



# Forecast Predictions of Winds, Waves and Storm Surge during Hurricane Arthur (2014)

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**Young Coastal Scientists and Engineers Conference 2015**



# Outline

## **PART 1 : Real-time storm surge forecasting in NC**

- Review of ASGS
- Sharing forecast guidance in NC
- Providing forecast guidance in other formats
- Introducing *Kalpana*

## **PART 2 : Forecast predictions during Arthur (2014)**

- Influence of track uncertainty on ASGS results
- Evolution of water levels
- Sensitivity of maximum surge to track

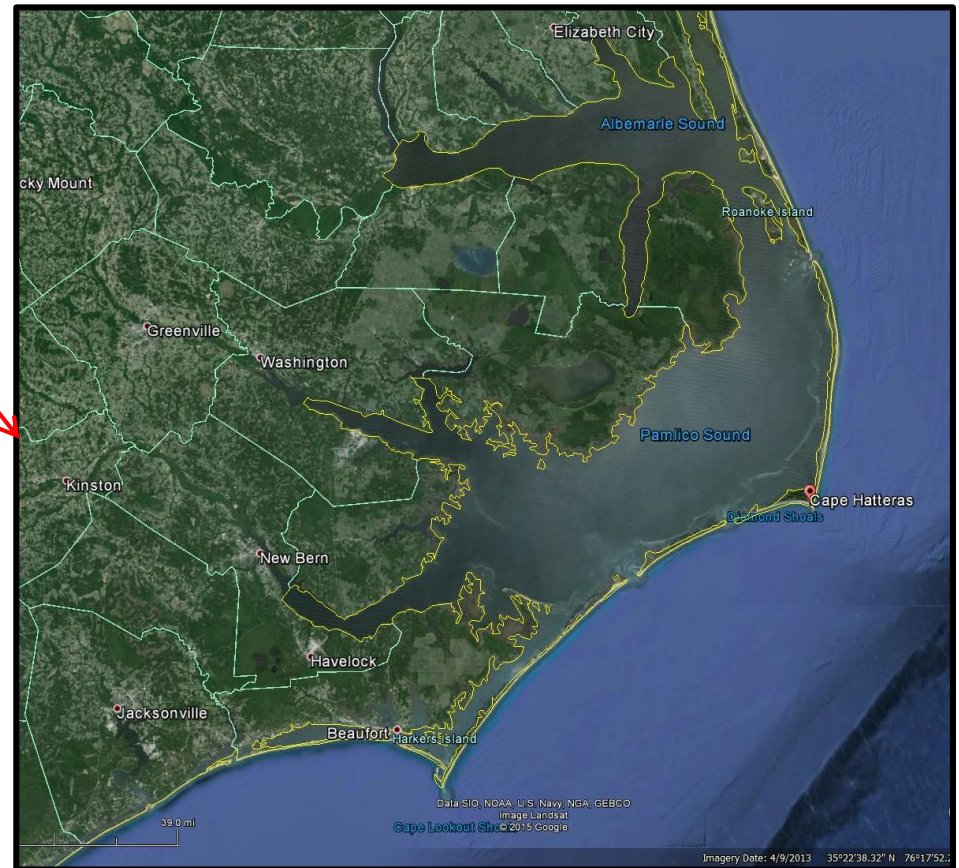
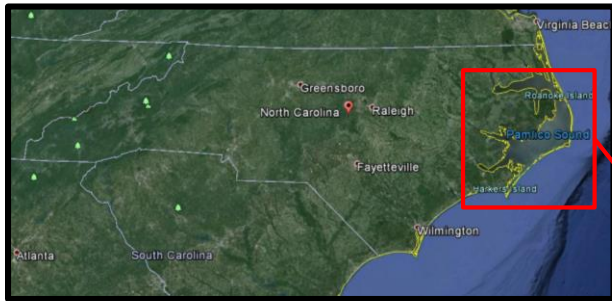
## **PART 3 : More about *Kalpana* – A visualization tool**

- Key Features
- Procedure
- Demonstration of visualization products
- Future Work

## **General summary**

# PART 1: Real-time storm surge forecasting in NC

- Atlantic hurricanes pose a severe threat to North Carolina (NC) every year
- Hazel (1954), Fran (1996), Floyd (1999), Isabel (2003) and Irene (2011) are historical hurricanes that have severely affected NC coastal communities
- NC coastline characterized by a unique network of barrier islands, sounds, bays and estuaries



# PART 1: Real-time storm surge forecasting in NC

## Review of ADCIRC Surge Guidance System (ASGS)

- ADCIRC Surge Guidance System (ASGS) – software that automates storm surge and wave forecasting during a hurricane event
- Key features:
  - Initiates ADCIRC+SWAN simulations in real time
  - Receives meteorological input from NHC advisories issued during the event
  - Constructs asymmetric hurricane wind field using parametric Holland wind model (1980)
  - Forecast guidance archived and distributed in different formats
- 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))
  - 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

# PART 1: Real-time storm surge forecasting in NC

## Sharing forecasting guidance in NC

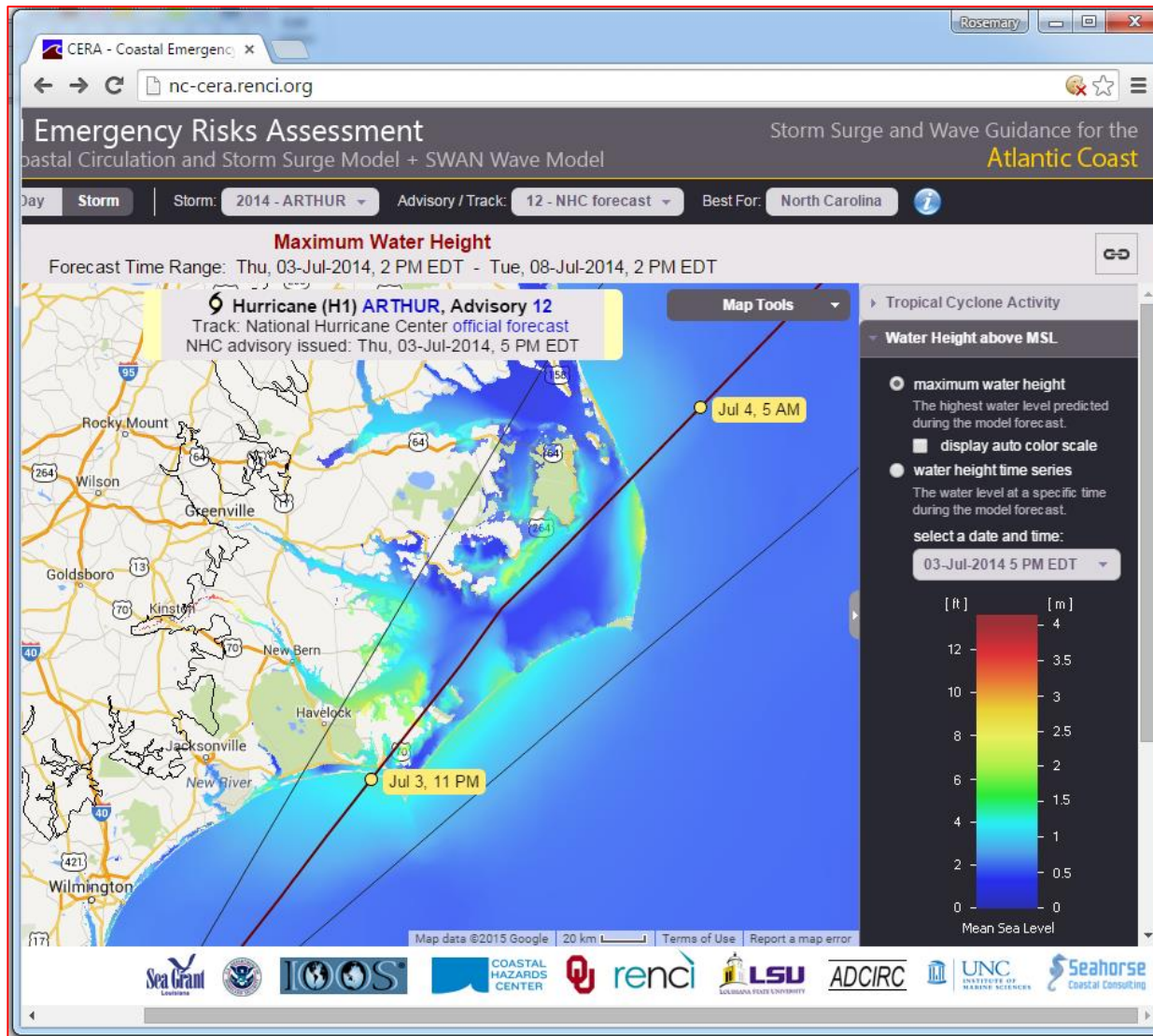
Interactive guidance offered via Google Maps by Coastal Emergency Risks Assessment (CERA) Team

- ASGS results provided as geo referenced raster images
- Shared via web portal - [nc-cera.renci.org](http://nc-cera.renci.org)
- Can view real-time and historical storm results as time series or maxima
- Select layers for:
  - Water Levels (above MSL or above ground)
  - Waves (significant heights, peak periods)
  - Wind Speeds
  - Hydrographs at NOAA/NOS gage stations



# PART 1: Real-time storm surge forecasting in NC

During Arthur (2014): [nc-cera.renci.org](http://nc-cera.renci.org)



# PART 1: Real-time storm surge forecasting in NC

## Providing forecast guidance in other formats

Visualization of ADCIRC outputs in vector based formats:

- Polygon-based formats:
  - Shapefiles and ancillary files for GIS
  - KML files for Google Earth

Advantages of proposed formats:

- Easy to store and visualize large amount of data in a geographical information system
- These files can be overlaid with other spatial data (such as road networks, evacuation routes, locations of emergency shelters etc.)
  - May be useful for emergency managers

We developed a Python-based script to convert ADCIRC+SWAN output to these formats

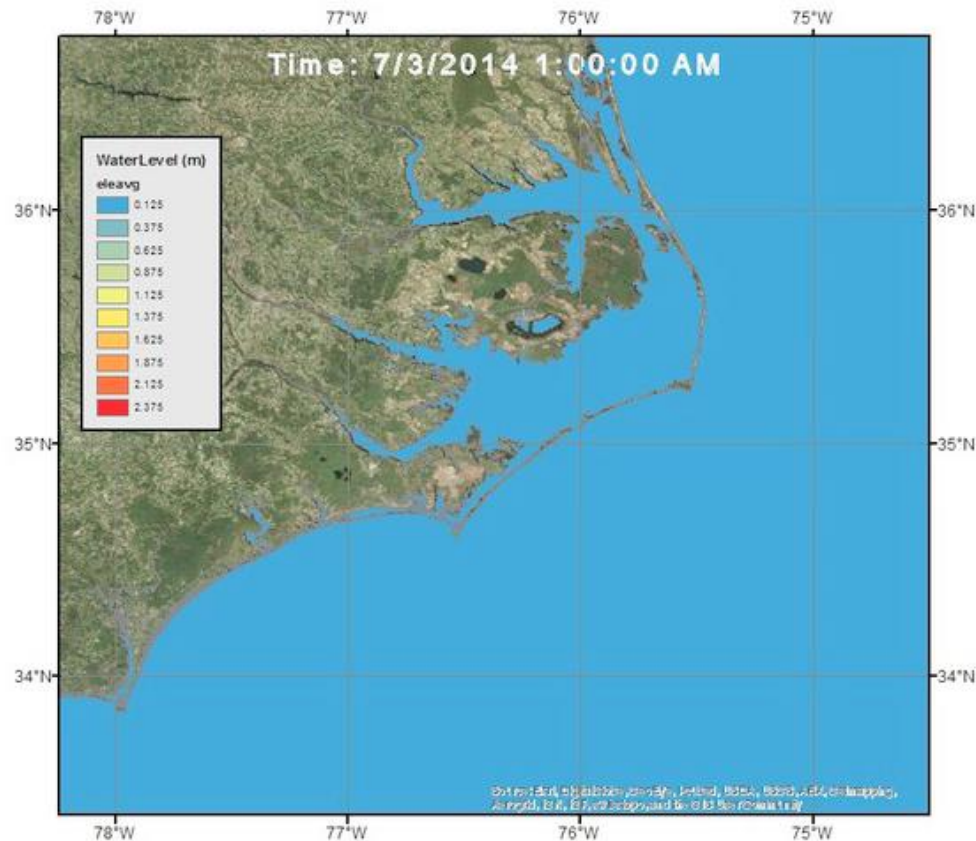
- Part of NC Sea Grant project to expand forecast guidance to end users
- Based on older scripts from Brian Blanton and Rick Luettich
- Expanded to consider time series information, KML formats

# PART 1: Real-time storm surge forecasting in NC

## Introducing *Kalpana*

Our Python-based script is called *Kalpana*

- Visualizes guidance in GIS and Google Earth formats
- Tested with the forecast predictions for Arthur (2014):





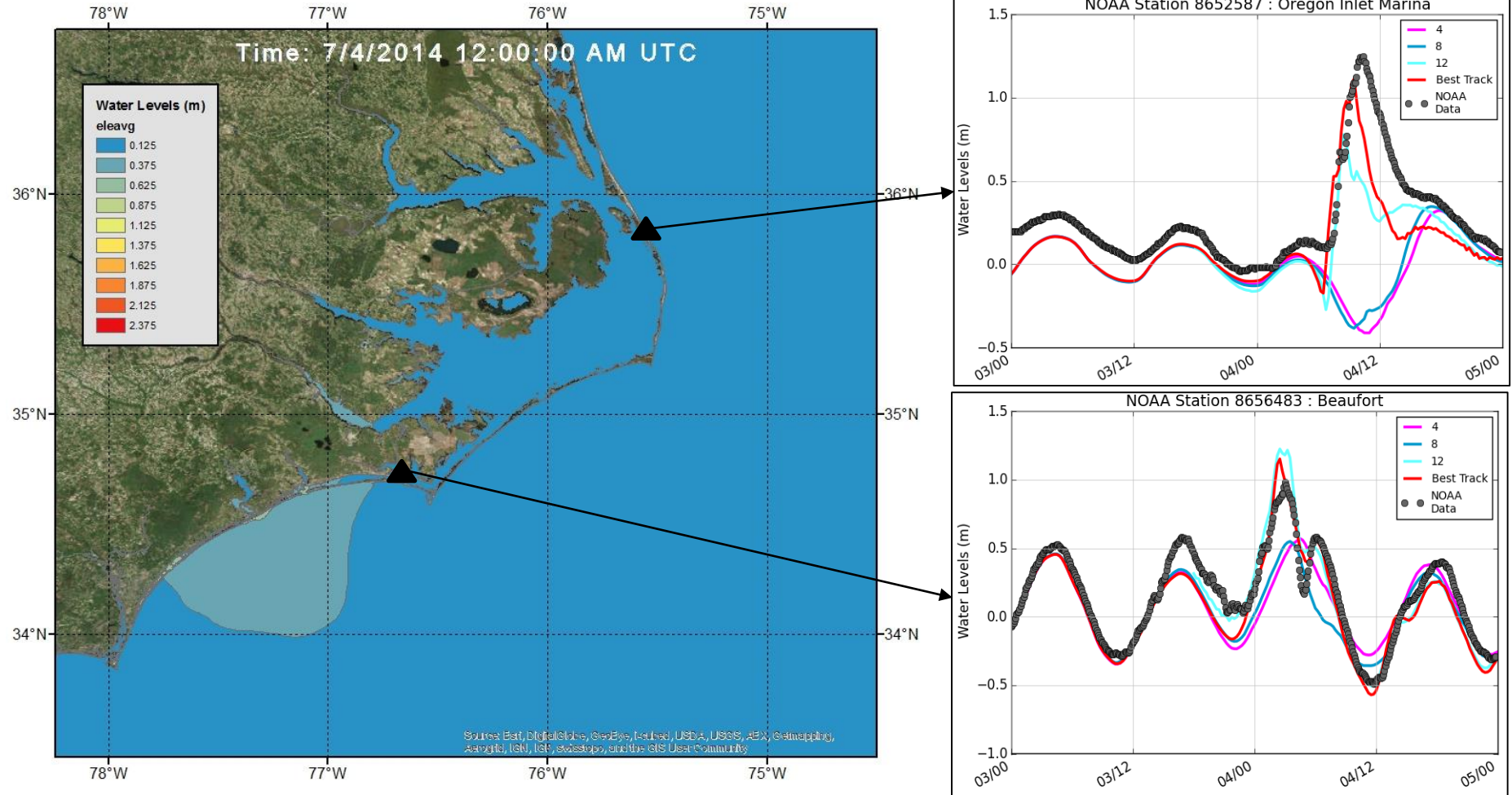
## Influence of track uncertainty on ASGS results



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

# PART 2: Forecast predictions during Arthur (2014)

## Evolution of water levels

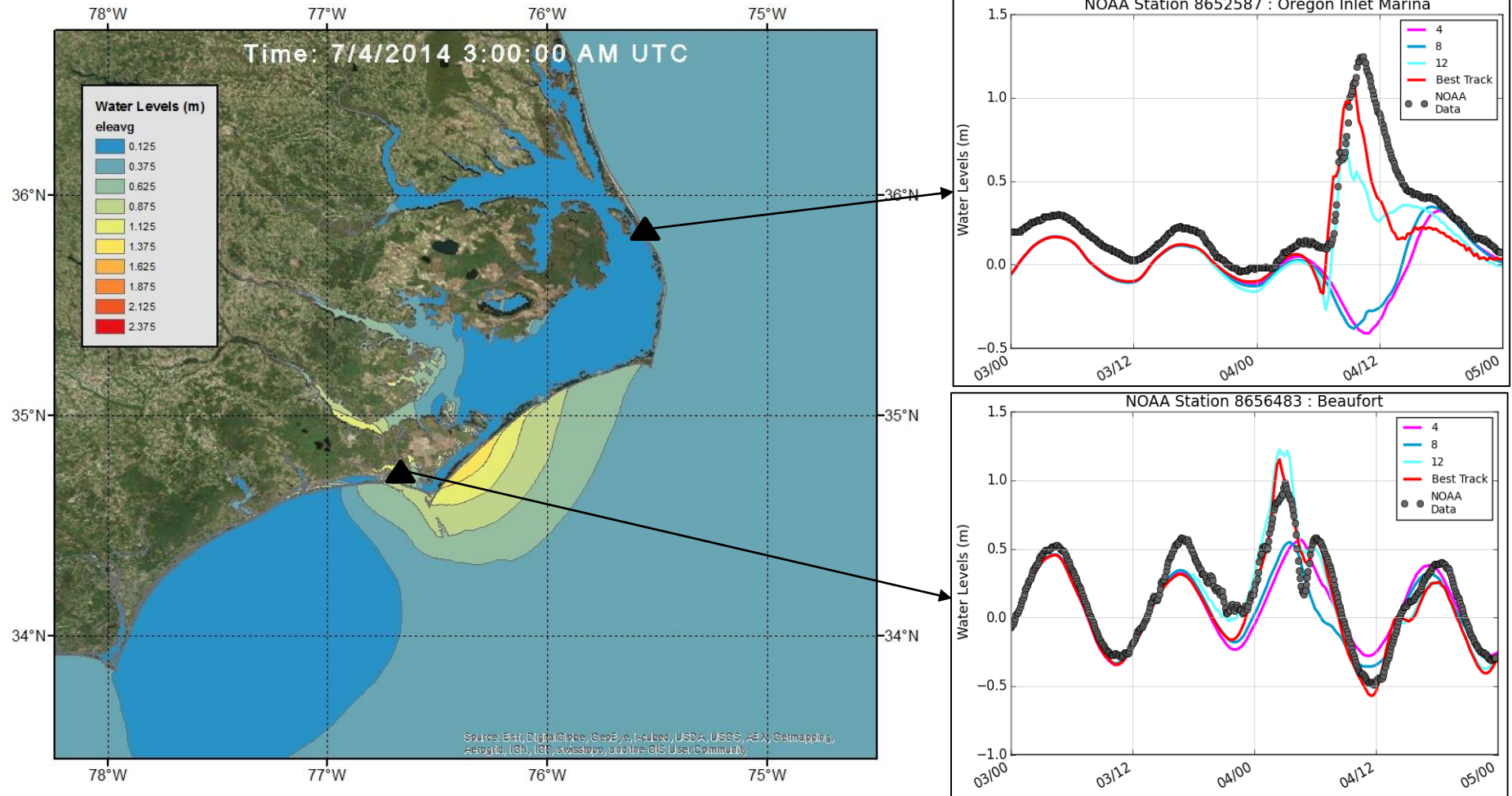


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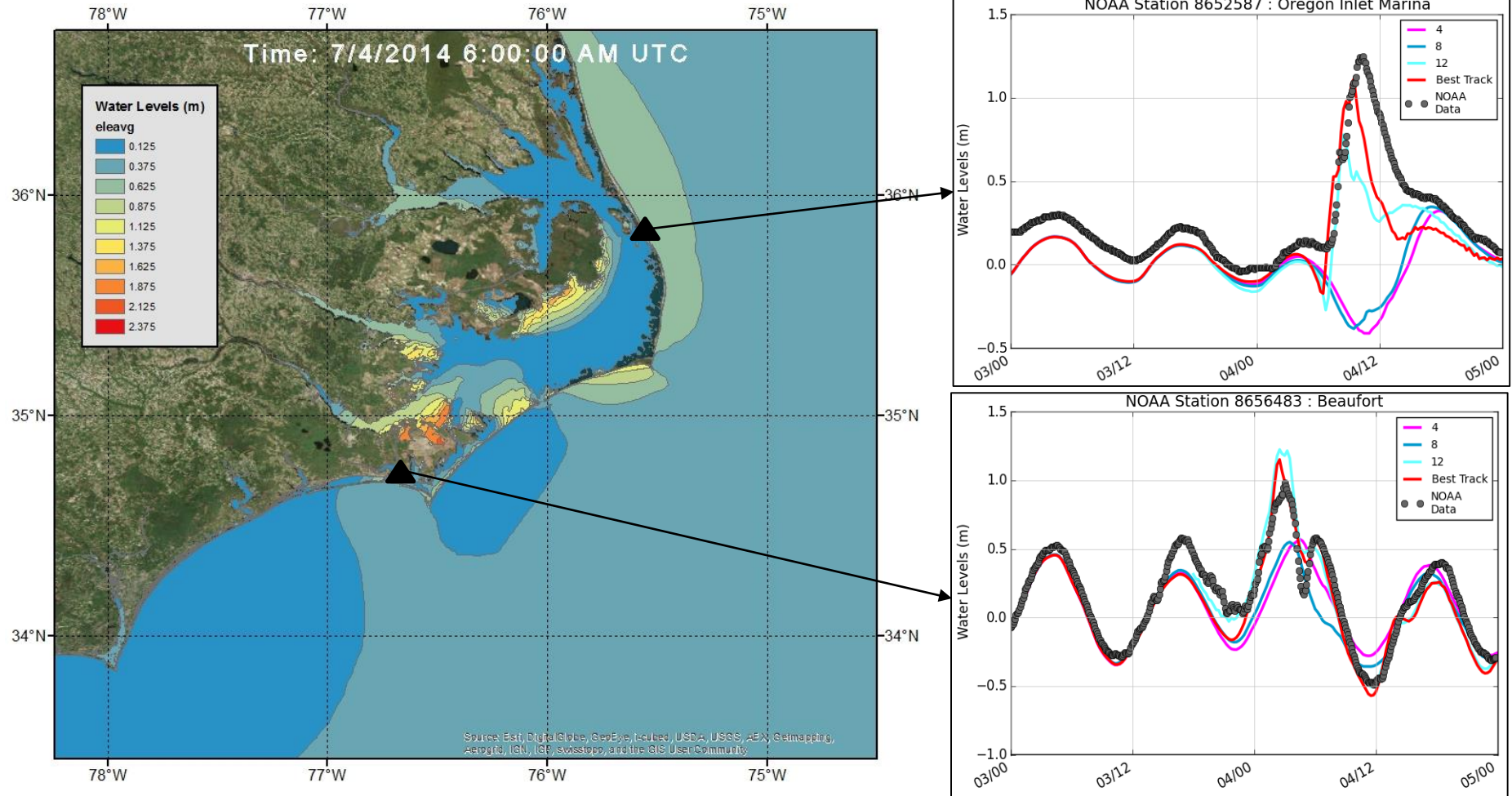
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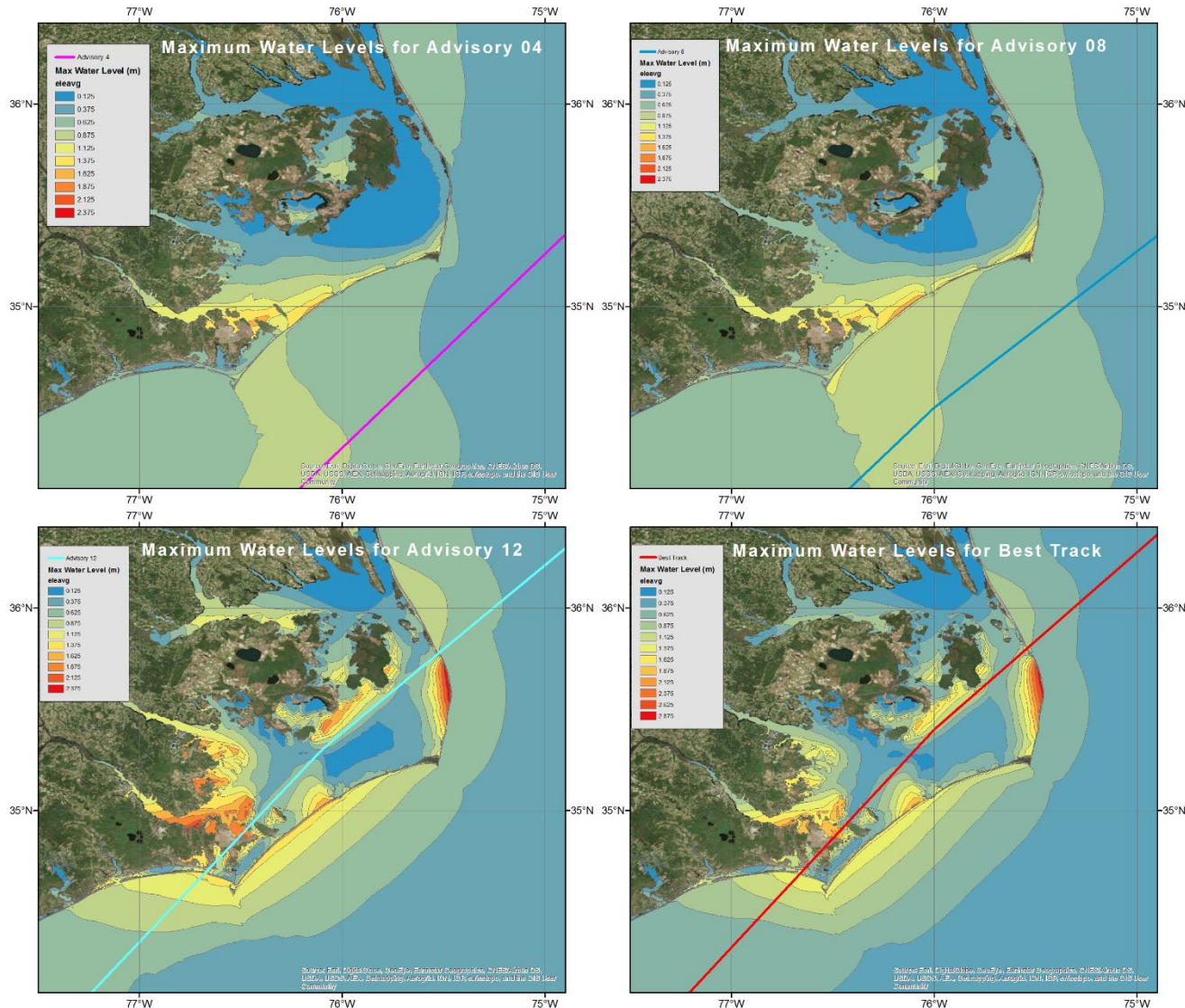


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# PART 2: Forecast predictions during Arthur (2014)

## Sensitivity of maximum surge to track



# PART 3 : More about Kalpana – A visualization tool

## Key features

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 shape files and KMZ file formats compatible with ArcGIS and Google Earth respectively
  - Python is usually available in most Linux clusters on which ADCIRC runs
  - Libraries are free and relatively easy to download and install – we can help you with their installation
- Identifies polygons from the user-defined contour levels
- Can work with single time step or full time series ADCIRC output data
- Quick generation of visualization products
- To be distributed as an open source code which work in Windows and Linux platforms
- Incorporated into ASGS by Jason Fleming in January 2015

# PART 3 : More about Kalpana – A visualization tool

## Procedure

*Kalpana* visualizes forecast guidance in the following steps:

1. Accept user input
  - netCDF ADCIRC output file, geometry type, number of contour levels etc
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
4. Contour information is extracted as *shapely* polygon objects, processed and stored as outer and inner polygons
  - Received help from Carola Kaiser at LSU for processing the polygons and removing errors in polygon geometry
  - Multi-geometry objects are used for KMZ files
5. Polygons are written into the corresponding shapefile or KMZ files using *fiona* or *simplekml* library respectively

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# PART 3 : More about Kalpana – A visualization tool

Demonstration of visualization products created by Kalpana



# PART 3 : More about Kalpana – A visualization tool

## Future work

- Currently KML creation implemented in Kalpana has been specialized for the NC coast - need to extend this capability to general conditions
- KML creation for time series ADCIRC output data is to be explored
- Collecting feedback from emergency managers and other end users about the visualization products and incorporate their suggestions for further improvements

To obtain a copy of Kalpana please contact me at: *rcyriac@ncsu.edu*

# General summary

- Real Time forecasting for NC coast implemented through ASGS and CERA Web-based guidance - [nc-cera.renci.org](http://nc-cera.renci.org)
- ASGS forecast system gave realistic predictions during Arthur but displayed sensitivity to the track uncertainties
- Introduced new Python based visualization tool – Kalpana, that converts ADCIRC outputs to GIS and KML based formats
  - Tested during 2014 Atlantic hurricane season

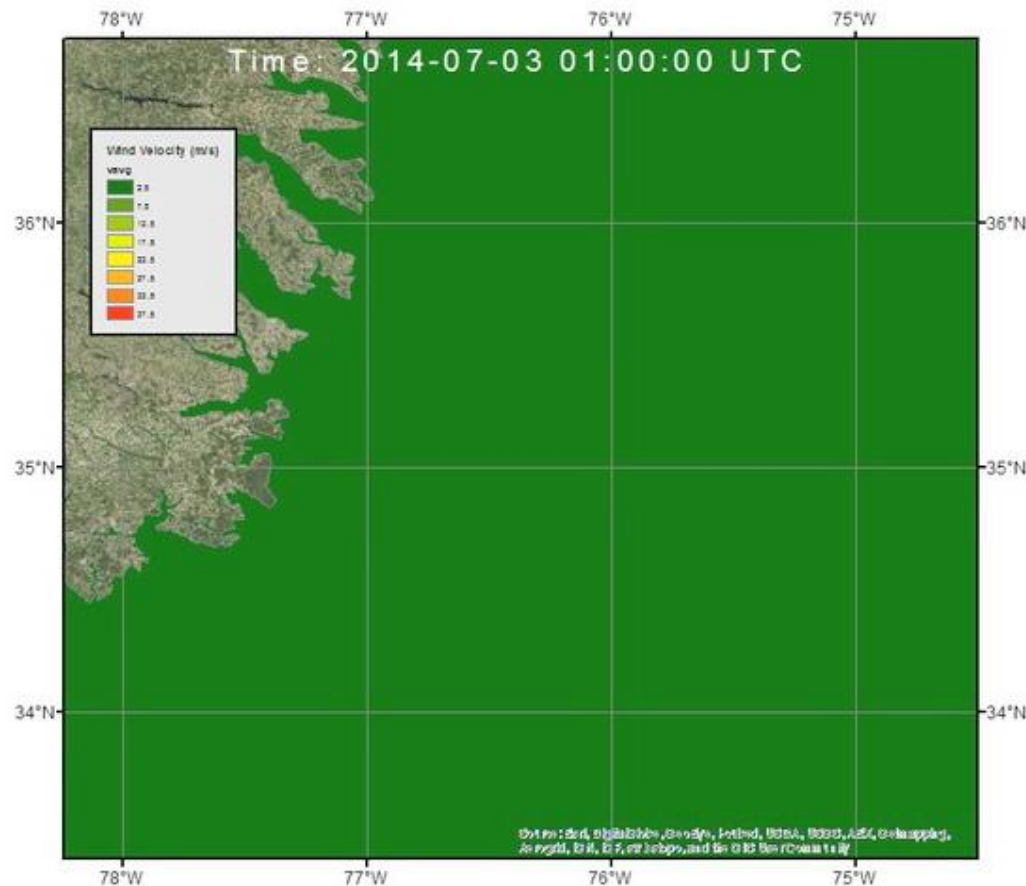
THANK YOU!

Contact me at : [rcyriac@ncsu.edu](mailto:rcyriac@ncsu.edu)



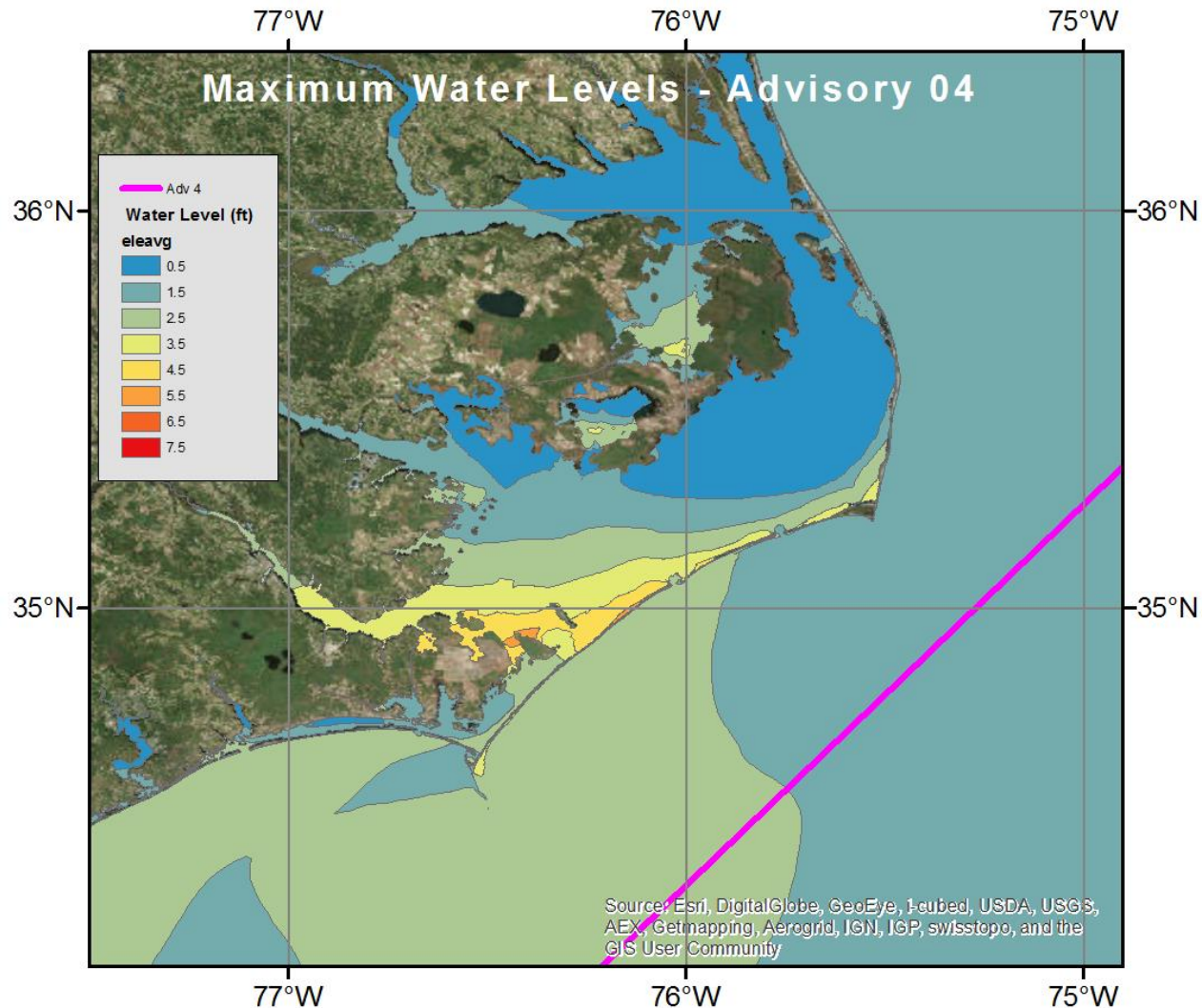
## PART 2: Forecast Predictions during Arthur (2014)

Hurricane Arthur – a Category 2 hurricane which made landfall at Cape Lookout, NC at 2014/07/04/0315 UTC



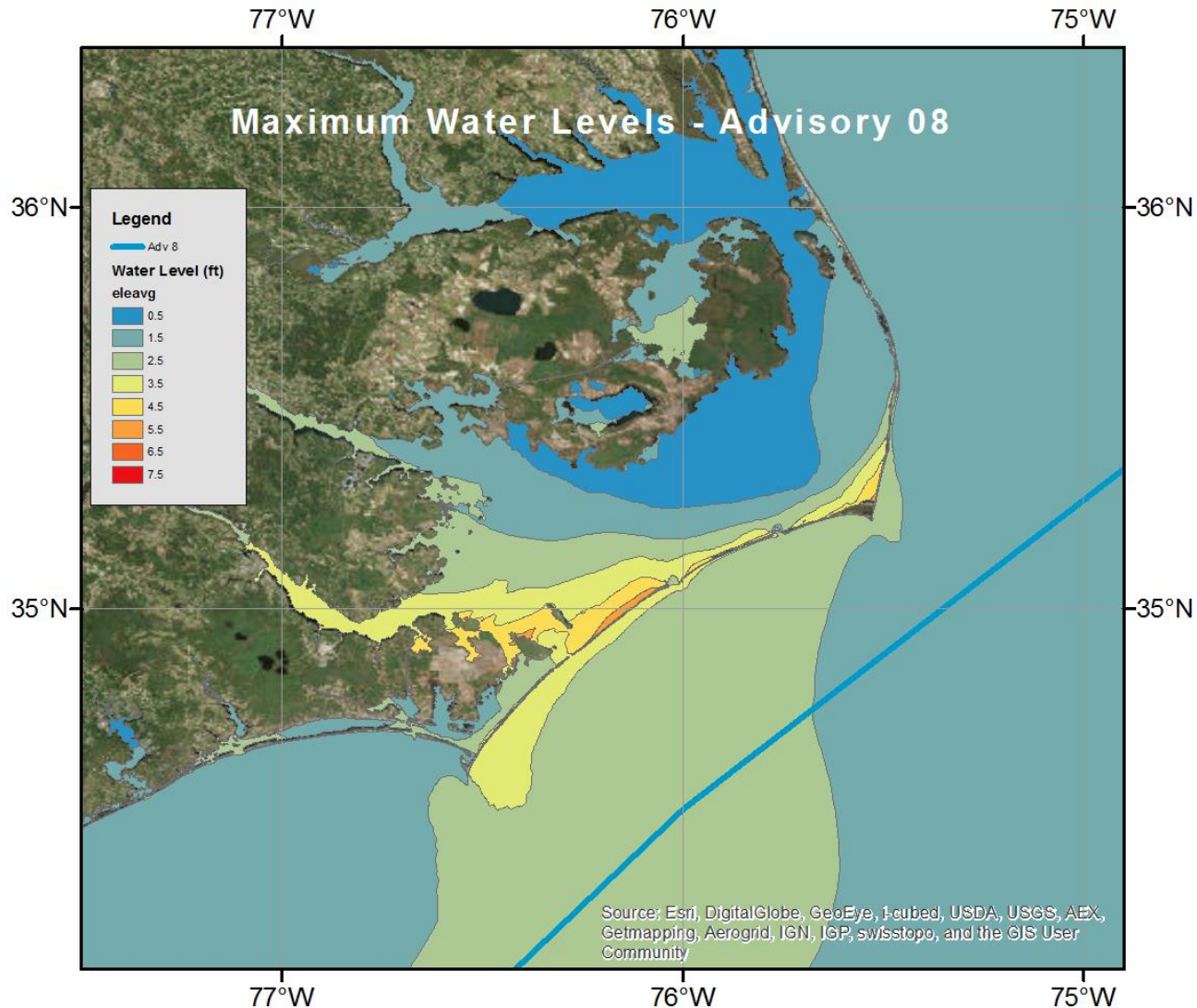
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## Sensitivity of Maximum Surge to Track



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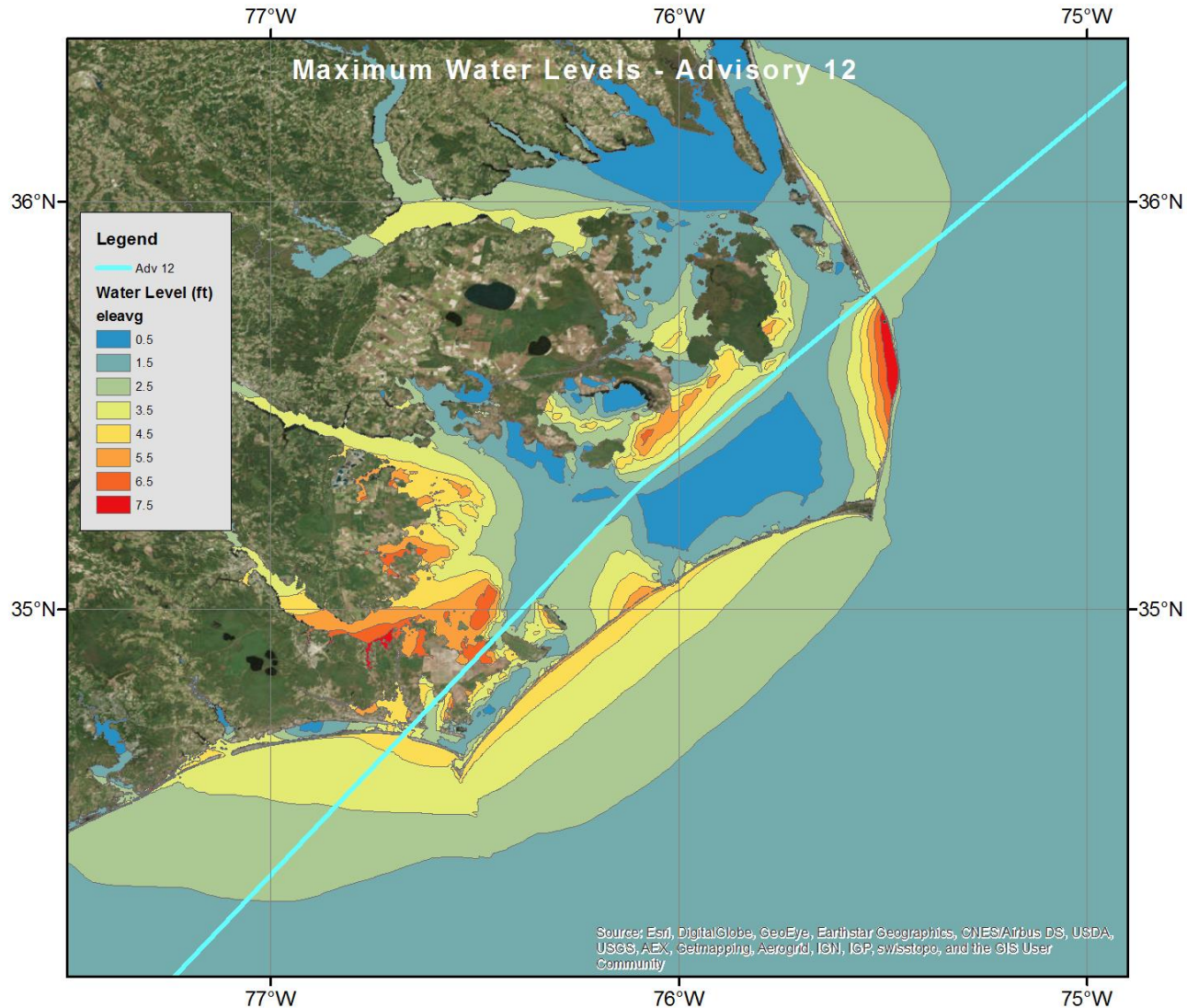
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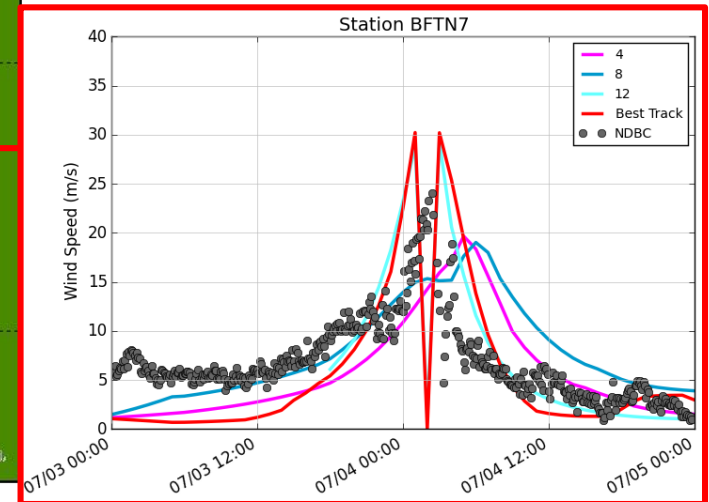
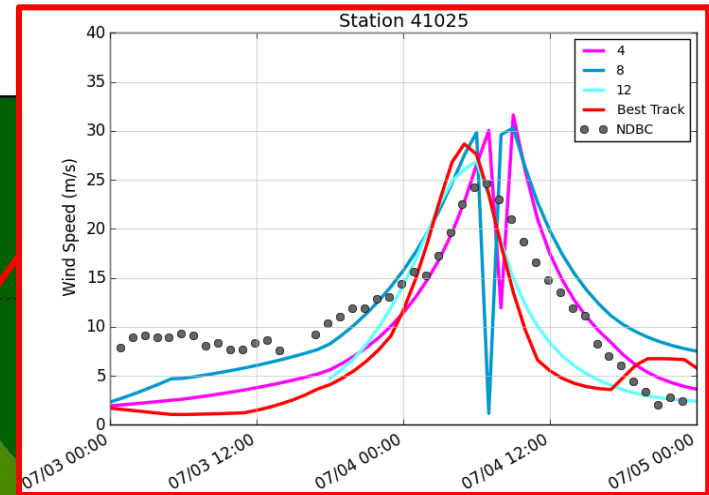
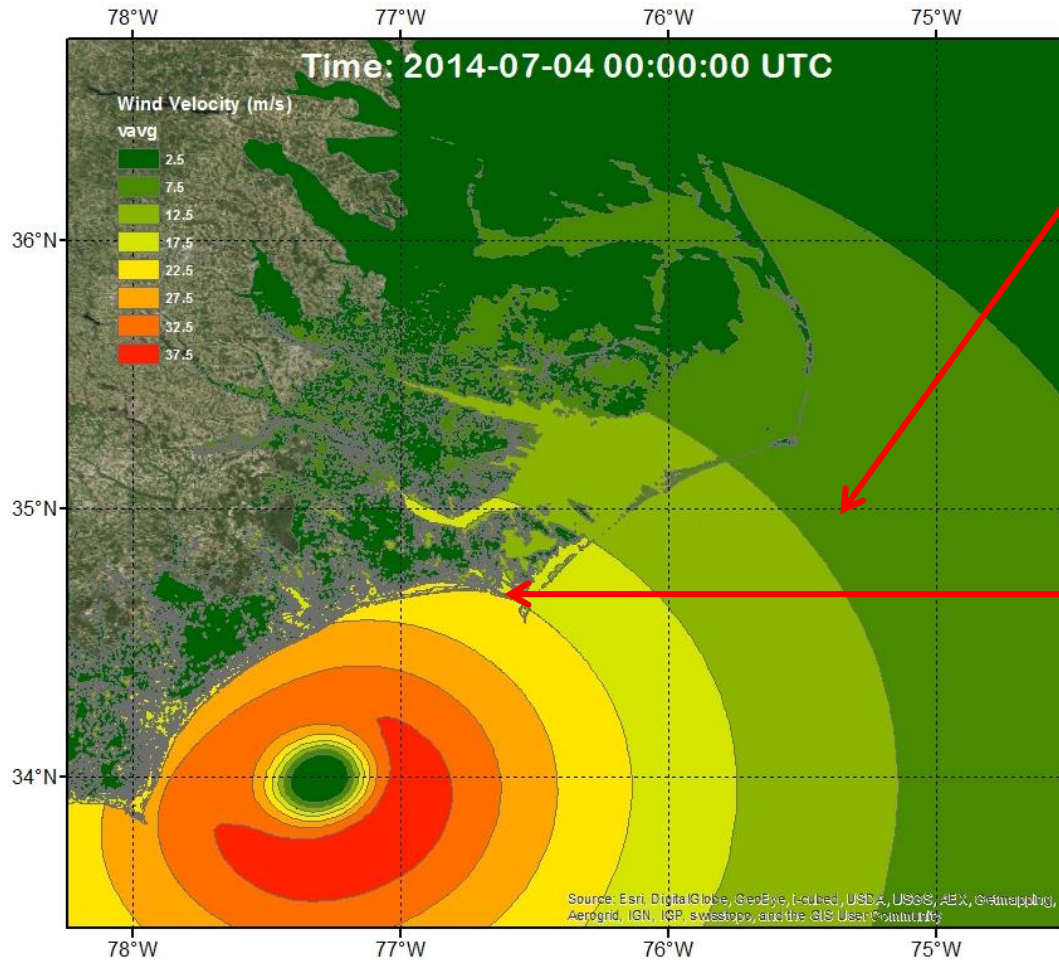
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# Arthur (2014) Effects in Coastal NC

## Evolution of Wind Fields

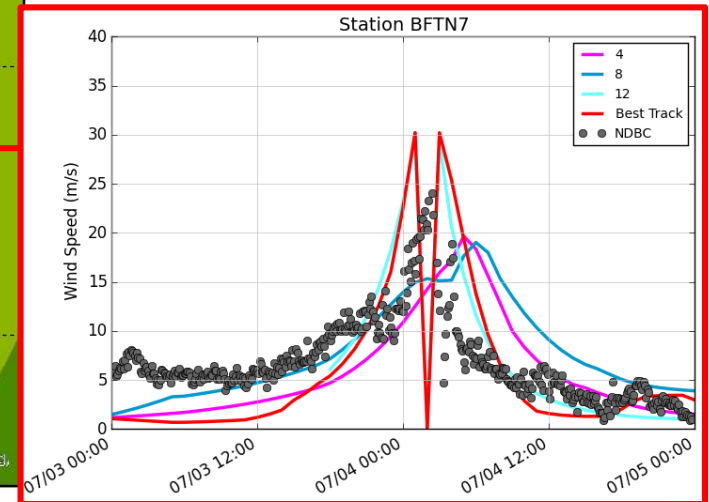
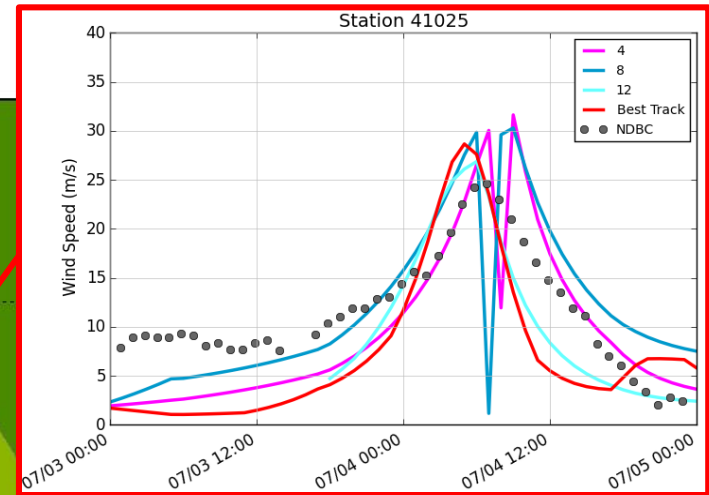
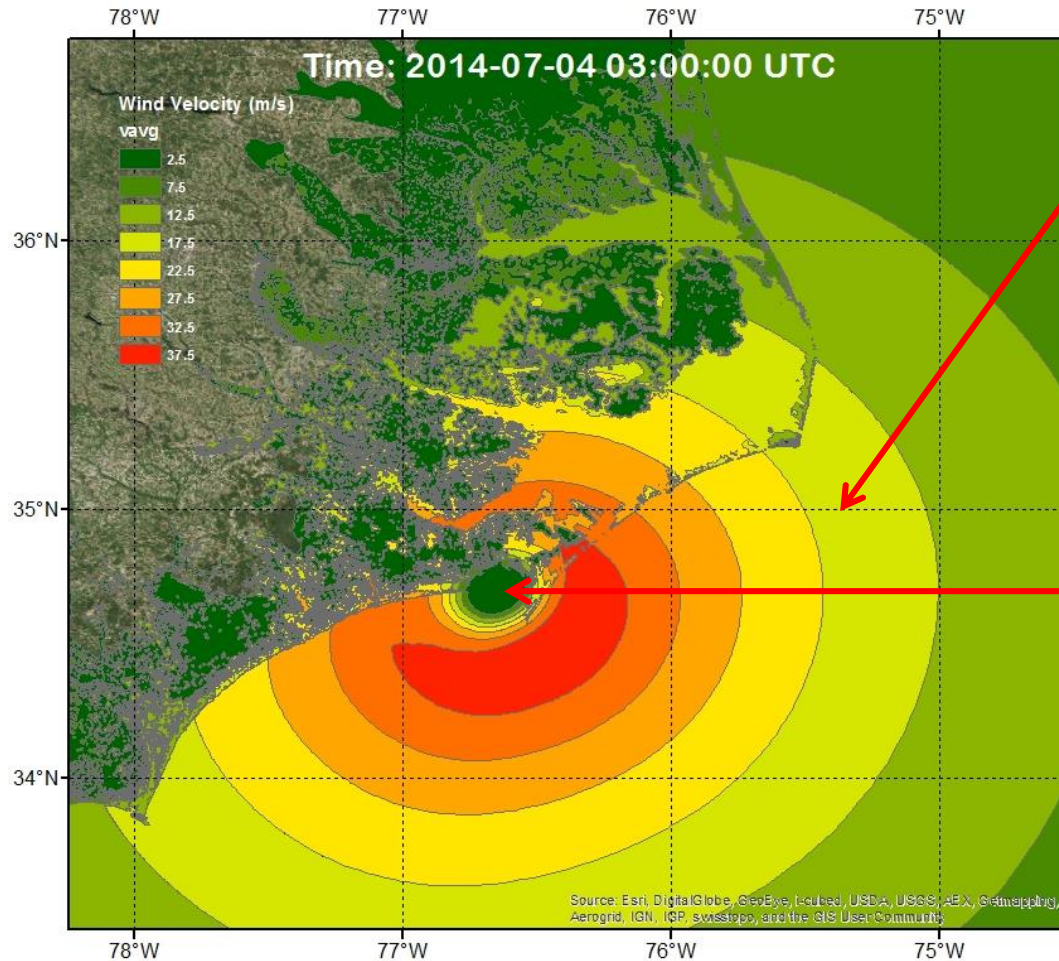


Lines show tracks for advisories:

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

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## Evolution of Wind Fields



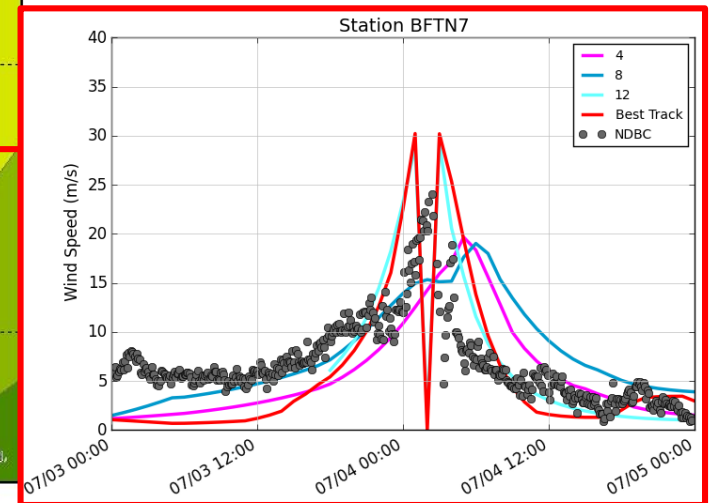
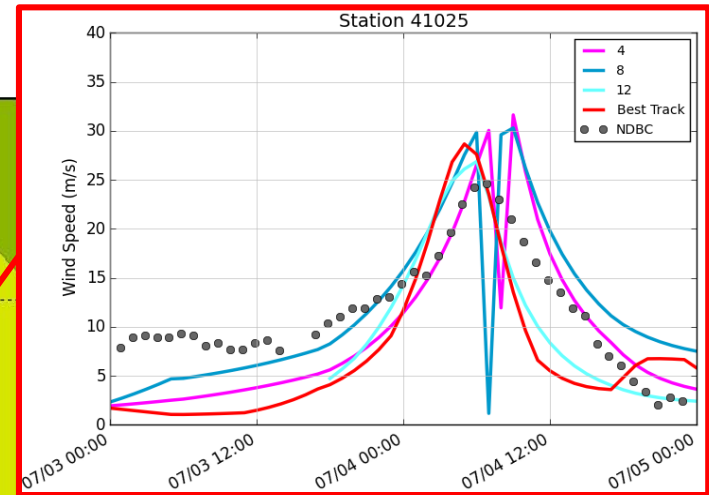
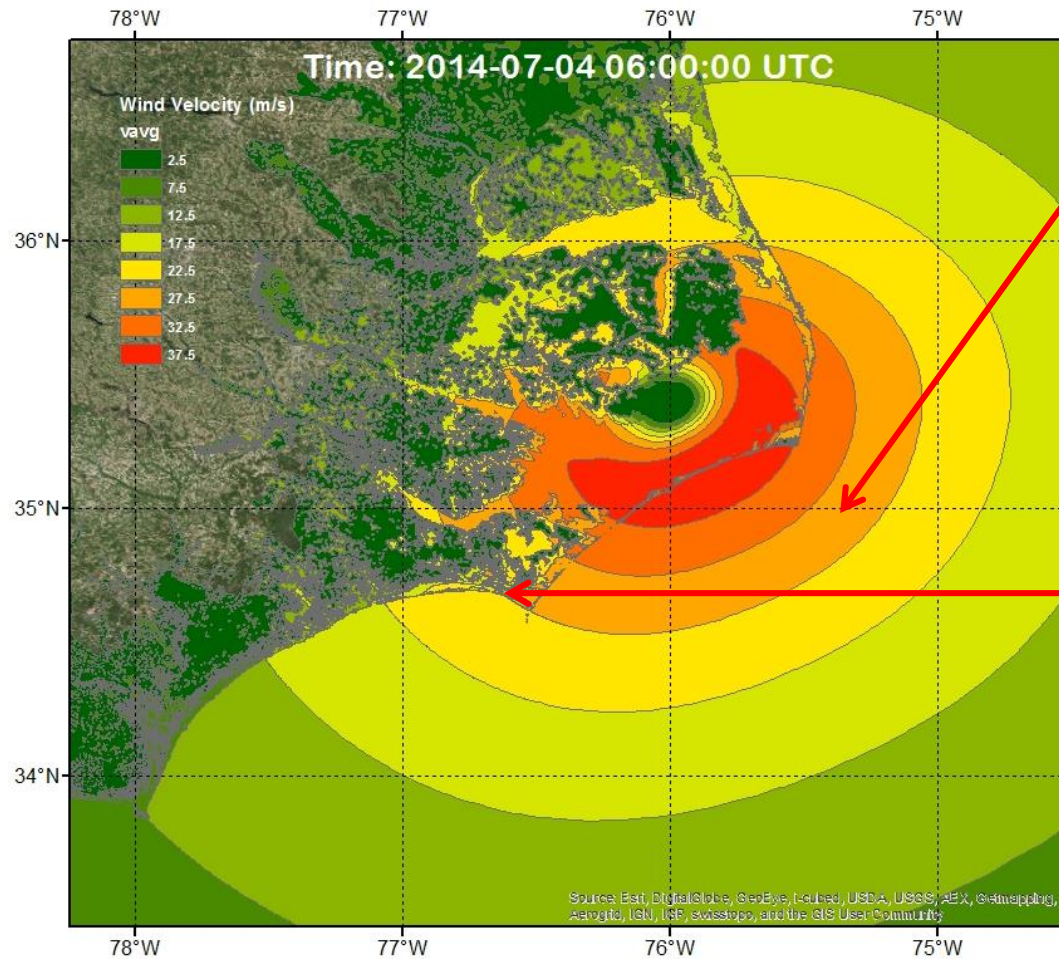
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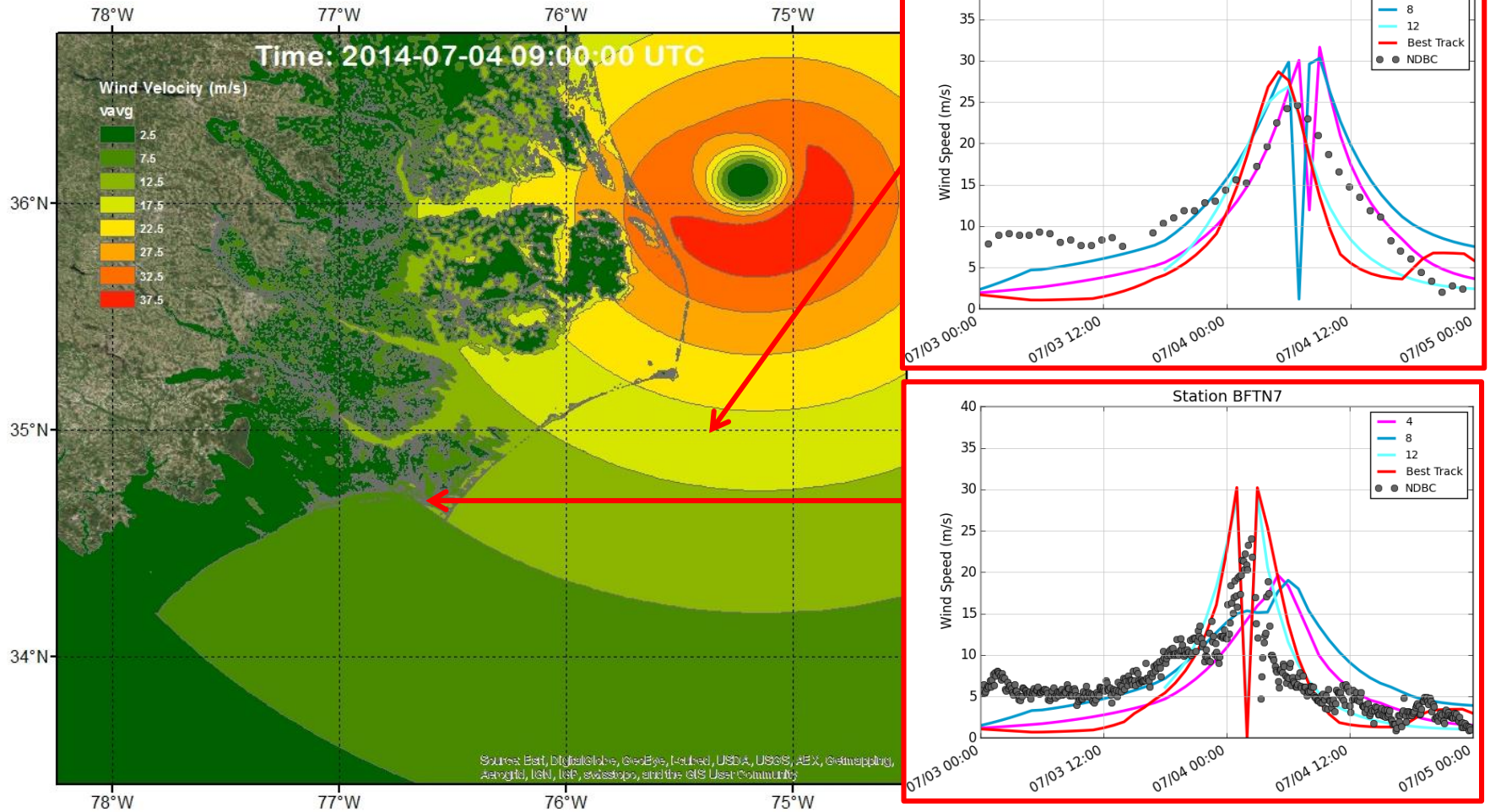


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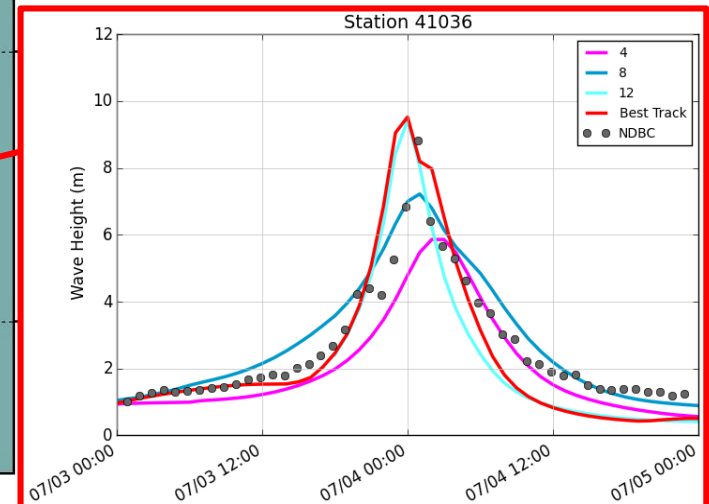
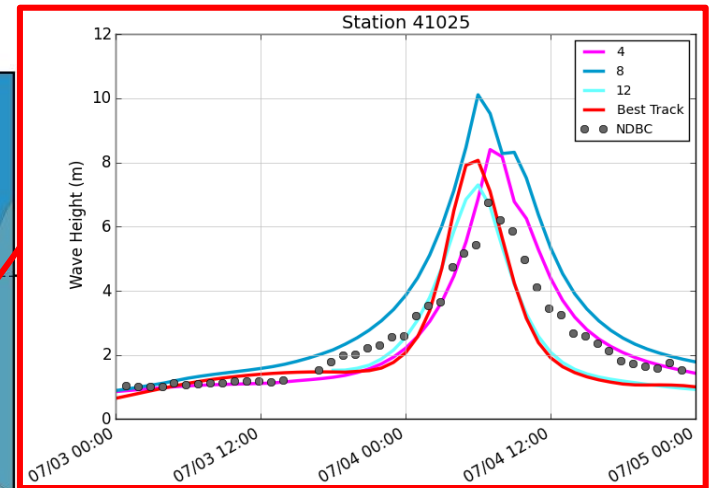
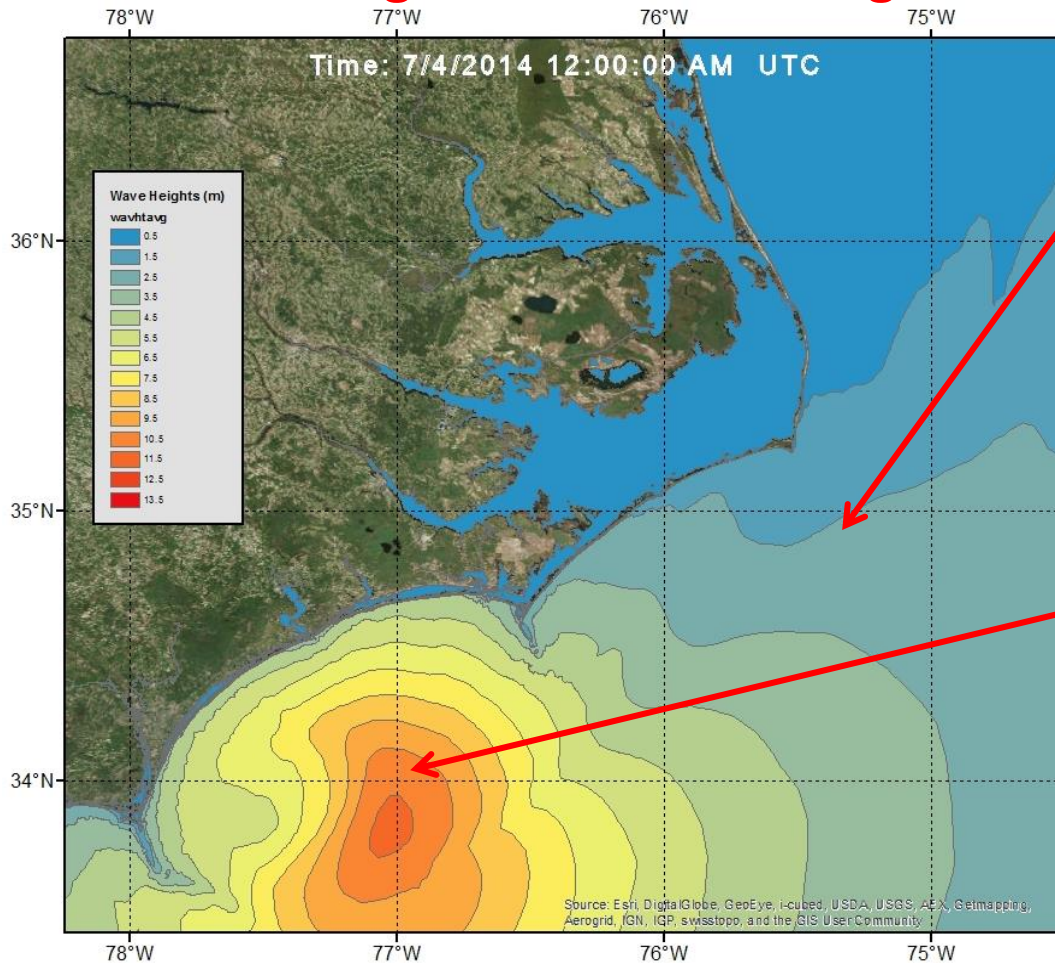
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## Evolution of Significant Wave Heights

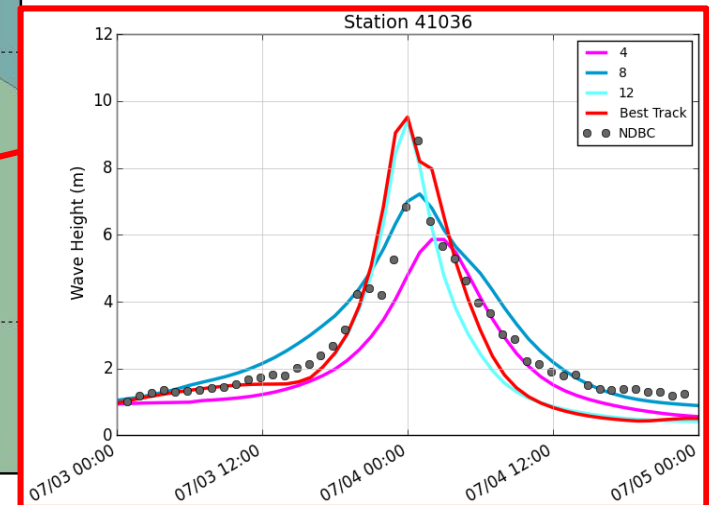
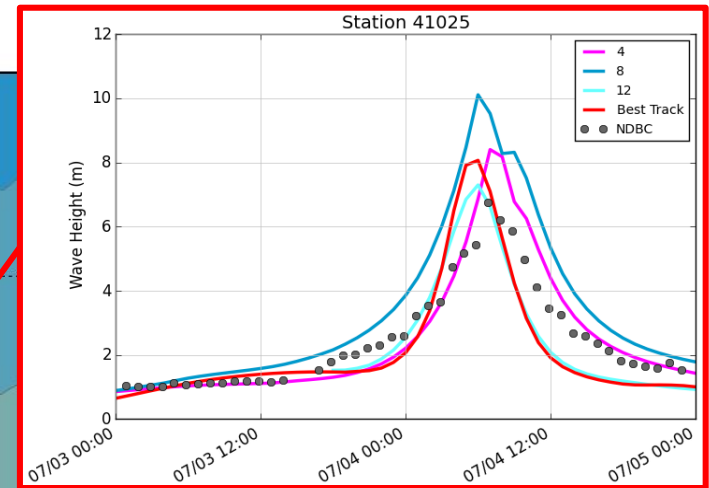
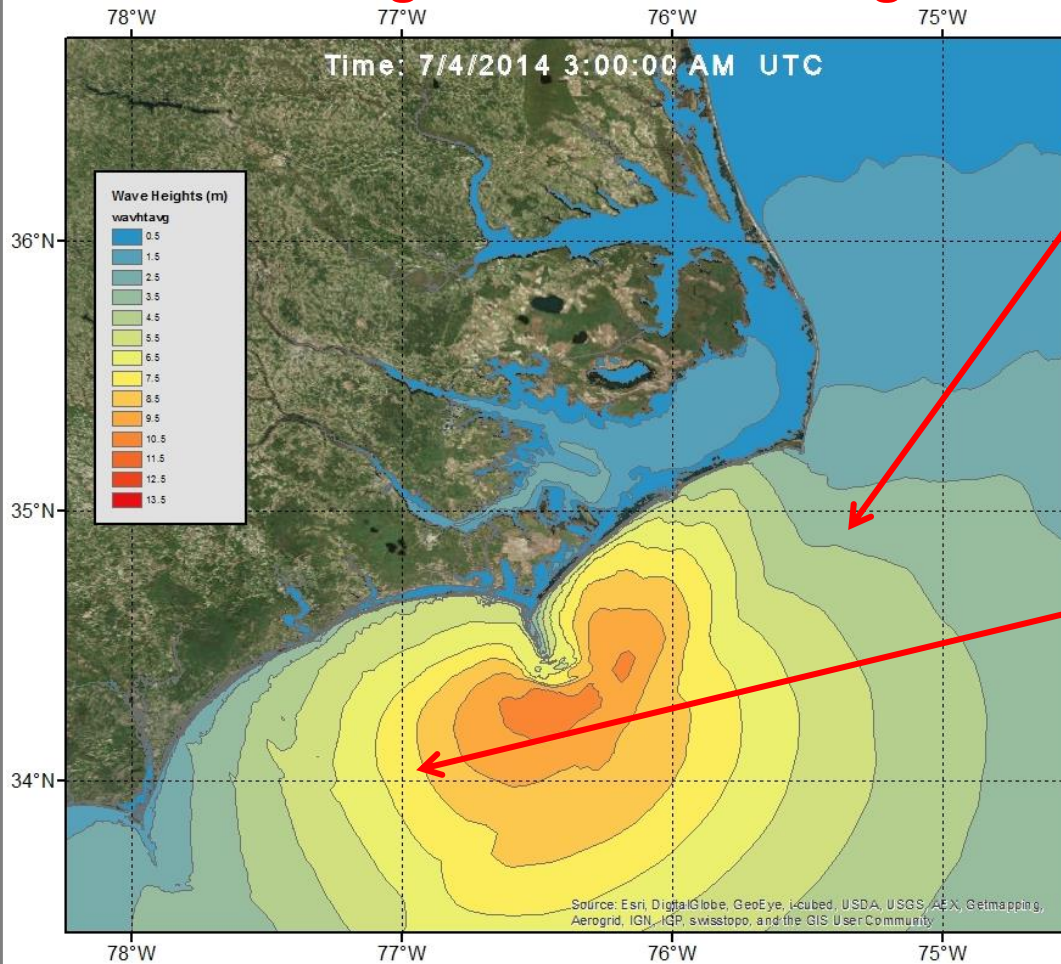


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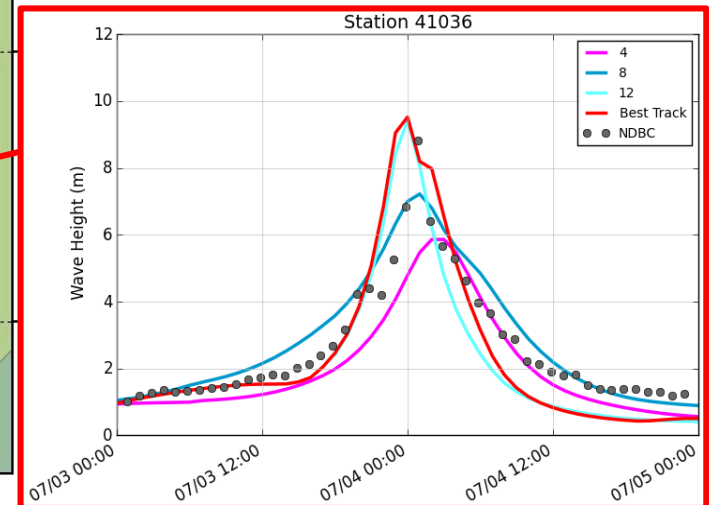
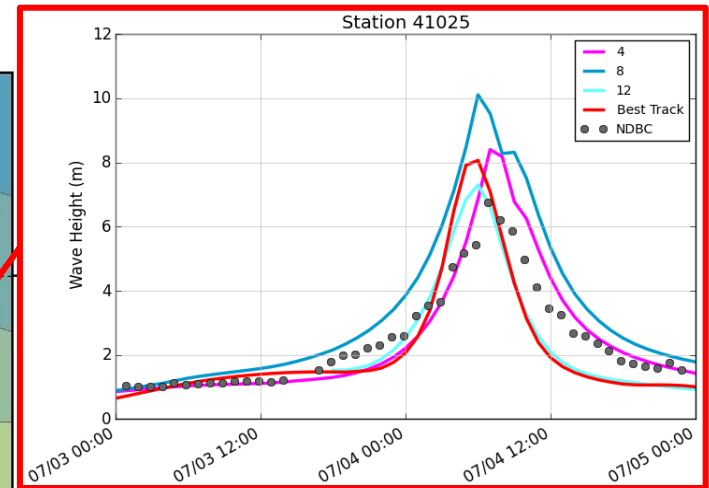
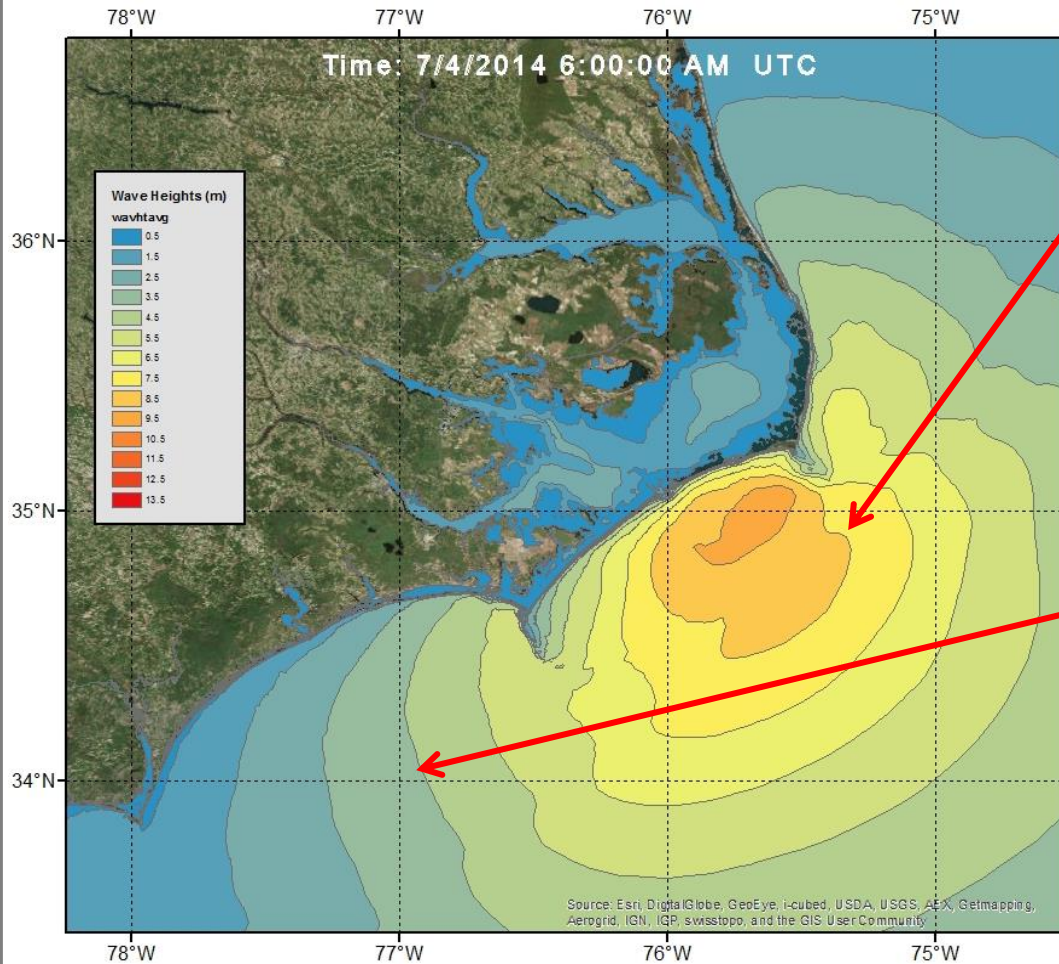


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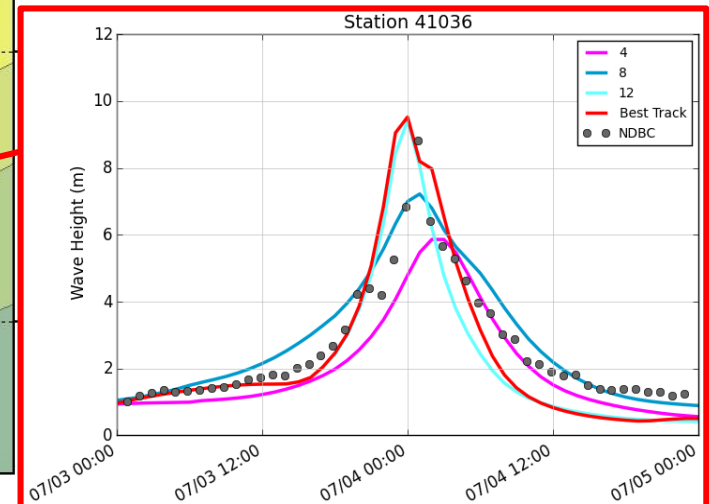
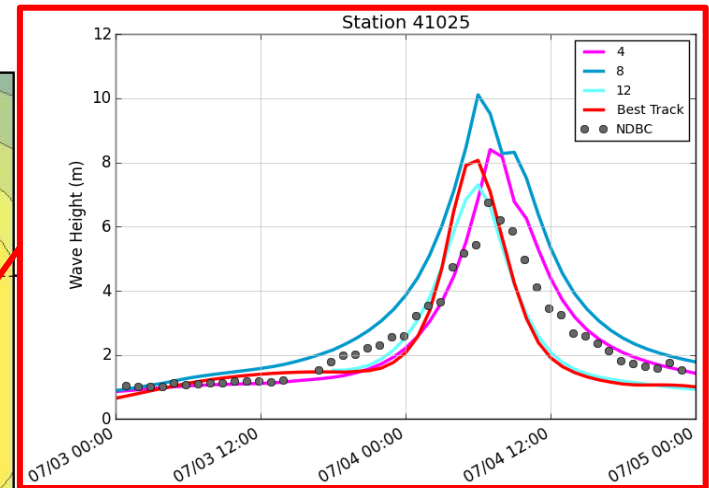
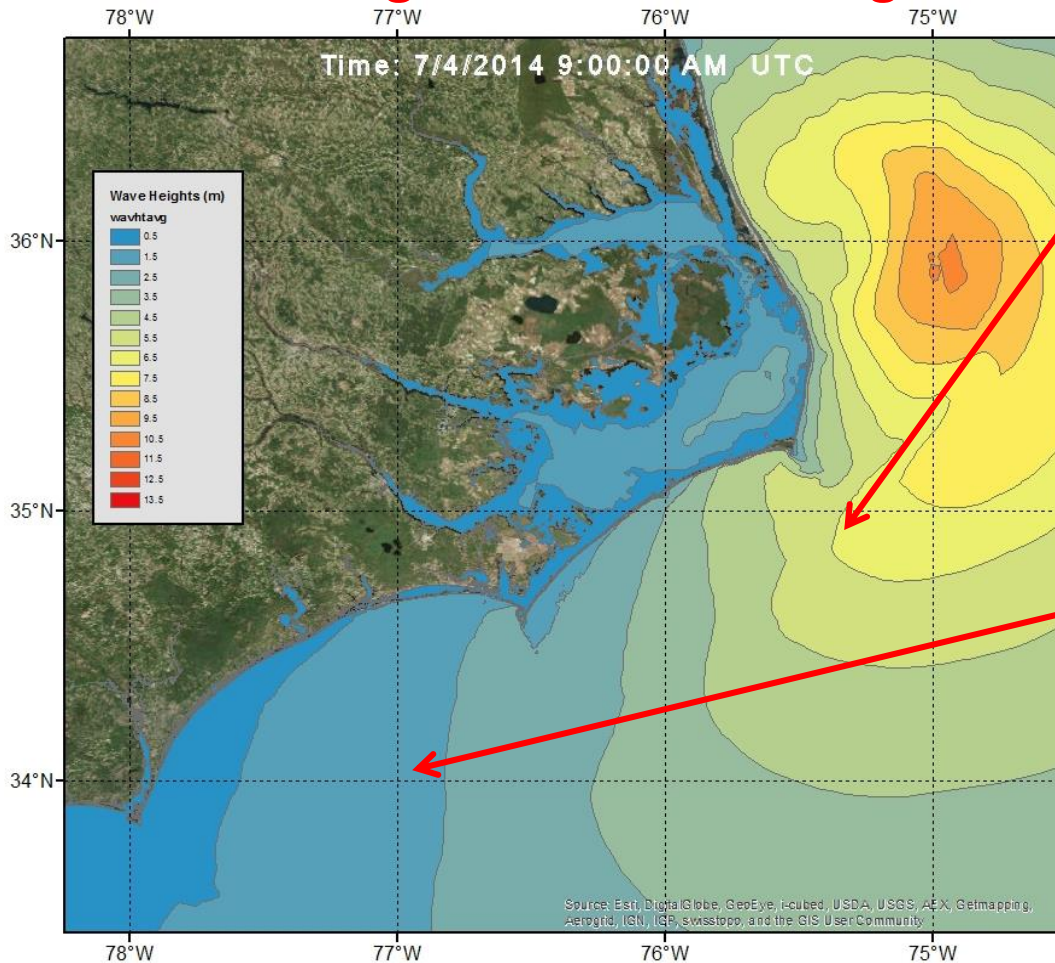
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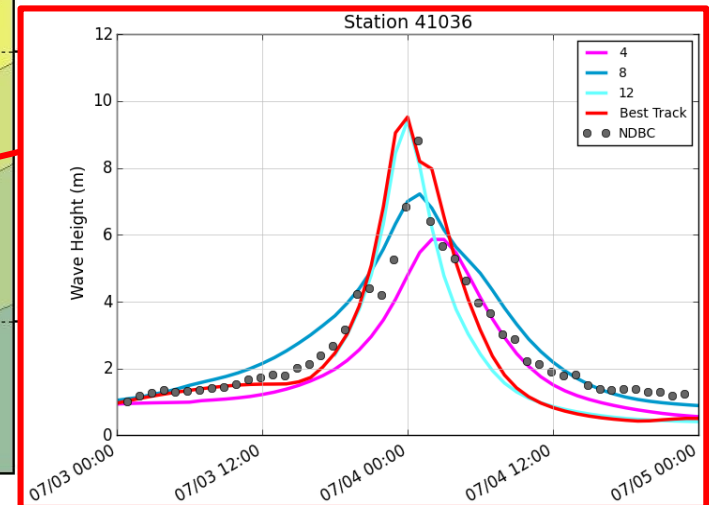
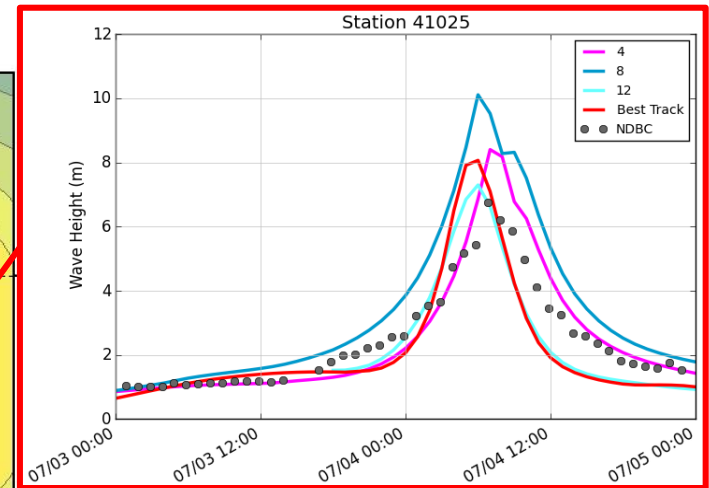
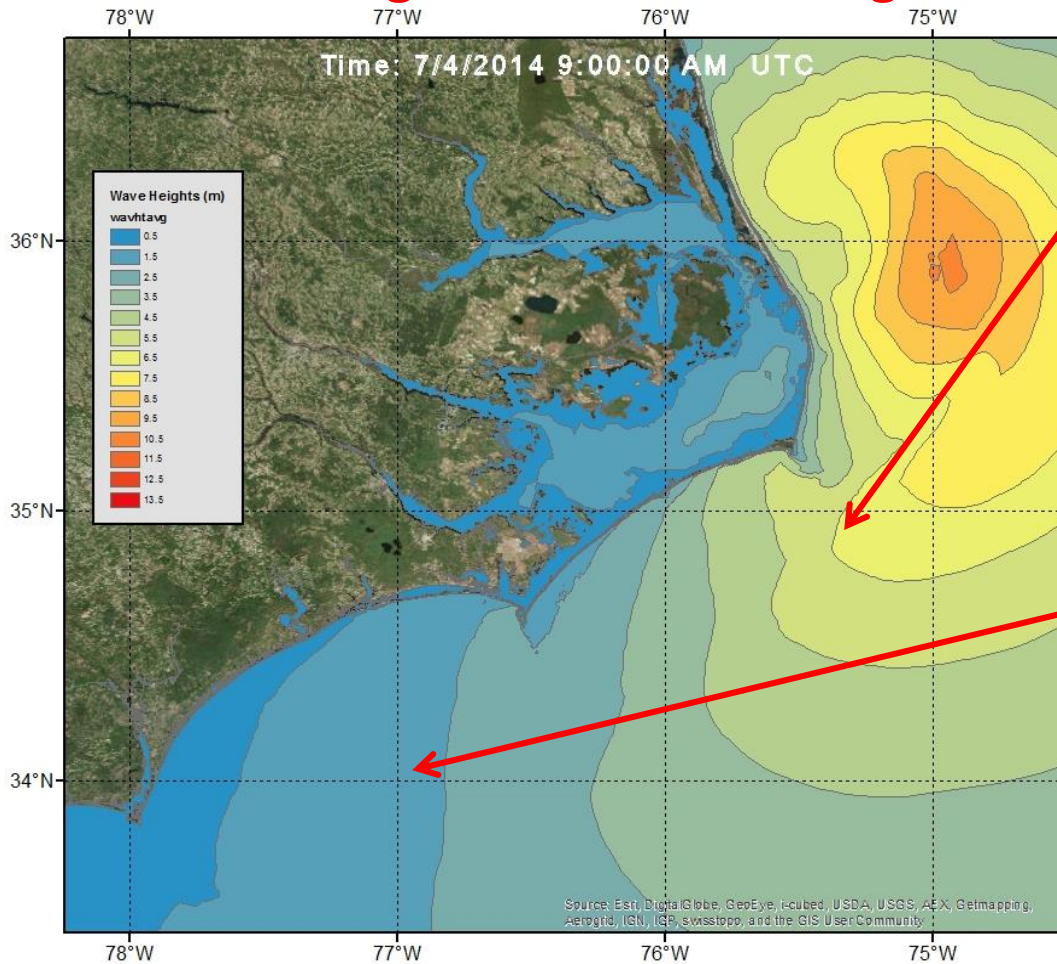


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# PART 3 : More about Kalpana – A visualization tool

## Procedure

*Kalpana* visualizes forecast guidance in the following steps:

1. Accept user input:
  - NetCDF-formatted ADCIRC output file (can also read from an OPeNDAP server)
  - Choice of vector geometry (polygon or polyline)
  - Number of contour levels
  - Palette file for KML creation
  - Domain Information for KMZ files
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
  - Google Earth has limitations on the size of polygons that can be drawn and visualized (should not have more than 31000 vertices)
  - Therefore for KMZ files, domain divided into sub domains
  - Kalpana interpolates mesh and variable data for each of the local domains, and contours them separately



# PART 3 : More about Kalpana – a visualization tool

## Procedure contd.

4. Contour information is extracted as *shapely* polygon objects, processed and stored as outer and inner polygons
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