ADCIRC_Lite: Rapid Tropical Cyclone Surge and Wave Evaluations using Pre- computed ADCIRC Solutions

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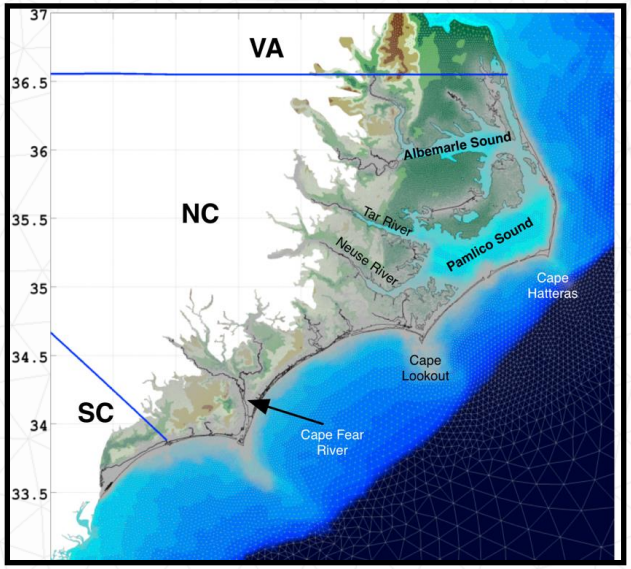
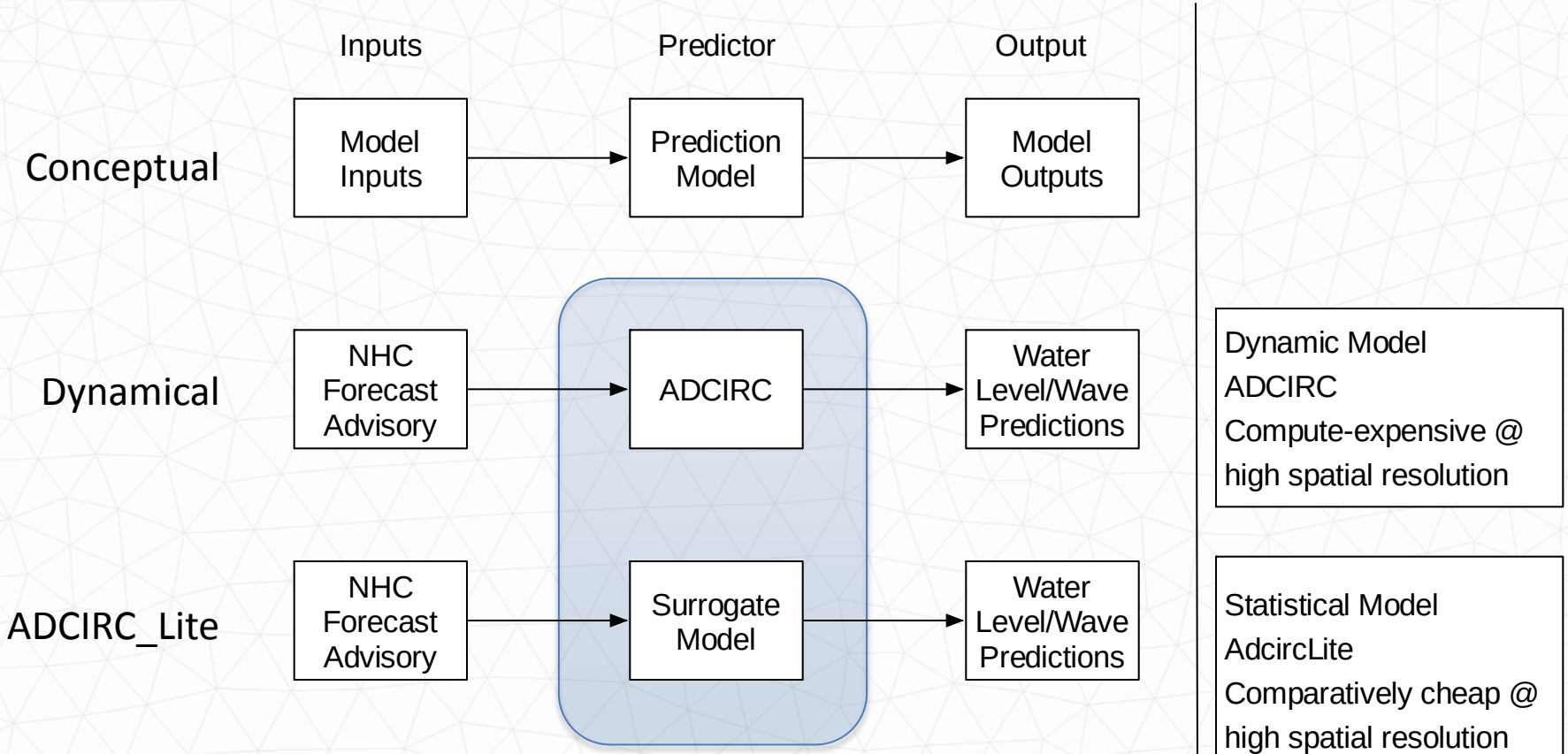
The Issue

- Short forecast windows
  - Forecast cycle typically 6 hours
  - Need information well within this 6-hour window
  - Want guidance information ASAP
- High-resolution, dynamic surge & wave simulations are resource intensive
  - Typical 1 - 3 hours run time on 192 processors
  - Multiple member ensemble requires more
- How to accelerate model throughput
  - Much more computer hardware (someday…)
  - Take advantage of pre-computed, high resolution solutions (e.g., Surge Atlas)



Our Approach – Surrogate Models



Dynamic Model
ADCIRC
Compute-expensive @ high spatial resolution

Statistical Model
AdcircLite
Comparatively cheap @ high spatial resolution (once the Surrogate Model is developed)

Surrogate Modeling

Implement a surrogate model that rapidly predicts a response (storm surge, waves) using familiar variables (hurricane parameters)

- Surrogate models approximate complex systems
  - Replace ADCIRC with AdcircLite
- Leverage ***existing*** database of high-resolution storm surge simulations
  - recent FEMA coastal National Flood Insurance Program Study for North Carolina
  - similar FEMA NFIP databases available for other areas
  - Supplement existing databases as desired / needed
- Results look like and distributable via standard protocols, e.g., THREDDS servers

AdcircLite Surrogate Model

Response Surface Method

- Long history in engineering, chemistry…
- More recently used for storm surge – JPM OS D. Resio; also J. Irish
- AdcircLite uses 2nd order moving least squares
- Much better accuracy compared to zeroth-order methods

$$\hat{z}_i(\mathbf{x}) = \sum_{j=1}^{NB} b_j(\mathbf{x}) a_{ij}\{\mathbf{x}\}$$

response estimate

vector of hurricane parameters

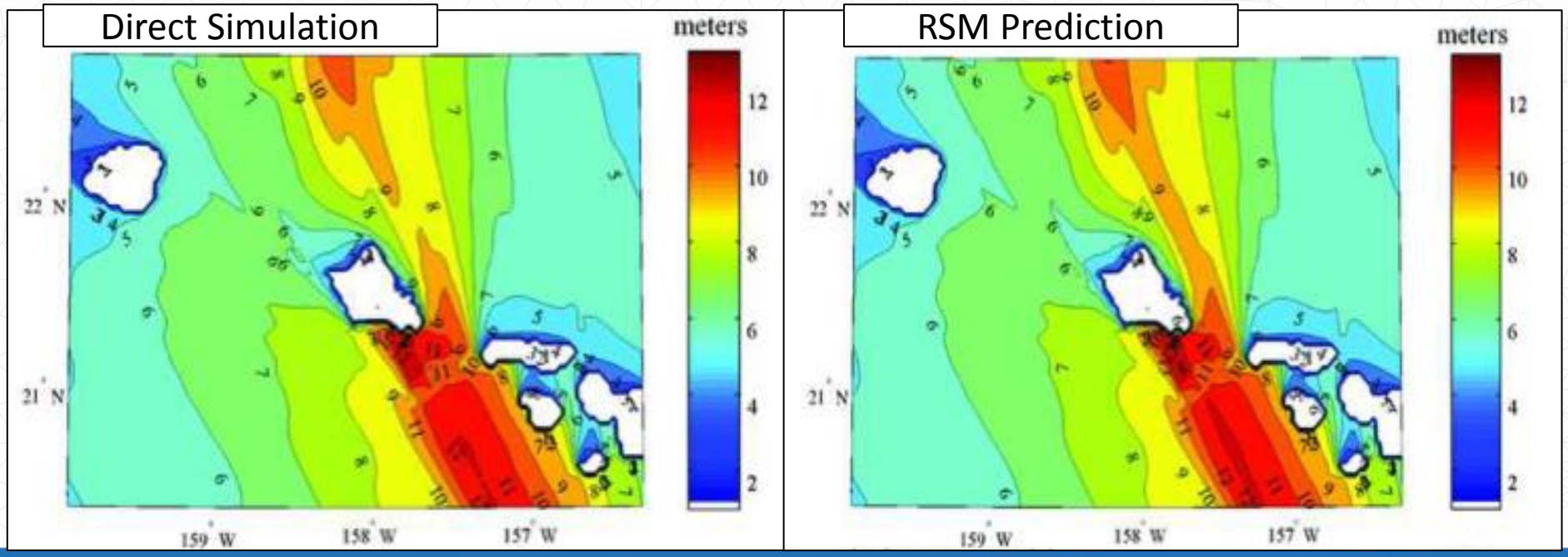
basis functions

database of dynamic model solutions x weighting coefficient found by optimization

Response Surface Method

2nd order moving least squares

Hawaii Wave Prediction Example, from Taflanidis et al (2012)

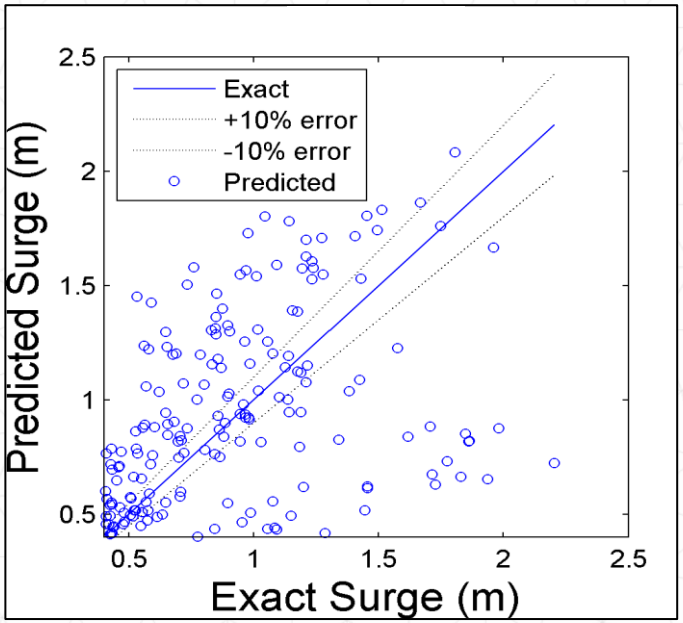


Response Surface Methods

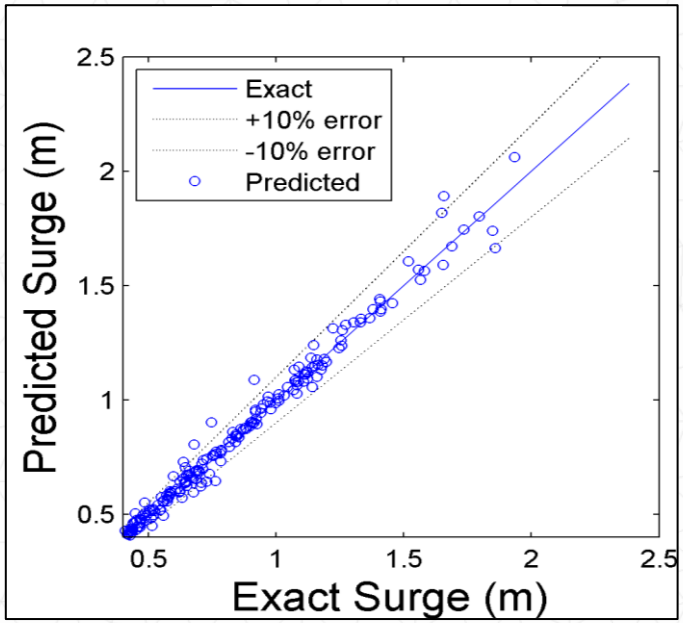
2nd order moving least squares

Storm Surge Prediction Example

0th order nearest neighbor



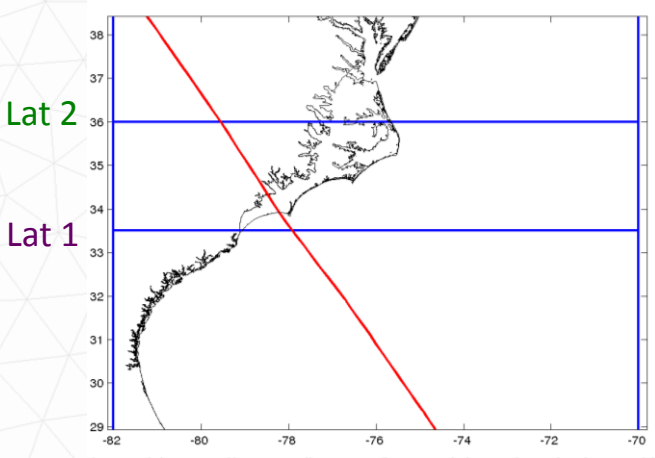
2nd order Moving Least Squares



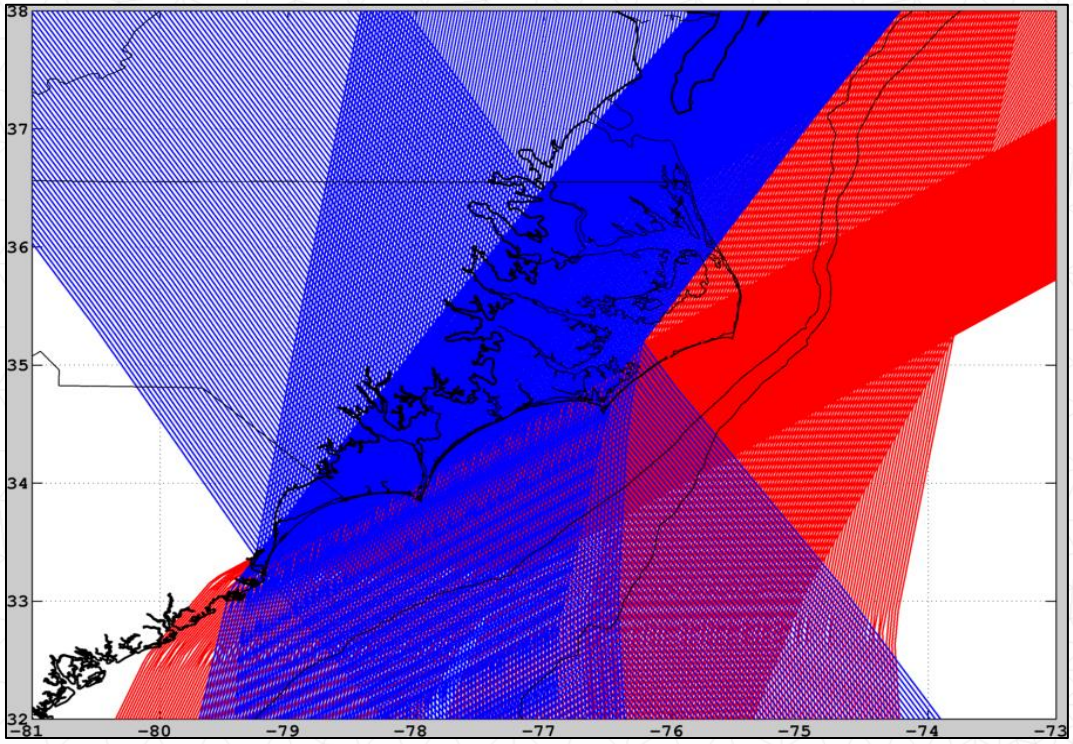
NC - Hurricane/Surge Database

- 648 hurricane tracks and surge/wave responses on an ADCIRC grid

Central pressure deficit (D_p)
Storm forward speed (V_f)
Radius to maximum winds (R_m)
Holland B shape parameter (H_B)
Latitude Crossings (Lat 1, Lat 2)

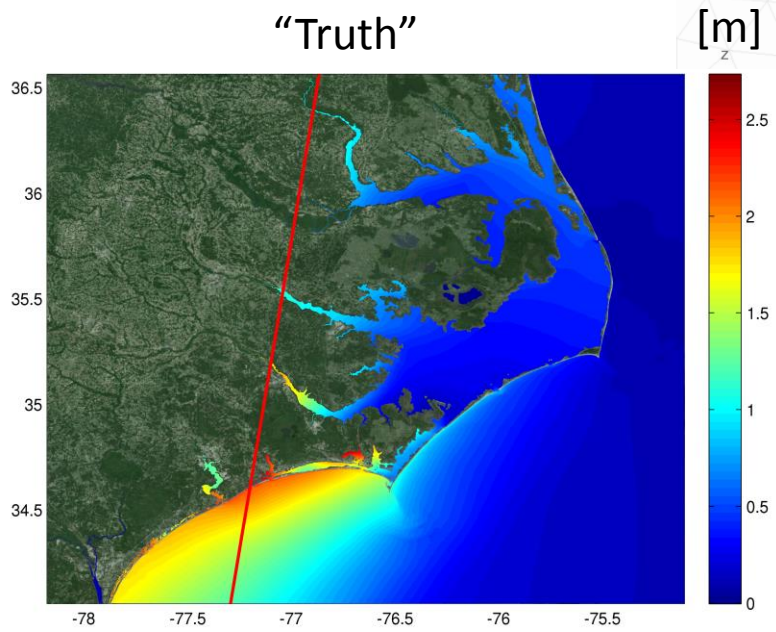


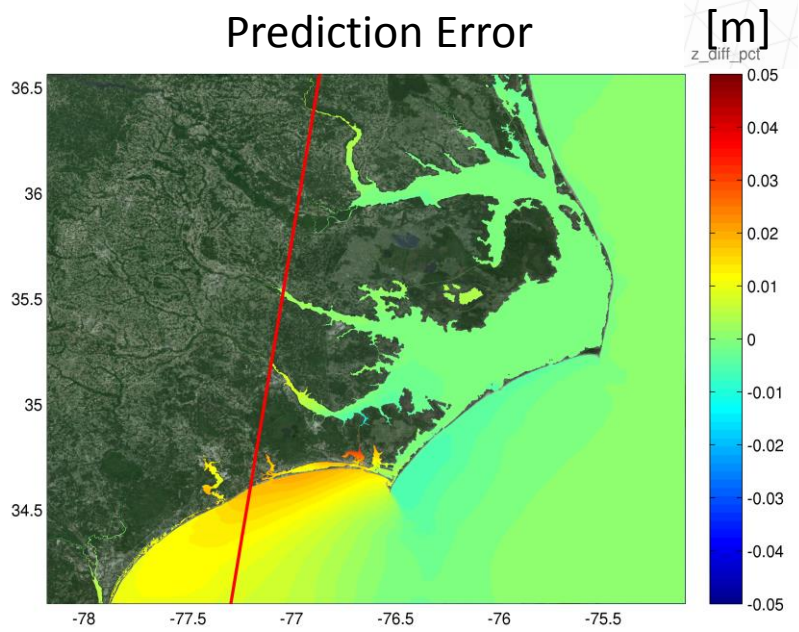
Storm Population



Prediction Tests

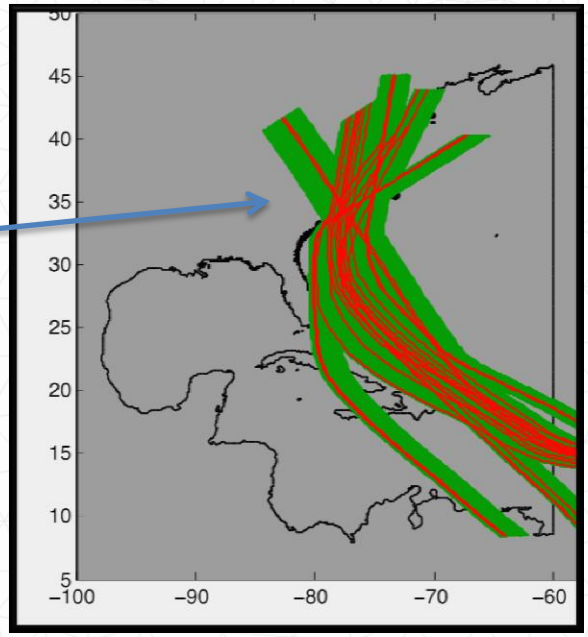
- Surrogate model computed on full ADCIRC domain
- Prediction of one particular storm omitted from model

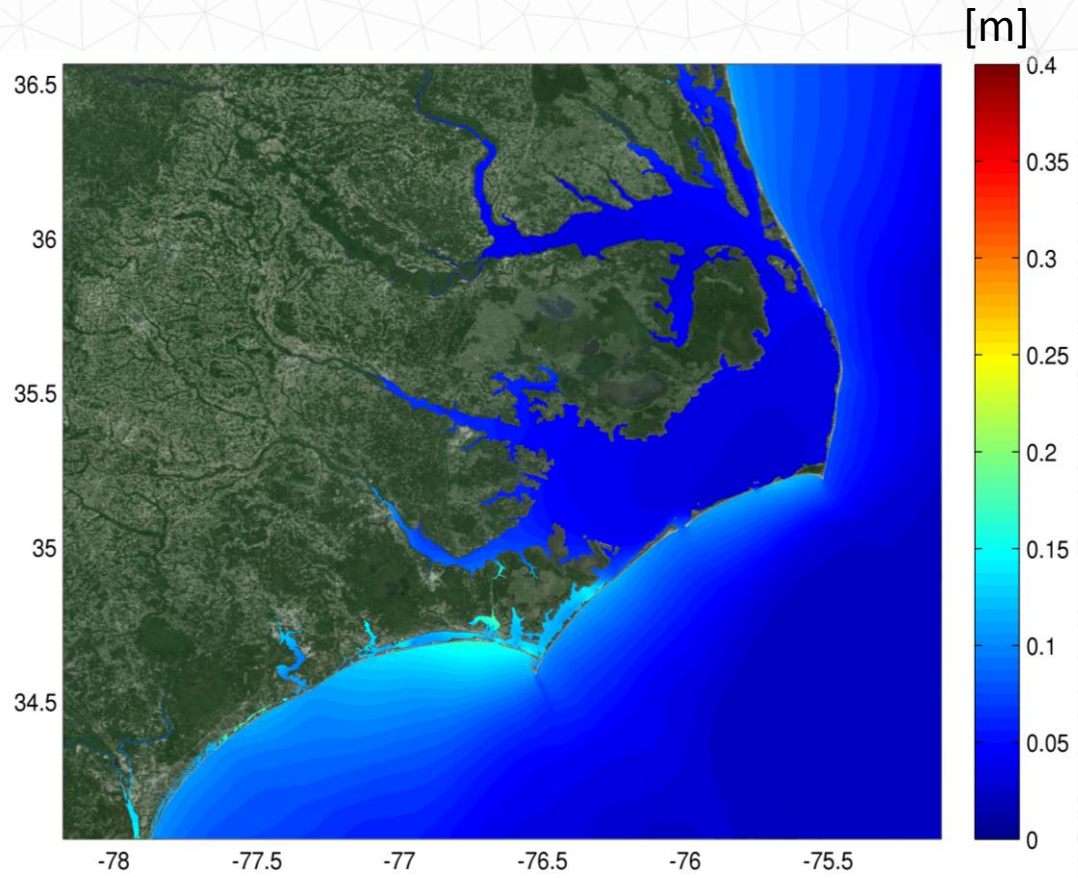




Prediction Tests

- RMSE at each node for all omitted storms
- Overall, small RMSE (< 15 cm)

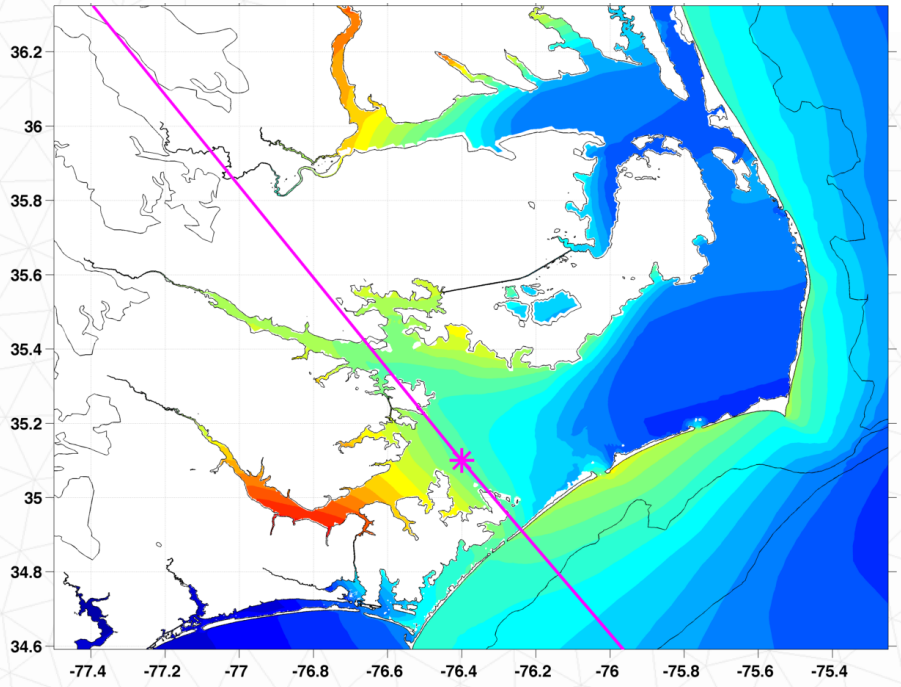




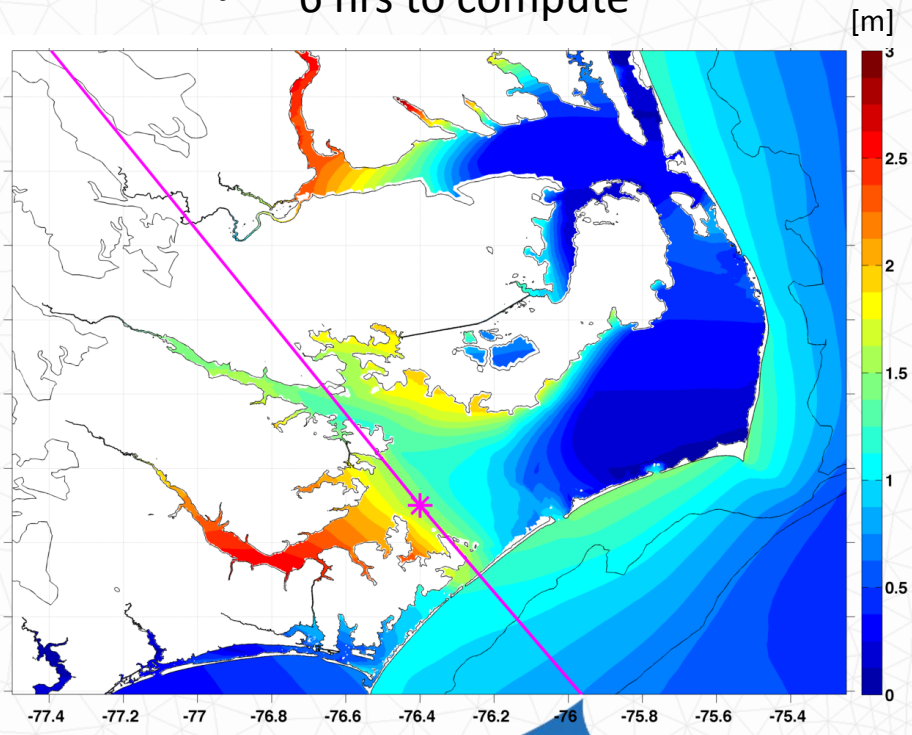
Historical Storm Results – Isabel 2003

Maximum
Water Level

AdcircLite-NC Model Prediction
- 4 secs to compute



FEMA Validation Study
- ~6 hrs to compute

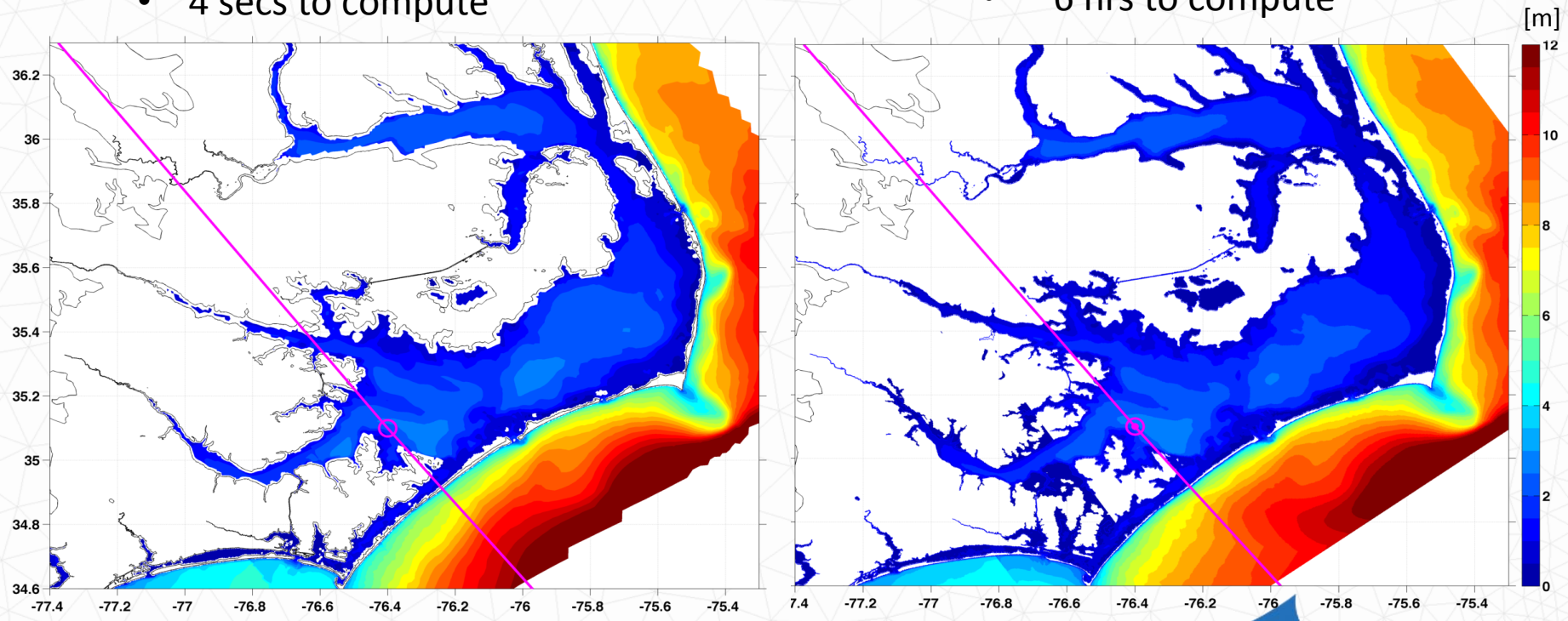


Historical Storm Results – Isabel 2003

Maximum
Significant Wave Height

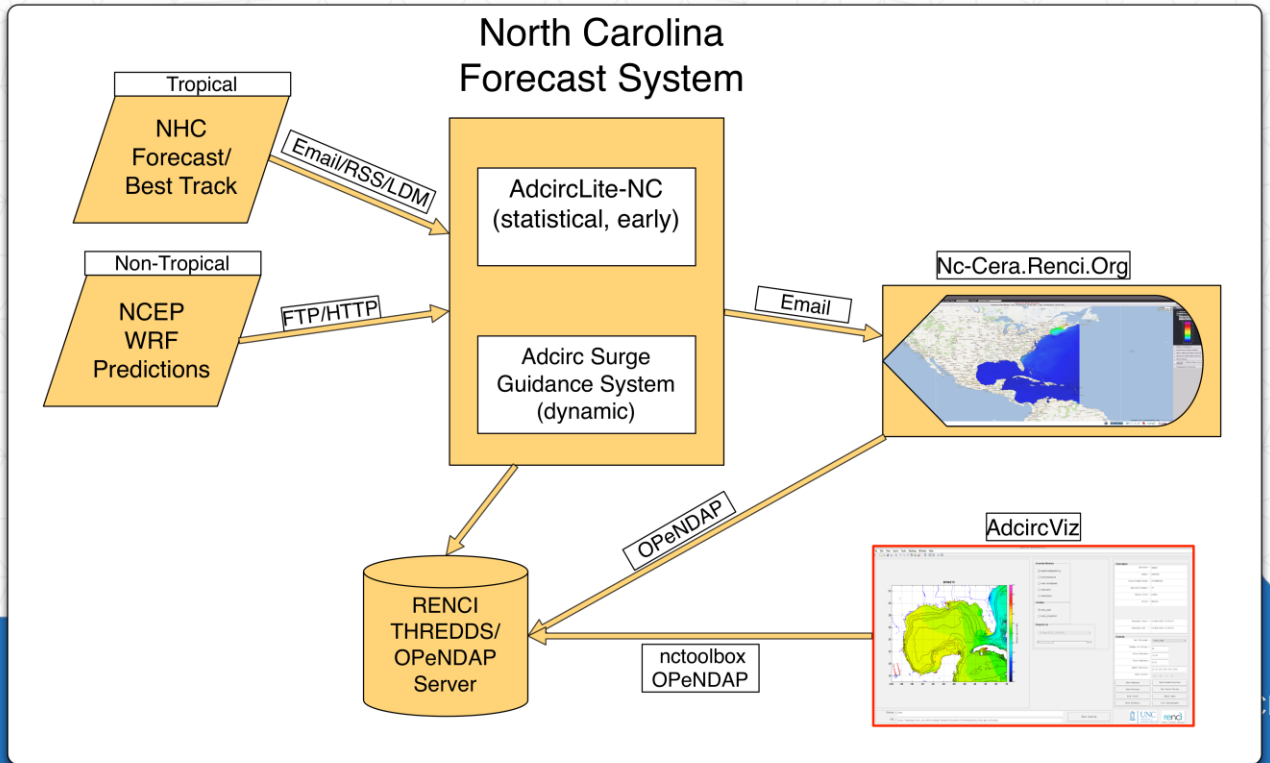
AdcircLite-NC Model Prediction
- 4 secs to compute

FEMA Validation Study
- ~6 hrs to compute



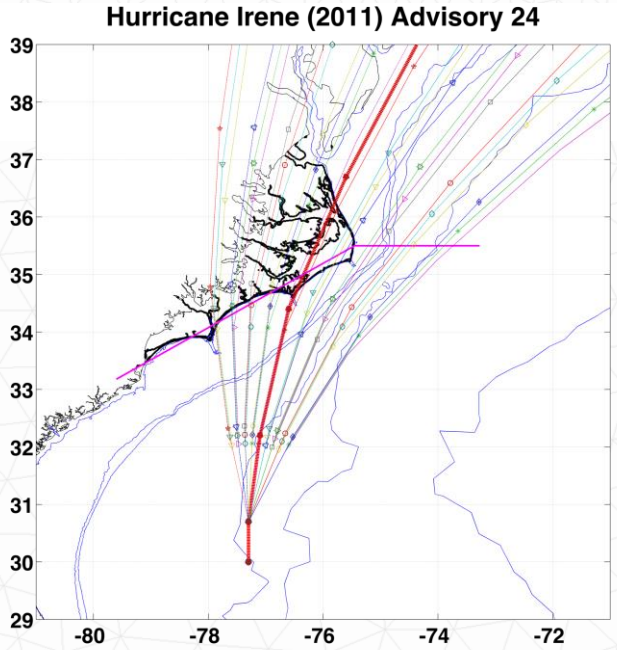
Ongoing Activities

- Extensive , validation/verification study against historical events
  - For surge and waves
- Extending to inundation
- Embedding in Forecast System, functionally equivalent to ADCIRC
  - Output is the same format described in previous JHT talk (CF-UGRID)
  - Results will be available on the web and from within AdcircViz (2015)

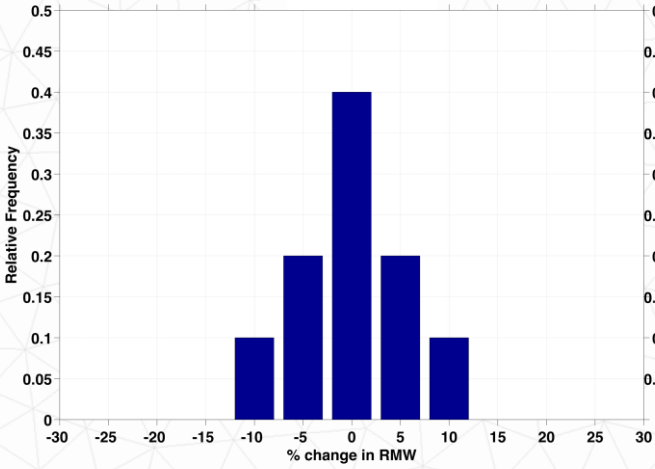


Ongoing Activities

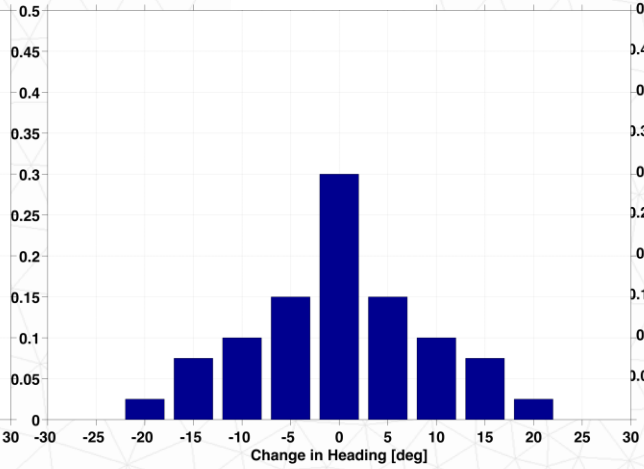
- Ensemble Forecasting with AdcircLite
  - Method to perturb NHC forecast track
  - Outputs ADCIRC fort.22 files
  - Basic parameter variation, test distributions for RMW, Heading, Forward Speed
  - 135 ensemble members (5*7*3)



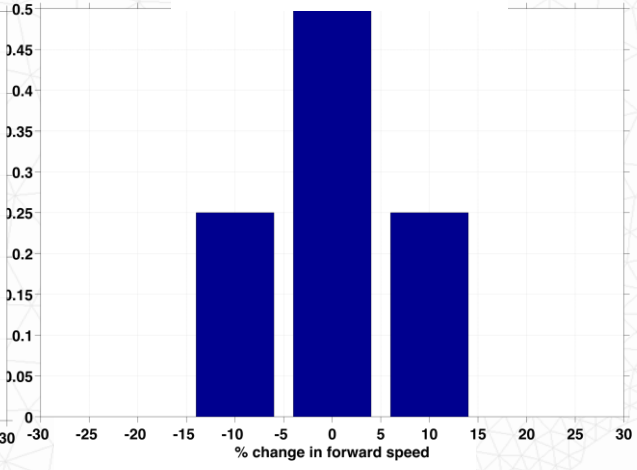
RMW



Heading



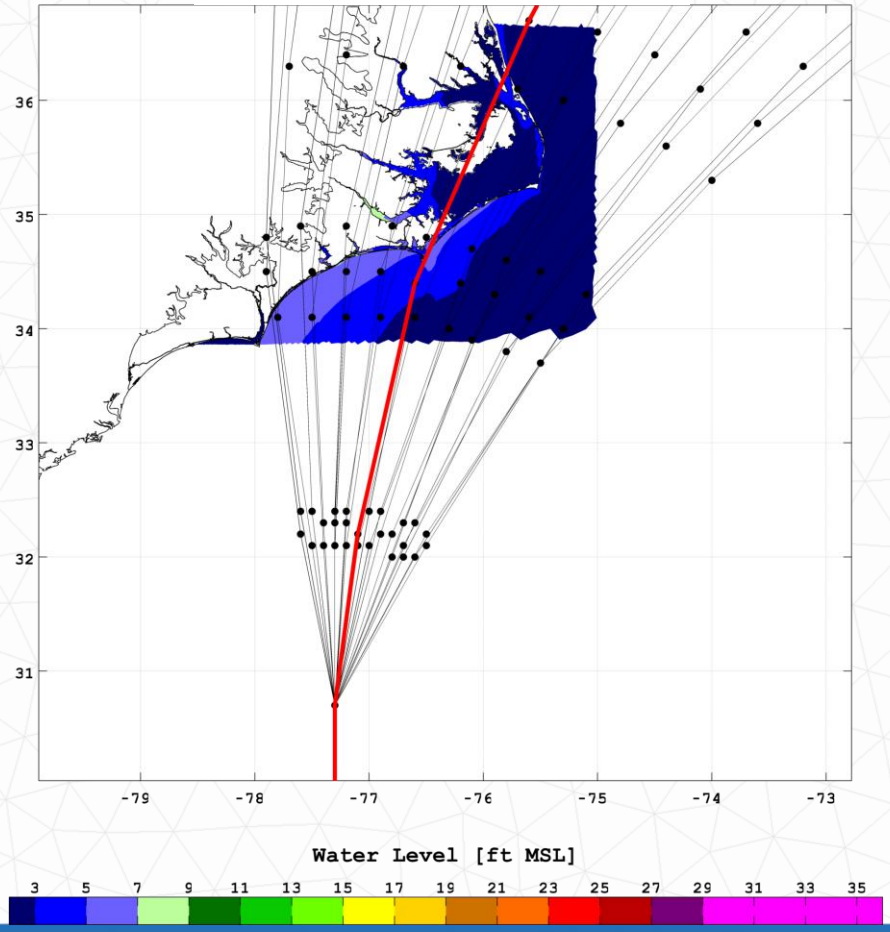
Forward Speed



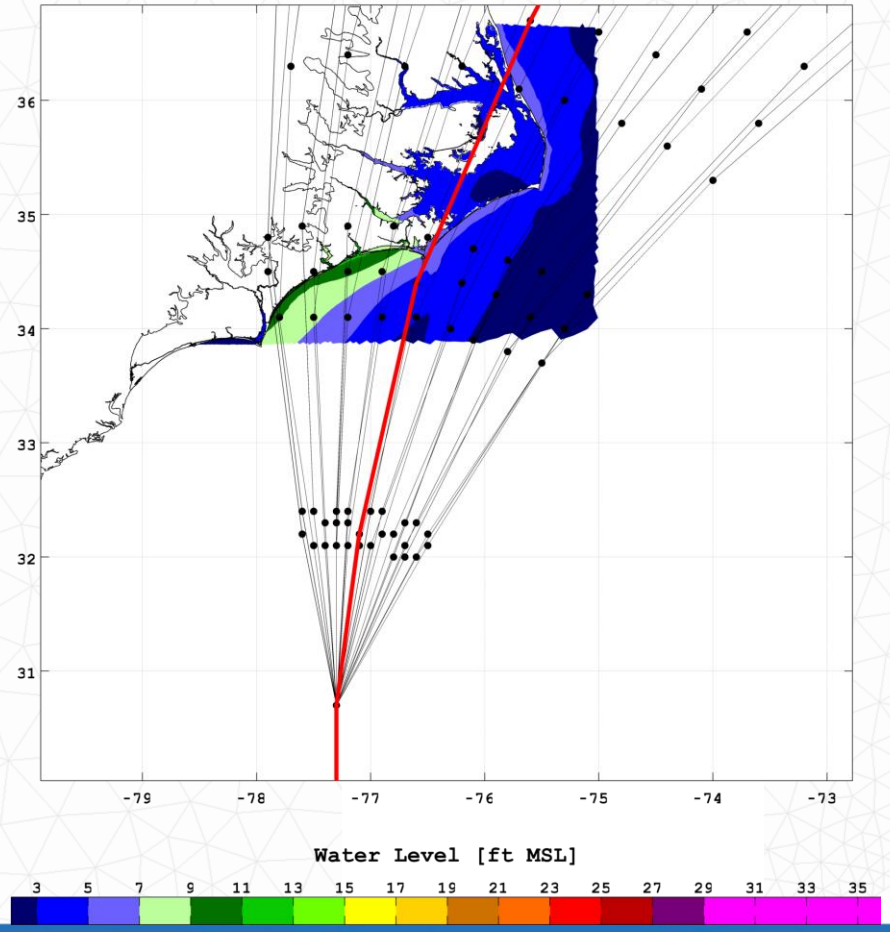
Ongoing Activities

Hurricane Irene (2011), Advisory 24

50% Exceedence Level



10% Exceedence Level



Conclusions

- Surrogate modeling approach can fill a storm surge / wave prediction gap between coarse resolution (fast) and high resolution (slow) dynamic models
- AdcircLite – Moving (Local) Least Squares Response Surface Method
  - Robust and fast once surrogate model is defined
  - Quantifiable error estimates can be obtained
- Simple to run once surrogate model defined
- Provides a mechanism to develop large, ensemble-based (probabilistic) high-resolution water level predictions