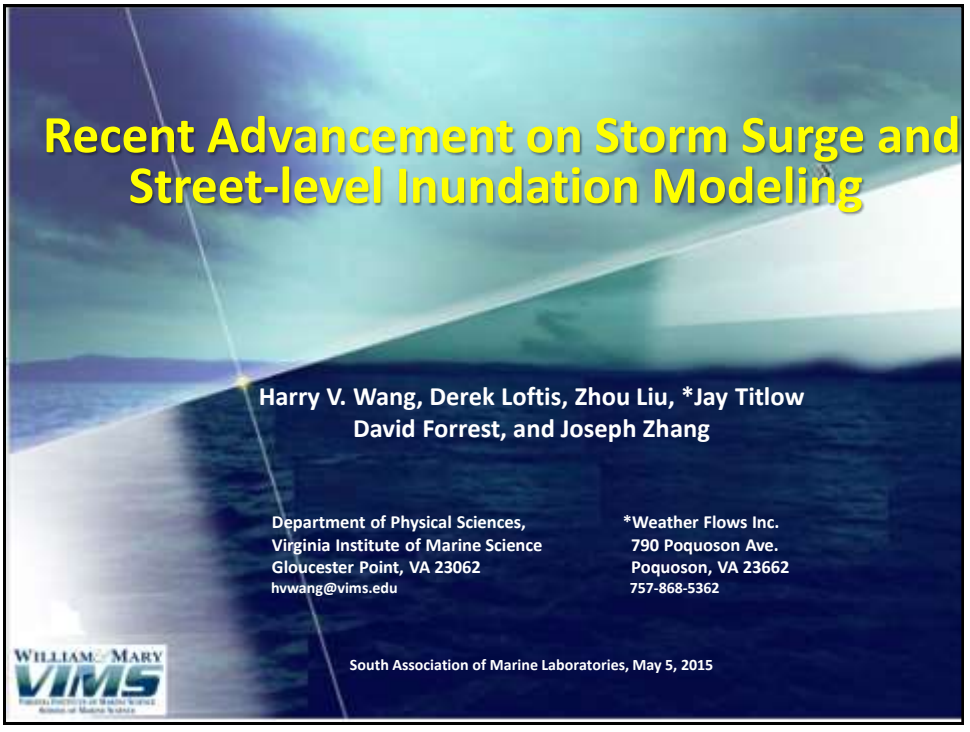
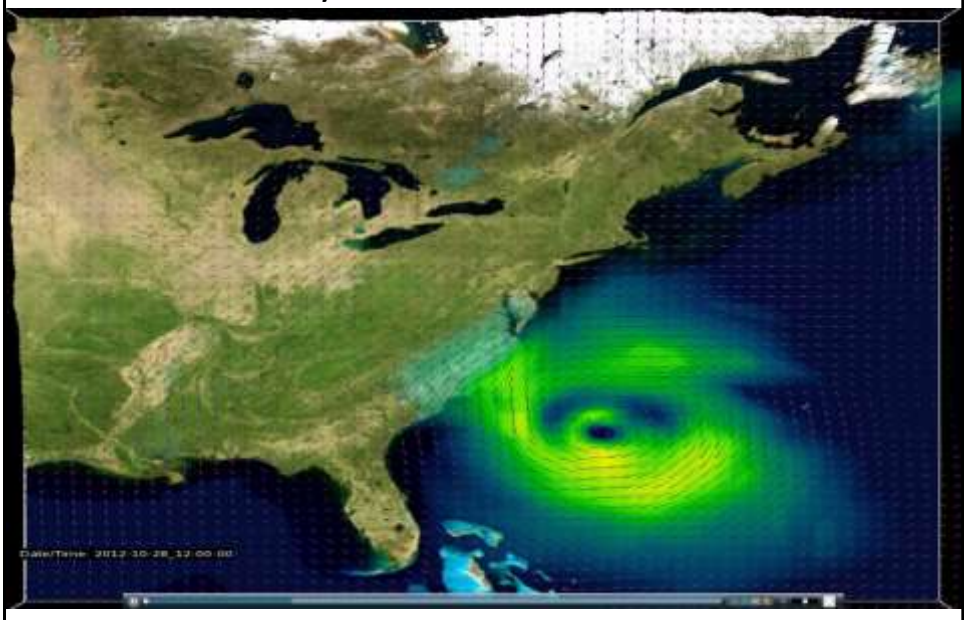


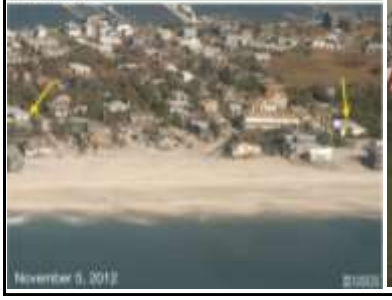
Outline

- The storm tide and street-level inundation modeling during recent event of Hurricane Sandy
- The storm tide and inundation modeling during 2003 Hurricane Isabel in the Potomac River of the Chesapeake Bay
- The reconstruction of historical 1936 Potomac River Great flood in Washington, D.C.

I. Hurricane Sandy



Motivation



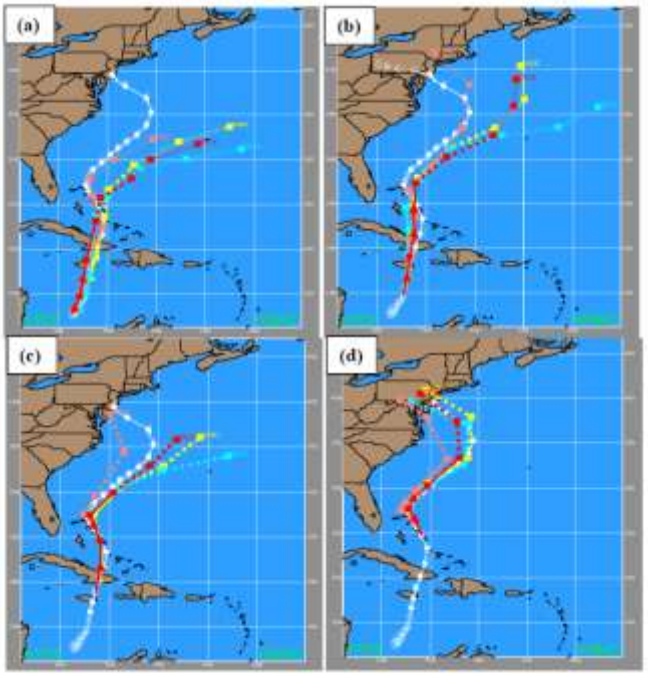
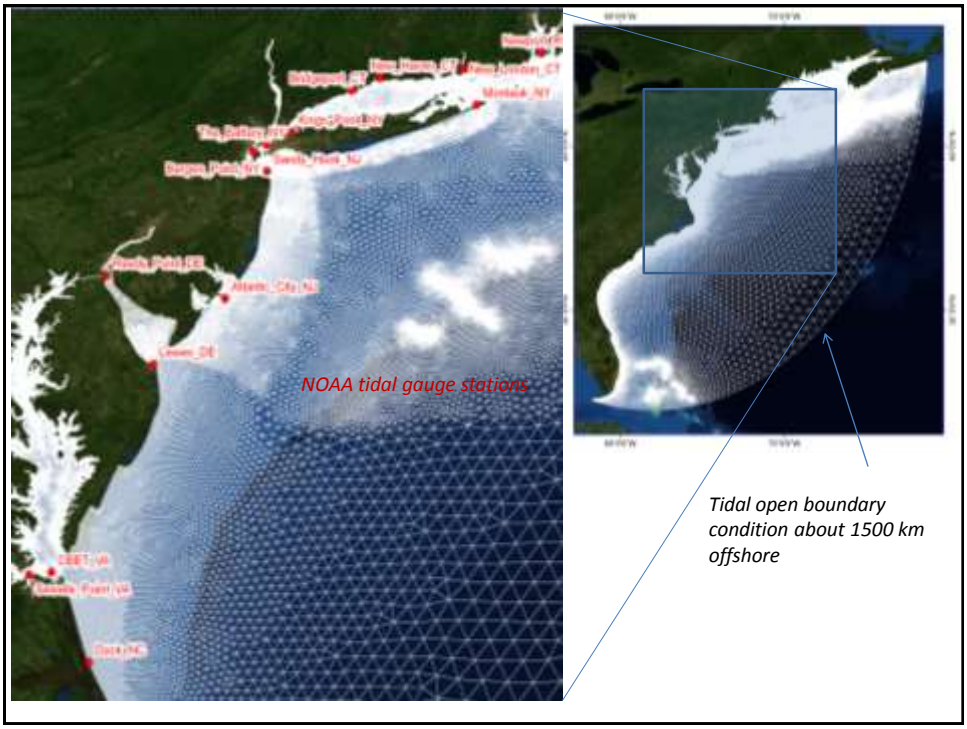
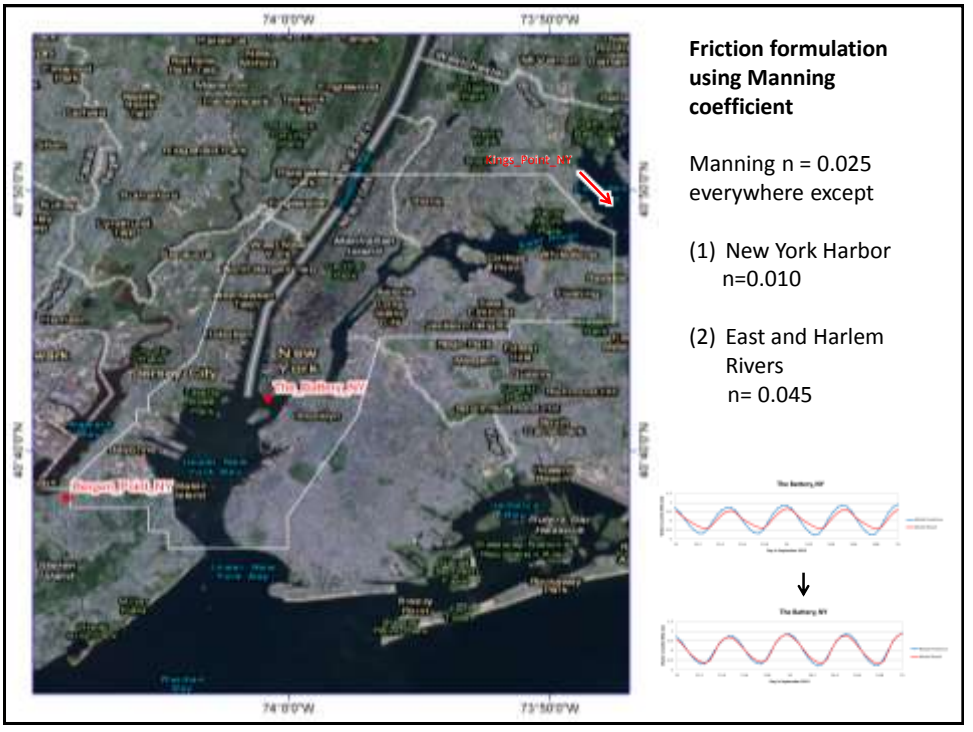


Figure 31: Model forecast tracks for Sandy at 0000 UTC 23 October (a), 000 UTC 24 October (b), 000 UTC October 25 (c), and 000 UTC 26 October, (d).

The ECMWF is in coral, the GFS ensemble in yellow, the GFS in cyan, and the TVCA model consensus is in red

From: Blake, Eric, et al. (2013): Tropical Cyclone Report: Hurricane Sandy, National Hurricane Center,



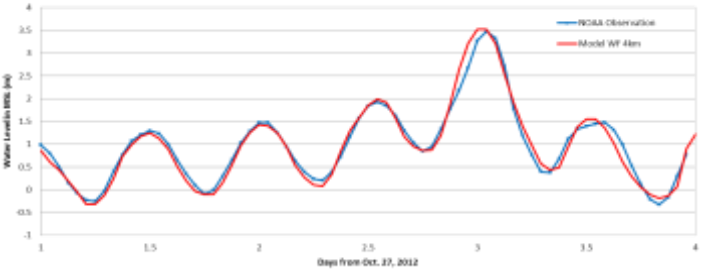


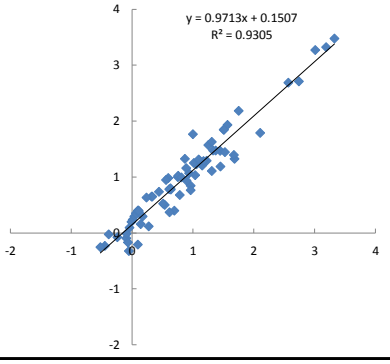
Friction formulation using Manning coefficient

Manning n = 0.025 everywhere except

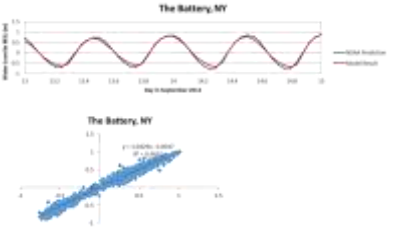
(1) New York Harbor n=0.010

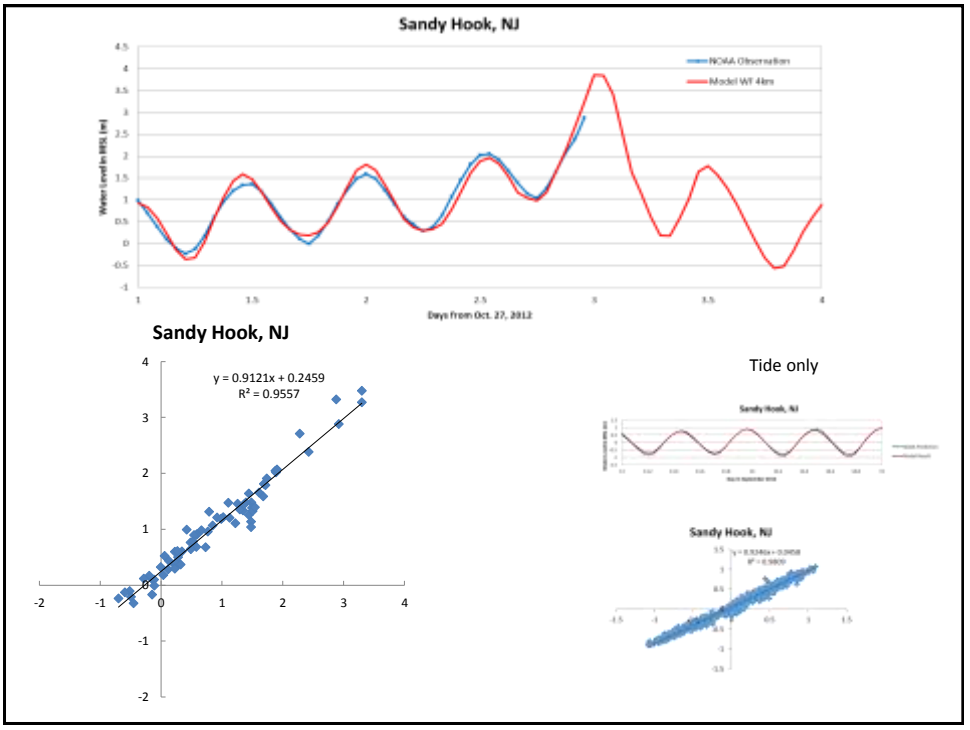
(2) East and Harlem Rivers n= 0.045





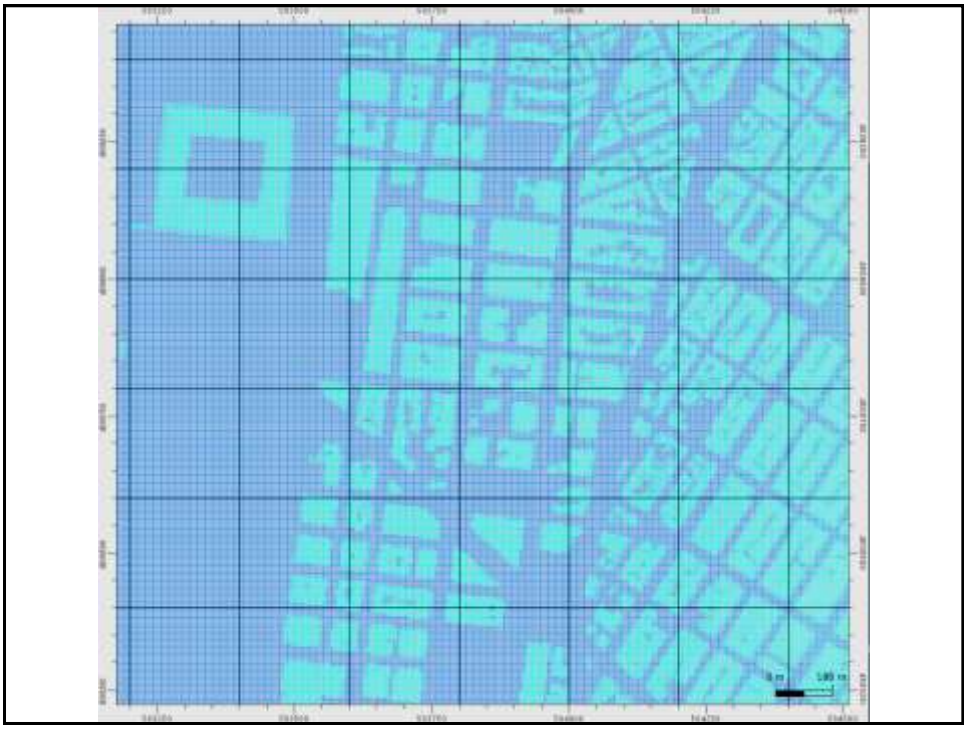
Tide only

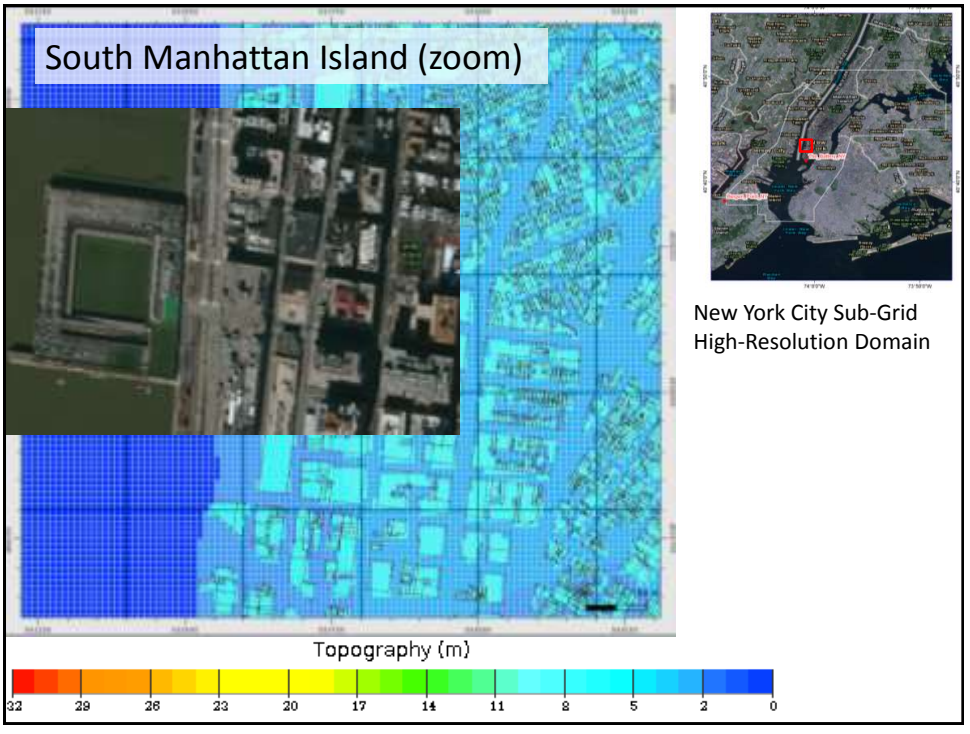


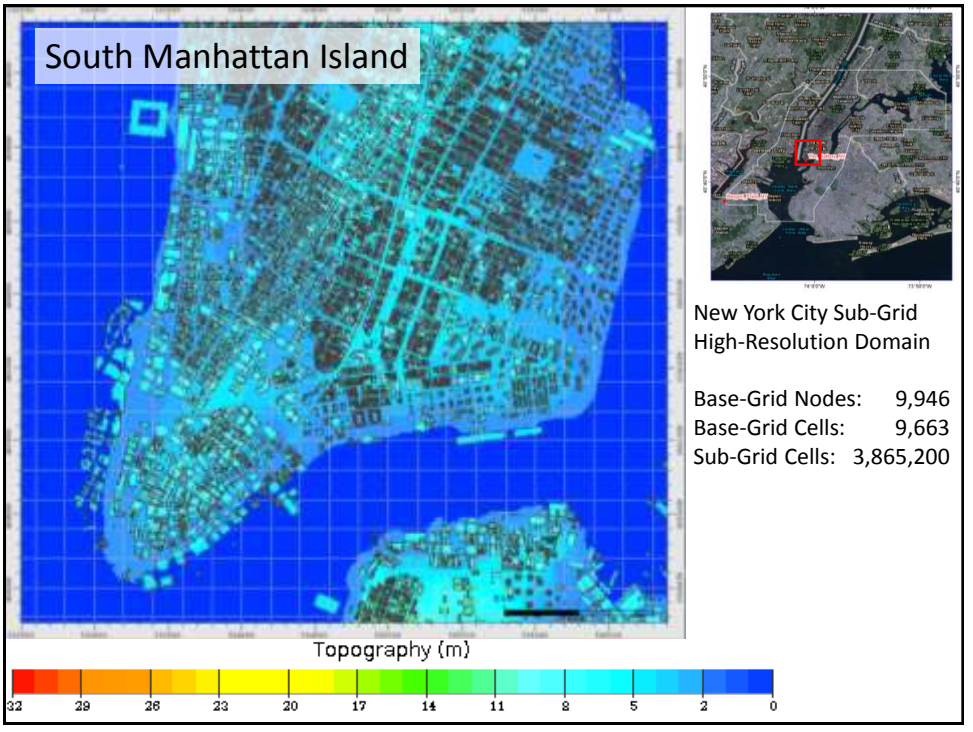


Additional street-level modeling Inundation

- Open Boundary Forcing from NOAA Stations
  - West Boundary: Bergen Point, NY NOAA Station #8519483
  - East Boundary: Kings Point, NY NOAA Station #8516945
  - South Boundary: near Sandy Hook, NJ NOAA Station #8531680
- Flux Boundary Forcing from USGS Station
  - North Boundary: Hudson River near Wappinger Falls USGS Station #01372500
- Model Setup for 10 days from 00:00, 10/25/2012 to 00:00, 11/04/2012
- Atmospheric pressure and wind data retrieved from Bergen Point, NY, at NOAA Station #8519483
- CPU time: 240 time of real time on Dell Precision T-3500 with Intel Xeon W3670; Windows 7, 64-bit OS; 24 GB RAM

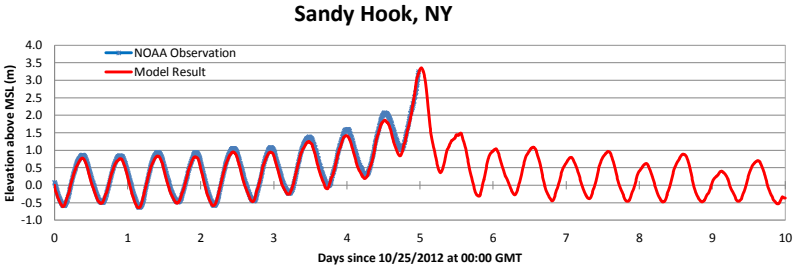


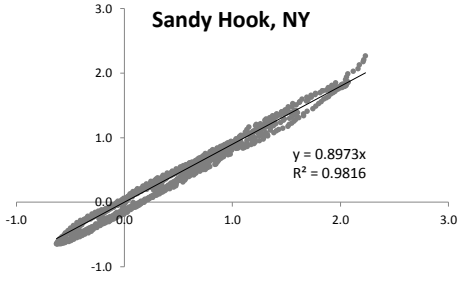

South Manhattan Island (zoom)
New York City Sub-Grid
High-Resolution Domain
Topography (m)
32
29
26
23
20
17
14
11
8
5
2
0

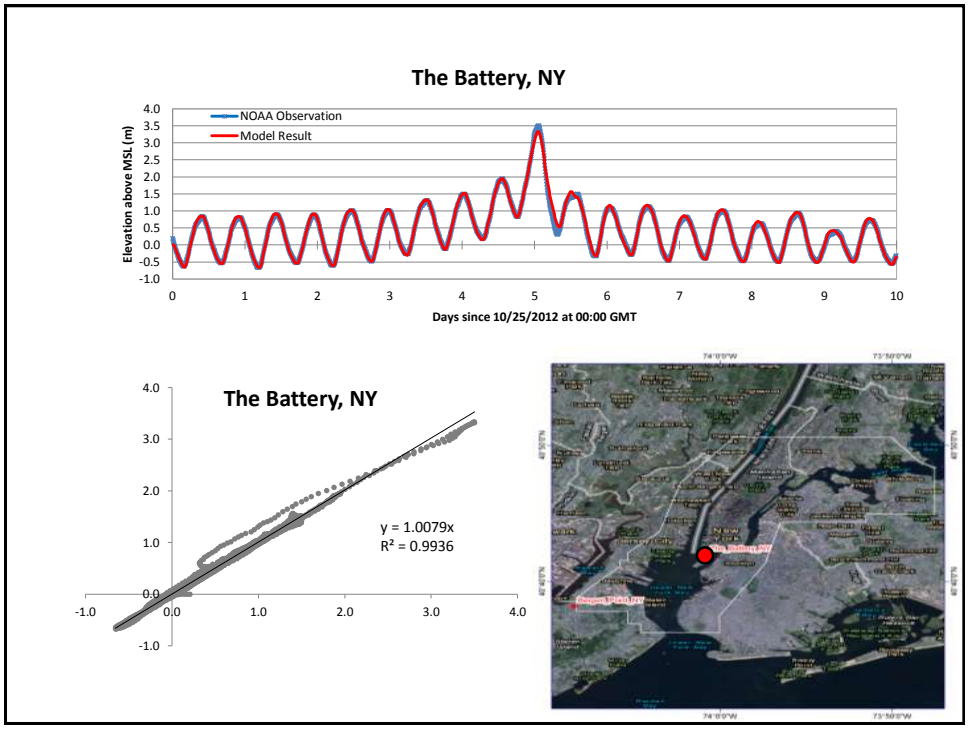


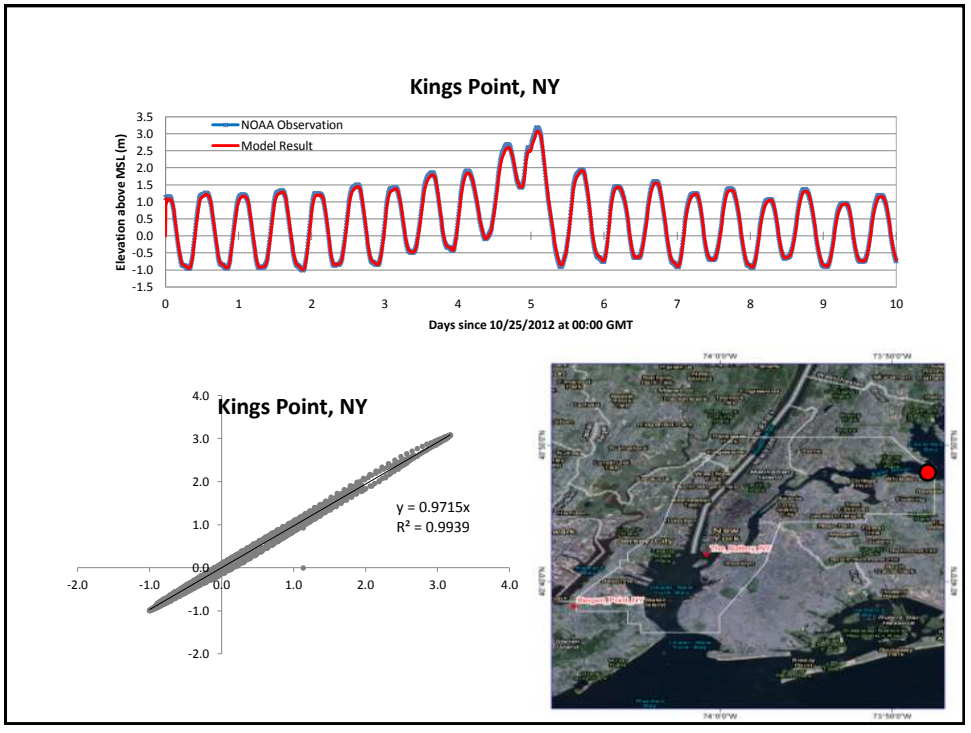
New York City Sub-Grid High-Resolution Domain

Base-Grid Nodes: 9,946
Base-Grid Cells: 9,663
Sub-Grid Cells: 3,865,200



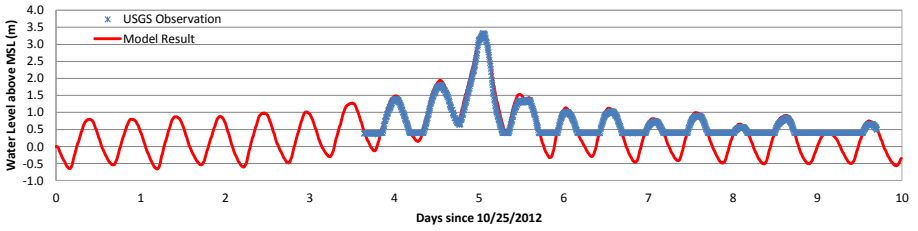


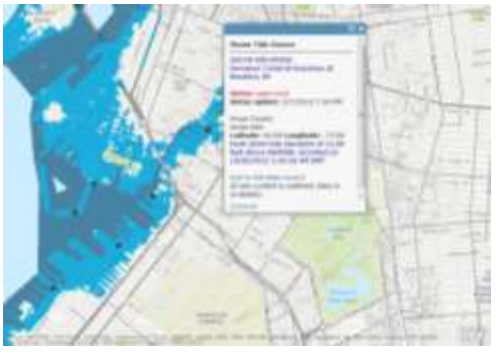

The Battery, NY
NOAA Observation
Model Result
Elevation above MSL (m)
Days since 10/25/2012 at 00:00 GMT
The Battery, NY
y = 1.0079x
R² = 0.9936


Kings Point, NY
NOAA Observation
Model Result
Elevation above MSL (m)
Days since 10/25/2012 at 00:00 GMT
Kings Point, NY
y = 0.9715x
R² = 0.9939

USGS Rapid Deployment Gauge Comparison

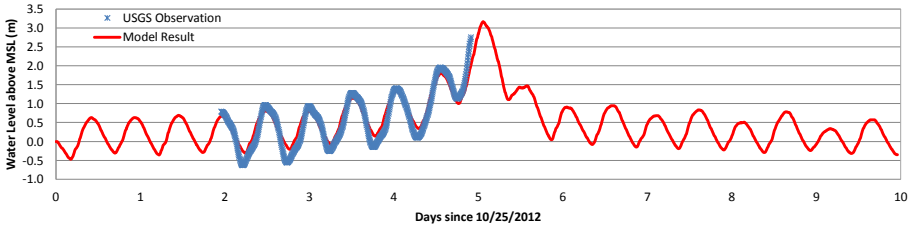
USGS Gowanus Canal, Brooklyn KIN-003WL





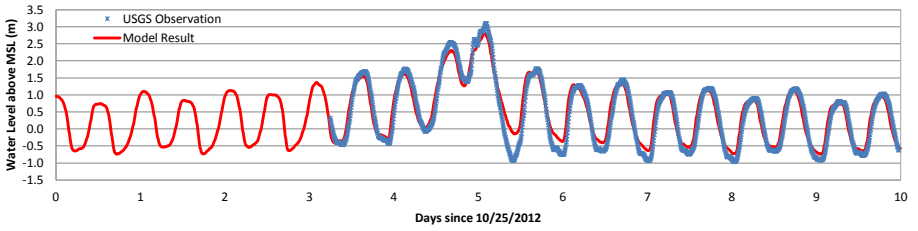
USGS Rapid Deployment Gauge Comparison

USGS Station #404810735538063 at Harlem & East River



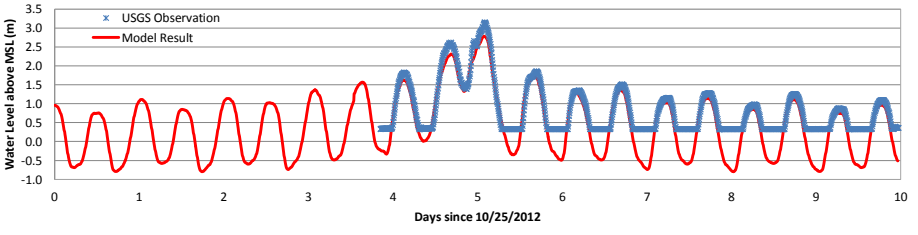
USGS Rapid Deployment Gauge Comparison

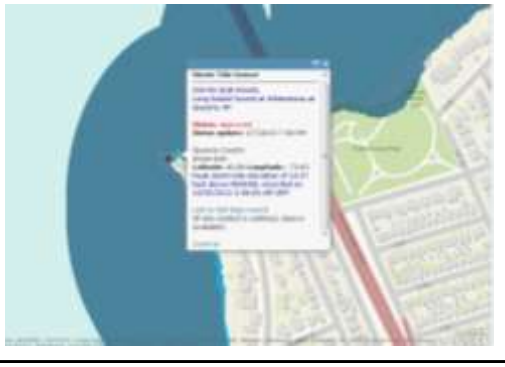
USGS Worlds Fair Marina Flushing Bay, Queens QUE-001WL

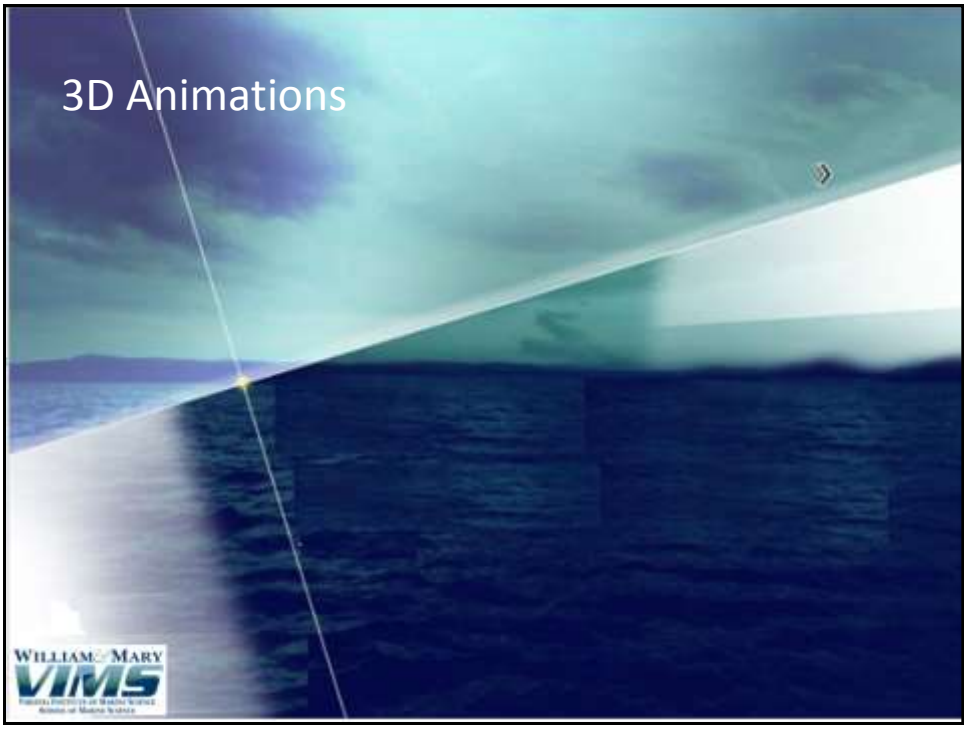


USGS Rapid Deployment Gauge Comparison

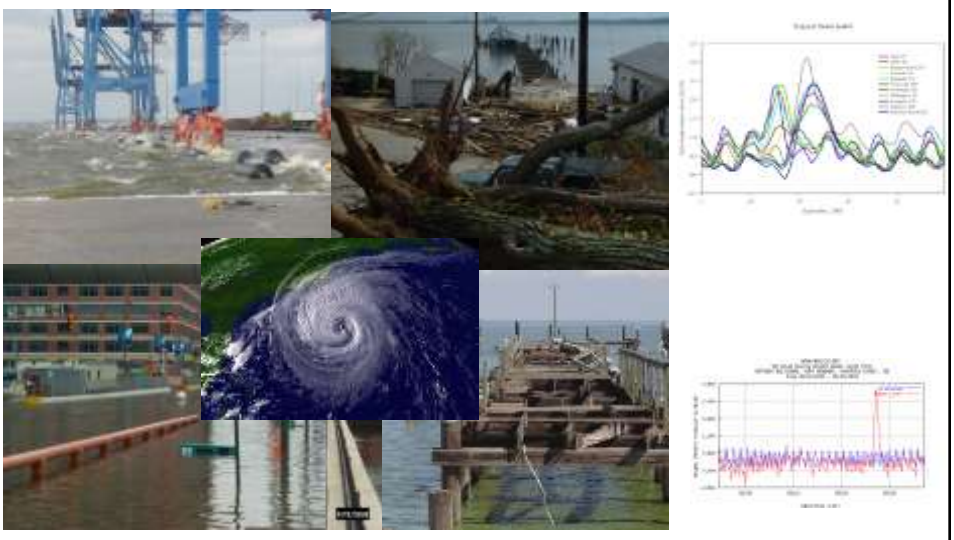
USGS Whitestone, Queens QUE-004WL






3D Animations
WILLIAM & MARY
VIMS

II. Hurricane Isabel in the Potomac River



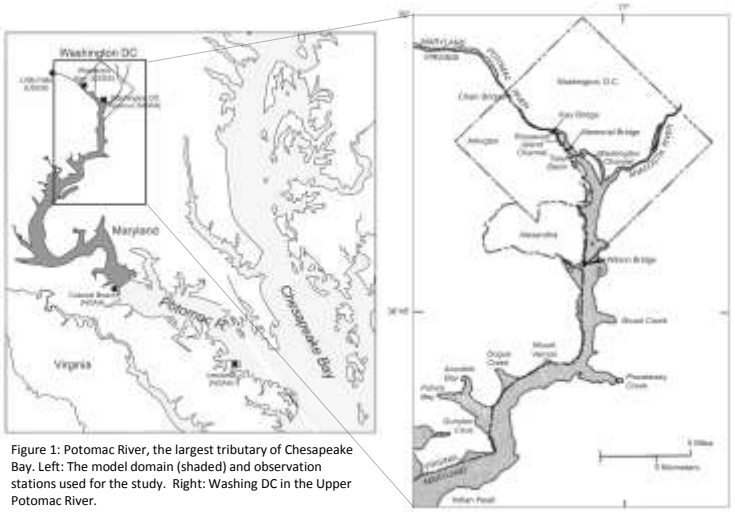


Figure 1: Potomac River, the largest tributary of Chesapeake Bay. Left: The model domain (shaded) and observation stations used for the study. Right: Washing DC in the Upper Potomac River.

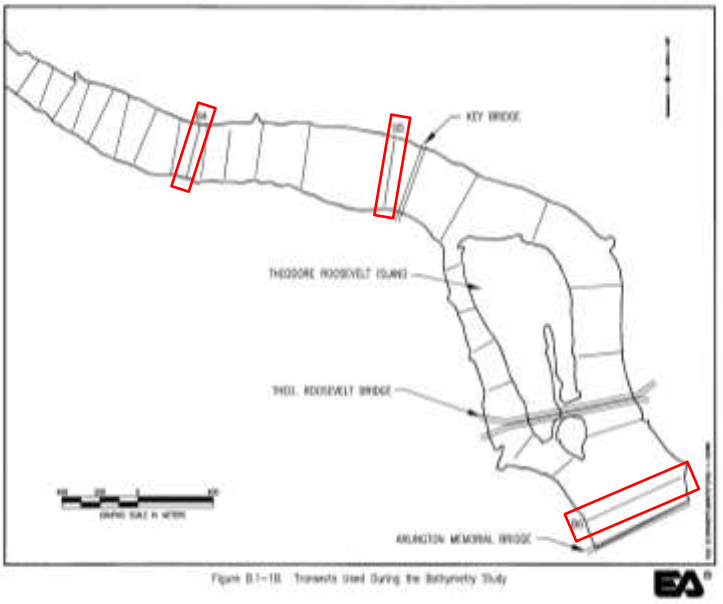


Figure B.1-1B Transects Used During the Bathymetry Study

Source: Water Quality Studies in the Vicinity of the Washington Aqueduct. 2001. U.S. Army Corps of Engineers Report.

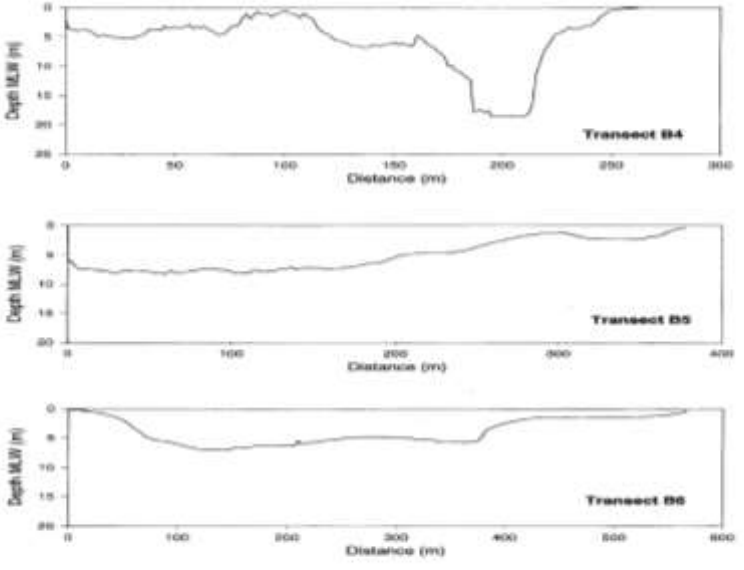
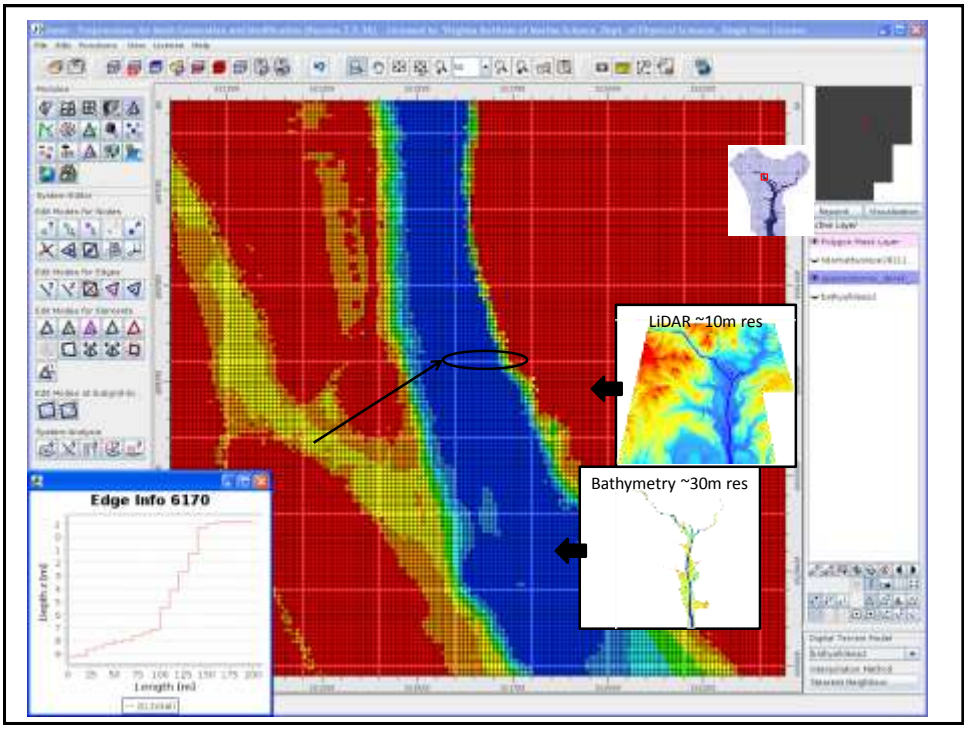
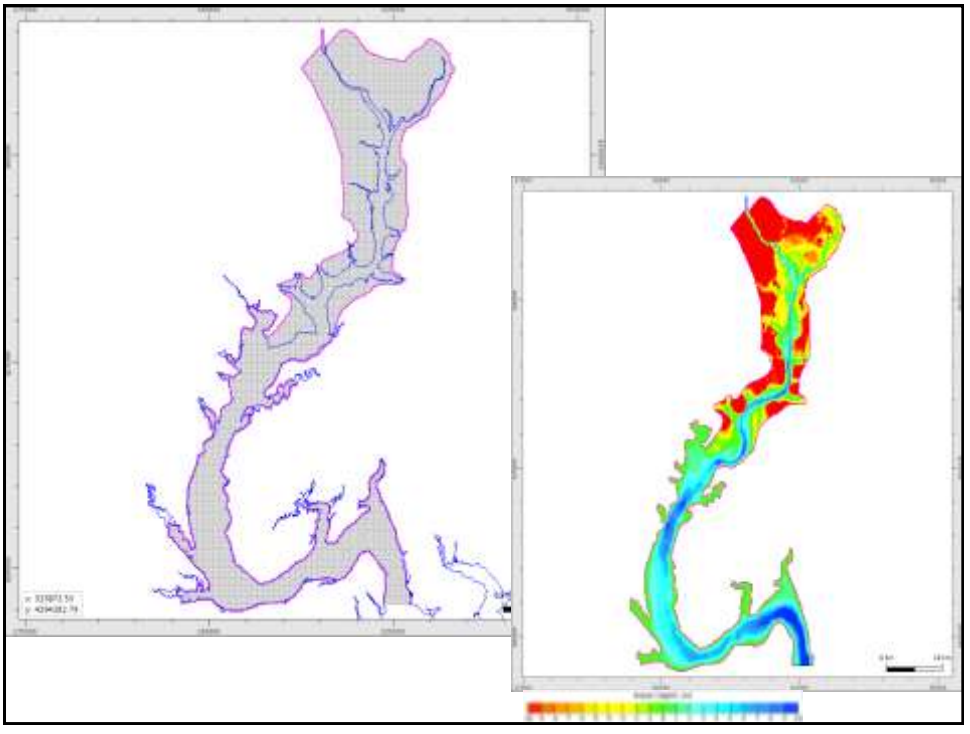


Figure B.1-3 Cross-Sectional Depth Profile at Transects B4, B5, and B6 During the 6-7 April 2000 Bathymetry Survey

EA Bathymetry


LiDAR ~10m res
Bathymetry ~30m res
Edge Info 6170
Length (m)



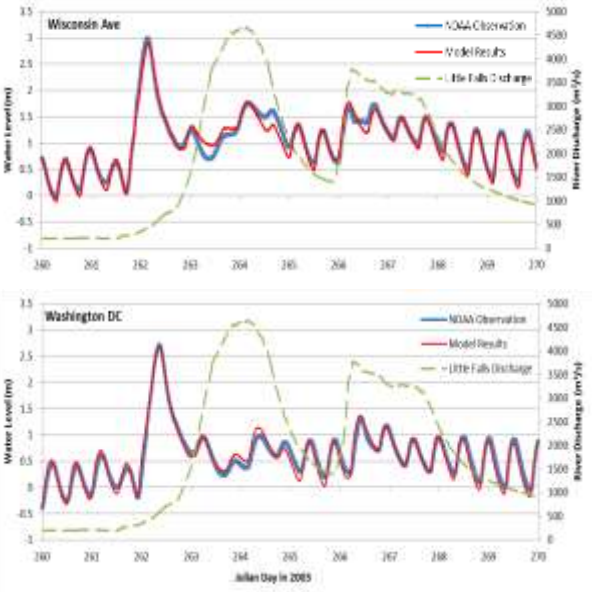


Table 1: Statistical comparison of modeled time series versus observations during Hurricane Isabel

Statistic	Wisconsin Ave.	Washington, D.C
R^2	0.9346	0.9792
RMS	14.3 cm	7.3 cm
MAE	11.4 cm	4.8 cm
Peak Difference	9.2 cm	2.4 cm

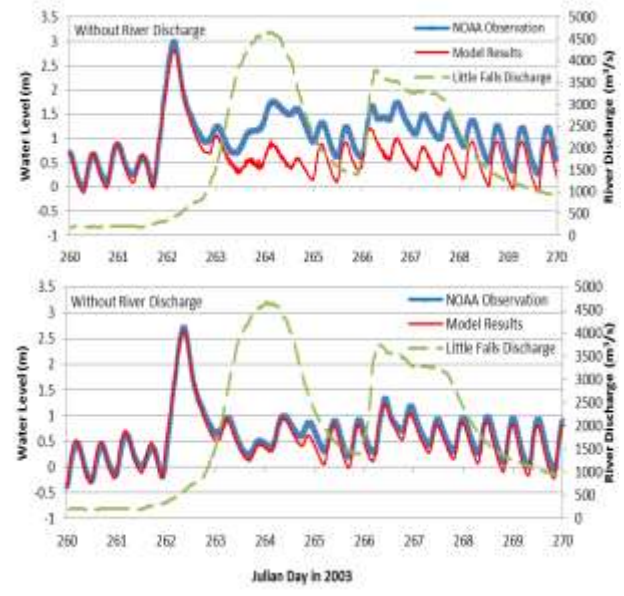
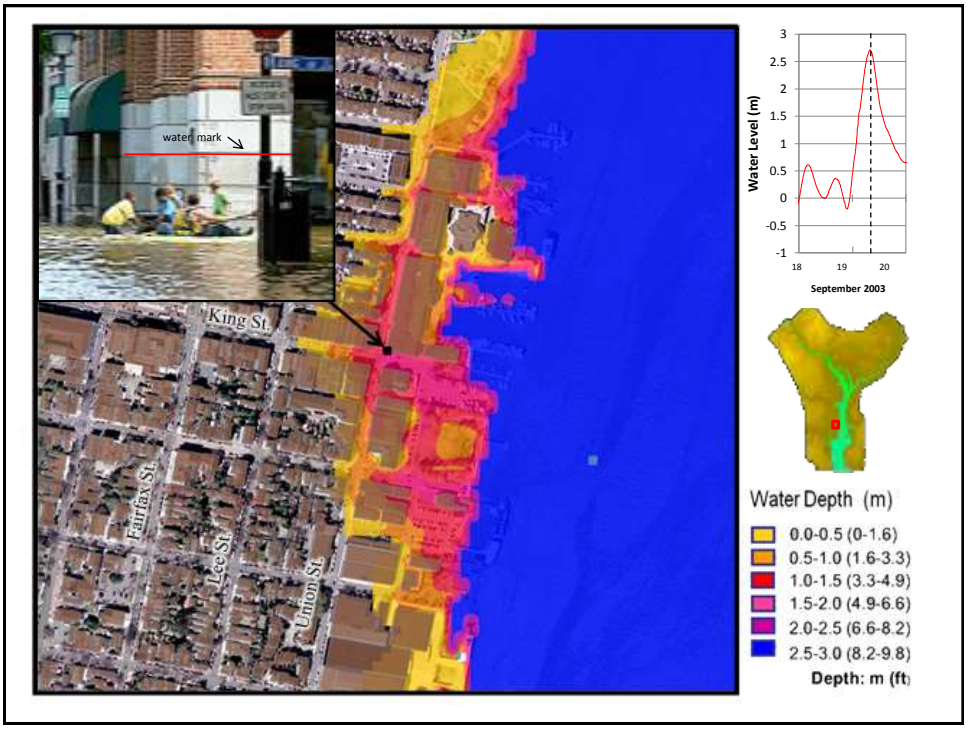
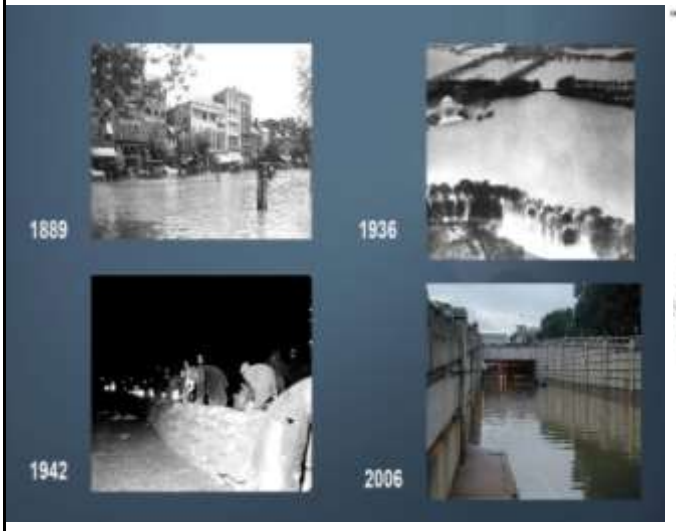


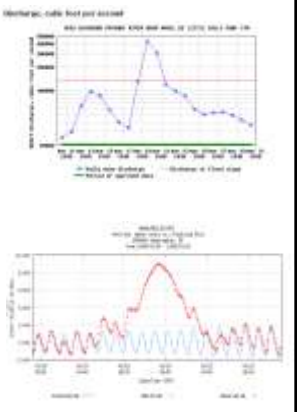
Table 2: Statistical comparison of modeled time series results with and without a 10 m sub-grid at Washington, D.C. during the 1936 Potomac River Flood

Statistic	With Sub-grid	Without Sub-grid
R^2	0.9814	0.7683
RMS	5.8 cm	41.0 cm
MAE	3.7 cm	36.0 cm
Peak Difference	2.9 cm	23.8 cm



III. Washington DC Floods





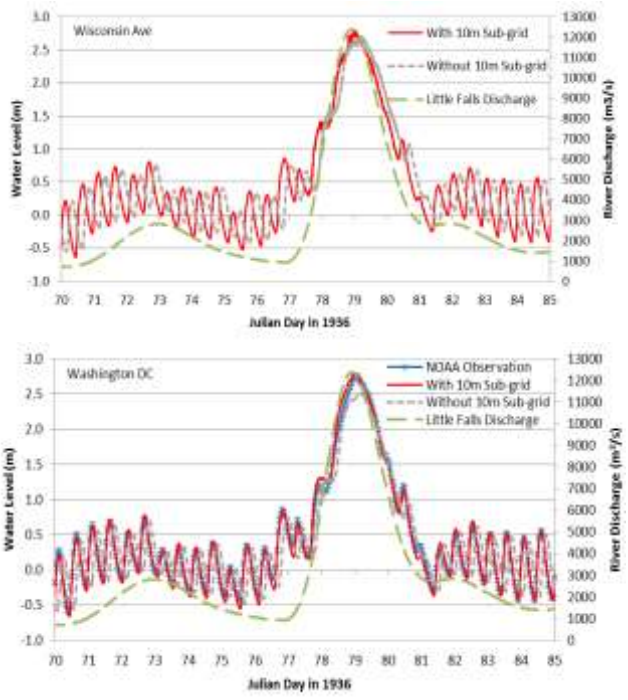


Figure 8: Time series plots comparing between observed water level heights at Washington, D.C. (top), with model results from simulations using a 10 m x 10 m sub-grids (red and without sub-grid embedded(gray dashed line) during the 1936 Potomac River Flood. River discharge from Little Falls, MD, is superposed in green for reference. There is no observation record during the event at Wisconsin Avenue (bottom).

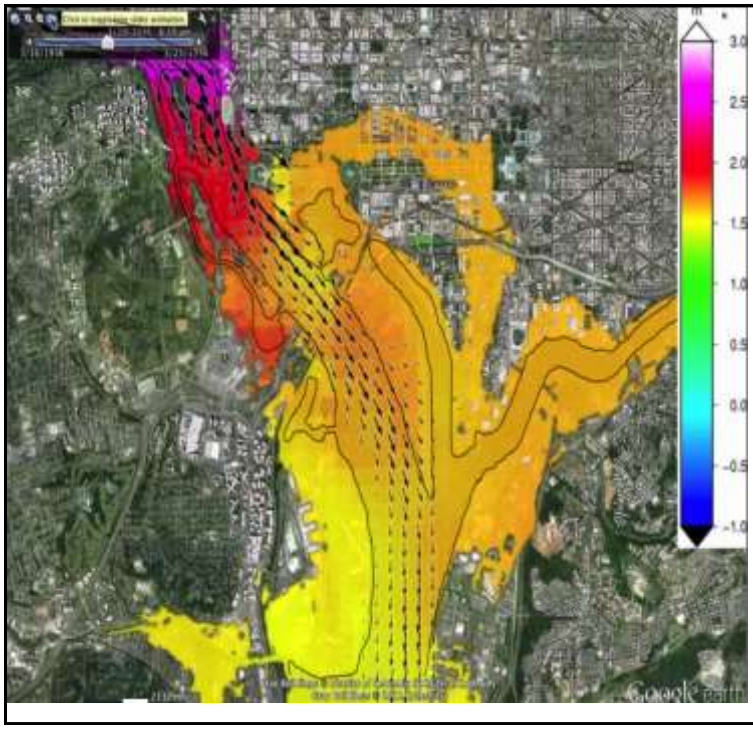


Figure 9: Visualization of the velocity vectors and water level (background color) from sub-grid model-simulation results for the Washington, DC, metropolitan area during 1936 Great Flood. The shoreline is shown superposed in black. It is revealed that at the height of the flooding, the river bank north of Potomac Park near DC was pinched through by a large (>2.7 m/s) velocities deflected from the Roosevelt Island and subsequently flooded the downtown area.

Figure 10: Modeled maximum inundation extent for the Greater Washington, D.C. area (left) and surveyed downtown D.C. flood area (right) during the 1936 Potomac River Flood.

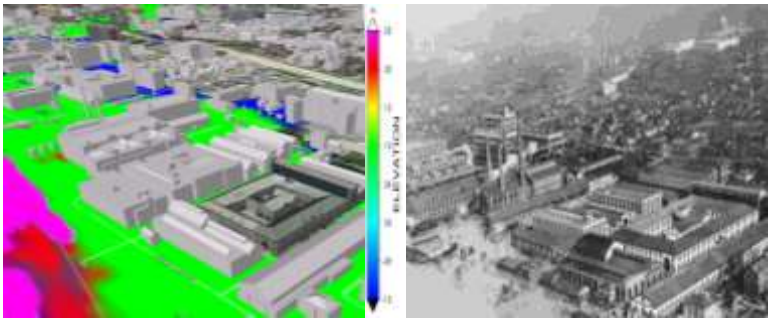
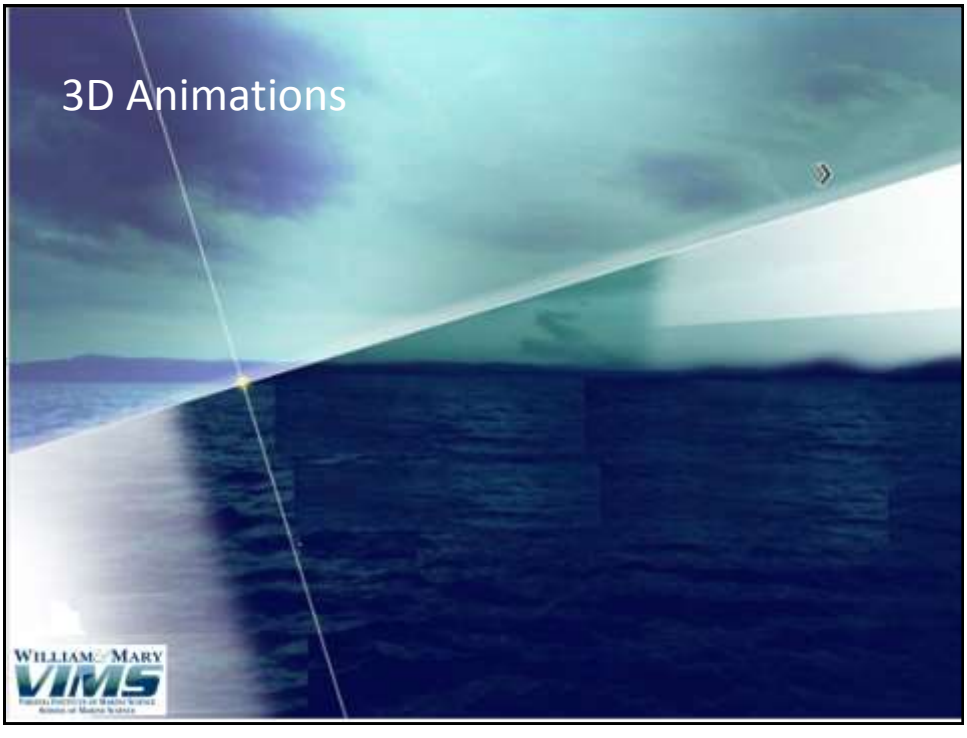


Figure 11: Spatial comparison of inundation at the Washington Naval Shipyard, showing sub-grid modeled results (left) and photographic archived image (right) during the 1936 Potomac River Flood.



Summary

1. The storm tide model that covers the domain of entire US East Coast can be executed efficiently, reliably, accurately with moderate computing resources.
2. The high resolution, sub-grid model using nonlinear solver, which directly incorporating LIDAR data into model proved to be capable of simulating street-level inundation robustly and accurately as demonstrated by the three applications presented today.
3. Going forward, future enhancements include the effects of precipitation, infiltration, urban storm water drainage, and coupling with sea level rise scenario.