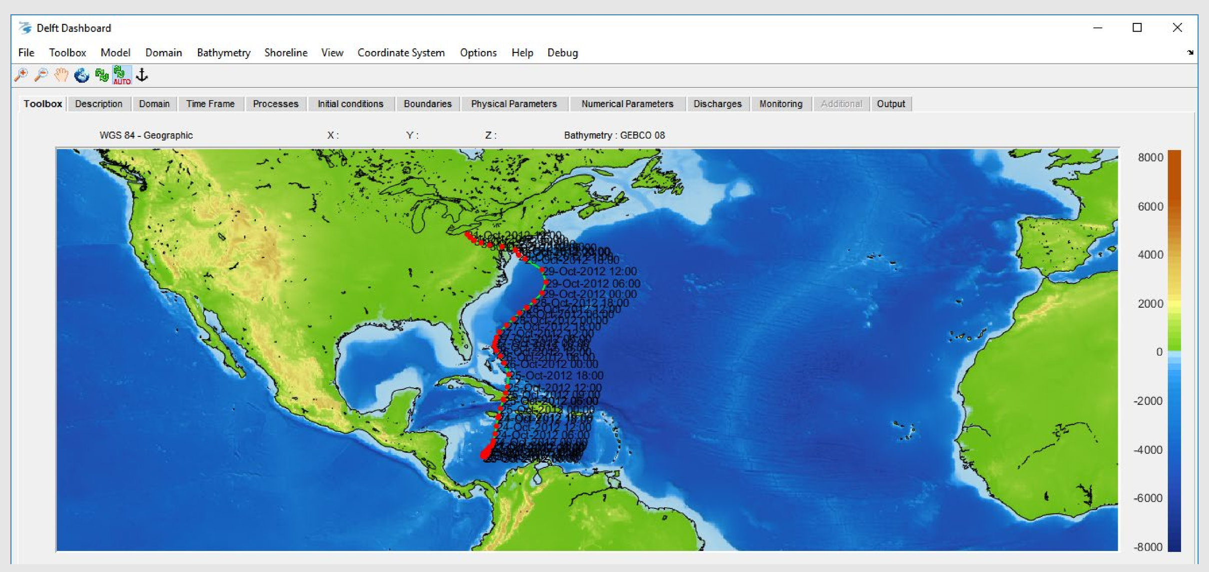
Examining the role of ensembles in storm surge prediction

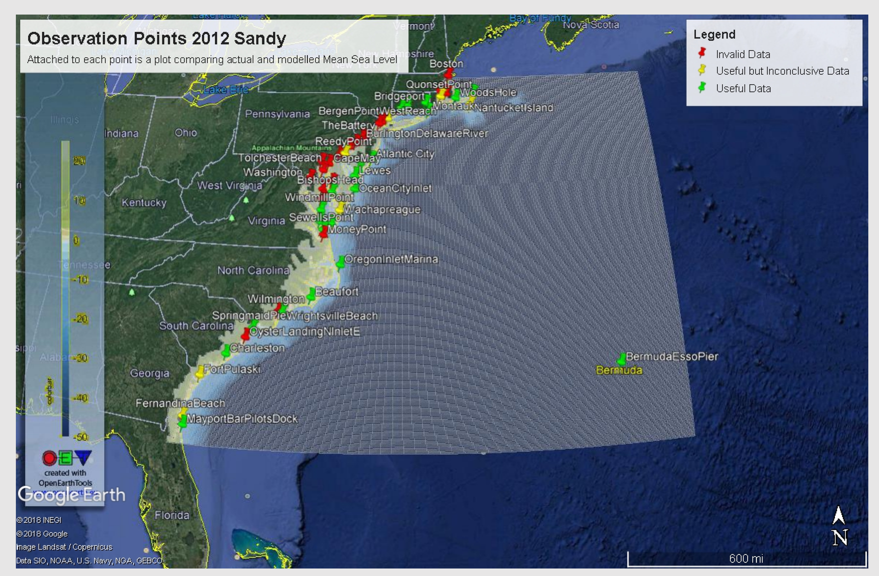
Kacey Edwards[1], Jay Veeramony[1], and Daniel Metzger[2]
[1]Naval Research Laboratory, Code 7320, Stennis Space Center, MS
[2]Louisiana School for Math, Science, and the Arts, Natchitoches, LA

1. ABSTRACT

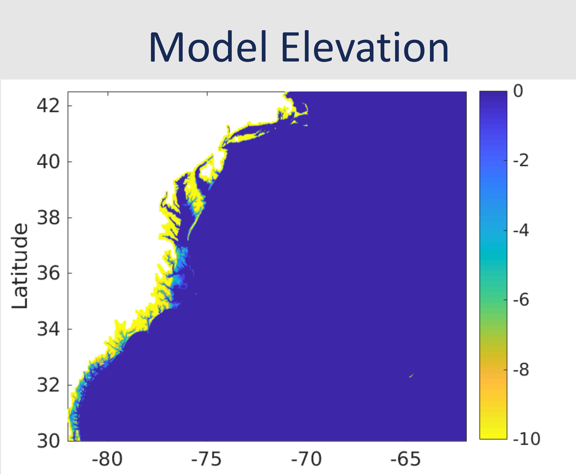
Because of the uncertainty in storm track, forecasting storm surge and inundation using a deterministic model is difficult. Slight changes in storm track greatly impact predictions, and forecast errors are likely. For this reason, predicting the probability of surge using an ensemble approach provides more reliable information. Deterministic hind cast models show that for many storms, wave forcing on the water column is an important component for predicting the surge. Unfortunately, using ensembles of the wave model is computationally expensive and prohibitive under operational timescales. Here, we investigate an approach to determine the wave component of the predicted surge from the deterministic model and apply it to the ensemble members. Ensemble and deterministic model results with and without the wave contribution will be compared to each other and data.

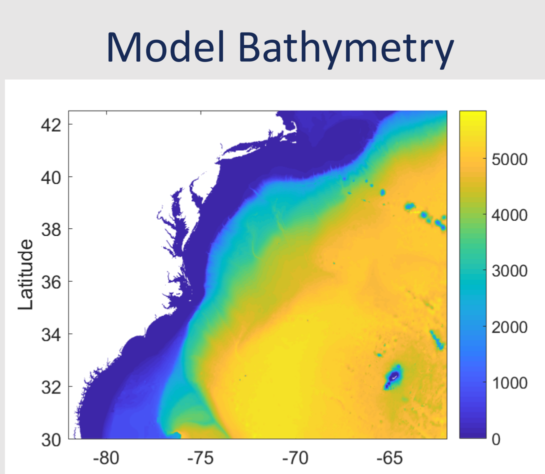
2. HURRICANE SANDY MODEL





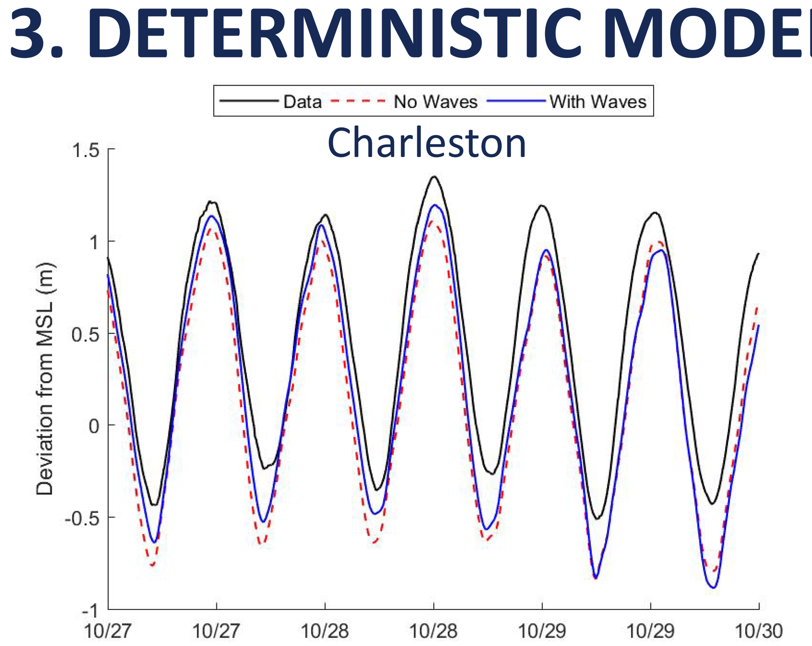
Made landfall on October 29, 2012 northeast of Atlantic City near Brigantine, New Jersey. Storm surge impacted New York City flooding streets, tunnels, and subway lines.

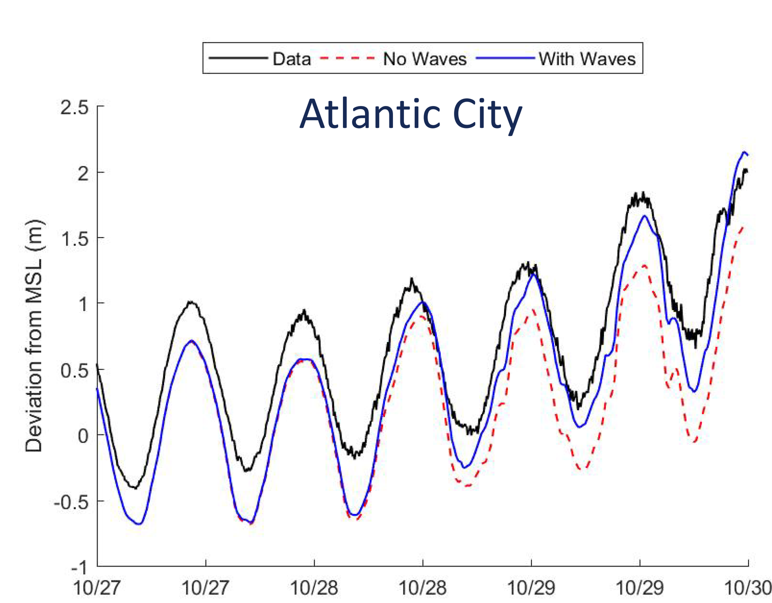




Horizontal Resolution: 2km
Grid Points: 1001 X 626 grid points
Bathymetry: GEBCO + Coastal Relief
Duration: 23-31 October 2012
Atmospheric Forcing: COAMPS
Flow Boundary Conditions: Astronomic
Wave Boundary Conditions: None

3. DETERMINISTIC MODELS





As seen in the Atlantic City comparison plot to the left, however, waves are an important component of the model.

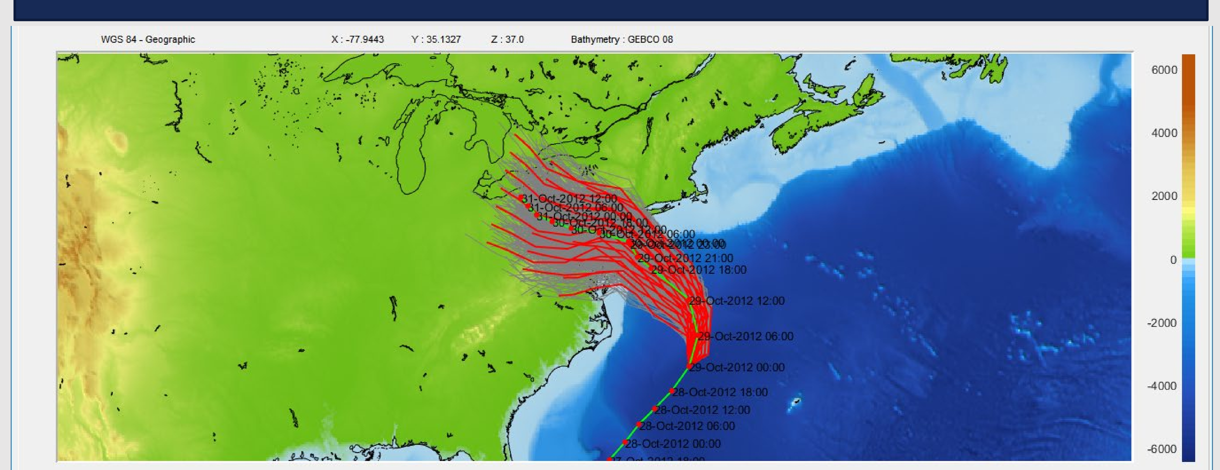
The deterministic models (with and without waves) agree with data at many locations. For example, the comparison at Charleston (above) where the storm has passed.

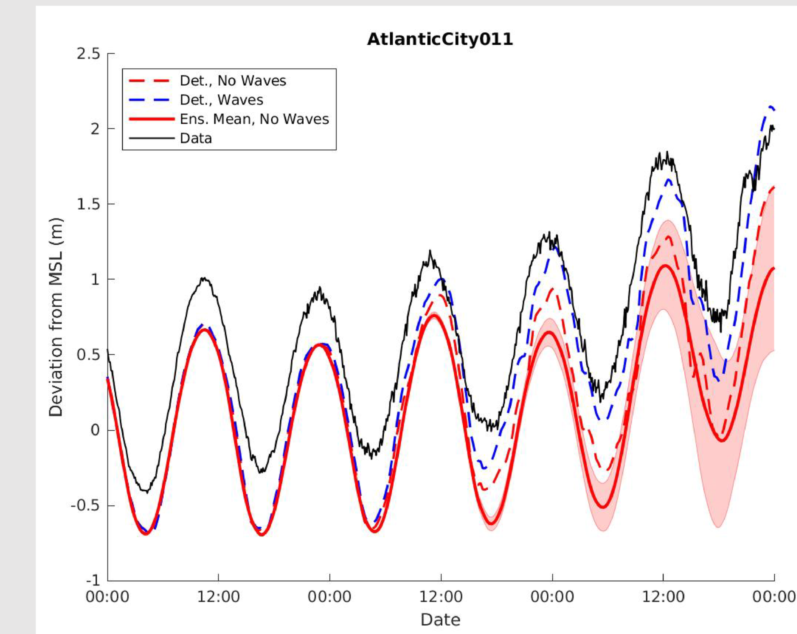
Here, the atmospheric model, COAMPS, is tuned. In a forecasting scenario, errors in the wind and track inputs can greatly impact the resulting water elevations. To account for such errors, we replace deterministic models with an ensemble or probabilistic approach.

4. ENSEMBLE APPROACH

1. Generate 1000 perturbations of wind and track input given the Monte Carlo method (gray lines in the figure below).
2. Bin the perturbations to give 63 representative ensemble members (red lines in the figure below).
3. Determine means and standard deviations of the ensemble members at data locations.
4. Construct probability maps for water surface elevations.

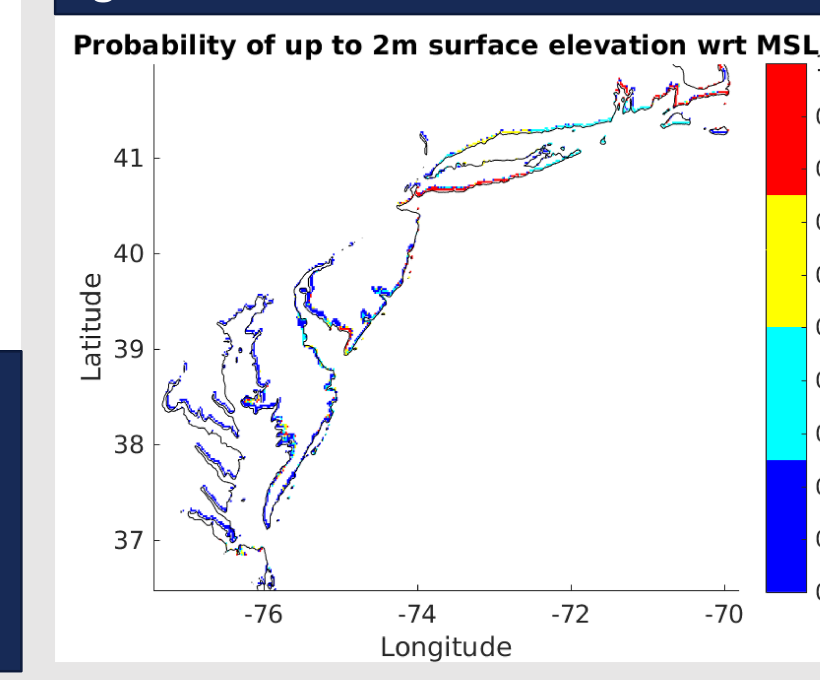
NOTE: ENSEMBLE SIMULATIONS DO NOT INCLUDE WAVES!





The ensemble approach allows for an average, or mean, model, and we can examine the spread, or standard deviation, of the model results, as shown in the figure above.

Additionally, we can provide a probability of surface elevation for the model domain, as shown in the figure below.



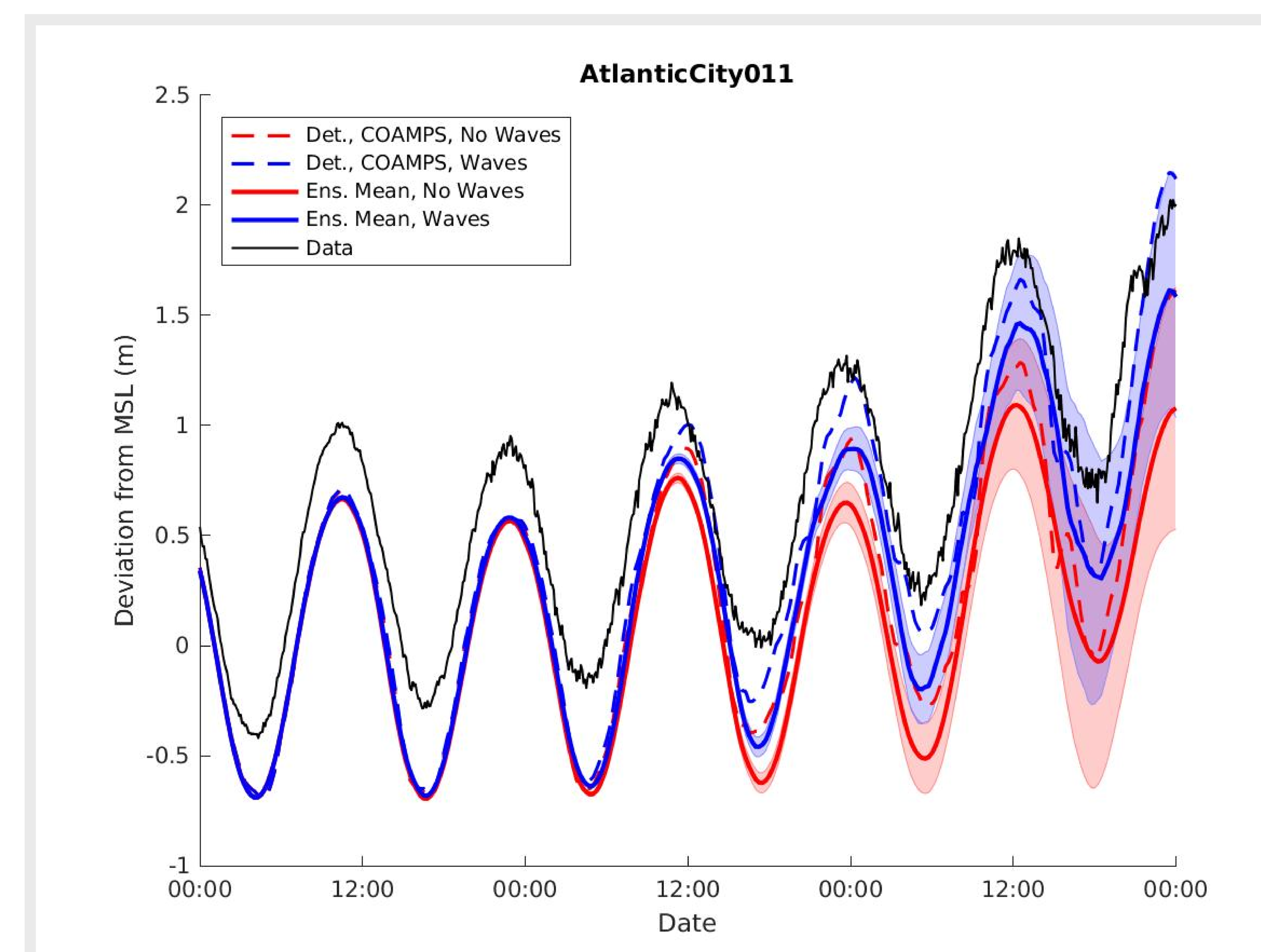
It is easy to see from the time series plot of the ensemble results at Atlantic City that the ensembles do not account for the omission of wave effects. Additionally, the waves are needed to accurately predict the water surface elevation for Hurricane Sandy.

5. ENSEMBLES WITH WAVES

Including waves for all of the ensemble members is computationally prohibitive, but we need to represent the wave contribution in our ensemble forecast. We take a simplistic approach for each data location.

1. Determine the difference in water surface elevation between the deterministic models with waves and without waves.
2. Add the difference to the water surface elevation for each ensemble member.
3. Determine the means and standard deviations of the ensemble members at data locations.

We can complete this approach for every model grid cell, and produce probability maps for water surface elevations that include the wave contribution, but we do not include those products here.



6. SUMMARY

A model configured for Hurricane Sandy predicts water surface elevations. We apply the configuration in deterministic and ensemble approaches. All model results are compared to tide gages along the US East Coast. Comparisons of the deterministic models show that the inclusion of wave effects increase the accuracy of the model. Because deterministic models provide only one answer and errors in the wind and track forcing greatly influence the model results, an ensemble approach provides more useful information. The ensemble approach provides a range of answers given reasonable perturbations of the wind and track inputs. However, including waves in the ensemble approach is computationally prohibitive. Therefore, a simplistic approach to accounting for the effects of waves in the ensemble model post processing is implemented and found useful.