Monitoring and Mapping
Hurricane Storm Surge

Prepared by Charles Berenbrock, Robert R. Mason, Jr., Steve Blanchard, and many, many others.

U.S. Geological Survey
Presentation Outline

• Need and motivation
• Monitoring Approach
  ◦ New instruments
  ◦ Mobile network
• Example deployment
• Monitoring Results for Rita
• Mapping Rita storm tide
• Plans for improvement
Experience from Katrina
High Water Marks

USGS
Problem: Need Inland Storm-Surge Data

- Coastal gages are scarce and vulnerable (USGS and NOAA lost about 35 gages during Katrina)
- HWMs provide limited information and are difficult to interpret
Factors Affecting Storm-Surge

- Storm intensity
- Forward speed
- Landfall approach angle
- Inclination of the sea floor - shallower inclines lead to high and more penetrating surge
- Local topography - bays, shore orientation, and offshore islands can funnel and amplify the storm Surge.
USGS Storm-Surge Program Objectives

• Provide data for:
  ◦ Development of inundation maps
  ◦ Calibration/verification of storm-surge models
  ◦ Aide development of model parameterization schemes (inland wind-water drag and wave height relationships)
  ◦ Assess performance of topographical or engineered structures
  ◦ (Eventually) real-time assessments and warnings
New Technology

- Unvented pressure transducers (40/storm)
  - Record temperature and pressure for 8 days at 30 second intervals
  - Mobile
  - Self-contained
  - Inexpensive
  - Accurate (+/- 0.05)

- Steel-pipe housing units

- **Entire** hydrograph—not just peak
First Deployment - Hurricane Rita

- Study area positioned east of the hurricane track
- Covered approx. 4,000 square miles
- Extended approx. 30 miles inland and 140 miles along the coast
- Site selection emphasized road access
- Target bridges and piers near waterways
- Supplement with “transects” when possible
Sensor Deployment

- USGS Storm-Tide Response Centers (Ruston, LA., Atlanta, and Orlando) and storm-affected USGS offices

- Involve 8-15 people
  - Rita 6, Wilma 8
  - Ernesto 11

- 30 to 70 sites per storm
  - Rita 47, Wilma 35,
  - Ernesto 70

- 2-person crews

- Deploy 24-36 hours prior to landfall
Sensor Deployment – Con’t

• Strap-on sensors, mark Ref Pts, take pictures, get GPS coordinates
• Check-in each hour
• “Clear out” at 12 hours to landfall

Time in field: Rita 11 hours, Wilma 15, and Ernesto 15
Sensor Recovery

- Retrieve sensors, flag HWMs, tape-down to $\text{H}_2\text{O}$, run local levels Download, adjust data for barometric pressure, salinity, and upload to web.

- Follow-on GPS crews run levels and determine local datum.
Pipe bomb look-alike blown up at Pier 14
Device placed to gauge storm surge of Ernesto
By Janelle Frost and Tonya Root
The Sun News

A device meant to measure Tropical Storm Ernesto's impact caused an evacuation at Myrtle Beach's Pier 14 restaurant and drew a crowd of onlookers Friday after it was thought to be a pipe bomb.

Myrtle Beach police were called about 10:30 a.m. by someone who saw a yellow box strapped to a pylon under the pier at 14th Avenue North, Myrtle Beach Police Chief Jim Smith said. He said police checked to see whether the device was registered with the U.S. Geological Survey, which uses such devices to monitor storm surges. The device was not registered and police evacuated the pier.

The pier was restored by 11:15 a.m. and the evacuation was lifted.
Results ... Water-Level Hydrographs

Storm Surge Data from Hurricane Rita -- Site: La9b

High-water mark
Initial process yielded unrealistic map

(Modified from figure 8 of McGee and others, 2006b)
Initial process yielded unrealistic map

(Unrealistic boundaries)

(Ignores hydraulic barriers (roads, islands))

(Unrealistic flooding)

(Modified from figure 8 of McGee and others, 2006b)
Improved map — Barrier Mapping Process

- Identify/remove data affected by riverine runoff
- Create initial spline-fit of water surface (WS)
- Identify/digitize hydraulic barriers and flow connections
  - Elevated roads, levees, islands
  - Roadway sags, dune breaches, levees break, culverts
- Contour zero depth (where DEM meets WS)
- “Seed” control points on zero contour
- Refit data with “high-tension spline”

(New spline will optimize around barriers and through hydraulic connections.)
Storm Surge at 12:00 am (midnight)

Explanation

- USGS Storm surge sensor LC11

Storm-tide elevation, in feet above NAVD88

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16

Gulf of Mexico

Road obstructing flow

Rita Storm Track

Constance Beach
Rutherford's Beach
Calcasieu River
Calcasieu Lake
Cameron Prairie River
Storm Surge at 3:00 am

Explanation

- Storm-tide elevation, in feet above NAVD88

<table>
<thead>
<tr>
<th>USGS Storm surge sensor</th>
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<tbody>
<tr>
<td>LC11</td>
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Road overtopped

Islands obstructing flow

Canal berm obstructing flow
Storm Surge at 9:00 am

Explanation

Storm-tide elevation, in feet above NAVD88

- USGS Storm surge sensor
- LC11

Gulf of Mexico

Constance Beach

Rutherford's Beach

Calcasieu River

Calcasieu Lake

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Explanation

Storm-tide elevation, in feet above NAVD88

- 0 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
Storm Surge at 12:00 pm (noon)

Explanation

Storm-tide elevation, in feet above NAVD88

▲ USGS Storm surge sensor LC11
Planned 2008 Improvements

- Collect continuous salinity at select sites
- Automate pressure and salinity adjustment
- Real-time reporting at select sites (10 test units purchased)
- Improve real-time dissemination
Summary

• Non-vented pressure transducers (sensors) are accurate, reliable, and inexpensive tool to document storm surge and coastal flooding.
• Data collected from sensors can be utilized for a variety of purposes, both long-term and real-time.
• Sensor data and HWMs compliment one another. Sensor data are more consistent, but HWMs cover larger area and greater extremes.
• High Tension Spline mapping including physical structures/barriers provided more realistic inundation maps.
Questions?

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Reports and Data

USGS Rita Data Report

USGS Rita Factsheet

Current Hydrologic Hazards Map
http://water.usgs.gov/waterwatch/hazards

Inundation-Depth
http://gisdata.usgs.gov/website/gulf