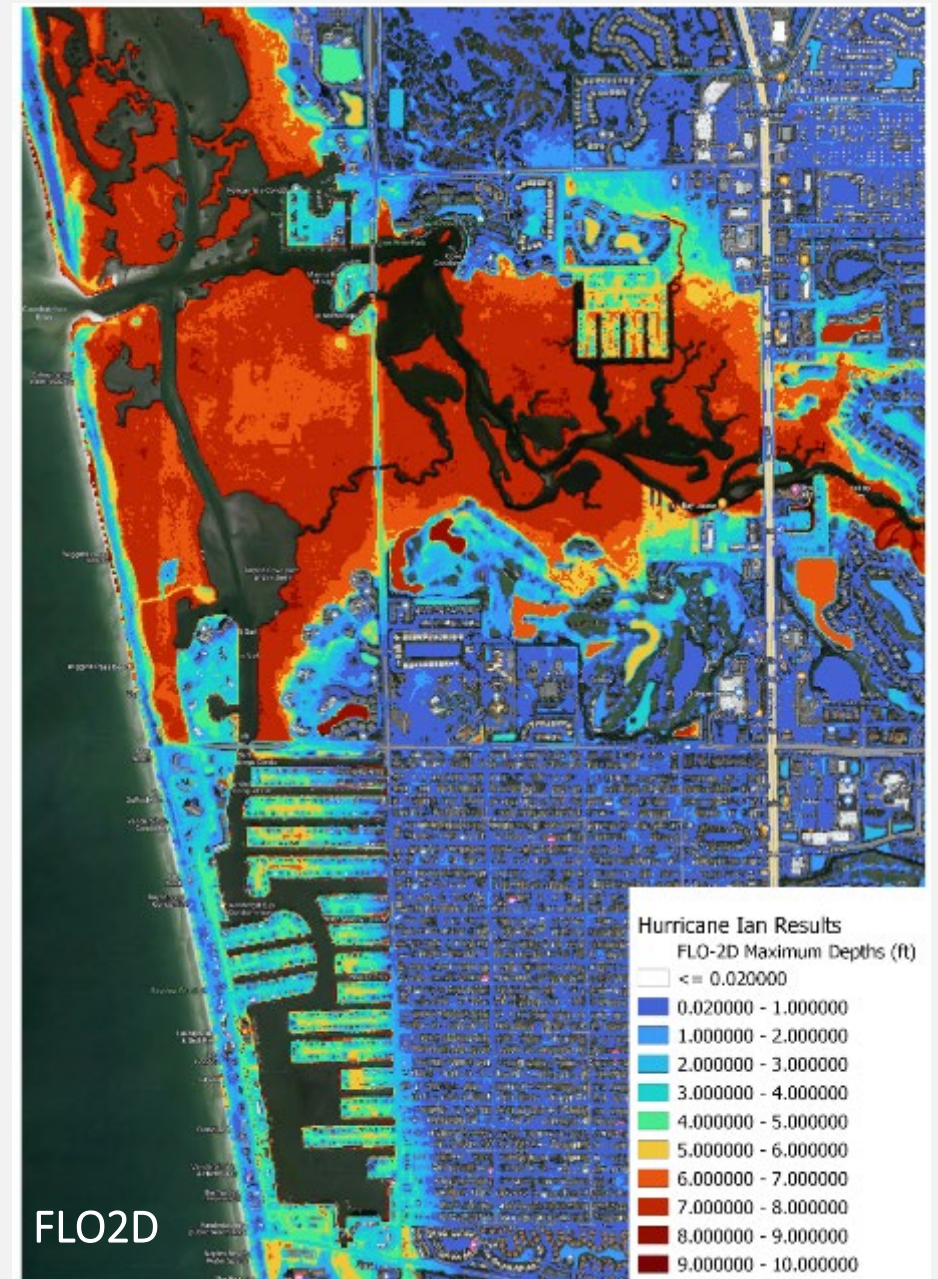
# COUPLED D3D & FLO2D H&H



Model vs Measurements at COCO1 (SFWMD WL Gauge at Cocohatchee near US41-Tamiami Train)

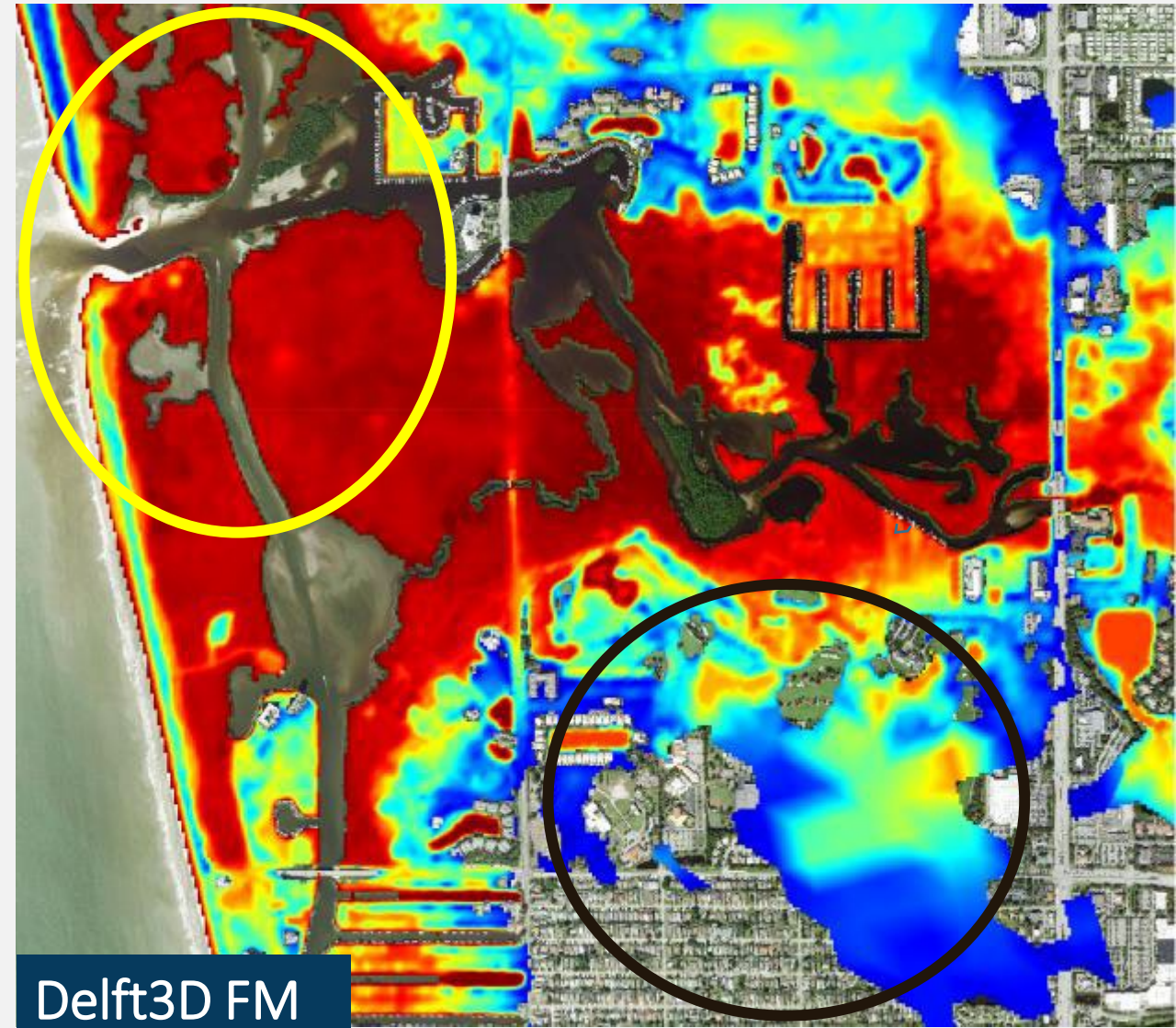


Model vs Measurements (USGS High Water Marks)

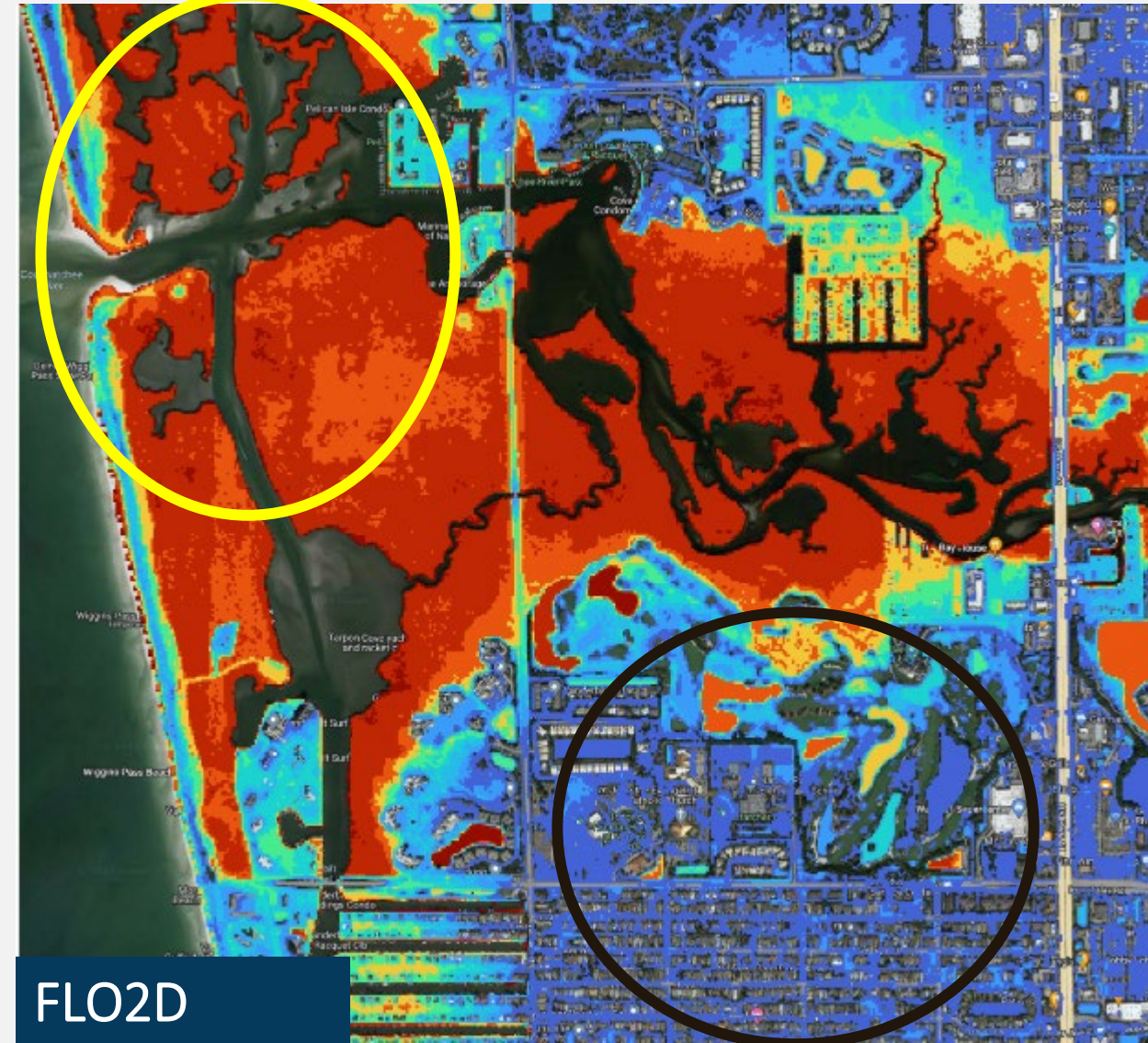




# DELFT3D-FM AND D3D-FLO2D IAN HINDCASTS



Delft3D FM



FLO2D



# So which Model is the best? it depends...

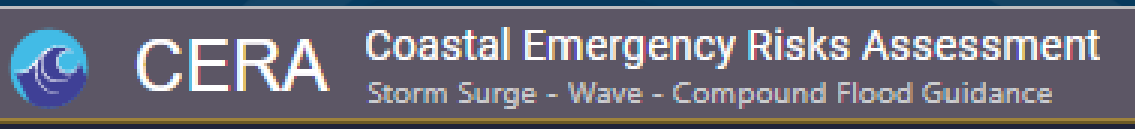
- CERA-ADCIRC is an improvement over SLOSH for regional surge forecast
- Delft3D-FM is an improvement over ADCIRC for interior coastal flooding, especially around interior waterways and when there is a need to include major hydraulic structures (gates, pumps)
- Coupled D3D-FM & Fo2D is an improvement over Delft3D-only for urban flooding
- Most situations require a combination of models & judgement

# FINAL CONSIDERATIONS

- H. Ian's storm surge and associated flooding was unprecedented (>100-year event) - powerful, large, slow-moving storm on a wide and gentle continental shelf with intense rainfall.
- Both ocean-scale hydrodynamic processes and hydrological-hydraulic processes are important to properly simulate storm induced coastal flooding in Florida (under present or future sea levels).
- Delft3D-FM can now include hydrologic processes and hydraulic structures, which is a significant improvement over other hydrodynamic models, but H&H urban flood routing models may be also needed.
- With RSL coastal flooding will become more frequent, better coastal flooding simulations and operational forecasts will be required, and active water management will be of vital importance.



## Special thanks to:



**FLO-2D ACUNE**

Akash and all the colleagues at CPE!



## Contact Information:

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