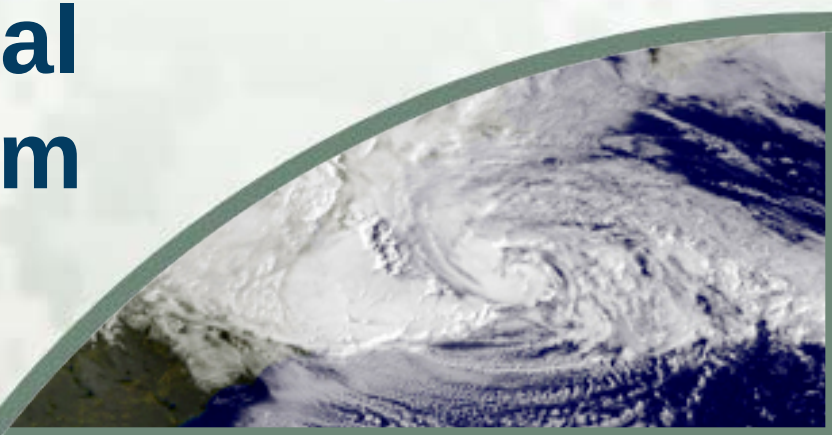
ERDC
Engineer Research and Development Center

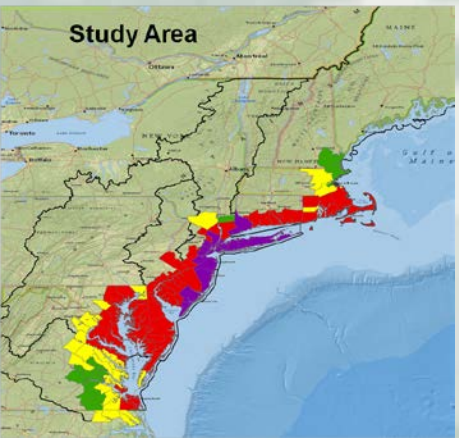
USACE ERDC's Coastal Storm Modeling System



Chris Massey, Jay Ratcliff, and Mary Cialone

USACE-ERDC-Coastal & Hydraulics Lab

Vicksburg, MS

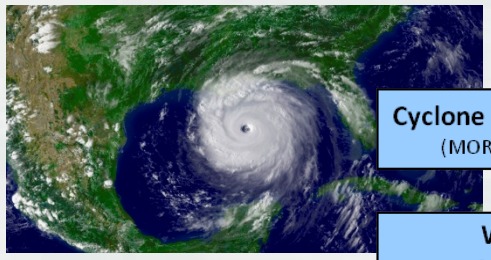


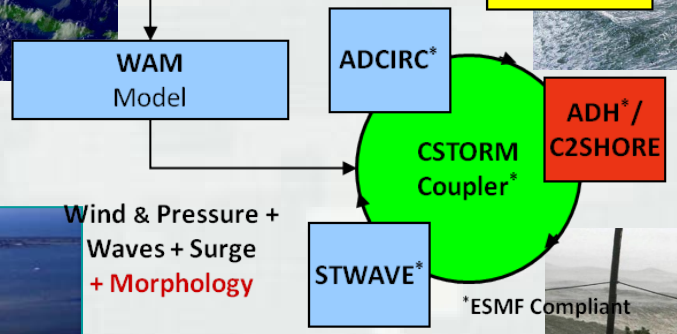
ERDC's Coastal Storm-Modeling System

(ERDC CSTORM-MS)

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.





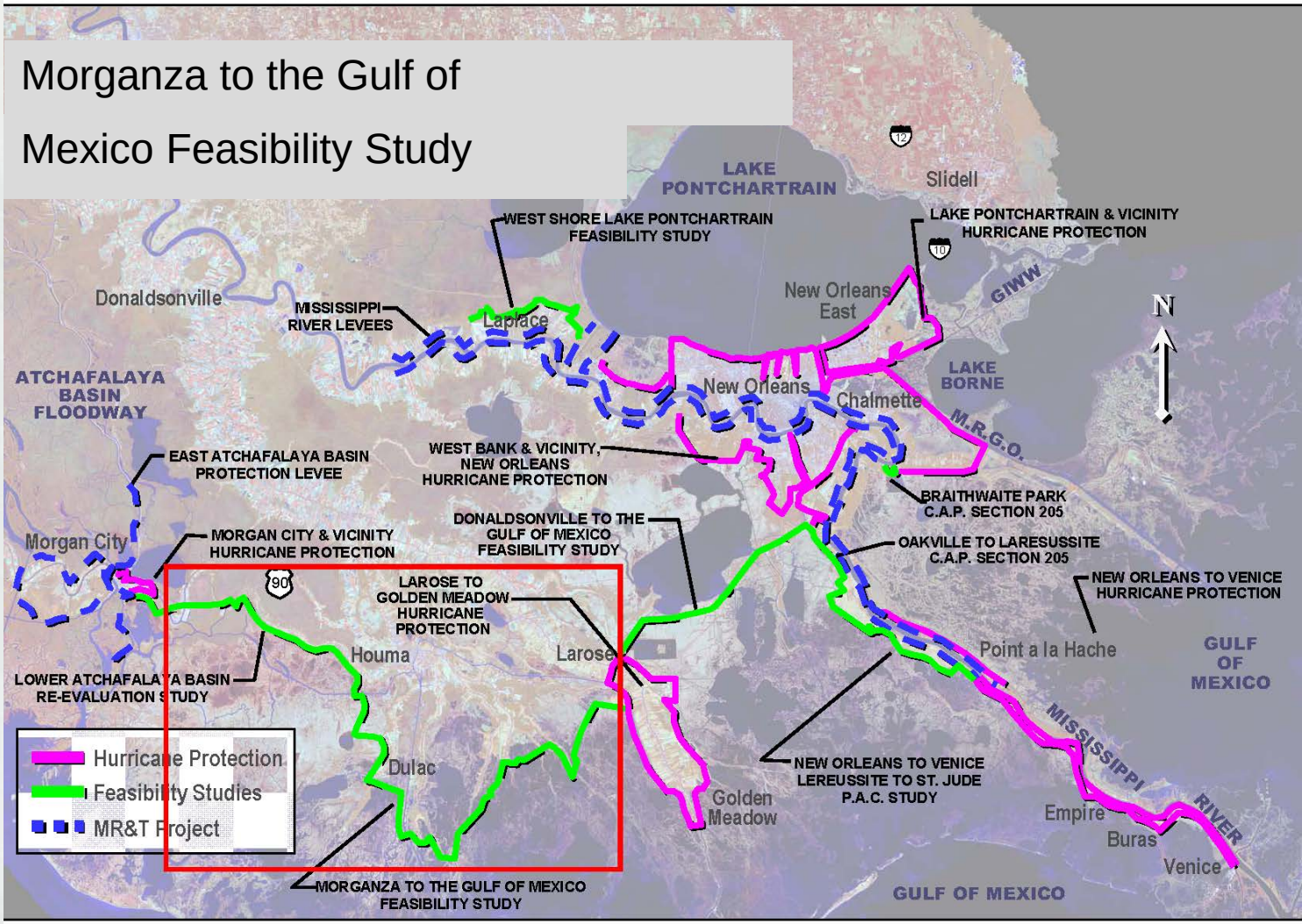
Next Generation Workflow

Expandable and upgradeable system.

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

An Example Storm Surge and Wave Problem

Morganza to the Gulf of Mexico Feasibility Study



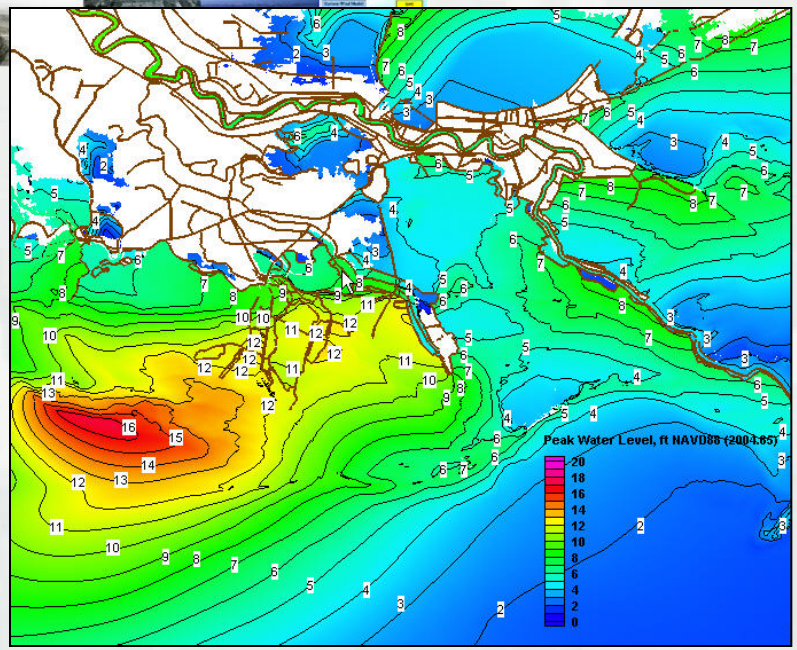
CSTORM-MS

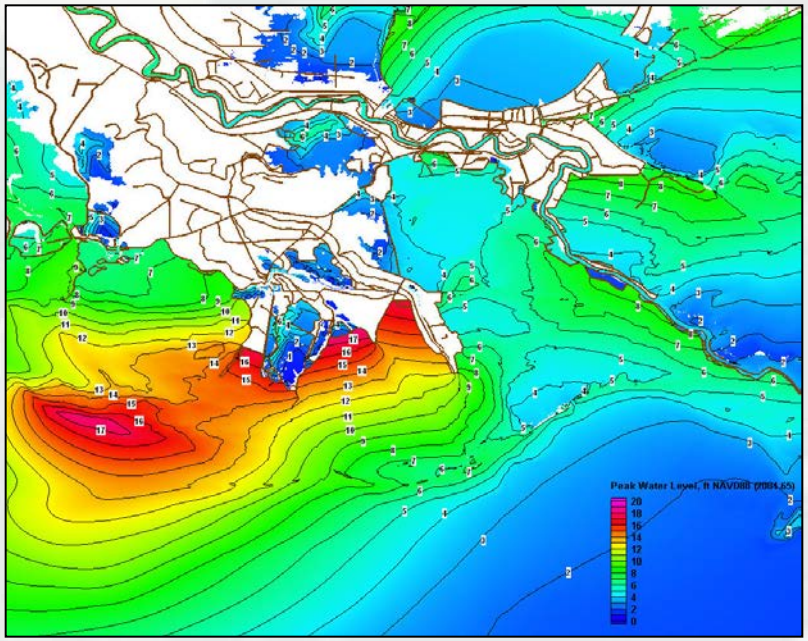
Without Project

With Project

Storm 314

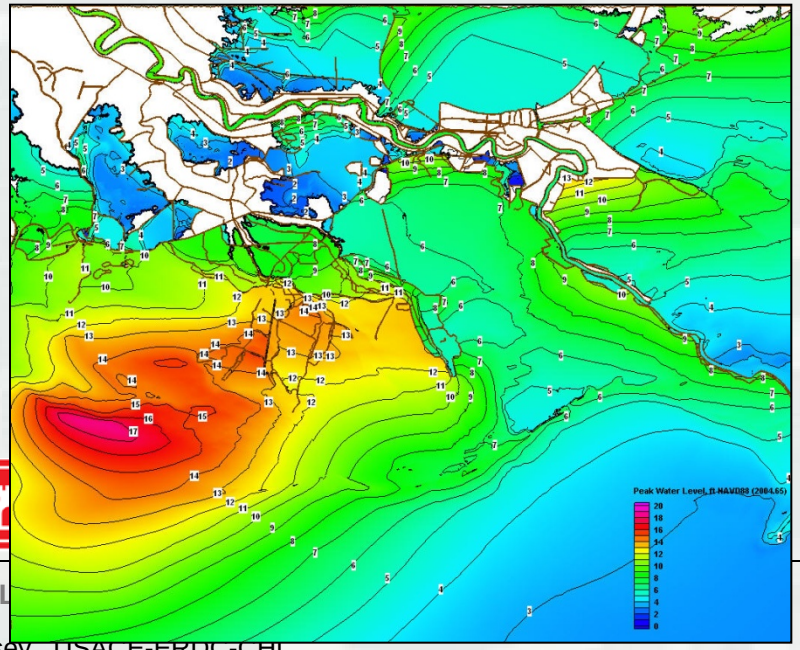
Existing Water Level

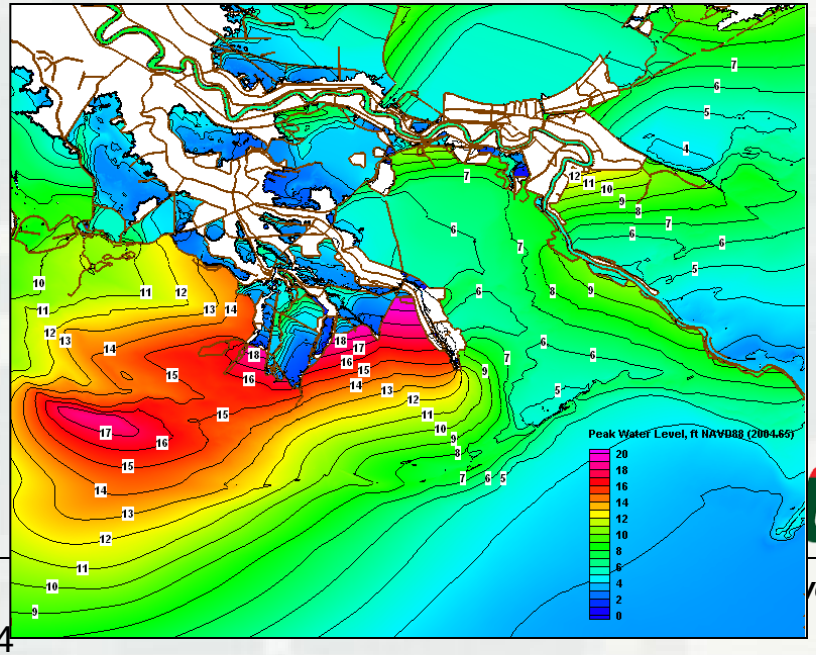




Existing Water Level

Sea Level Rise 0.35 m

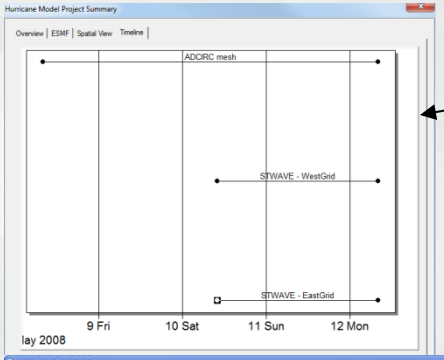




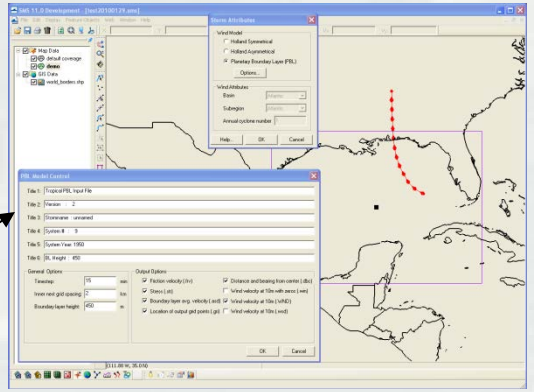
Sea Level Rise 0.35 m

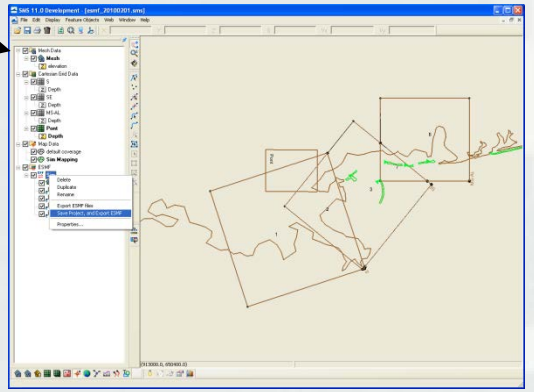
SMS Graphical User Interface

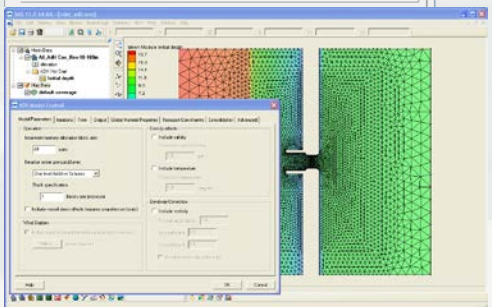
Through the SMS GUI's users can setup and execute models as well as visualize model results.

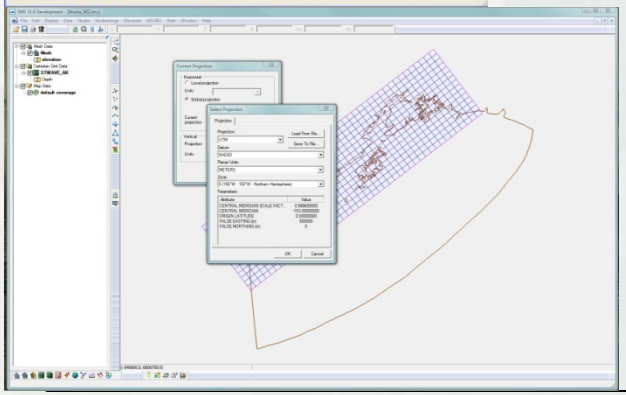


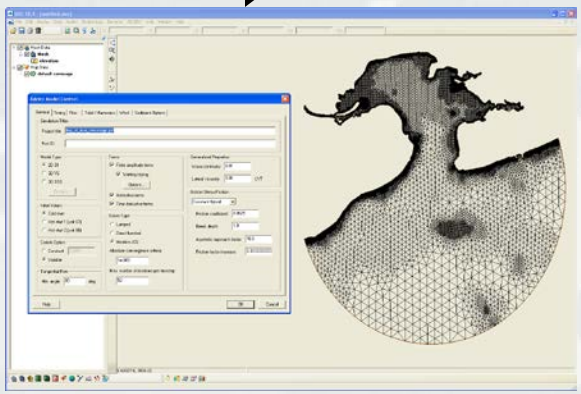
- New GUI for Project Overview
- New GUI for MORPHOS PBL Cyclone Model
- New GUI for CSTORM Coupled Models
- Updated GUI for AdH
- New GUI for WAM Wave Model
- Updated GUI for STWAVE
- Updated GUI for ADCIRC

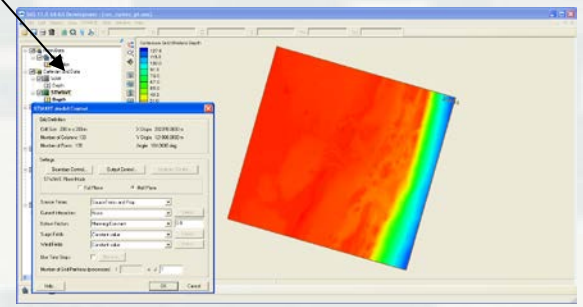








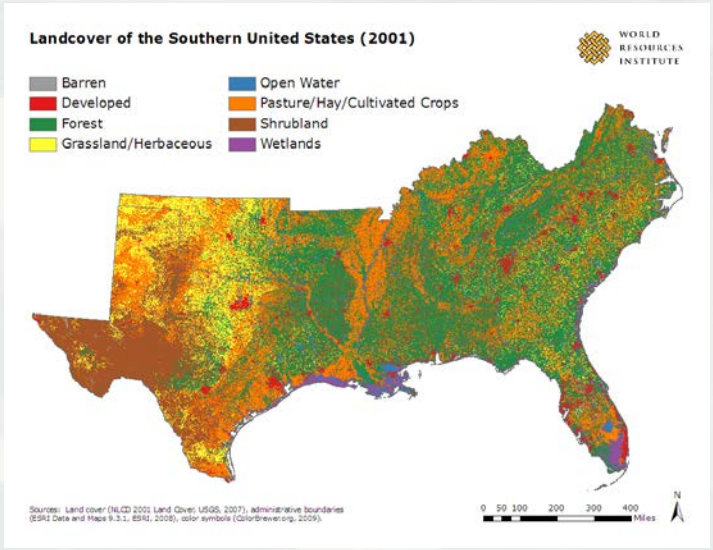


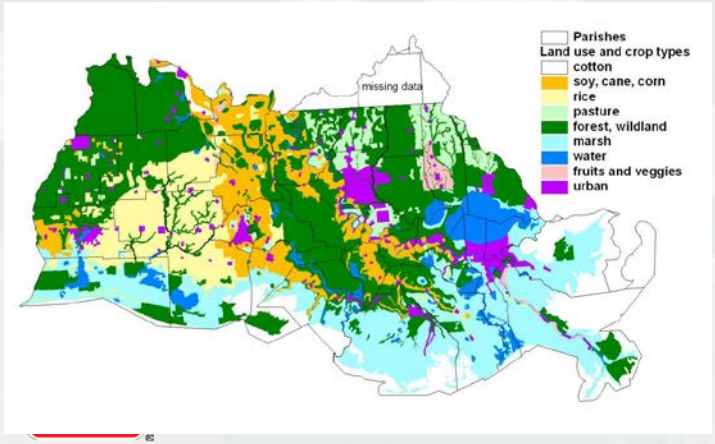


ERDC

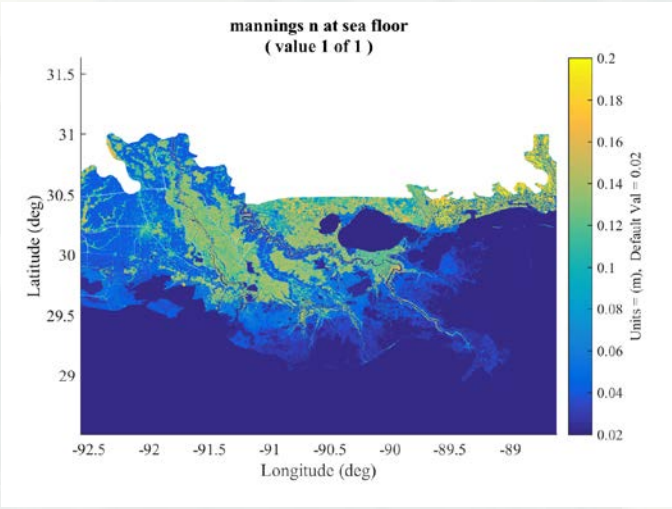
Incorporating Land Use Types

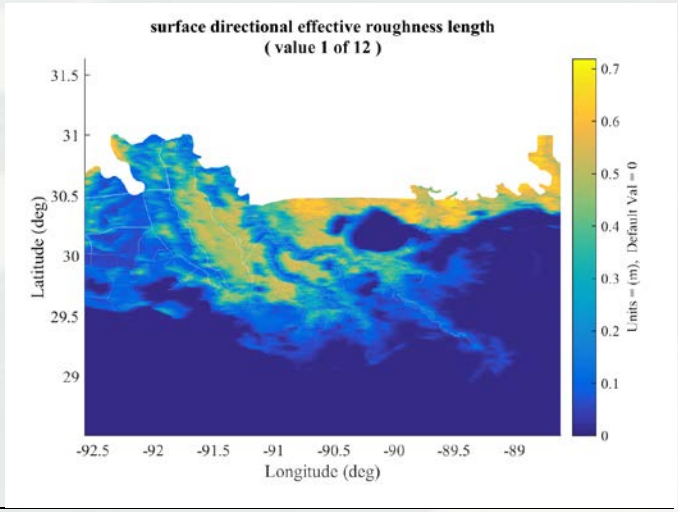
Land Cover





Model Attributes

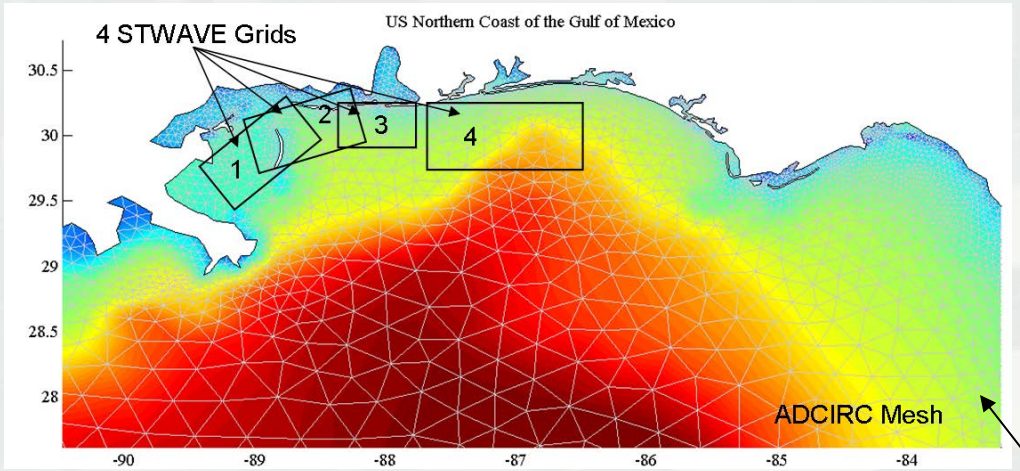




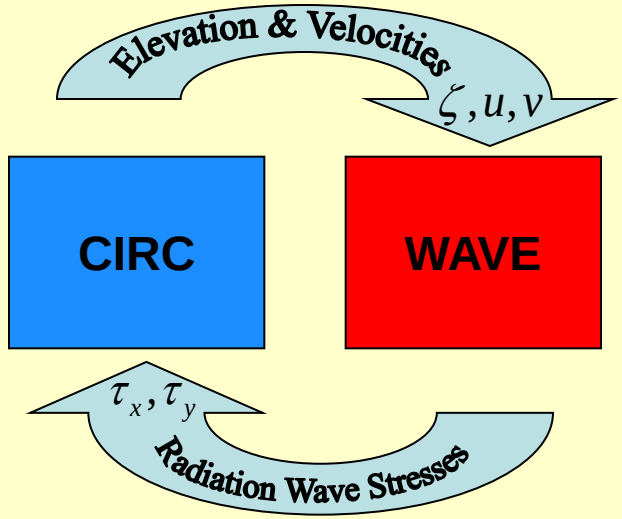
CSTORM Coupling Framework

(Example Waves + Circulation)

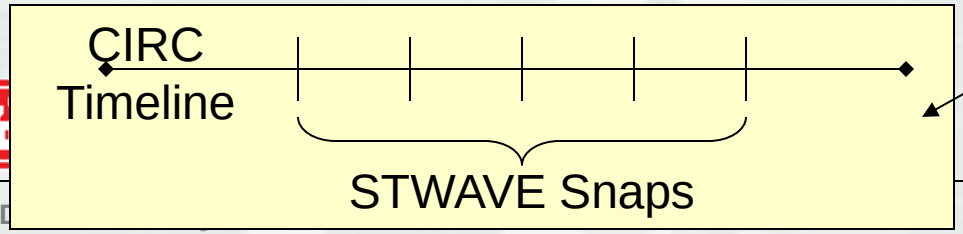
- One unstructured finite element circulation mesh
  - A single instance of ADCIRC/ADH
- One or more structured wave grids
  - Multiple instances of STWAVE
    - Half-Plane
    - Full-Plane



Information to Exchange

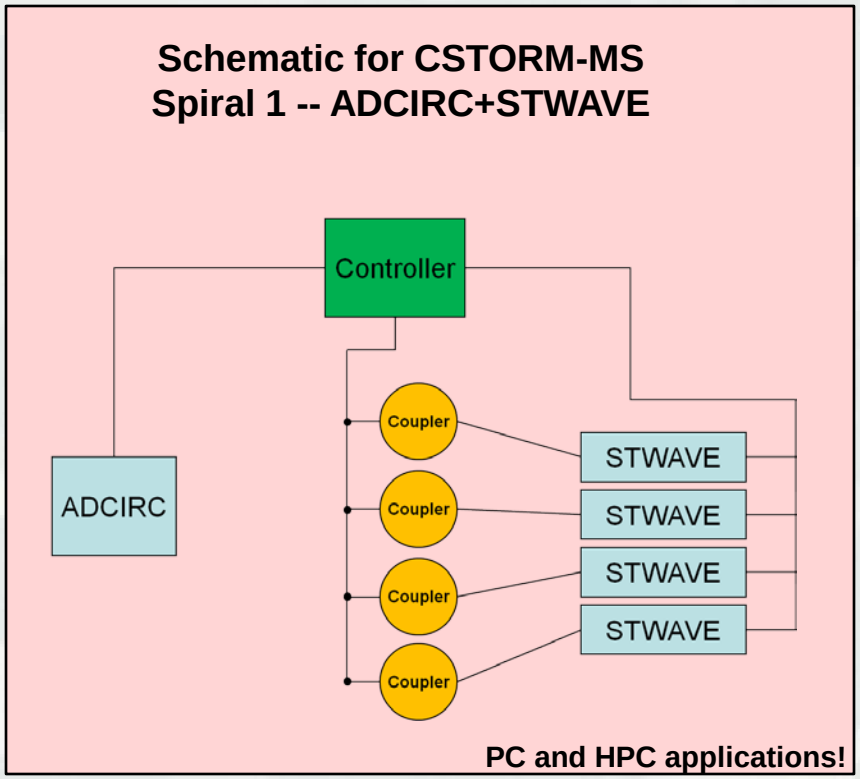


For consistency use the same winds and bathymetry (can be passed also)



Need to be able to synchronize both time and spatial frames of reference.

Circulation ←→ Wave Coupling



- Controller – 1 cpu
- Coupler – 1 cpu (1 coupler/STWAVE)
- CIRC/STWAVE share cpu's

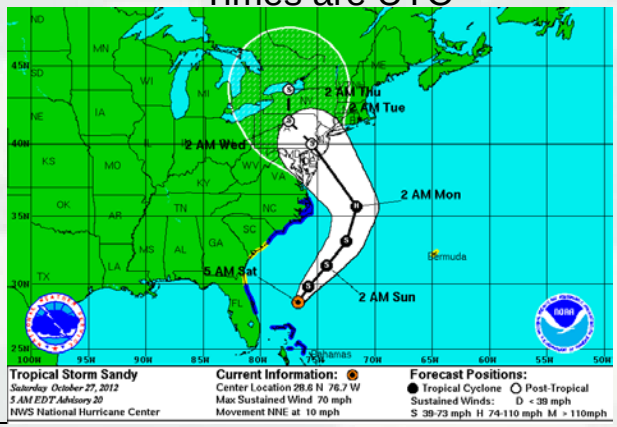
Expandable !

- Model coupling between ADCIRC/ADH and STWAVE is performed using CSTORM-MS Couplers written in FORTRAN and MPI.
- Models run sequentially, so Circ. and Wave models share processors
- One benefit of using the ESMF coupling standards is that the individual codes stay virtually autonomous.
- Specification of how the two models are to interact is done with a simple control file (mf_config.in).
- If more than one STWAVE grid is involved, fine detail control over any overlapping regions can be specified by using a (merge_file).

Hurricane Sandy Response

Advisory 31 Time Series Water Elevation (ft MSL)

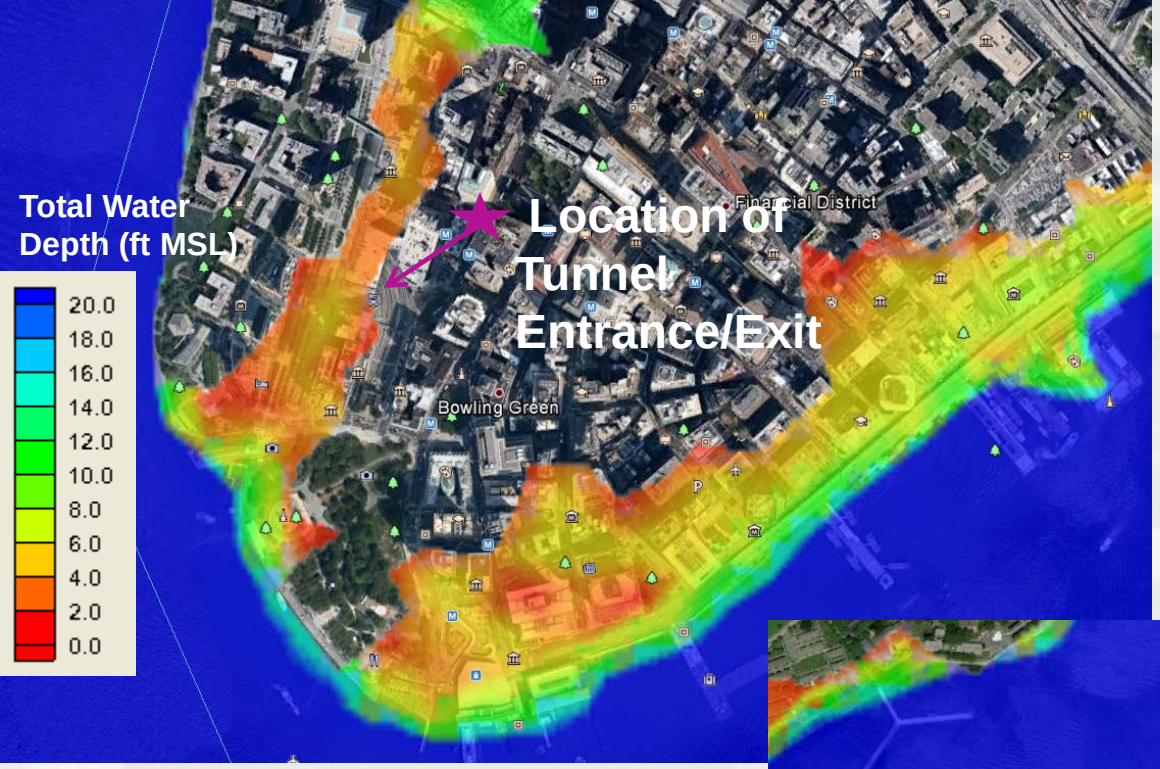
Times are UTC

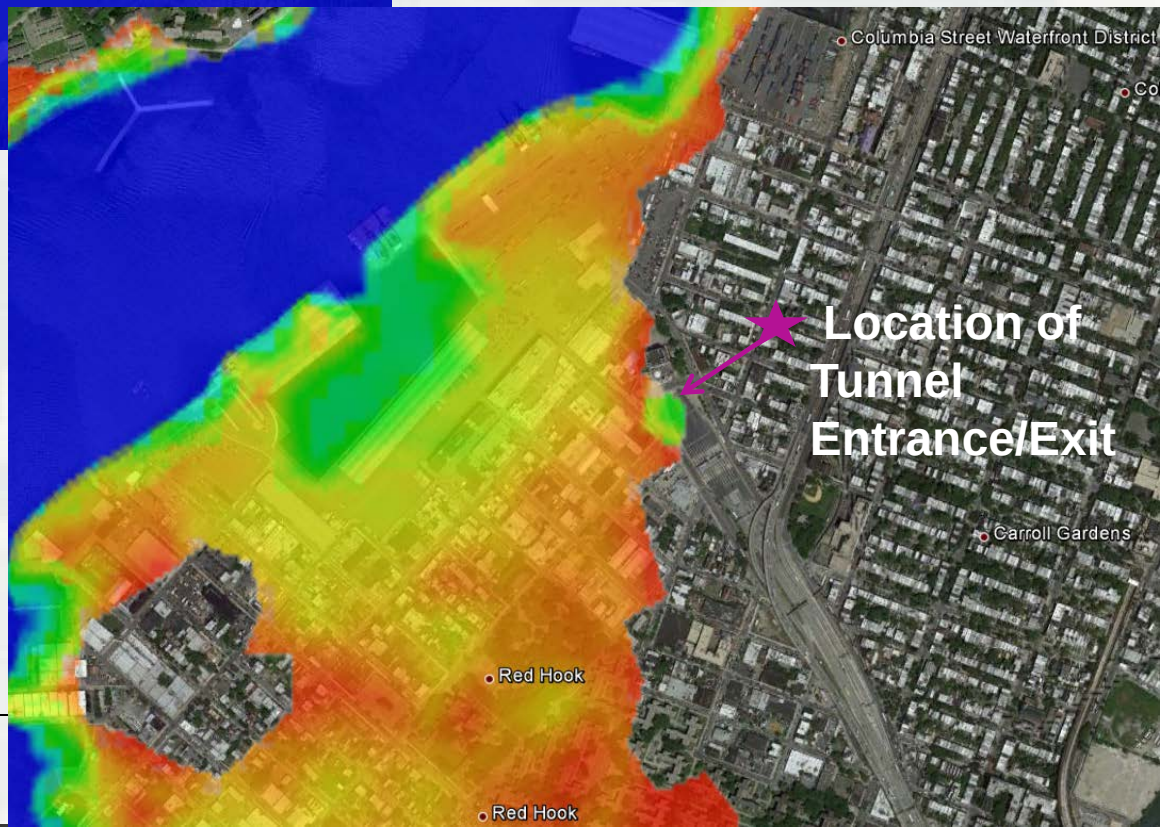


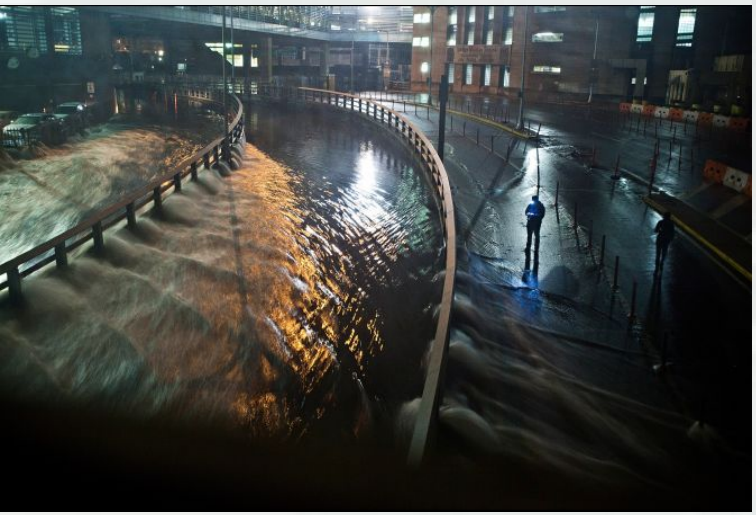
- Used two ADCIRC meshes
  - EC2001FIMP Grid
  - FEMA Region 2 Grid
- Used tidal forcing
- Used an imbedded asymmetric vortex Holland wind/pressure model with inputs derived from the NHC forecast using the ASGS
- *Now able to use winds/pressure from NOAA's GFDL models*

Total Water Depth (feet MSL)

Results from ADCIRC, using the FEMA Region 2 Mesh and NWS Forecast Winds from Advisory 31 of Hurricane Sandy.



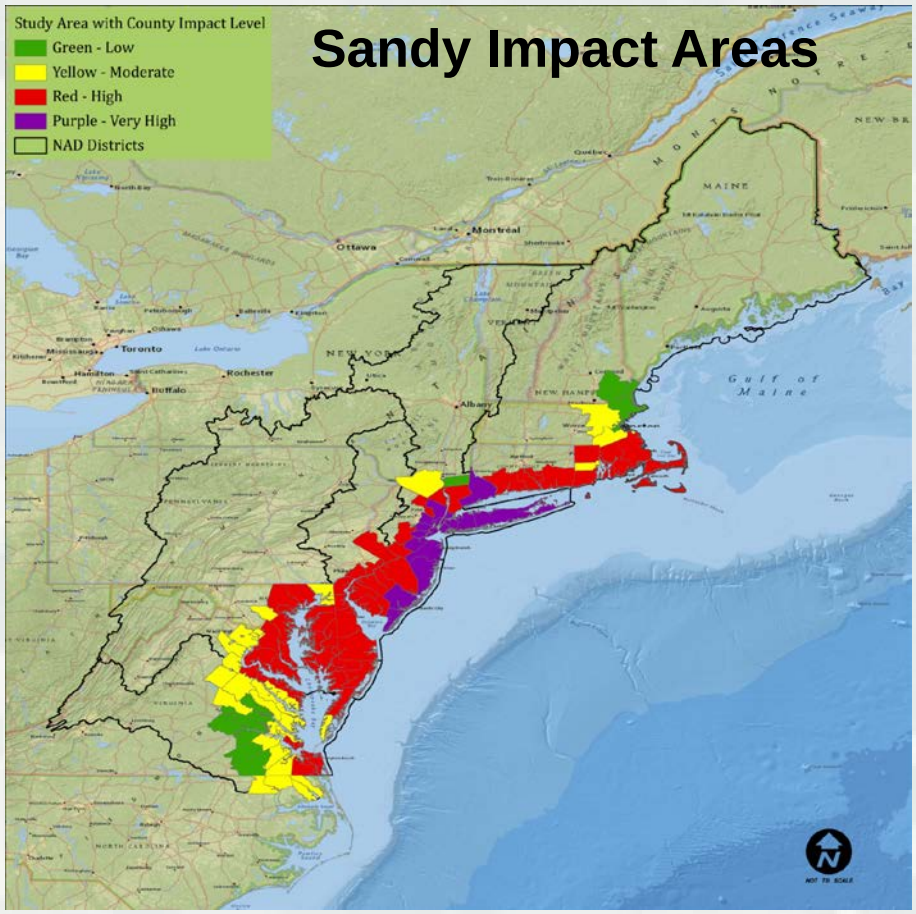




BUILDING STRONG®

Chris Massey USACE-ERDC-CHL

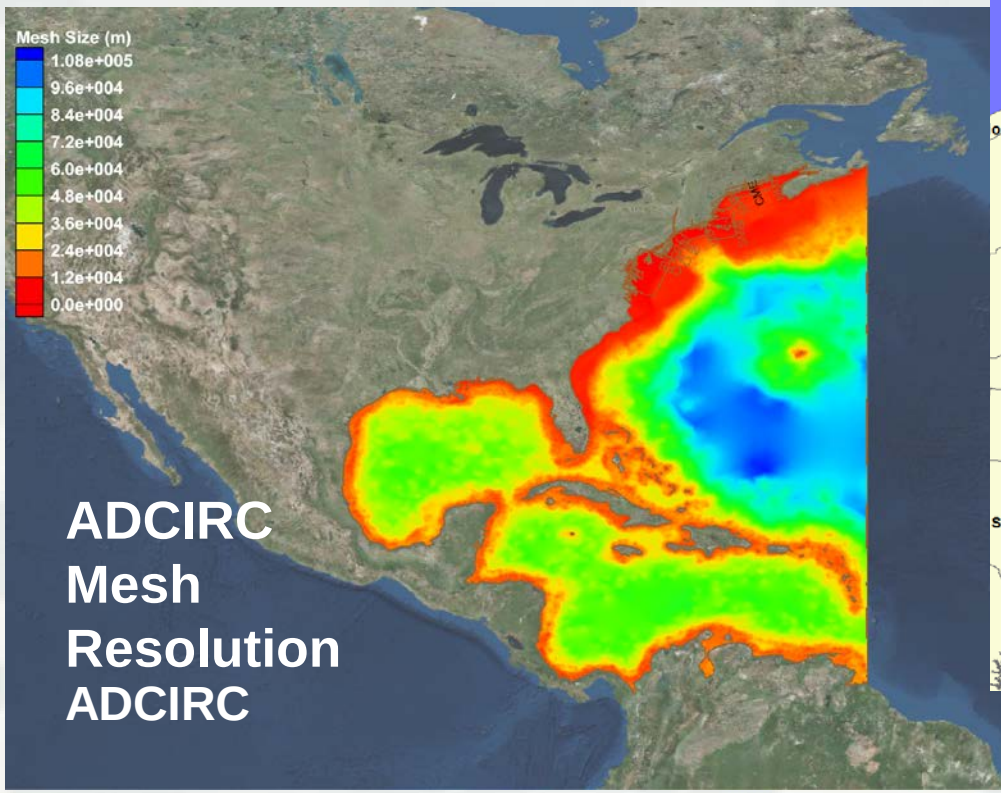
North Atlantic Coast Comprehensive Study

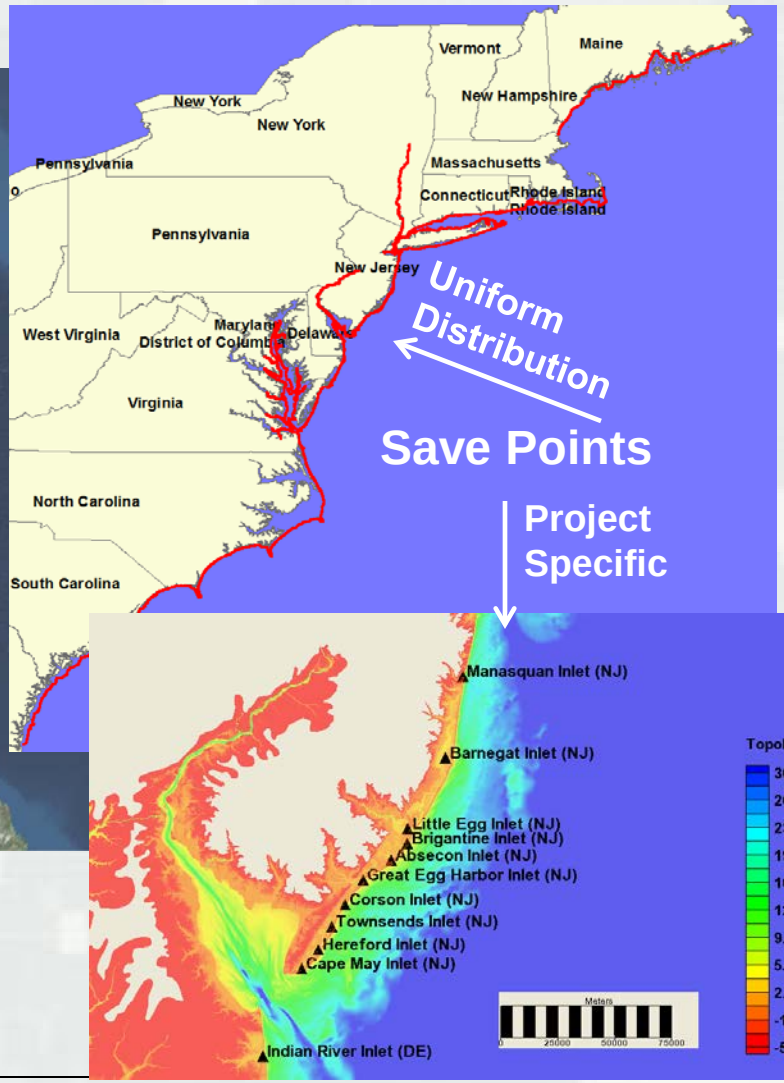


This study computed the joint probability of Hurricane Sandy and historical coastal storm forcing parameters for the east coast region from Maine to Virginia as a primary requirement for project performance evaluation. The primary focus was on **storm winds**, **waves** and **water levels** along the coast for both tropical and extra-tropical storm events.

Chris Massey USACE-ERDC-CHL

NACCS Grids and Save Points

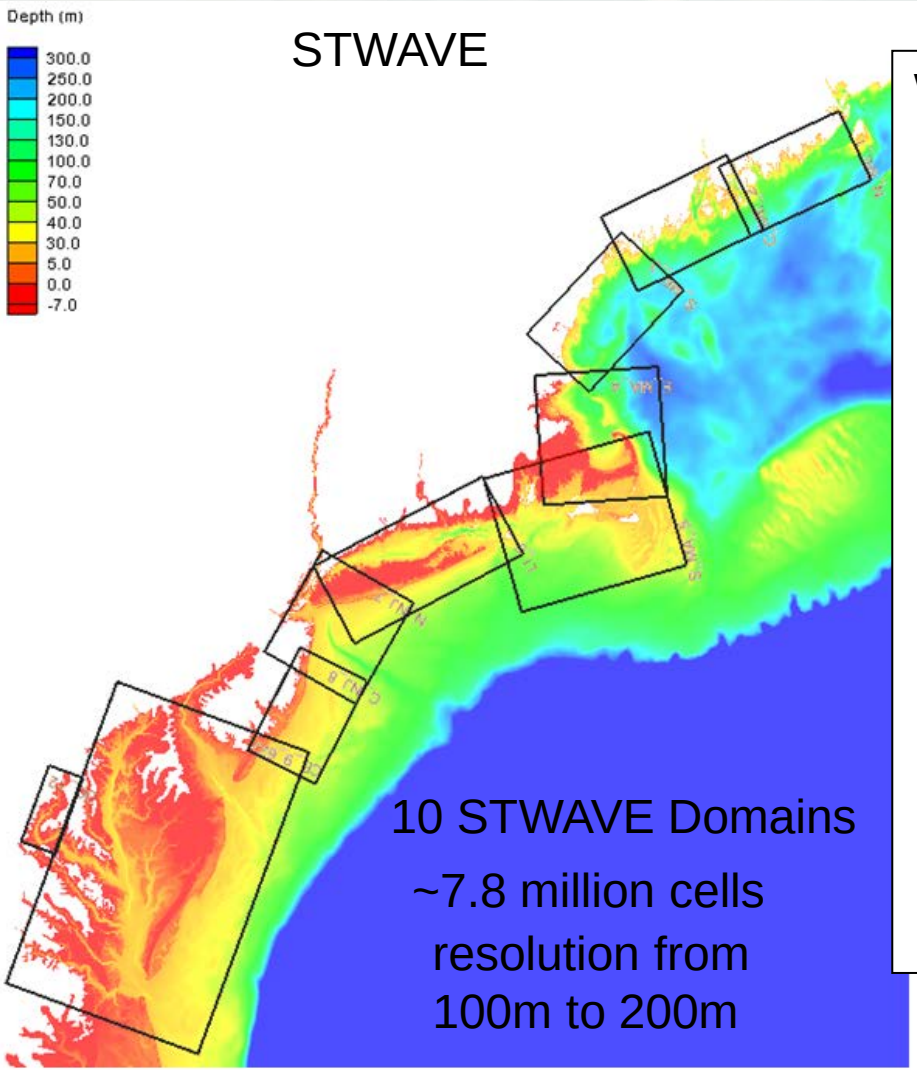




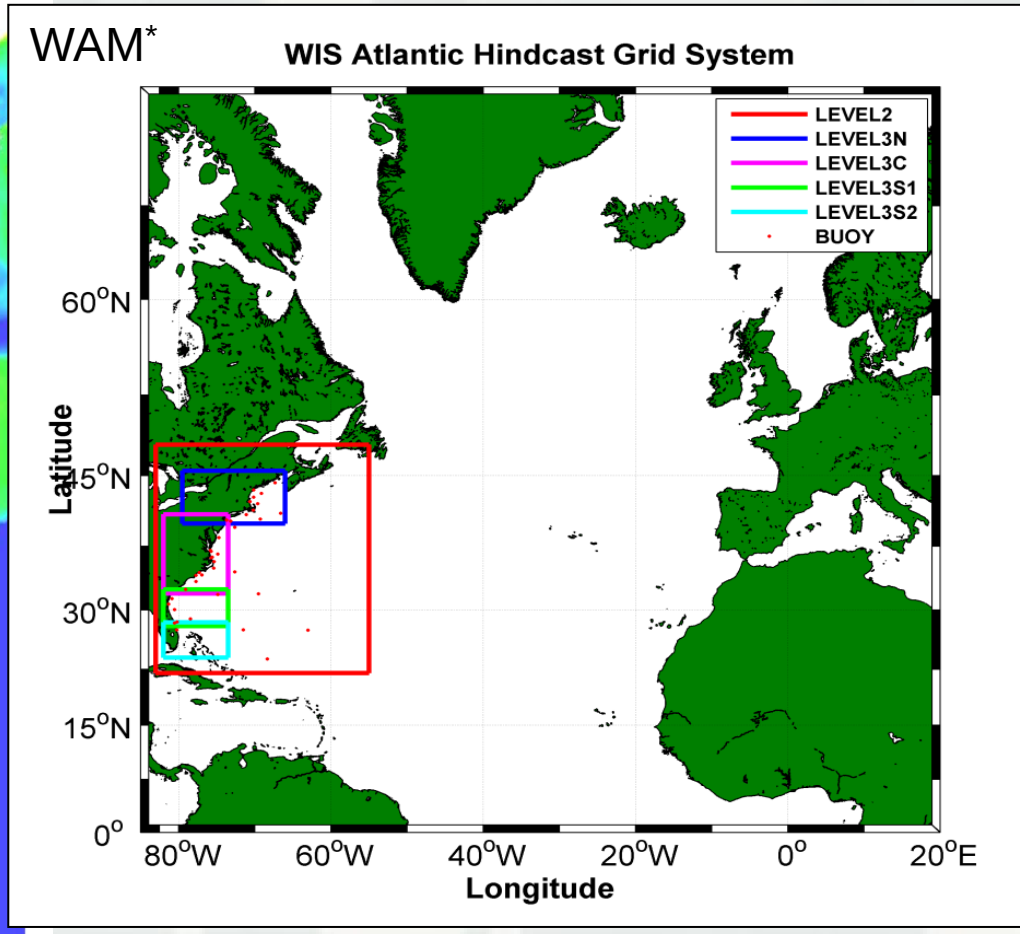
~ 3.1 million nodes
Resolution from 10 m to 100 km

Wave Grids

STWAVE

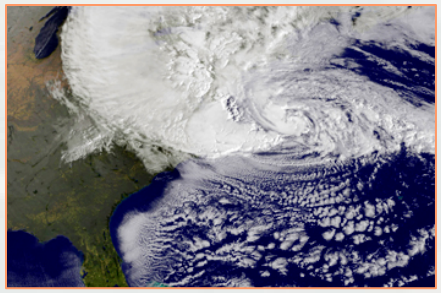


WAM*



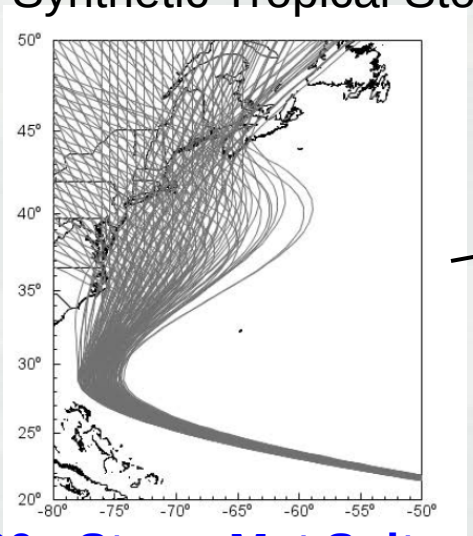
Combined Joint Probability of Coastal Storm Hazards

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

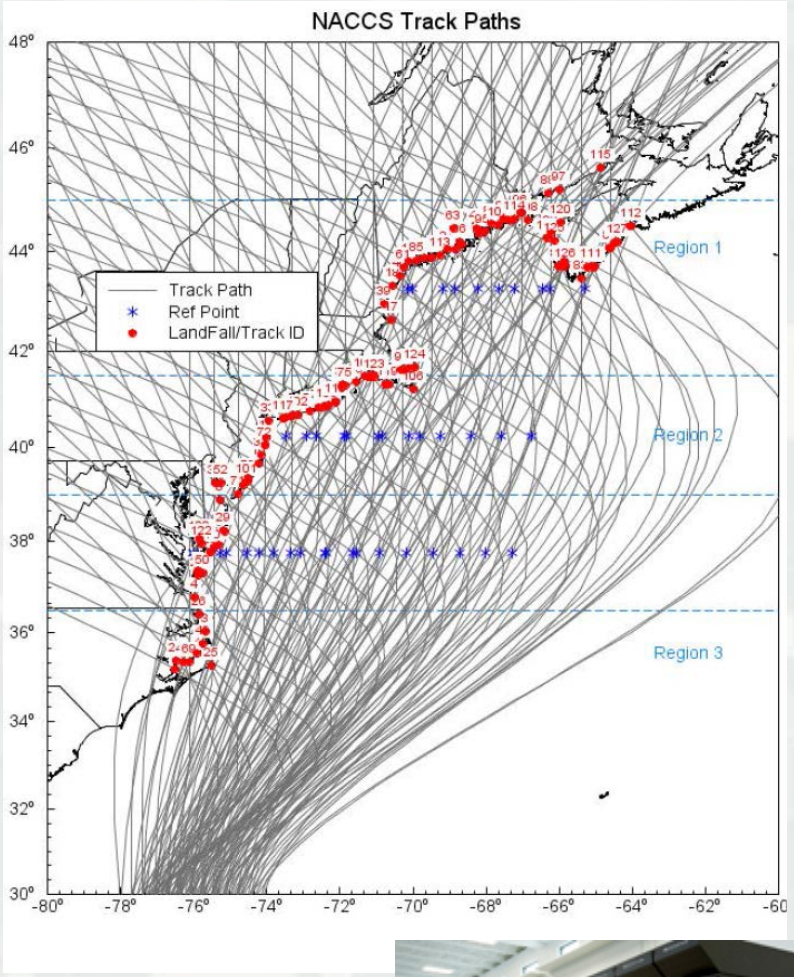


NACCS Storm Suite

- 100 Historical Extratropical Storms
- 1050 Synthetic Tropical Storms



zoom



The 1000+ Storm Met Suite was simulated for 3 conditions:

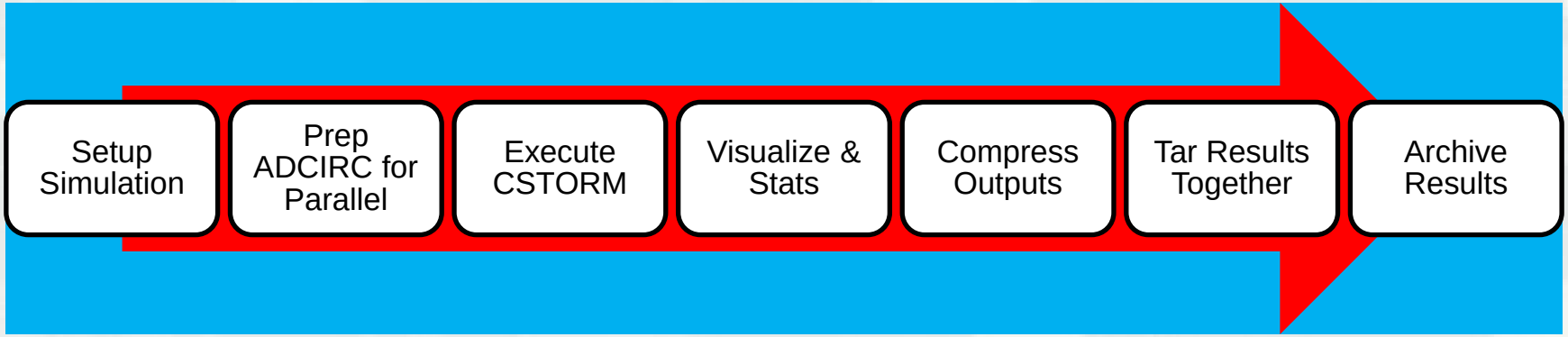
- Surge and wave only
- Two additional water levels to account for sea level change and tide

Total Simulated Events: 3,400+

Over 100 Million CPU Hours

CSTORM Production System

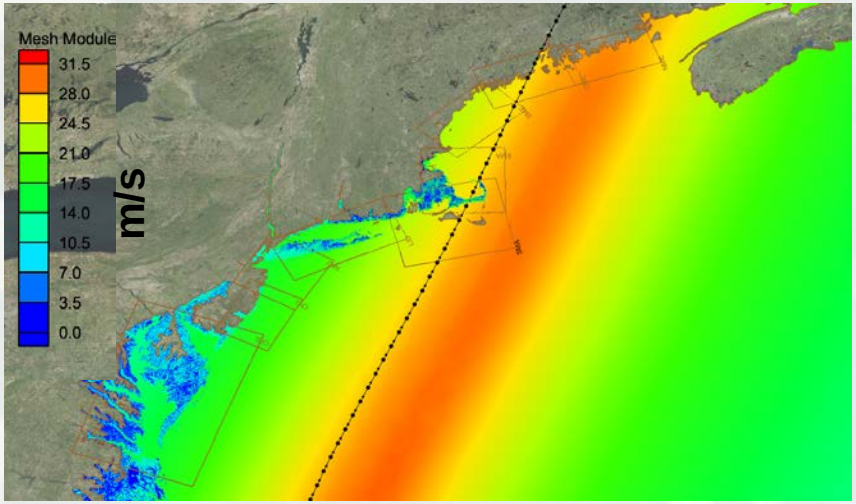
- The **CSTORM Production System** (CSTORM-PS) makes use of standard Linux/Unix tools (bash scripting) and readily available open source software, Python
- The production system allows for
  - Rapid preparation of necessary input files for individual CSTORM-MS production runs (Reduces chances for human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



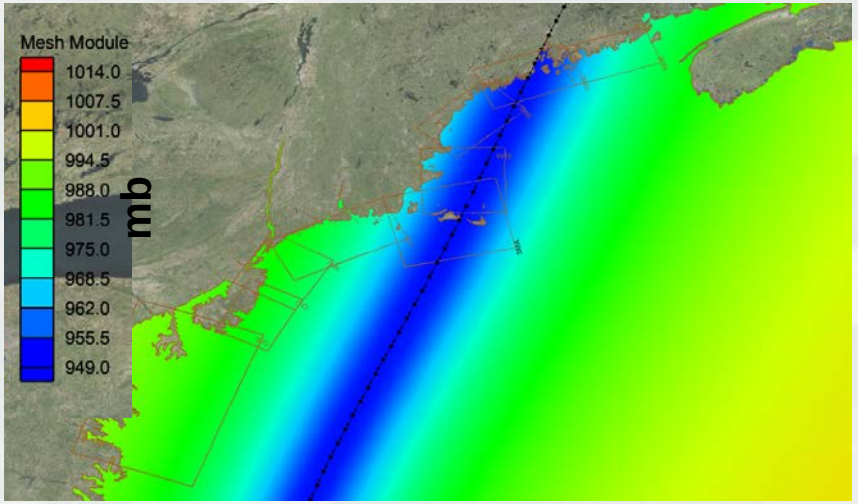
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Maximum Wind Speeds



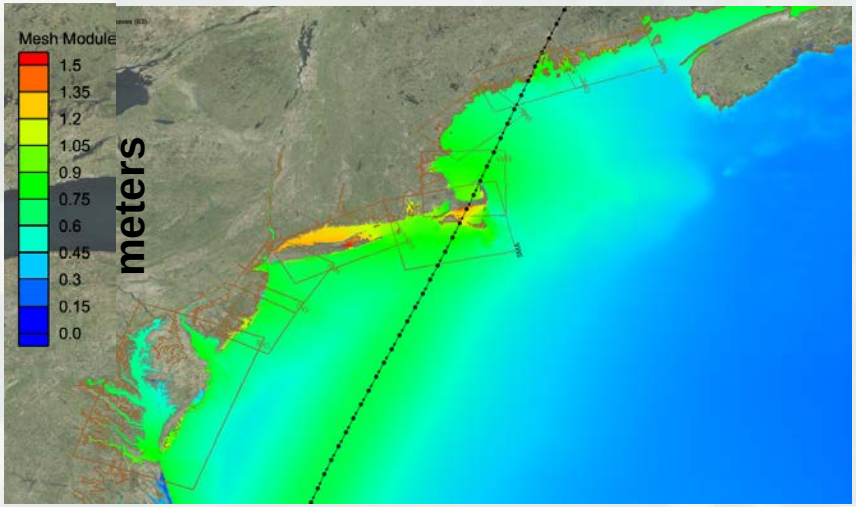
Minimum Central Pressure



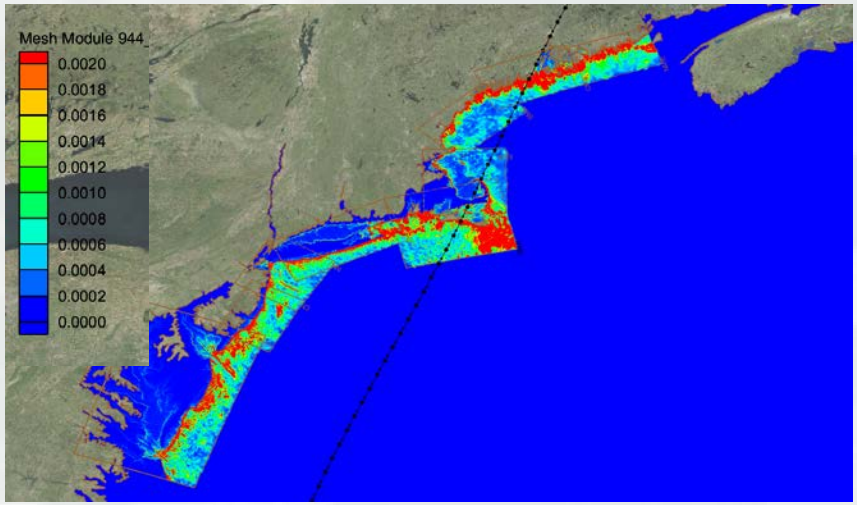
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Maximum Sea Surface Elevation



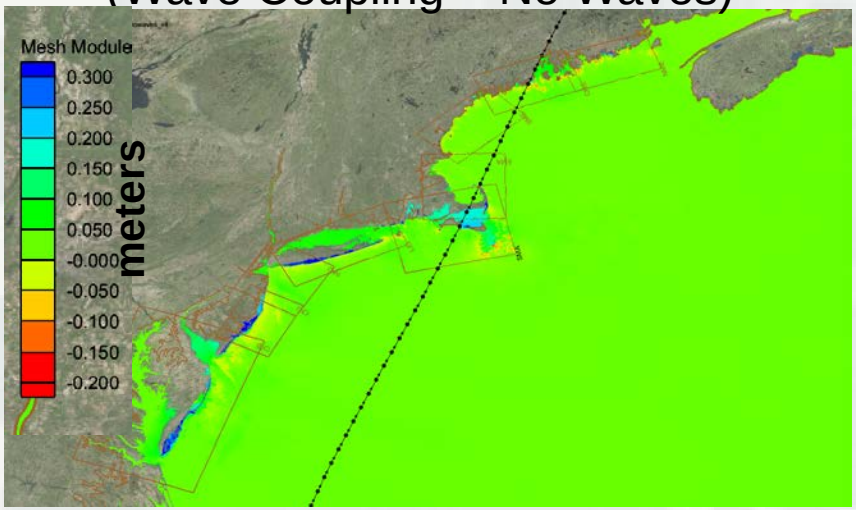
Maximum Magnitude Gradients of Surface Wave Stress



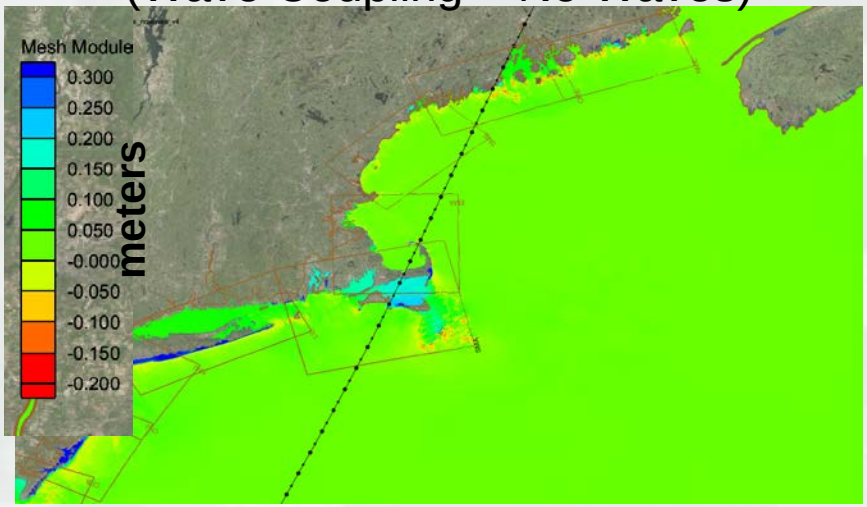
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Difference Max. Sea Surface Elevation (Wave Coupling – No Waves)



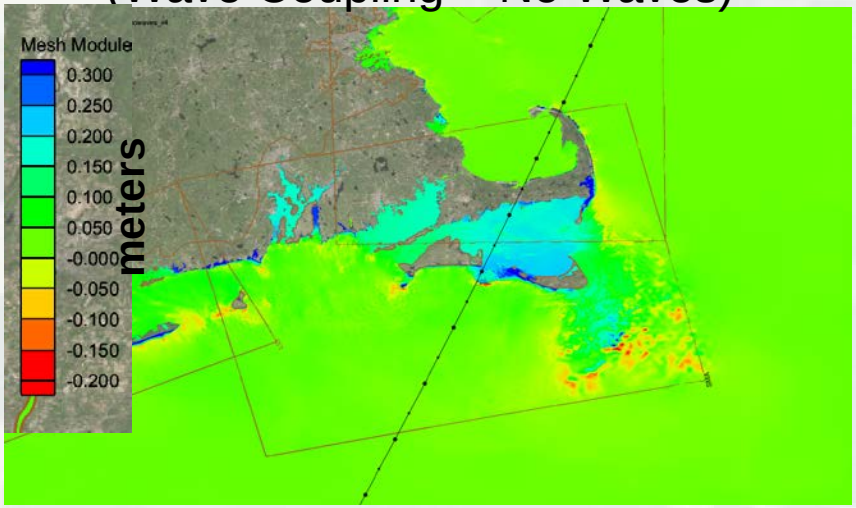
Difference Max. Sea Surface Elevation (Wave Coupling – No Waves)



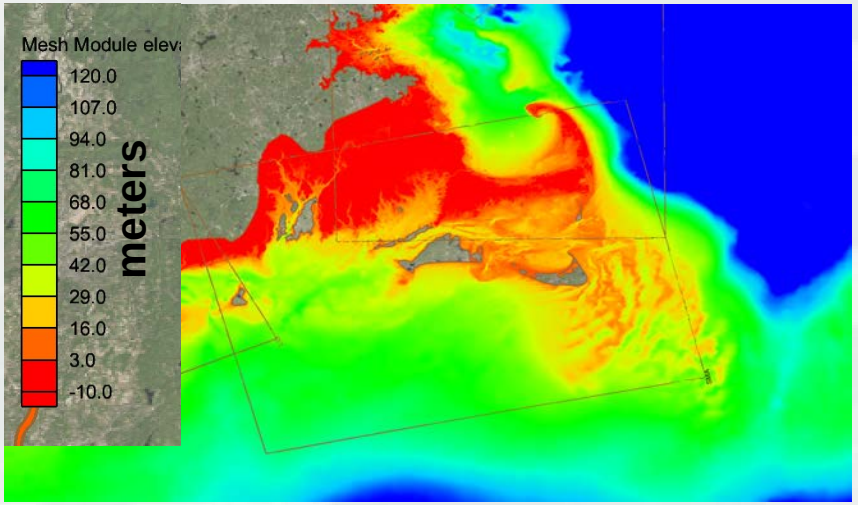
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Difference Max. Sea Surface Elevation (Wave Coupling – No Waves)



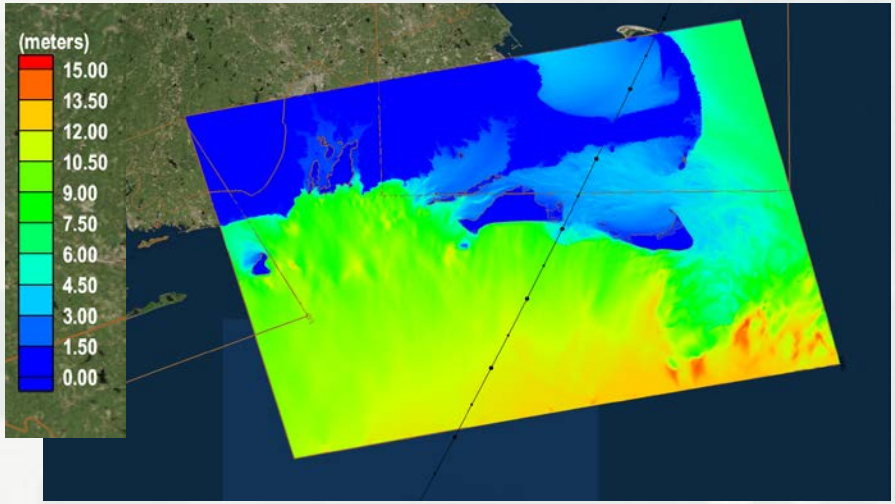
Topography/Bathymetry



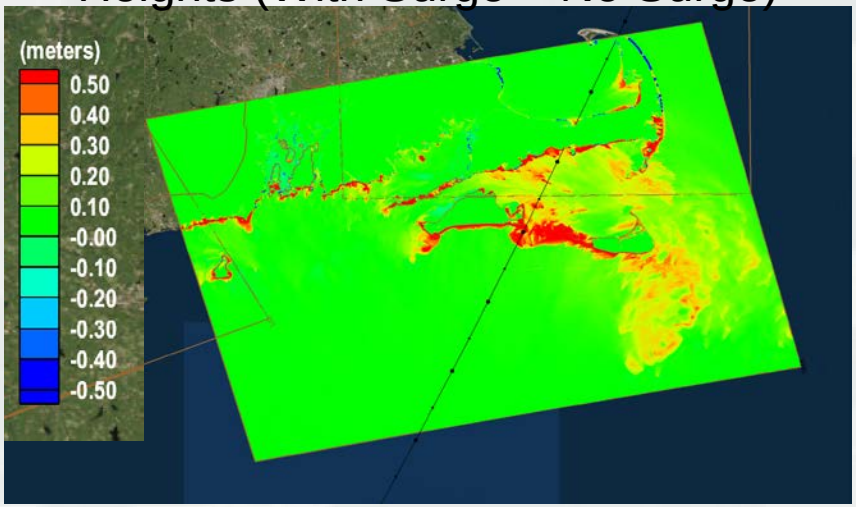
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Maximum Significant Wave Heights



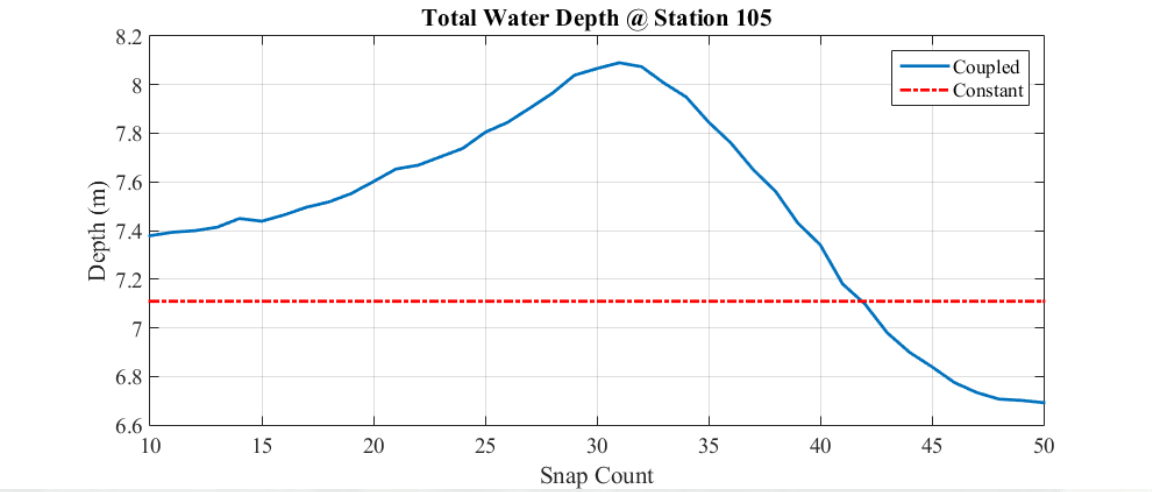
Difference Maximum Significant Wave Heights (With Surge – No Surge)



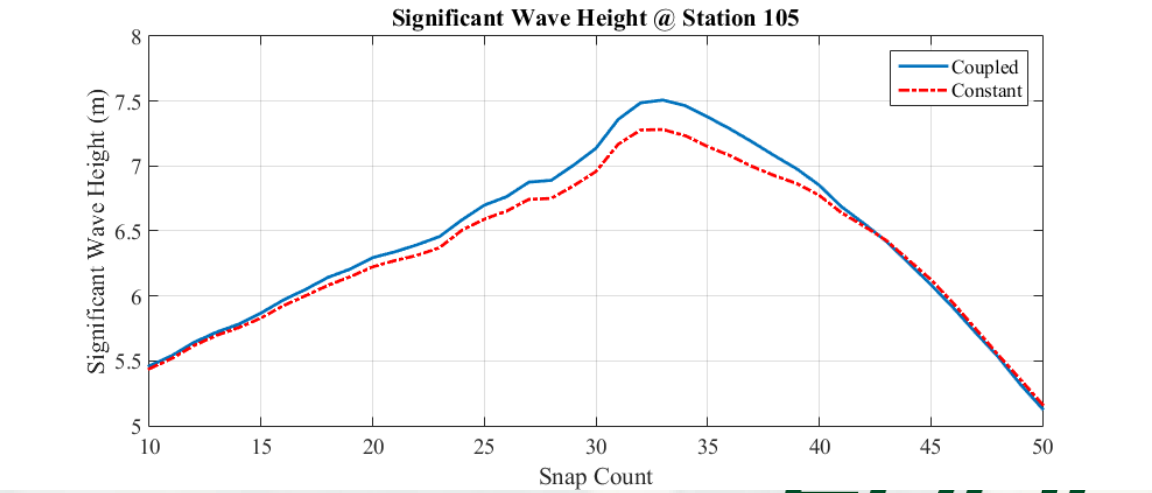
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Total Water Depths at Station 105



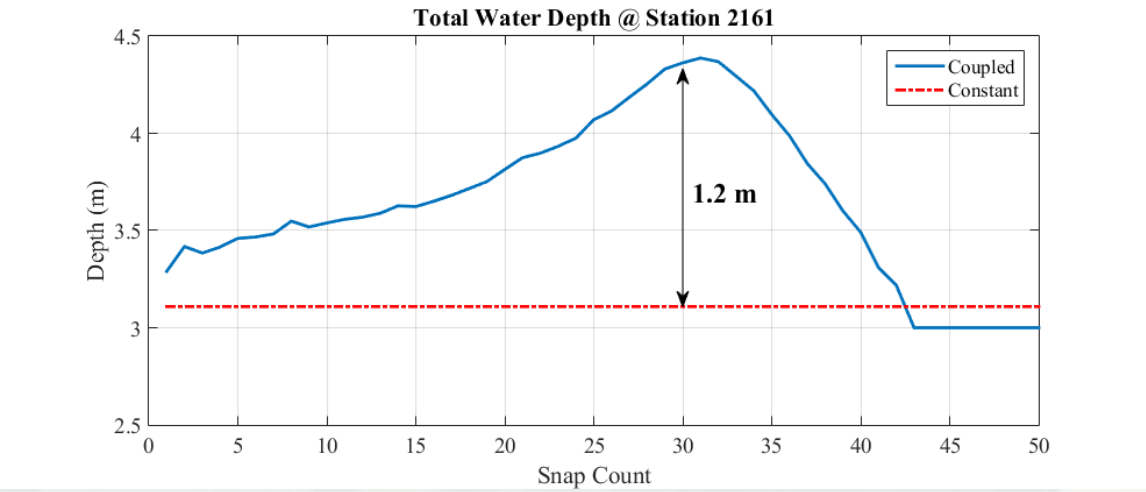
Significant Wave Height at Station 105



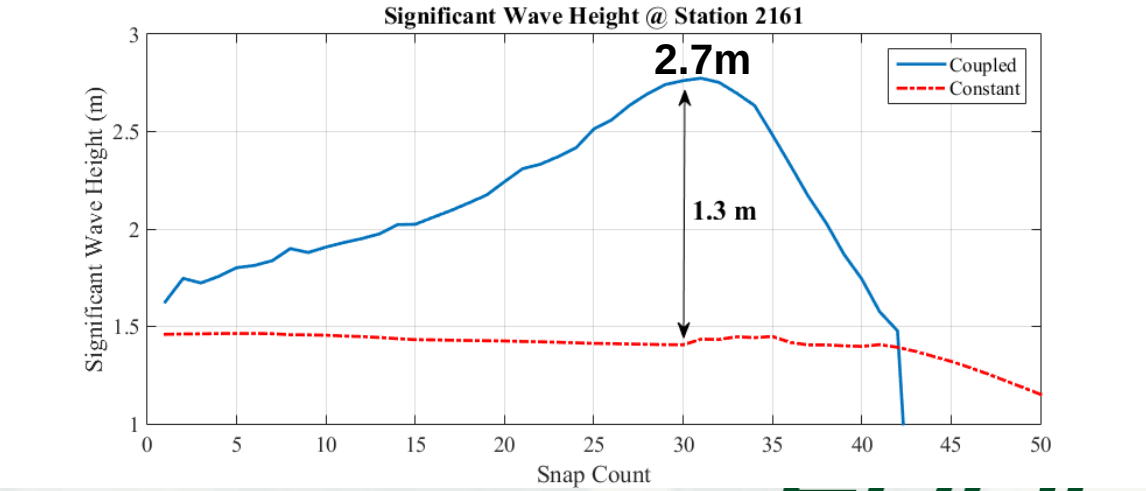
Effects of Wave-Surge Coupling

Synthetic Tropical Storm 0944

Total Water Depths at Station 2161

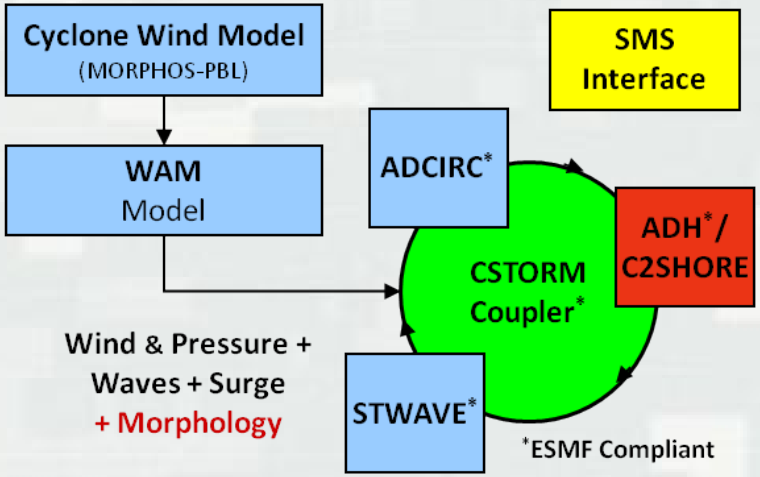


Significant Wave Height at Station 2161



CSTORM System Components 2015

- **Winds/Pressure:** PBL Cyclone Model
- **Waves:**
  - Regional: WAM
  - Nearshore: STWAVE*
  - Unstructured WaveWatch3* (FY15/FY16)
- **Circulation/Surge:**
  - ADCIRC*
  - ADH*
- **Morphology:** SEDLIB/C2Shore
- **Coupling Framework:** CSTORM-MS*
- **Graphical User Interface:** SMS
- **Overland Flow** – GSSHA (FY16/FY17)



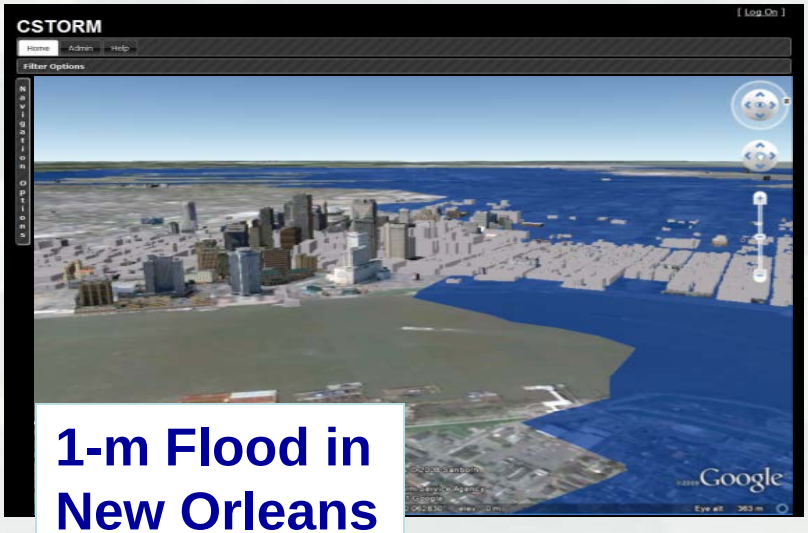
Earth System Modeling Framework (ESMF) Compliance

- Multiple federal agency support ESMF
- ESMF compliant models are readily available to be linked with each other and with other agencies' ESMF compliant models.
- Individual models stay virtually autonomous when coupling.

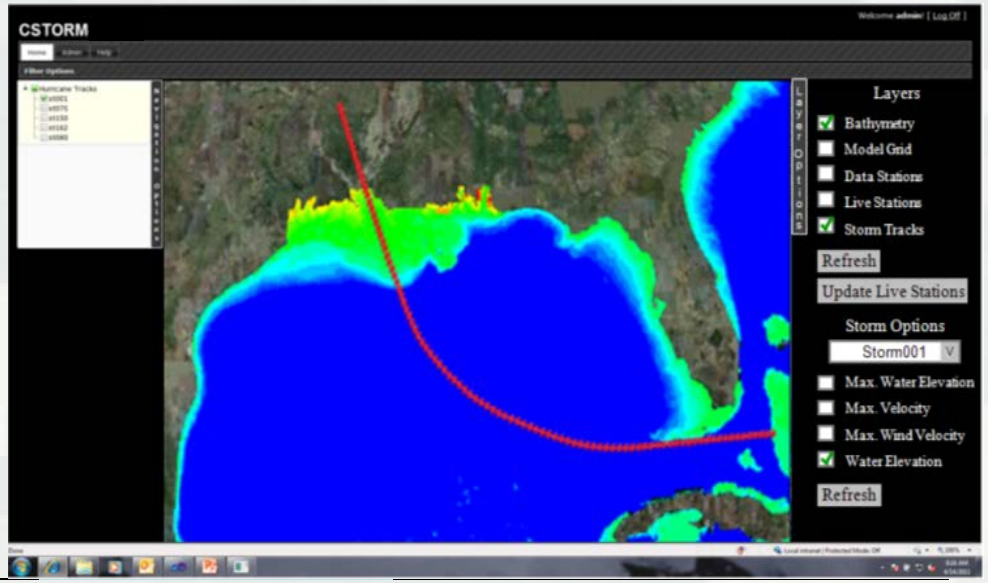
Coastal Hazards System (CHS)

https://chs.erdc.dren.mil

- 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)



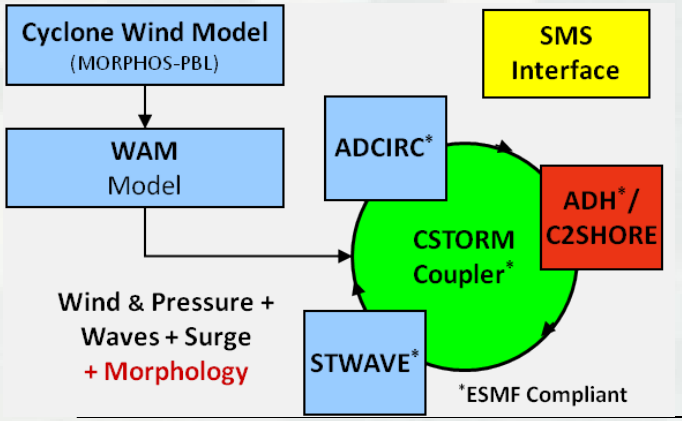
1-m Flood in New Orleans

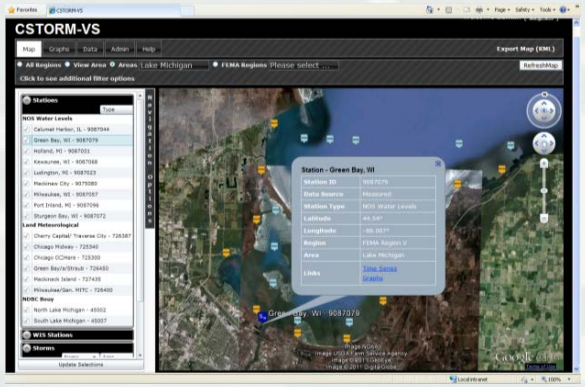


Summary

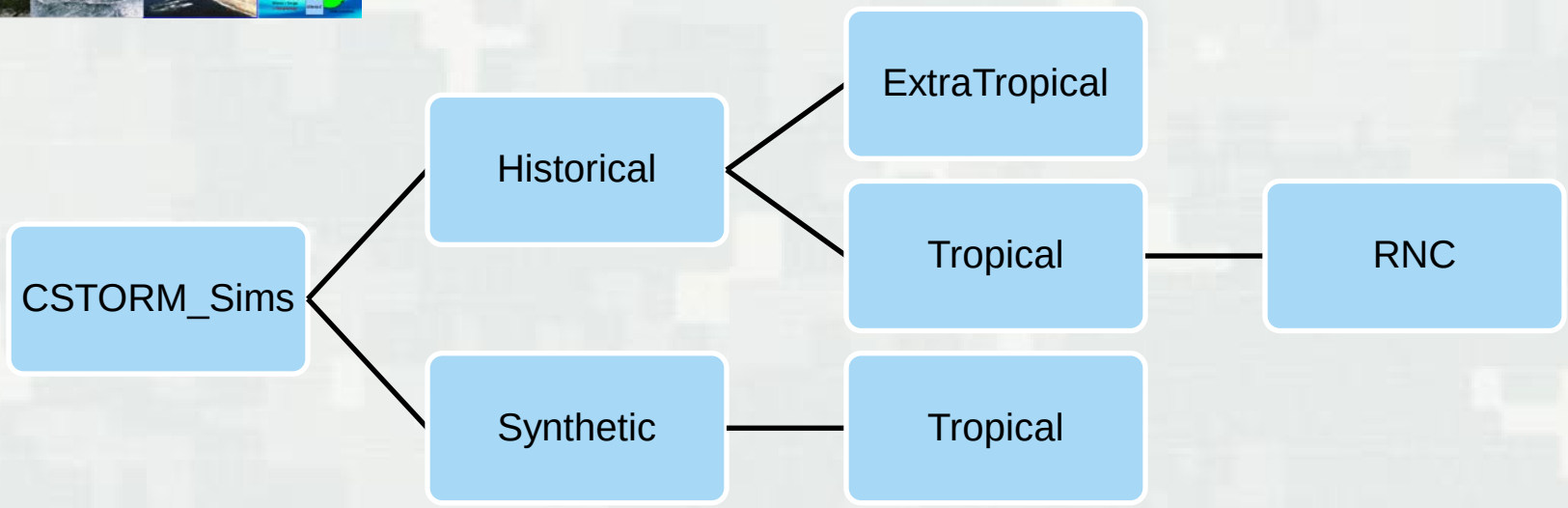
- CSTORM-MS is an efficient, robust, extensible modeling system for quantifying the risk of coastal communities to storm events.
- Its' streamlined workflow saves time and reduces both computational and personnel cost.
- Model data feeds into CHS for easy access and reuse purposes.
- Stay connected to other users and get help via the Knowledge Hub

Coastal Hazards System Webpage
https://chs.erdc.dren.mil





Basic Directory Hierarchy



RNC = Run_NM_Tides_TN_SLC_SN_RFC_RN_WAV_WN_GCP_PN_UID_IDV

- Run_NM = Storm Number, NM = 0001 to 1050
- Tides_TN = Tidal Scenario, TN = 0 to 5
- SLC_SN = Sea Level Change/Steric Adjustment Scenario, SN = 0 to 2
- RFC_RN = River Forcing Conditions, RN = 0 to 2
- WAV_WN= Waves Off/On, WN = 0 or 1
- GCP_PN = Grid Configuration Packet
- UID_IDV = User Identification, IDV = person performing simulation