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# FEMA Region III Coastal Storm Surge Study

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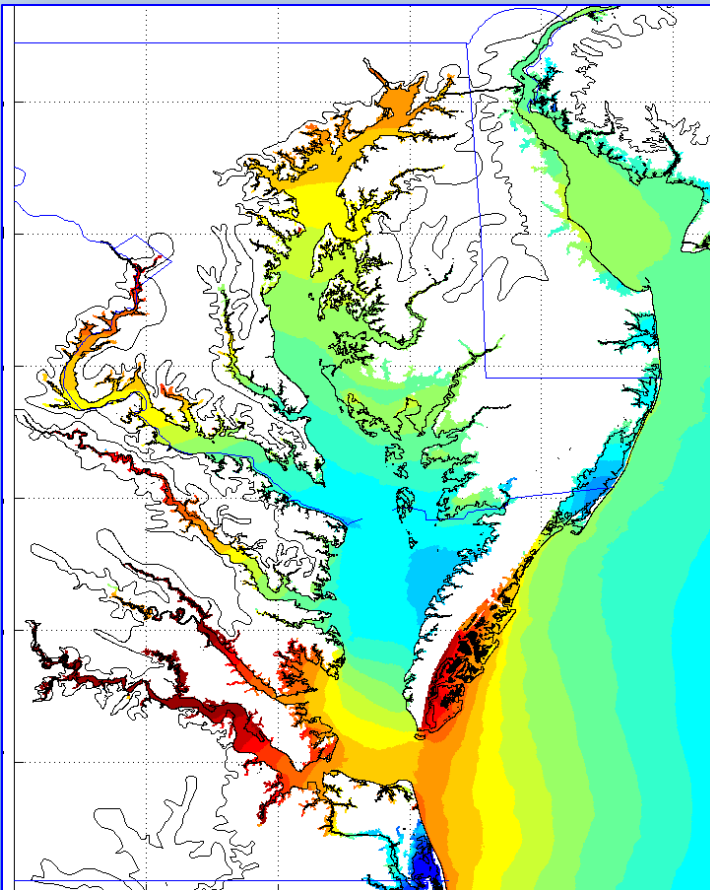
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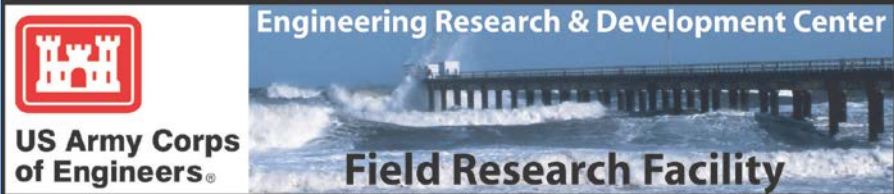
# FEMA REGION III

# COASTAL STORM SURGE STUDY



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Project Specialist

**Jeff Hanson, Ph.D.**  
Project Leader

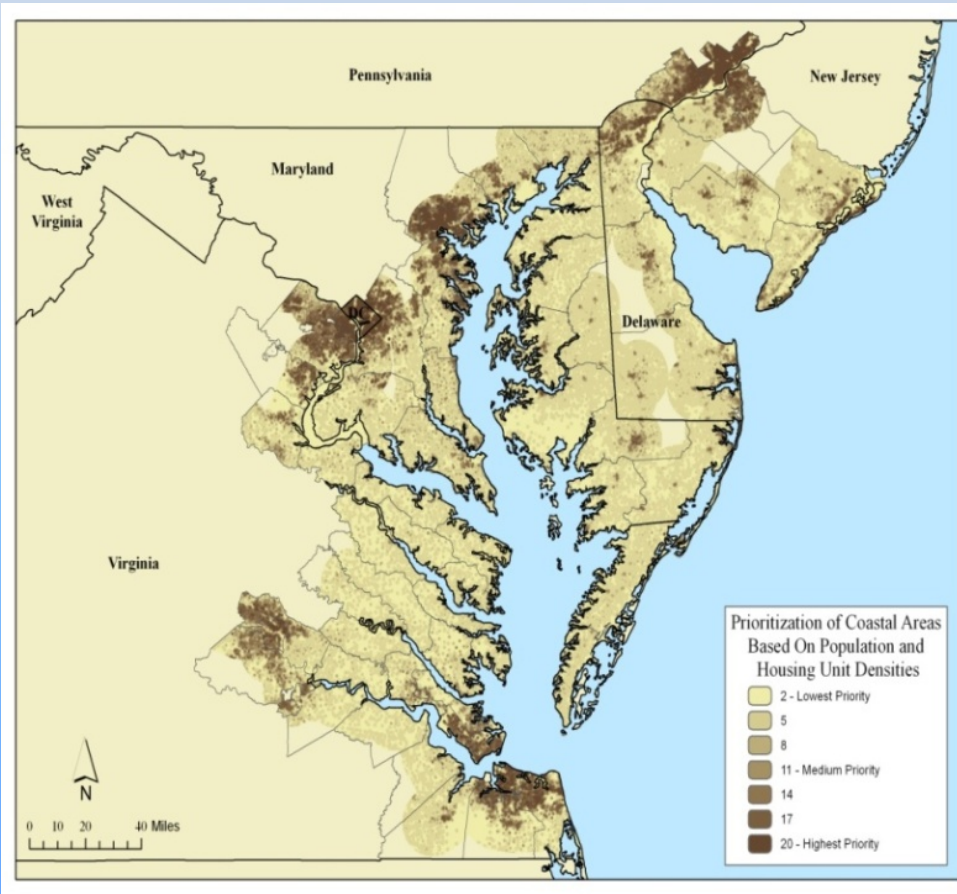


March 2013

Hampton Roads Sea Level Rise/  
Flooding Adaptation Forum



## Region III Population Density



## Study Motivation

- Implement New Guidelines:
  - *Atlantic Ocean and Gulf of Mexico Guidelines Update (2007)*
  - *Sheltered Water Report (2008)*
  - *PM 50 Limit of Moderate Wave Action (LiMWA) (2008)*

## Study Area

- Influenced by six states
- Five metropolitan areas
- Complex coastal geomorphology
- A very ambitious coastal study!



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# Study Partners

**USACE** – Project Oversight, DEM, Model Validations, Extratropical Analysis, Mapping review



**Renaissance Computing Institute** – DEM, Modeling System, Production, GIS Viewer, Analysis



**University of North Carolina** – Water level modeling guidance



**Applied Research Associates** – Hurricanes, JPM Return Period Analysis



**ARCADIS** – DEM, Modeling Mesh



**Oceanweather** – Extratropical and Hurricane Wind Fields



**Elizabeth City State University** – GIS Displays



**RAMPP** – Study Review, Mapping Phase Lead

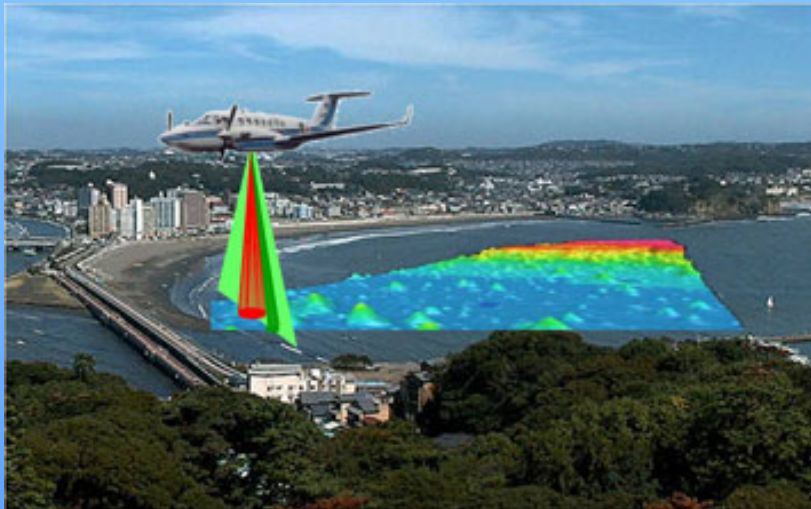
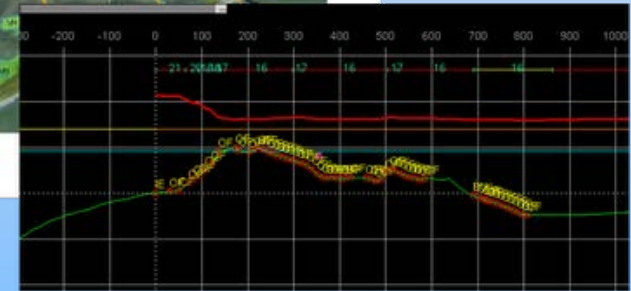
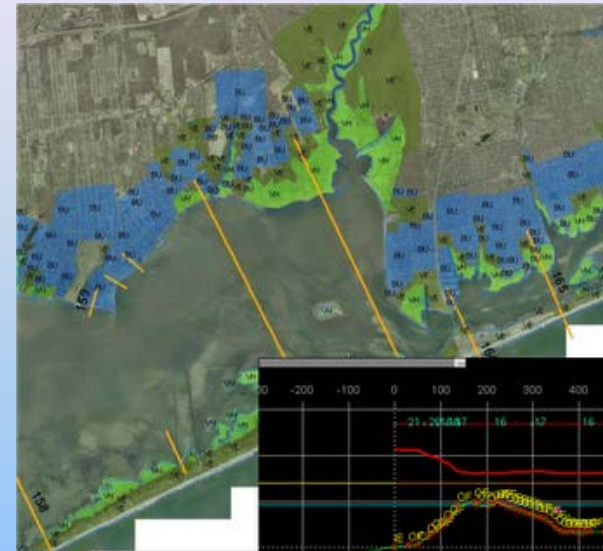




# Why Update Now?

## Modern Advances

- Longer gage records (20+ years longer)
- Improved models – Hurricane Katrina
- High-performance computers
- High-resolution LiDAR survey data





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# Modeling Foundation: Digital Elevation Model (DEM)

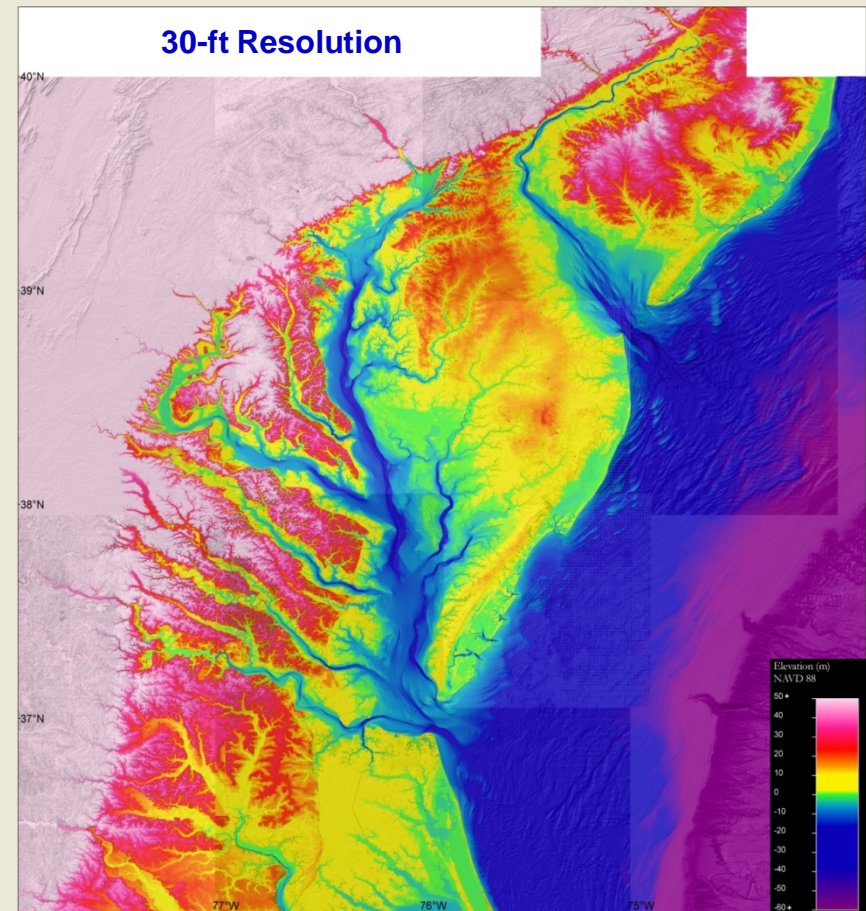


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## A National Resource

- Most complete, up to date, bathy-topo surface available for Mid-Atlantic Region
- Comprised of 120 datasets (~2TB)
- LiDAR used where available
- Consistent elevation surface with 30-ft horizontal resolution
- Provides quality foundation for storm surge modeling

FEMA Region III Digital Elevation Model (DEM)



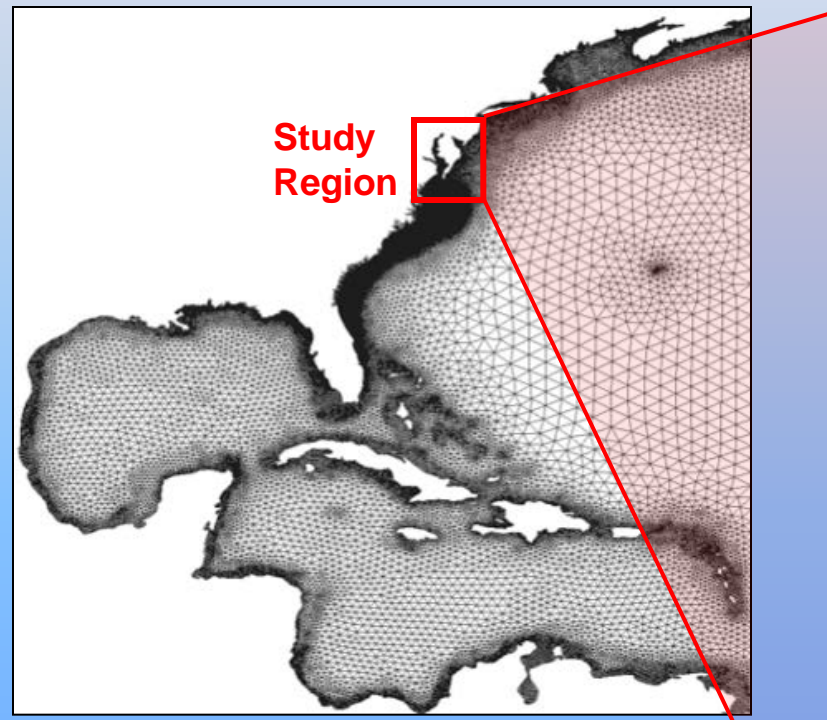




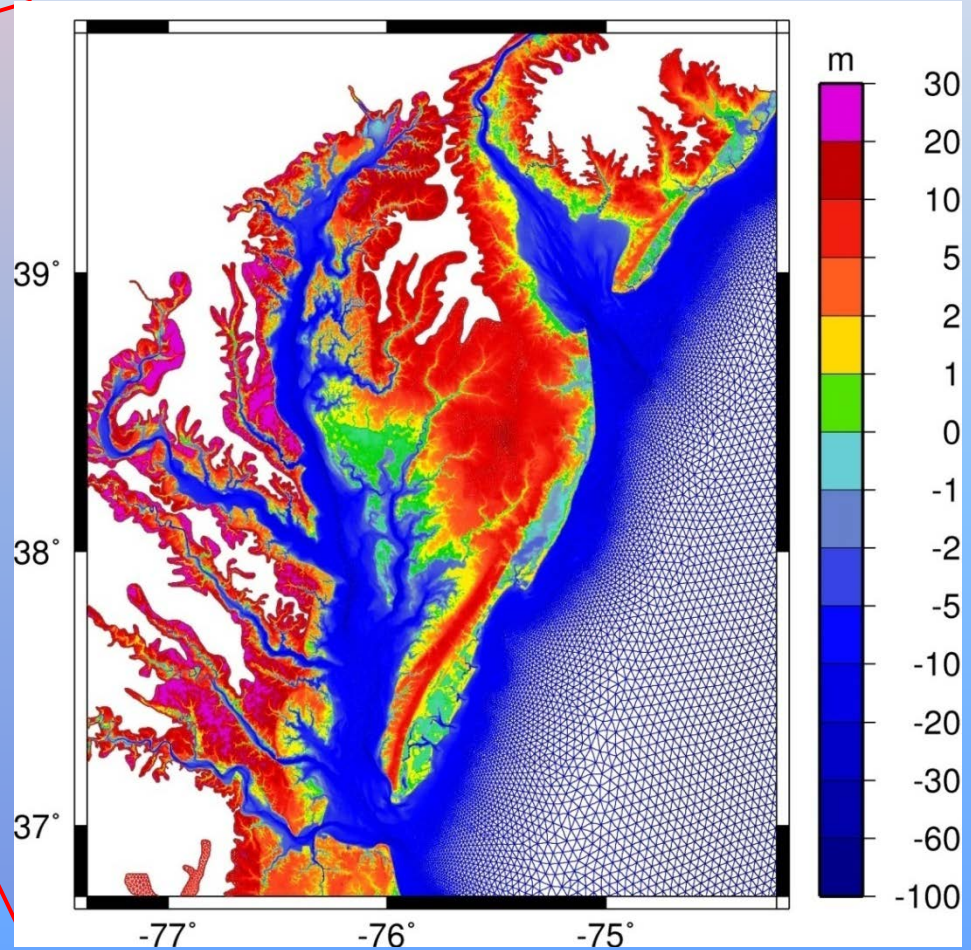
# Unstructured Modeling Mesh

## DEM Interpolated onto Mesh Elements

### Western Atlantic Mesh



### Rich Detail in Study Area



- Specifies land elevation at each calculation point
- Provides a framework for all model components

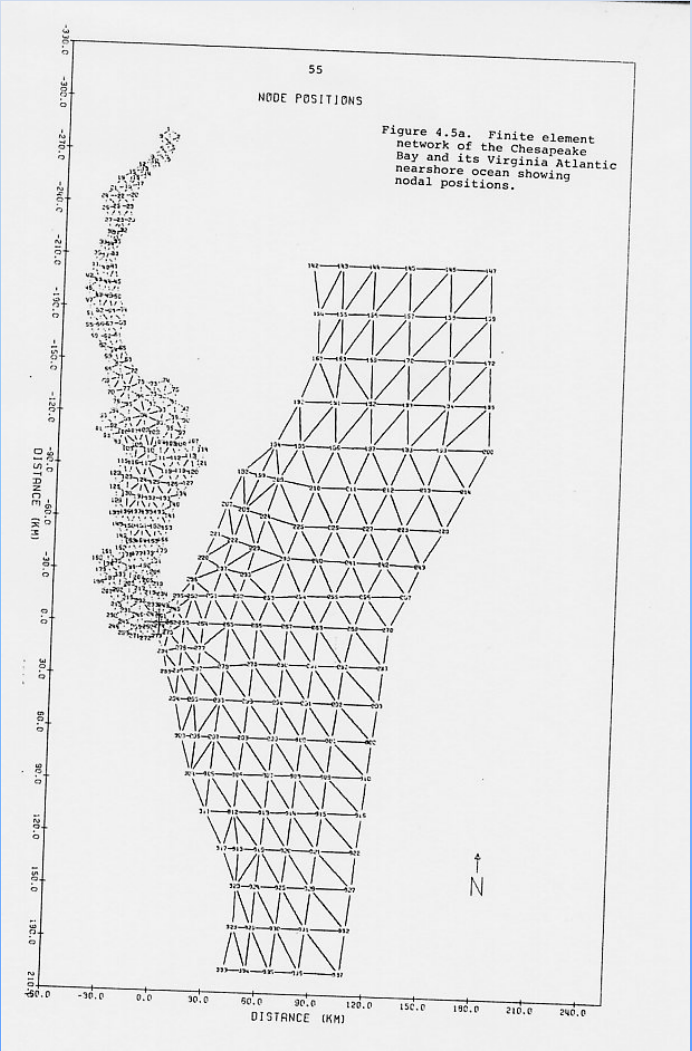


# A Significant Advancement

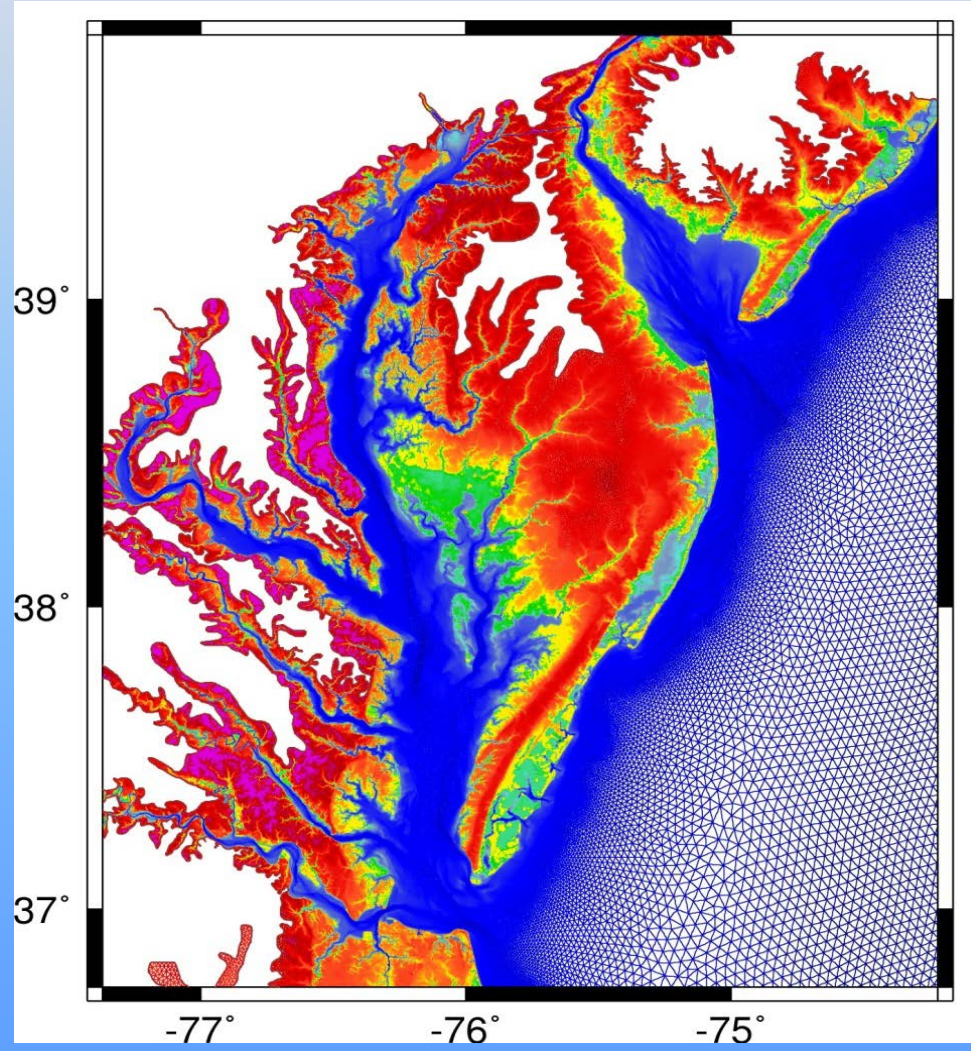


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## 1978 Mesh 3-6 mile resolution



## 2011 Mesh 100 ft Minimum Resolution





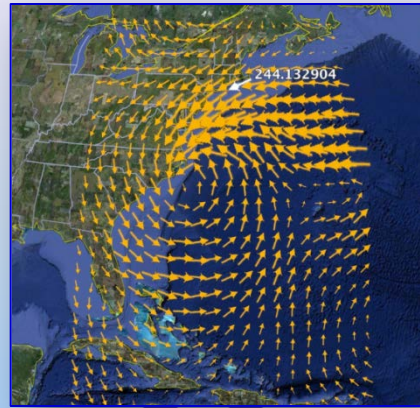


# Storm Surge Modeling System



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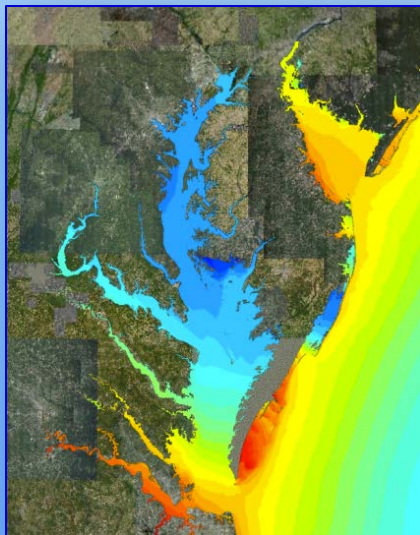
## Model Components



**Atmospheric Forcing**  
- Wind and Pressure Fields

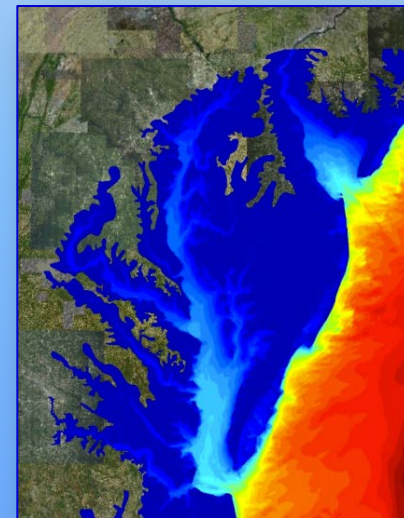
**HBL** Hurricane Boundary Layer Model  
Extratropical Storm Reconstructions

**Circulation Model**  
- Tides, - Currents



**ADCIRC**  
Advanced CIRCulation model

**Wave Model**  
- Surface waves



**unSWAN**  
un-structured Simulating WAVes Nearshore model

**Coupling**



**Water Levels**



**Wave Stress**



# Modeling System Validation

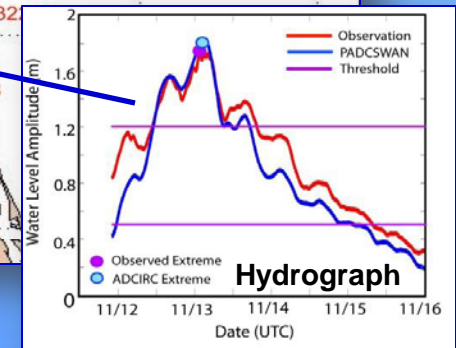
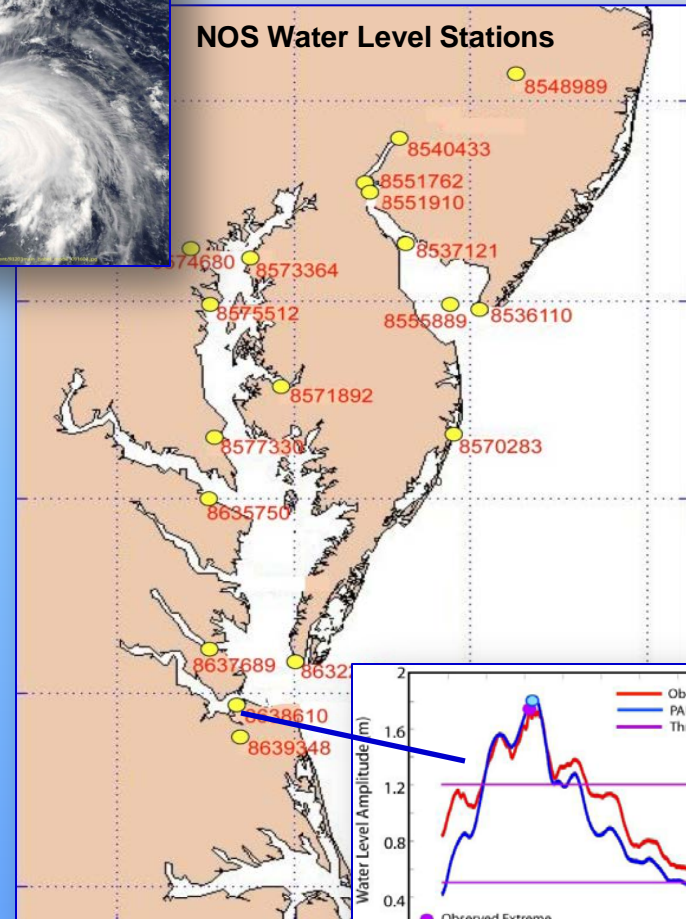
## A Critical Step in the Storm Surge Study

### Why Validate?

- Establish credibility
- Quantify expected errors
- Demonstrate accuracy
- Build confidence that model can be applied over range of conditions



Isabel





# Validation Storms



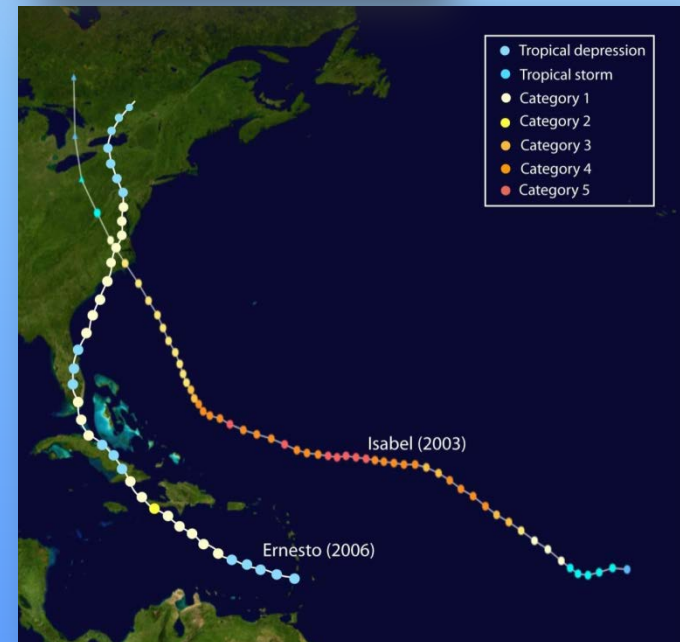
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## Event Reconstruction

- Three major storms selected
  - Hurricane Isabel
  - Hurricane Ernesto
  - Extratropical Storm Ida (Nor'Ida)



Extra-Tropical Storm Ida, Norfolk, VA





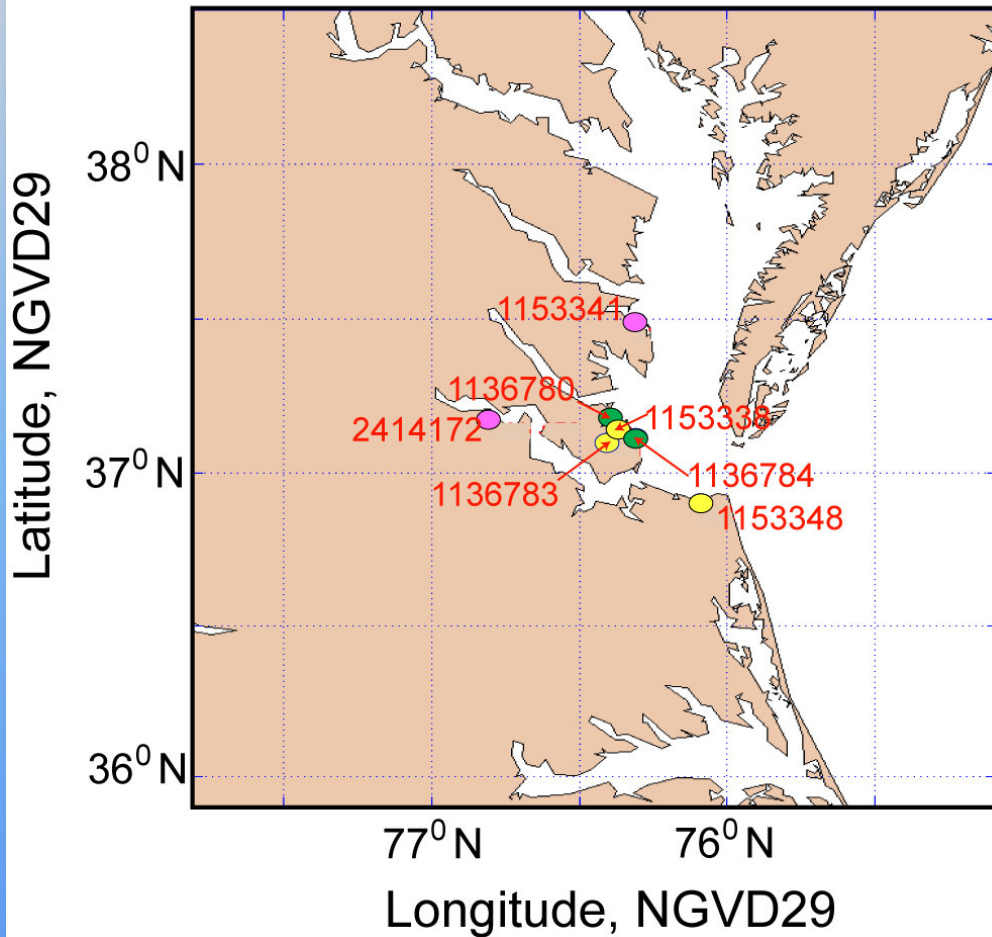


# Nor'Ida: USGS Rapid Response Water Level Validation



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USGS Rapid-Response Storm Surge  
Validation Stations, Nor'easter Nor'Ida



## Rapid Response:

- Water level gauges deployed on land in projected storm path
- Observations and validations include tides
- Four stations inundated by Nor'Ida



# Nor'Ida: USGS Rapid Response

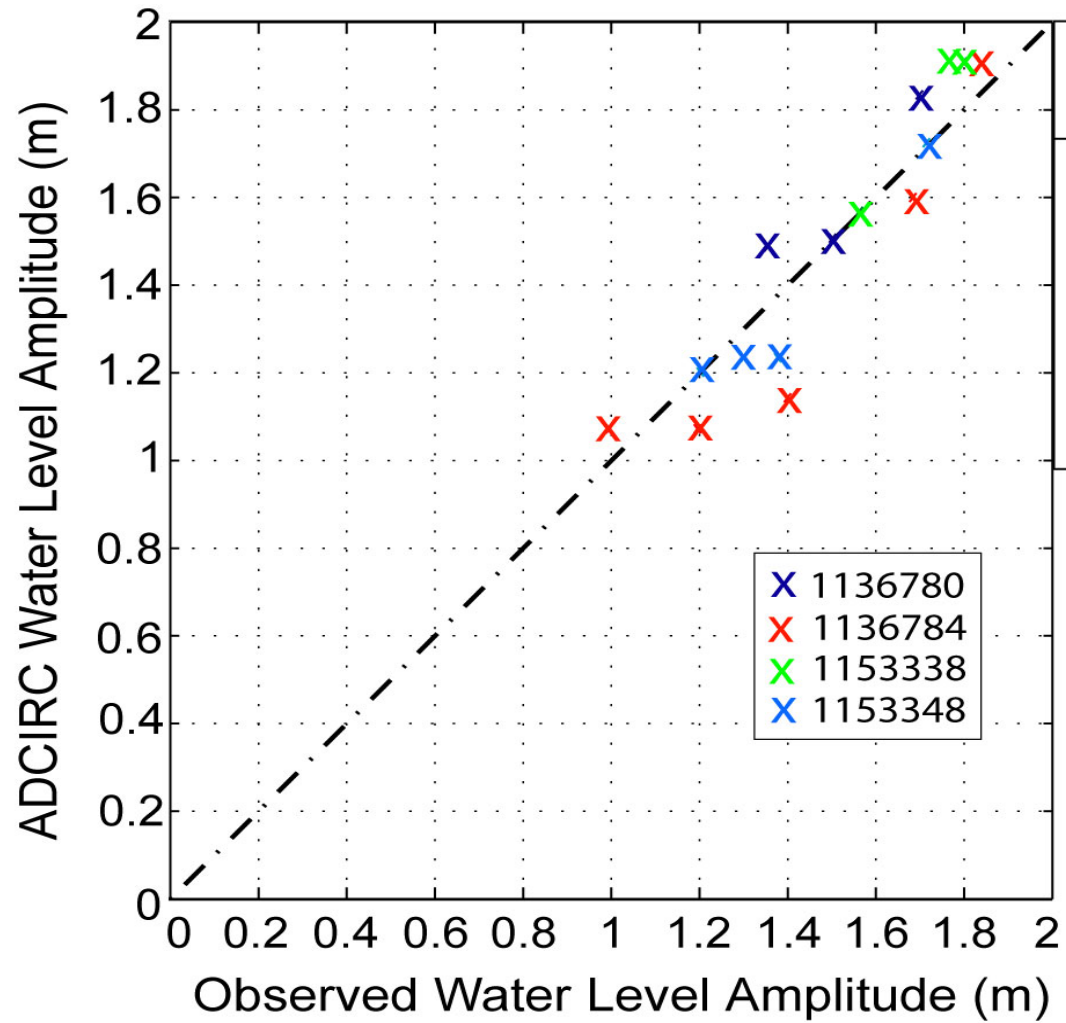
## Peak Water Levels



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ADCIRC High Water Level Amplitude Plot:  
Extremes Analysis, USGS Rapid Response, Nor'Ida, Nov. 2009



Statistics	
bias (m)	= 0.00
rms (m)	= 0.11
SI	= 0.08
Perf	= 0.96

- X 1136780
- X 1136784
- X 1153338
- X 1153348

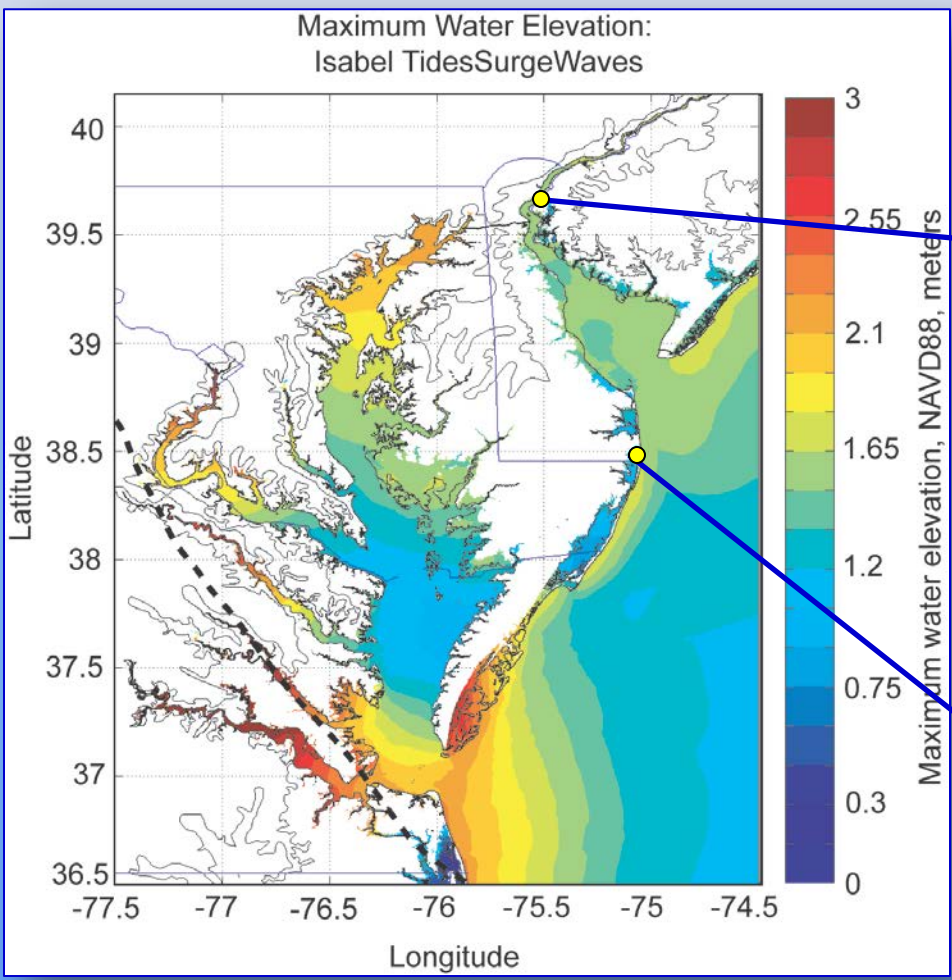


# Example Hurricane Isabel Water Levels

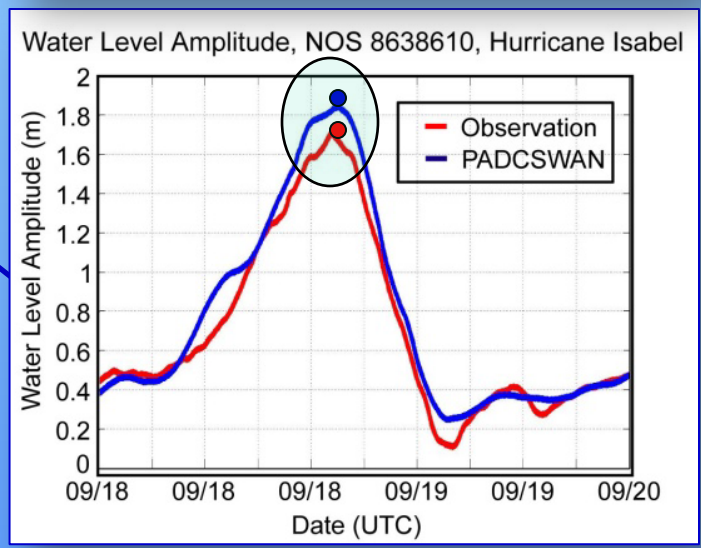
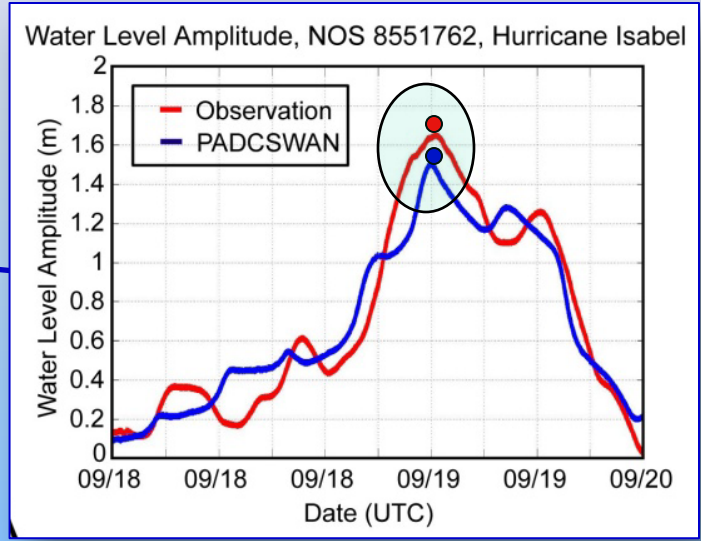


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## Max Elevation (m)



## Hydrographs (m)





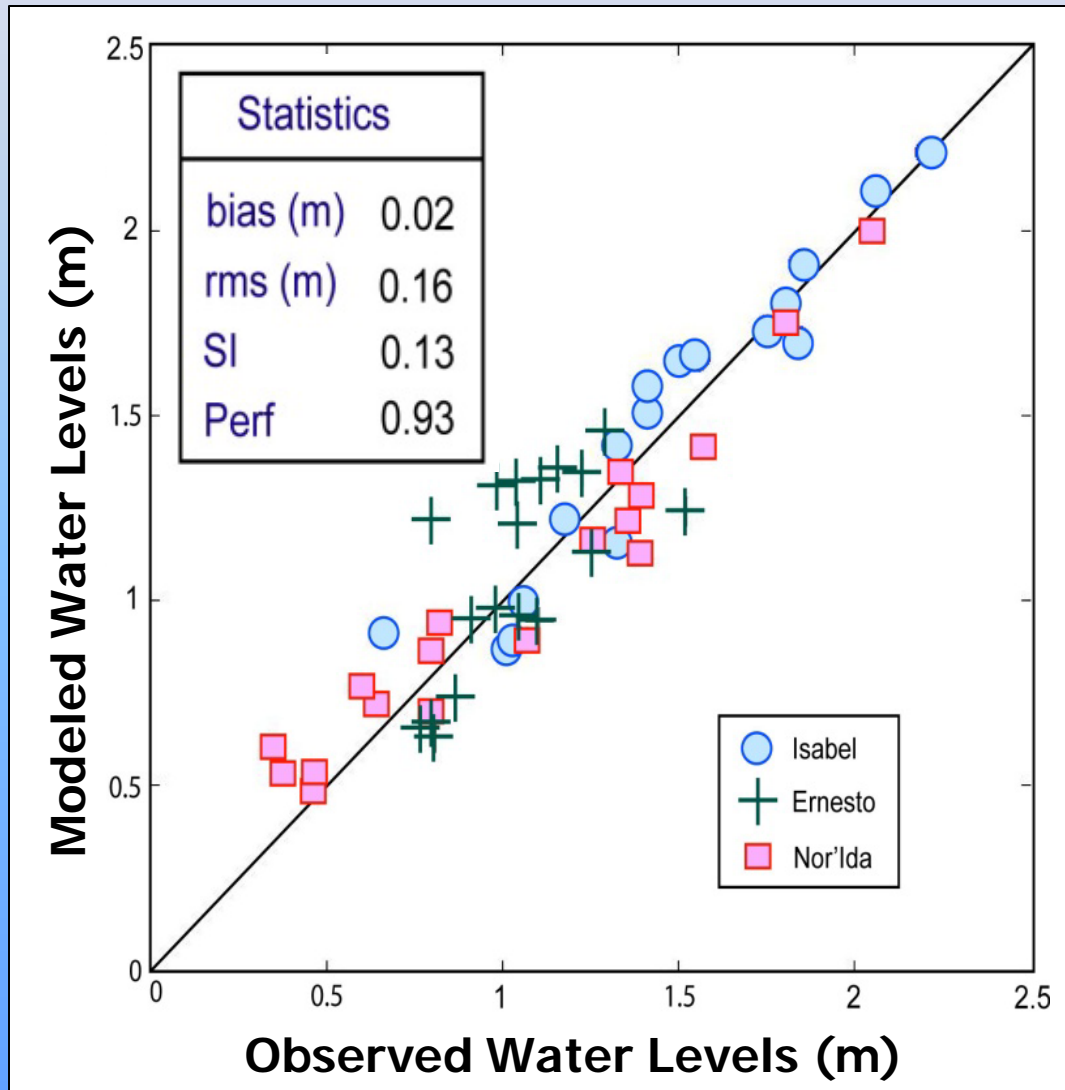


# Modeling System Validation



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## Peak Water levels – NOS Stations



## Validation Results

- Modeling system demonstrates an extremely high skill level
- Average offset is < 1 inch
- Mean square error is only 6 inches

## Conclusion

- System can be applied with confidence across the Region III Domain for the Risk MAP program



# Production Run Storms



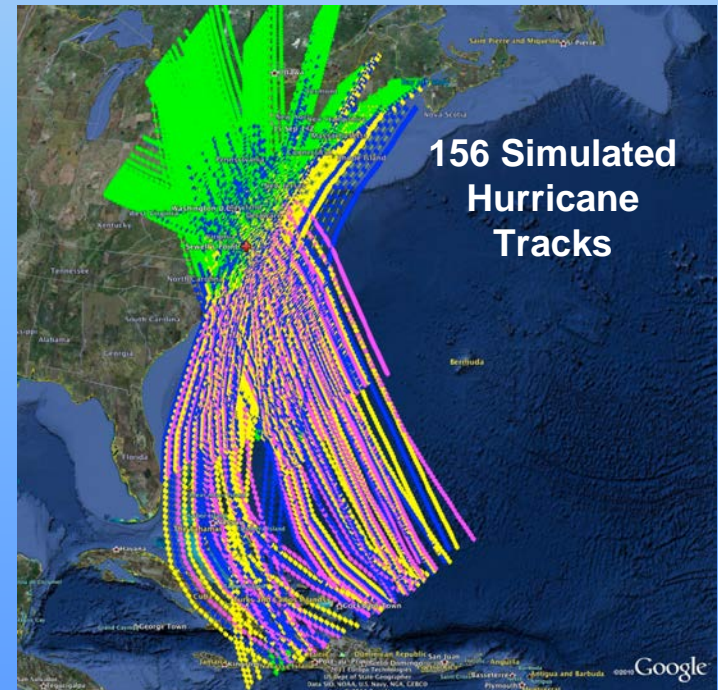
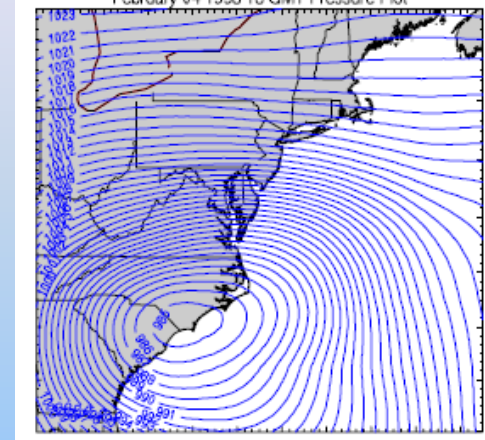
## Extratropical Storms

- 30 Top ranked storms 1975-2009
- Based on water levels at 10 stations
- Careful reanalysis of wind/pressure fields

## Tropical Storms

- Record of 20 hurricanes in 60 years insufficient for 100- yr analysis
- 156 Representative events sampled from ASCE 100,000-year synthetic storm set
- A 1-year effort!
- Intensities range from Tropical Storm to Cat 3

February 4, 1998 Pressure Field







# Sample Results



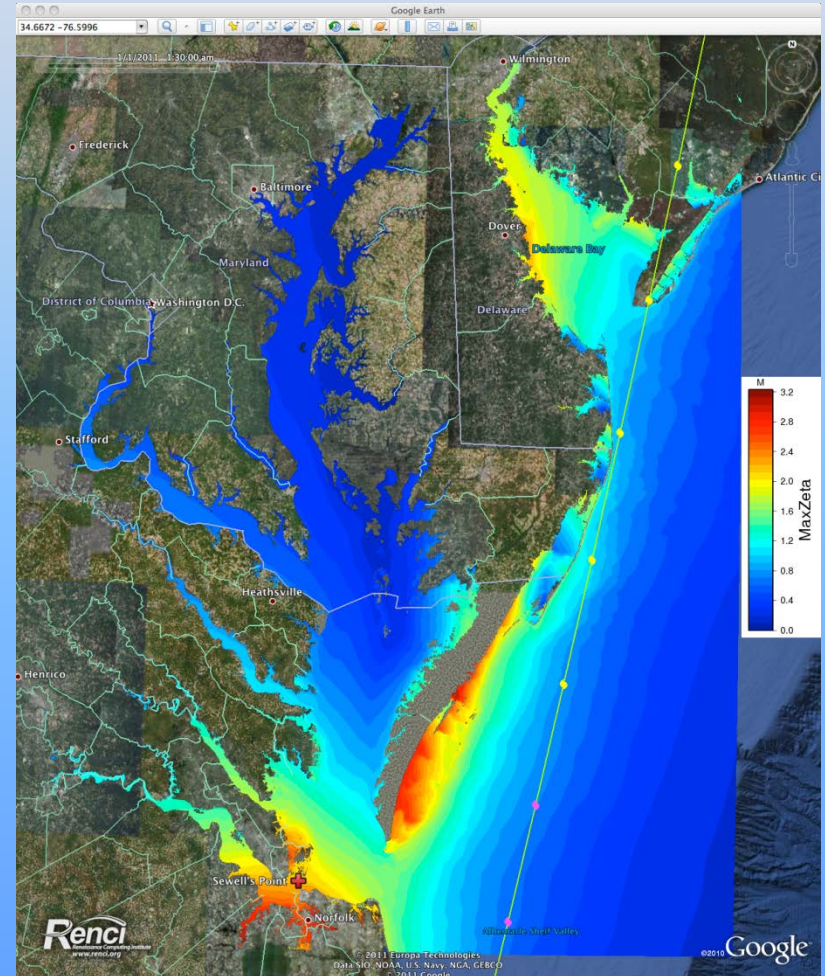
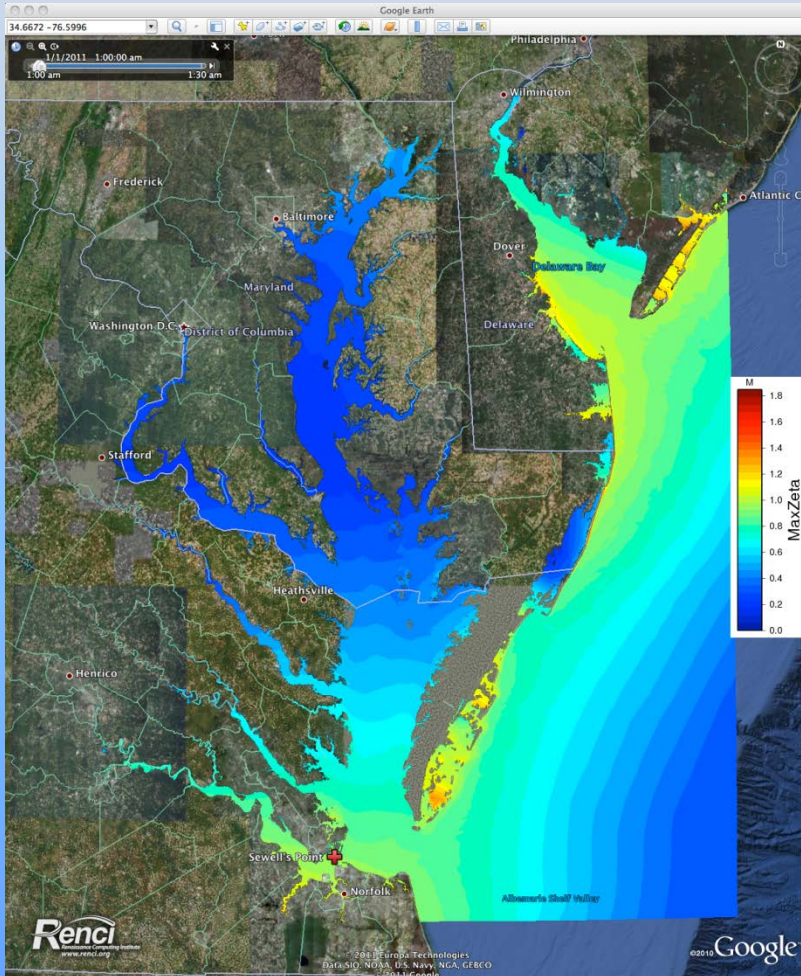
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## Maximum Water Elevations (m)

### Extratropical Storm 2005 10 25

### Tropical Storm dp3rlblch5ll



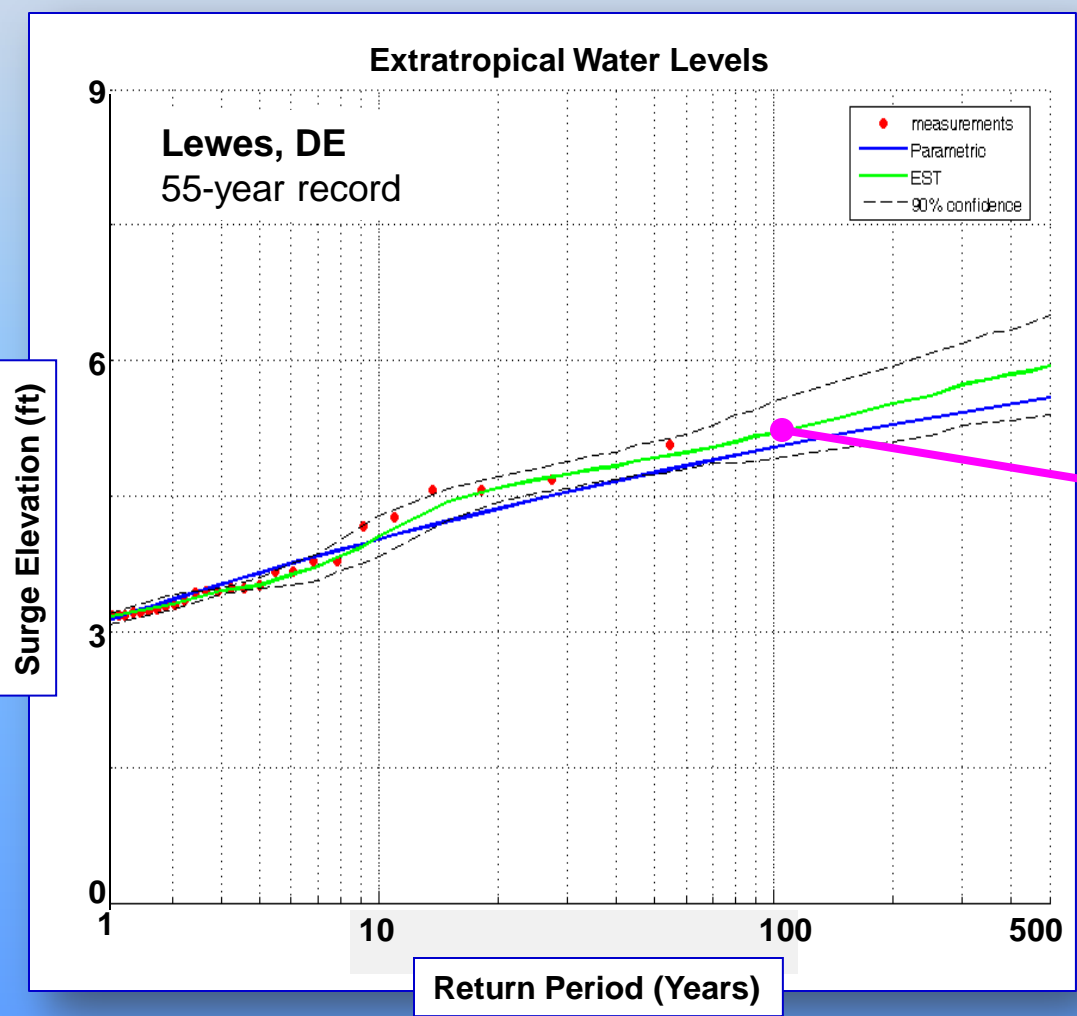




# Reoccurrence Analysis

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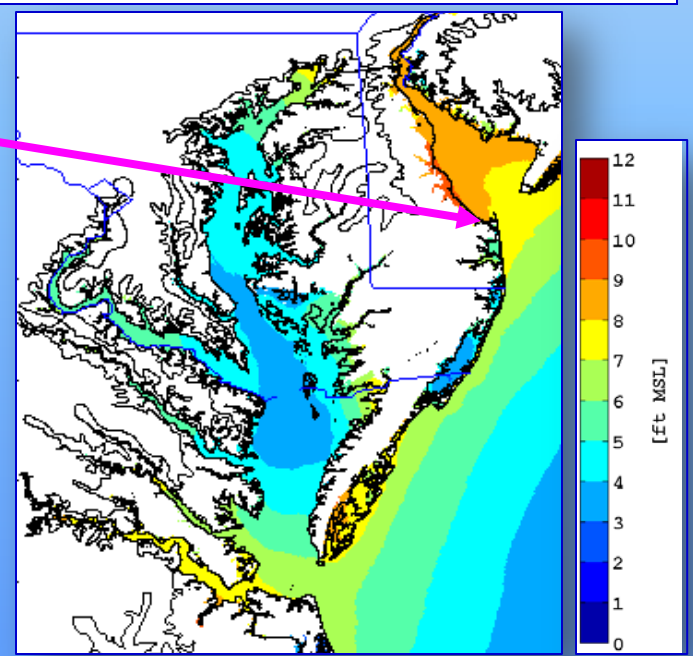
## A Projection of Future Flood Risk



## Combined Analysis

- Extratropical water levels
- Hurricane water levels
- Tidal contributions

## Combined 100-yr Water Levels (ft)





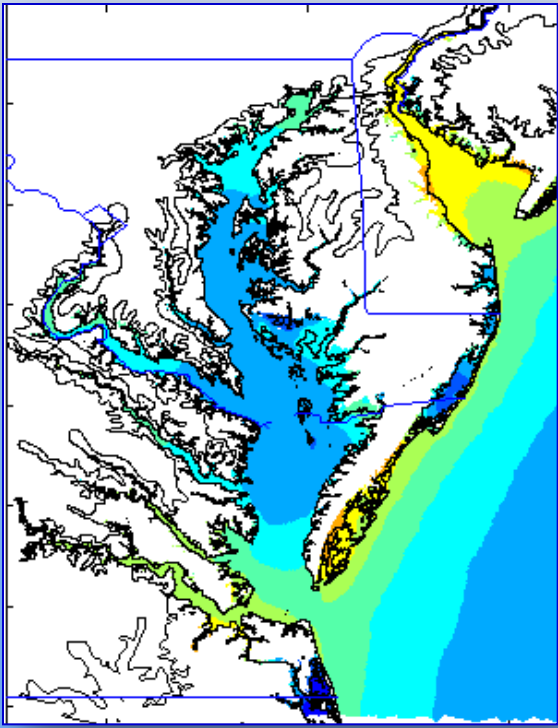
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# Updated 100-yr Water Levels (MSL)

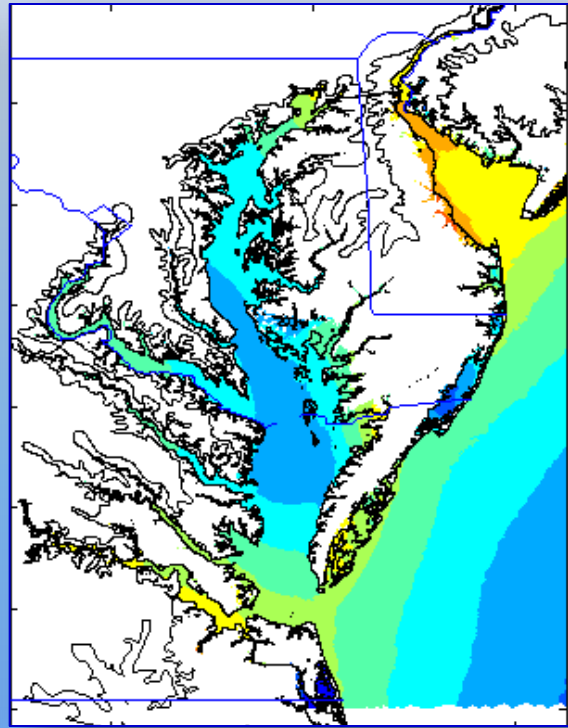


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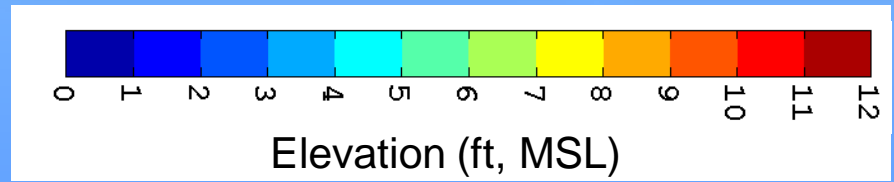
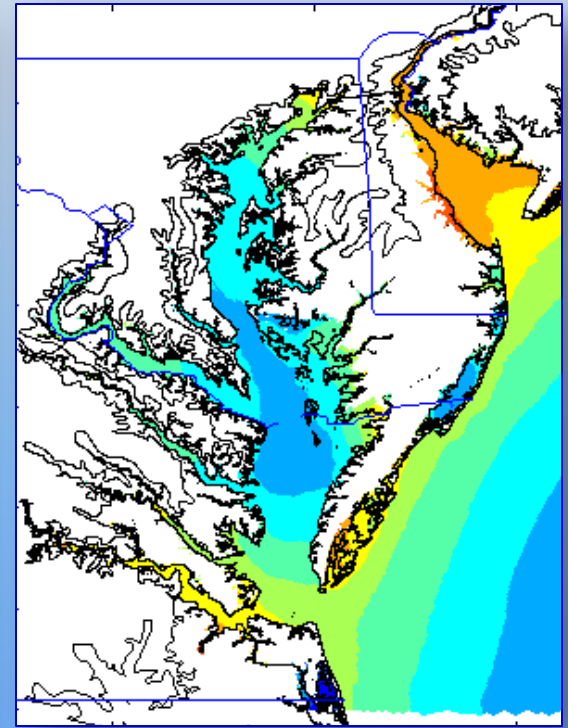
### Hurricanes



### Extratropicals



### Combined



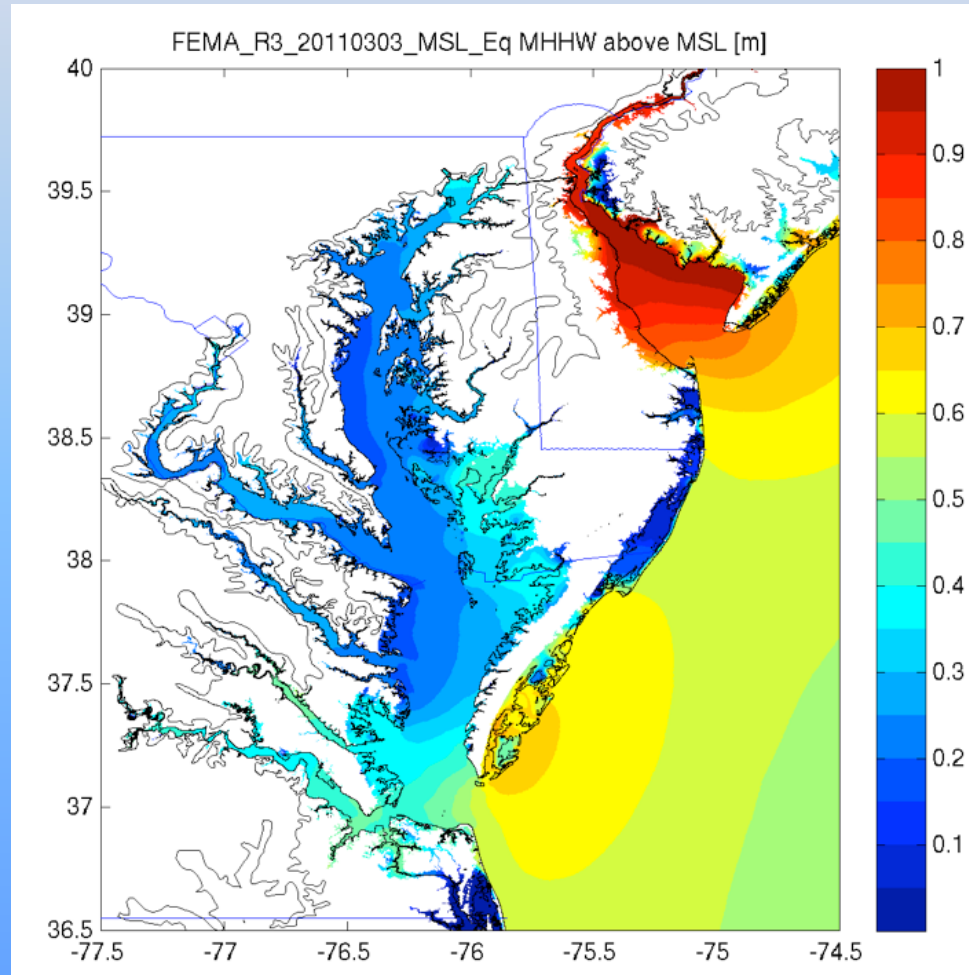
**On average, updated results are 0.5-ft lower than published levels**



# Tidal Contributions



## Average High Tide Elevation MHHW above MSL (m)







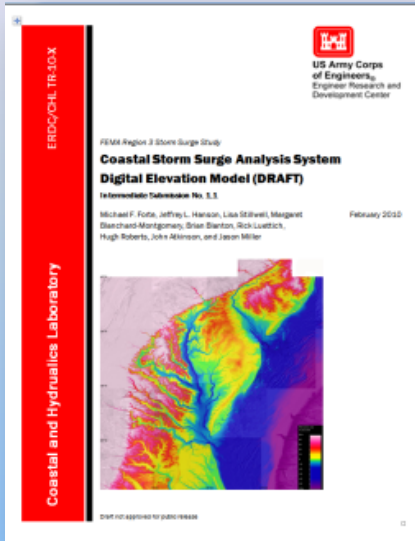
# Study Results

DODReports.com

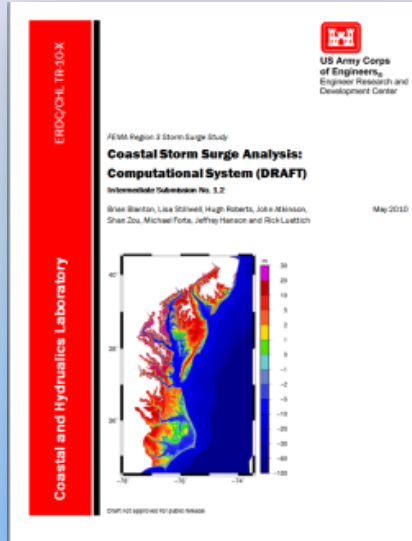


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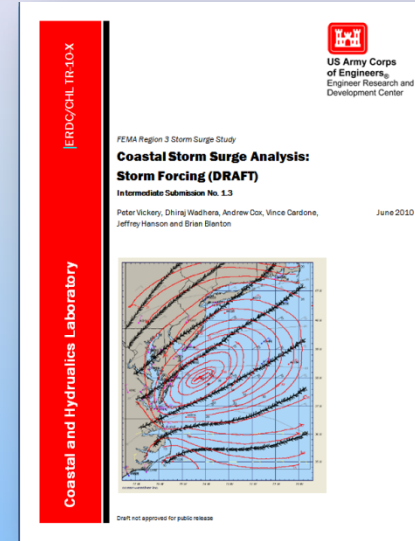
## 1.1 DEM



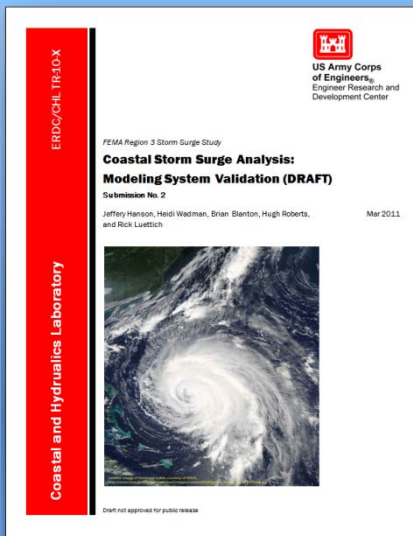
## 1.2 Modeling System



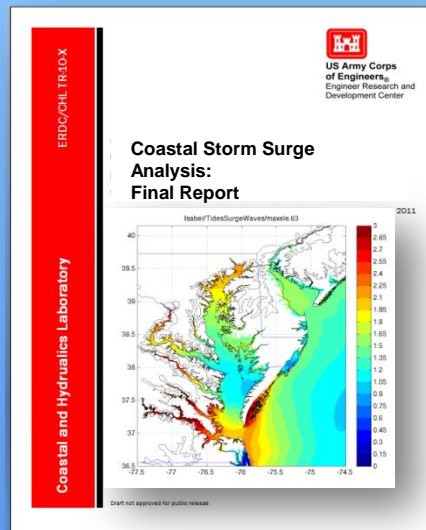
## 1.3 Storm Forcing



## 2. Model Validation



## 3. Final Analysis



- Methods and results
- Multi-tiered review
- Released as formal reports
- Available at <http://dodreports.com/>