ERDC'S COASTAL STORM MODELING SYSTEM

SOUTH ATLANTIC COAST STUDY

Chris Massey, PhD

Research Mathematician,

USACE-ERDC

Coastal & Hydraulics Lab

2nd International Workshop On Waves, Storm Surges And Coastal Hazards
Melbourne, Australia November 10-15, 2019

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ENGINEER RESEARCH & DEVELOPMENT CENTER

U.S. ARMY ENGINEER DIVISION SOUTH ATLANTIC

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Team Acknowledgements

- Chris Massey – (CSTORM Modeling Team Lead)
- Norberto Nadal-Caraballo – (Statistics and Storms Lead)
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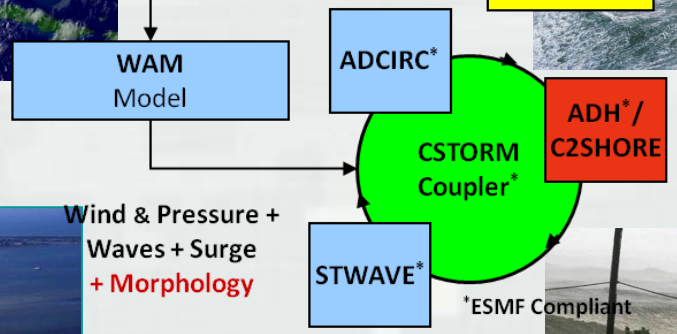
- USACE South Atlantic Division (SACS) Project Team
- Andy Cox of OceanWeather Inc. -- (Storm Climatology and Storms Support)
- Joannes Westerink (Notre Dame) – New ADCIRC Mesh (SA)
- Scott Hagen (LSU) – New ADCIRC Mesh (GoM)

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.



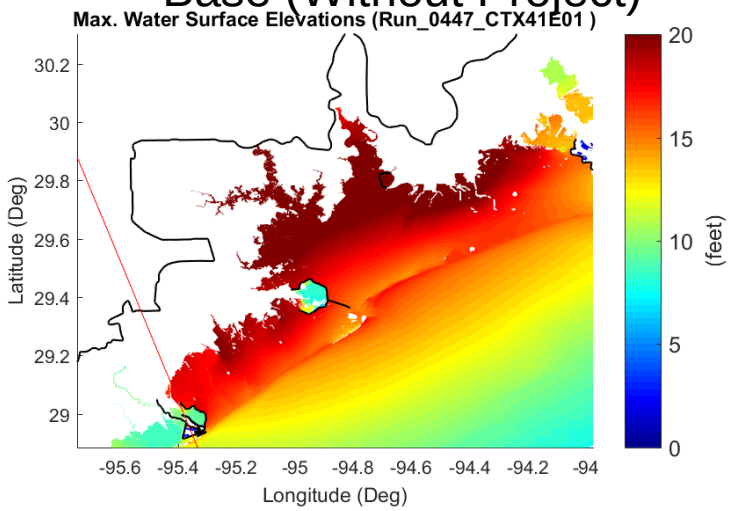
Next Generation Workflow

Expandable and upgradeable system.

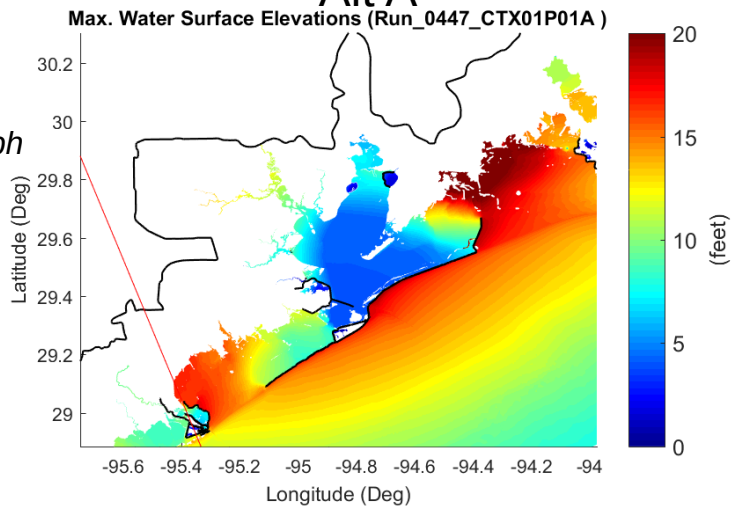
Provides for a robust, standardized approach to model coupling. Used for establishing the risk of coastal communities to future occurrences of storm events and evaluating flood protection measures.

Example Coastal TX Project Alternative Comparison

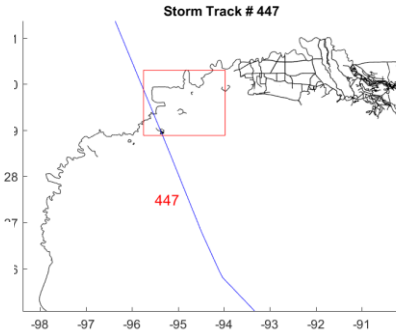
Base (Without Project)



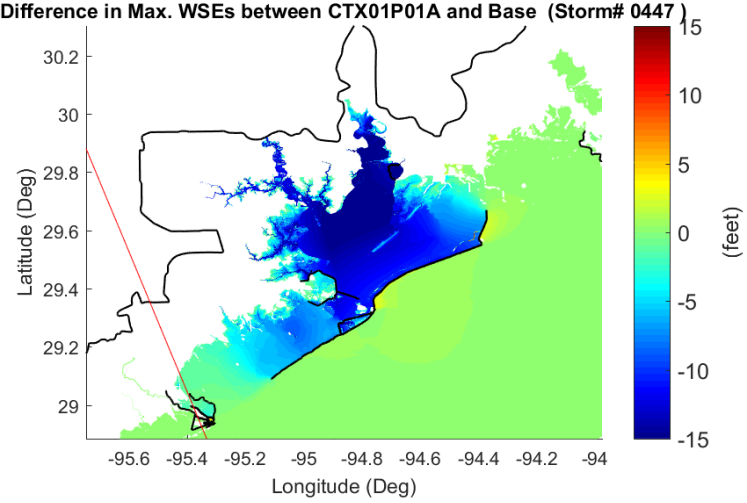
Alt A



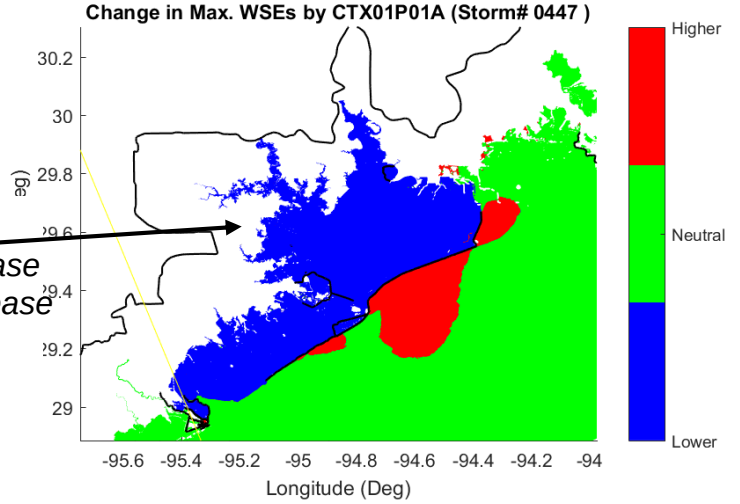
Max. Wind Speed: 105 mph (Cat. 2)
Min. Cp: 905 mb
Rmax: 44.6 nm
Forward Speed: 8.6 kts



Difference (Alt A – Base)



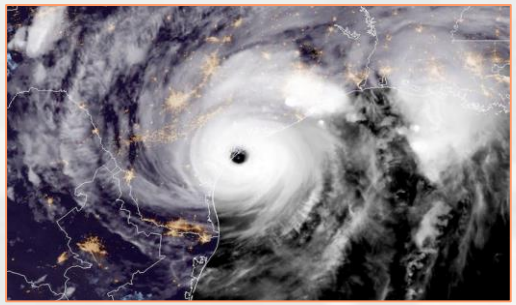
Difference (Alt A – Base)



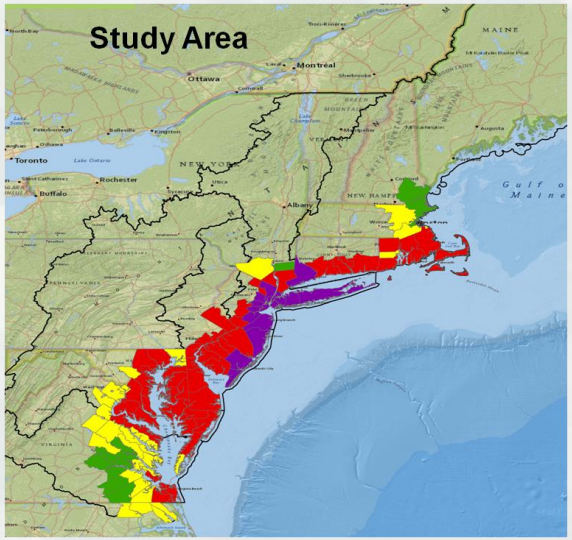
Change in WSEs:
Higher: > 1/2 ft increase
Lower: > 1/2 ft decrease
Neutral: in between

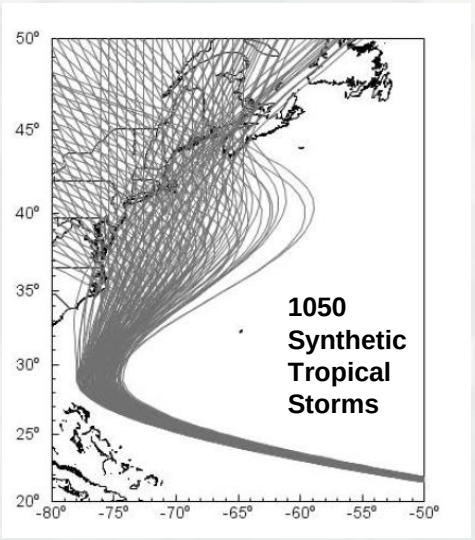
Combined Joint Probability of Coastal Storm Hazards

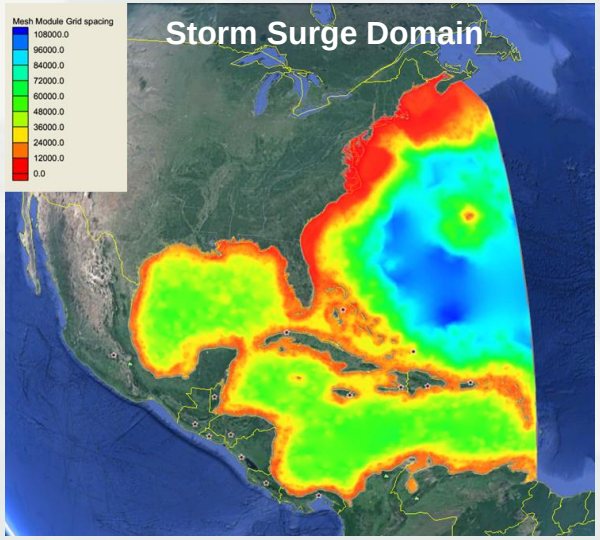
- ***Forcing***
  - Tropical cyclones
  - Extratropical cyclones
  - River Flows
- ***Response***
  - Water level (storm surge, astronomical tide, SLC)
  - Currents
  - Wave height, peak period, direction
  - Wind speed, direction



North Atlantic Coast Comprehensive Study



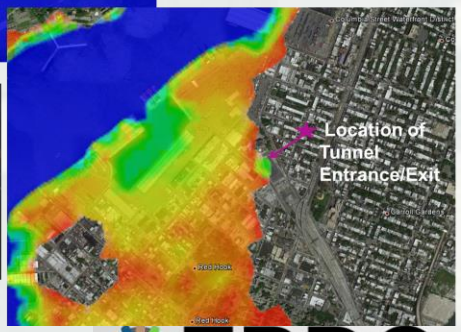




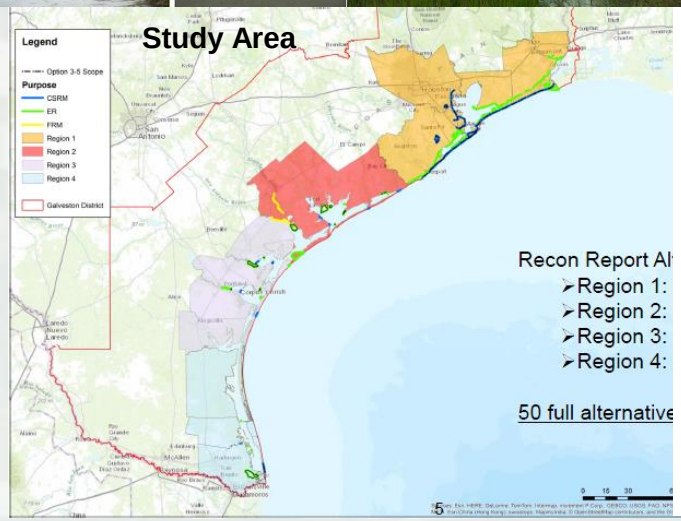
- Over 3400 high resolution CSTORM simulations for winds, waves and surge levels including sea level rise scenarios.
- 1,050 Synthetic Tropical + 100 Extra Tropical Storms
- Water Levels:
  - Present Day No Tides
  - Present Day Random Tides
  - 1m SLR No Tides

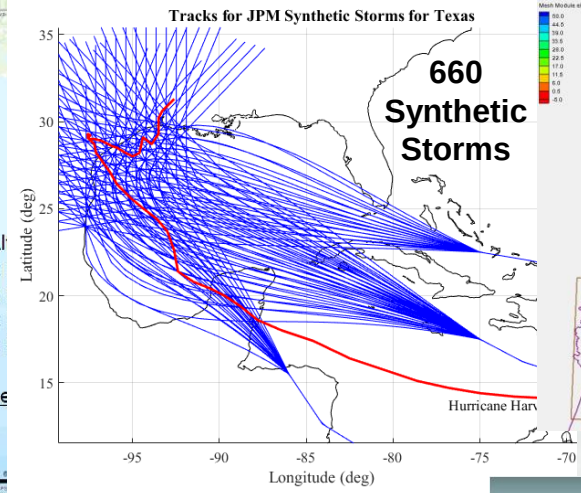
Total Water Depth (feet MSL)

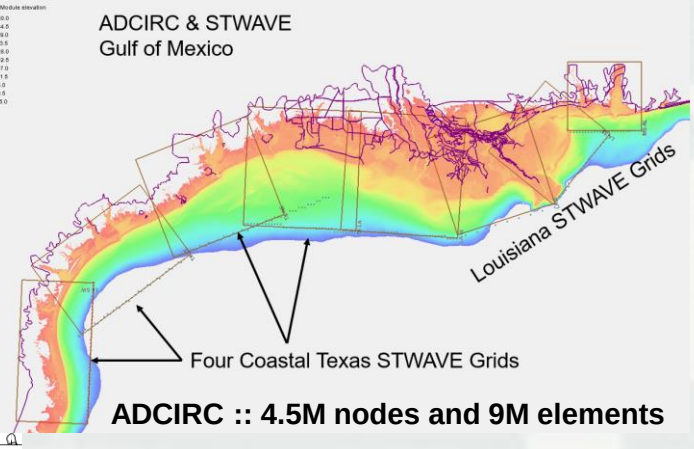
Results from ADCIRC, using the FEMA Region 2 Mesh and NWS Forecast Winds from Advisory 31 of Hurricane Sandy.



Coastal Texas Comprehensive Study







- Over 1,900 high resolution base CSTORM simulations for winds, waves and surge levels including 2 sea level rise scenarios
- 660 Synthetic Tropical Storms
- Water Levels: Present Day, 1.5 m SLR, and 0.75m SLR
- With project alternatives simulations for feasibility study (Four alternative designs)

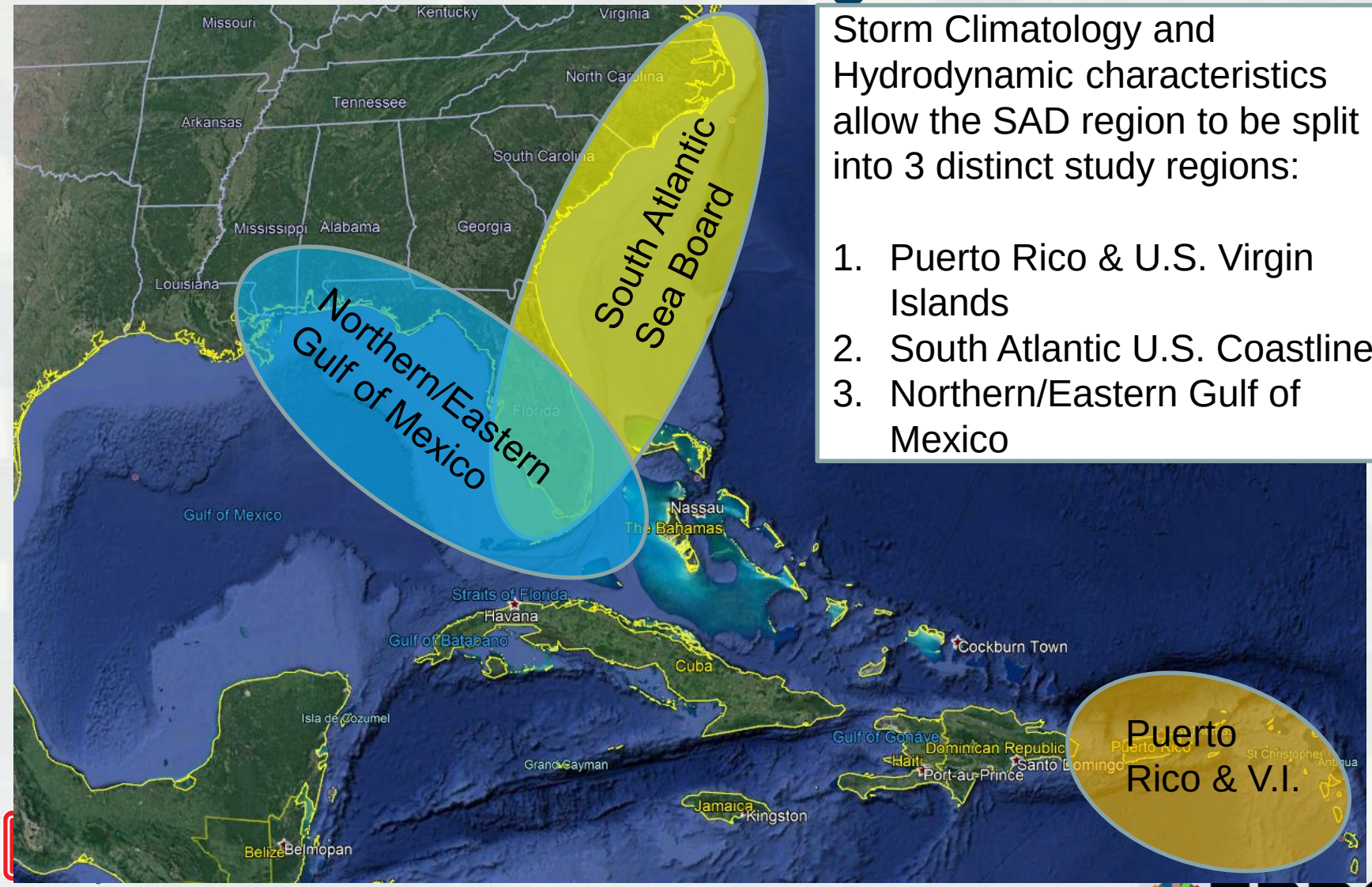
SACS

The South Atlantic Coastal Study was authorized by Section 1204 of WRDA 2016. Guidance was issued on Nov. 16, 2017, requiring the study to follow planning guidance for watershed assessments. Public Law 115-123 provided Federal funding in the amount of $16M to cover 100% of the Study costs.

Study Goals

- Provide a Common Operating Picture of Coastal Risk
  - Provide decision-makers at all levels with a comprehensive and consistent regional assessment of coastal risk.
- Identify High-Risk Locations/Focus Current and Future Resources
  - Enable resources to be focused on the most vulnerable areas
- Identify and Assess Risk Reduction Actions
  - Assess actions that would reduce risk to vulnerable coastal populations
- Promote and Support Resilient Coastal Communities
  - Ensure a sustainable coastal landscape system, considering future sea level rise scenarios and climate change. Provide information to stakeholders to optimize existing efforts to reduce risk.
- Promote Sustainable Projects and Programs
  - Develop and provide consistent foundational elements to support coastal studies and projects; Regionally manage projects through Regional Sediment Management and other opportunities.

Three Distinct Study Regions for Modeling/Statistics

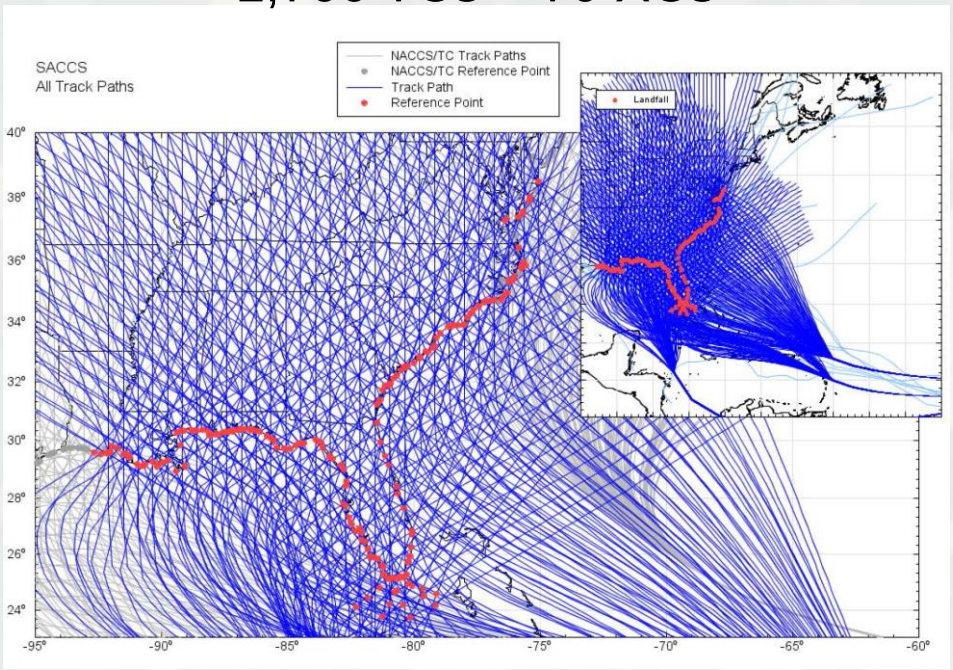


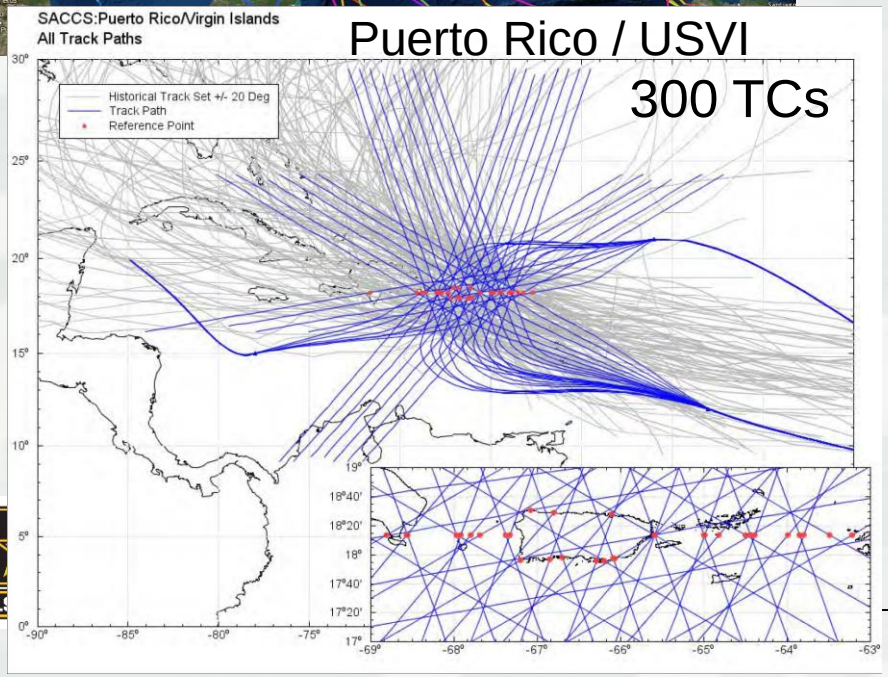
Storm Climatology and Hydrodynamic characteristics allow the SAD region to be split into 3 distinct study regions:

1. Puerto Rico & U.S. Virgin Islands
2. South Atlantic U.S. Coastline
3. Northern/Eastern Gulf of Mexico

South Atlantic Storm Suite

South Atlantic / Gulf of Mexico
1,700 TCs + 70 XCs





Puerto Rico / USVI
300 TCs

Tropical Cyclone Parameters (CONUS)

- Heading direction: -60º, -40º, -20º, 20º, 40º, 60º
- Central pressure deficit: 8 hPa to 148 hPa
- Radius of maximum winds: 8 km to 156 km
- Translational speed: 8 km/h to 60 km/h
- Holland B: 0.48 to 1.82

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Modeling Scenarios

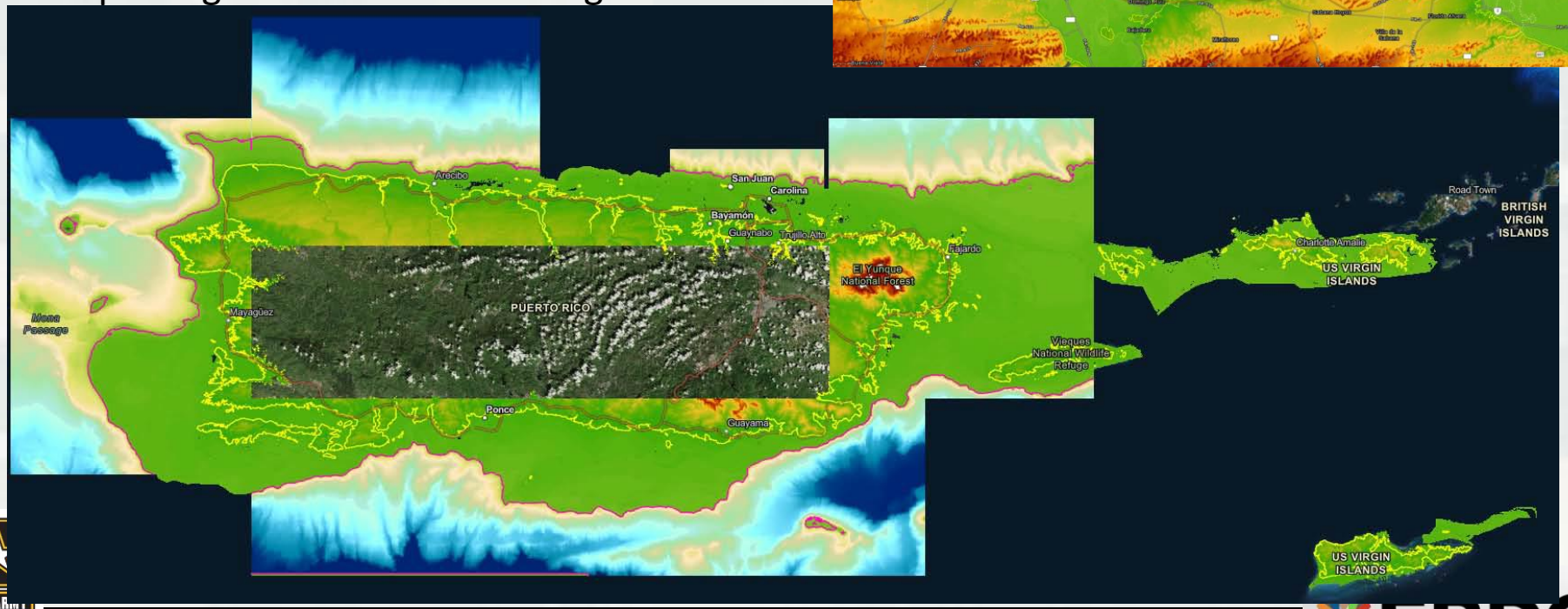
- Sets of Modeling and PCHA results for CHS South Atlantic:
  1. Puerto Rico & U.S. Virgin Islands ~ 300 Storms
     - Storm surge + waves
     - Storm surge + waves + SLC 1 (50% of storms)
     - Storm surge + waves + SLC 2 (50% of storms)
  2. South Atlantic (North Carolina to South Florida) ~1200 Storms
     - Storm surge + waves
     - Storm surge + waves + astronomical tides
     - Storm surge + waves + SLC 1 (50% of storms)
     - Storm surge + waves + SLC 2 (50% of storms)

     (Includes Tropical and Extratropical Storms)
  3. Gulf of Mexico ~ 750 Storms
     - Storm surge + waves
     - Storm surge + waves + SLC 1 (50% of storms)
     - Storm surge + waves + SLC 2 (50% of storms)

JALBTCX SACS DEM Development

Puerto Rico and US Virgin Islands

- Esri Mosaic Dataset comprised of 11 individual source mosaic datasets
- Source mosaic datasets are ranked 1-11 (1 is most-recent is the top layer).
- Thick, yellow line depicts the 25m elevation contour.
- Thick, magenta line depicts the -75m elevation contour.
- Exporting 3m DEM for modeling use



WaveWatch III v5.16: PR/USVI Setup

- Fully Parallel phase-averaged spectral wave model developed by the NOAA National Centers for Environmental Prediction
- Runs in both structured and unstructured grids and has the option for explicit and implicit (not ready for primetime) solvers
- Presently being used by the Wave Information Study for the Atlantic and Pacific wave hindcasts.

WW3 will use two way coupling at the boundaries of 3 grids with nesting

Grid cell spacing decrease from 0.5 degrees to 0.02 degrees or about 2 km around islands

Grid	Longitude (W deg)	Latitude (N deg)	Resolution (deg)
Basin_l1	-98.0, -59.75	7.5, 45.75	0.25 x 0.25
Pr_l2	-74.0, -62.0	14.0, 23.0	0.125 x 0.125
Pr_l3	-67.5, -63.5	17.5, 19.0	0.02 x 0.02

ADCIRC Mesh PR/USVI

San Juan

Resolution Before: 70-100 m

Resolution After: 30-85 m

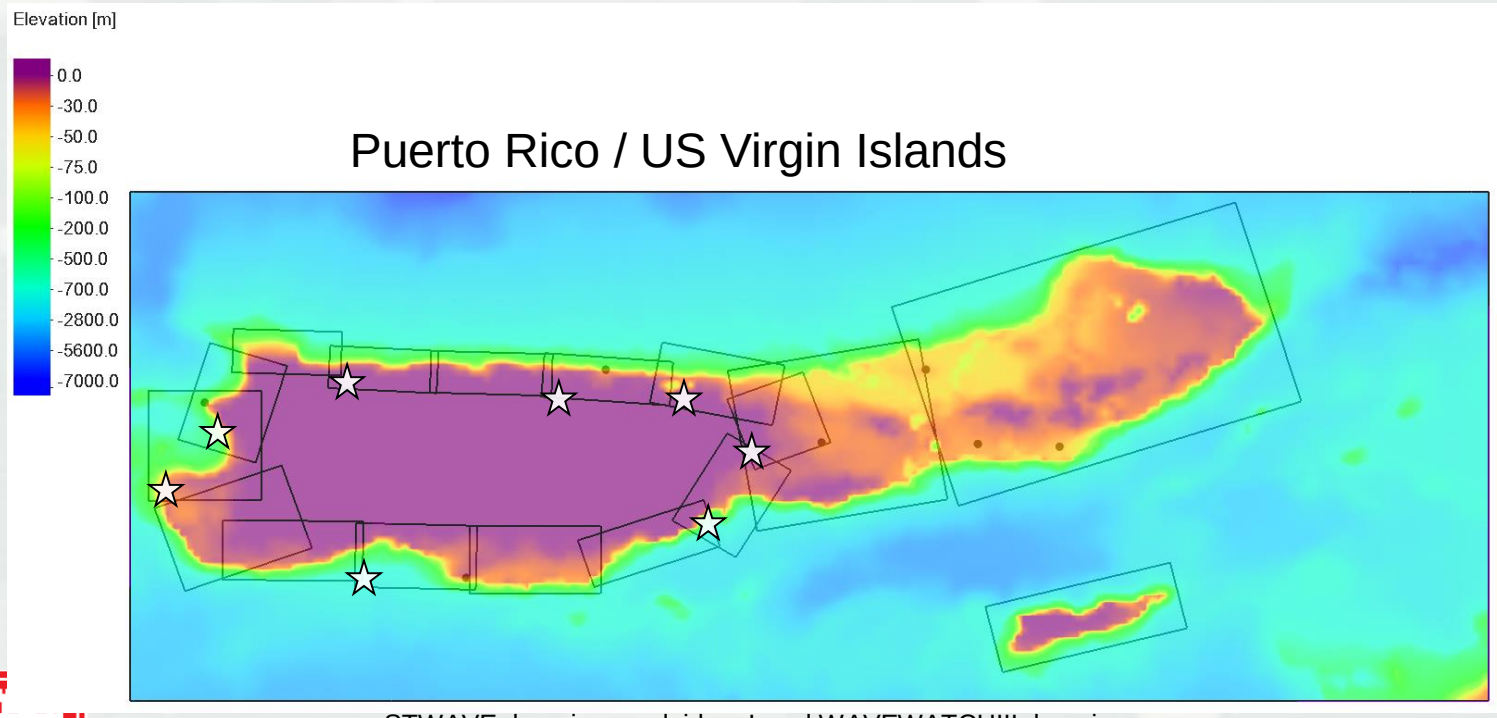
Notes:

- The largest city in Puerto Rico, contains significant amount of critical infrastructure

Base ADCIRC Mesh – Courtesy of Dr. Juan Gonzalez-Lopez

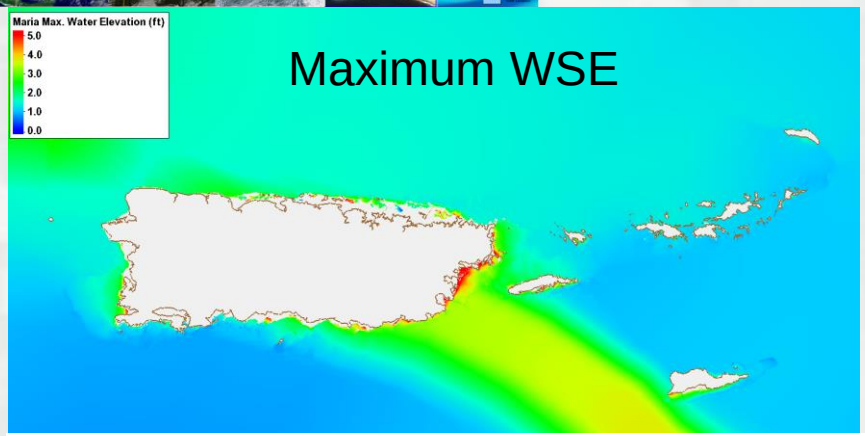
STWAVE for PR/USVI

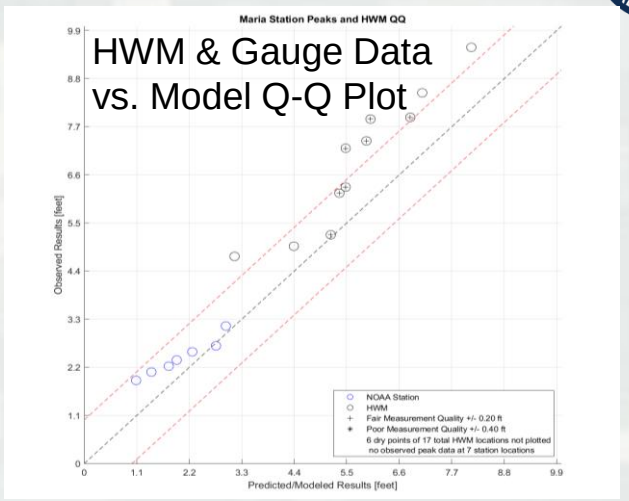
- Nearshore spectral wave model
- 17 STWAVE domains
  - starred domains are 150-m resolution, focused on PR population centers
  - others, including Vieques, Culebra, St. Croix, and the Virgin Islands, are 200-m
  - extended into deep water where possible for wave transformation over reefs/shallow water to be estimated by STWAVE model
- Black dots indicate location of buoys for validation

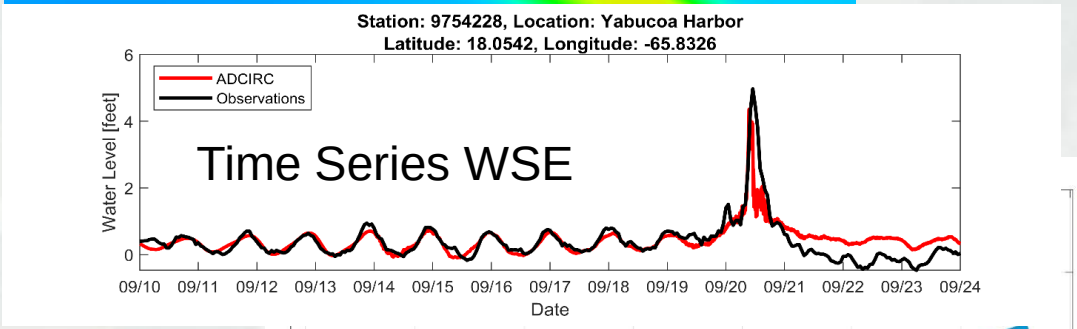


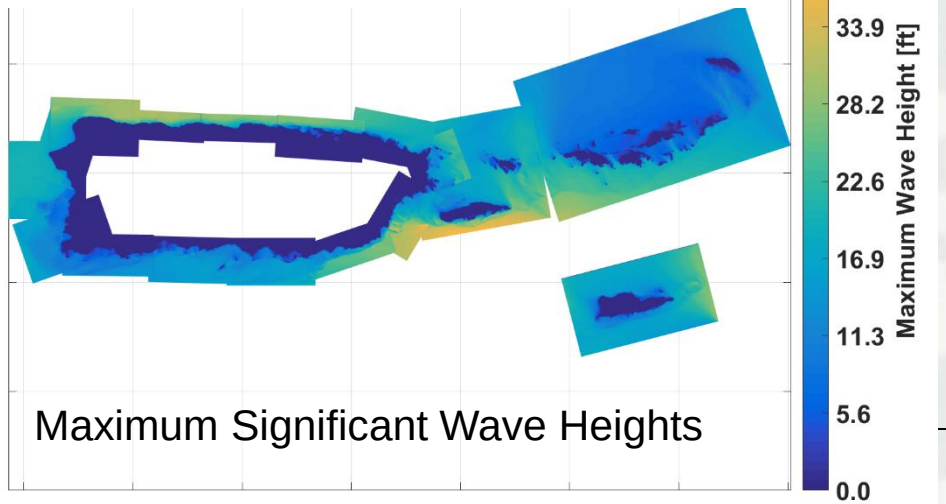
STWAVE domains overlaid on Level WAVEWATCHIII domain.

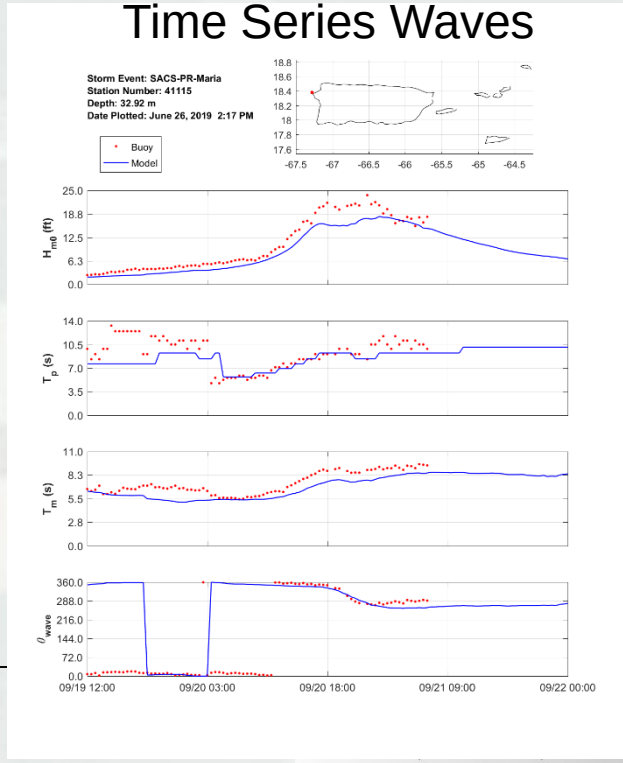
Hurricane Maria Results











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 input files (Reduces chances for human error)
  - Execution of the simulation and post processing (Optimized CPU usage)
  - With Project Condition Scenario Evaluations Enabled
  - Efficient file storage and archival

CSTORM Production System

Setup Simulation → Prep ADCIRC for Parallel → Execute CSTORM → Visualize & Stats → Compress Outputs → Tar Results Together → Archive Results

Onyx

Topaz

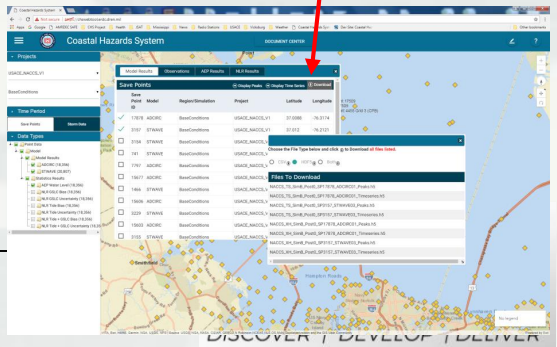
Thunder

Conrad

Cray XC40/50		SGI Ice X		SGI Ice X		Cray XC40	
6.06 PFLOPS		4.66 PFLOPS		5.62 PFLOPS		2 PFLOPS	
4,810 nodes	44 cores/node	3,456 nodes	36 cores/node	3,216 nodes	36 cores/node	1,523 nodes	32 cores/node
211,640 processors		124,416 processors		115,776 processors		48,736 processors	

Coastal Hazards System (CHS)

- The CHS is the only US national database and web-based data mining and visualization tool for probabilistic coastal hazard analysis (PCHA) results.
- Based on high-resolution / high-fidelity probabilistic, atmospheric and hydrodynamic modeling of coastal storms.
- Directly supports:
  - SMART planning/feasibility studies (3x3x3 rule)
  - PED, stochastic-forcing structure design
  - Hazard analysis and risk assessments



https://chs.erdc.dren.mil

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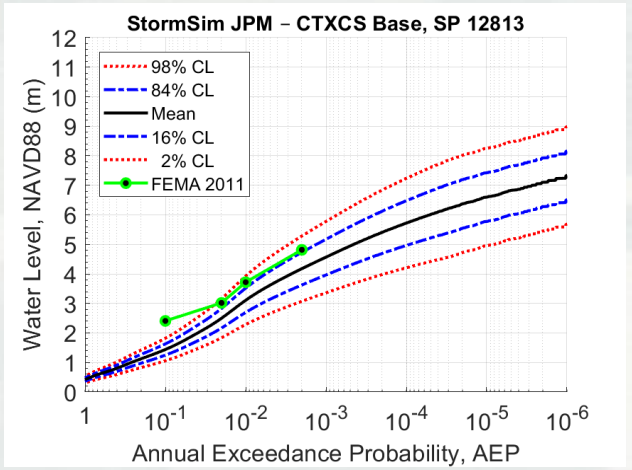
Coastal Hazards System (CHS)

PCHA results and deliverables:

- +20,000 output locations per study region
- Response Hazard Curves: surge, water level, sea level change, waves, wind, currents
- Annual Exceedance Probability (AEP) values: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10000 (1/years)
- Confidence Limits: 2%, 16%, 84%, 90%, 98%
- Uncertainty quantification & SLC nonlinear residuals
- Peaks and time series files for all storms in NetCDF/CSV formats
- Atmospheric and hydrodynamic model inputs
- Model grids, technical reports



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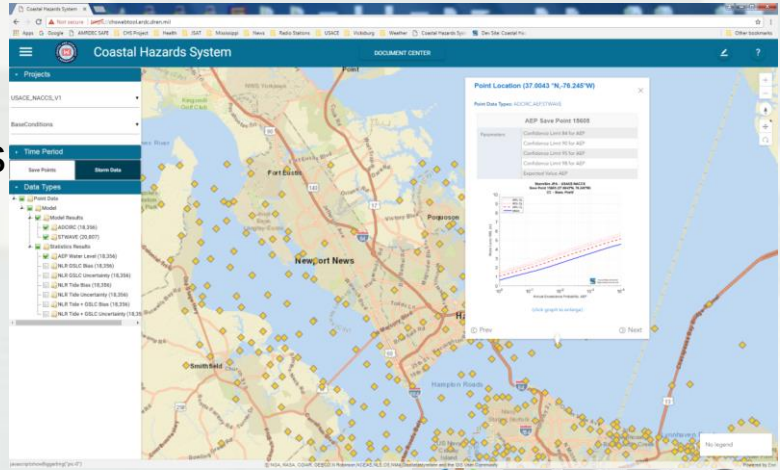
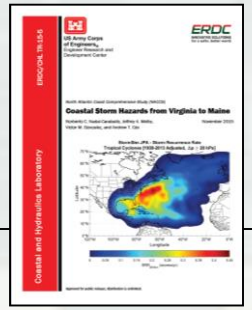
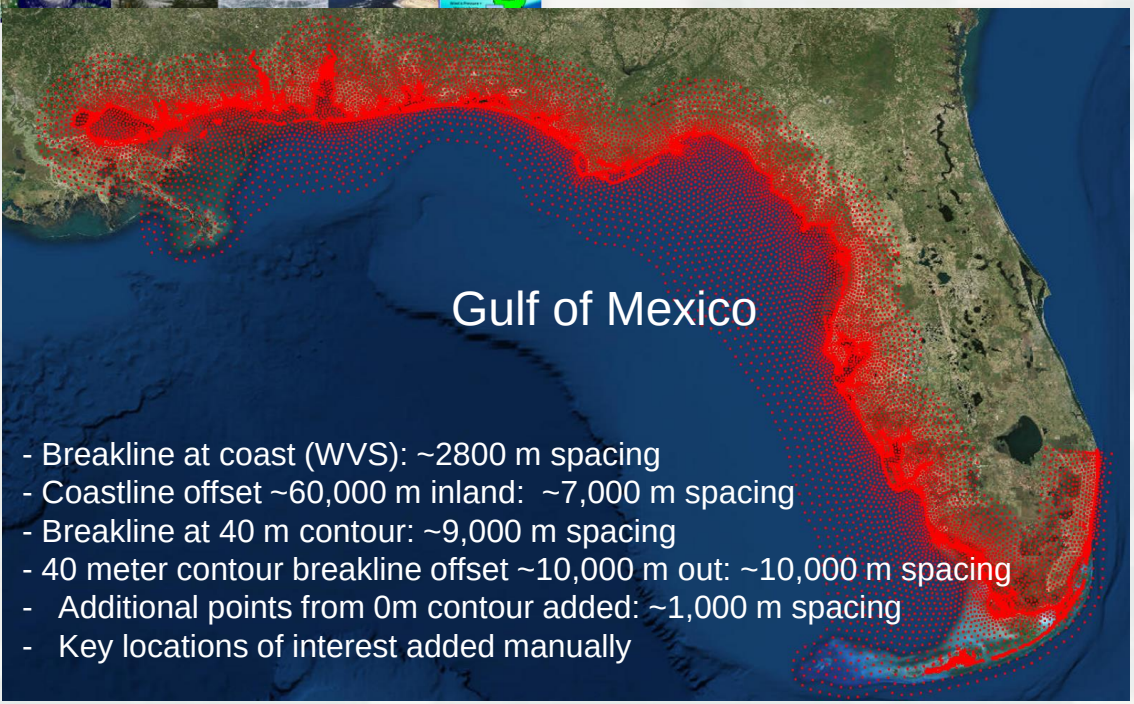
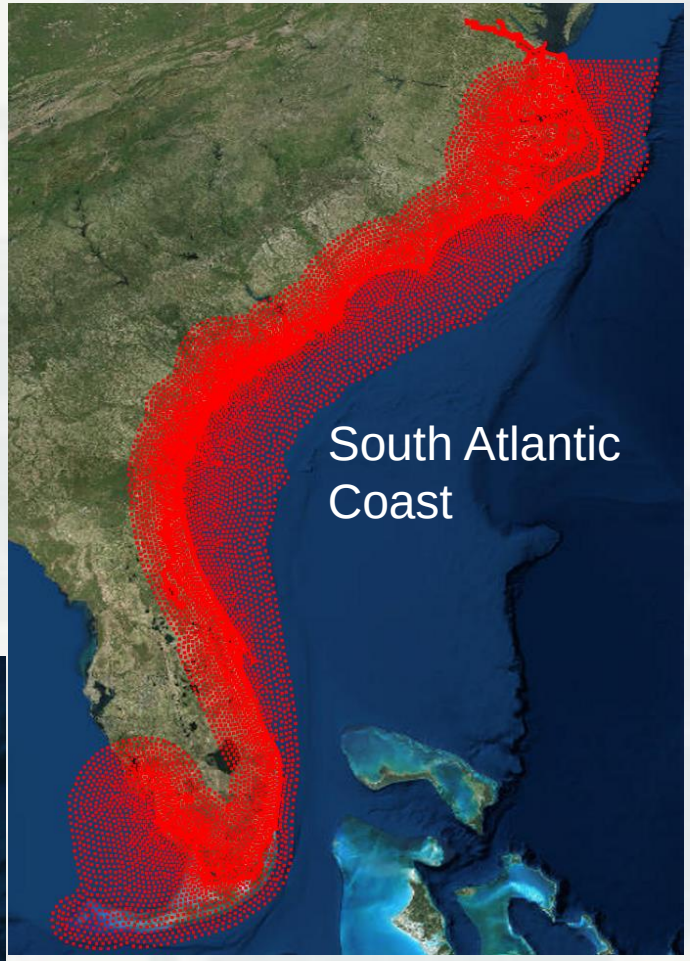




Preliminary Save Point Locations





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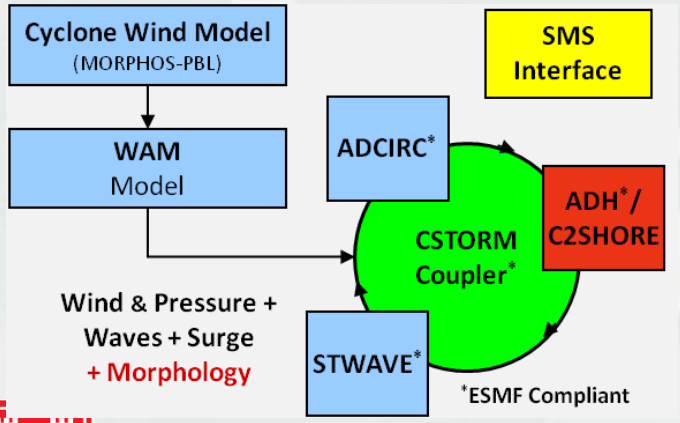
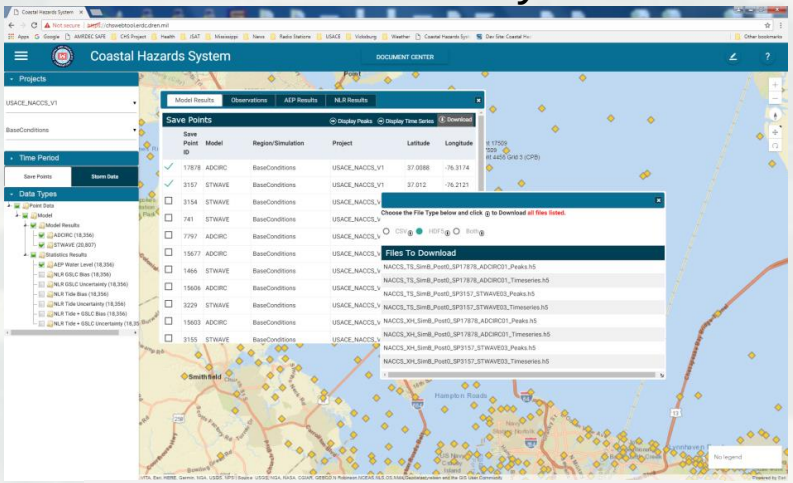
Summary

- 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.
- SACS results will provide valuable data in support of the Corp missions and those of other agencies and communities for many years to come.

CSTORM-MS



Coastal Hazards System



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Questions?
Contact Information

Chris Massey, PhD

Leader, Coastal Storm Modeling Team

U.S. Army Engineer R&D Center

Coastal and Hydraulics Laboratory

email: Chris.Massey@usace.army.mil

Norberto C. Nadal-Caraballo, PhD

Leader, Coastal Hazards Group

U.S. Army Engineer R&D Center

Coastal and Hydraulics Laboratory

email: Norberto.C.Nadal-Caraballo@usace.army.mil