Session 16

Don Slinn

University of Florida

Improved Storm Surge Anaylsis

Topic Description

There were two major goals for the Storm Surge project. In previous work we found that coupling wave models together with storm surge models had a strong influence on the total surge. Typically waves contribute about 30% to the total water elevation. In this study we wanted to introduce two-way coupling between the wave and surge models to see if the change in water levels from the surge would effect the wave field enough to make significant adjustments to the wave contribution to the total surge. The second aspect we examined was the effect of including different sizes of bays and inlets to the open coast storm surge models during hurricanes. We wanted to test how much the open coast storm surge changed when a bay was well resolved along the coast. In both studies, we were surprised by the results.

Speaker Biography

Dr. Slinn teaches Civil and Coastal Engineering at the University of Florida. He specializes in computer modeling of coastal processes. He teaches classes in Open Channel Hydraulics, Fluid Dynamics, Sediment transport and beach erosion, Wave mechanics, and Computer modeling techniques for describing natural systems. In recent years a lot of his work has centered around prediciting hurricane impacts on the coast.

Improved Storm Surge Modeling System: Part 2: Wave-Surge Coupling

Don Slinn, Max Sheppard, Frederique Drullion

University of Florida
Department of Civil and Coastal Engineering

Motivating Issue

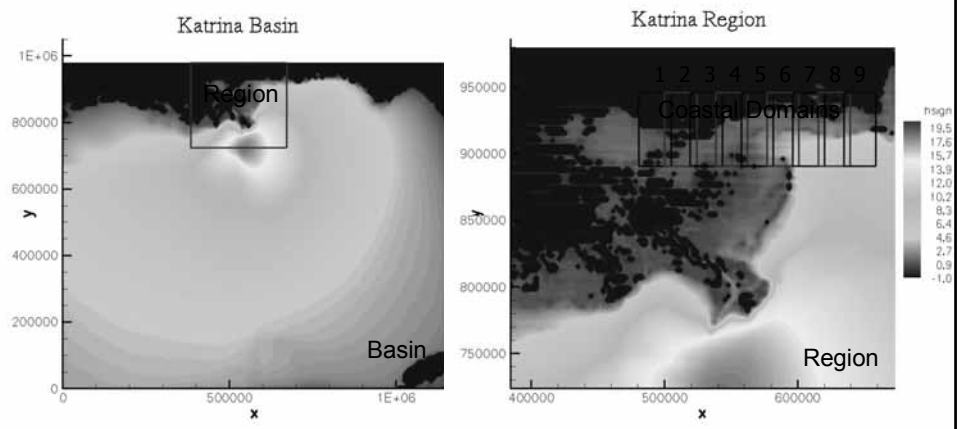
- Wave fields depend on water depth
  - κ = Wave height / Water depth = 0.78
  - Linear theory suggests that Setup = 20% of deep water wave height
  - Offshore waves of 10-20 meters common in hurricanes.
- Surge Changes the Water Depths, sometimes dramatically.
- Two-way coupling could potentially change coastal wave heights enough to adjust wave induced setup at shoreline

Wave Setup Modeling System

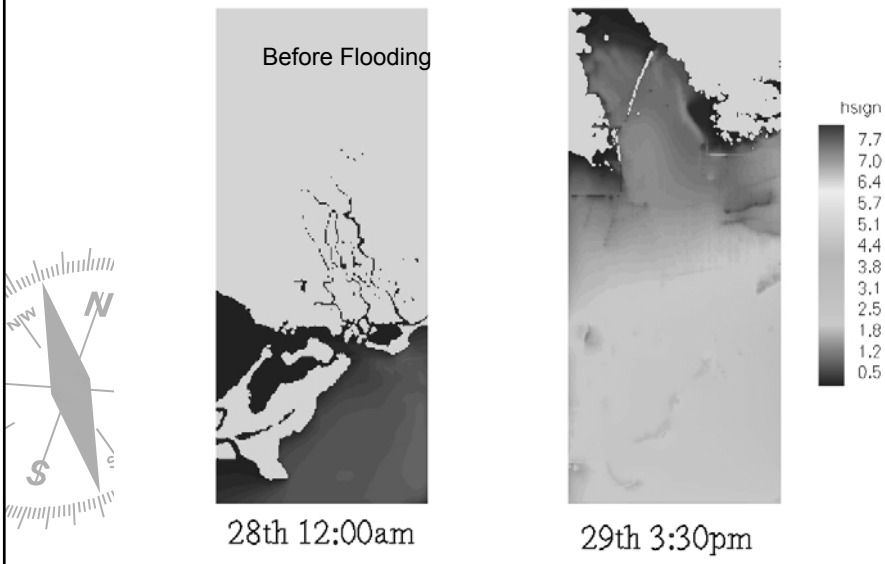
1. Calculate deep water waves in Gulf of Mexico in Basin domain.
2. Pass the time dependent Spectral Wave Boundary Conditions to SWAN (Simulating WAves Nearshore) in nested Coastal Region domain.
3. Run ADCIRC (ADvanced CIRCulation model) with wind & wave forcing in the Gulf to get time dependent water elevations.
4. Rerun Regional SWAN model with ADCIRC water elevations.
5. Pass Regional SWAN Spectral B.C.'s and ADCIRC water elevations to 9 High Resolution nested Coastal SWAN domains.
   - Include barrier island overtopping and inland flooding.
6. Calculate Surge and Wave Setup from improved wave fields.
7. Examine sensitivity to time step of two-way coupling

Test System on Hurricanes Katrina and Ivan

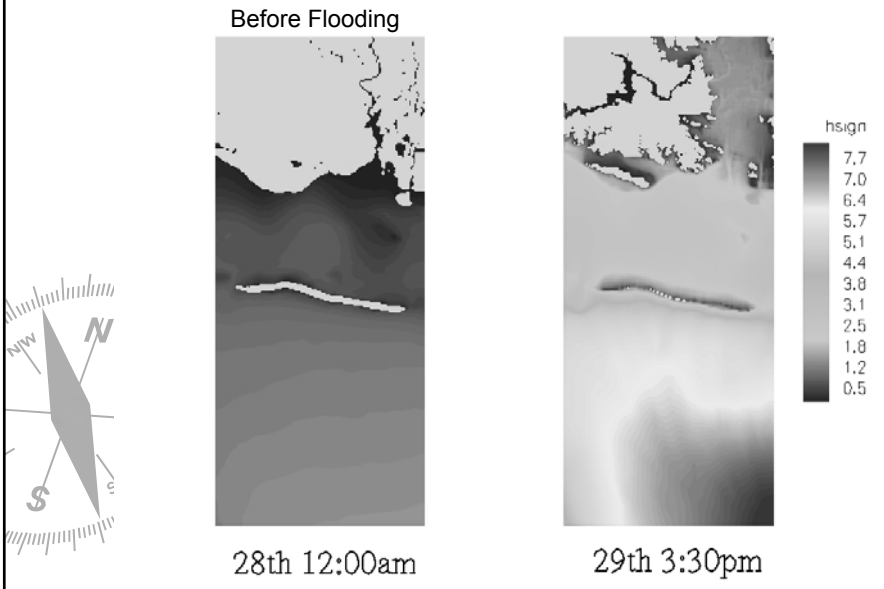
Basin and Region Wave Domains showing the 9 Nested Coastal Domains

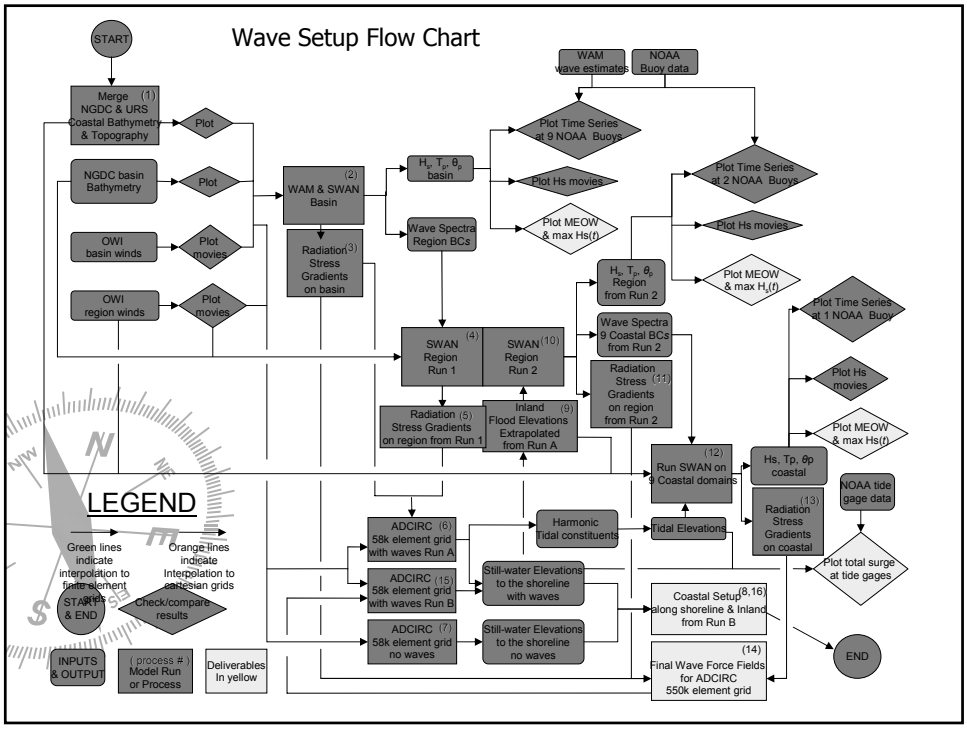


Coastal Domain 2



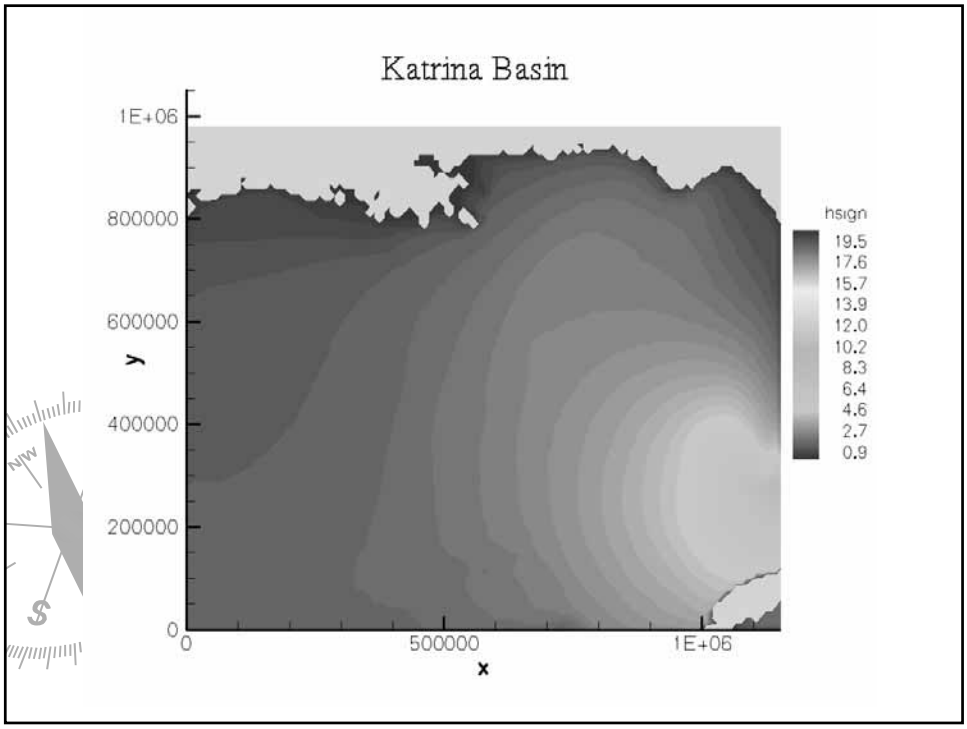
Coastal Domain 7

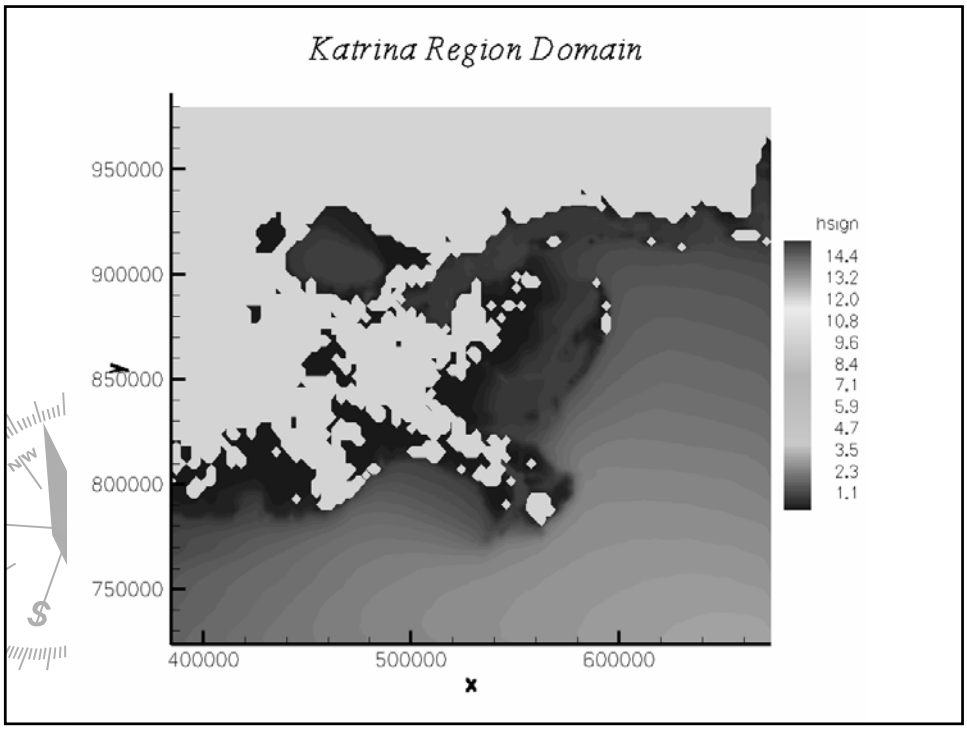


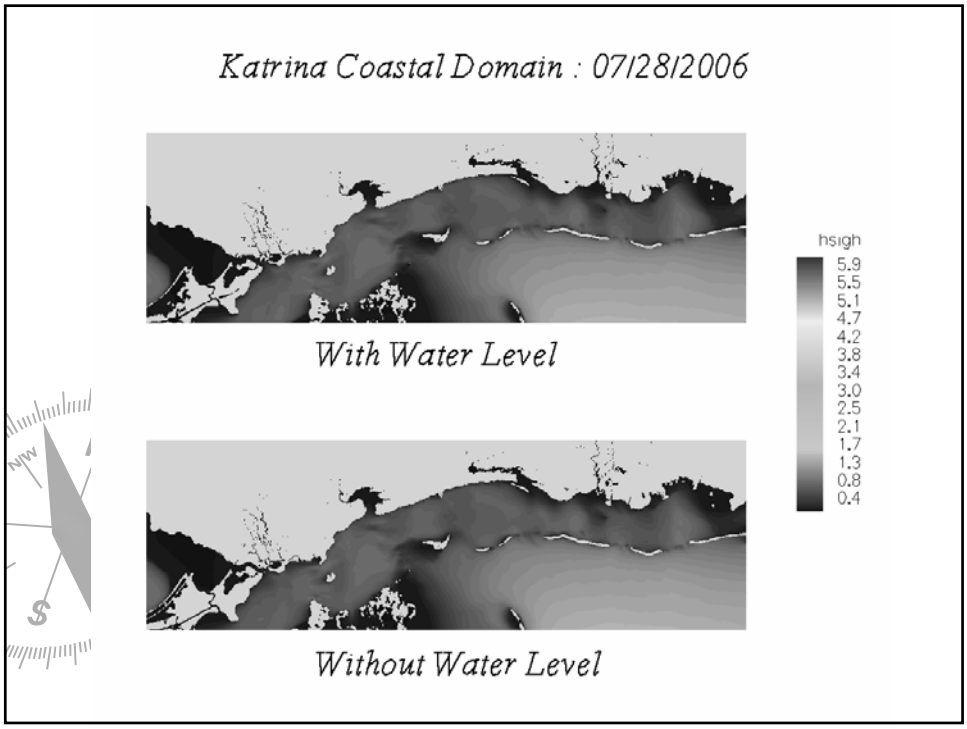


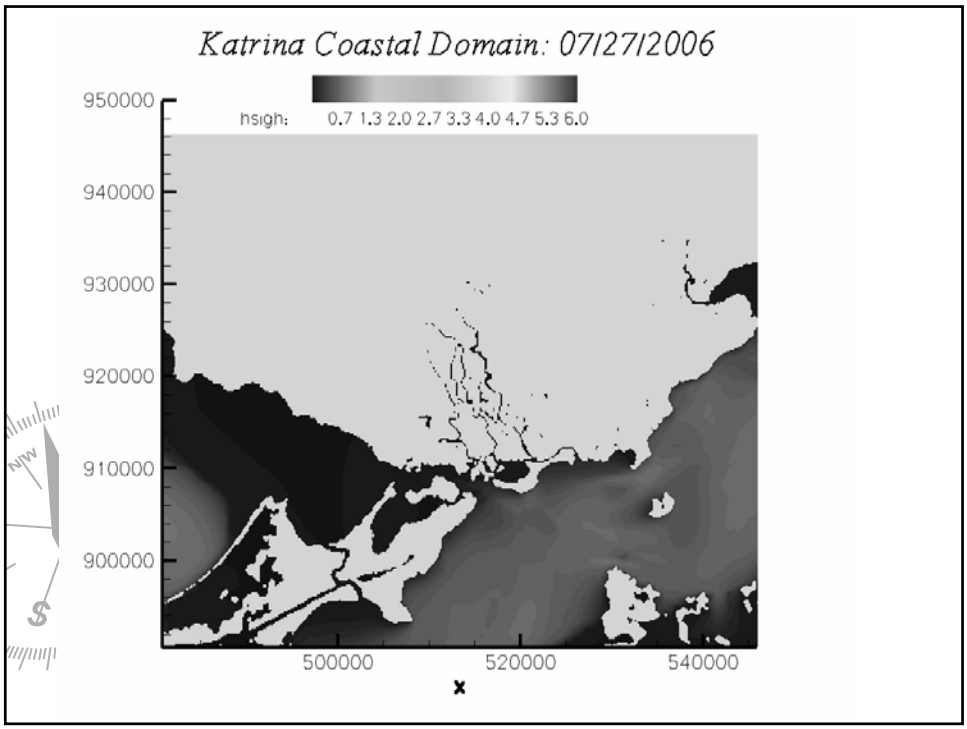
Coastal Wave Model Details

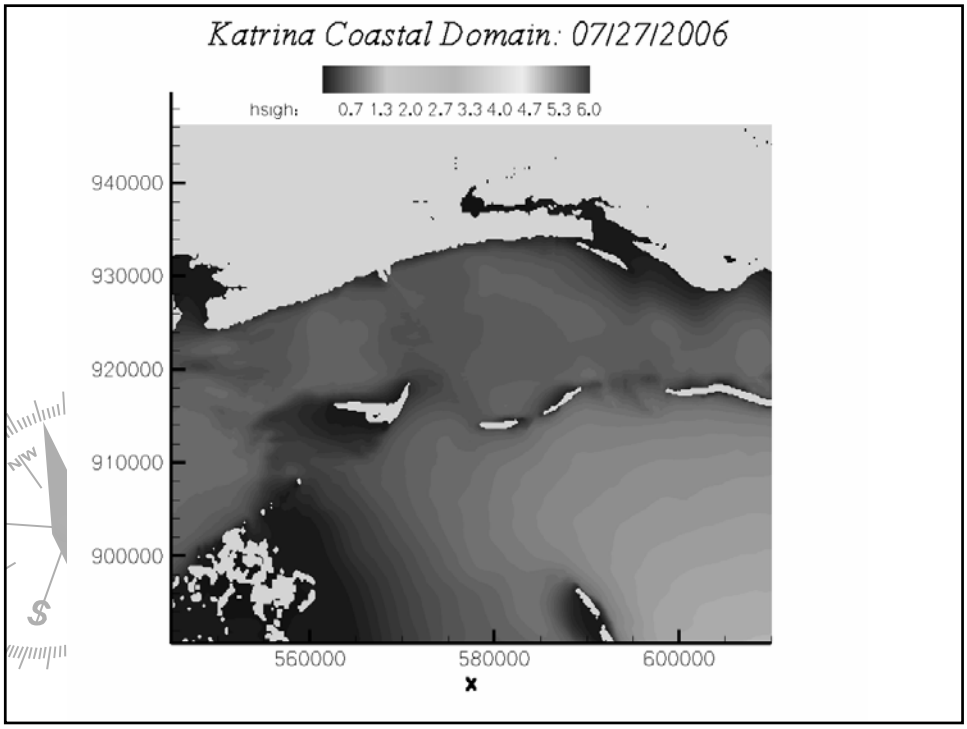
- 5 degree directional wave spectra (72 directional bins)
- 26 frequency bins (0.03138 to 0.4177428 Hz)
- Spatial resolution: 160 meters
- 301 x 151 grid points in Coastal Domains
- Physics:
  - Non-Stationary
  - bottom friction
  - depth limited breaking
  - White capping
  - Triad and Quadratic wave-wave interactions.

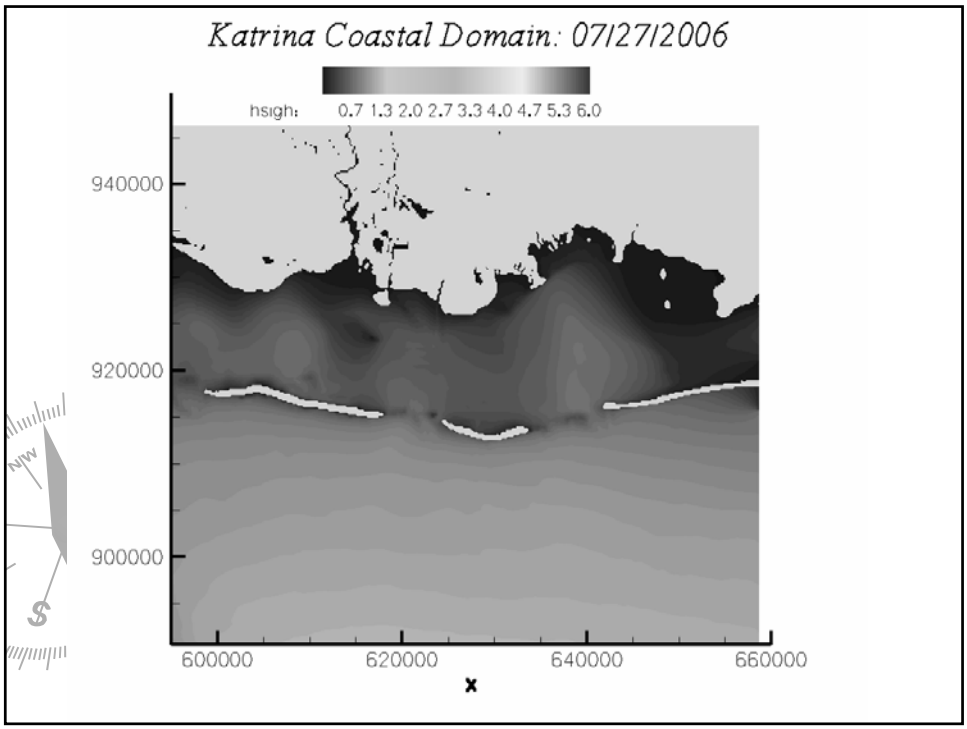

Katrina Basin
1E+06
800000
600000
400000
200000
0
y
0
500000
1E+06
x
hsign
19.5
17.6
15.7
13.9
12.0
10.2
8.3
6.4
4.6
2.7
0.9
NW
S


Katrina Region Domain
950000
900000
850000
800000
750000
y
400000
500000
600000
x
hsign
14.4
13.2
12.0
10.8
9.6
8.4
7.1
5.9
4.7
3.5
2.3
1.1
NW
S

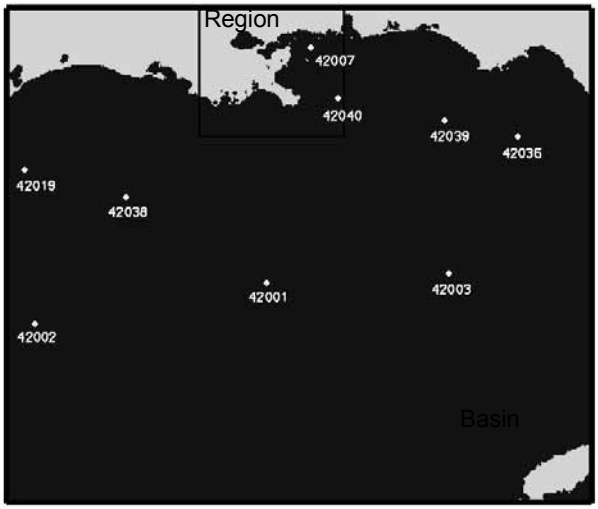

Katrina Coastal Domain : 07/28/2006
hsigh
5.9
5.5
5.1
4.7
4.2
3.8
3.4
3.0
2.5
2.1
1.7
1.3
0.8
0.4
With Water Level
Without Water Level


Katrina Coastal Domain: 07/27/2006
hsigh: 0.7 1.3 2.0 2.7 3.3 4.0 4.7 5.3 6.0
950000
940000
930000
920000
910000
900000
500000
520000
540000
x

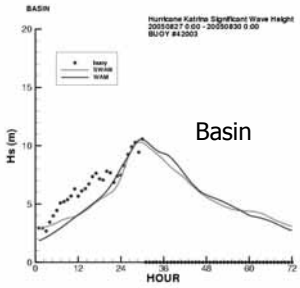

Katrina Coastal Domain: 07/27/2006
hsigh: 0.7 1.3 2.0 2.7 3.3 4.0 4.7 5.3 6.0
940000
930000
920000
910000
900000
560000
580000
600000
x
NW
S

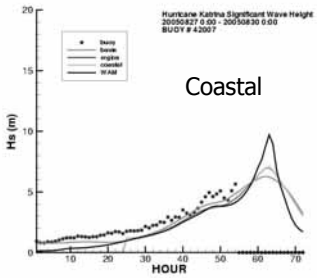

Katrina Coastal Domain: 07/27/2006
hsigh: 0.7 1.3 2.0 2.7 3.3 4.0 4.7 5.3 6.0
940000
920000
900000
600000
620000
640000
660000
x
NW
S

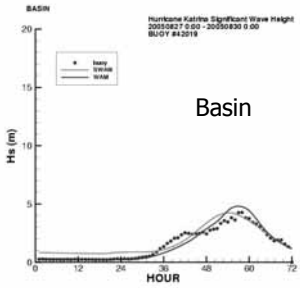
Location of Moored Buoys in Basin and Region Model Domains

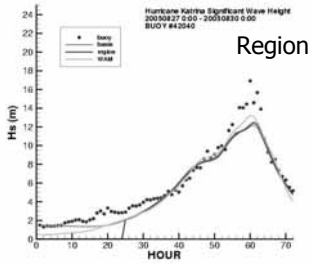


Wave Buoy Comparisons for Katrina



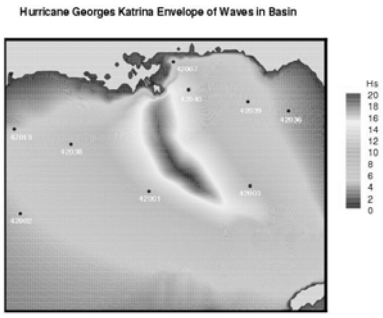


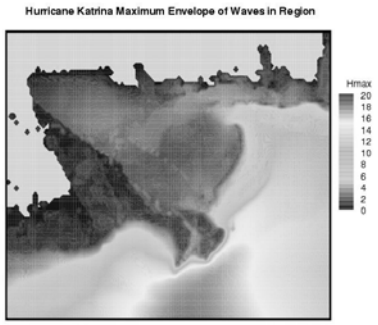




Maximum wave heights during storm

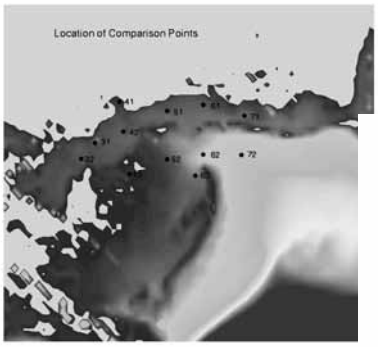
Hurricane Katrina

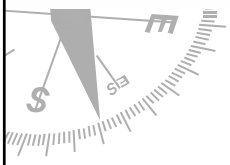


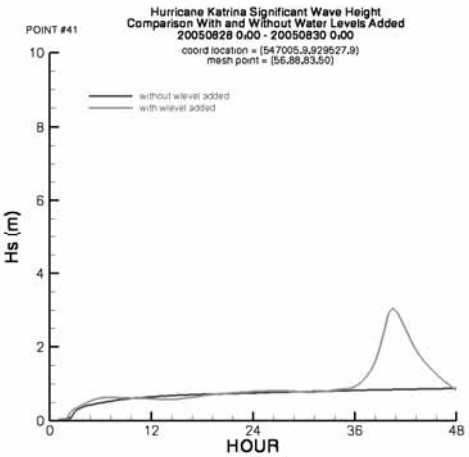


Buoy 42040 near strong wave height gradient

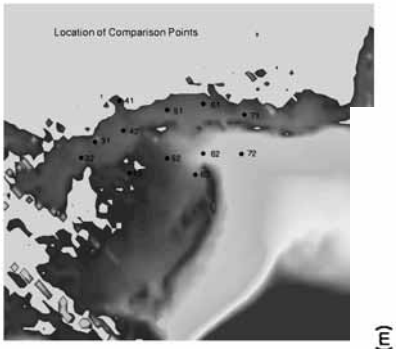
Effect of Water elevations on wave predictions

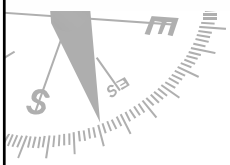


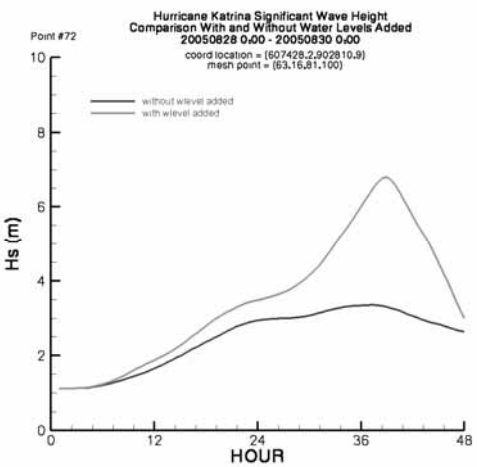


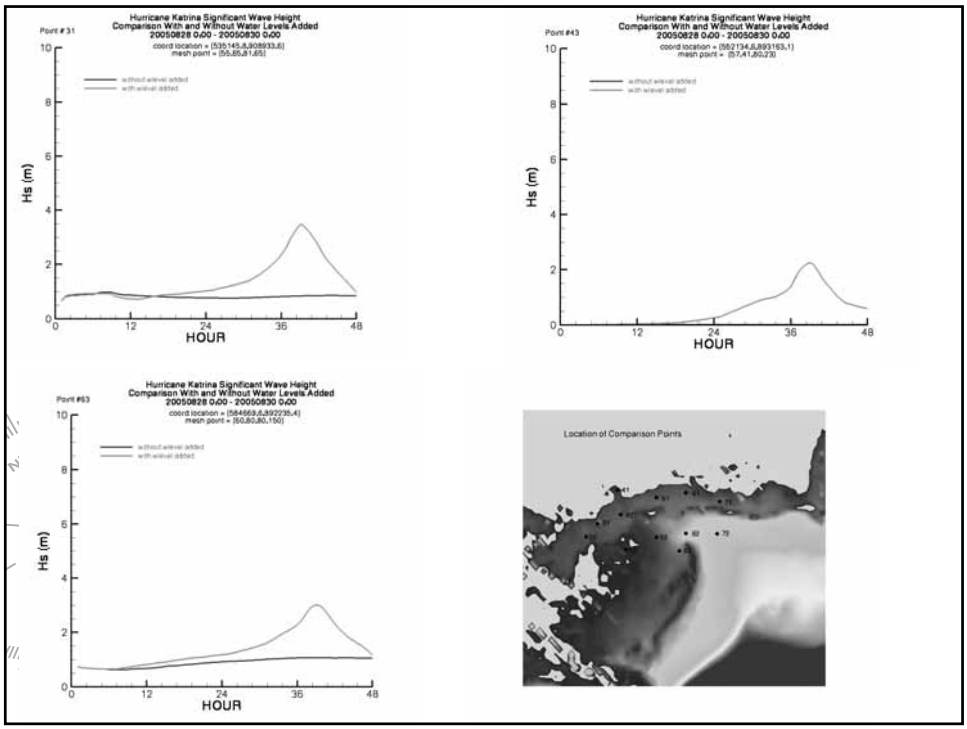


Effect of Water elevations on wave predictions

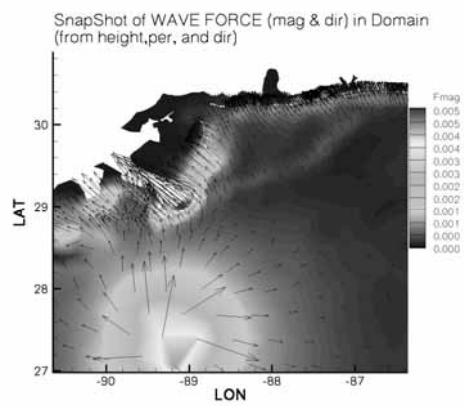


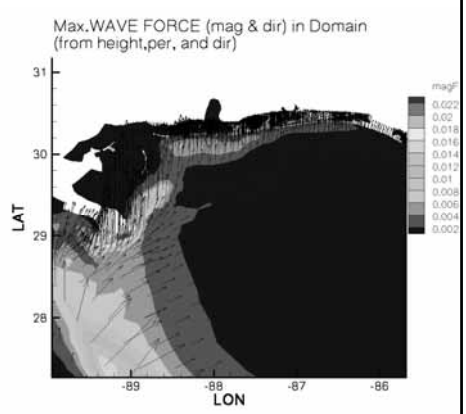




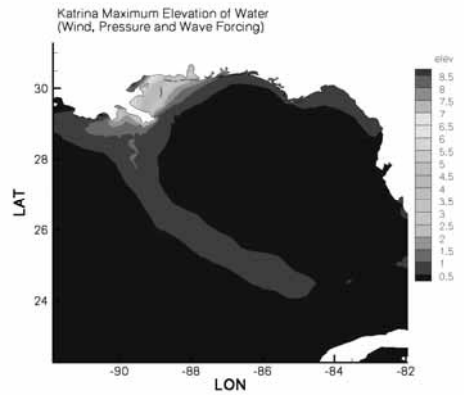


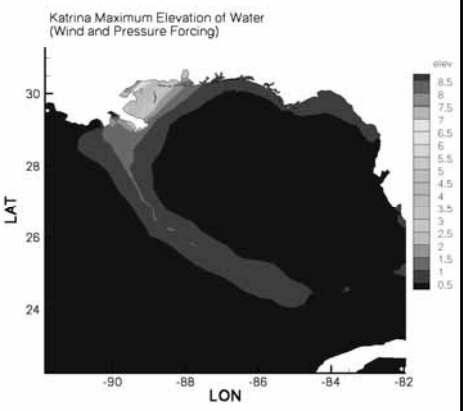
Wave Forces (Radiation Stress Gradients)

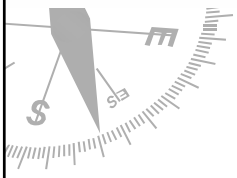


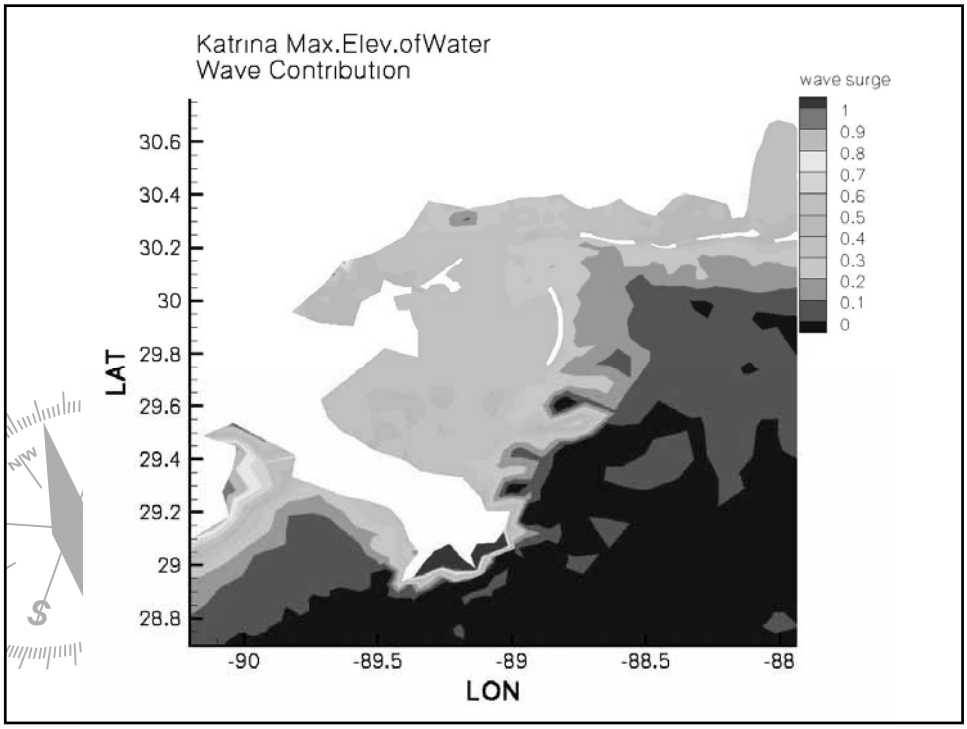


Maximum Envelope of Water (MEOW)

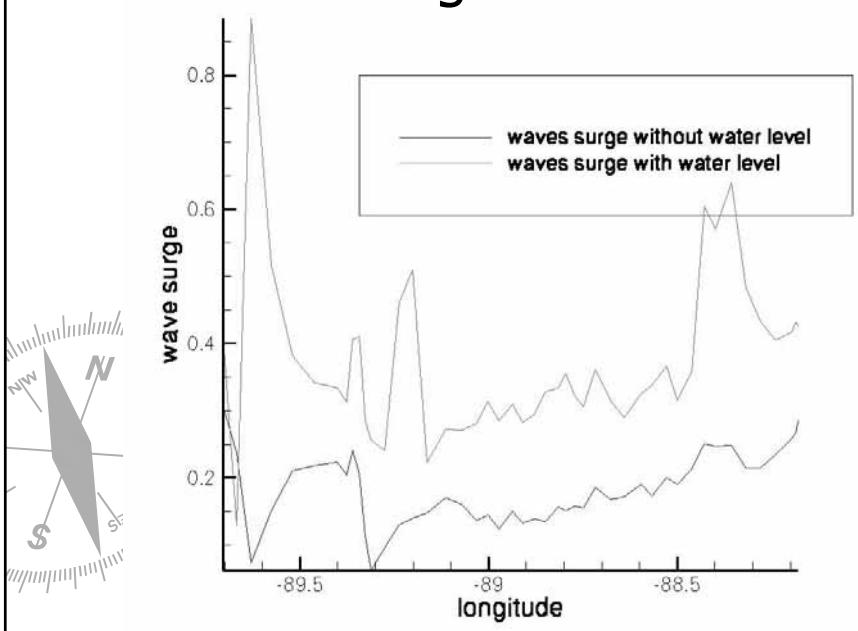








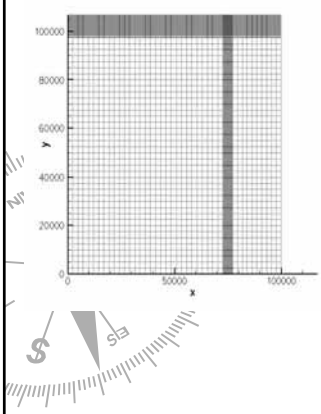
Coastal Surge from Waves



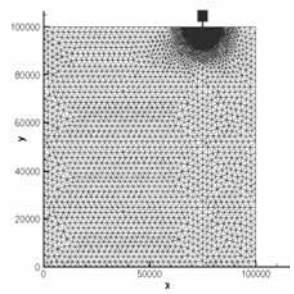
Idealized Storm Study

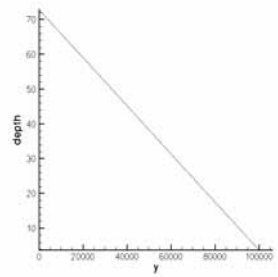
The depth in the inlet and in the bay is constant and = 3.7m

Cartesian grid



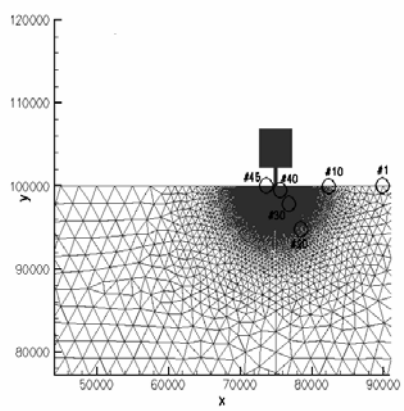
FE grid

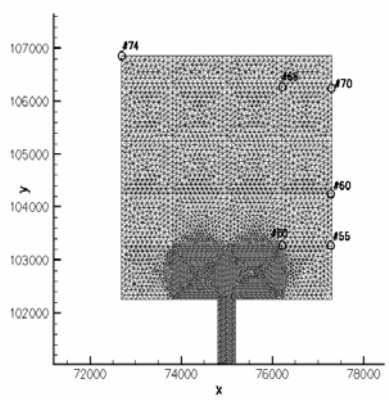




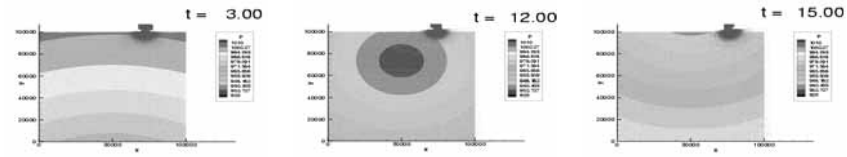
Bottom contour

Output locations

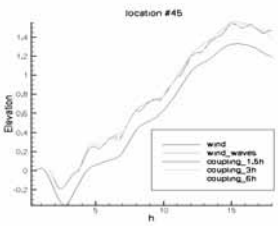


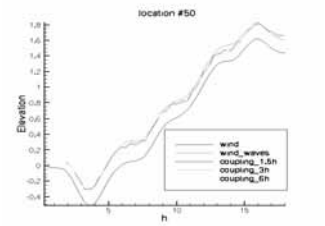


Hurricane with properties similar to Ivan

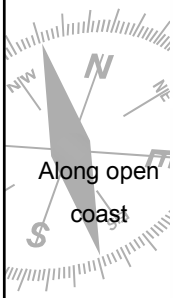


By Mouth of inlet

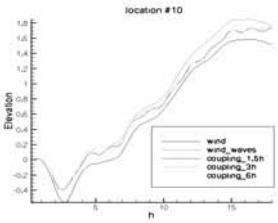


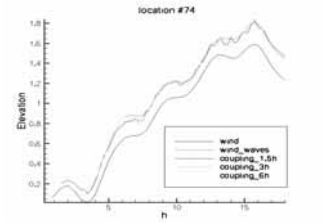


Middle of Bay



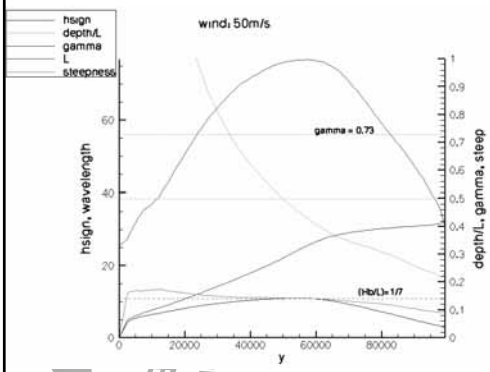
Along open coast

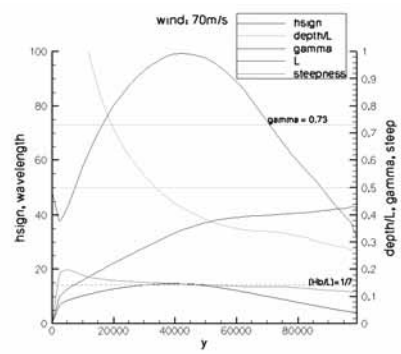




Back corner of Bay

Waves across the shelf – steady winds, 50 m/s, 70 m/s





Summary of Idealized Storm Tests

- The waves have a modest impact on the overall surge in this idealized example.
- The two-way coupling doesn't have a significant impact on the solution.
- The set up due to waves is around 10% of the overall surge for a mild slope and over 20% for a steeper slope.

- The majority of wave height decrease is caused by the steepness limited breaking condition
  - (i.e., the theoretical limit for monochromatic waves is approximately H / L = 1/7).
- This occurs in regions farther offshore than where depth limited breaking would occur.
  - Depth limited breaking, i.e., g = H / h = 0.73 is not often reached on shallow shelves for large wave conditions.
- As the deep water wave spectrum shoals across intermediate depth water on the shelf, the wavelength decreases, causing the significant wave height to decrease through white capping. Since this occurs in relatively deep water, the resulting setup is relatively small.

Steady State Leading order momentum balance between wave forcing and Cross-shore Wave Height distribution

$$\frac{d\eta}{dx} = -\frac{1}{\rho g(h+\eta)}\frac{dS_{xx}}{dx}$$

$$S_{xx} = \frac{1}{16}\rho g H^2[2n\cos^2(\theta) + (2n-1)]$$

Summary

Tested two-way coupling between Waves and Surge for idealized and historical storms.

- Two way coupling gives more accurate wave field estimates for Hurricane Katrina.
- Iterative coupling (at refined time steps) produces limited improvement.
- Results depend significantly on Shelf Topography!