ERDC
Engineer Research and Development Center

ERDC's Coastal Storm (CSTORM) Modeling System

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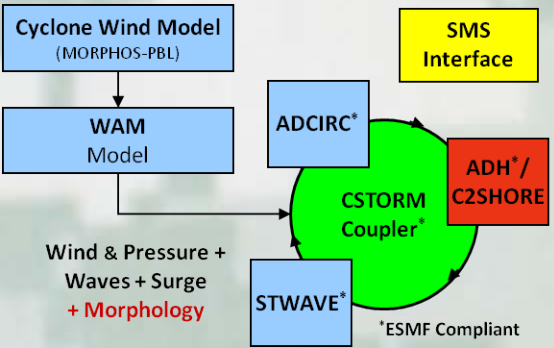
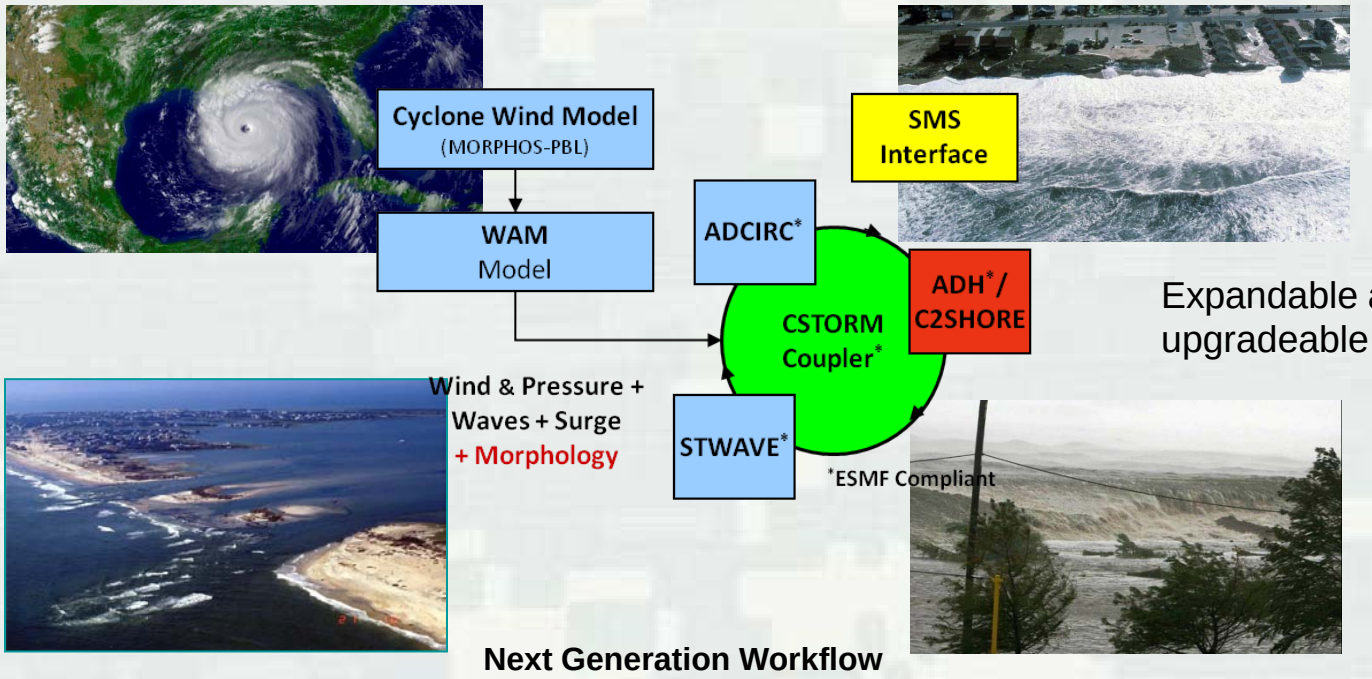


ERDC's Coastal Storm-Modeling System

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 establishing the risk of coastal communities to future occurrences of storm events.

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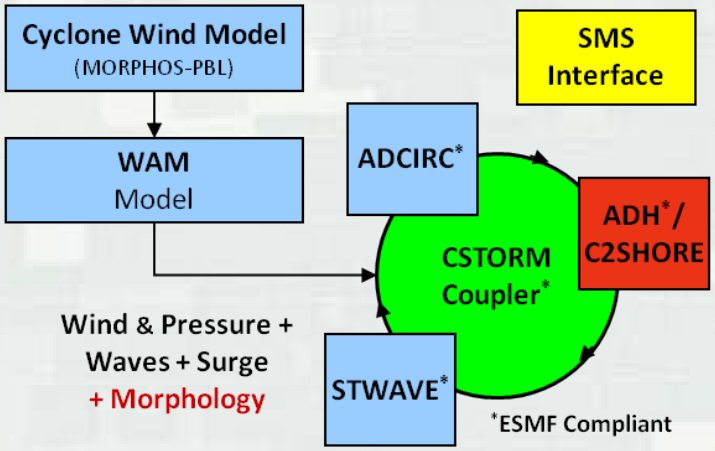
CSTORM System Components 2014

- **Winds/Pressure:** PBL Cyclone Model
- **Waves:**
  - Regional: WAM
  - Nearshore: STWAVE* (Parent/Child)
- **Circulation/Surge:**
  - ADCIRC*
  - ADH* (Multiple Instances)
- **Morphology:** SEDLIB/C2Shore
- **Coupling Framework:** CSTORM-MS*
- **Graphical User Interface:** SMS
- **Unstructured Waves, Overland Flow, SEA Ice DEM – FY15-17?**



Earth System Modeling Framework (ESMF) Compliance

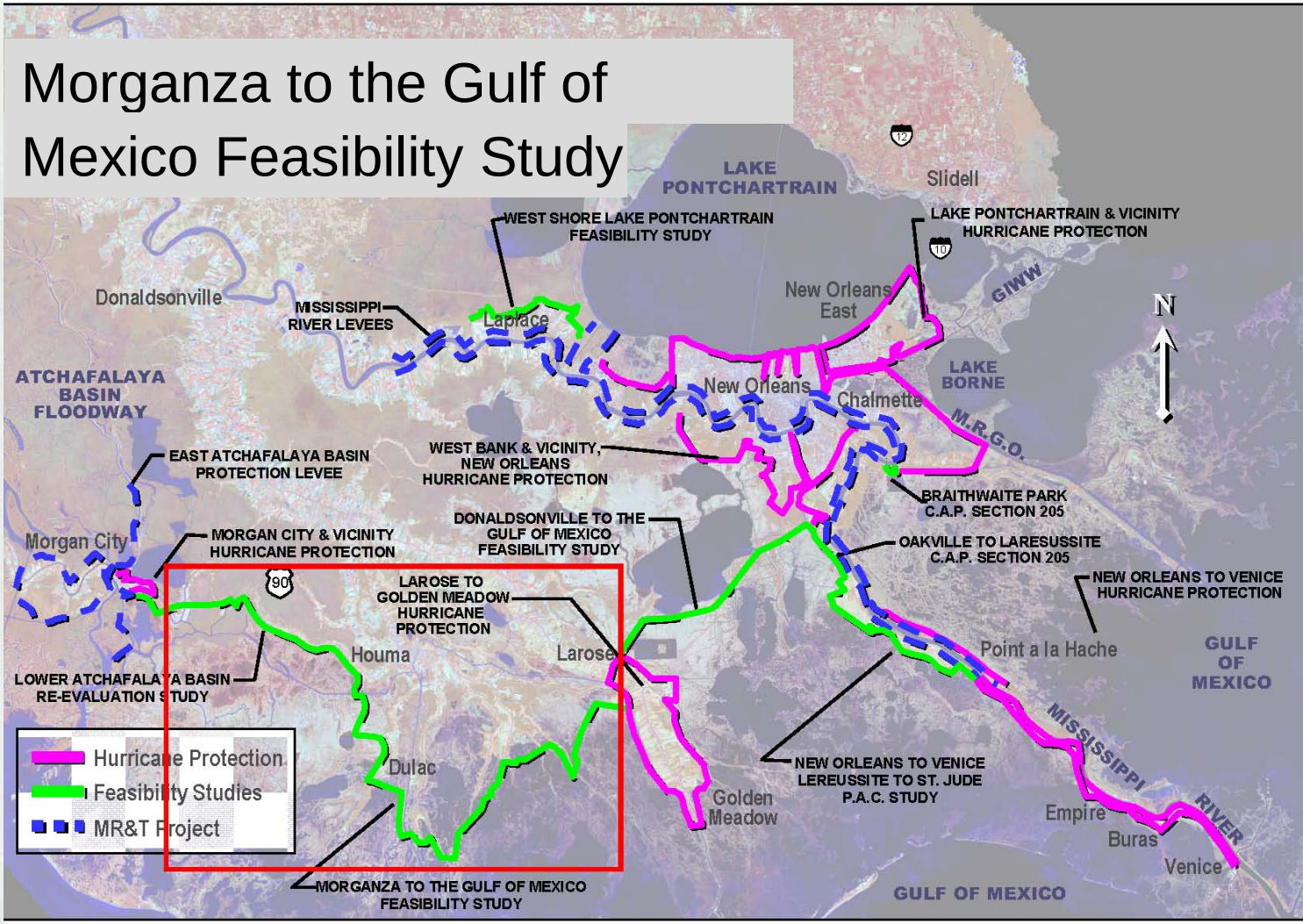
- Multiple federal agency support ESMF
- ESMF compliant models are readily available to be linked with each other and with other agencies' ESMF compliant models.
- Individual models stay virtually autonomous when coupling.

BUILDING

RDC

er, better world

An Example USACE Storm Surge Project



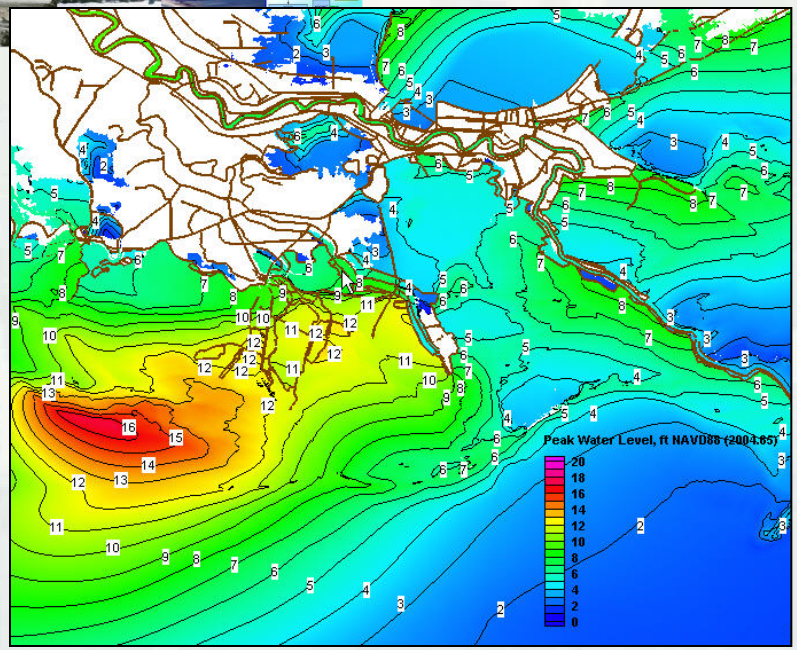
CSTORM-MS COASTAL STORM MODELING SYSTEM

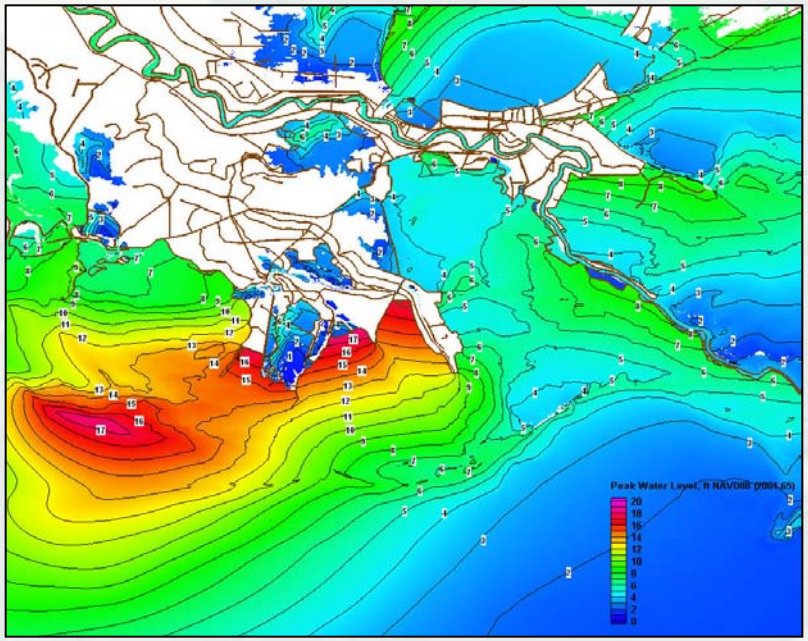
Storm 314

Without Project

With Project

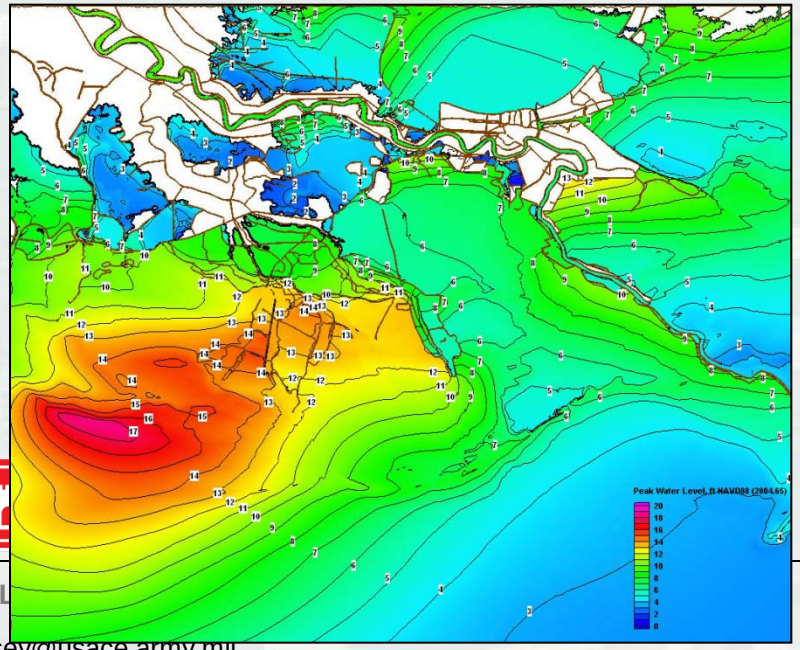
Existing Water Level

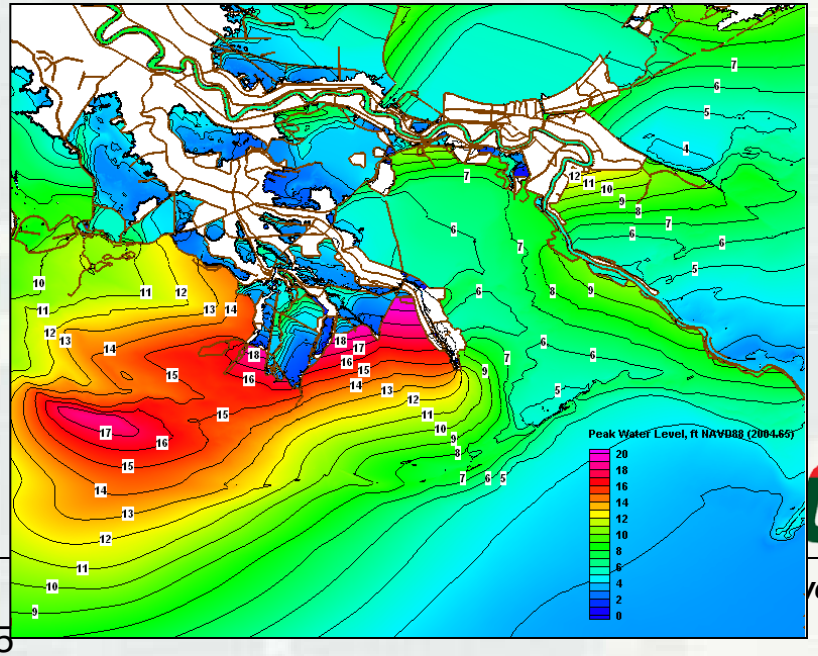




Existing Water Level

Sea Level Rise 0.35 m





Sea Level Rise 0.35 m

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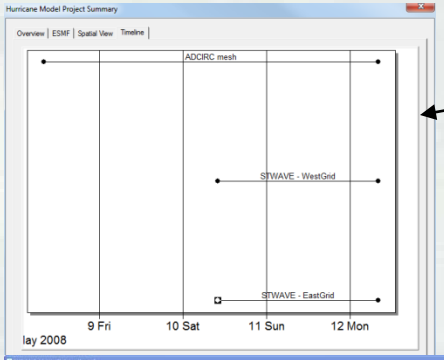
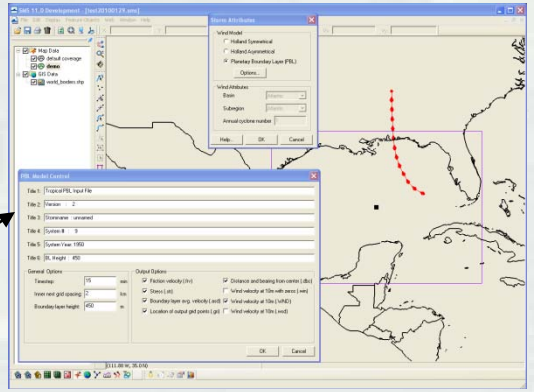
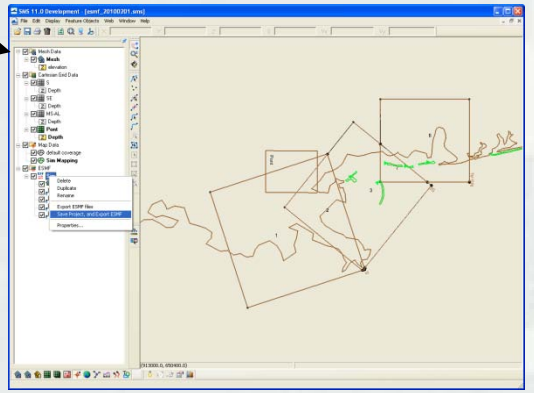
SMS GUI's

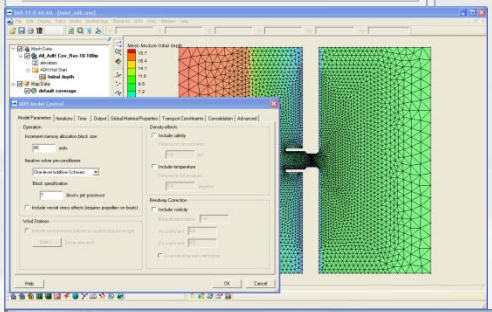
Through the SMS GUI's users can setup and execute models as well as visualize model results.

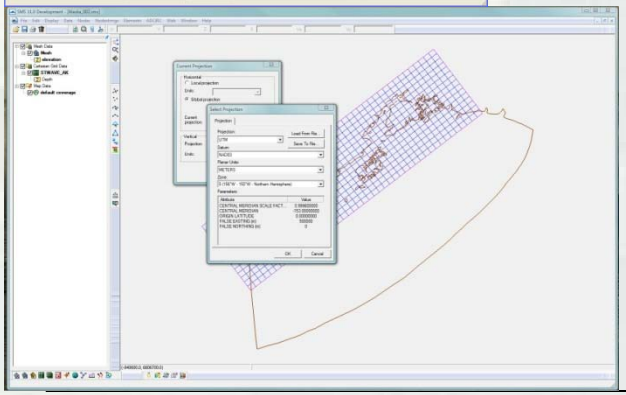


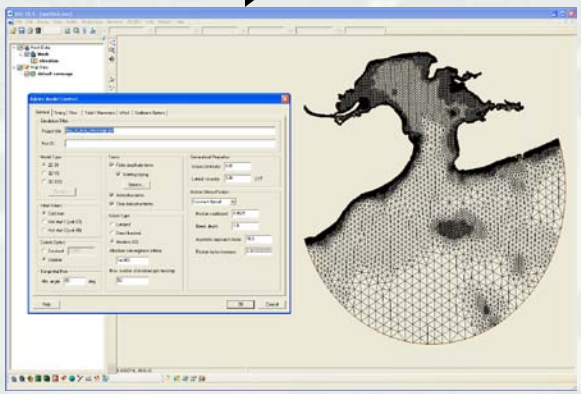
- New GUI for Project Overview
- New GUI for MORPHOS PBL Cyclone Model
- New GUI for CSTORM Coupled Models
- Updated GUI for AdH
- New GUI for WAM Wave Model
- Updated GUI for STWAVE
- Updated GUI for ADCIRC

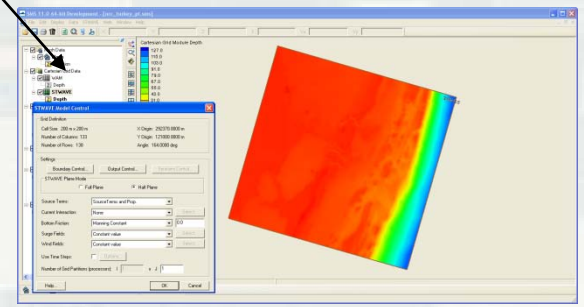












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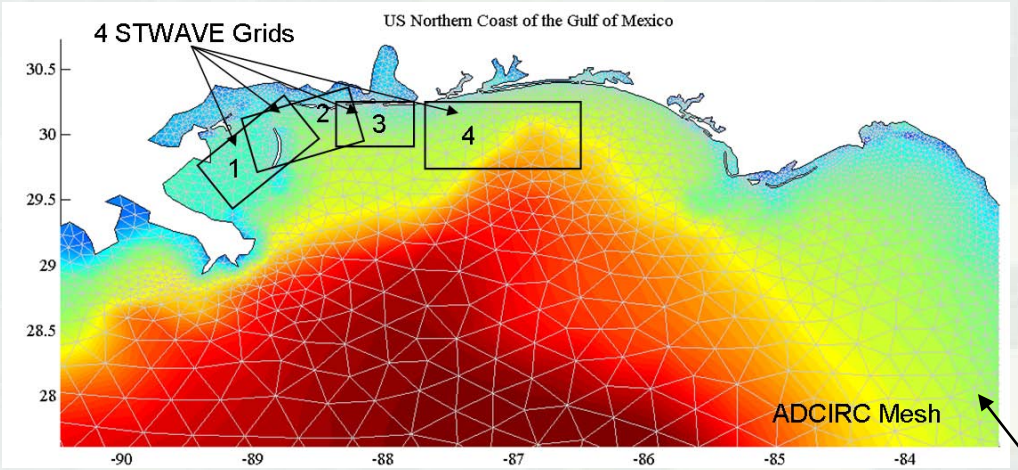
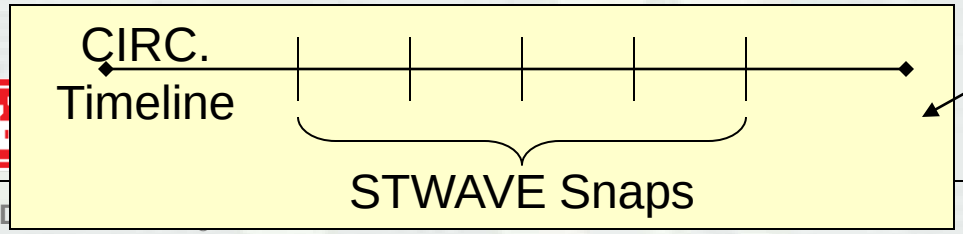
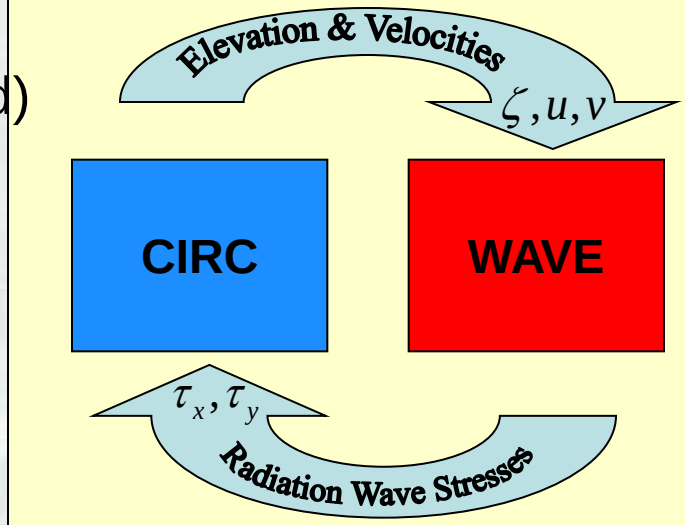
Tight Two-Way Coupling Circulation ←→ Wave

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





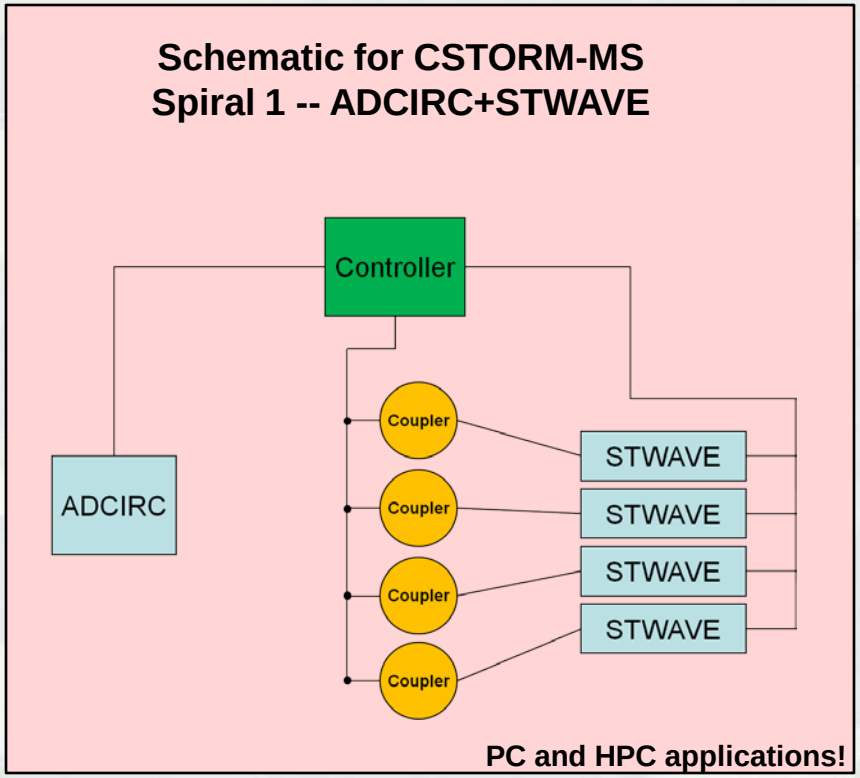
Information to Exchange



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

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

- Model coupling between ADCIRC/ADH and STWAVE is performed using CSTORM-MS Couplers written in FORTRAN and MPI.

- 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).

- Single executable code.

Expandable !

Features of ADH Shallow Water

- Adaption
- Part of System-wide program
- Links to CRREL, HEC, NFS
- Internal links to groundwater
- Supercritical and subcritical flow
- Vessels
- Static lids (culverts, floating guidewalls, . . .)
- Friction library (vegetative, Manning's, ice)
- Linking to WQ library and ICM

- Structures (weirs, flapgates, …)
- Bendway correction
- Baroclinic options
- Coupled sediment transport (sands, clays, mixed)
- Wave effects on sediment
- Portable – PC to distributed memory HPC
- Dam failure, levee over-topping (example Ark-White-Miss River)
- Local mass conservation
- 3D companion for 2D shallow water

Advances in Morphology Response
Philosophy: Efficient and Robust

CSTORM-MS COASTAL STORM MODELING SYSTEM

Model Components

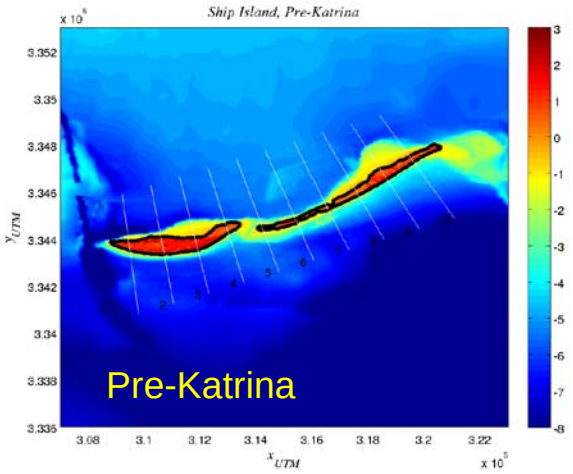
- Quasi-3D Shallow Water Hydrodynamics
- Probabilistic Representation of Sediment Transport
- Includes both Wave and Current Transport
- Bed load and Suspended load

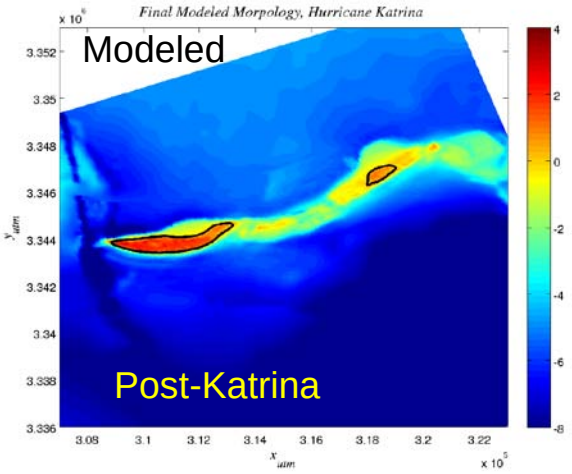
CSHORE → C2SHORE

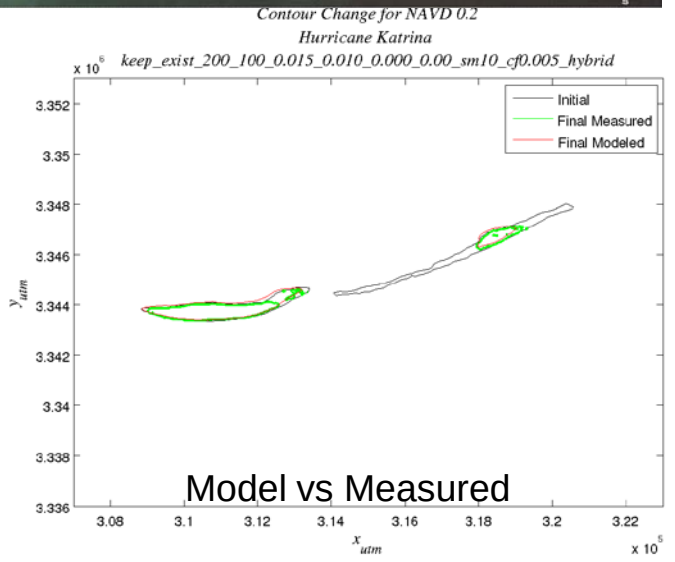
Profile Response | Quasi-2D | 2DH

Mississippi Coastal Improvement Program (MsCIP)

Ship Island Lidar



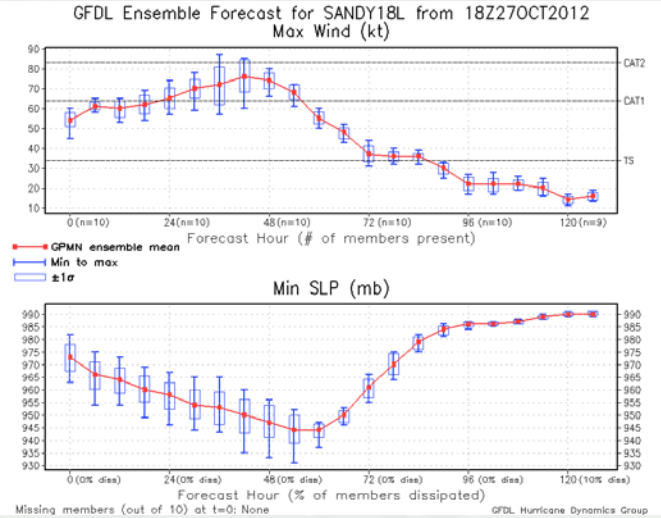


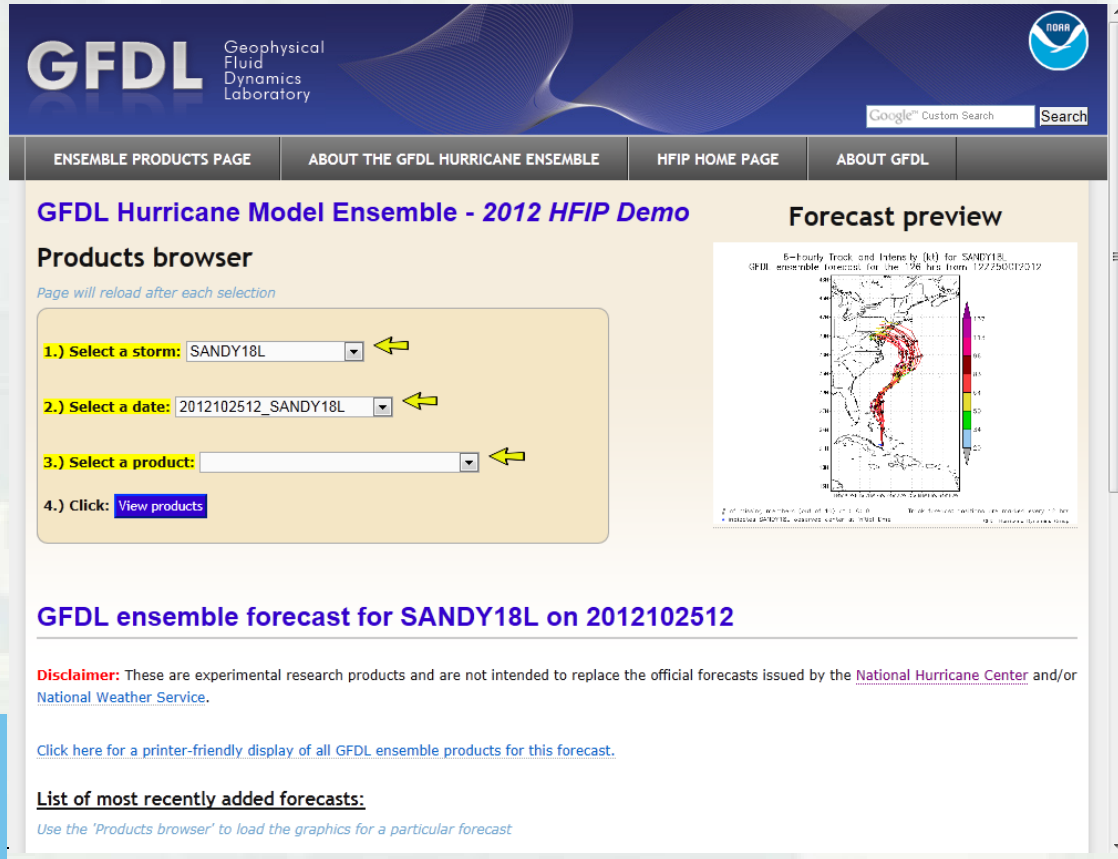


*GFDL Met Option for CSTORM

The NWS/Geophysical Fluid Dynamics Laboratory model. The GFDL and HWRF models are the only models that provide specific intensity forecasts of hurricanes. More detailed GFDL information is available at http://www.gfdl.noaa.gov.

1. Operational Hurricane Forecast
2. Ensemble Hurricane Modeling





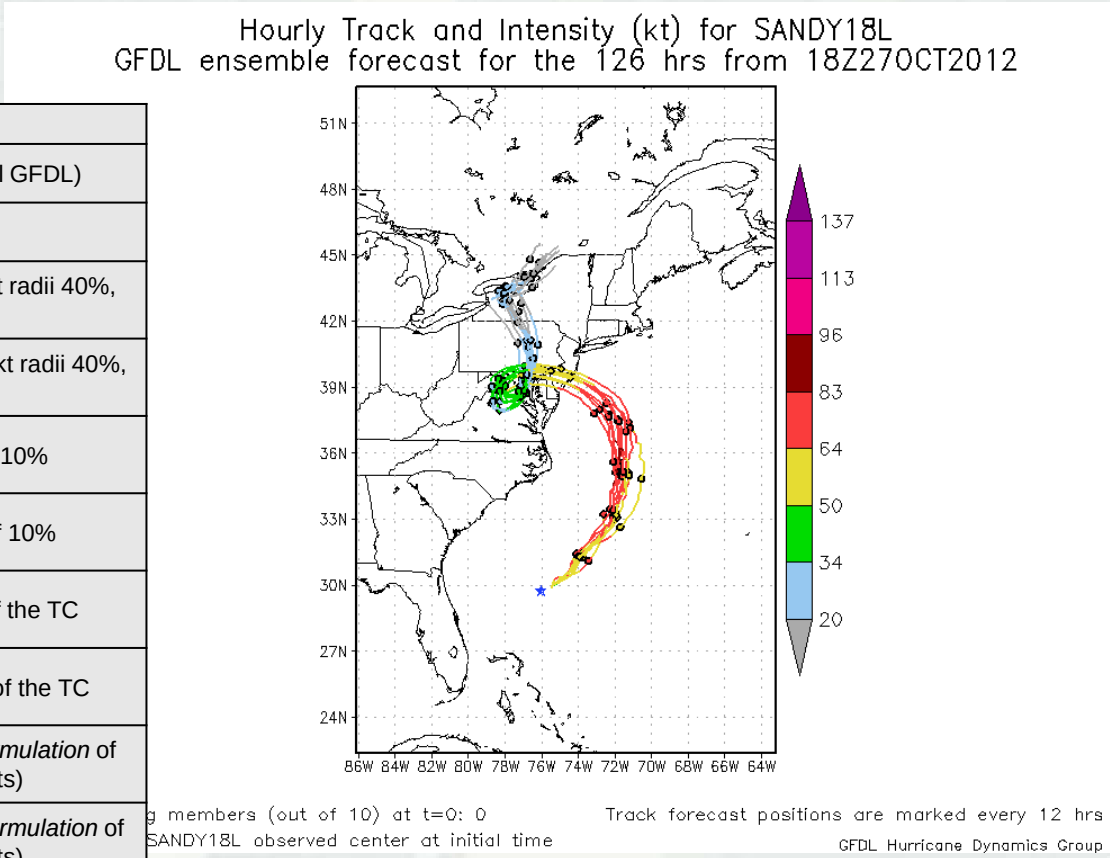
*This is an ongoing collaboration with Morris Bender and Matt Morin at NOAA's GFDL.

Innovative solutions for a safer, better world

*GFDL Ensemble for Hurricane Sandy

Ensemble Members

ATCF ID	Description
GP00/GT00	Control forecast (same model as NCEP 2013 operational GFDL)
GP01/GT01	Unbogussed forecast using the 2013 control model
GP02/GT02 ↑	Increase NHC-observed V_{max} 10%, 34-kt radii 25%, 50-kt radii 40%, ROCI 25%
GP03/GT03 ↓	Decrease NHC-observed V_{max} 10%, 34-kt radii 25%, 50-kt radii 40%, ROCI 25%
GP04/GT04 ↑	Modification to increase inner-core moisture by a max of 10%
GP05/GT05 ↓	Modification to decrease inner-core moisture by a max of 10%
GP06/GT06 ↑	Increase SSTs by a max of 1°C within the initial extent of the TC
GP07/GT07 ↓	Decrease SSTs by a max of 2°C within the initial extent of the TC
GP08/GT08 ↑	Surface physics modification: *GFDL 2011 operational formulation* of C_D & C_H (surface drag and enthalpy exchange coefficients)
GP09/GT09 ↓	Surface physics modification: *HWRF 2012 operational formulation* of C_D & C_H (surface drag and enthalpy exchange coefficients)
GPMN/GTMN	Ensemble mean computed at each lead time where the member availability is at least 4 members (40% threshold)



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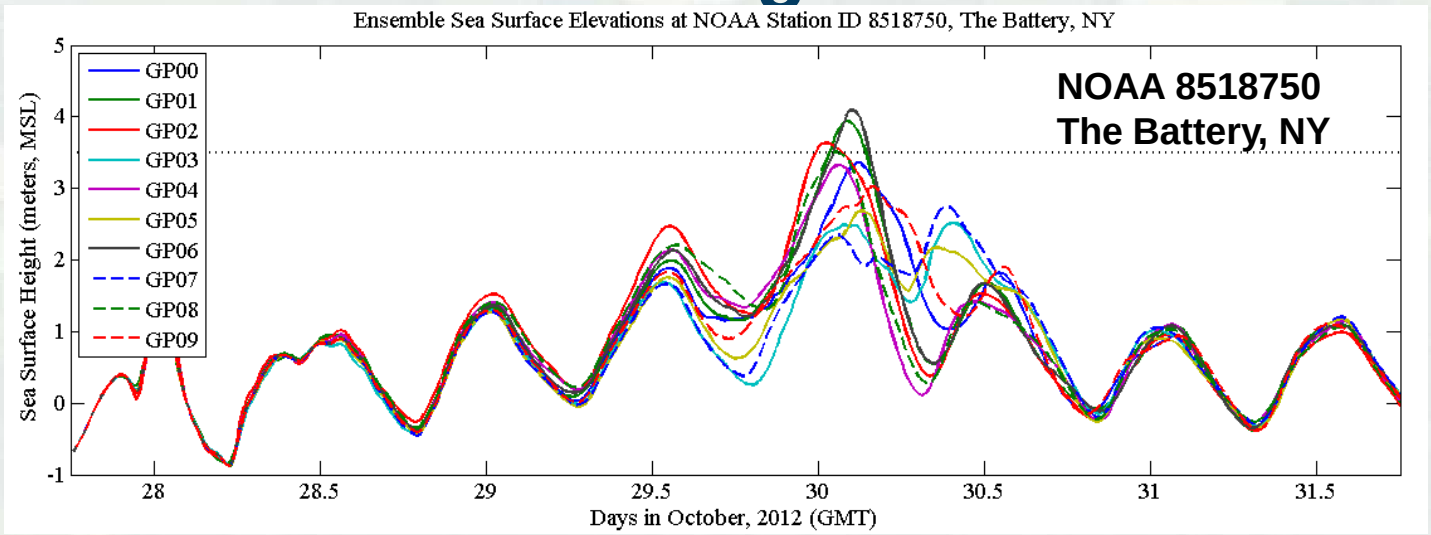
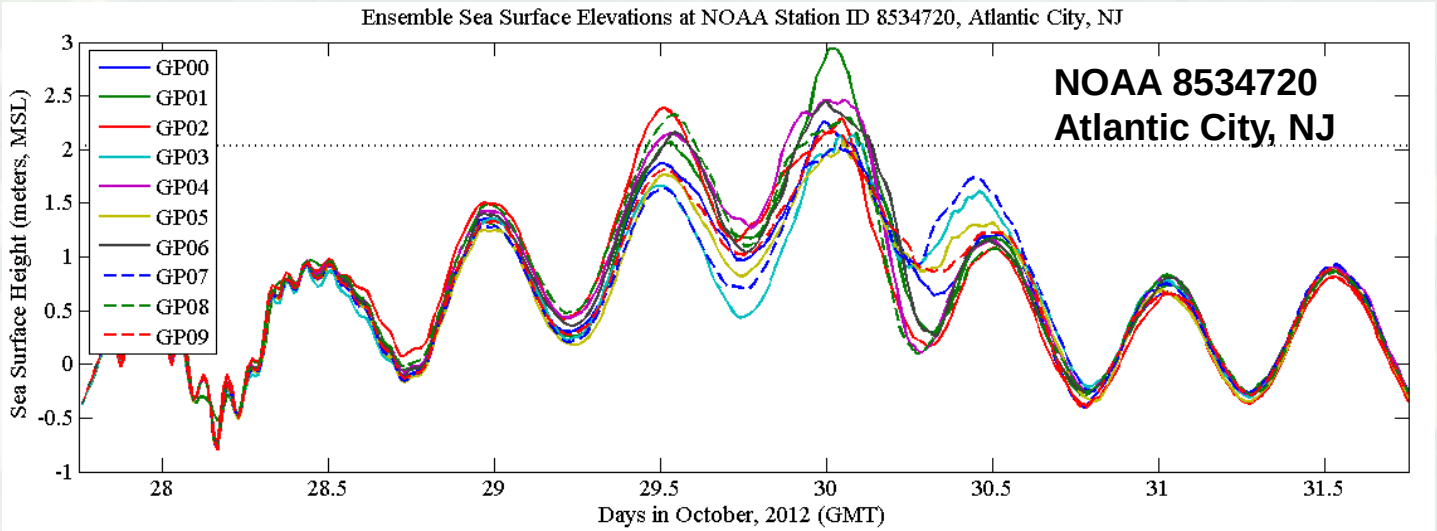
ADCIRC Sea Surface Elevations Using GFDL Ensemble (Sandy)

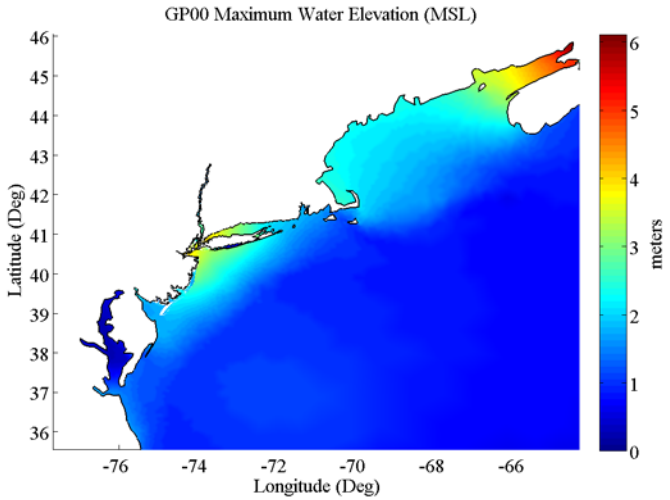


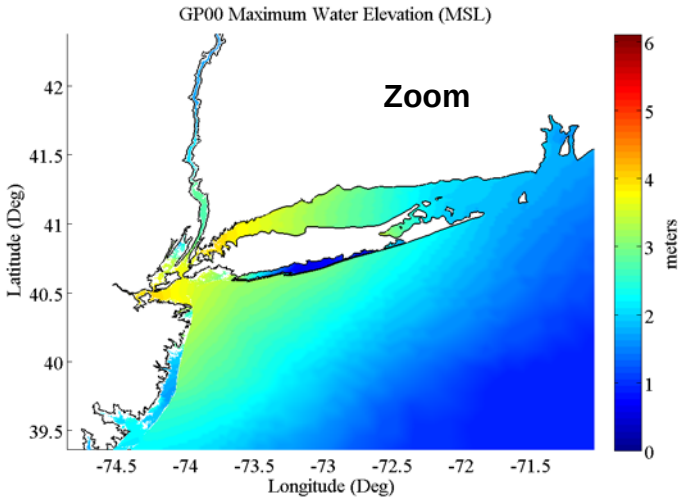


ADCIRC simulations included tides, winds and pressures (no waves)

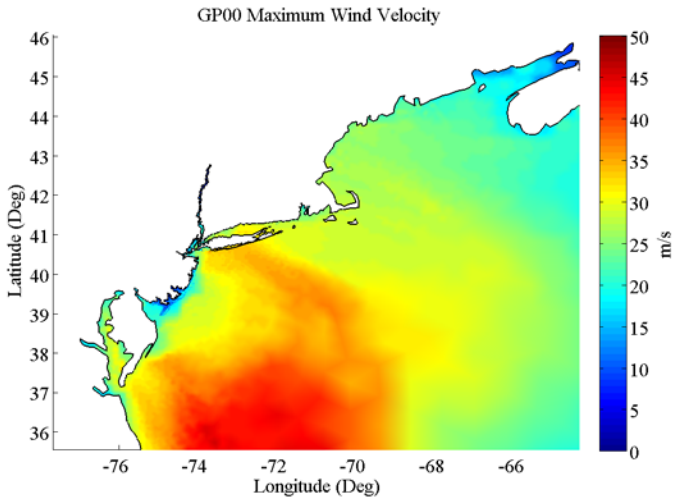
GFDL Ensemble from the 18Z Oct. 27, 2012 product

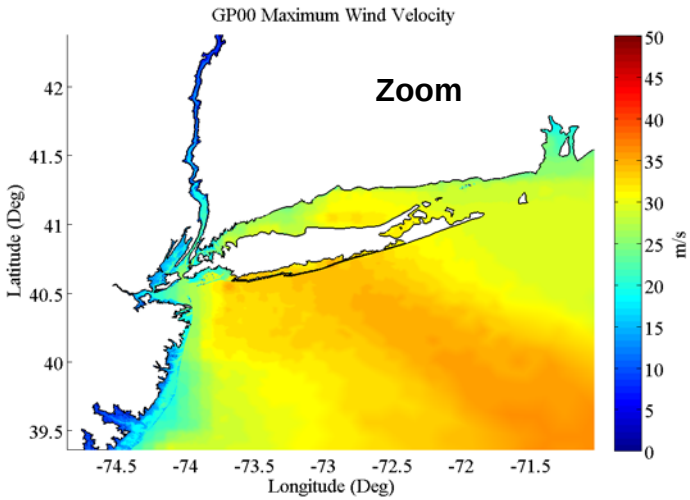
ADCIRC Maximum Sea Surface Elevations/Wind Velocity (GP00)





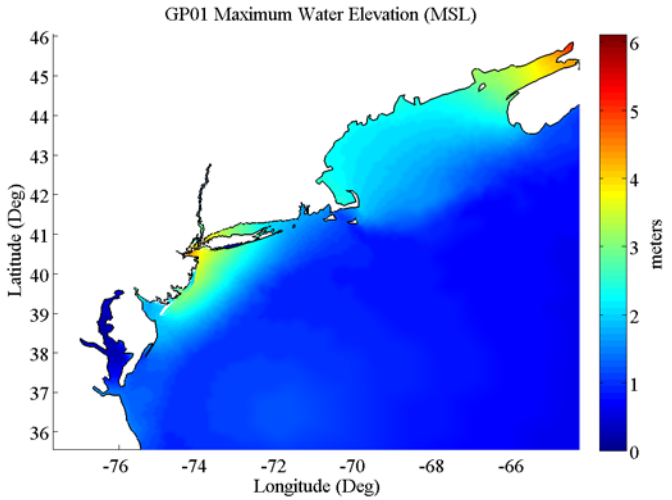
Maximum Sea Surface Elevation

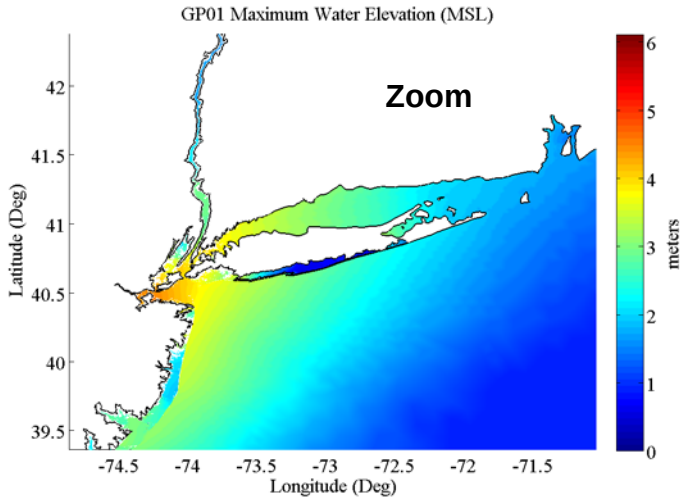




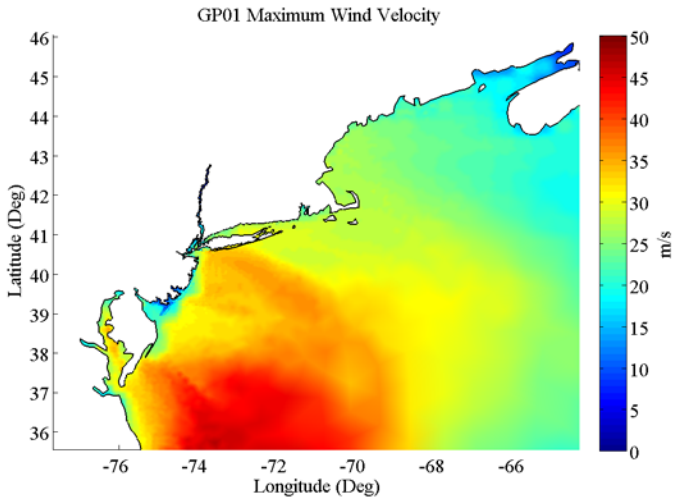
Maximum Wind Velocity (Interpolated)

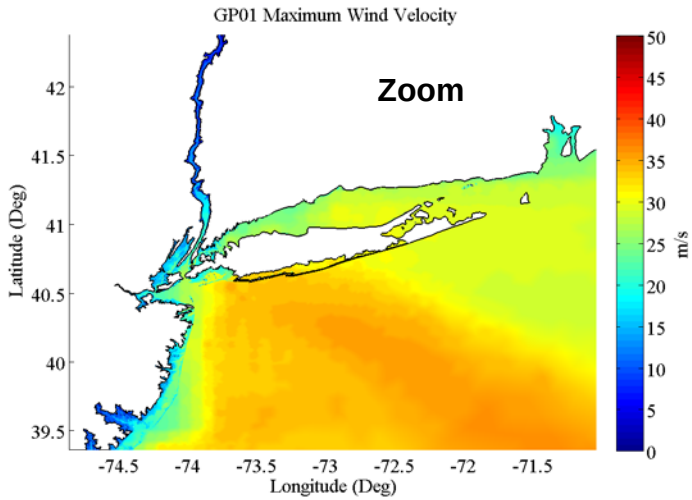
ADCIRC Maximum Sea Surface Elevations/Wind Velocity (GP01)





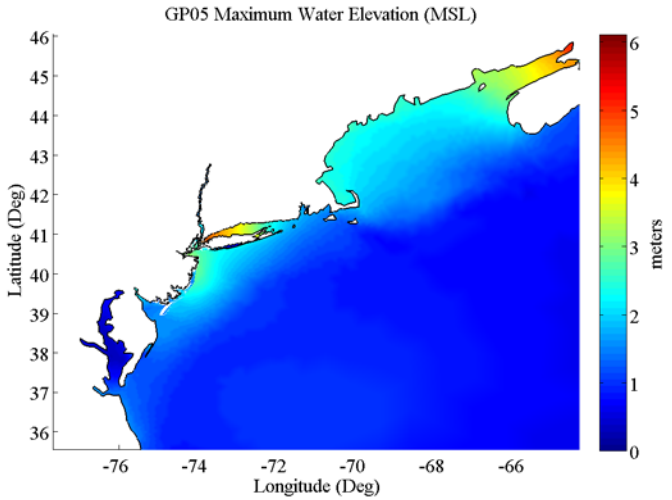
Maximum Sea Surface Elevation

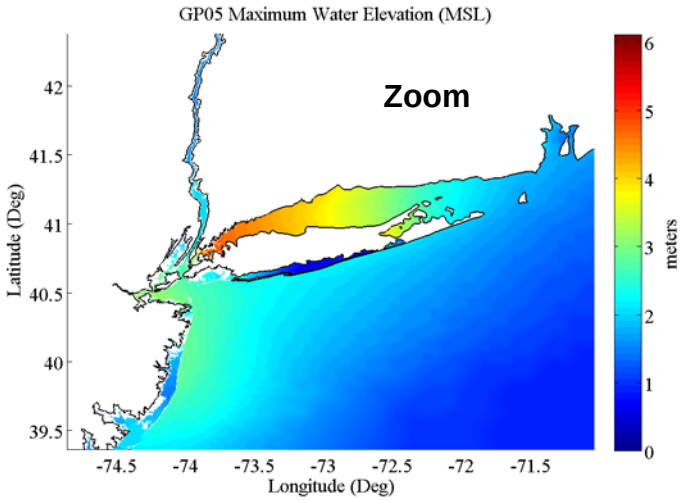




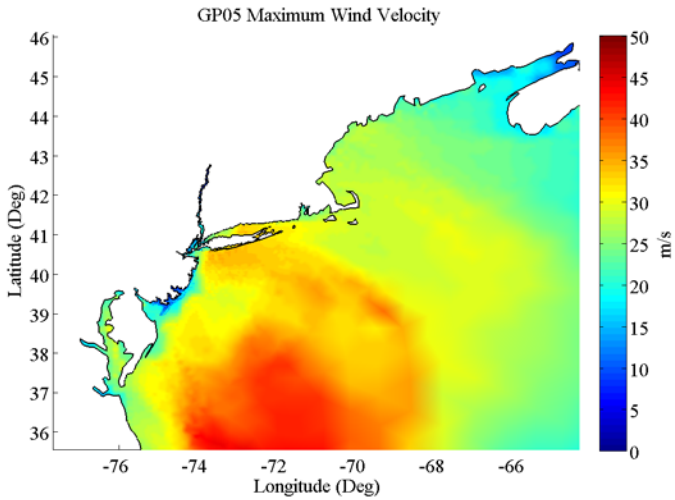
Maximum Wind Velocity (Interpolated)

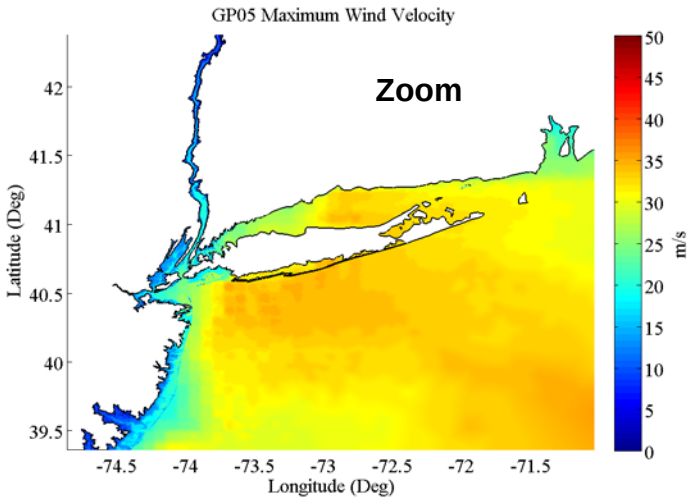
ADCIRC Maximum Sea Surface Elevations/Wind Velocity (GP05)





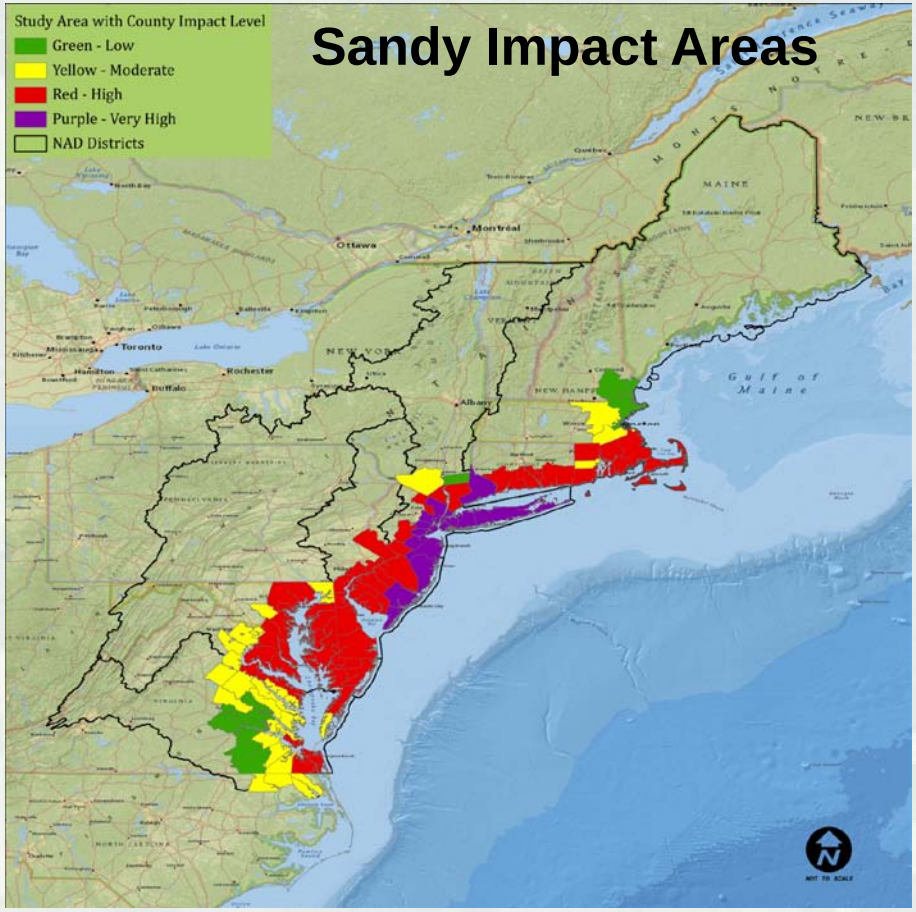
Maximum Sea Surface Elevation





Maximum Wind Velocity (Interpolated)

North Atlantic Coast Comprehensive Study



This study will compute 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 is on **storm winds**, **waves** and **water levels** along the coast for both tropical and extra-tropical storm events.

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Combined Joint Probability

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

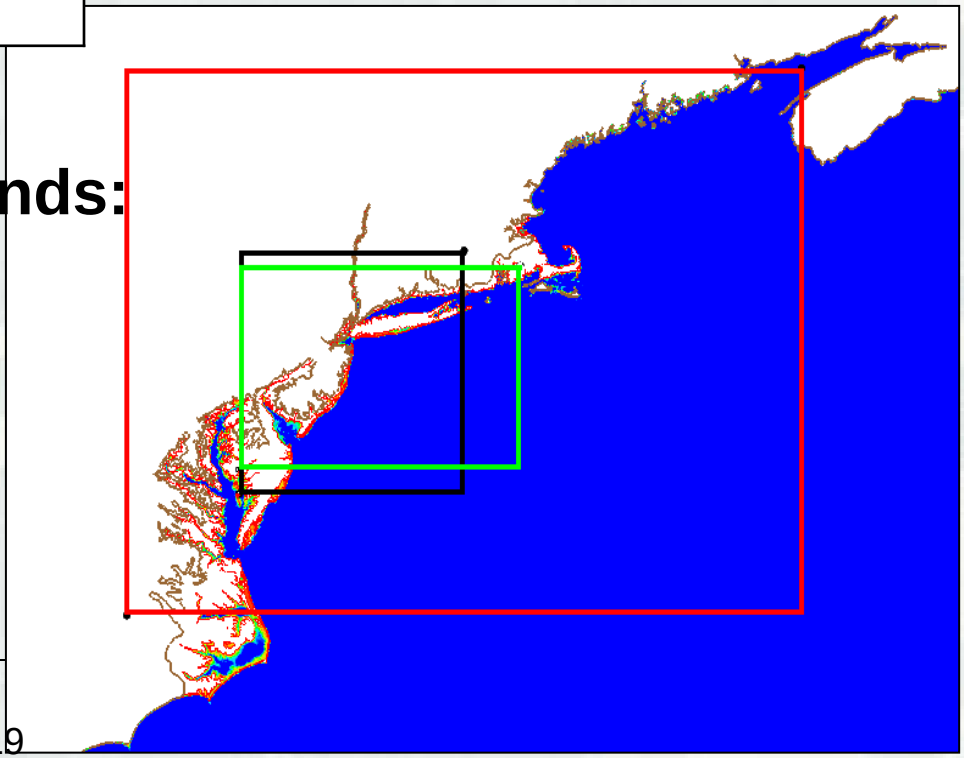
NACCS JPM Approach

Past Efforts vs. NACCS JPM

Study	Number of JPM-OS Simulations		
	Region 3	Region 2	Region 1
FEMA III	156	-	-
FEMA II	-	159	-
NACCS*	**360**	**330**	**310**
*current estimates			
FEMA IV: Northeast Florida + Georgia (178 simulations)			

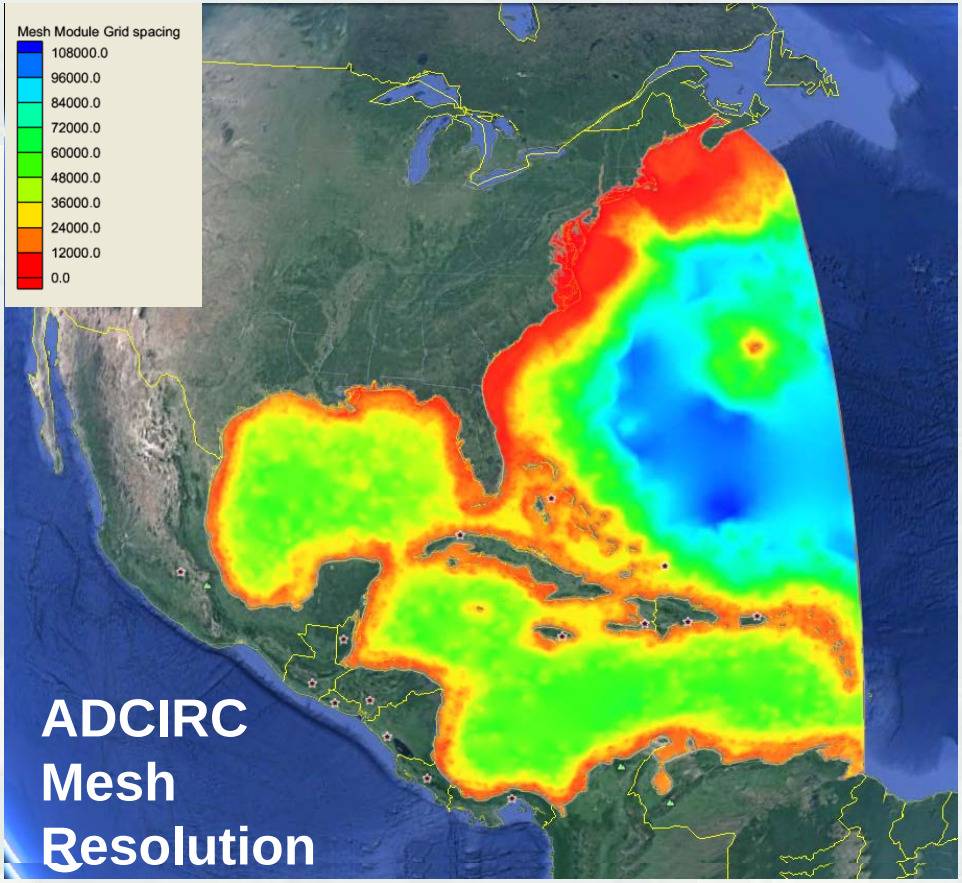
Extent of the fine resolution winds:

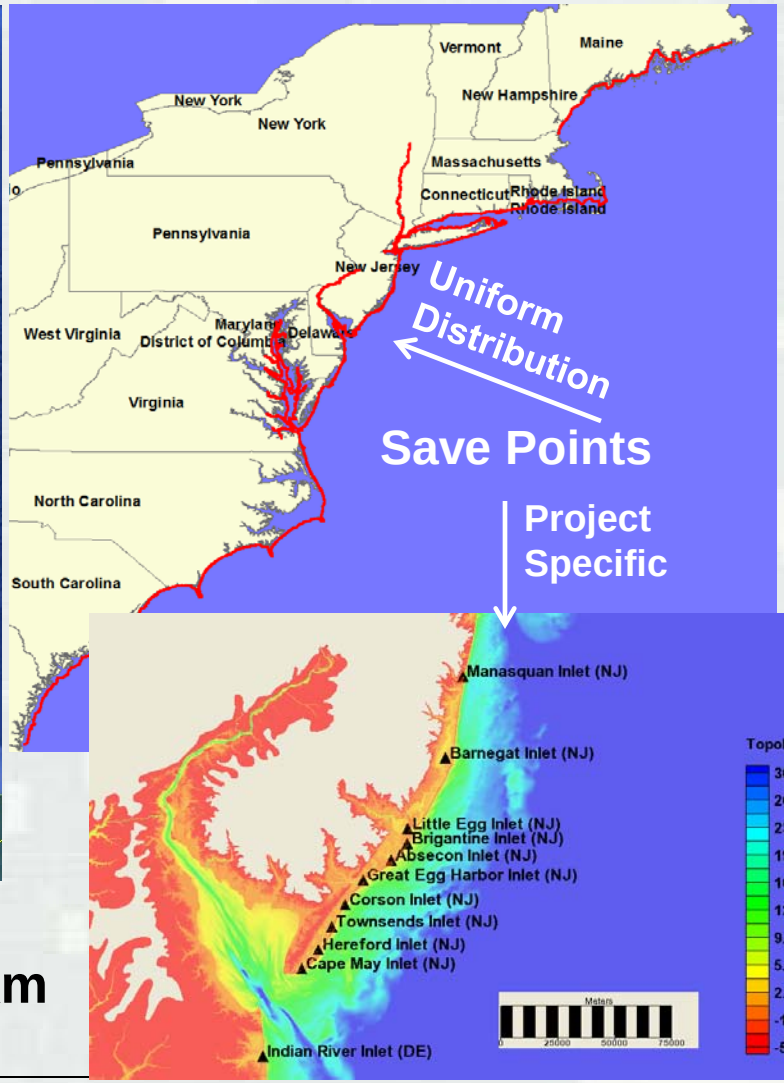
- FEMA Region II (green box)
- Other Validation (black box)
- NACCS (red box)



CSTORM-MS COASTAL STORM MODELING SYSTEM

Grids and Save Points



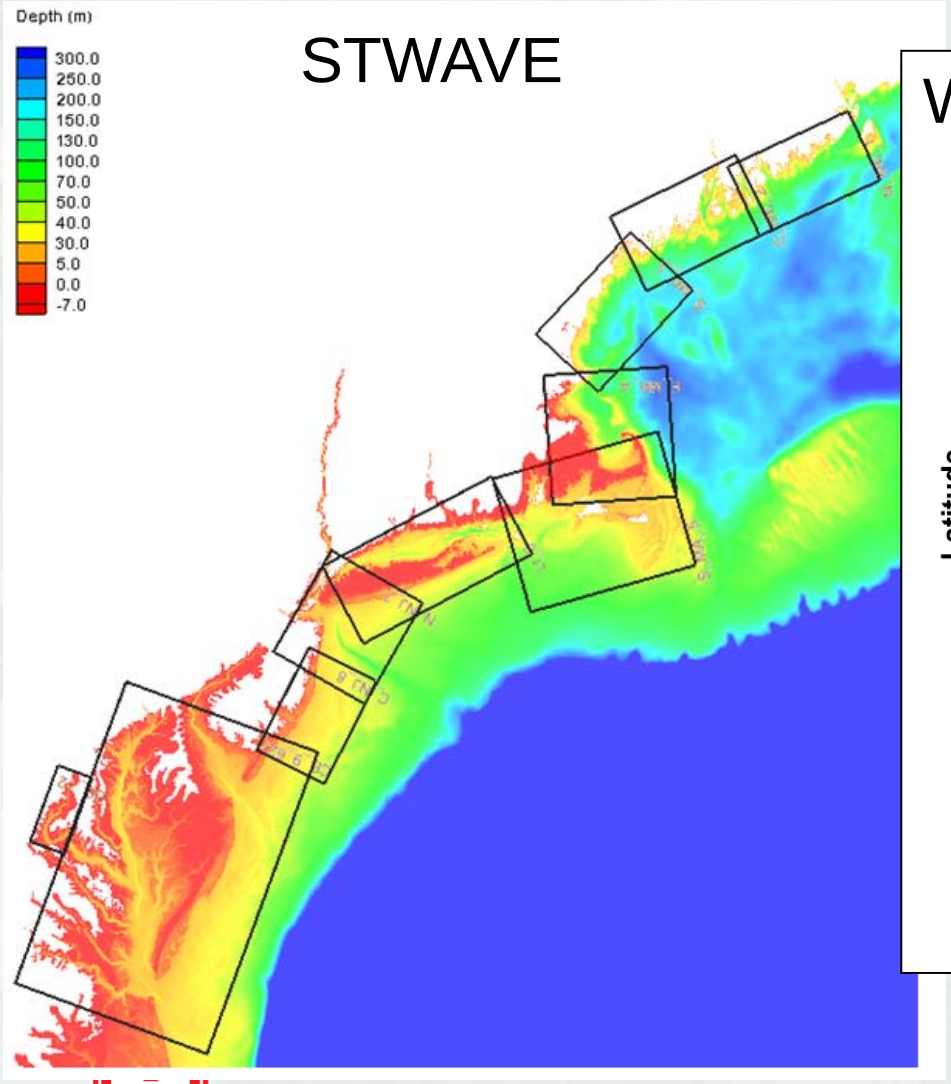


~ 3.2 million nodes

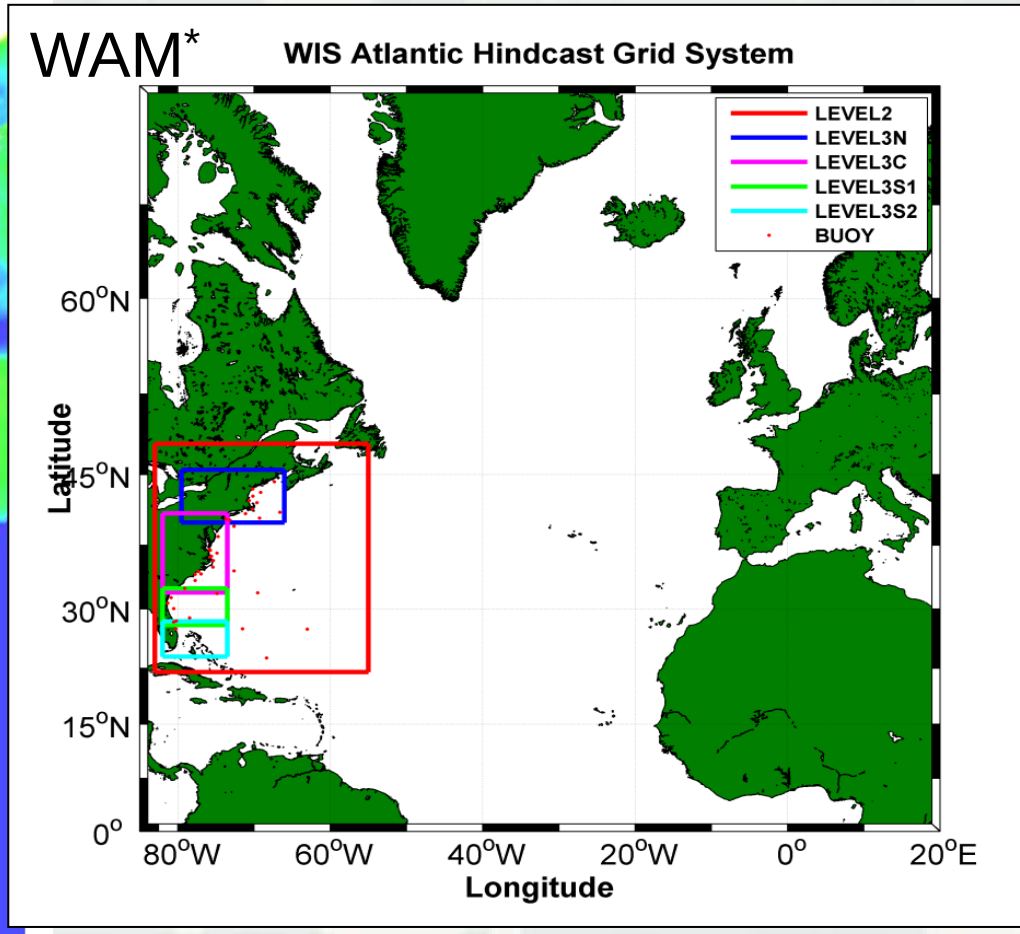
Resolution from 10 m to 100 km

Wave Grids

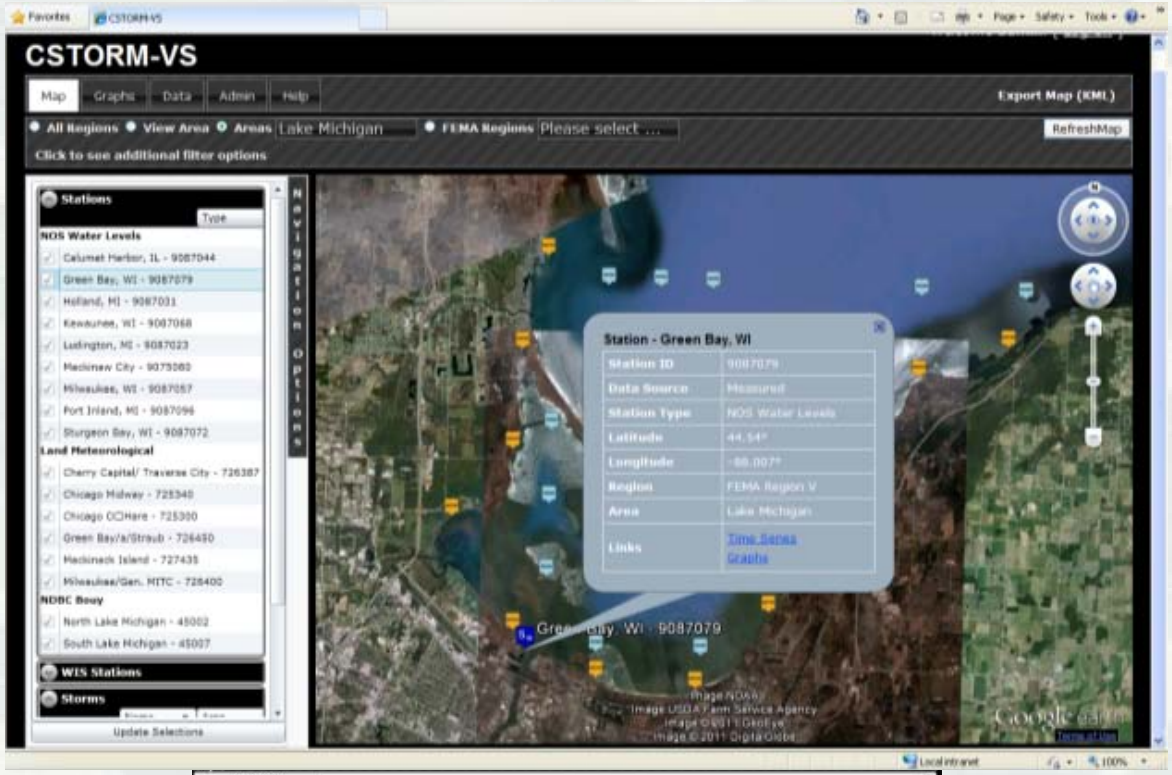
STWAVE



WAM*

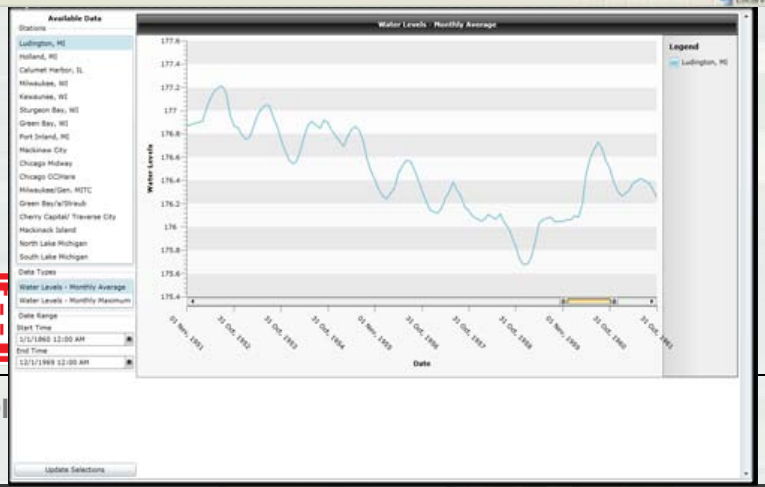


Coastal Storm - Database and Data Mining Tool



Goals

- Provide a long-term archive/database of measured and modeled coastal storm data
- Make data easily accessible and understandable to team members
- Integrate contextual data products and tools that support federal decision making
  - Emergency management
  - Risk management/assessment/communication
  - Project design and evaluation



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ERDC

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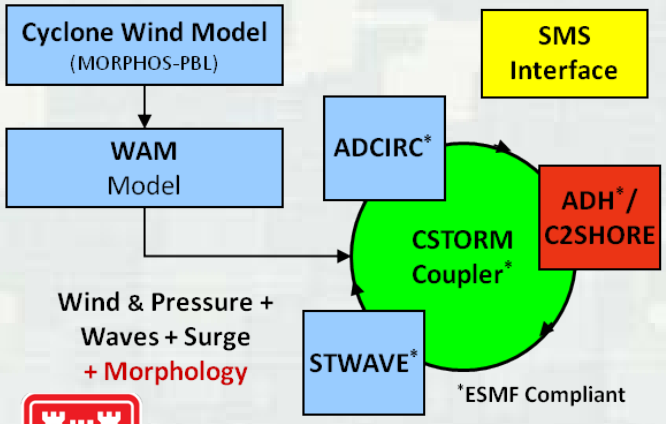
Summary & Next Steps

- CSTORM-MS is a standardized, 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.
- Linkage with GFDL ensemble products allows for "predictive" surge/wave modeling for impending coastal storm events.
- How to incorporate the ensemble "surge" results into a useful predictive product for USACE needs.

Project Level Mode



Ensemble Predicative Mode