Session 29

Max Sheppard

Ocean Engineering Associates Inc.

Coastal Analysis of Bridge Failures: I-10 in Florida & US-90 in Mississippi

Topic Description

Several major bridge failures have occurred during the last two hurricane seasons. The procedures used in the Bridge Hydraulics Reports for the replacement bridges at three locations (I10 – Escambia Bay, US90 – Biloxi Bay, and US90 – Saint Louis Bay) are discussed including the wind, wave, storm surge, and depth-averaged current hindcasts of Hurricanes Ivan and Katrina.

Speaker Biography

Max Sheppard is President of Ocean Engineering Associates, Inc. (OEA, Inc.) and Professor Emeritus in the Civil and Coastal Engineering Department at the University of Florida. His areas of expertise include: bridge scour, coastal hydraulics, sediment transport, coastal structures, and wave loading on coastal and offshore structures.

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Speaker Biography

Mark Gosselin is the Vice President of Ocean Engineering Associates Inc. He is an accomplished Coastal Engineer, Hydraulic Modeler, and Wave Modeler. Mark graduated from Dartmouth College with a Bachelors degree, earned his Masters degree from University of California at Berkeley in Naval Architecture, and earned a Ph.D. from the University of Florida, Department of Coastal Engineering. Mark is a registered Professional Engineer in Florida and Louisiana.

Coastal Analysis of Bridges: I-10 in Florida and US-90 in Mississippi

Mark Gosselin, Ph.D., P.E.
D. Max Sheppard, Ph.D.

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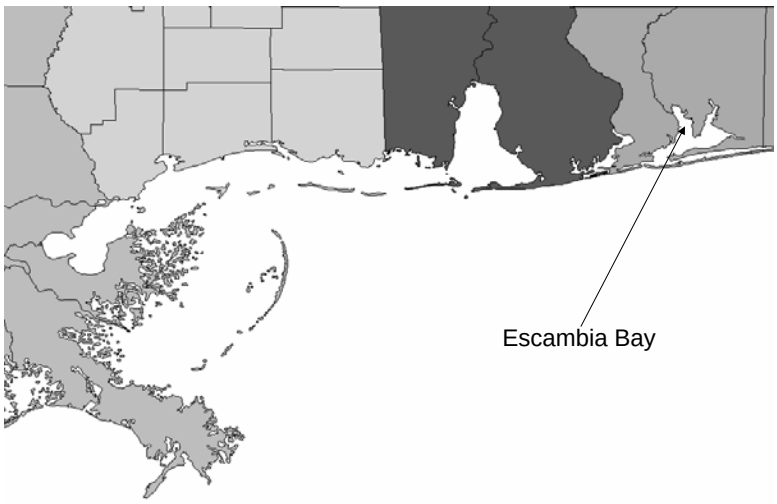
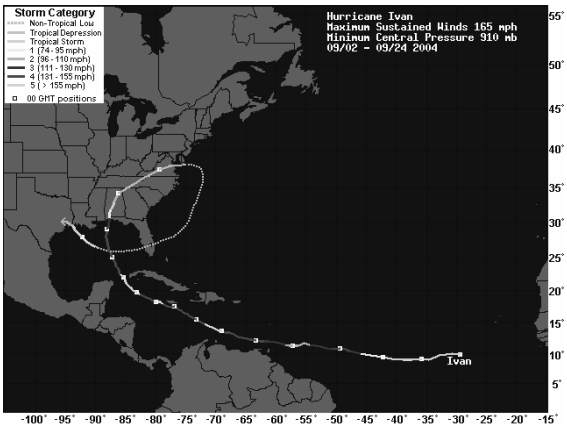
Designing For More Than Bridges and Roads

I-10 over Escambia Bay



Hurricane Ivan

- Landfall
  - West of Pensacola, Florida
  - 130 mph (Category 3)
  - September 16, 2004
- Storm Surge
- Waves
- Wind Setup



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Project Objectives

- Simulate Impacts of Hurricane Ivan at the I-10 Escambia Bay Bridge
- Develop the 100- and 500-yr Hurricane Storm Surge and Wave Heights at the Bridge Location
- Provide Recommendations for the Bridge Length and Touch-down Locations

Procedure

- Multi-phased Modeling Approach
  - WAM – Offshore Wave Model
  - SWAN – Nearshore Wave Model (Coastal Areas and Bay)
  - ADCIRC – Tidal Circulation and Hurricane Storm Surge Model
- Input Conditions Provided By Oceanweather

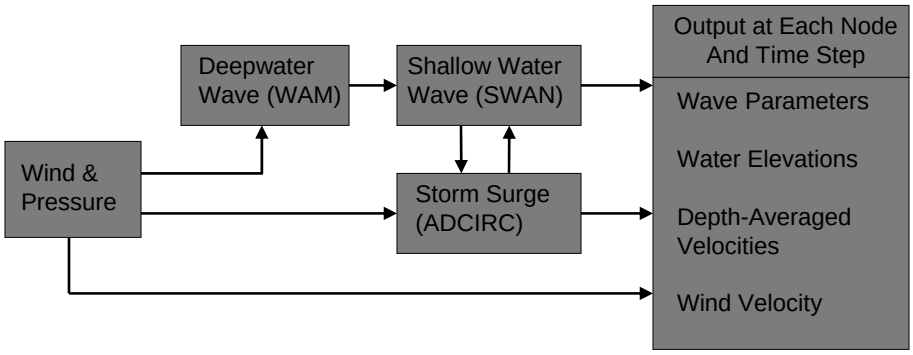
Procedure (continued)

- Perform Extremal Analysis of Hurricane Sustained Wind Speeds at Landfall for Region
- Determine Relationship between Wind Speed and Central Pressure for Region
- Scale Wind Speed Data and Central Pressure for Ivan Data to Develop 100- and 500-year Hurricanes

Procedure (continued)

- WAM — Open Ocean Wave Conditions
- SWAN —Coastal Wave Conditions
- ADCIRC — Storm Surge Elevations
- SWAN — Bay Wave Conditions

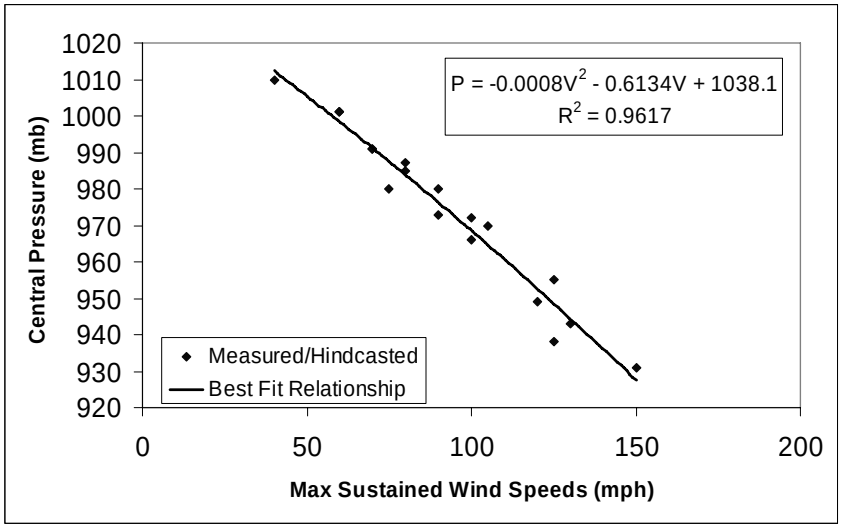
Procedure (continued)



Extremal Analysis

- Most Probable Extreme Values:
  - 100-year – 120.7 mph
  - 152-year – 125.4 mph
  - 200-year – 129.8 mph
  - 350-year – 136.5 mph
  - 500-year – 140.8 mph
- Ivan (130 mph) ~ 200-year Storm

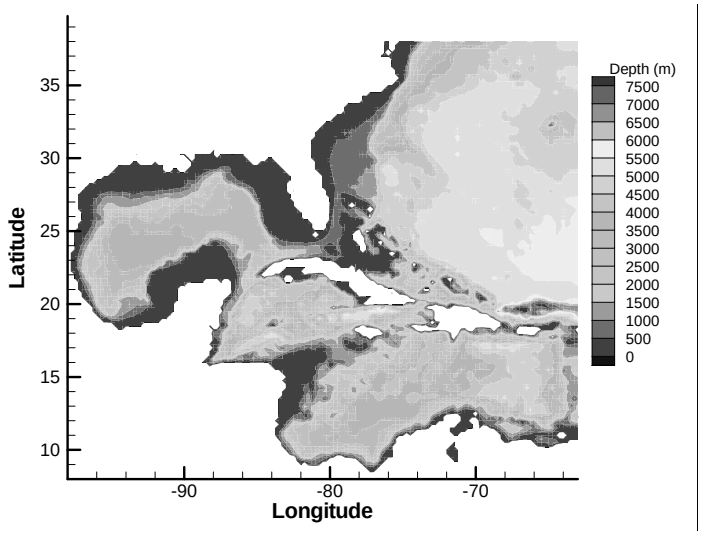
Wind Speed vs. Central Pressure



WAM

- Developed Grid for North Atlantic and Gulf of Mexico
- 15 minute Resolution Grid
- Boundary Conditions – Ivan and Design Wind Speeds

WAM Grid



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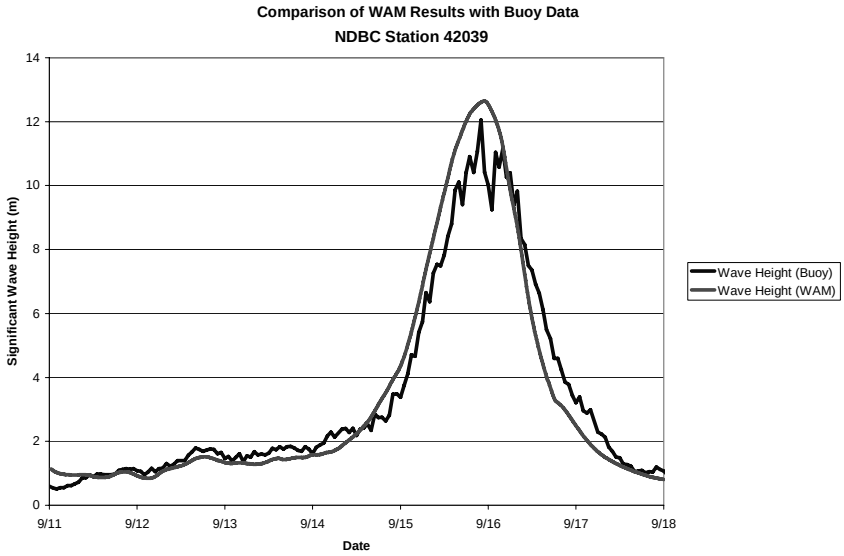

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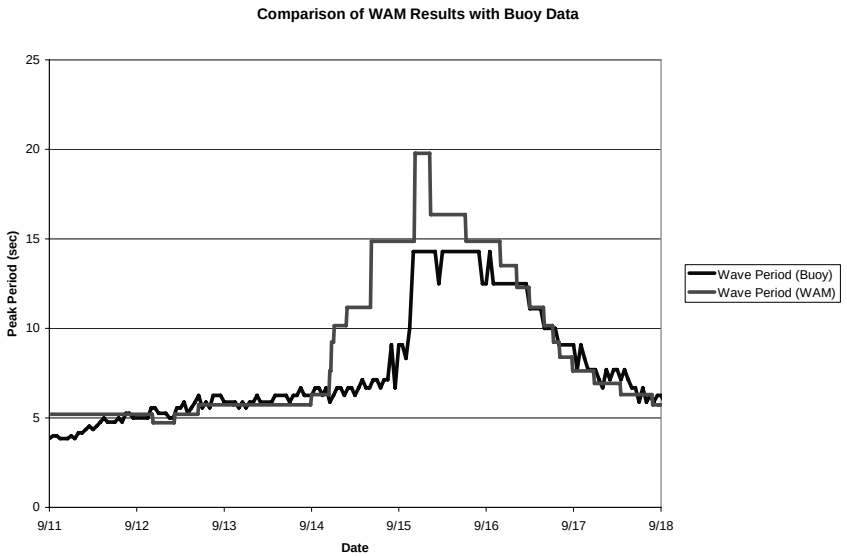

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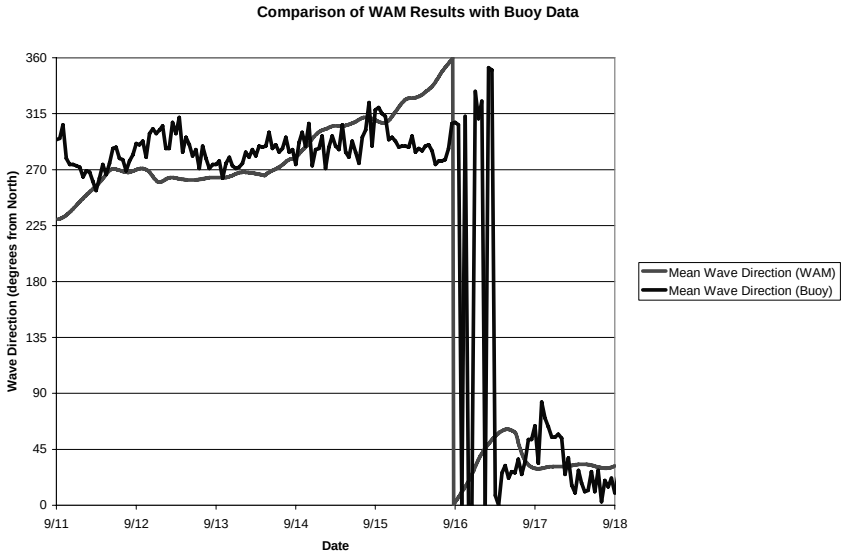

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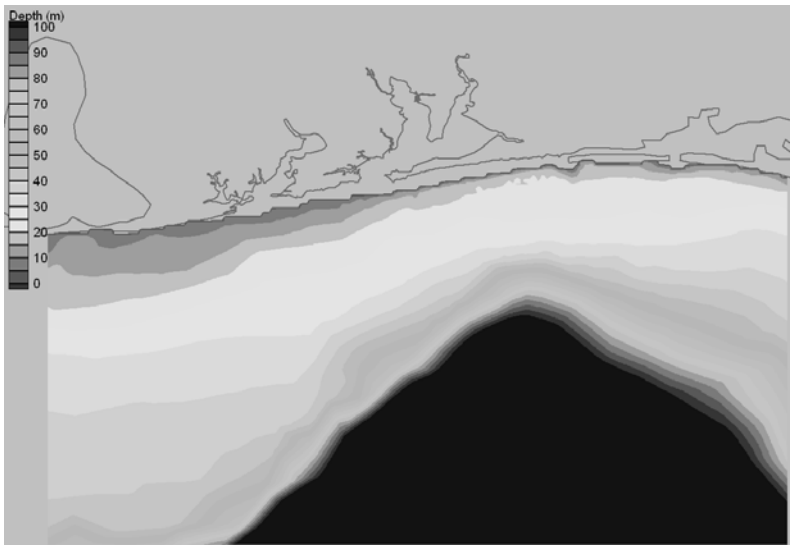
SWAN

- Developed Grid for Panhandle Coast
- 3 minute Resolution Grid
- Boundary Conditions:
  - Ivan and Design Wind Speeds
  - Output Spectra from WAM

SWAN Coastal Grid



ADCIRC

- Mesh for N. Atlantic and Gulf of Mexico
- Increased Resolution in Pensacola Bay
- Boundary Conditions:
  - Ivan and Design Wind Speeds
  - Ivan and Design Pressures
  - Radiation Stresses from SWAN

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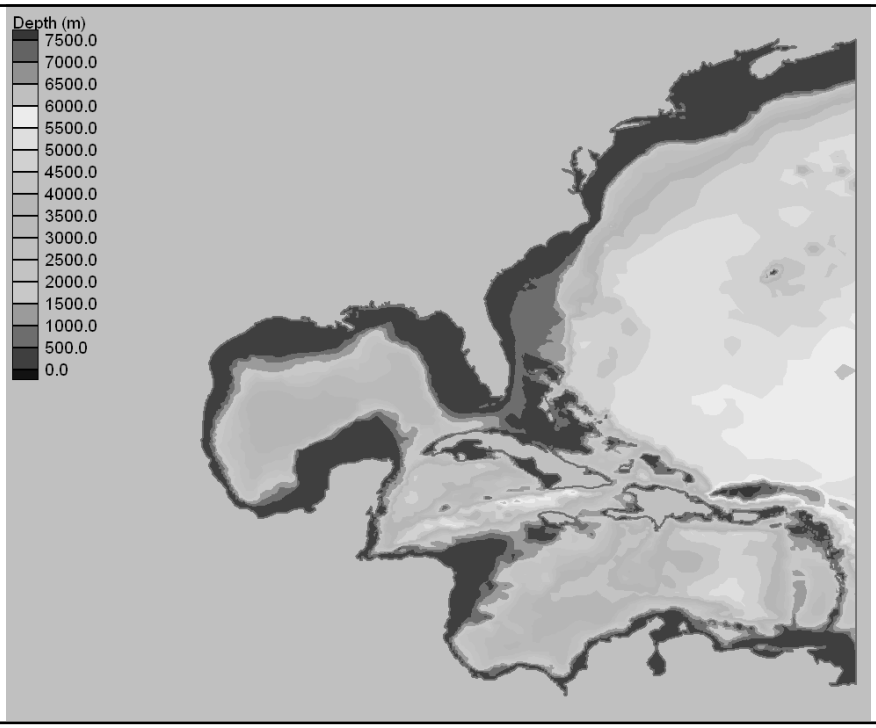

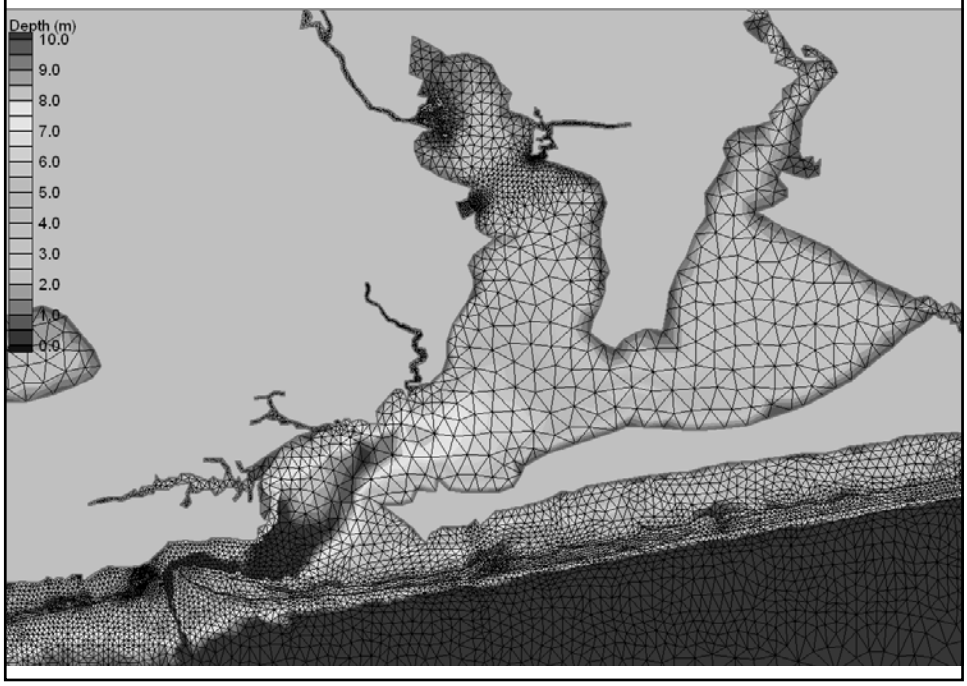

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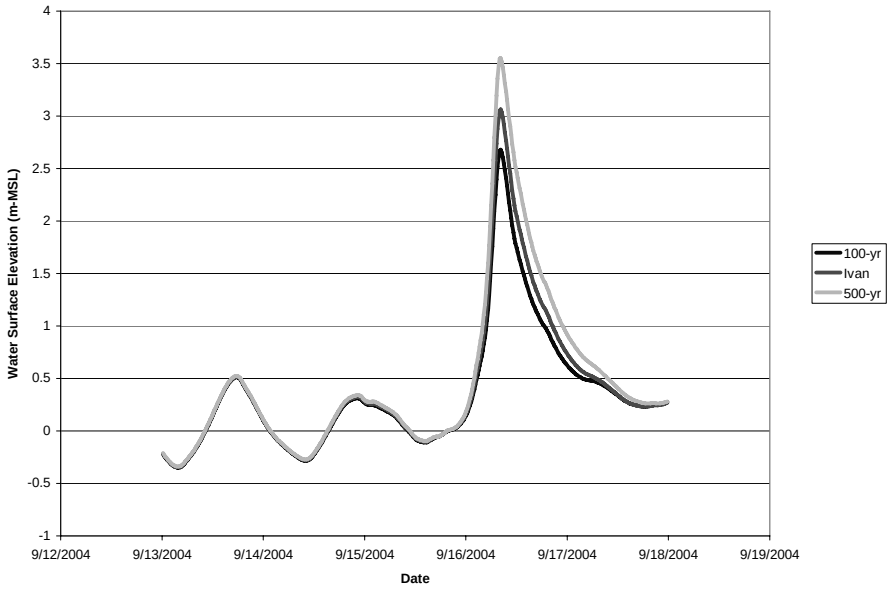

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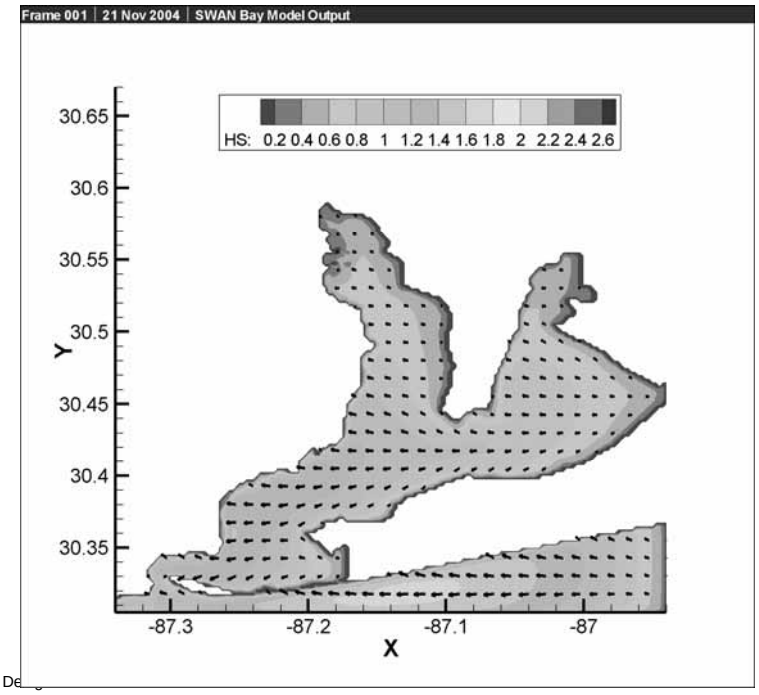
SWAN Bay

- Mesh for Pensacola and Escambia Bay
- 9 second Resolution
- Boundary Conditions:
  - Ivan and Design Wind Speeds
  - WSE from ADCIRC

SWAN Bay Grid



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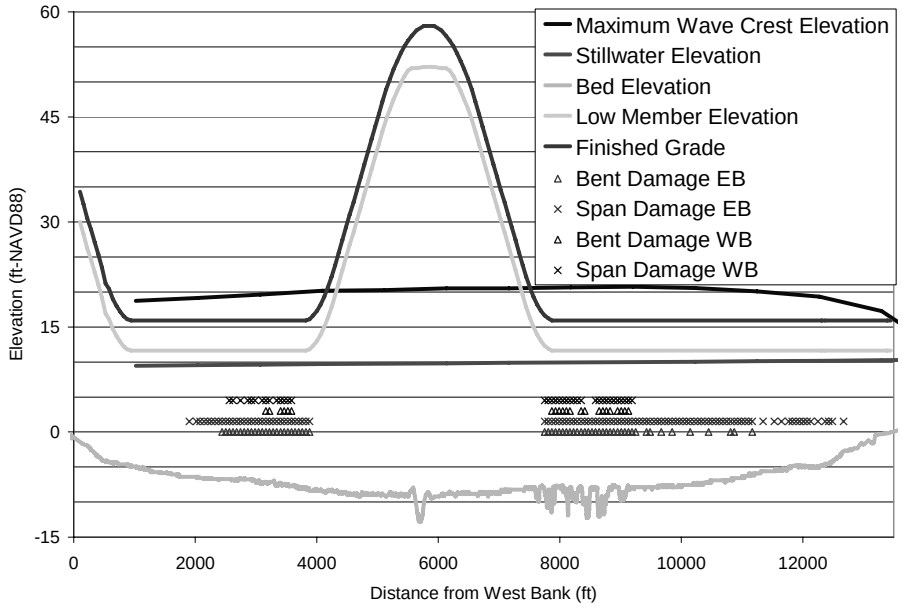

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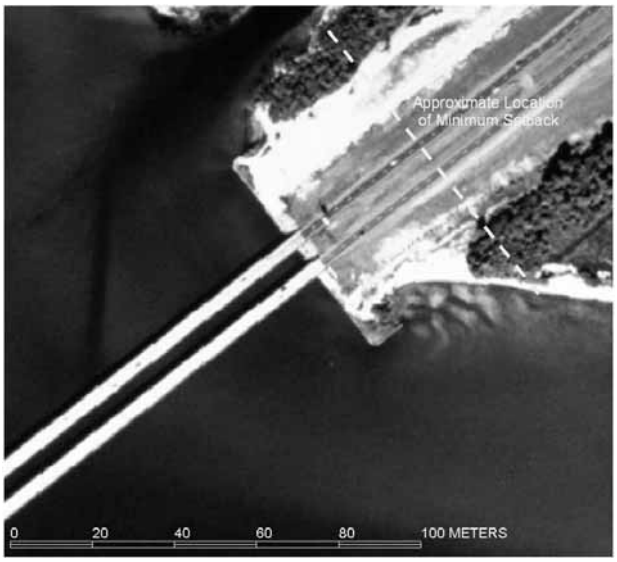
East Abutment

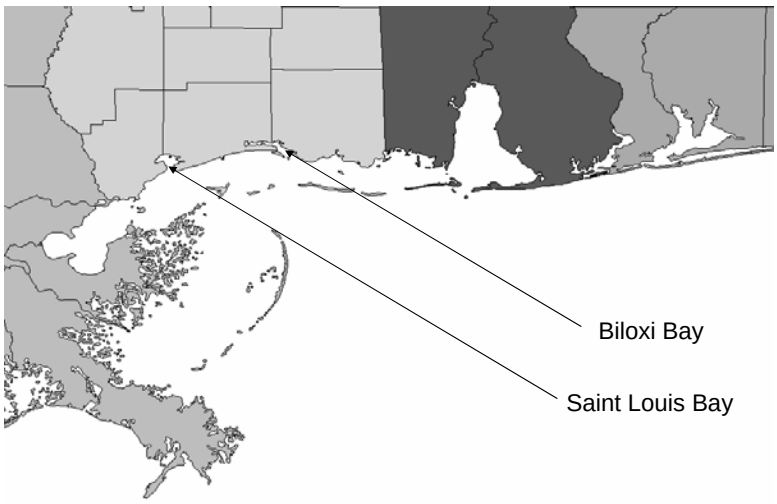
- Setback Location
- Wave Climate
- Surge Elevation
- Historical Aerials



I-10 over Escambia Bay Study Results

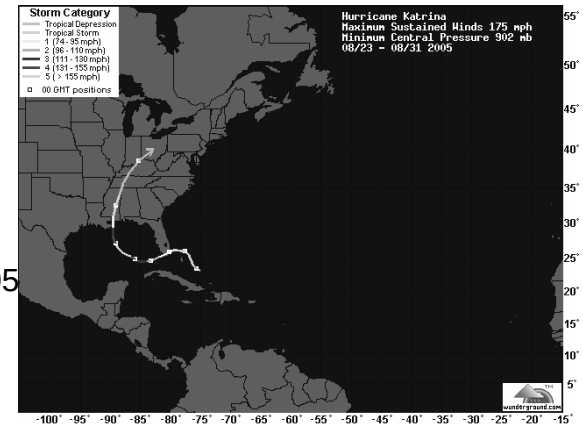
- Identified Mode of Failure
- Established Design Criteria
  - Wave Crest Elevations
  - Storm Surge Elevations
  - Flow Velocities
- Established East Abutment Location

US-90 over Saint Louis and Biloxi Bays



Hurricane Katrina

- Landfall
  - Pearl River at the Louisiana-Mississippi Border
  - 150 mph (Category 3)
  - August 29, 2005
- Storm Surge
- Waves



US-90 over Saint Louis Bay

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US-90 over Biloxi Bay

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Project Objectives

- Develop Design
  - Water Levels
  - Depth-averaged Velocities
  - Wave Parameters
  - Wave Loads
  - Scour depths
- Design Conditions
  - Katrina
  - 50 and 500-year storm surge events and
  - 100 and 500-year river flood events

Procedure

- Multi-phased Modeling Approach
  - WAM – Offshore Wave Model
  - SWAN – Nearshore Wave Model
  - ADCIRC – Tidal Circulation and Hurricane Storm Surge Model
  - RMA2 – Runoff Models
- Input Conditions Provided By Oceanweather

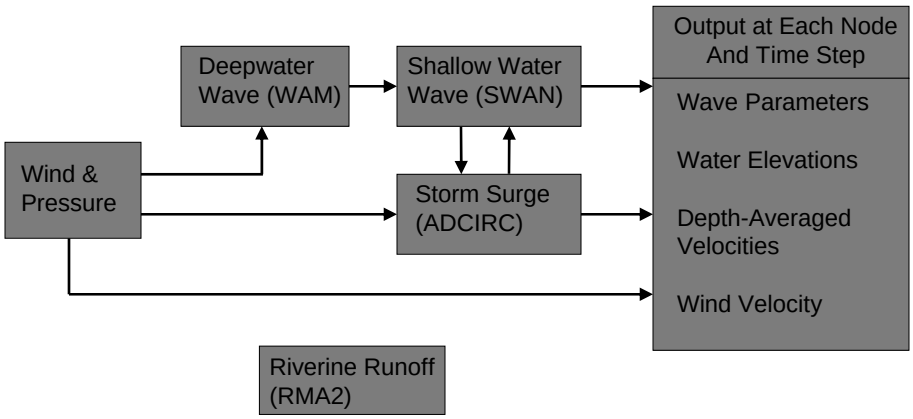
Procedure (continued)

- Perform Extremal Analysis of Hurricane Sustained Wind Speeds at Landfall for Region
- Determine Relationship between Wind Speed and Central Pressure for Region
- Scale Wind Speed Data and Central Pressure for Katrina Data to Develop 50- and 500-year Hurricanes

Procedure (continued)

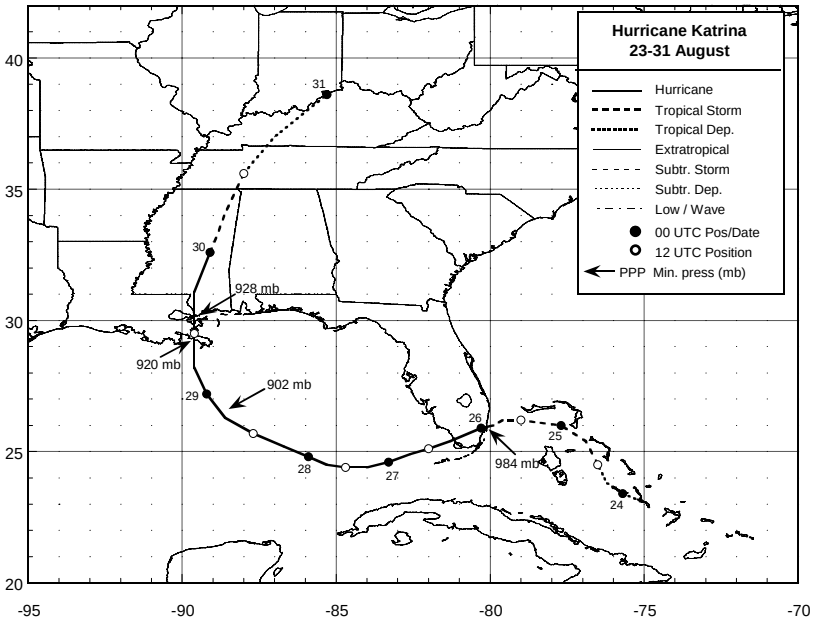
- Modeling
  - WAM — Open Ocean Wave Conditions
  - SWAN — Coastal Wave Conditions
  - ADCIRC — Storm Surge Elevations
  - RMA2 — Riverine Runoff Conditions
- Calculate
  - Wave Forces on Piles
  - Scour Depths (not for design)
- Hydraulics Report

Procedure (cont.)

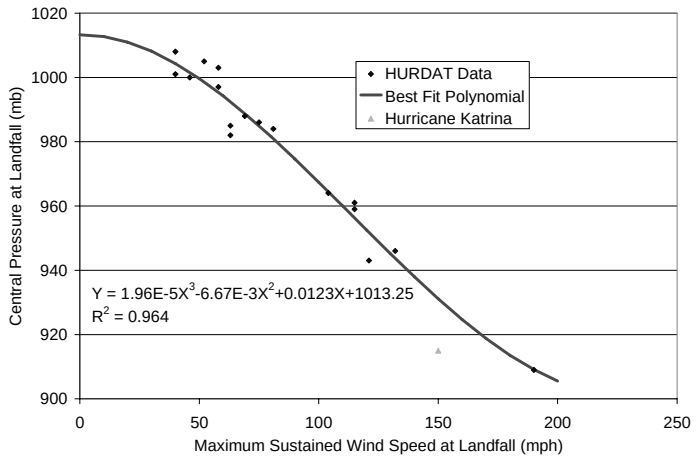


Extremal Analysis

- Most Probable Extreme Values:
  - 50-year – 128.7 mph
  - 100-year – 151.0 mph
  - 500-year – 199.2 mph
- Hurricane Katrina (150 mph) ~ 100-year Storm *in Terms of Land-falling Wind Speed*
- Greatest Wind Speed – 190 mph Hurricane Camille (1969)



Wind Speed vs. Central Pressure



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WAM

- Developed Grid for North Atlantic and Gulf of Mexico
- 15 minute Resolution Grid
- Boundary Conditions – Hurricane Katrina, 50- and 500-year Design Wind Speeds

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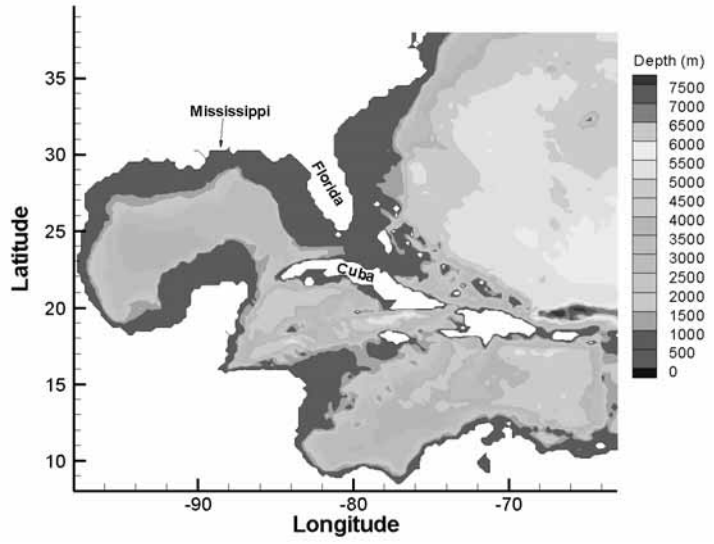
WAM Grid



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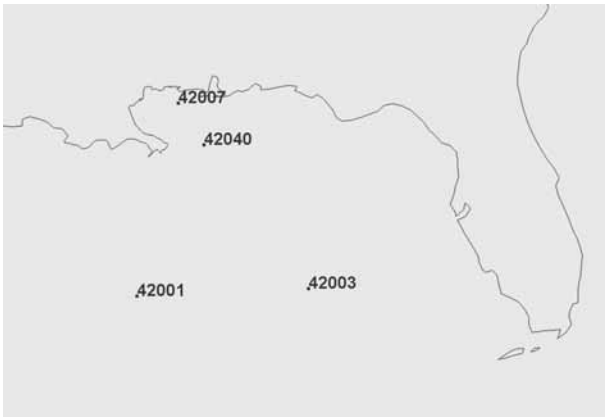
NDBC Wave Buoy Locations



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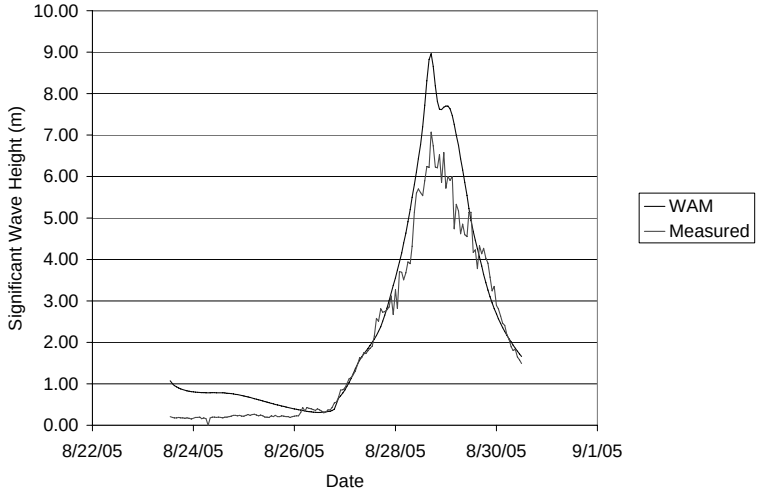
Significant Wave Heights - 42001



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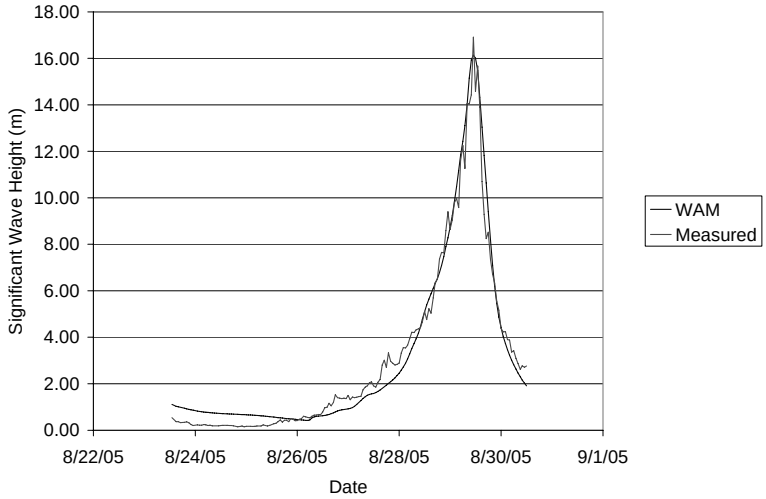
Significant Wave Heights - 42040



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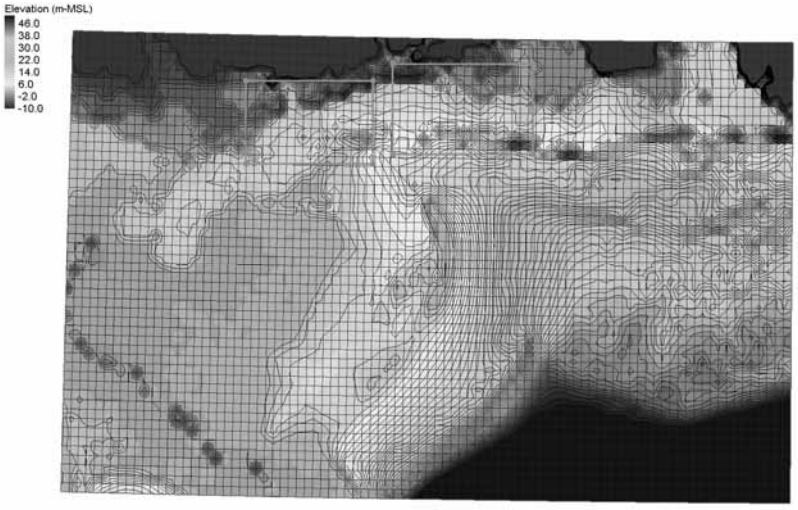
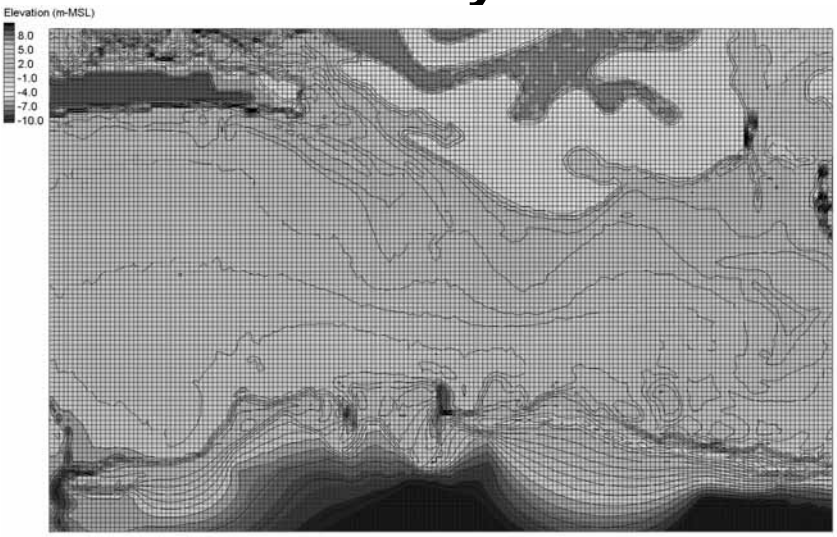
SWAN

- Developed Grids for Coastal Mississippi
- Nested Grids
- Boundary Conditions:
  - Katrina, 50-, and 500-year Winds
  - Output Spectra from WAM
- Output
  - Wave Parameters at Bridges
  - Wave Radiation Stresses – ADCIRC BCs

SWAN Grids



Biloxi Bay Grid



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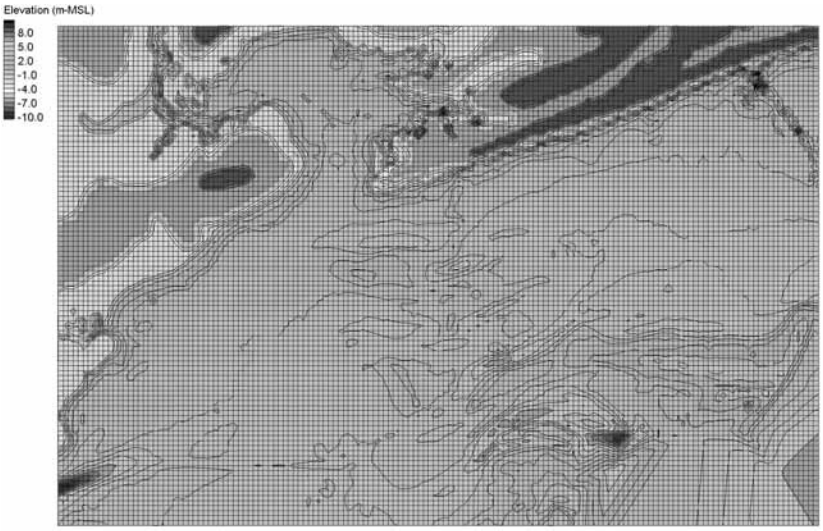
Saint Louis Bay Grid



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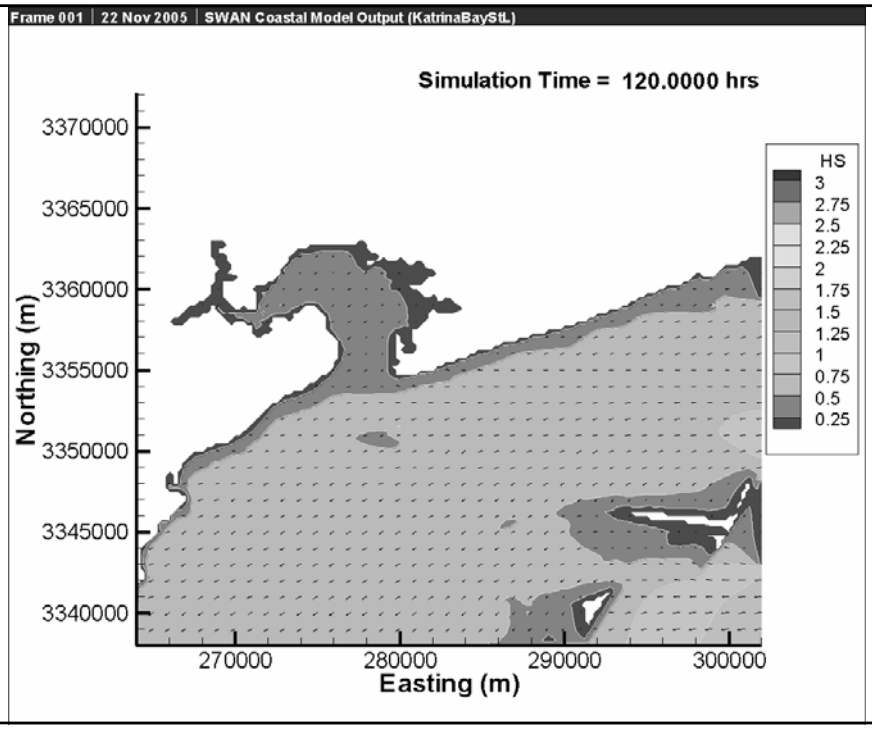
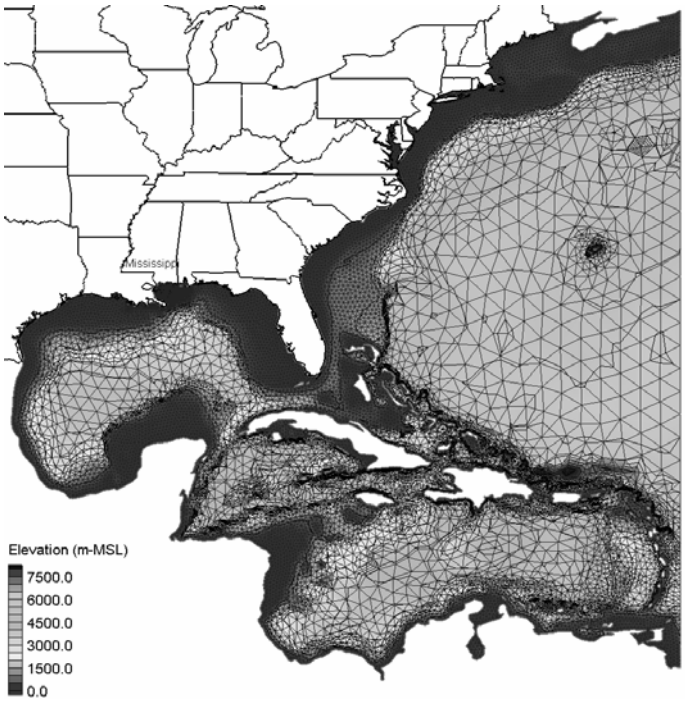


ADCIRC

- Mesh for N. Atlantic and Gulf of Mexico
- Increased Resolution in Biloxi and Saint Louis Bay
- Boundary Conditions:
  - Katrina, 50-, and 500-year Wind Speeds
  - Katrina, 50-, and 500-year Pressures
  - Radiation Stresses from SWAN



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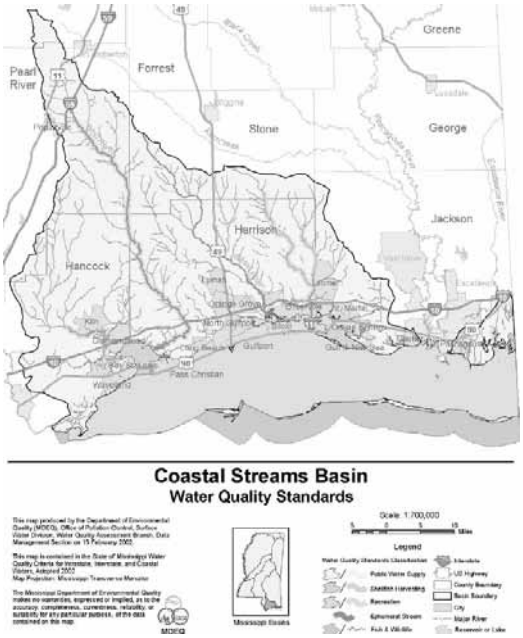
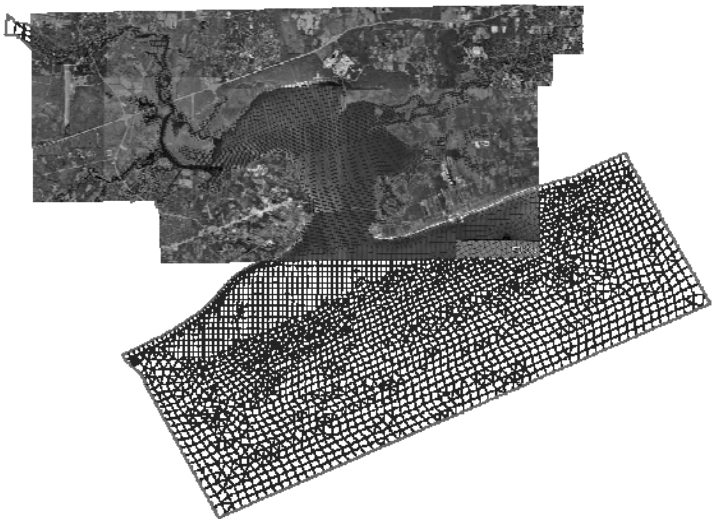
Velocity Magnitude (m/s)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
2547900.00

Velocity Magnitude (m/s)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
2547900.00

Maximum Waves

- Determine Maximum Wave Height, Amplitude, and Period
- SWAN Wave Spectra at Bridge
- PDF of Heights and Amplitude
- Joint PDF of Amplitude and Period to Find Most Probable Period
- Includes Steepness Criteria





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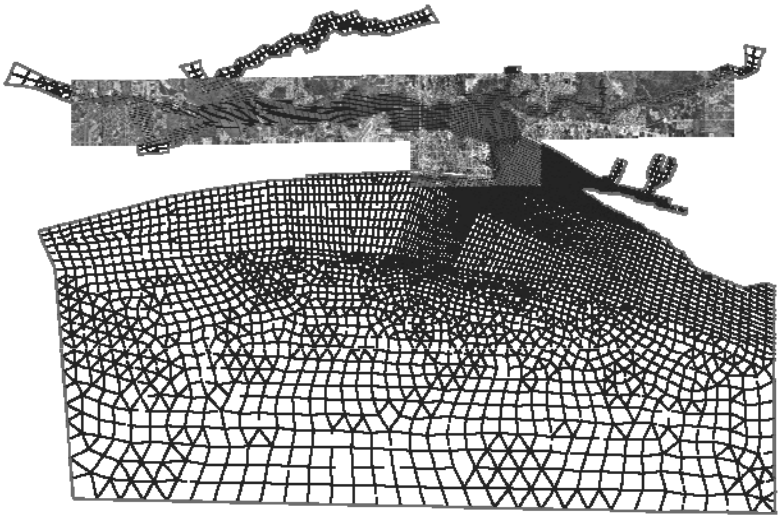

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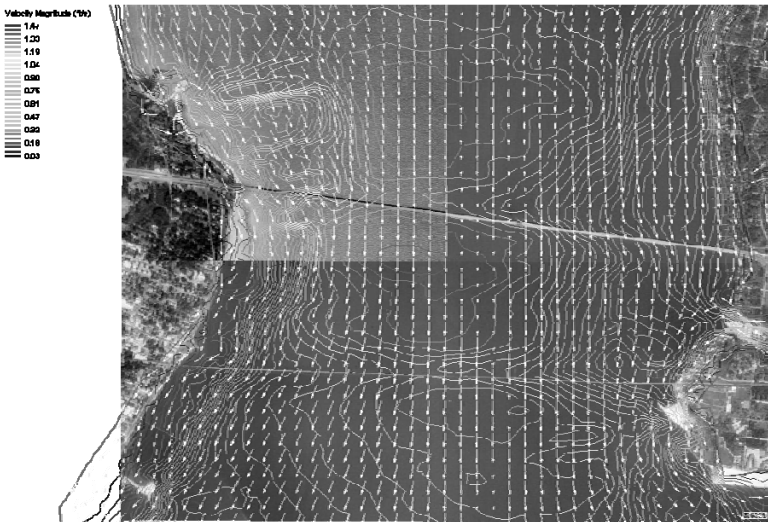
100-year Saint Louis Bay



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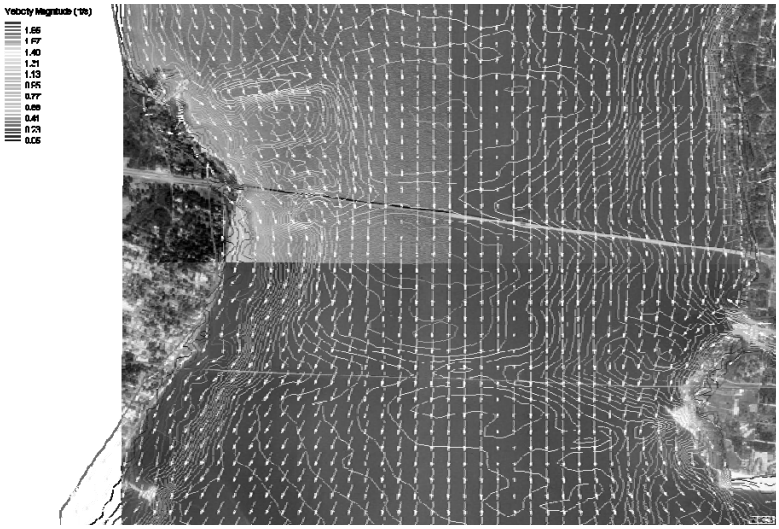
500-year Saint Louis Bay



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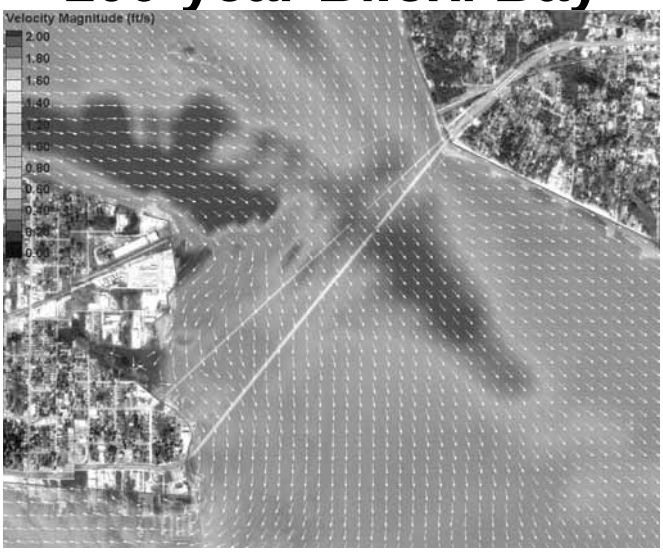
100-year Biloxi Bay



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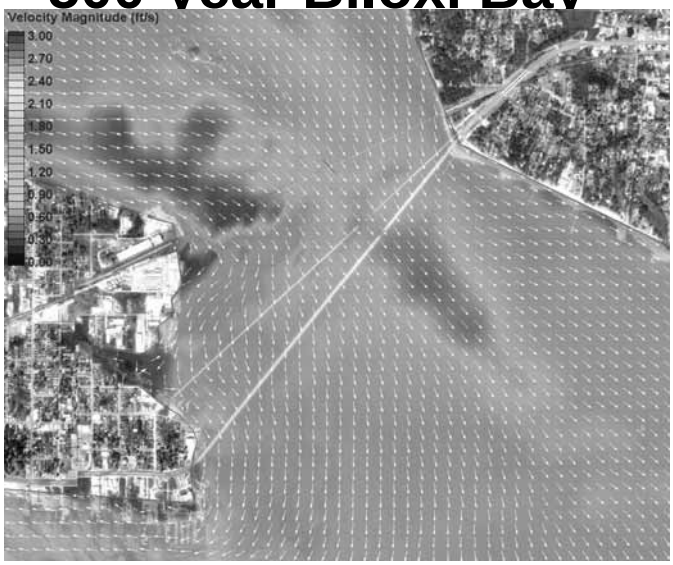
500-year Biloxi Bay



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US-90 over Saint Louis and Biloxi Bays Study Results

- Hindcasted Hurricane Katrina
- Established Design Criteria
  - Wave Crest Elevations
  - Storm Surge Elevations
  - Flow Velocities
  - Scour (not for design)
  - Wave Forces on Bridge Piers

Questions, Comments

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