Was Super Storm Sandy a Once-in-a-Lifetime Event? An Analysis of the Risks

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Storm Surge Frequency

- Mean sea level
- 15 ft Surge
- 17 ft storm tide
- 2 ft normal high tide

NOAA/The COMET Program
Data for 37 tide stations through 2007 were obtained from:

- NOAA/NOS Headquarters in Silver Spring, MD
- CO-OPS data base http://co-ops.nos.noaa.gov

All stations had at least 19 years of record; 34 stations had more than 30 years of record, and 8 stations had 80 or more years of record.

Annual maximum elevations were in feet (NAVD) and determined from monthly maximums.
Tide Gage Stations

LOCATION OF STATIONS IN
SOUTH ATLANTIC AND GULF AREA

LOCATION OF STATIONS IN
MIDDLE ATLANTIC AREA

Stations

- Region 1
- Region 2
- Region 3
- Region 4
- At-site analyses

Stations

- Region 5
- Region 6
- Region 7
- At-site analyses
NOAA/NOS Trend Analysis for Baltimore, MD

Tide Gage

Data were updated to current mean sea level to achieve stationary data sets

- Used trend lines developed by NOAA/NOS
- Adjusted annual maximum elevations for rate of sea level rise
- Regional analysis using the L-moment method
- The L-moment method includes screening data, partitioning stations into homogeneous regions, and fitting probability distributions in each region
Seven homogeneous regions were defined for the Atlantic and Gulf Coast from New Jersey to Alabama.

Within each region, an average slope of the frequency curve was estimated.

The x-percent-chance flood elevation was estimated.
## Regional Average Elevations, NAVD

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<th>REGION</th>
<th>10-PERCENT</th>
<th>2-PERCENT</th>
<th>1-PERCENT</th>
<th>0.2-PERCENT</th>
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Operating Guidance 8-12
Joint Probability – Optimal Sampling Method for Tropical Storm Surge Frequency Analysis

March 22, 2012

FEMA
1. Discretize $\Delta P$ into multiple broad slices

2. Within each slice, discretize the joint probability distribution of $\Delta P$, $R_p$, $V_f$ and $\theta$ using Bayesian Quadrature

3. Discretize landfall location by offsetting each synthetic storm by $R_p$, as measured perpendicular to the track

4. Compute the probability, $p_i$, assigned to each synthetic storm as the product of the probabilities from the first 3 steps

$$P[\eta_{\text{max}(1\text{ yr})} > \eta] = \lambda \int \ldots \int_x f_X(x) P[\eta_m(x) + \varepsilon > \eta] \, dx \approx \sum_{i=1}^{n} \lambda_i P[\eta_m(x_i) + \varepsilon > \eta]$$

Annual rate for synthetic storm $i$

Numerical model estimate of storm surge elevation

Annual rate (storms/km/yr)

Storm generated surge

Baker

JPM Development

Joint Probability Distribution of Storm Characteristics

Annual rate for synthetic storm $i$

Numerical model estimate of storm surge elevation

$P[\eta_{\text{max}(1\text{ yr})} > \eta] = \lambda \int \ldots \int_x f_X(x) P[\eta_m(x) + \varepsilon > \eta] \, dx \approx \sum_{i=1}^{n} \lambda_i P[\eta_m(x_i) + \varepsilon > \eta]$
Storm Parameterization

\[ \eta = f(x_1, \ldots, x_D) \]

- storm size
- storm intensity
- storm speed
- storm heading
- peakedness of wind profile
- tidal stage
- tidal phase
- etc.
Probabilistic Characterization

\[ \Pr[\eta] = \Pr[x_1, \ldots, x_D] \]

- storm size
- storm intensity
- storm speed
- storm heading
- peakedness of wind profile
- tidal stage
- tidal phase
- etc.
Data Availability

- Storm surge observations are scarce
- There are rich archives of meteorological data that contains information about storms dating back over 100 years
- It is relatively easy to reconstruct the storm surge events from meteorological information
Hurricanes are rare and random phenomena

Statistical inferences based on historical observations alone may possess significant sample bias, stemming from the “luck of the draw”
The Joint Probability Method (JPM) attempts to reconstruct the climatology of a study area from the historical storm record.

- Uses a synthetic suite of storms.
- This way, we circumvent sampling error associated with sole reliance on sparse storm surge records.
Storm Forcing

- Storm Rate and Storm Characterization
- JPM-OS and Representative Synthetic Storms
- Validation of “OS” using ADCIRC mesh
Production storm runs use supercomputer resources with about 528 processor units
Tracks of all October Category 1 and 2 Hurricanes Within 2 degrees of Sandy Between 1851 and 2011
CURRENTS INFLUENCING OUR WEATHER
Sea Surface Temperature
Has the Gulf Stream weakened or disappeared?
Super Storm Sandy

October 29, 2012
8:59 pm EST
(time of forecast [download])

top speed: 45.1 mph
average: 9.4 mph
Findings From Sandy

An Evaluation of the Impact of Hurricane Sandy on Coastal Elevations in New York and New Jersey

Prepared for Federal Emergency Management Agency
November 29, 2012
Comparison of Tide Gages to JPM

THE BATTERY, NY 8518750
Lower Manhattan
The IMPACT of CLIMATE CHANGE and Population Growth on the National Flood Insurance Program

prepared for
Federal Insurance and Mitigation Administration
Federal Emergency Management Agency
Climate Change in the Atlantic

Figure 4-32. Estimated median (50th percentile) change in the coastal flood hazard area for the Mid-Atlantic Coast (left) and North Atlantic Coast at epoch 5 (2100). Changes are with respect to current conditions for fixed shorelines.

The results are for use in determining national averages and should not be interpreted locally.
QUESTIONS & ANSWERS