Storm Surge Adaptation Modeling: Potential Surge Reductions from Channel Depth and Wetland/Oyster Restoration

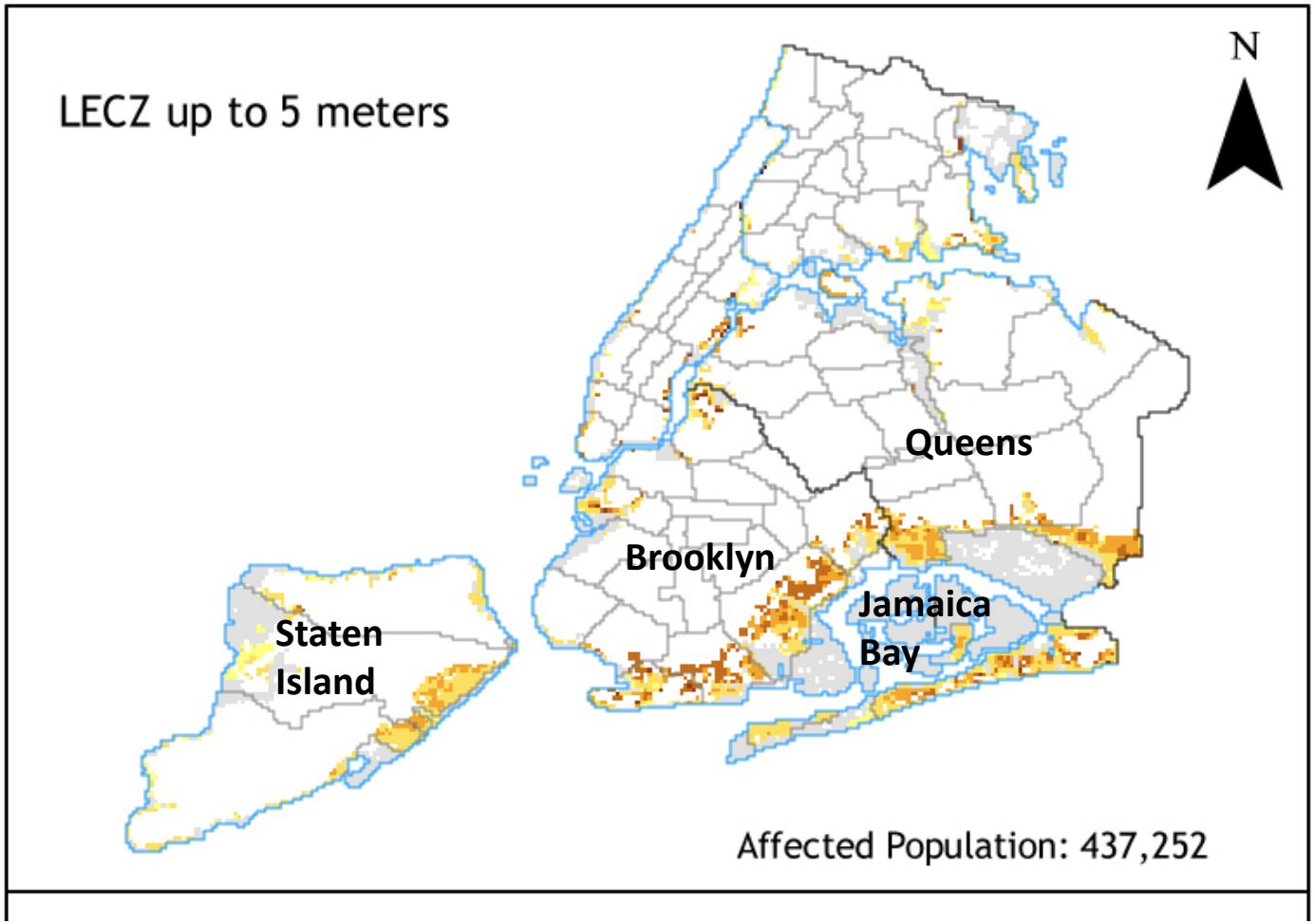
Philip Orton, Nickitas Georgas and Alan Blumberg

Davidson Laboratory, Stevens Institute of Technology

Funding: NOAA's RISA Program (Rosenzweig PI) "Consortium for Climate Risk in the Urban Northeast (CCRUN)"

This research was supported, in part, by a grant of computer time from the City University of New York High Performance Computing Center under NSF Grants CNS-0855217, CNS-0958379 and ACI-1126113

Where is the Vulnerable Population?



Population Density in Low Elevation Coastal Zones (LECZs)

New York City

Population Density, 2000
(persons per sq km)

- 0
- 1 - 100
- 101 - 5,000
- 5,001 - 10,000
- 10,001 - 25,000
- 25,001 - 50,000
- 50,001 +
- Area outside of 10 meter LECZ

CIESIN Columbia University

Baruch COLLEGE The City University of New York

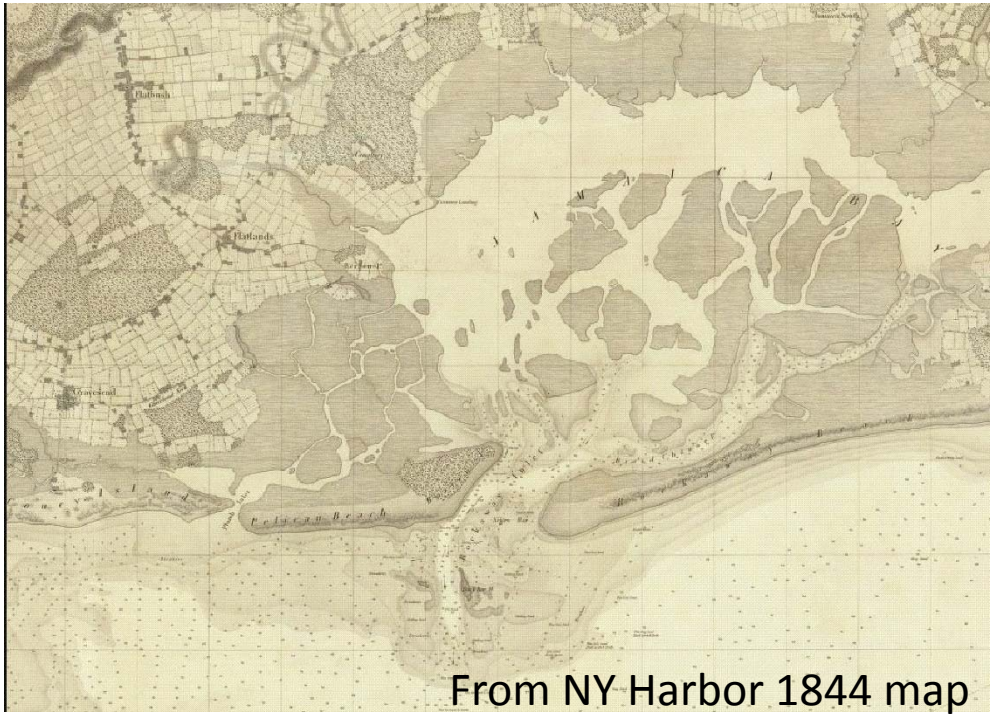
http://sedac.ciesin.columbia.edu/gpw/lecz.jsp

Historic Changes in Jamaica Bay

The loss of interior wetlands for the bay since the mid-1800s is estimated to be 12000 of the original 16000 acres [*DEP*, 2007].

The bay once supported a large oyster fishery producing 700,000 bushels of oysters per year in the early 1900s [Franz, 1982].

Volume of the Bay has increased 350% and average depth has gone from 1m to 5m since the late 1800s. [NYC-DEP, 2007]

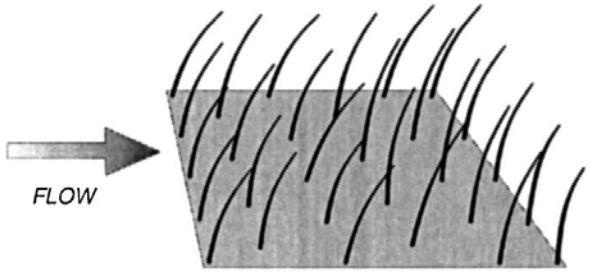


From NY Harbor 1844 map

Relating to this last point: Tide ranges in the bay have increased ~0.5 m (25-45%), and high tide levels have increased ~0.10 to 0.25 m [Swanson and Wilson, 2008]

Channel Depth and Wetland Restoration (or “green engineering”)

- Reversing dredging – shipping channel depths
- Restoring wetlands, oysters and islands (below)



Wetlands and oysters have hydrodynamic “roughness” of 1-2 cm


Elders East Island, Jamaica Bay, NYC, 2006

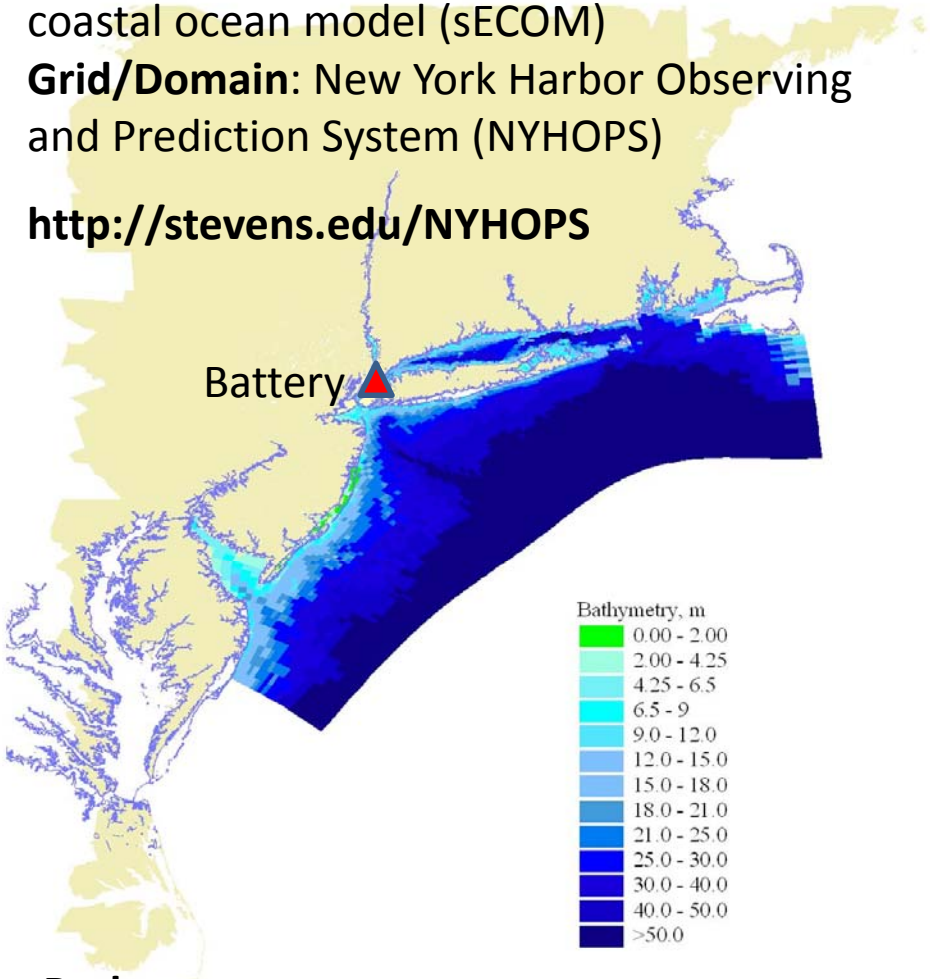

Elders East Island, Jamaica Bay, NYC, 2010

Photo credits: US Army Corps of Engineers

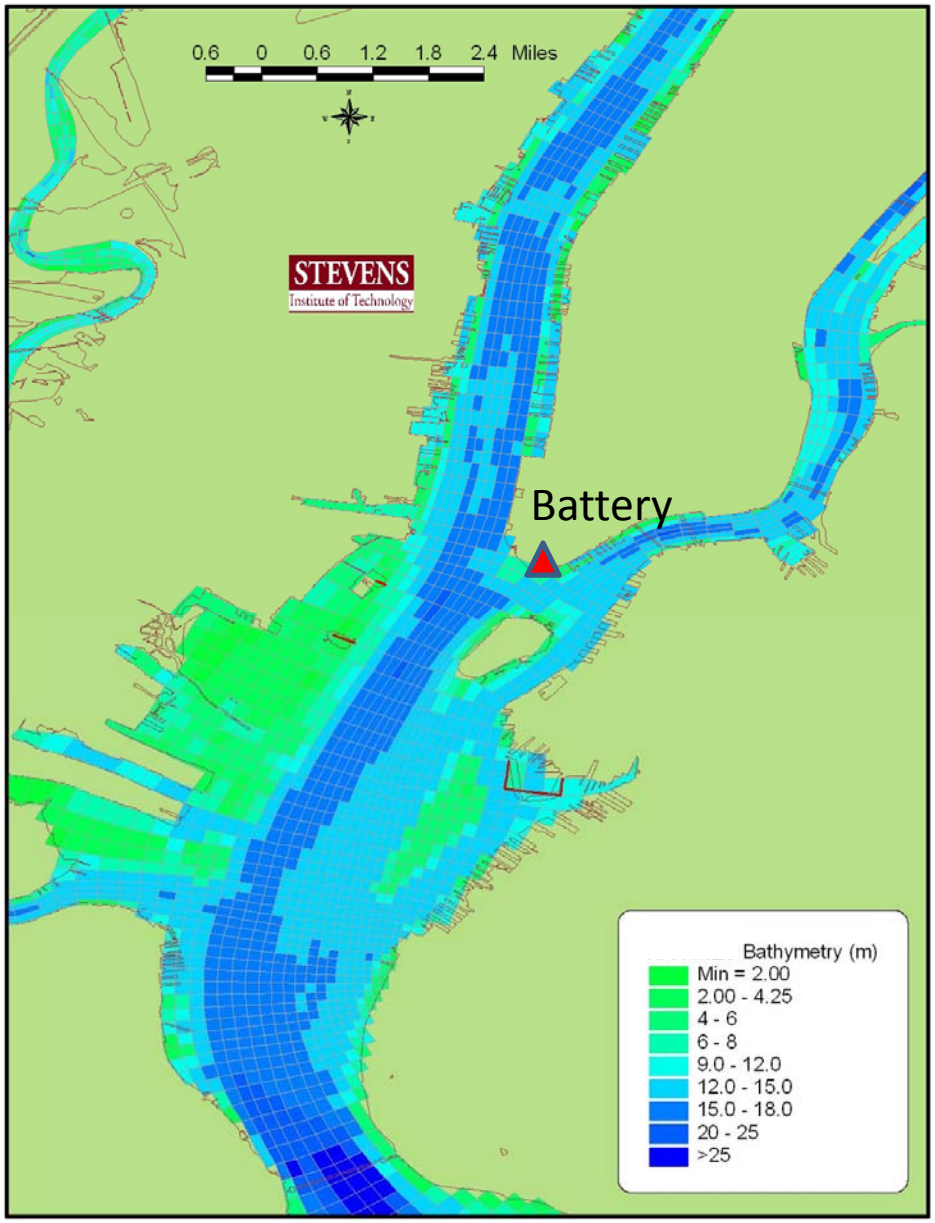
Modeling Methods, Validation

Hydrodynamic model: Stevens estuary and coastal ocean model (sECOM)
Grid/Domain: New York Harbor Observing and Prediction System (NYHOPS)

http://stevens.edu/NYHOPS



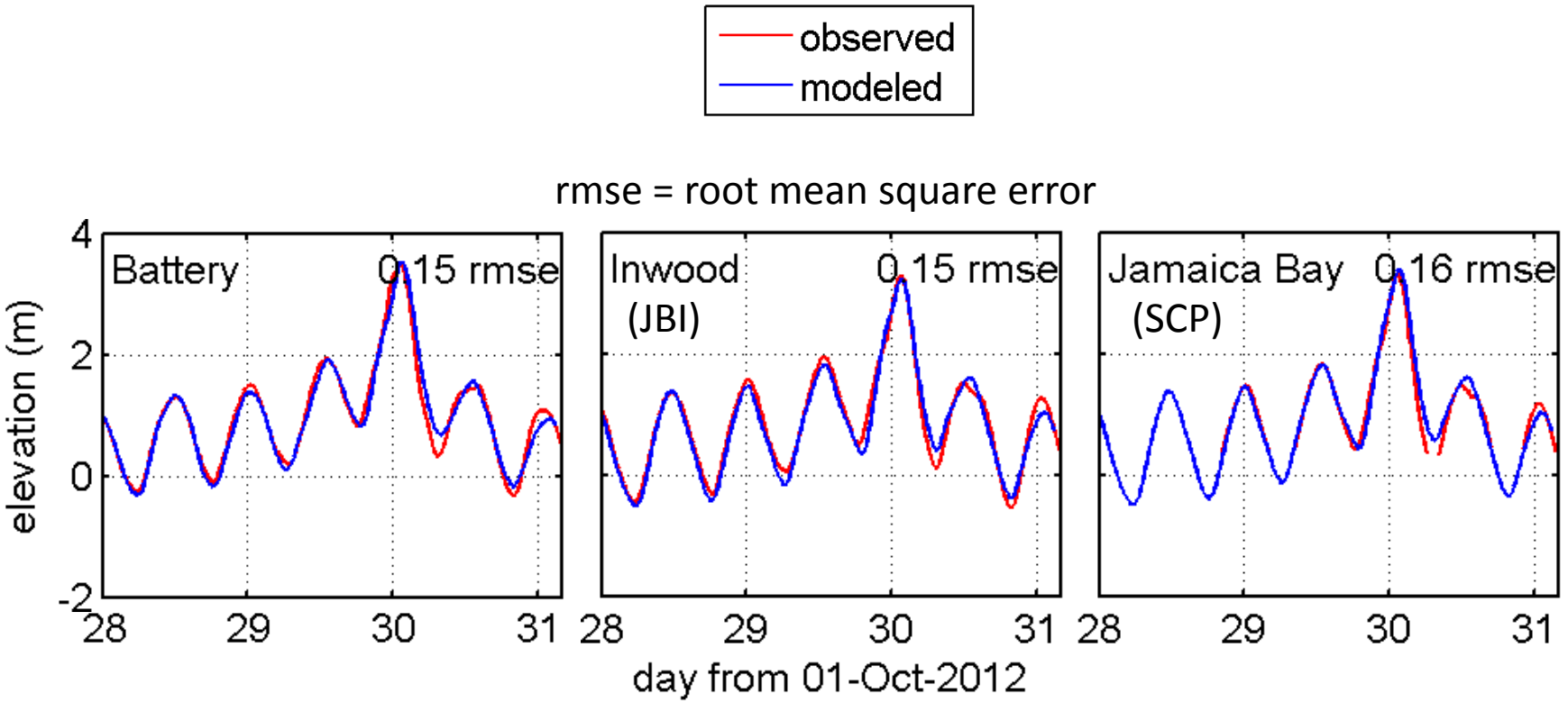
Bathymetry:
Over 1M soundings combined!



One high-resolution model grid (147x452 x10 sigma). 150,680 water cells.

From 7.5km to <50m variable resolution. 200m to 2m depths.

Storm Tide Model Evaluation: Sandy



Model also validated for Hurricane Irene (2011) and a nor'easter (2010) [Orton et al., 2012] as well as six years operational forecasts [e.g. Georgas and Blumberg, 2010].

Orton et al., paper in prep.

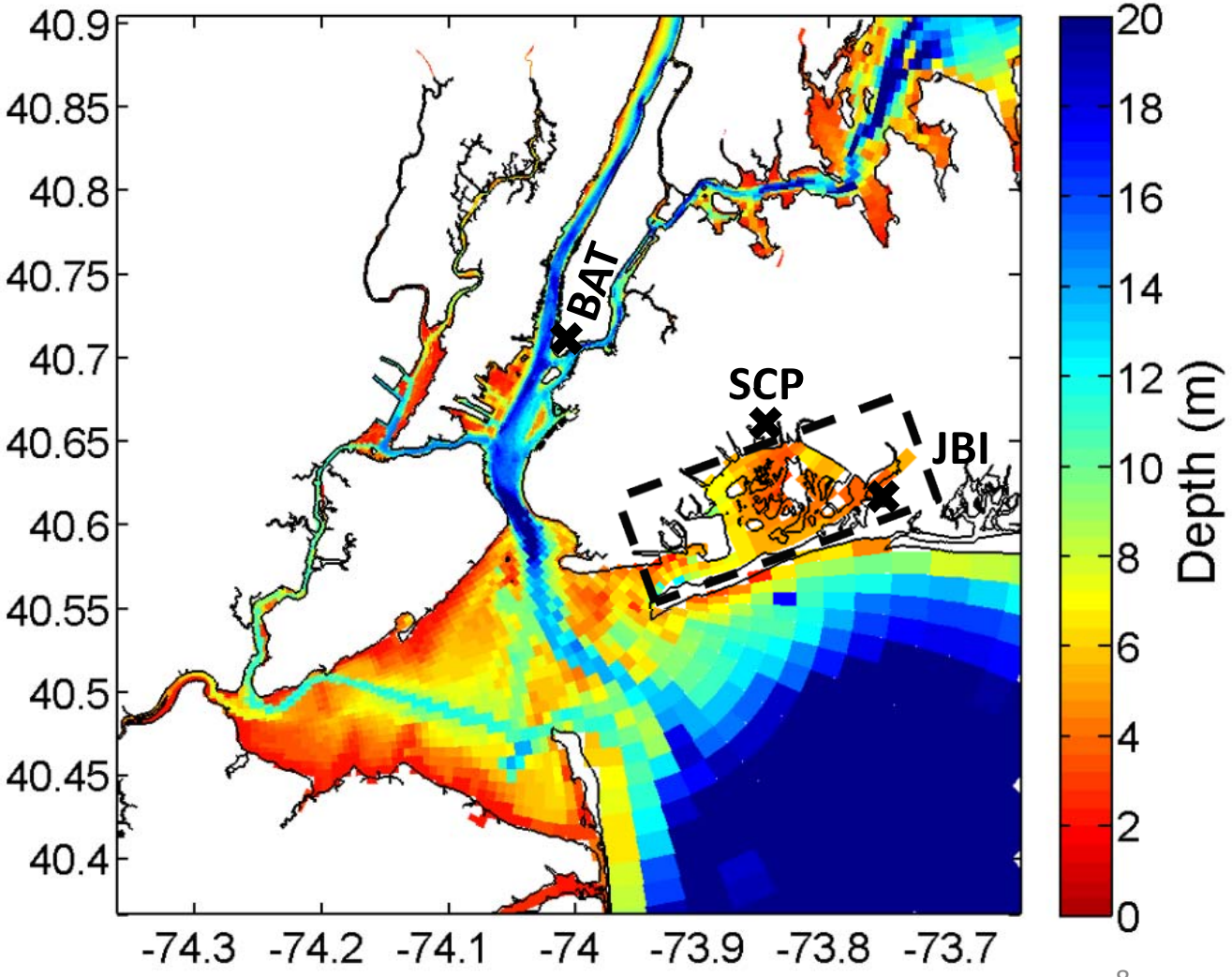
Adaptation Experiments

Designed as simplistic; not necessarily recommended

For model experiment A, Jamaica Bay depths were shallowed to 1/3 of these modern-day values.

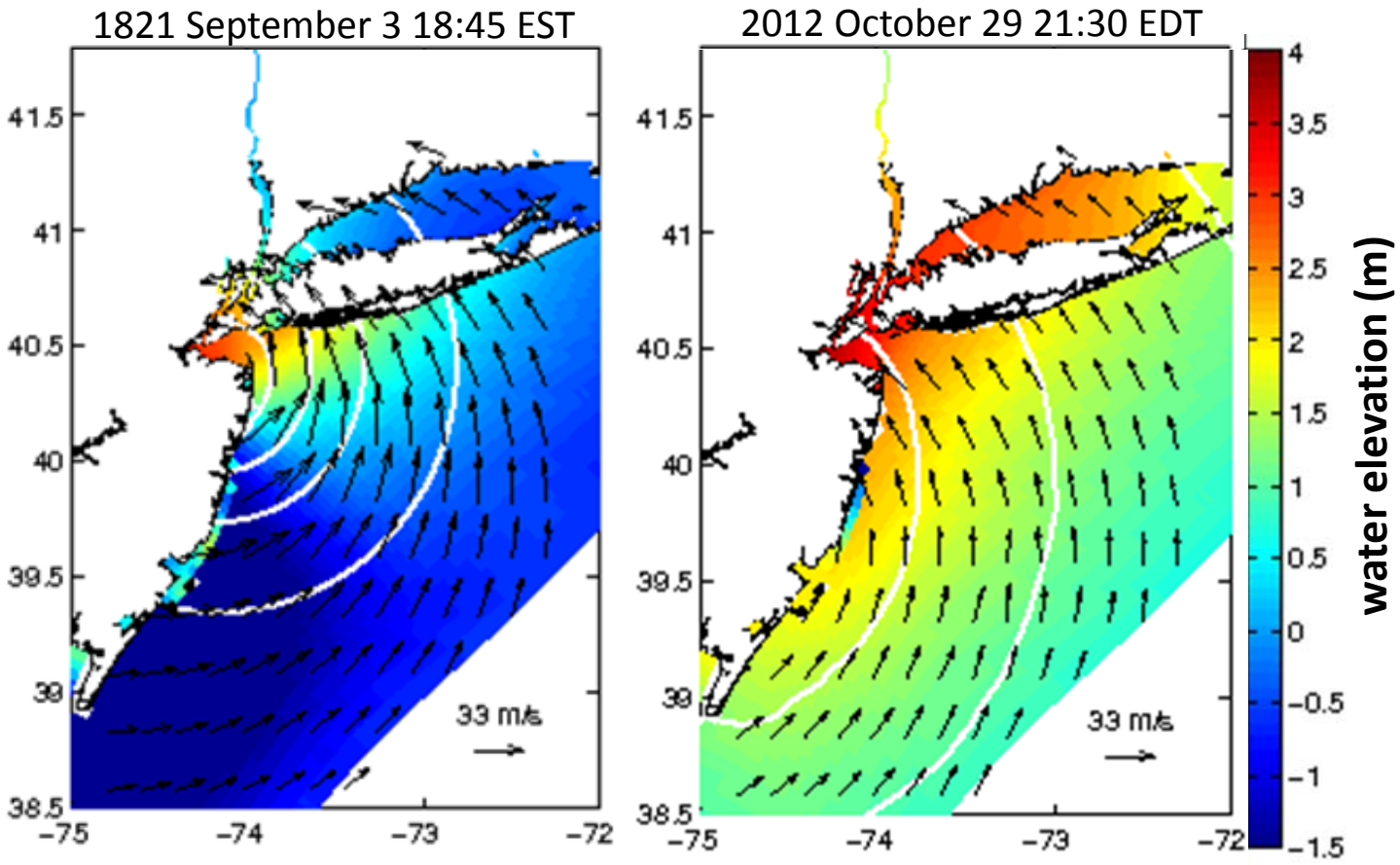
For model experiment B, the same shallowing is used, PLUS bed "roughness" representing wetlands or oyster beds was added.

Map of the New York City region and shaded bathymetry. Shown also are Jamaica Bay (dashed line box), The Battery (BAT), Inwood (JBI), and Spring Creek Park (SCP).



Hurricanes: 1821 and Sandy

Modeled water elevation relative to local mean sea level (LMSL) during (left) the Category-3 1821 Hurricane and (right) 2012 Hurricane Sandy, with wind vectors and white isobar lines. Local observed times are shown.



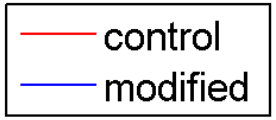
Orton et al., paper in prep.

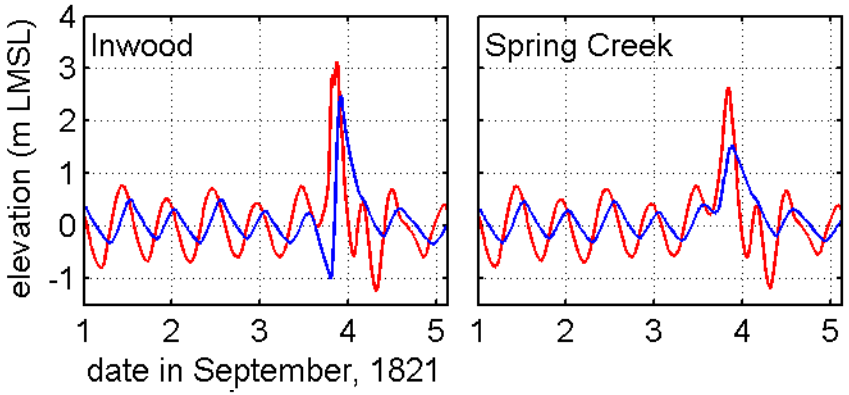
Experiment Results

Shallowing Only

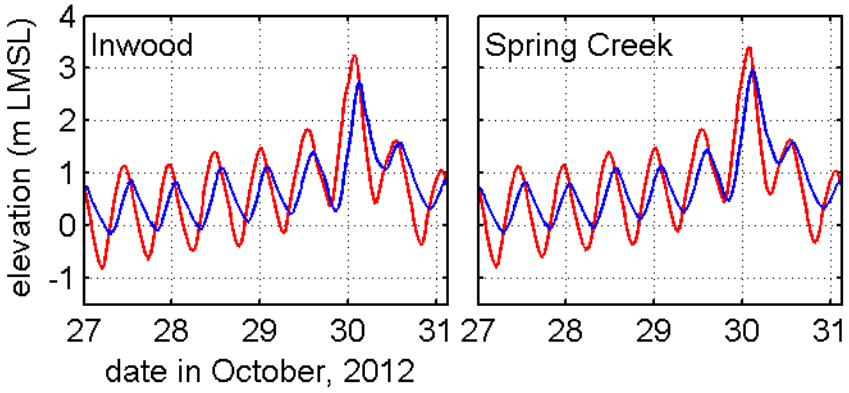
Experimental shallowing results for Jamaica Bay, showing water elevations for both the control and modified systems.

1821 Category 3 Hurricane (on today's sea level)





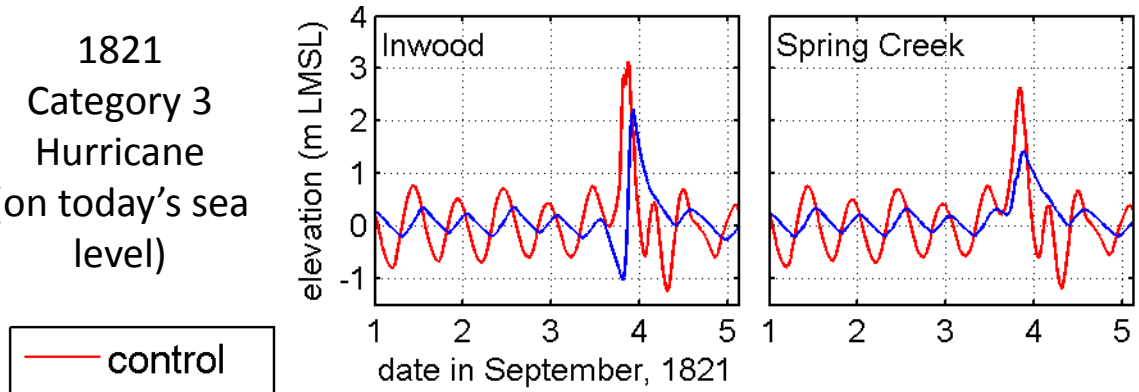
2012 Hurricane Sandy



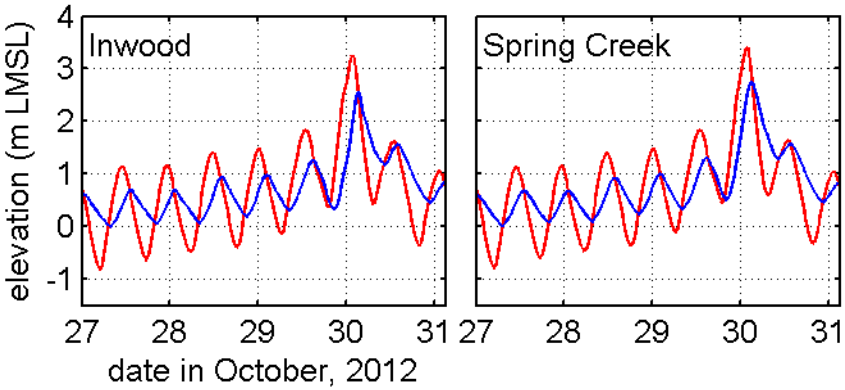
Flood reductions are:
66 cm, 113 cm for 1821.
50 cm and 44 cm for Sandy.

Shallowing + Wetland/Oyster Roughness

1821
Category 3
Hurricane
(on today's sea level)



2012
Hurricane
Sandy



Flood reductions are:
92 cm, 121 cm for 1821.
69 cm and 65 cm for Sandy.

Philip Orton, Stevens Institute of Tech.

Shallowing as Flood Protection

- The shallowing concept is a new one that we have been exploring
  - Not simple; In some places, shallow depths can make surges worse
  - In an enclosed waterway or inlet, a shallowed or narrowed channel can act as a bottleneck on the flow
- In research-in-progress with NYC, we have found similar results using a different ocean model, ADCIRC, which has much higher detail in Jamaica Bay
  - Broad coverage of wetland islands only slightly reduced flooding
  - Wetlands plus shallowing of channels reduced flooding substantially
  - Wetlands helped reduce wave heights, however

Conclusions: Surge Adaptation Modeling

- We have demonstrated techniques for quantifying flood protections (can assess surge barriers, wetlands, etc)
  - We are now widely applying them and have many people contributing designs for protection – talk to me later, and share your ideas!
- We have shown the potential role of channel shallowing
  - It reduced hurricane flood levels for Jamaica Bay by up to 46% or 1.2 m
  - This general approach may have broader applicability for coastal bays of Long Island, New Jersey, and worldwide
  - This approach (like most) has many limitations
    - requires massive amount of sediment
    - requires giving up shipping channel