ERDC'S COASTAL STORM MODELING SYSTEM

COASTAL TEXAS, USA

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1st Int. Workshop on Waves, Storm Surge and Coastal Hazards

11-15 September 2017 Liverpool, UK

ERDC Engineer Research and Development Center

CSTORM-MS COASTAL STORM MODELING SYSTEM

US Army Corps of Engineers®

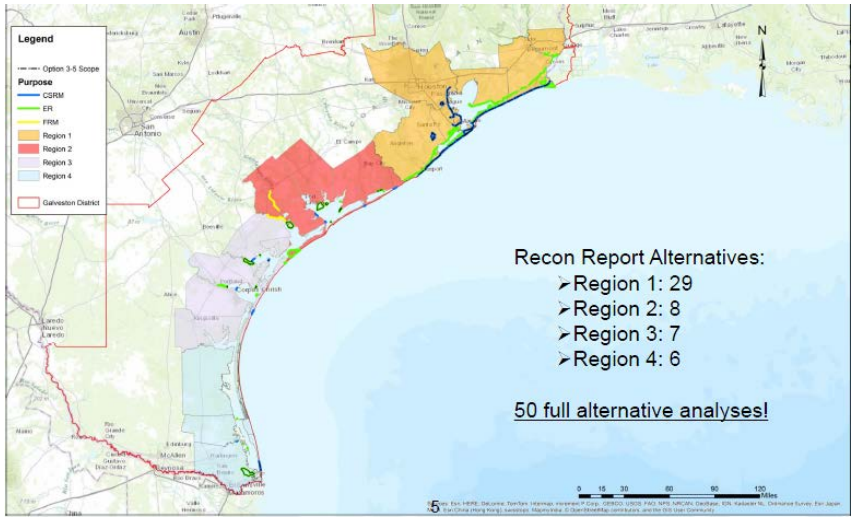
COASTAL & HYDRAULICS LABORATORY

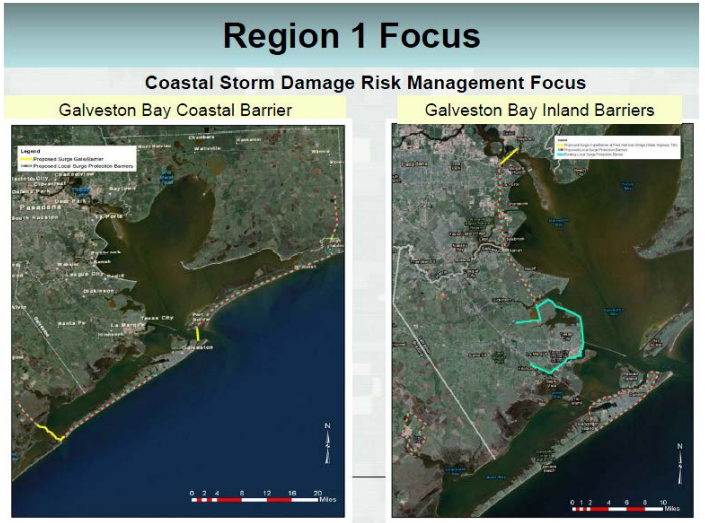
U.S.ARMY

Team Acknowledgements

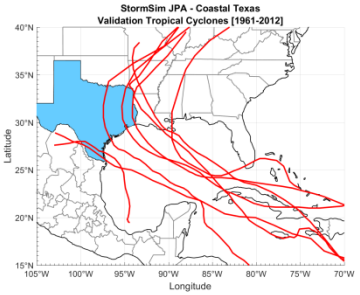
- Norberto Nadal-Caraballo & Amanda Lewis – (Statistics and Storms)
- Andy Cox of OceanWeather Inc. -- (Storm Climatology and Storms Support)
- Bob Jensen and Al Cialone – (Deep Water Waves)
- Mary Bryant – (Nearshore Waves)
- Yan Ding, Margaret Owensby, Greg Slusarczyk, Amanda Tritinger, John Goertz and Ty Hesser – (Production Modeling Team)
- ERDC DSRC – (HPC Access)
- USACE Galveston District Project Engineers

Coastal Texas Protection and Restoration Study





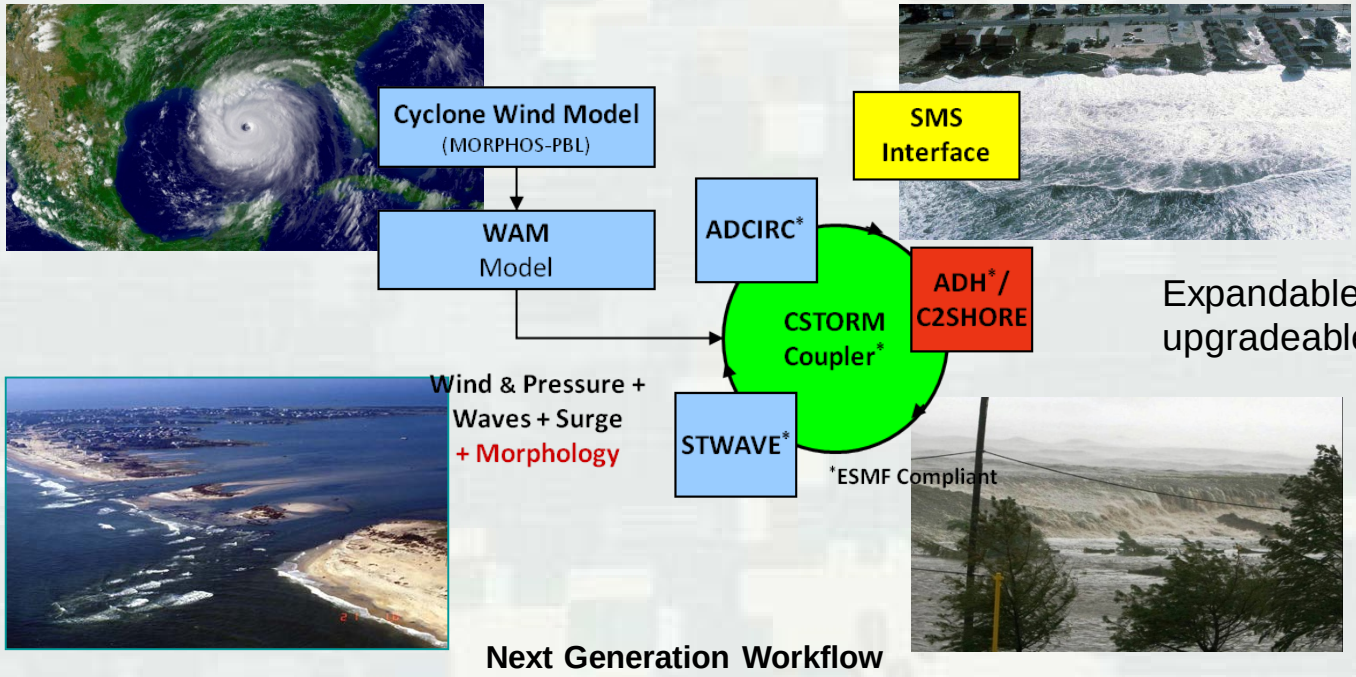
- Update Coastal Storm Surge/Wave Modeling and Return Period Statistics (CSTORM-MS & StormSim)
- With Project Evaluations for Region 1 (Coastal Barrier / Inland Barriers)
  - Storm Surge/Wave impacts – CSTORM-MS
  - Water Quality and Sedimentation – AdH Modeling
  - Navigation – Ship Simulator Study
- Beach Economics Analysis for South Padre Island – Beach-fx



ERDC's Coastal Storm - Modeling System

Application of high-resolution, highly skilled numerical models in a tightly integrated modeling system with user friendly interfaces

Not just hurricanes and not just in the Gulf of Mexico.



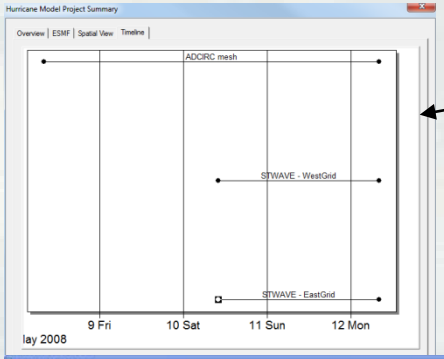
Expandable and upgradeable system.

Next Generation Workflow

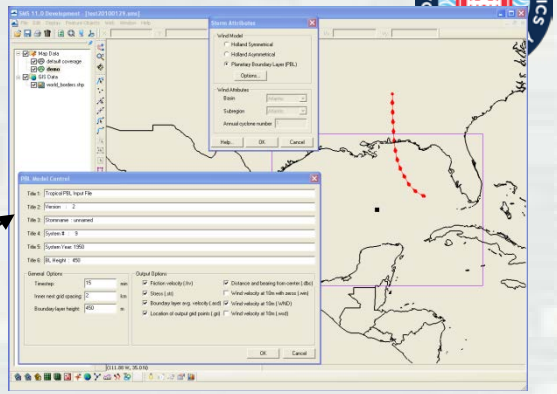
Provides for a robust, standardized approach to modeling coupling. Used for establishing the risk of coastal communities to future occurrences of storm events.

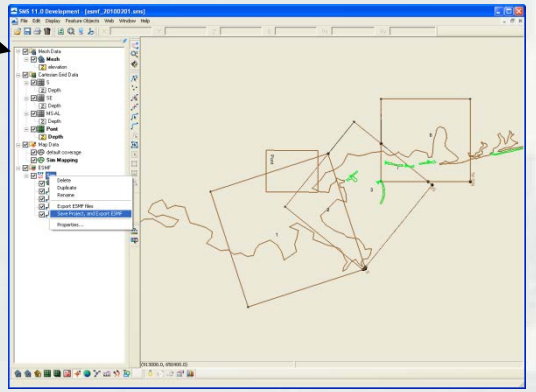
SMS GUI's

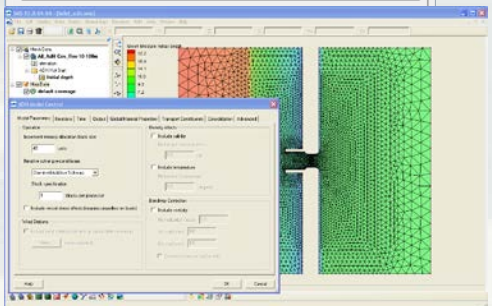
Through the SMS GUI's users can setup and execute models as well as visualize model results.

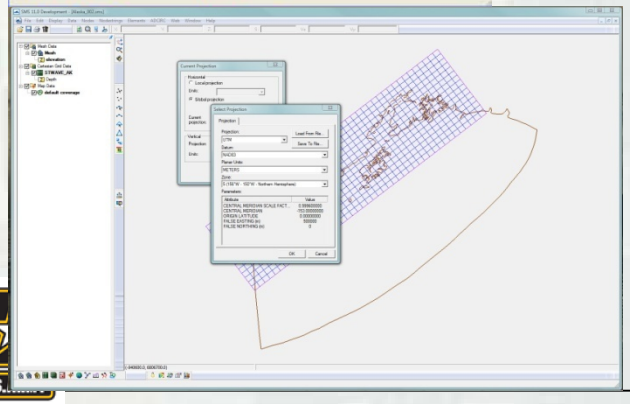


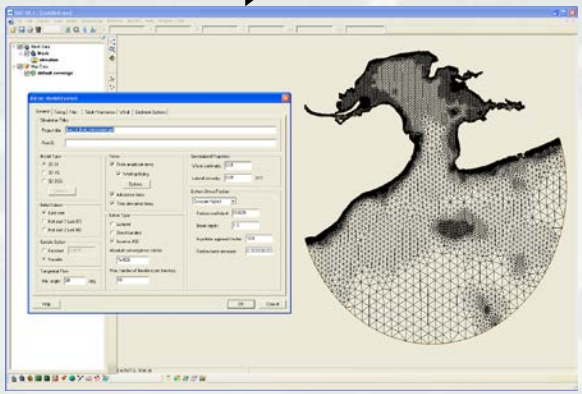
- New GUI for Project Overview
- New GUI for MORPHOS PBL Cyclone Model
- New GUI for CSTORM Coupled Models
- Updated GUI for AdH
- New GUI for WAM Wave Model
- Updated GUI for STWAVE
- Updated GUI for ADCIRC

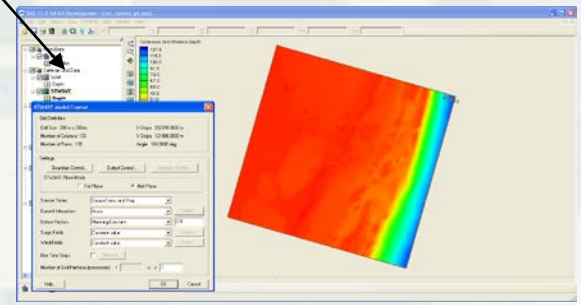






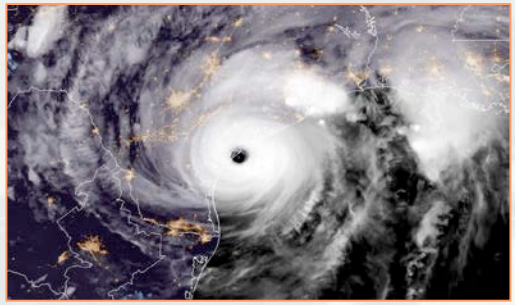






Combined Joint Probability of Coastal Storm Hazards

- ***Forcing***
  - Tropical cyclones
  - Extratropical cyclones
- ***Response***
  - Water level (storm surge, astronomical tide, SLC)
  - Currents
  - Wave height, peak period, direction
  - Wind speed, direction



Joint Probability Method

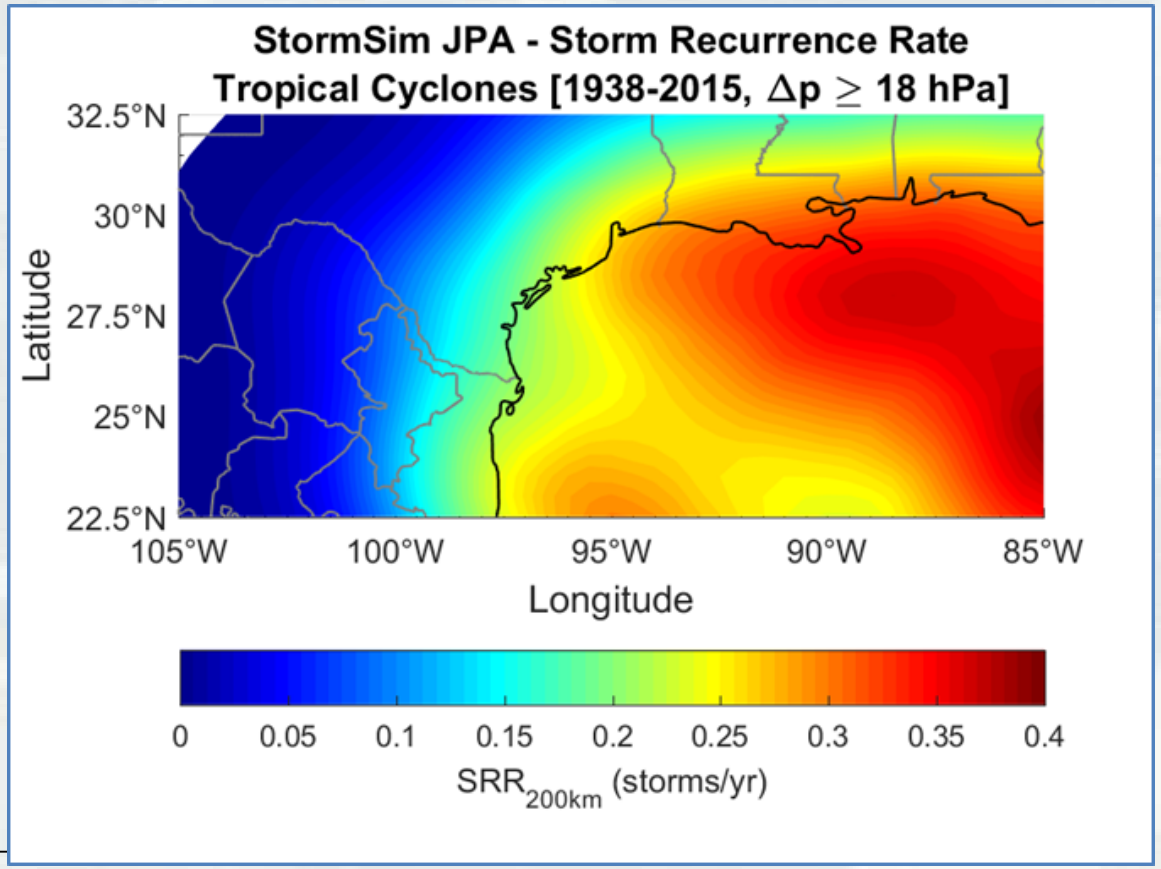
Objective - Probabilistic characterization of storm occurrences, parameters, and response.

Response = multi-dimensional continuous space

- Represented as a discrete population of **past** and **future** storms
- Developed based on the **ongoing storm-climatology**.
  - The ongoing storm-climatology is defined by the historical record.
- Optimized to encompass the entire probability and parameter space.

Coastal Texas Study

- **StormSim-JPA** probabilistic model
  - Hybrid Joint Probability Method (JPM)
  - 660 synthetic tropical cyclones (TCs)
  - 82 Master Tracks



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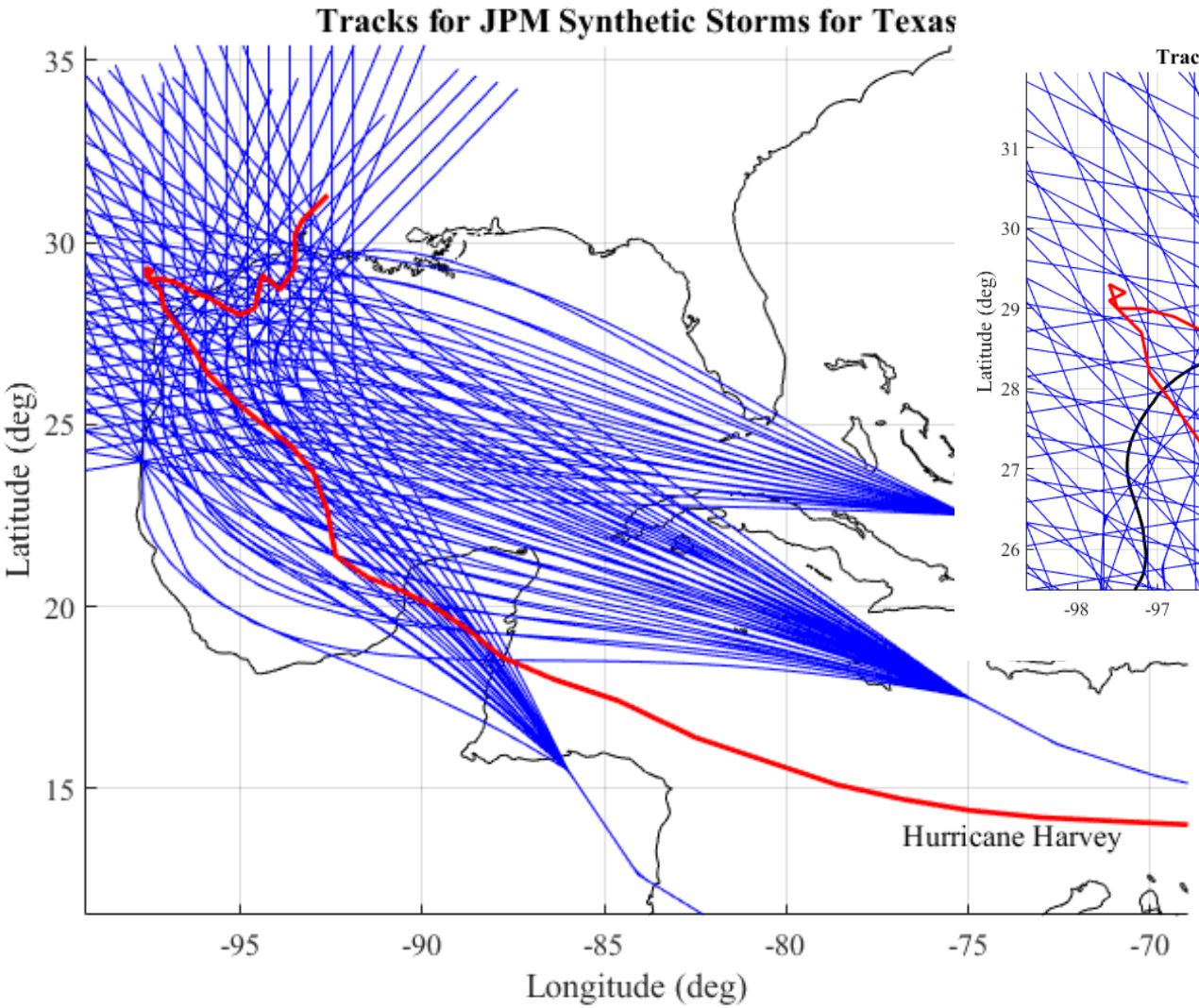
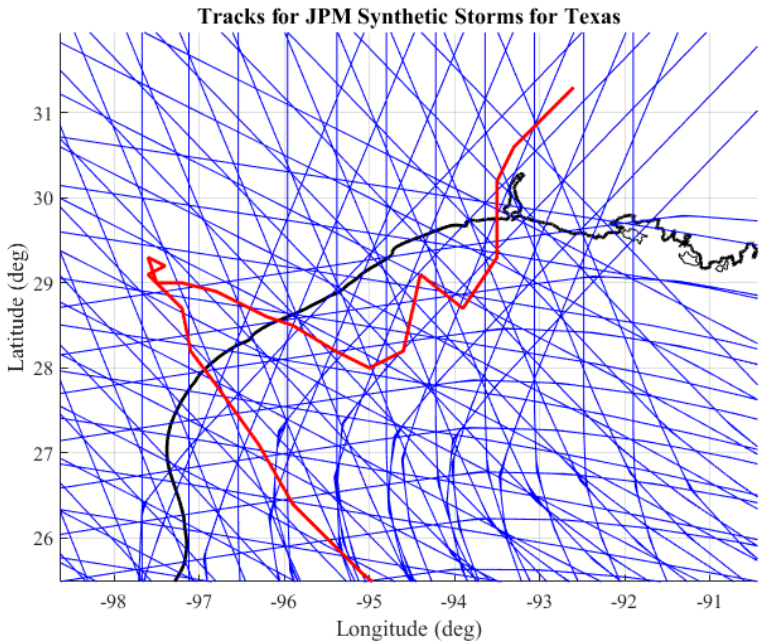
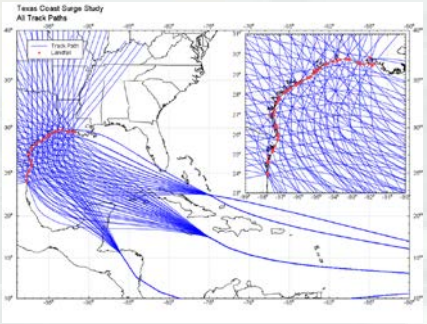
Storm Forcing
82 Master Tracks

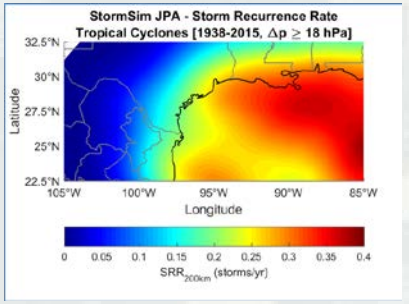




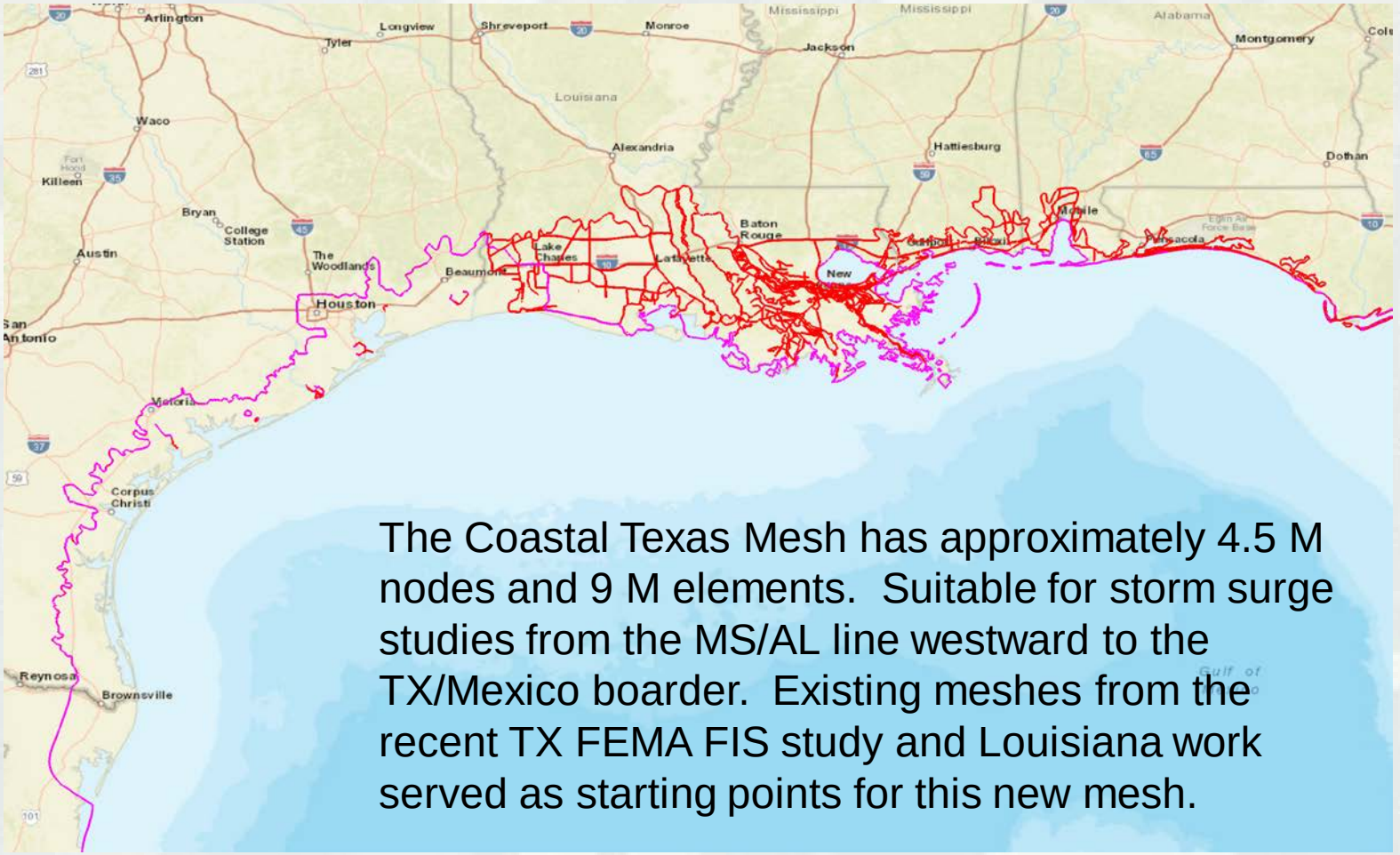
Storm Forcing



- **Radius of Maximum Winds** (R_{max})
  - Range: 8 km to 156 km
- **Translational Speed** (V_f)
  - Range: 4.3 knots to 24.1 knots (8 km/h to 45 km/h)
- **Heading Directions** (θ)
  - -100º, -80º, -60º, -40º, -20º, 0º, +20º, +40º
- **Storm Intensity** (Δp)
  - 8 mb (1005 mb) – very low intensity storms
  - 148 mb (865 mb) – catastrophic Cat 5+ hurricane
    - Atlantic record: 131 mb (882 mb) Hurricane Wilma, 2005
    - Worldwide record: 143 mb (870 mb) Typhoon Tip, 1979

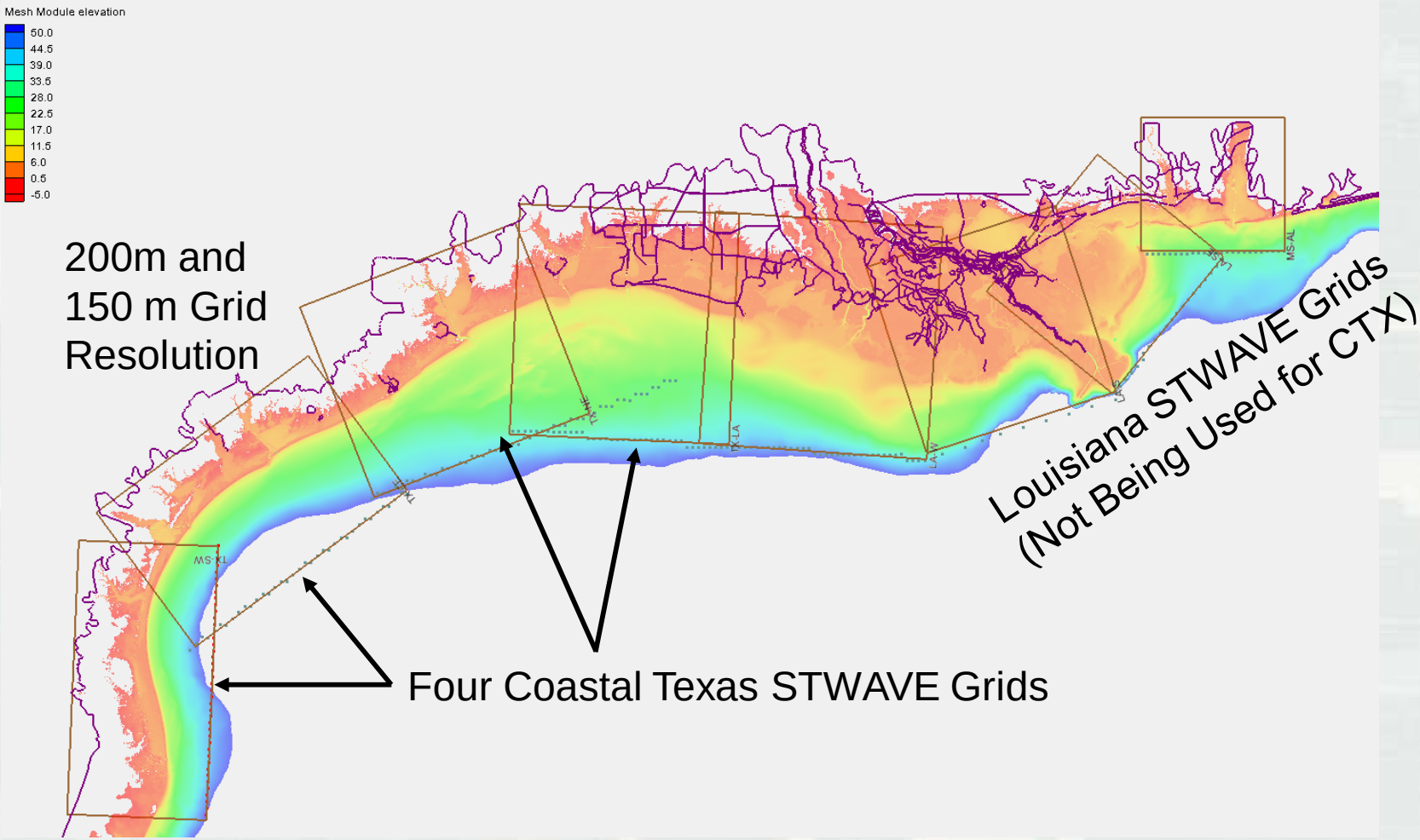


Coastal Texas/Louisiana Mesh



The Coastal Texas Mesh has approximately 4.5 M nodes and 9 M elements. Suitable for storm surge studies from the MS/AL line westward to the TX/Mexico boarder. Existing meshes from the recent TX FEMA FIS study and Louisiana work served as starting points for this new mesh.

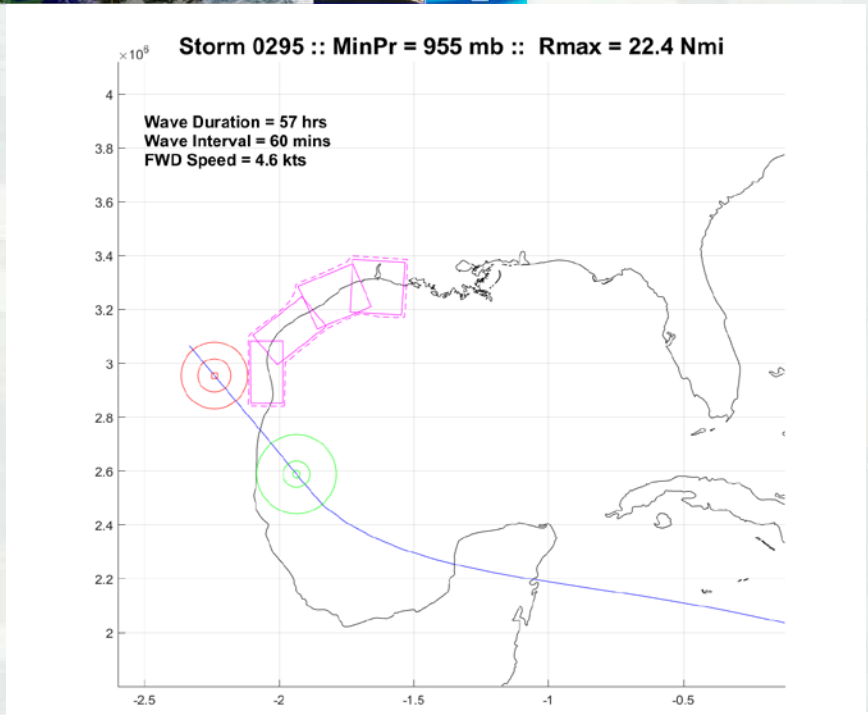
STWAVE Grids

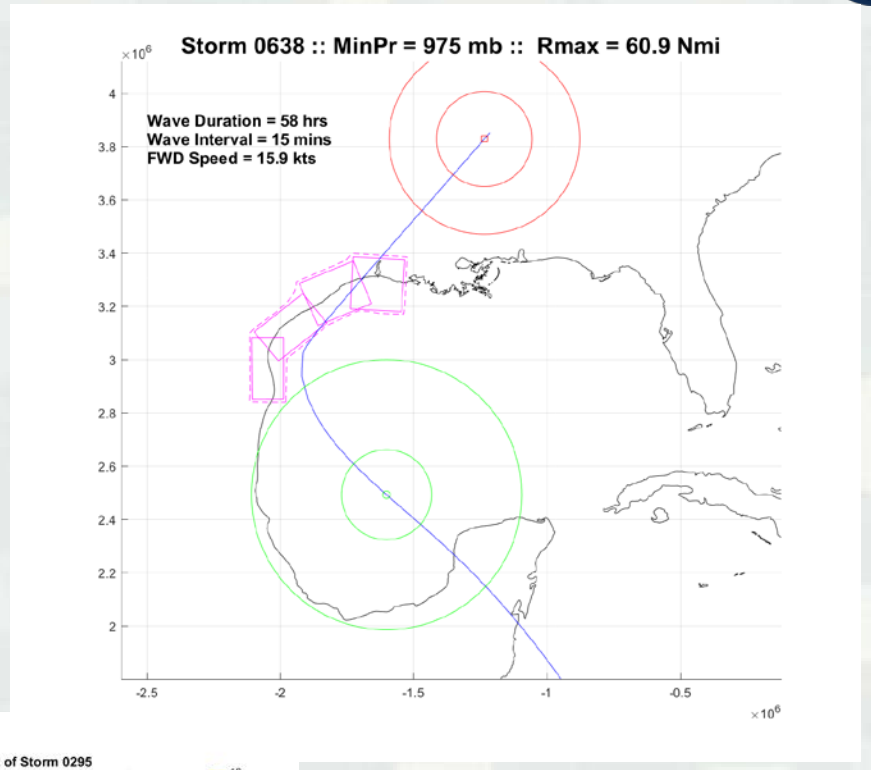


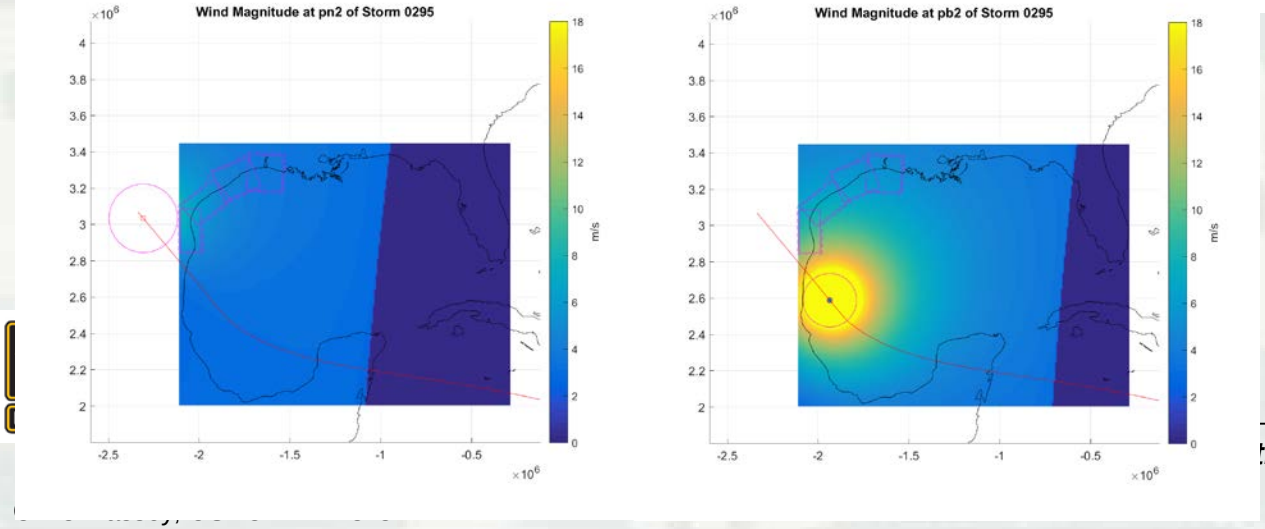
Storm Simulations for Waves

- WAM – A deep water wave model
  - Run once for all storms – provides boundary conditions to STWAVE
- STWAVE – A nearshore spectrally averaged wave model
  - CSTORM Coupled ADCIRC+STWAVE simulations
  - Nearshore waves start/end times and frequency of computation were based on storm proximity to STWAVE grids, storm size and the forward speed of the storm.

Example STWAVE Start/End



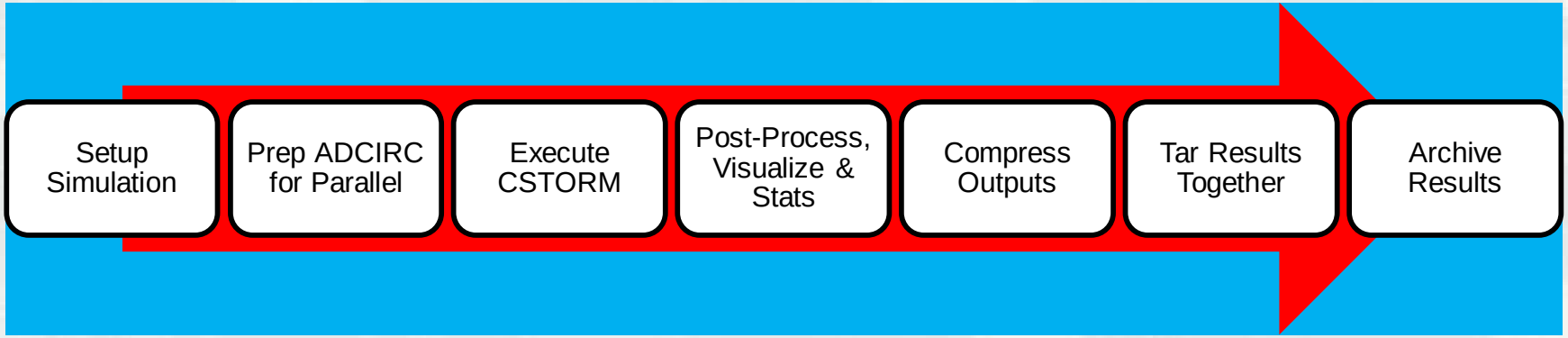




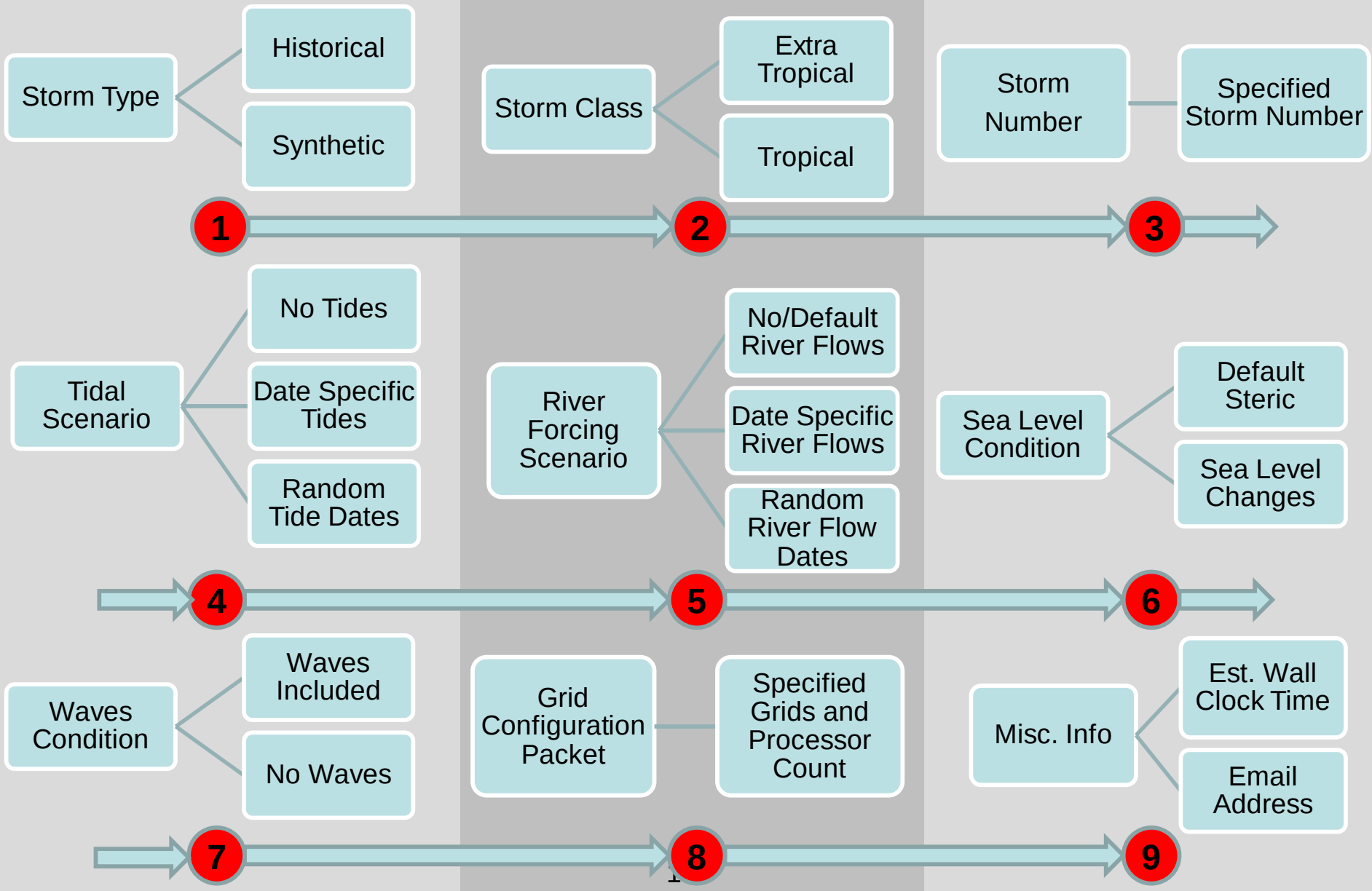
tive solutions for a safer, better world

CSTORM Production System

- The **CSTORM Production System** (CSTORM-PS) makes use of standard Linux/Unix tools (bash scripting) and readily available open source software, Python
- The production system allows for
  - Rapid preparation of necessary input files for individual CSTORM-MS production runs (Reduces chances for human error)
  - Execution of the simulation
  - Execution of the CSTORM Visualization and Report tool
  - Efficient file storage and archival



CSTORM-PS: Decision Tree



HPC Resources

ERDC's Coastal Hazard Modeling routinely makes use of several separate DSRC systems, ERDC's Onyx/Topaz/Garnet, AFRL's Lightning and Navy's Armstrong

Garnet

Topaz

Lightning

Armstrong

Cray XE6		SGI Ice X		Cray XC30		Cray XC30	
1.5 PFLOPS		4.62 PFLOPS		1.2 PFLOPS		786 TFLOPS	
4,716 nodes	32 cores/node	3,456 nodes	36 cores/node	2,370 nodes	24 cores/node	1,347 nodes	24 cores/node
150,912 processors		124,416 processors		56,880 processors		32,328 processors	

Modern Archived Results

ADCIRC:

CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_ADCIRC_GBL_Hydro.tar
CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_ADCIRC_GBL_Met.tar
CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_ADCIRC_MaxMins.tar
CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_ADCIRC_Stations.tar

STWAVE: **Repeated for each STWAVE Grid**

CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_STWAVE_CE_Outputs.tar
CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_STWAVE_CE_SurgeWind.tar
CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_STWAVE_All_Stations.tar

CSTORM:

CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_CSTORM_Data.tar

Viz:

CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_Report.pdf
CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_Viz_ADCIRC_pngs.tar.gz
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CTX_TP_0468_SYN_Tides_0_SLC_1_RFC_0_WAV_1_GCP_CTX34E01_Viz_STWAVE_pngs.tar.gz

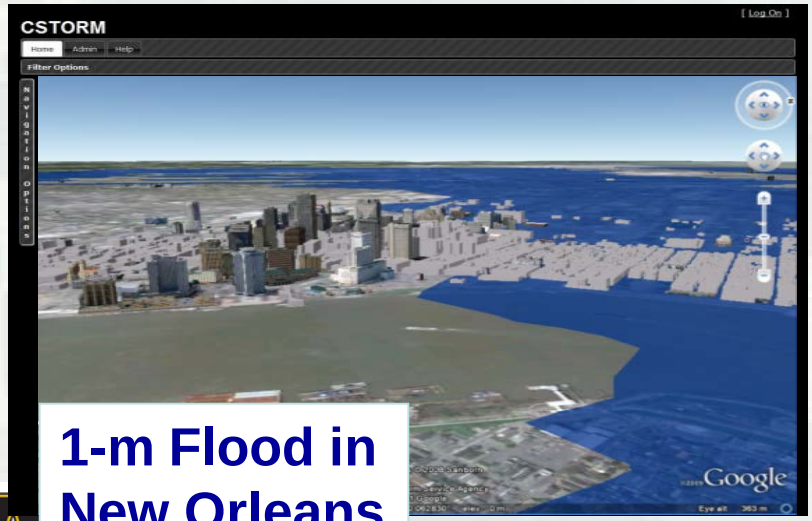
26 tar files with compressed results plus a copy of the PDF report.

Run properties log included within each tar file.

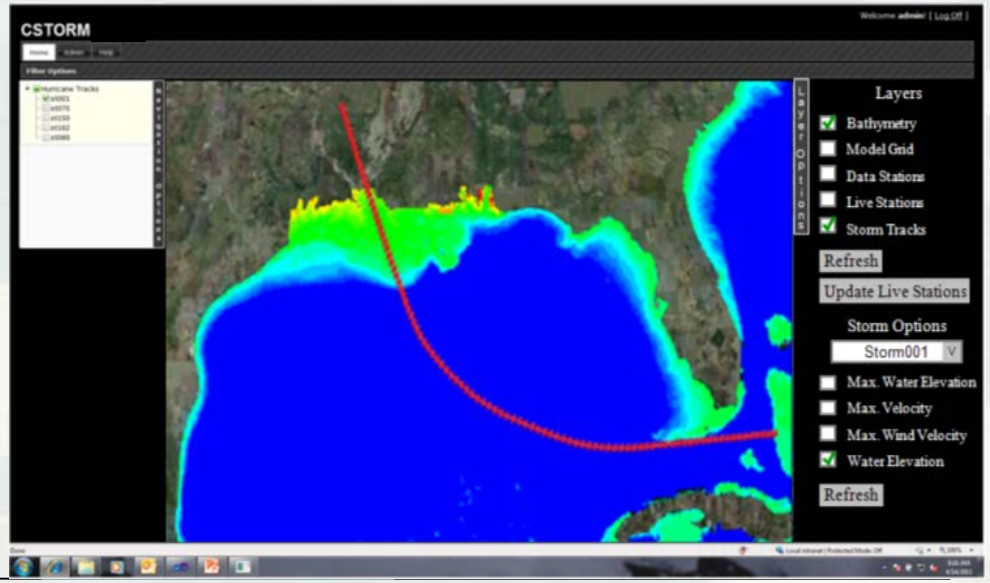
CHS

Coastal Hazards System

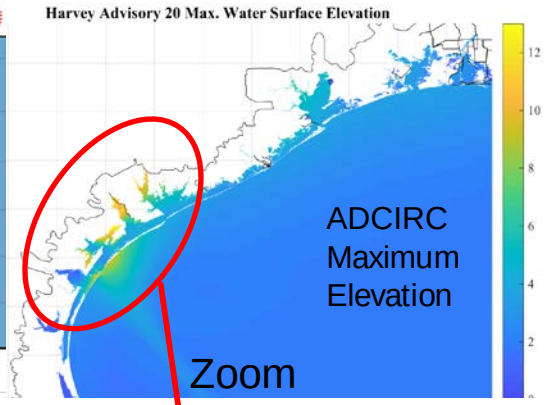
- Leveraging USACE regional coastal studies
- Gathering historical measurements and high-fidelity climate, surge, and wave modeling results
- Creating national storm database
- Web tool with Google Earth map interface
- Data mining and analysis tools (plotting, extremal analysis)
- Surrogate modeling from database (high-fidelity surge prediction layer)

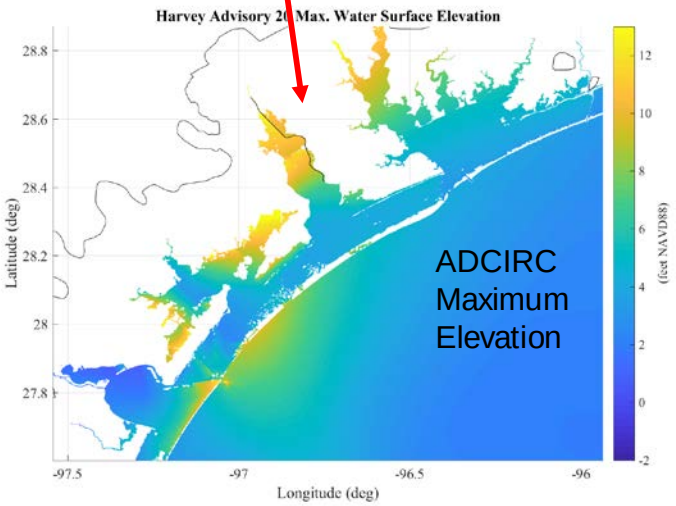


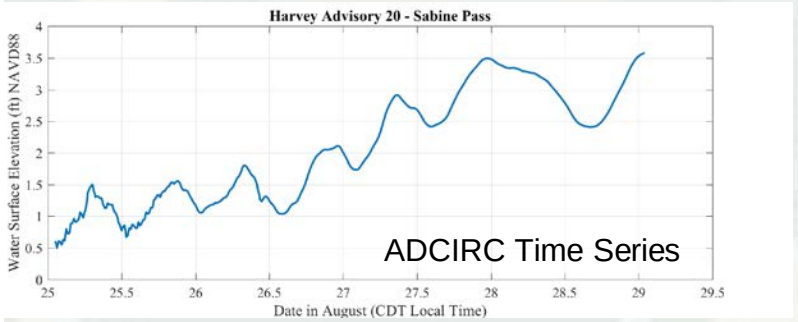
1-m Flood in New Orleans

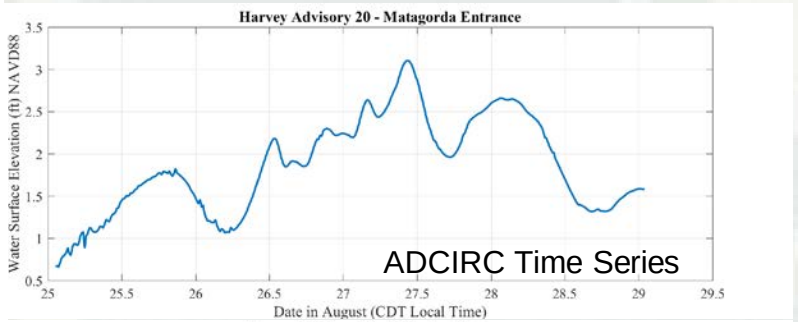


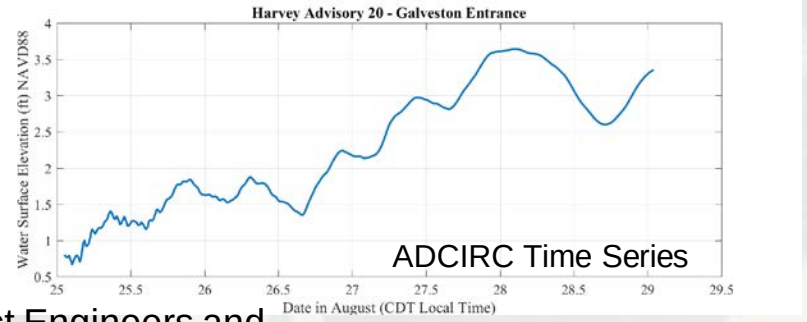
ADCIRC Storm Surge Results Advisory 20 Hurricane Harvey











The ADCIRC CSTORM simulations included tides, surface winds and surface pressures. 5 day "forecast" period performed in less than 2.5 hours using 1,716 processors on ERDC HPC systems.

These results were provided to USACE District Engineers and Operations Personnel. Not intended for public use and not to conflict with Official NHC forecast results.

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Chris Massey, USACE-ERDC-CHL

Summary

- CSTORM-MS is an efficient, robust, extensible modeling system for quantifying the risk of coastal communities to storm events.
- Its' streamlined workflow saves time and reduces both computational and personnel cost.
- Model data feeds into the Coastal Hazards System for easy access and reuse purposes.