Storm Surge Modeling and Climatology for the New York City Metropolitan Region

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Storm Surge Modeling for the New York City Region

Surface Wind Vectors and Water Level above MSL (in m)
ADCIRC Simulation of NYC Flooding
Lidar image of business district of Manhattan showing seawall locations and elevation (arrows). The imager is flying above the Hudson River looking east.
1992 Nor’easter Flooding

Source: Metro New York Hurricane Transportation Study, 1995
1950 Flooding of La Guardia airport and lower E side (Bloomfield, 1999 and NYC OEM)

FDR Drive during the December 1992 nor’easter (Bloomfield, 1999)

Flood areas for hurricane:

- CAT 1
- CAT 2
- CAT 3
- CAT 4

NYC area tracks obtained by observations and geological survey (Scileppi and Donnelly 2007)

Hurricane Flooding for NYC (Metro NY Hurricane Transportation Study 1995)
Tropical Storm Tracks: 1851-2005

Figure provided by J. I. Virmani, 2007
Outline

• How well can a coupled atmospheric (WRF) and ocean (ADCIRC) modeling system predict storm surge for nor-easters and landfalling hurricanes around NYC?

• How sensitive are the simulated water levels to relatively small changes in the track and timing of hurricanes?

• What is the climatology of storm surges and associated storm tracks for the NYC area in last 50 years? How will the climatology change as sea level rises?
Stony Brook Weather Research and Forecasting Model (WRF) Domains
Advanced Circulation Ocean Model (ADCIRC) Grid (~108 K nodes)

- Run in barotropic mode (1-layer in vertical)
- Use hourly MM5/WRF winds and surface pressures to force model
- Tidal forcing at boundaries
- No wave forcing (yet)
Detail of gridding in lower Manhattan up to +8 m contour
ADCIRC Water-level and Flooding

12-km MM5 Forecast 1200 UTC 11 December 1992

48-h WRF Hindcast of Hurricane Gloria

- Insert Cyclone Using NCAR-AFWA Method:
  - Davis and Low-Nam (2001)
  - Specify Radius of Maximum Wind
    Maximum Wind Speed m/s, Radius of storm, and Wind profile
12-km WRF (GFS-PBL) Cloud Top Temperatures (°C)

06z Sept 26th – 12z Sept 28th
4-km WRF: surface reflectivity (rain intensity) and 10-m winds (full barb = 10 kts)
4-km WRF Tracks for Gloria

- **Best Track**
- 4 km GFS PBL LIN MP
- 4 km GFS PBL FERR MP
- 4 km YSU PBL LIN MP
- 4 km YSU PBL FERR MP
- 4 km MY PBL LIN MP
Modeled Hurricane Gloria Storm Surge

GFS PBL 10m Winds
12km Run

The Battery, NYC

09z Sept. 27th – 00z Sept 28th
Storm Surge at Battery, NY

OBS

GFS PBL 4 km
CTL 10m Winds
15z Sept 27th

YSU PBL 4 km
10m Winds
15z Sept 27th

962 hPa

954 hPa

WRF CTL

L L

962 hPa

954 hPa

L L
Landfall Timing Impact on Water Levels

at High Tide

Flooding at Battery Relative to MLLW

Water Level, m

06:00 12:00 18:00 09/28/85 06:00

Time (GMT)

GFS PBL Lin MP
GFS PBL Lin MP 1 hr earlier
GFS PBL Lin MP 1 hr later
GFS PBL Lin MP high tide
Astronomical Tide
Observed Water Level
Gloria (1985) Water Level (MSL) at High Tide
Climatological Analysis of NYC Surges

A minor and moderate surge at the Battery would result in a coastal flood advisory and warning, respectively, by the NWS during a high tide (mean high water).

Minor: 0.60-1.00 m above MHW
Moderate: >1.00 m above MHW

Maximum daily surge at the Battery, NYC (1959 - 2007)
Minor Surge Events at the Battery, NY ‘59-‘07

5 yr running mean

'72-'73

'82-'83

'97-'98
Annual Moderate Surge Events at the Battery, NY ‘59-‘07

*Surge + tidal = total water level (storm tide)

NWS threshold Mod. Flooding = 2.44m above Mean Low-Low Water (MLLW)

Moderate observed flooding events absent after 1996
Impact of Sea-Level Rise on NYC Flood Events

IPCC (2007) 12-50 cm over next 50-100 yrs

Observed Moderate Flooding Events

After 12.5 cm Sea-Level Rise
Impact of Sea-Level Rise on NYC Flood Events
IPCC (2007), 12-50 cm over next 50-100 yrs)

After 25 cm Sea-Level Rise

After 50 cm Sea-Level Rise
Impact of Sea-Level Rise on Minor Storm-Tide Events (> 2.04 MLLW) (rise ~2.77 mm/yr at Battery--10-15 cm over 50 yrs)
Moderate Surge Cyclone Tracks -48/+12h

Cyclone Tracks

Position at Time of Max Surge

1.0 m events

Number of Cyclone Centers

- 9
- 6
- 5
- 4
- 3
- 2
- 1
NCEP Reanalysis SLP Composite of 46 > 1-m Surges at Battery, NY
Tropical Storm Surge Tracks (1959-2007)
Conclusions

• Current generation of atmospheric and ocean models can realistically simulate hurricanes and storm surge in the NYC area.

• Even a relatively small change in track and timing can impact the water level forecast significantly – Need to use ensemble of model forecasts.

• There is a lot of inter-decadal variability in storm surge (which we do not fully understand). We have not had a moderate coastal flooding event in NYC since 1996 – false sense of complacency?

• A wide variety of cyclone tracks can yield flooding problems for NYC. Flooding (even for nor-easters) will increase dramatically as sea level rises 10-50 cm over the next 50-100 years.
• 5 MM5 / 4 WRF members
• Run at 12 km resolution, once a day at 00z
• Storm Surge and Water elevation (MLLW) plotted

http://stormy.msrc.sunysb.edu
EXTRA SLIDES
Hurricane Gloria Initialization

Used NCAR-AFWA Bogus Scheme described by Davis and Low-Nam (2001)

SLP and Surface Temperatures/Winds plotted

Initialized at 00z 26th Sept.

No Bogus

Bogus
Radar Comparisons Between Observed and Modeled around 06z Sept 27th

Central Pressure - 943 mb
Moving 4 km
GFS-PBL

Reflectivity at 2.7-km with 2.7-km winds
(full barb = 5 m/s, flag = 25 m/s)

Central Pressure - 950 mb
Steady 4 km
Franklin, Lord and Marks Jr. (MWR May, 1988)

Flight Level Winds (full barb = 5 m/s, flag = 25 m/s)
Reflectivity sweep taken at 2.7 km, 21-38dbz = gray scale

Central Pressure - 942 mb

538z Sept 27th
Minor Surge Cyclone Tracks -48/+12h

Cyclone Tracks

Position at Time of Max Surge

0.6-1.0 m events

0.8-1.0 m events

Number of Cyclone Centers

9 6 5 4 3 2 1