

## Strengthening the Hurricane Wave and Surge Forecast Guidance provided to Coastal Communities in North Carolina

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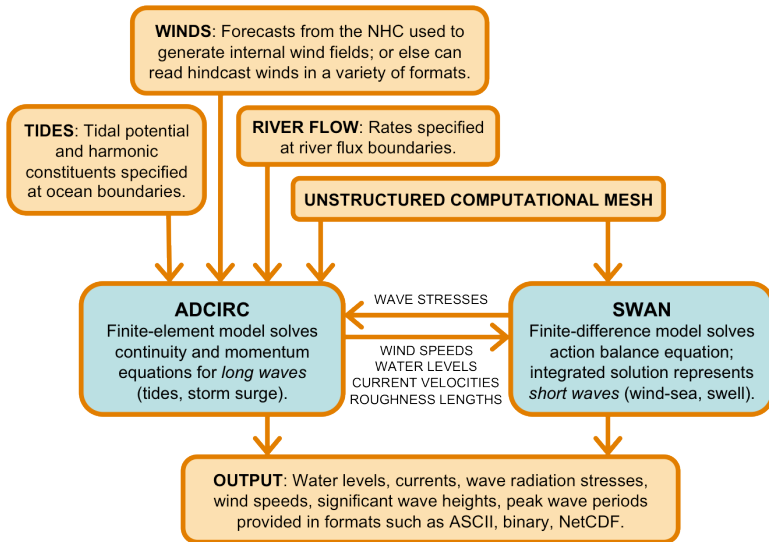
SIAM Conference on Computational Science and Engineering  
Advances in Computational Techniques for Coastal Ocean Modeling  
Salt Lake City UT, 17 March 2015





# Real-Time Forecasting for Hurricane Waves and Surge

## Flow Chart for SWAN+ADCIRC



# Real-Time Forecasting for Hurricane Waves and Surge

## ADCIRC Surge Guidance System (ASGS)

SWAN+ADCIRC can be employed in real-time via the ASGS

- ▶ **Everything happens automatically**

- ▶ Models are initialized, run and processed by Perl scripts

Wind fields from two sources:

1. Under normal conditions:

- ▶ Downloaded from NAM model output by NOAA/NCEP
  - ▶ Converted into format compatible with SWAN+ADCIRC

2. Under hurricane conditions:

- ▶ Download advisories from NOAA/NHC
  - ▶ Generate wind field using parametric model (Holland, 1980)

Guidance can be shared in multiple formats:

- ▶ Raster images (JPG, PNG, etc.)
- ▶ Geo-referenced raster images (Google Earth, GIS)
- ▶ Web service ([coastalemergency.org](http://coastalemergency.org))



# Real-Time Forecasting for Hurricane Waves and Surge

## ASGS Development Teams

### University of North Carolina at Chapel Hill

- ▶ Provide forecasts for Carolina and surrounding states via Google Maps application ([nc-cera.renci.org](http://nc-cera.renci.org))
- ▶ Guidance during Irene (2011) prompted Coast Guard to shift operations to avoid flooding of operations center



### Louisiana State University

- ▶ Provide forecasts for Louisiana and northern Gulf states via Google Maps application ([cera.cct.lsu.edu](http://cera.cct.lsu.edu))



### University of Texas at Austin

- ▶ Provide forecasts for storms impacting Texas coastline; partnerships with Texas State Operations Center
- ▶ During Isaac (2012), guidance shared with NWS offices in Fort Worth, Tallahassee and Miami



# Expanding Guidance for End Users

## Web-Based Guidance

In North Carolina, the guidance is available from the Coastal Emergency Risks Assessment (CERA) team:

- ▶ Shared via Web portal: [nc-cera.renci.org](http://nc-cera.renci.org)

Updated often with new guidance:

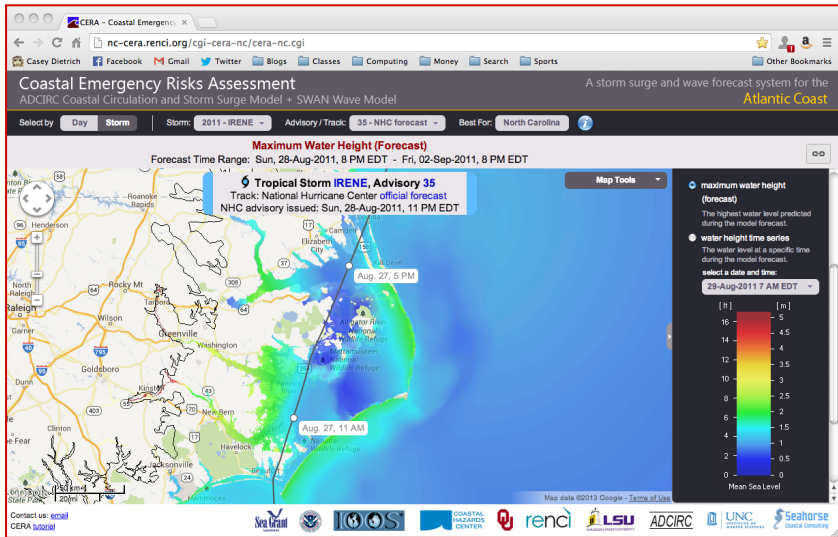
- ▶ Normal conditions with base meteorology from NOAA/NCEP
- ▶ Extreme conditions with storm advisories from NOAA/NHC

Guidance is interactive within Google Maps:

- ▶ View results as a time series or as maxima
- ▶ Select layers for:
  - ▶ Water levels (above MSL or above ground)
  - ▶ Waves (significant heights, peak periods)
  - ▶ Wind speeds
  - ▶ Hydrographs at NOAA/NOS gage stations

# Expanding Guidance for End Users

Example during Irene (2011): [nc-cera.renci.org](http://nc-cera.renci.org)



# Expanding Guidance for End Users

## Conversion of Output Products to Other Formats

Some partners prefer guidance in other formats:

- ▶ Polygon-based formats:
  - ▶ Shapefiles and ancillary files for GIS
  - ▶ KML files for Google Earth
- ▶ These files can be overlaid with information from other sources



We developed Python-based scripts to convert SWAN+ADCIRC output

- ▶ Based on older scripts from BO Blanton, RA Luettich Jr
- ▶ Expanded to consider time series information, KML formats

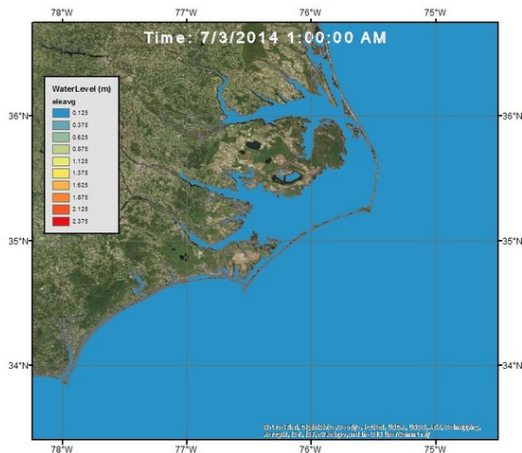
Now sharing guidance in developmental formats with partners at NWS offices, state and local emergency management teams

- ▶ **Guidance products are generated and shared automatically**
- ▶ Goal – Integrate these products as downloads from NC-CERA

## Expanding Guidance for End Users

Our Python-based script is called *Kalpana*:

- Visualizes guidance in GIS and Google Earth formats
- Example of water levels during Arthur (2014):



# Expanding Guidance for End Users

## Key Features of *Kalpana*

*Kalpana* has been developed with a range of capabilities:

- ▶ Utilizes specialized Python libraries to convert ADCIRC outputs (water levels, wind speeds, wave height, mean wave period, peak wave period, etc.) to .shp and .kmz formats compatible with ArcGIS and Google Earth respectively
- ▶ Polygons that represent user-defined contour levels
- ▶ Single time step or full time series ADCIRC output data

Requires input from its user:

- ▶ NetCDF-formatted ADCIRC output file
- ▶ Choice of vector geometry (polygon or polyline)
- ▶ Number of contour levels
- ▶ Palette file for KML creation
- ▶ Domain information for KMZ files

# Expanding Guidance for End Users

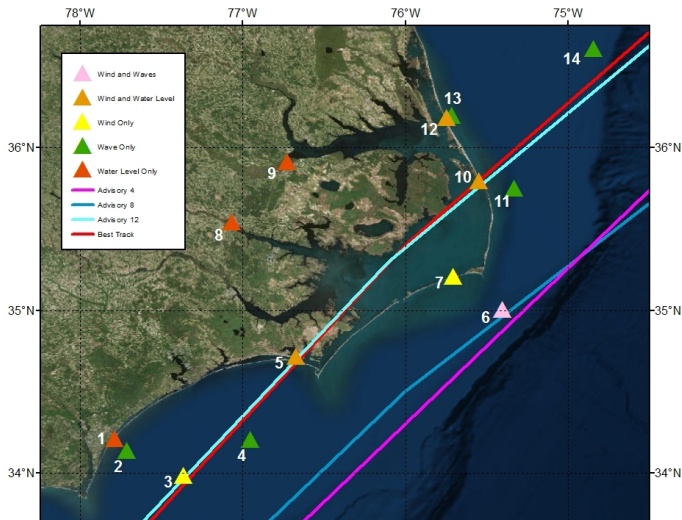
## Procedure for *Kalpna*

*Kalpna* visualizes guidance in the following steps:

1. Accept user input
2. Read mesh and variable data from the ADCIRC output file (using *netCDF4* library)
3. Contour ADCIRC variable data (using *matplotlib* library) into user-defined contour levels for each time step
  - ▶ For KMZ files, domain divided into sub domains
  - ▶ Interpolate mesh and variable data for each of the local domains, and contour them separately
4. Contour polygons into *shapely* objects, processed and stored as outer and inner polygons
  - ▶ Multi-geometry objects are used for KMZ files
5. Polygons written into shapefile or KMZ files using *fiona* or *simplekml* library, respectively

# Arthur (2014) Effects in Coastal NC

## Track Uncertainty



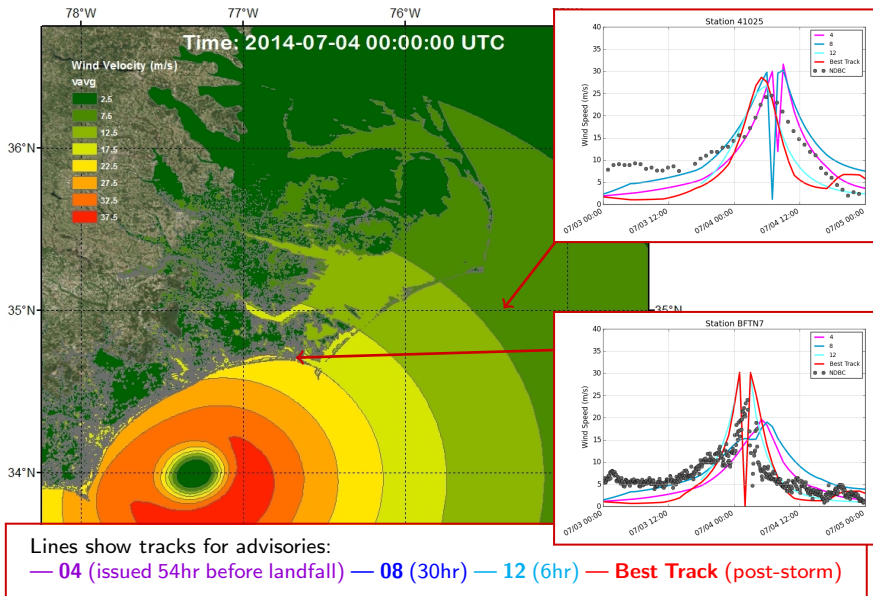
Lines show tracks for advisories:

— 04 (issued 54hr before landfall) — 08 (30hr) — 12 (6hr) — **Best Track** (post-storm)



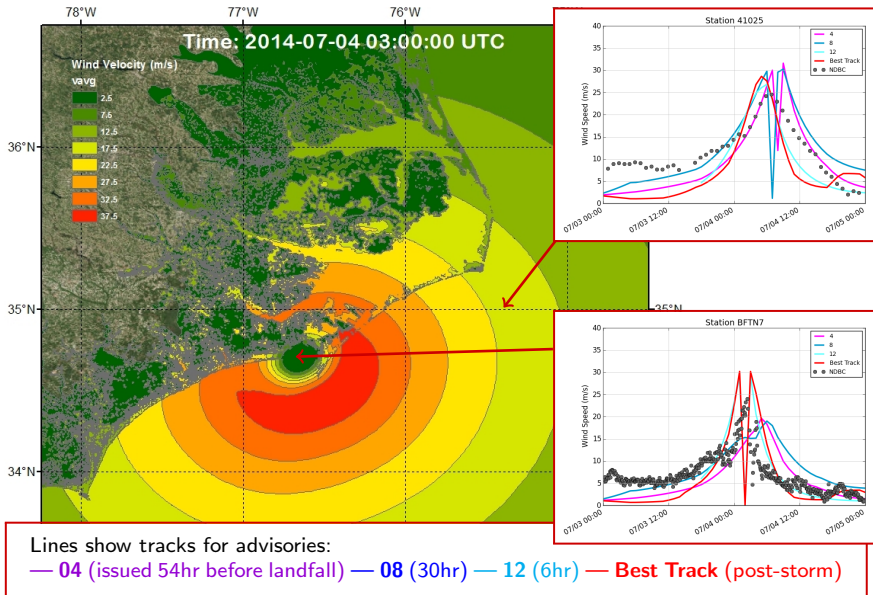
# Arthur (2014) Effects in Coastal NC

## Evolution of Wind Fields



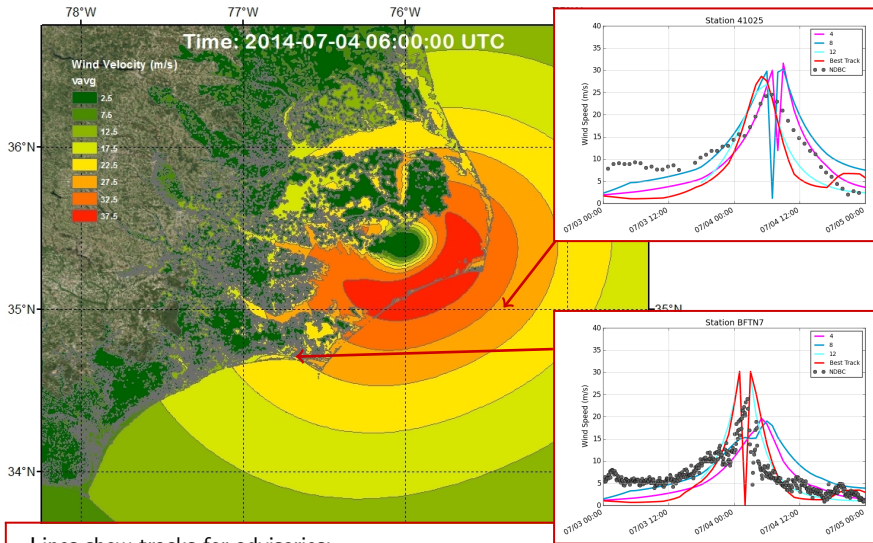
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## Evolution of Wind Fields



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## Evolution of Wind Fields

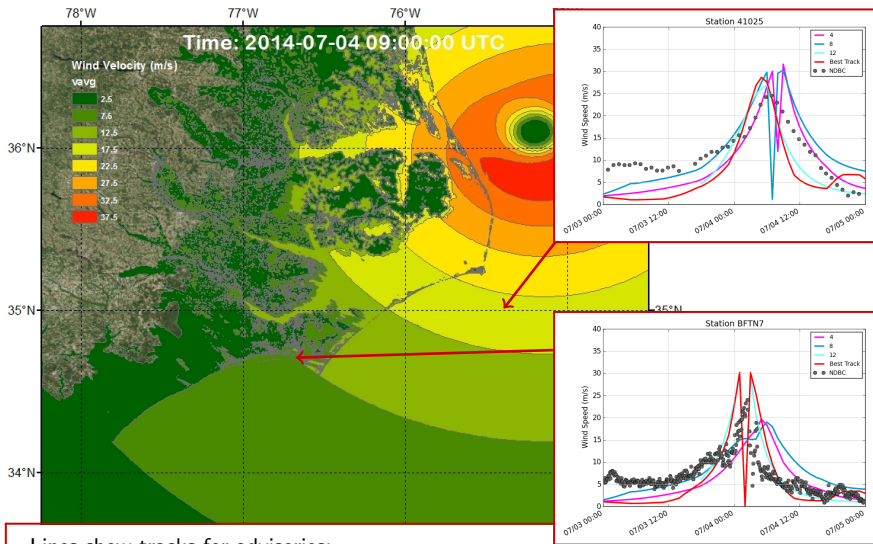


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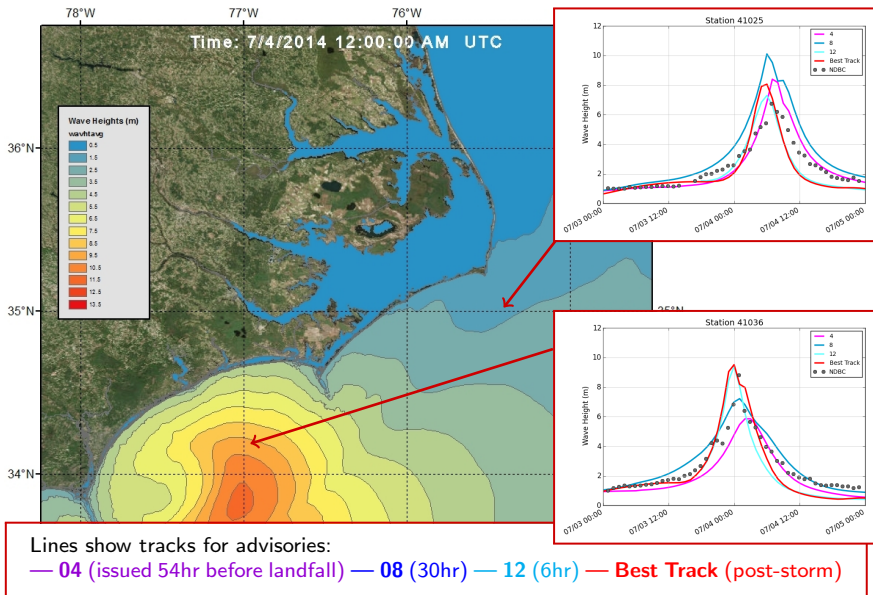


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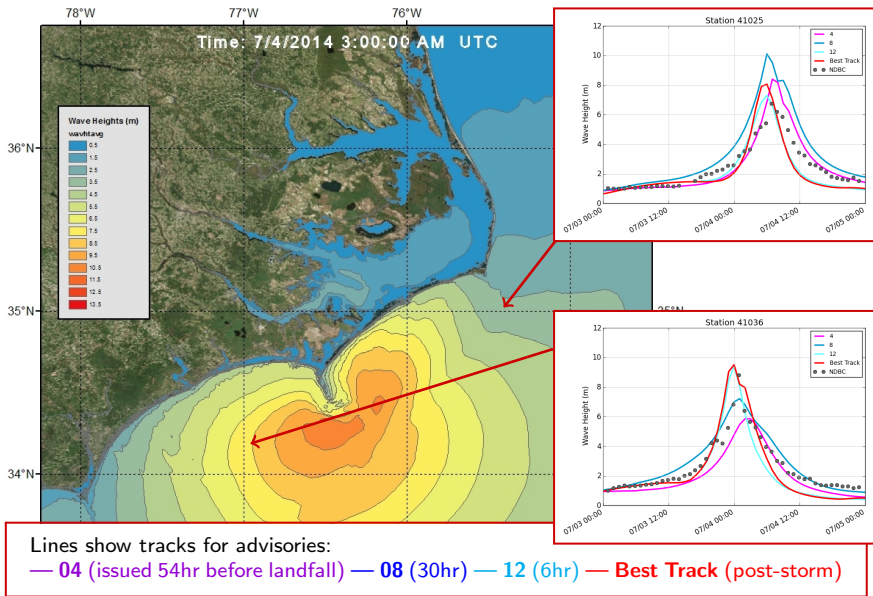
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## Evolution of Significant Wave Heights



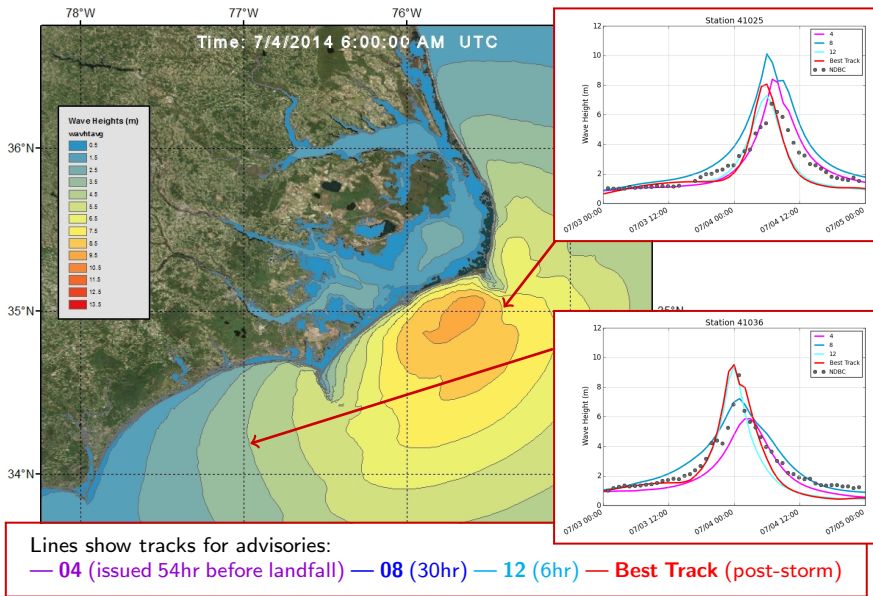
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## Evolution of Significant Wave Heights



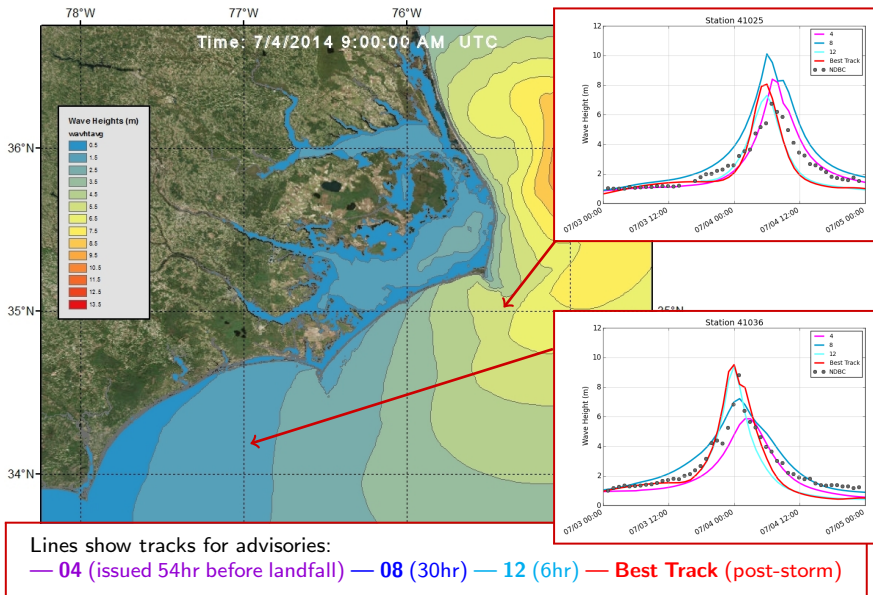
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## Evolution of Significant Wave Heights



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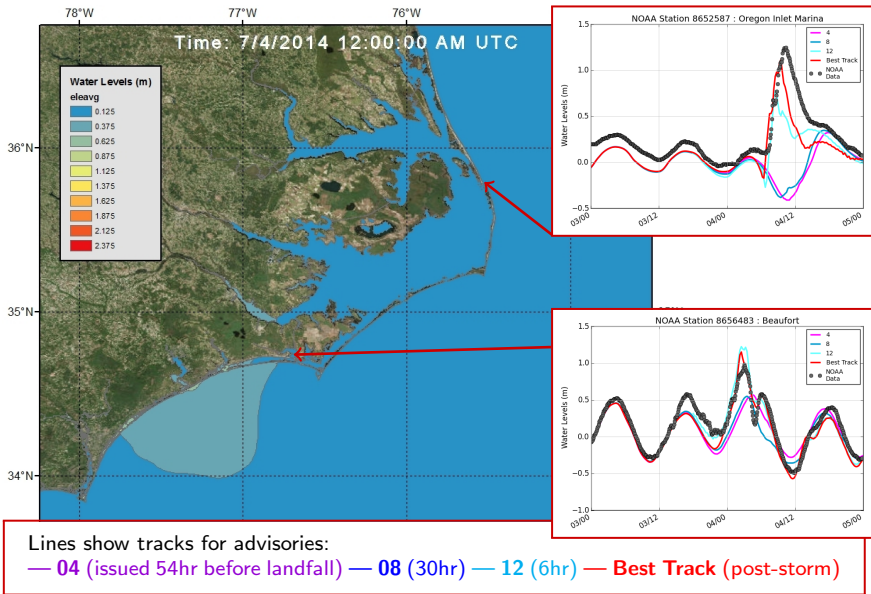
## Evolution of Significant Wave Heights





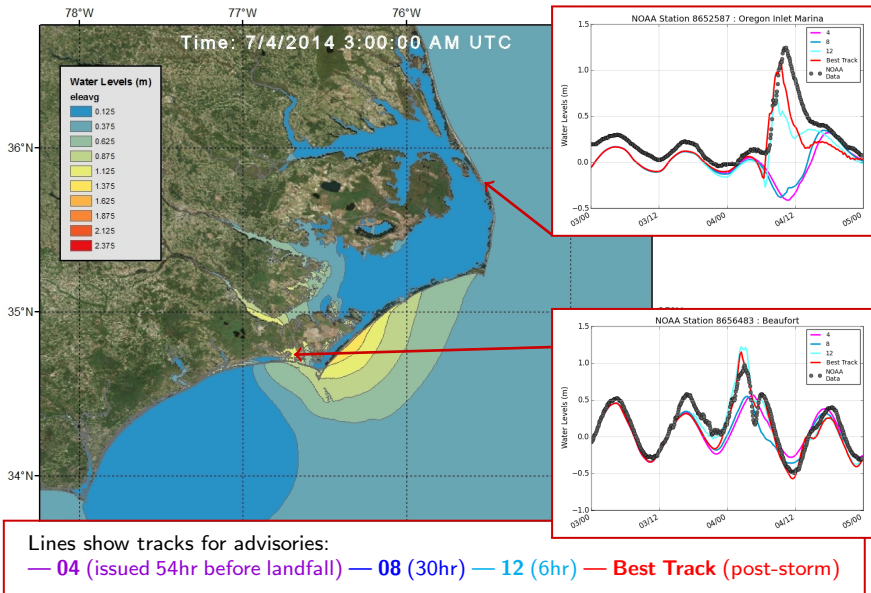
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## Evolution of Water Levels



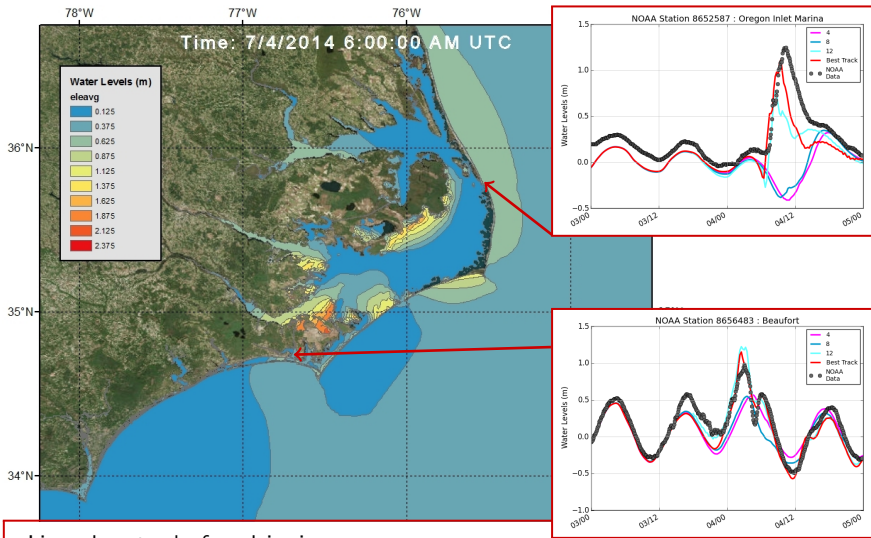
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## Evolution of Water Levels



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## Evolution of Water Levels

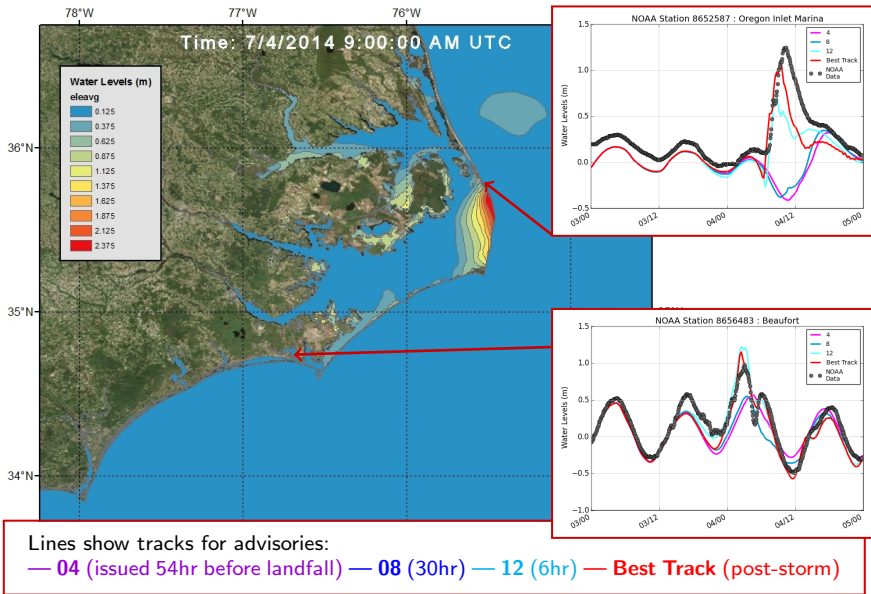


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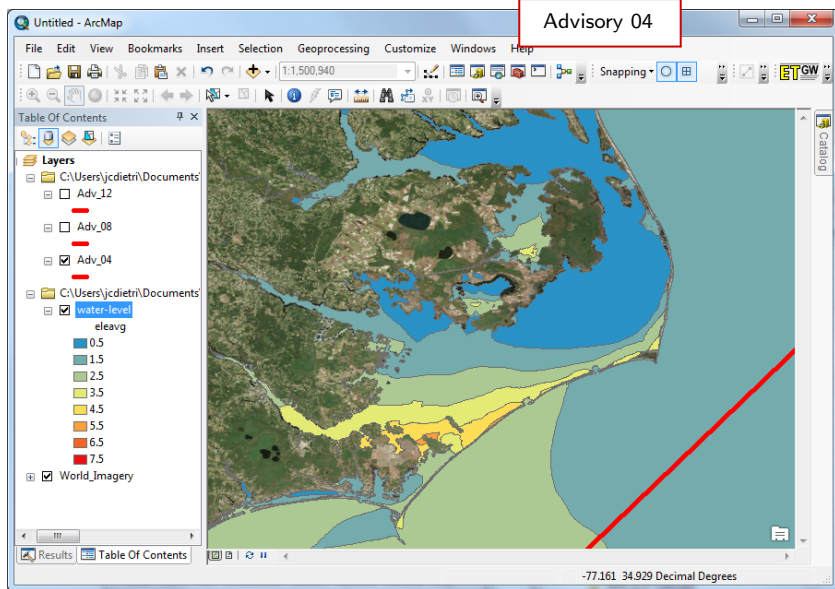
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## Evolution of Water Levels



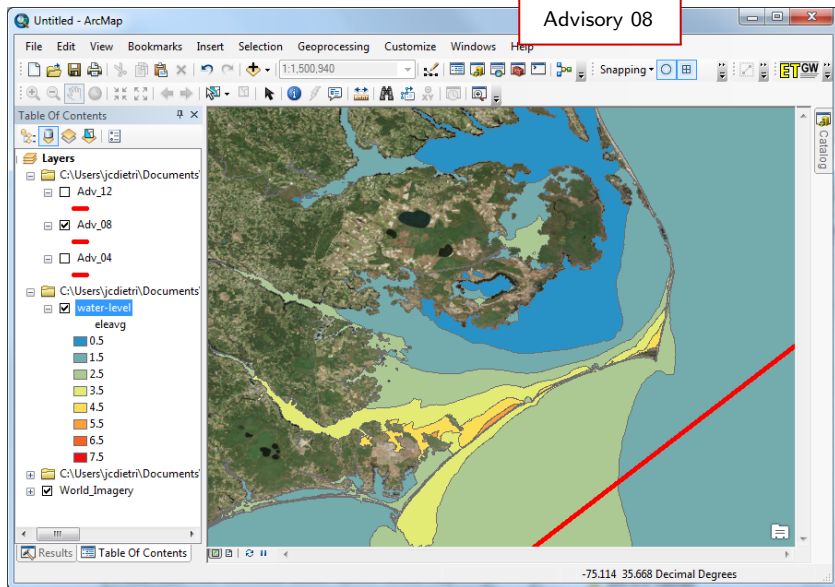
# Arthur (2014) Effects in Coastal NC

## Sensitivity of Maximum Surge to Track



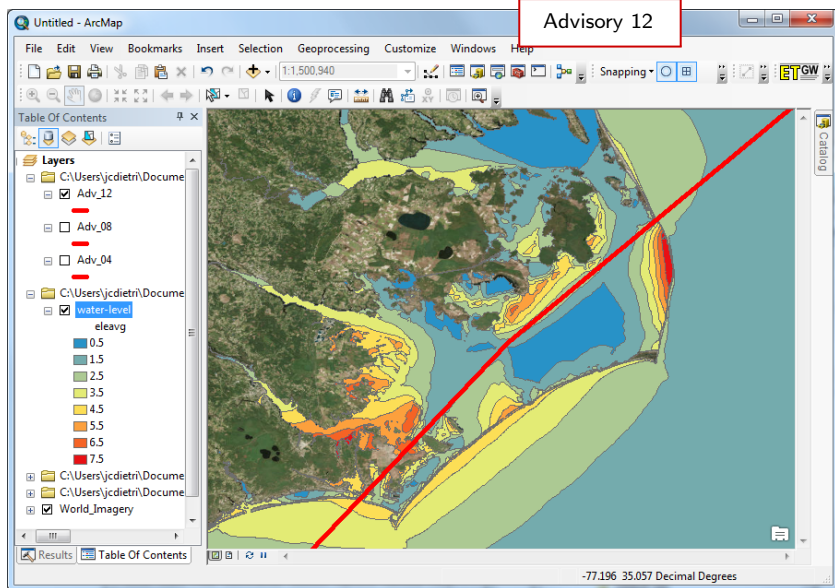
# Arthur (2014) Effects in Coastal NC

## Sensitivity of Maximum Surge to Track



# Arthur (2014) Effects in Coastal NC

## Sensitivity of Maximum Surge to Track



# Summary and Future Work

## Strengthening the Hurricane Wave and Surge Forecast Guidance

### Real-time forecasting for coastal North Carolina:

- ▶ CERA Web-based guidance for NC coast
  - ▶ Available several times per day at: [nc-cera.renci.org](http://nc-cera.renci.org)
- ▶ Expanding guidance to GIS and KML formats
- ▶ Useful information despite track uncertainties
  - ▶ Irene (2011) and Arthur (2014) in NC

### Working with emergency managers:

- ▶ Targeted improvements to unstructured mesh
- ▶ Better resolution of fine-scale features
  - ▶ Inlets, waterways, dunes, etc.

