

Modeling NY/NJ Harbor Storm Surge Flooding and Influences of Barriers and Natural Systems

Philip Orton

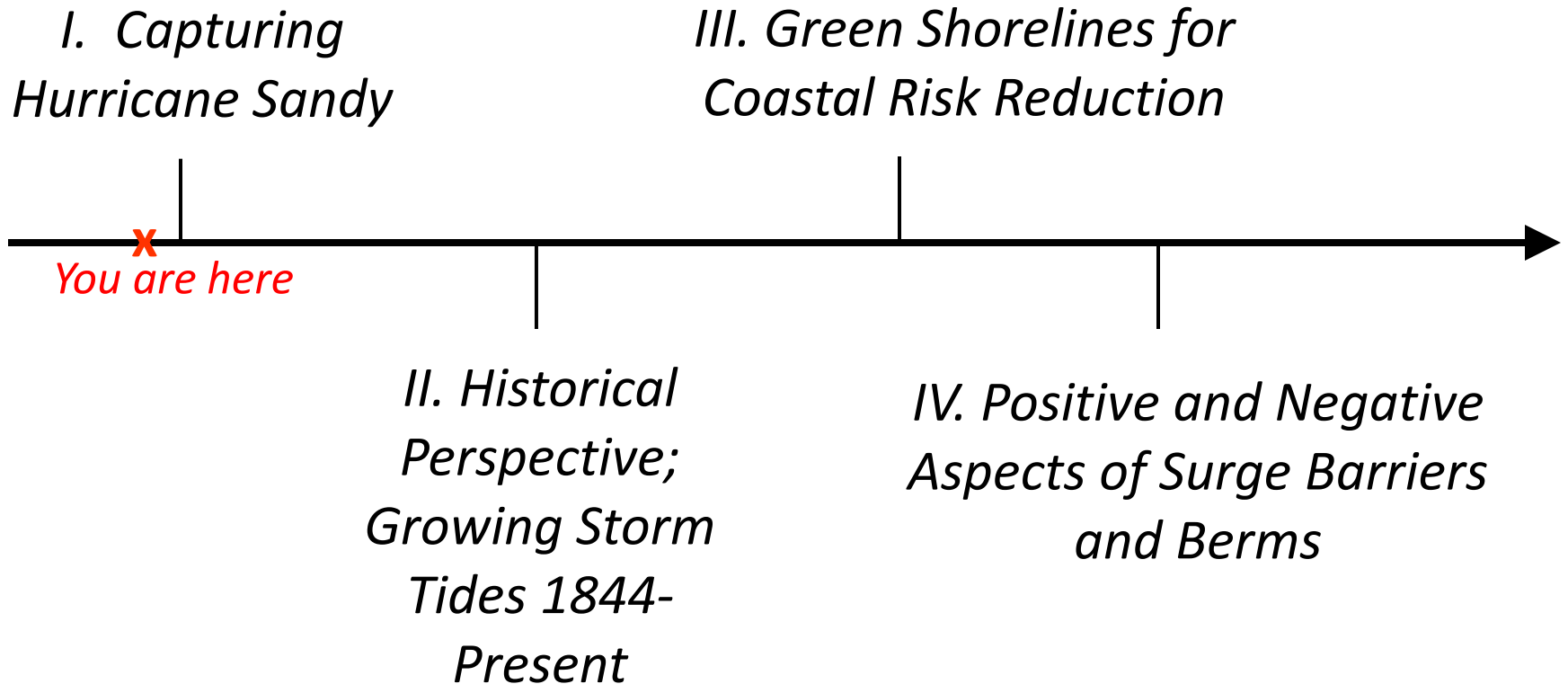
Much help from Nickitas Georgas, Sergey Vinogradov, Alan Blumberg
Davidson Laboratory, Stevens Institute of Technology



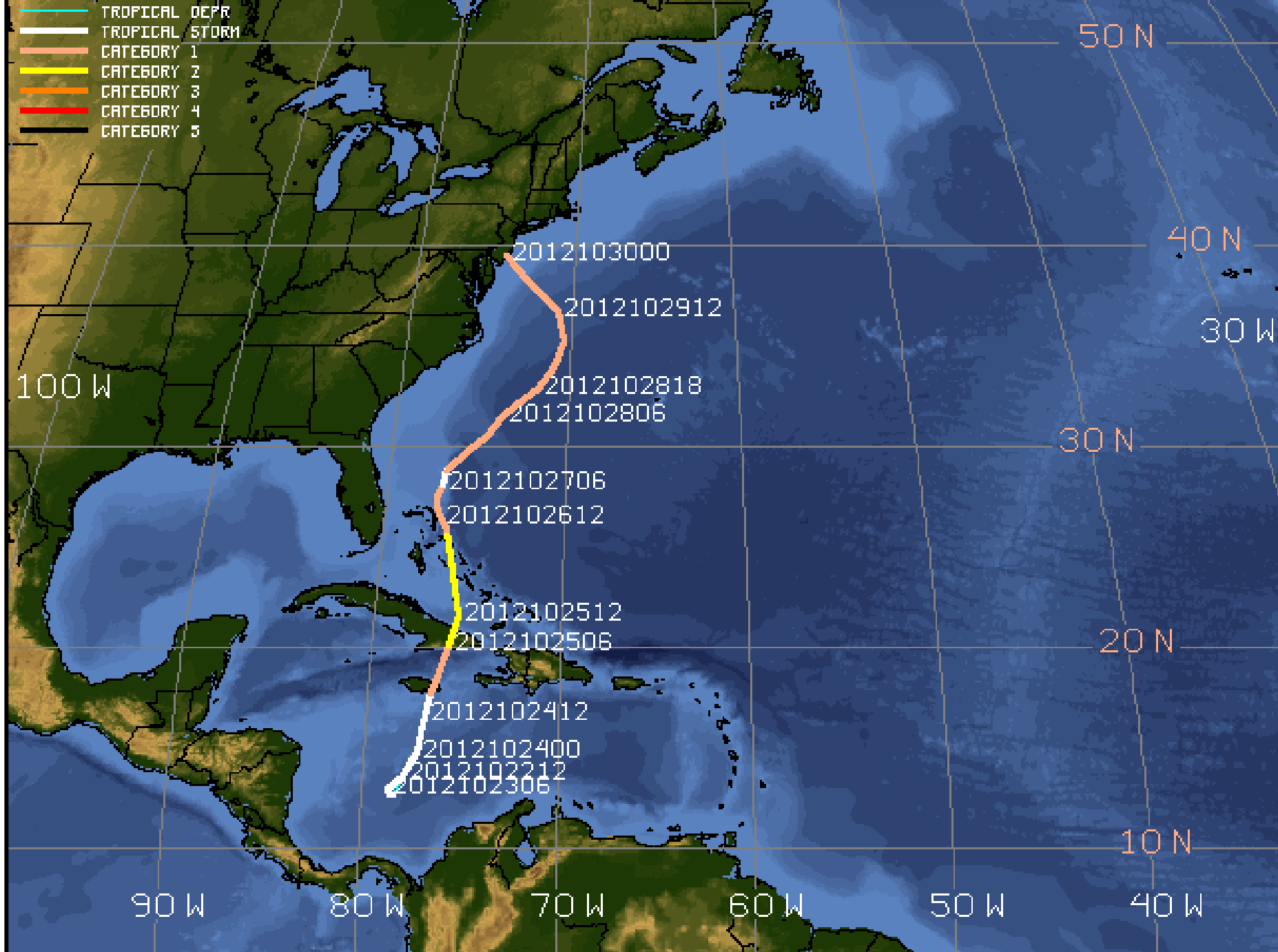
Funding from the NOAA RISA Program (Rosenzweig et al.) project:
“Consortium for Climate Risk in the Urban Northeast (CCRUN)”
and a NASA project for research supporting the Nat’l Climate Assessment
Thanks also to the CUNY High Performance Computing Center



Timeline



- TROPICAL DEPR
- TROPICAL STORM
- CATEGORY 1
- CATEGORY 2
- CATEGORY 3
- CATEGORY 4
- CATEGORY 5



Track Info : 22OCT2012/12:00UTC - 30OCT2012/00:00UTC

Sandy By the Numbers: NYC Flooding

- Coastal flood elevations in New York Harbor (14.1 ft MLLW) were the highest in all ~300 years of New York City history
- It beat the storm tide of Irene by 4.6 ft, the (80 year) tide gauge record of Hurricane Donna (1960) by 4.0 ft, and the estimated all-time record of about 12-13 ft from the Hurricane of 1821
- The flood elevation at Kings Point was 14.0 ft a few hours later, with a peak storm surge of 12.3 ft coming near LOW tide – fortunate!

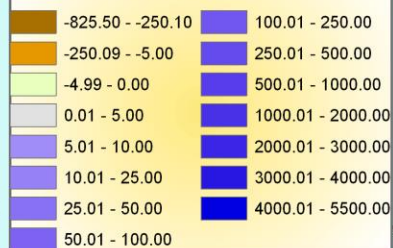
Stevens sECOM nested model grids

302 x 302
Average
resolution:
4.3 km

NYHOPS grid

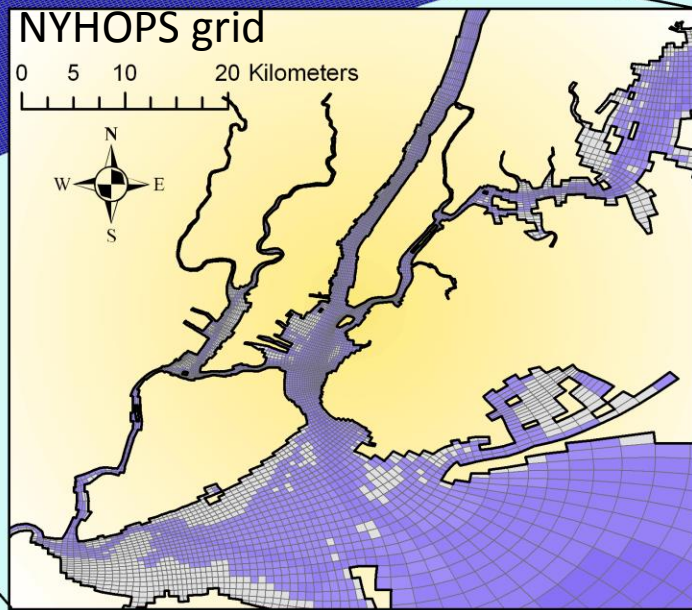
SNAP Grid

Bathymetry, meters



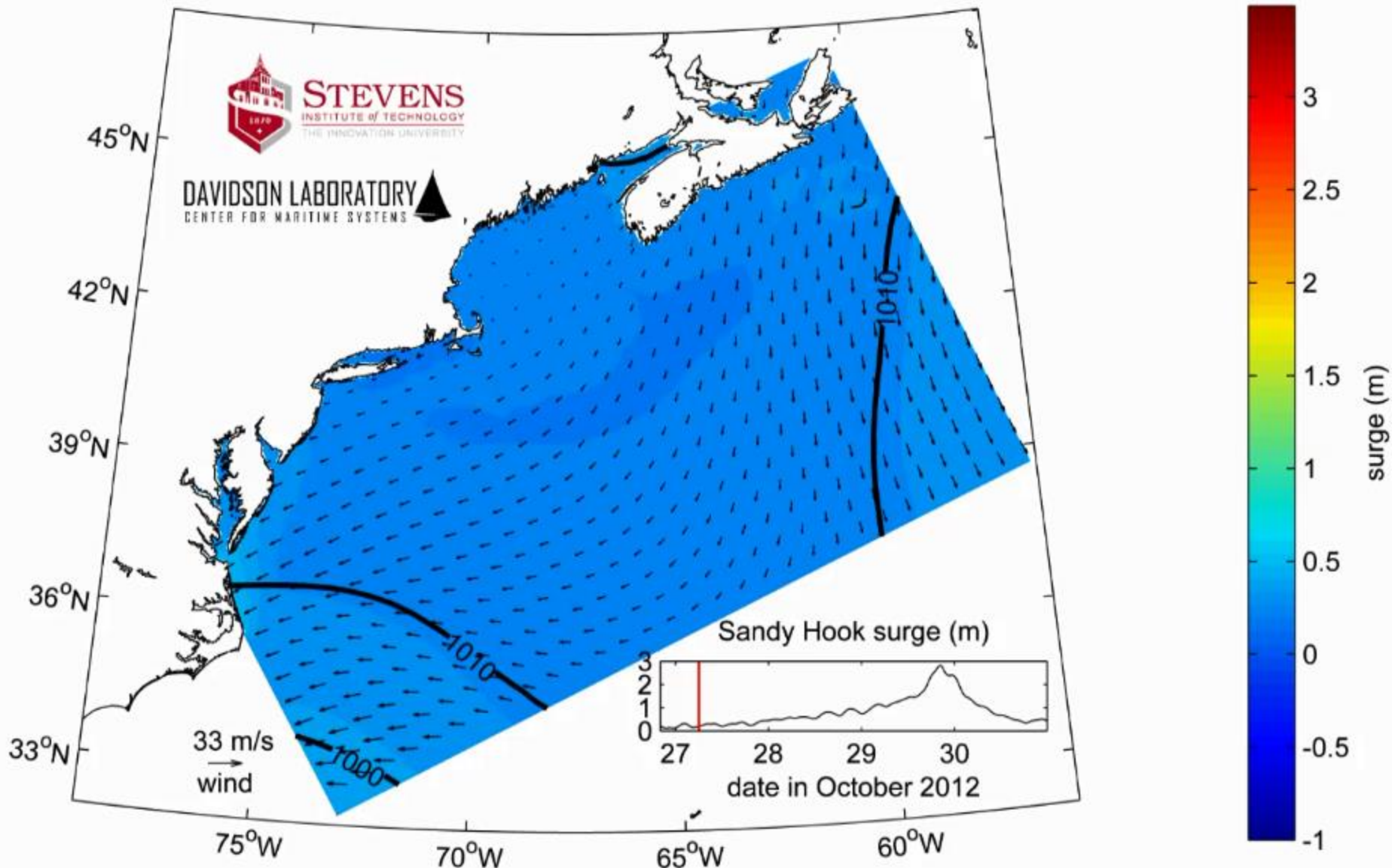
NYHOPS grid

0 5 10 20 Kilometers



Model Results Here Onward are Based on: Ocean Weather Inc. (OWI) meteorological reanalysis

27-Oct-2012 06:05:00 EDT

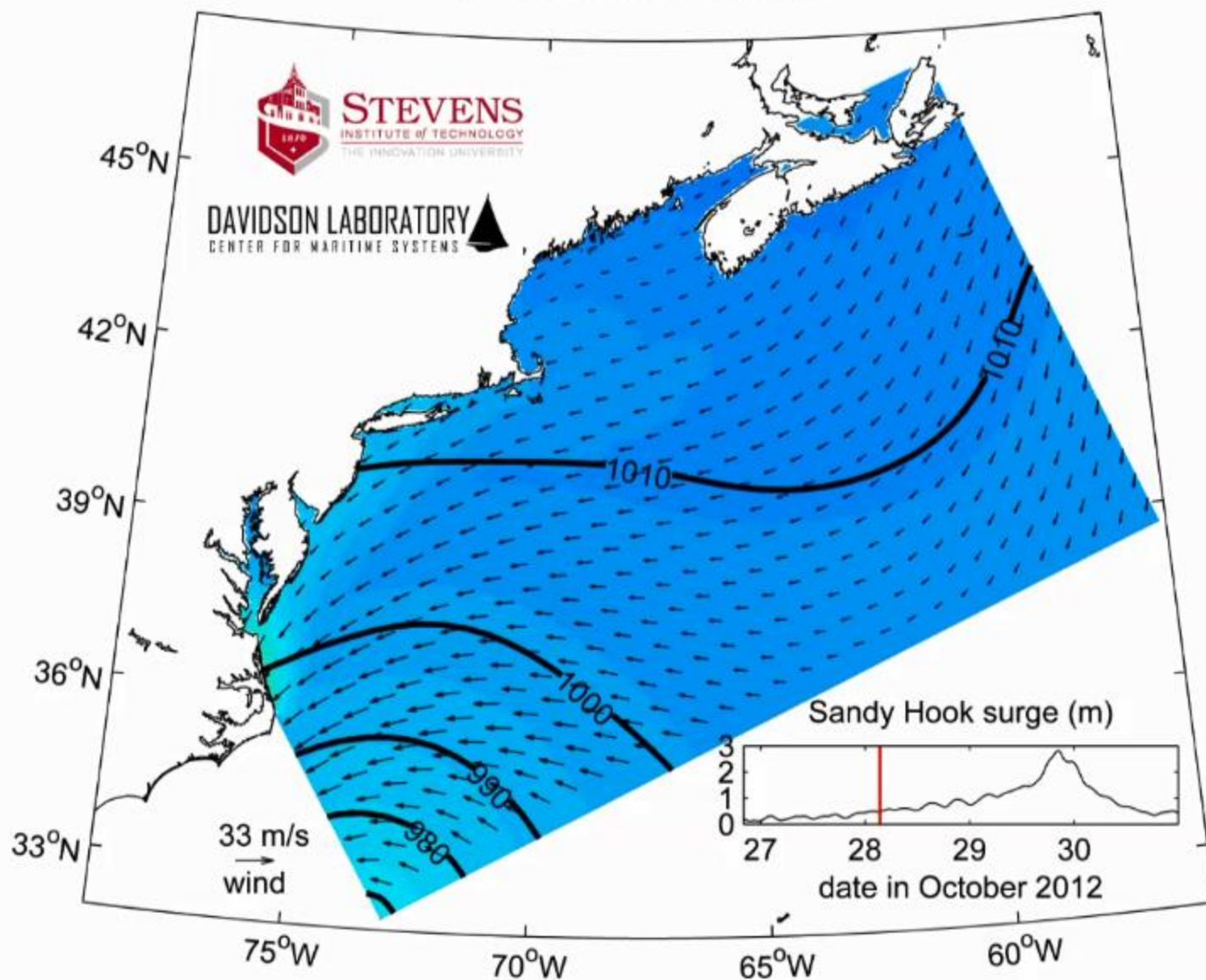


28-Oct-2012 03:25:00 EDT



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DAVIDSON LABORATORY
CENTER FOR MARITIME SYSTEMS

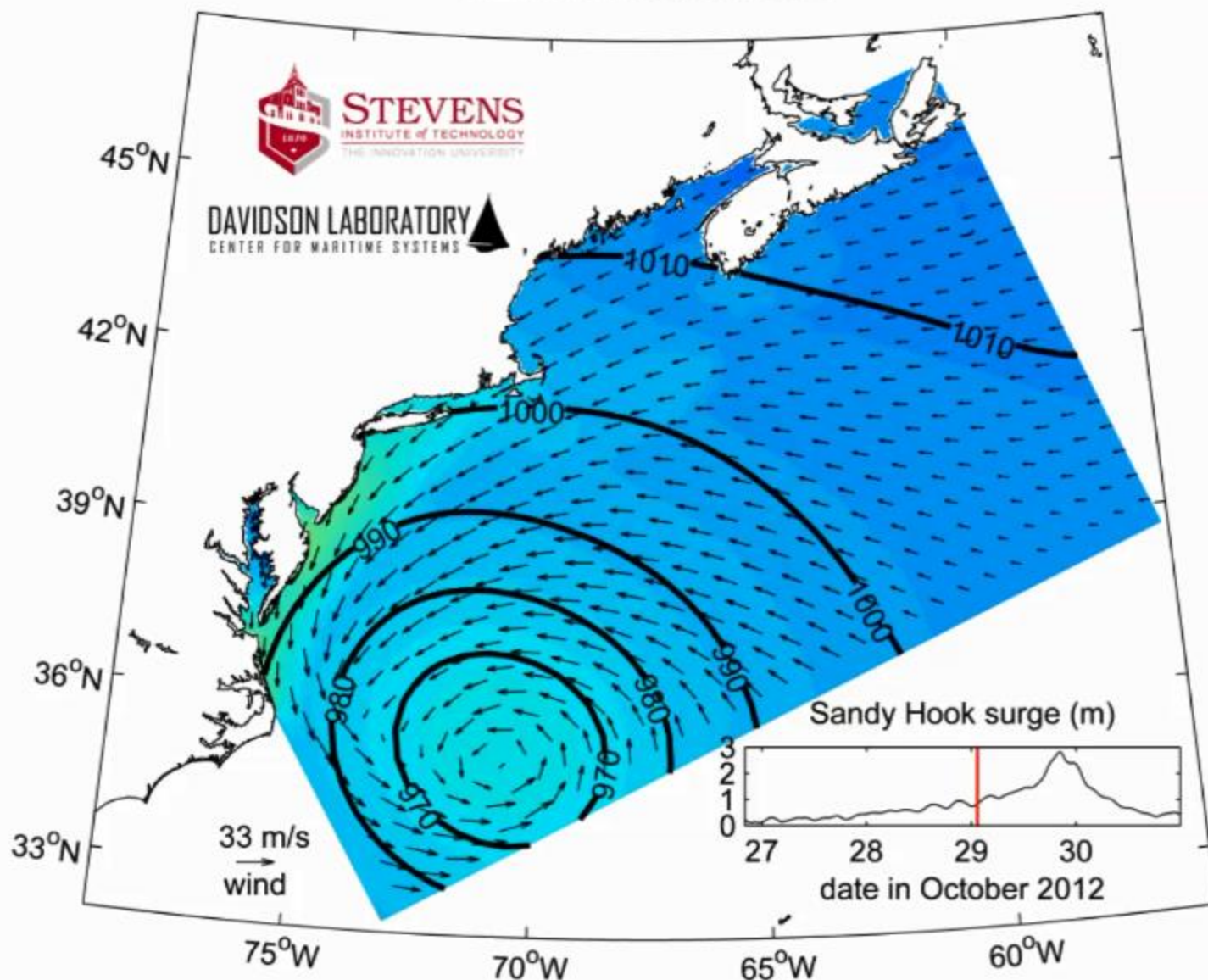


29-Oct-2012 01:25:00 EDT



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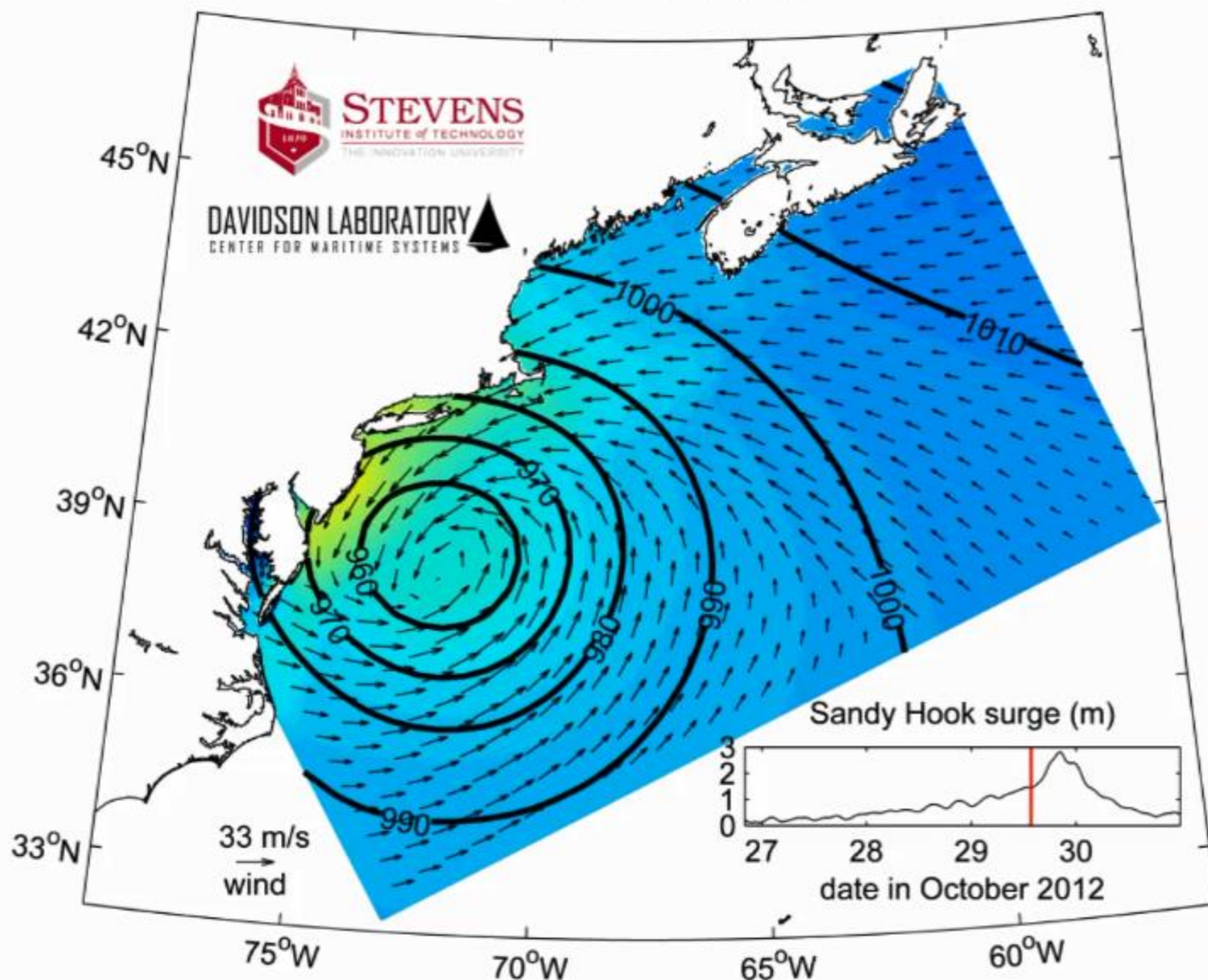


29-Oct-2012 13:45:00 EDT



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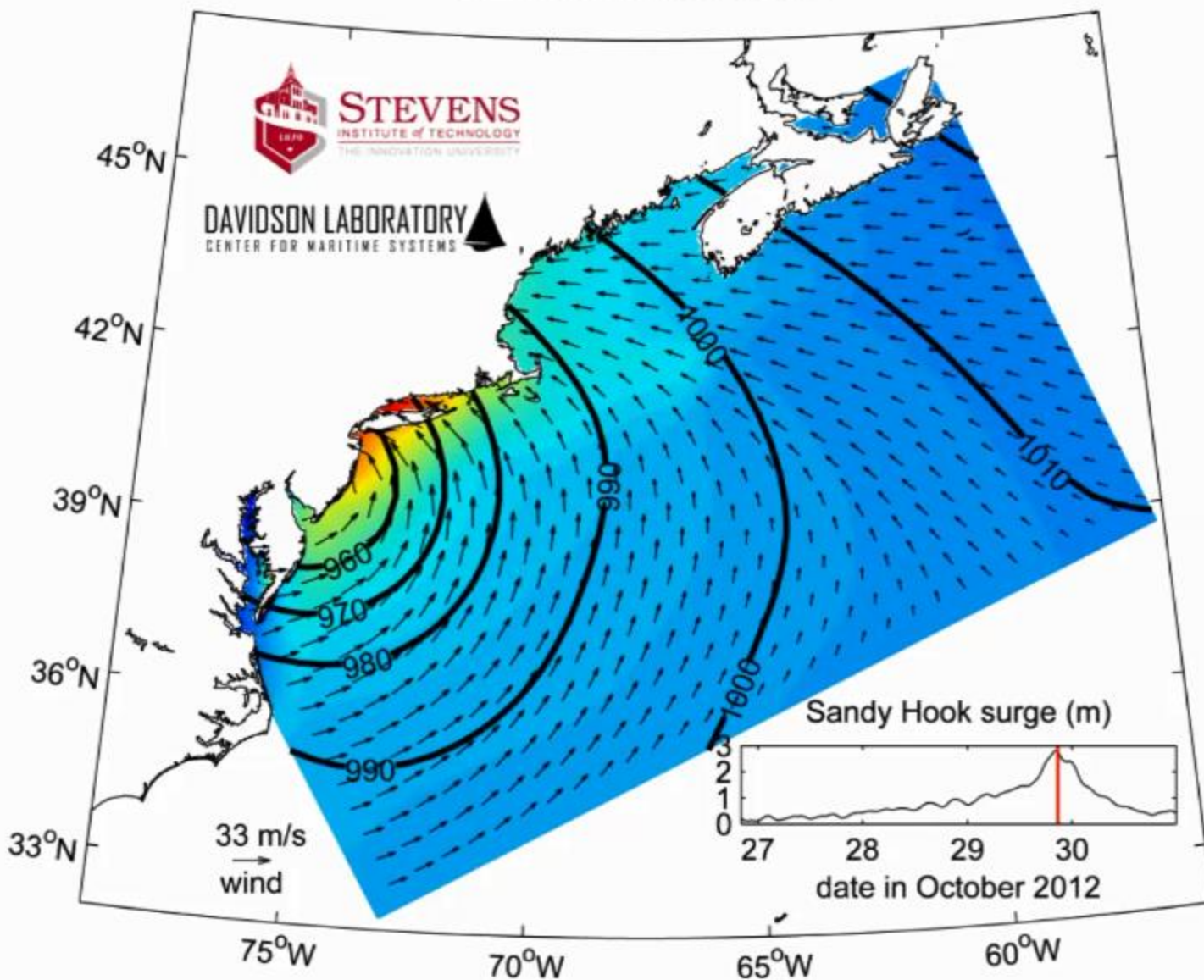


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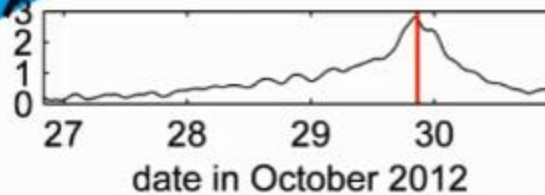


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Sandy Hook surge (m)

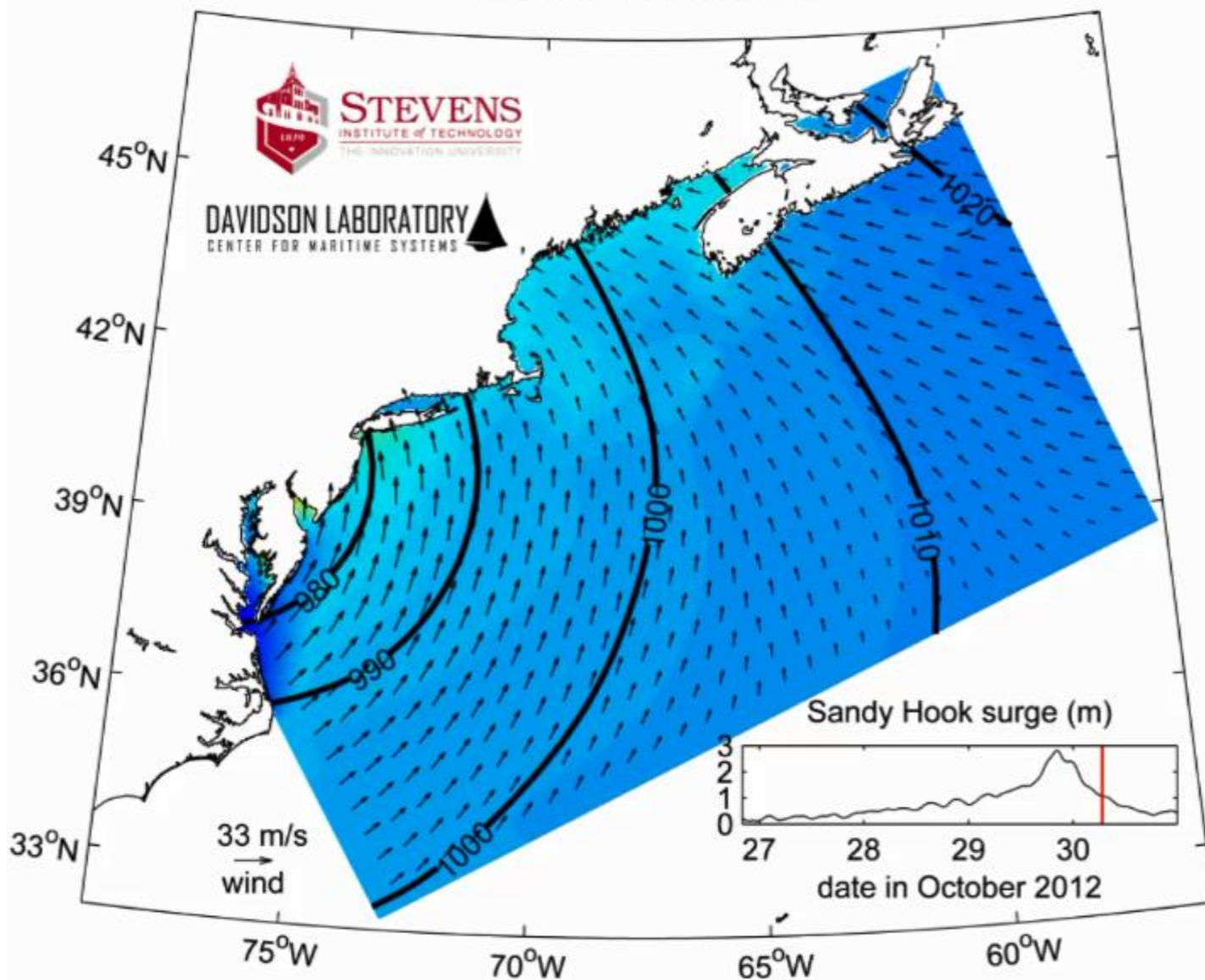


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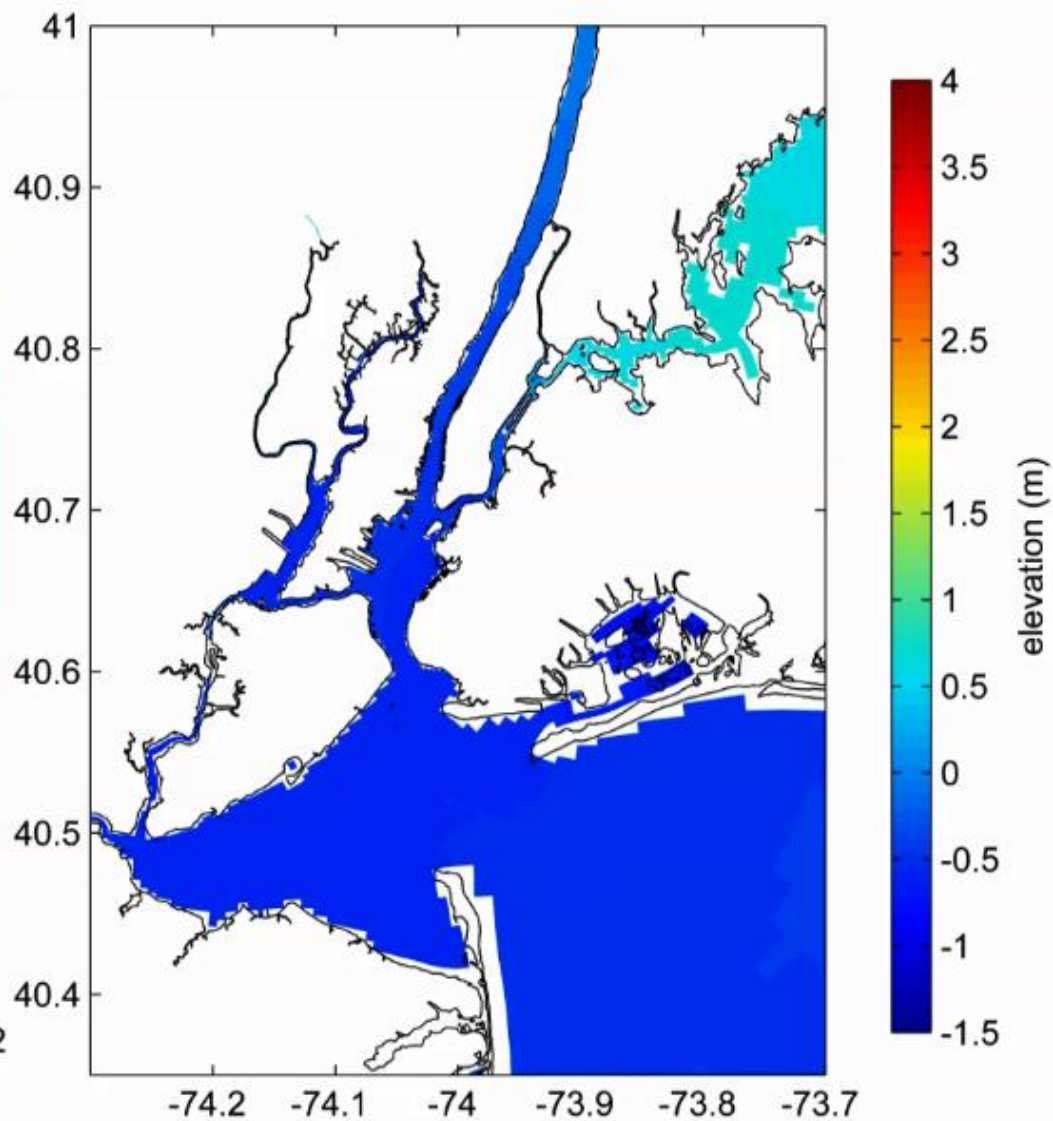
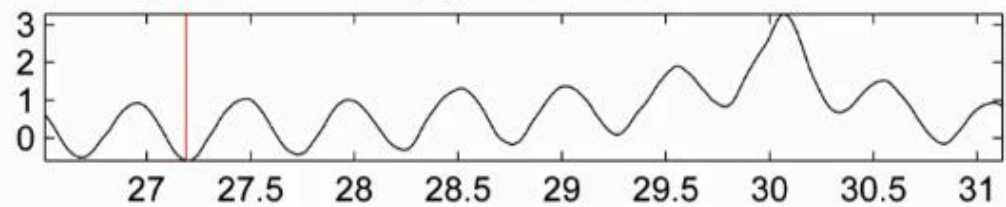
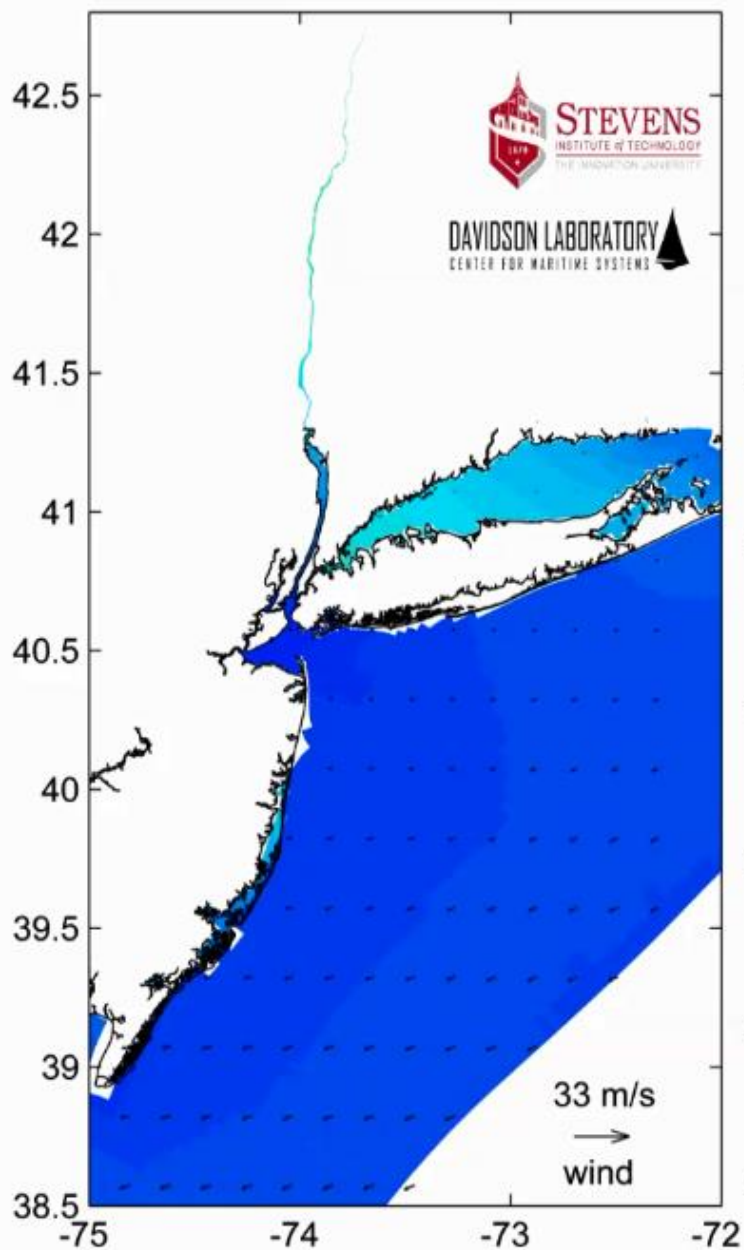


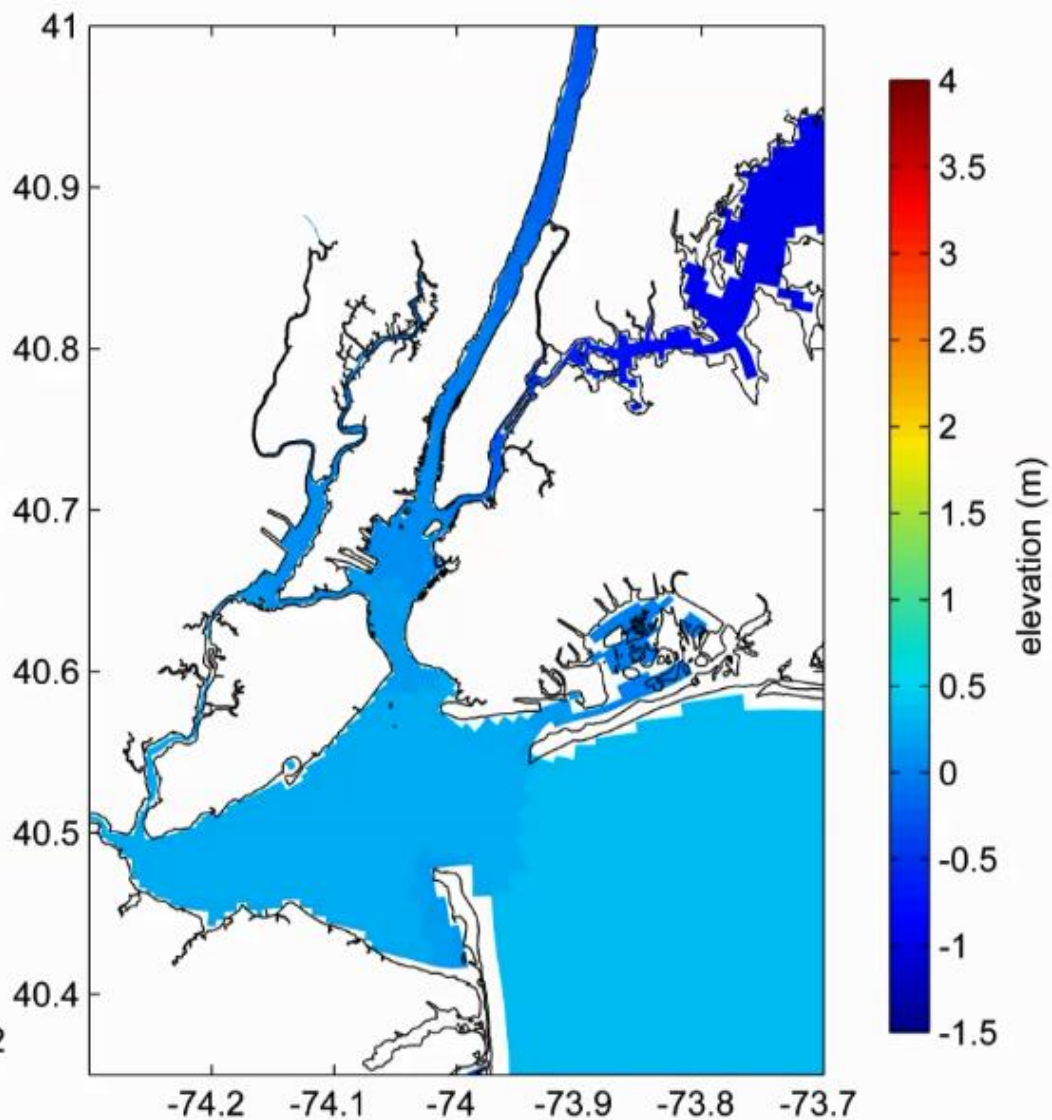
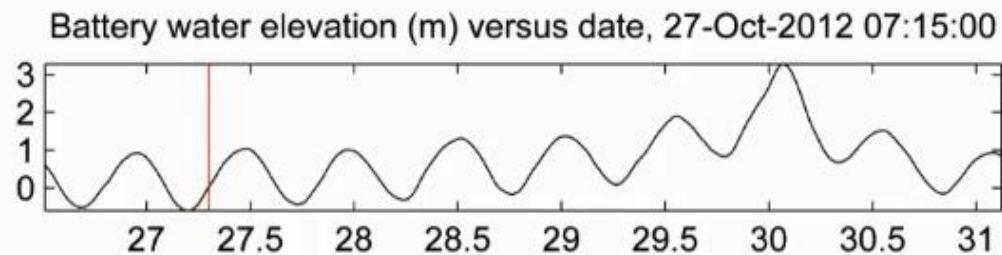
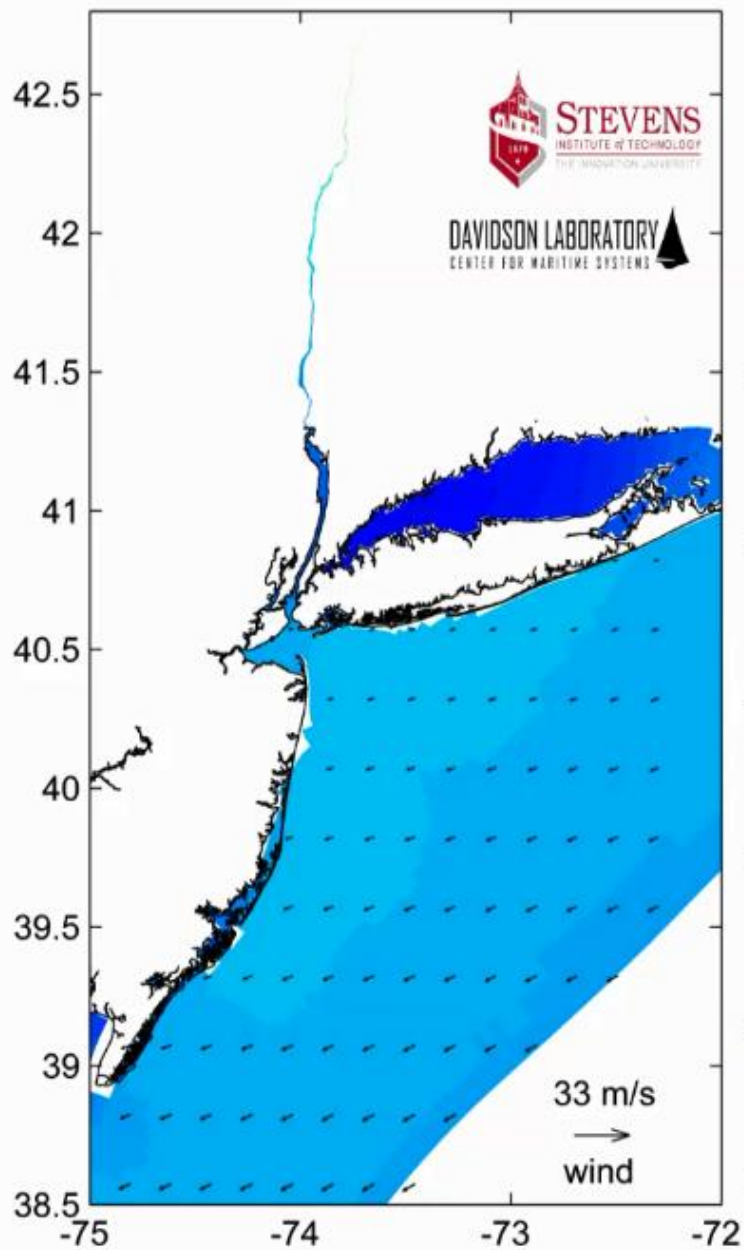
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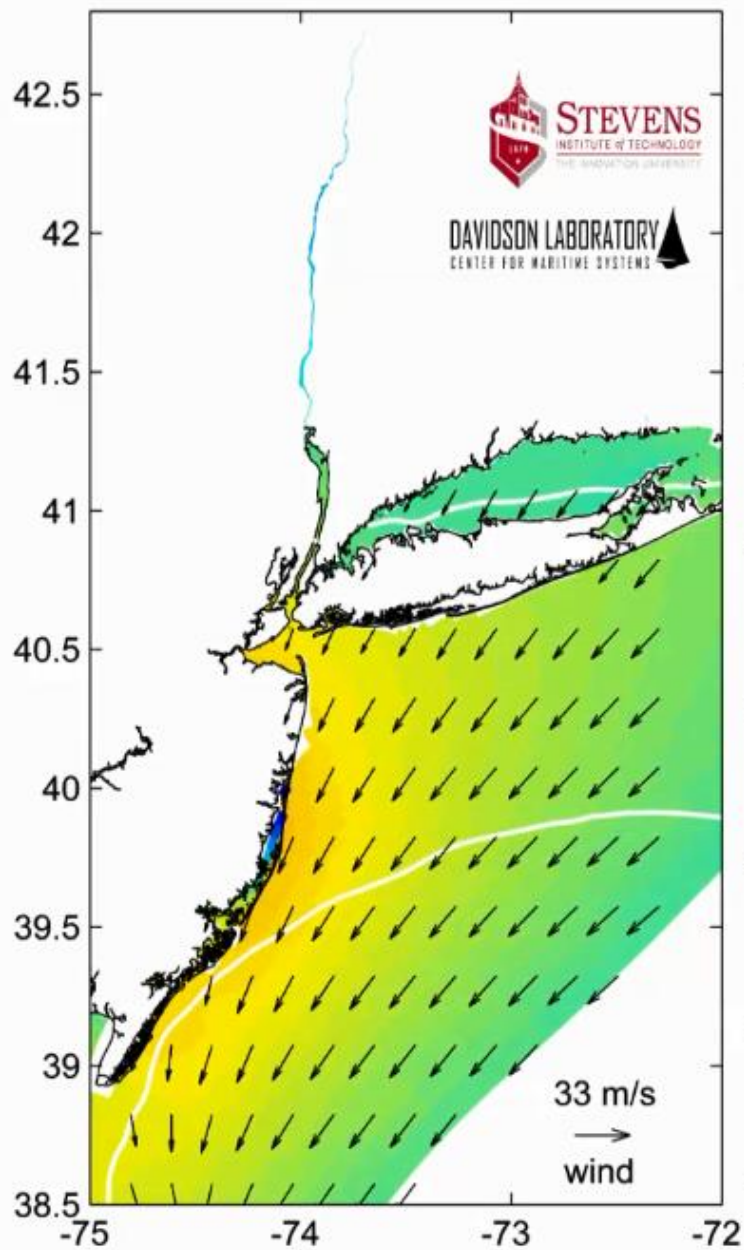
DAVIDSON LABORATORY
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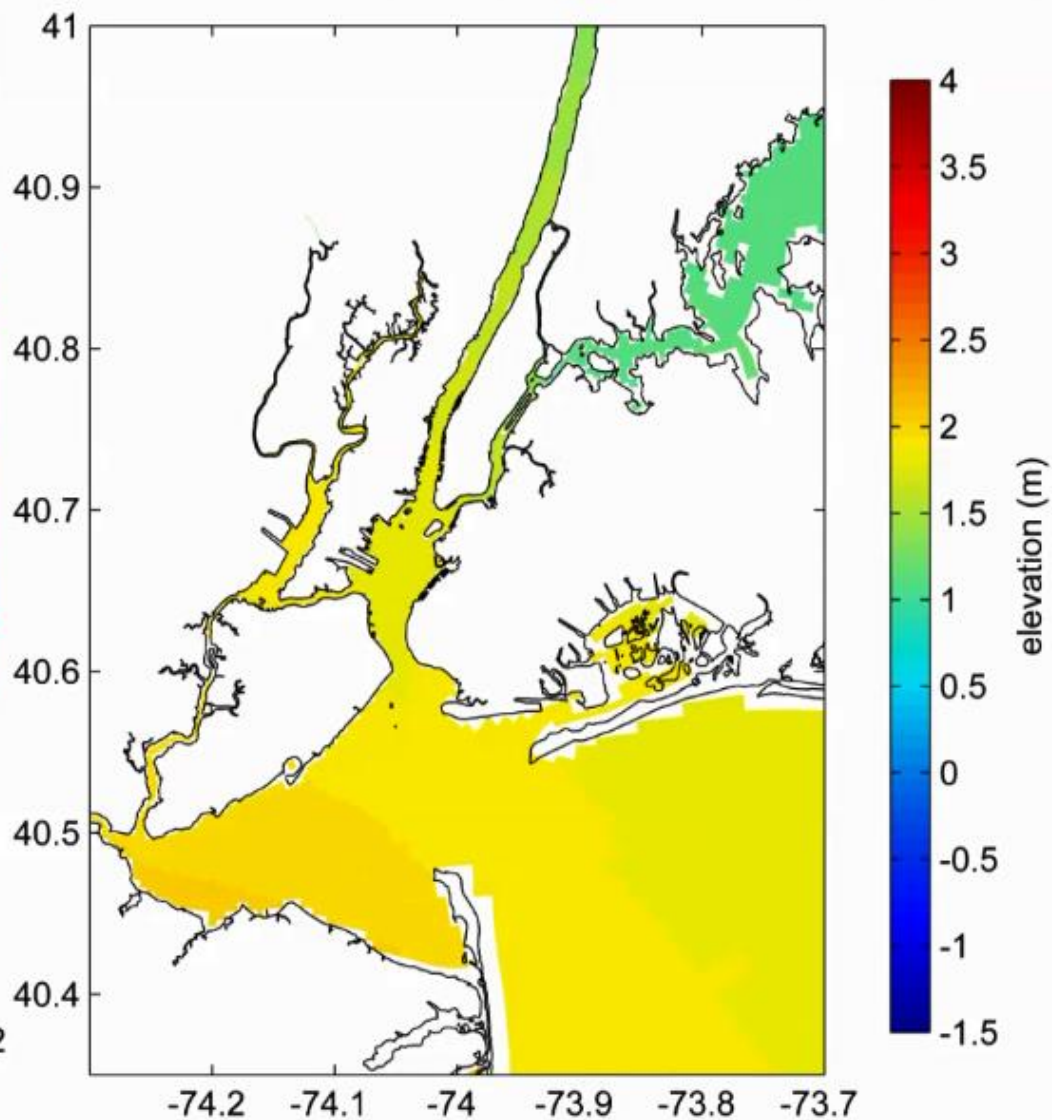
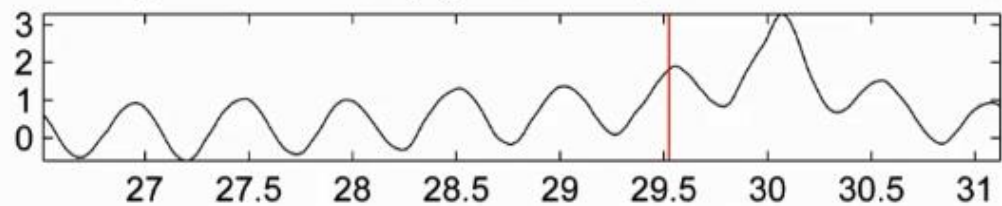
Battery water elevation (m) versus date, 27-Oct-2012 04:35:00



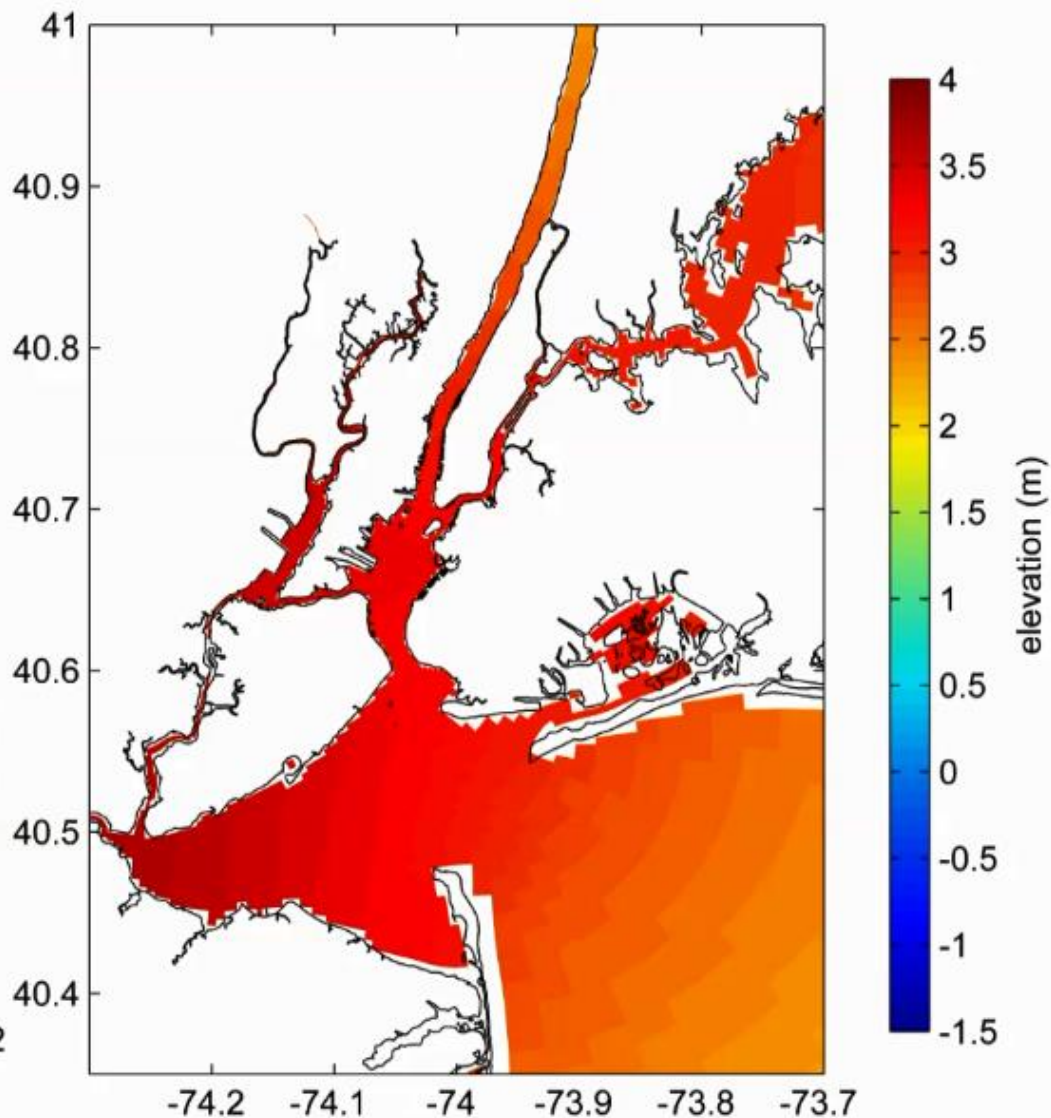
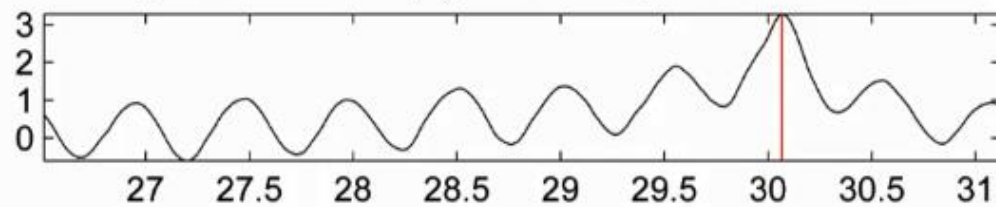
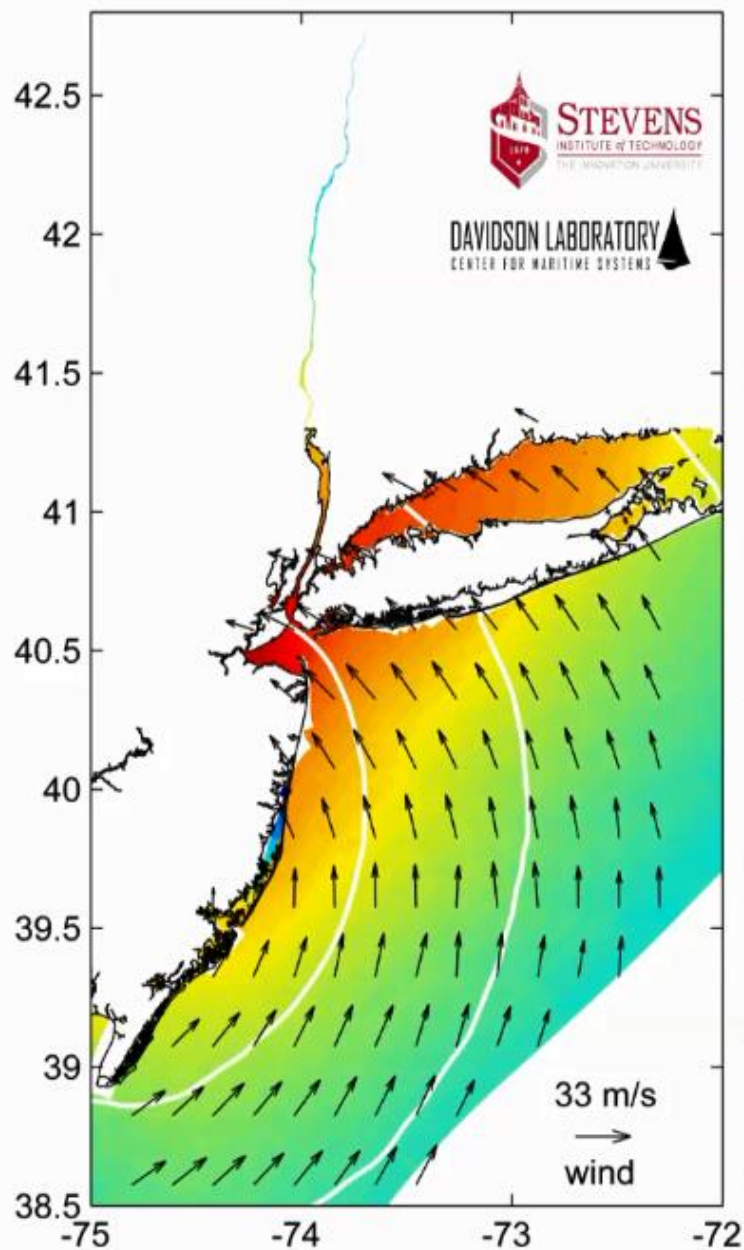


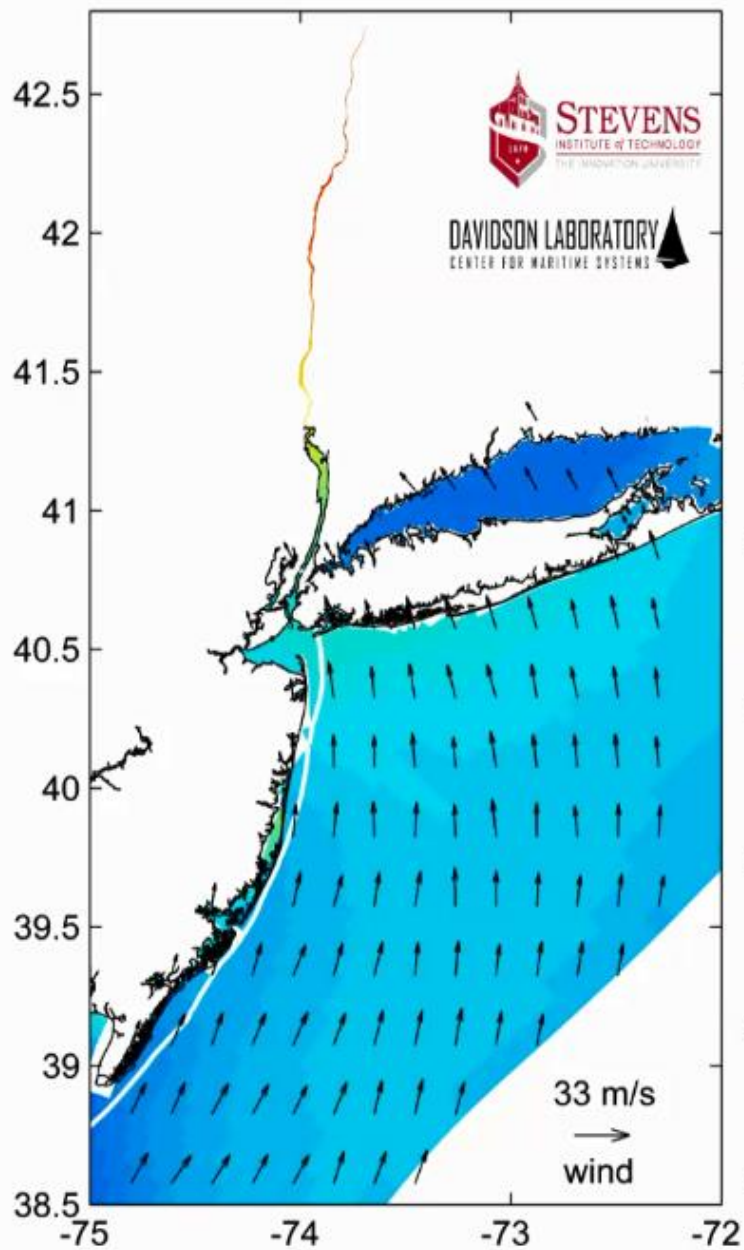


Battery water elevation (m) versus date, 29-Oct-2012 12:35:00

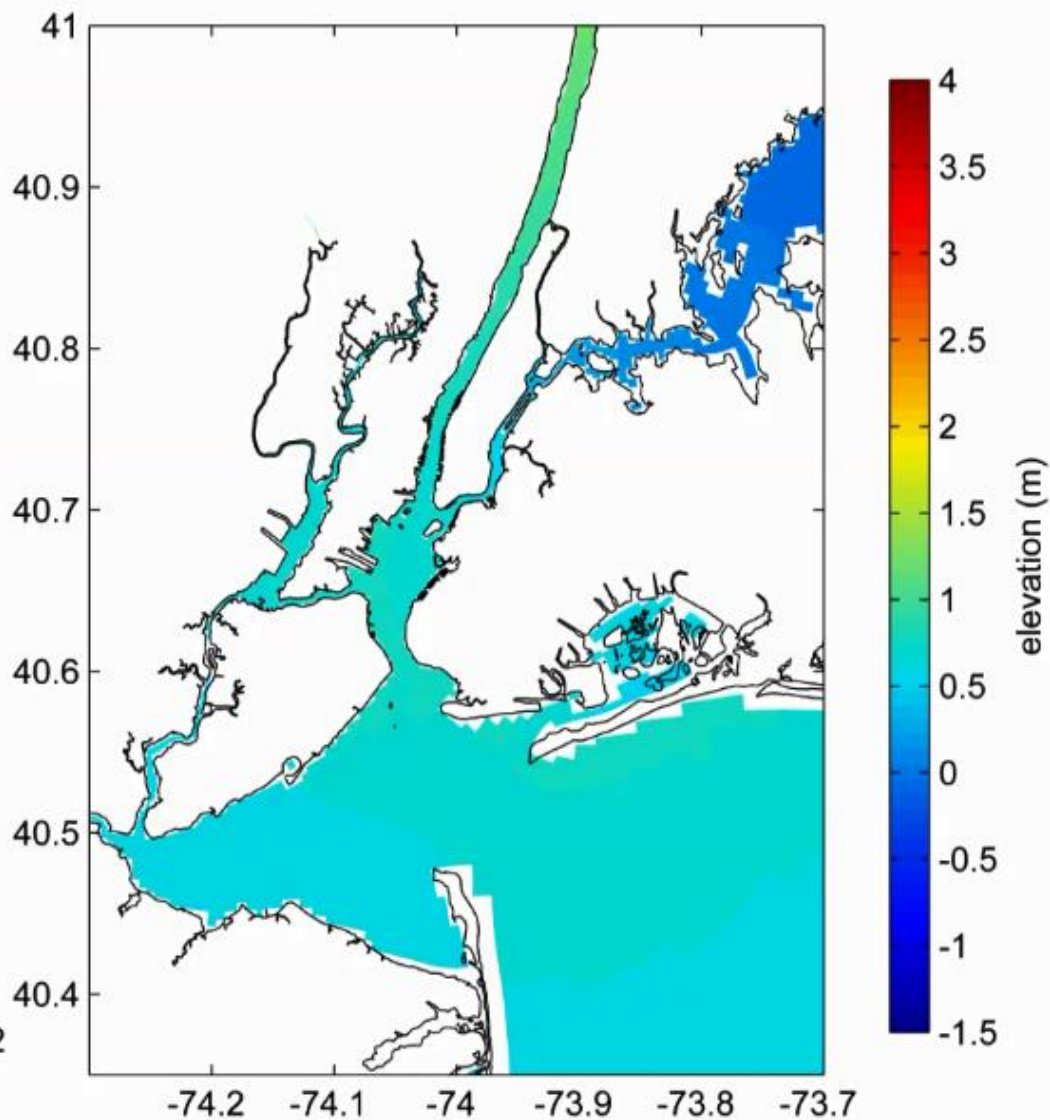
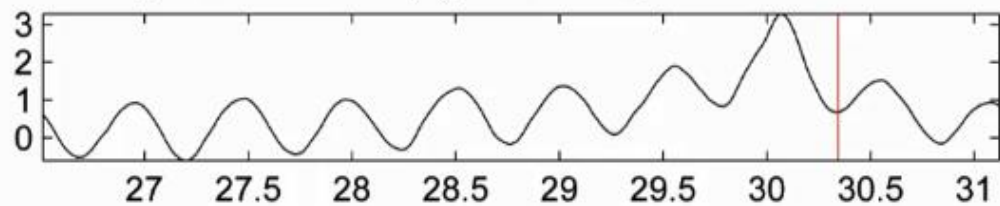


Battery water elevation (m) versus date, 30-Oct-2012 01:35:00

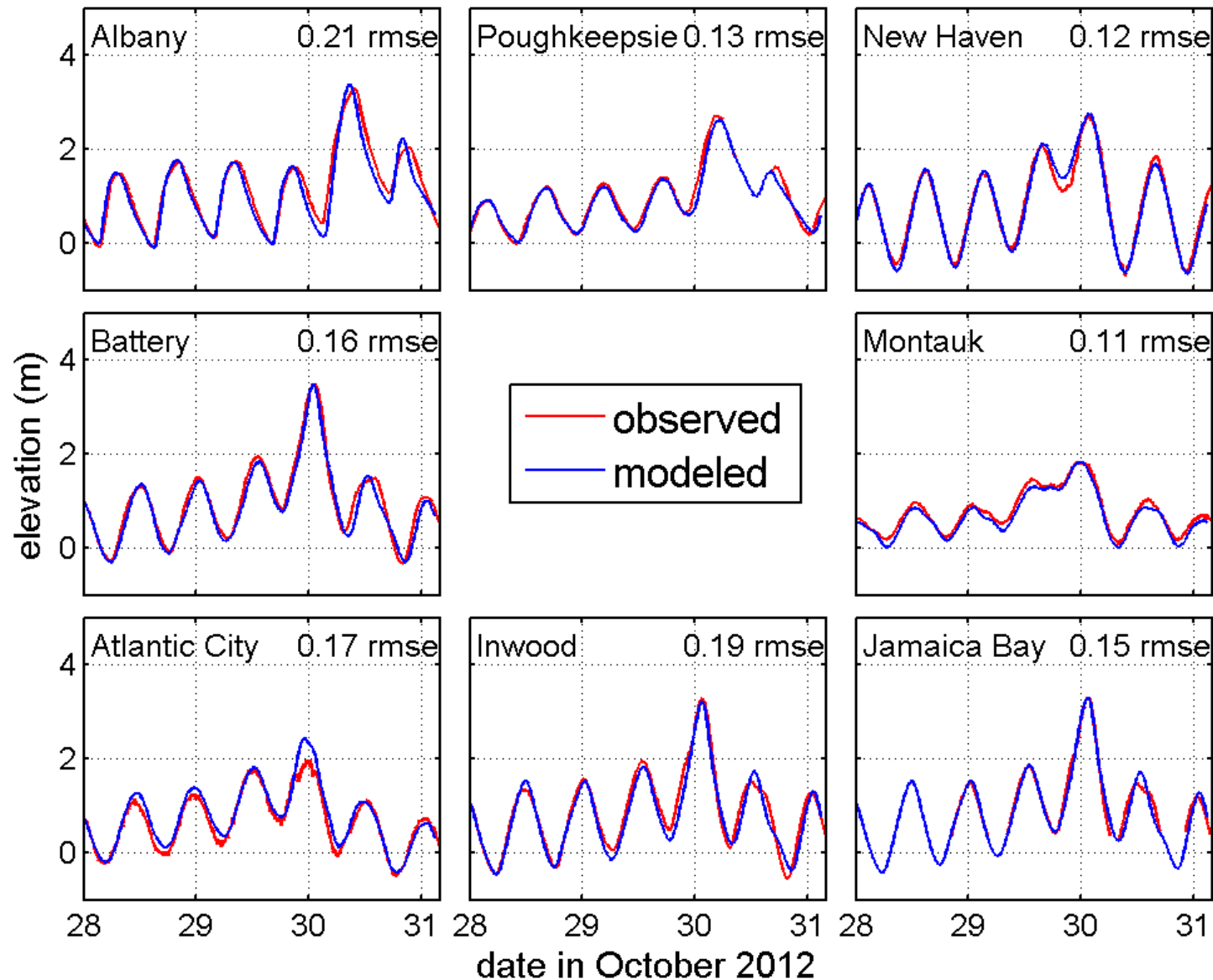




Battery water elevation (m) versus date, 30-Oct-2012 08:15:00



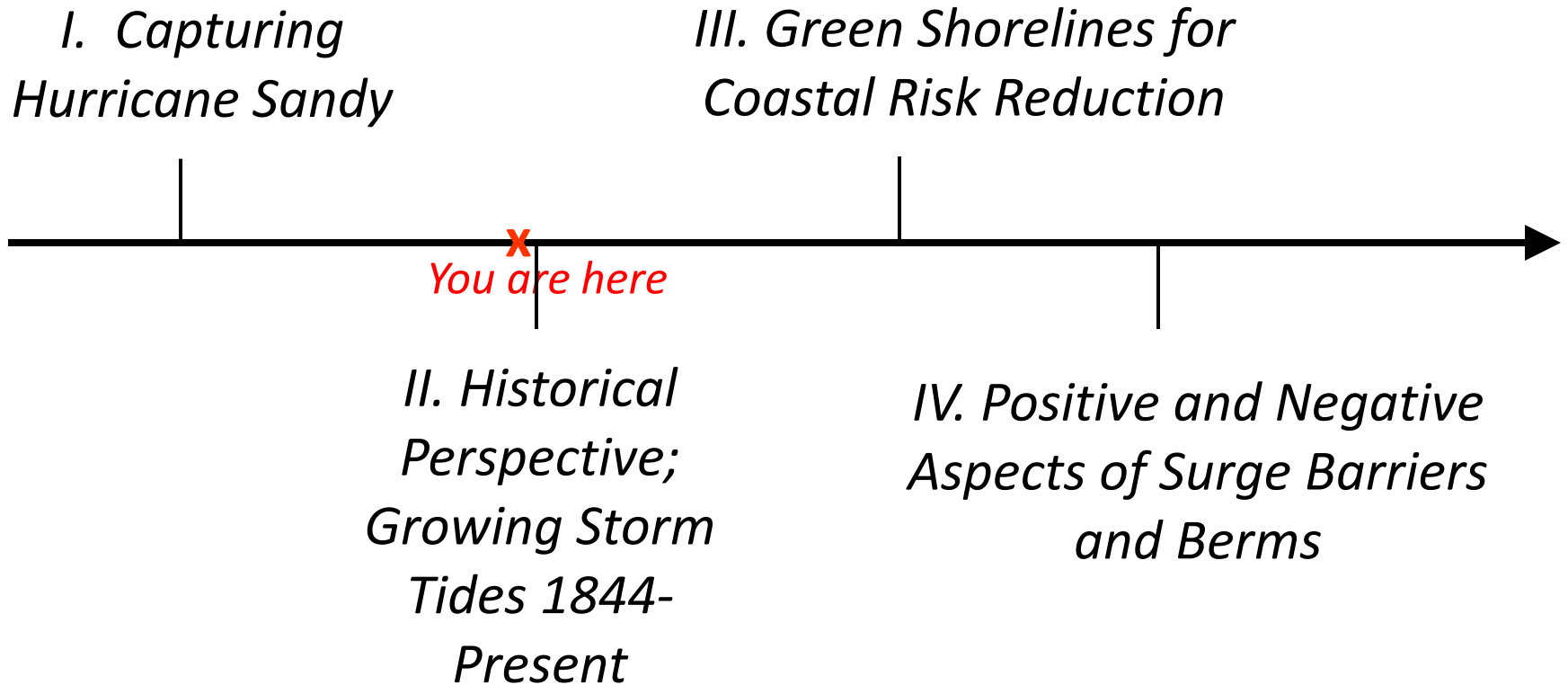
Model Validation for Sandy Hindcast



South Street Seaport, Just Behind Waterfront

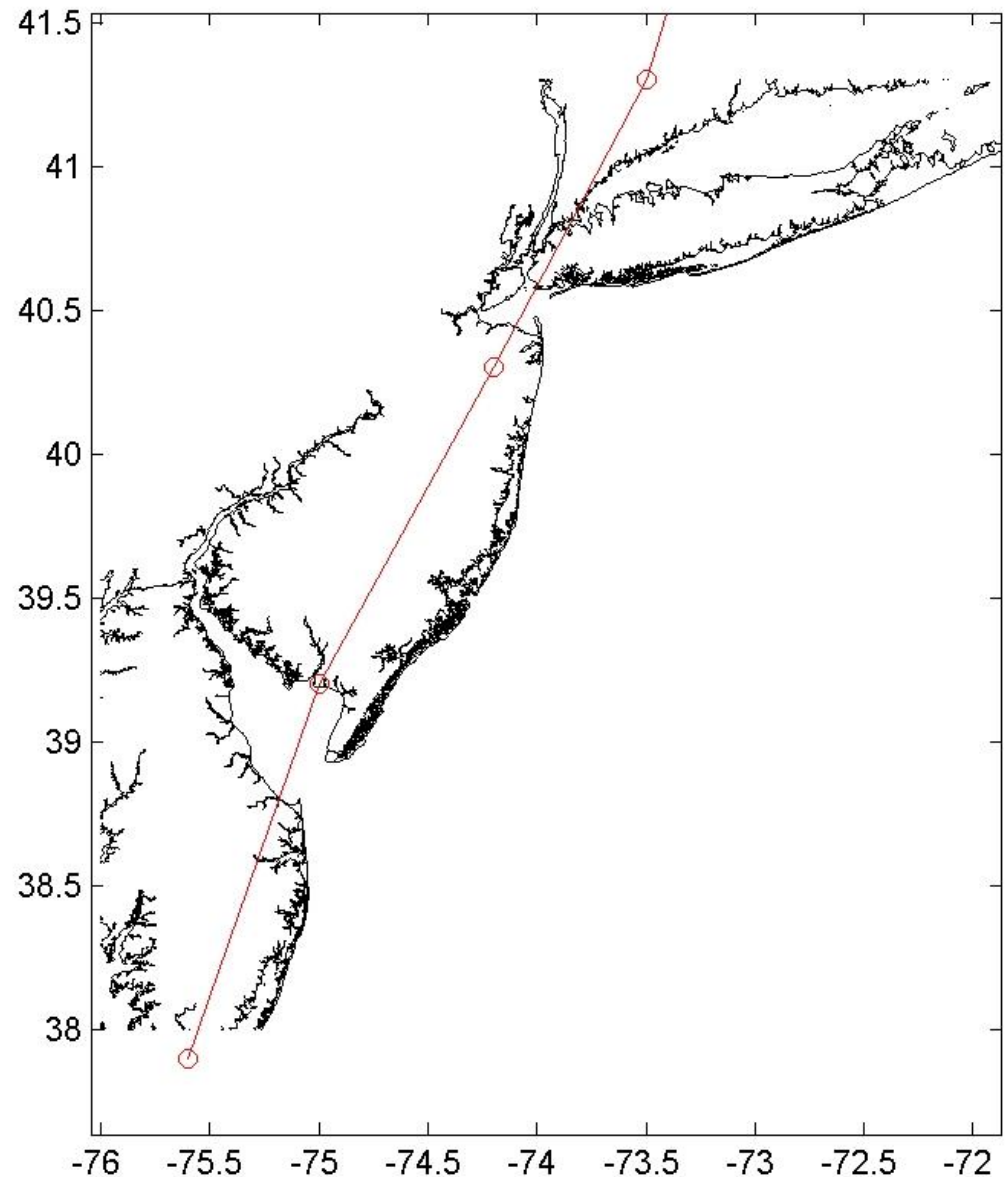


Timeline

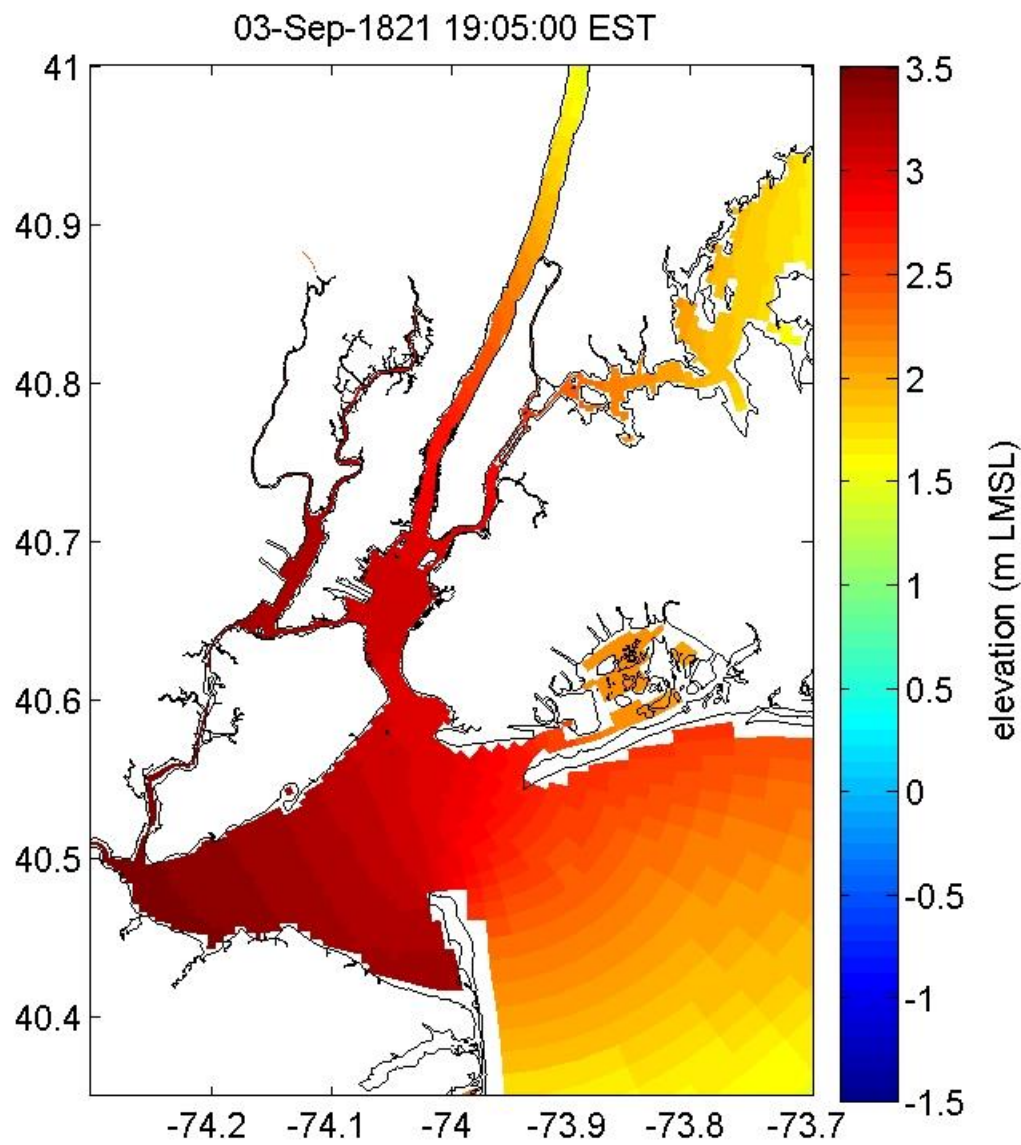
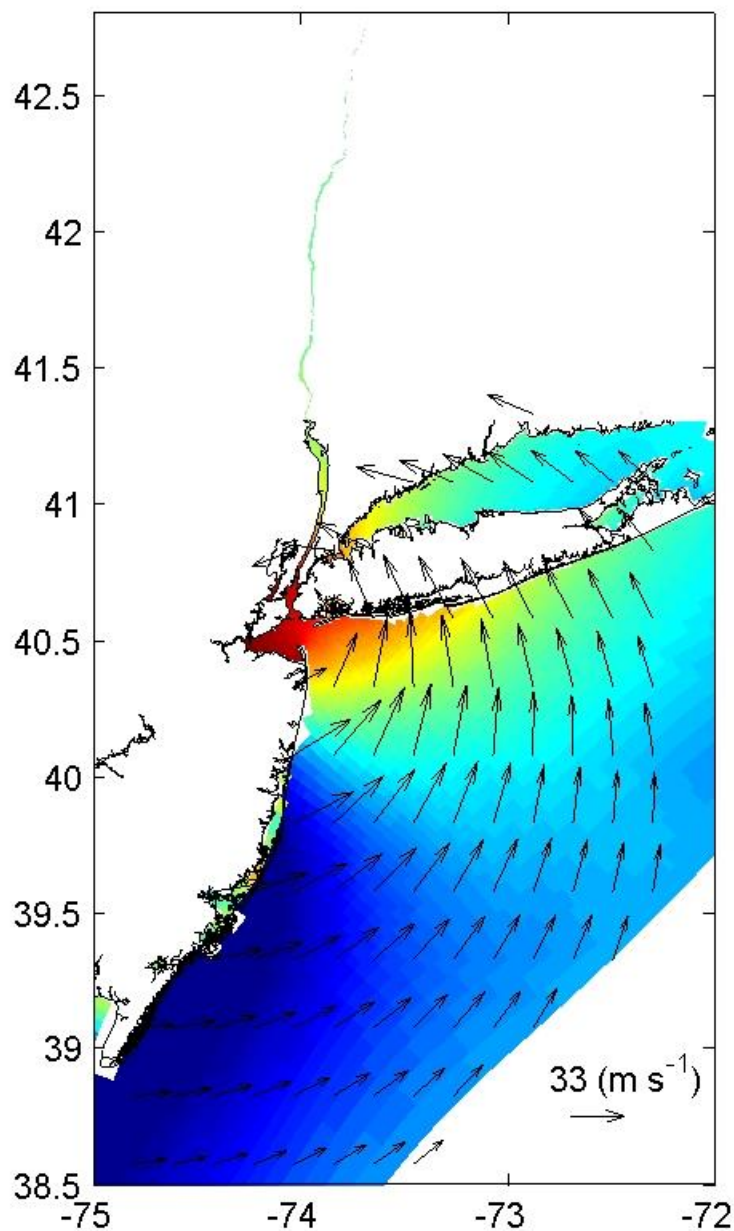


1821 Hurricane: Worse than Sandy?

- Estimated Cat-3 storm at NYC landfall
- Max wind speed: 108 mph (vs 80)
- 13 feet in one hour!?
- (don't just prepare for the next Sandy.)



1821 Simulated Wind Vectors and Water Elevation

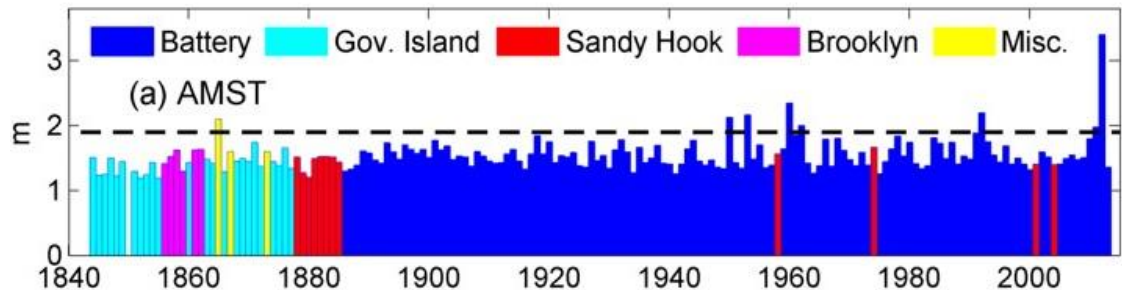


Historical Changes in Storm Tides

Talke, Orton, Jay – in press, *Geophysical Research Letters*

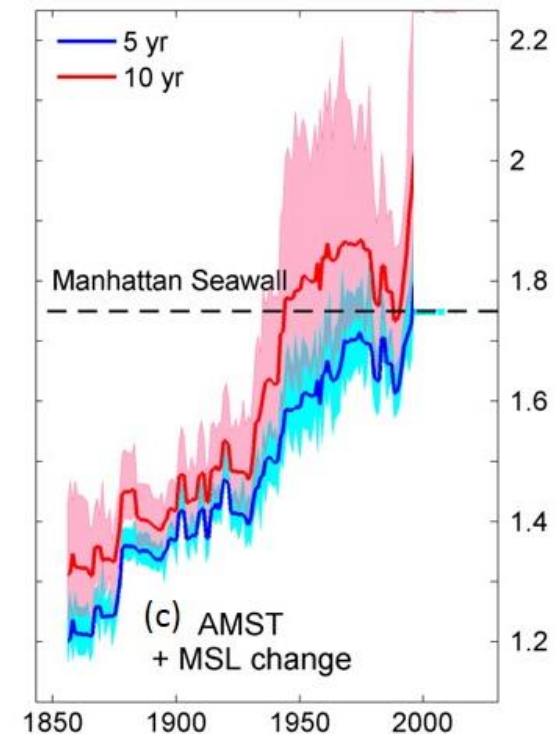
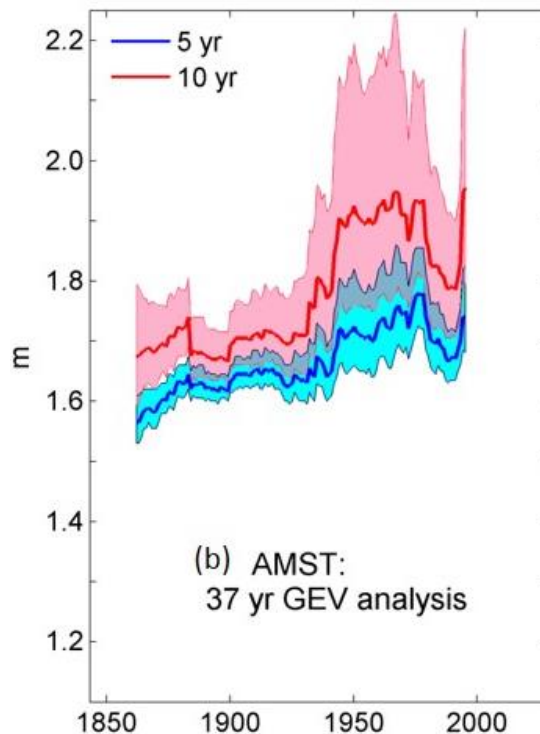
Mean time of Observation.		Reading of Tide staff.		WIND.		Baromet.	Thermom. Air.	WEATHER.	REMARKS.
Hrs.	Mins.	Feet.	Dec's.	Dir.	Force.				
6	54	6	40	SE	Force	29.8	58	Stormy	25 November
7	23								
7	30								
7	36	6	35						
7	43								
7	49								
7	56	6	30						
8	03								
8	10								
8	17								
8	24								
8	31	6	25						
8	38								
8	45								
8	52								
8	59								
9	06	6	20						
9	13								
9	20	6	20						
9	27								
9	34								
9	41								
9	48								
9	55								
10	02								
10	09	6	20						
10	16								
10	23								
10	30								
10	37								
10	44								
10	51								
10	58	6	15						
11	05								
11	12								
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5	42								

Rising 5-year and 10-year Storm Tides and Flood Elevations (with SLR)

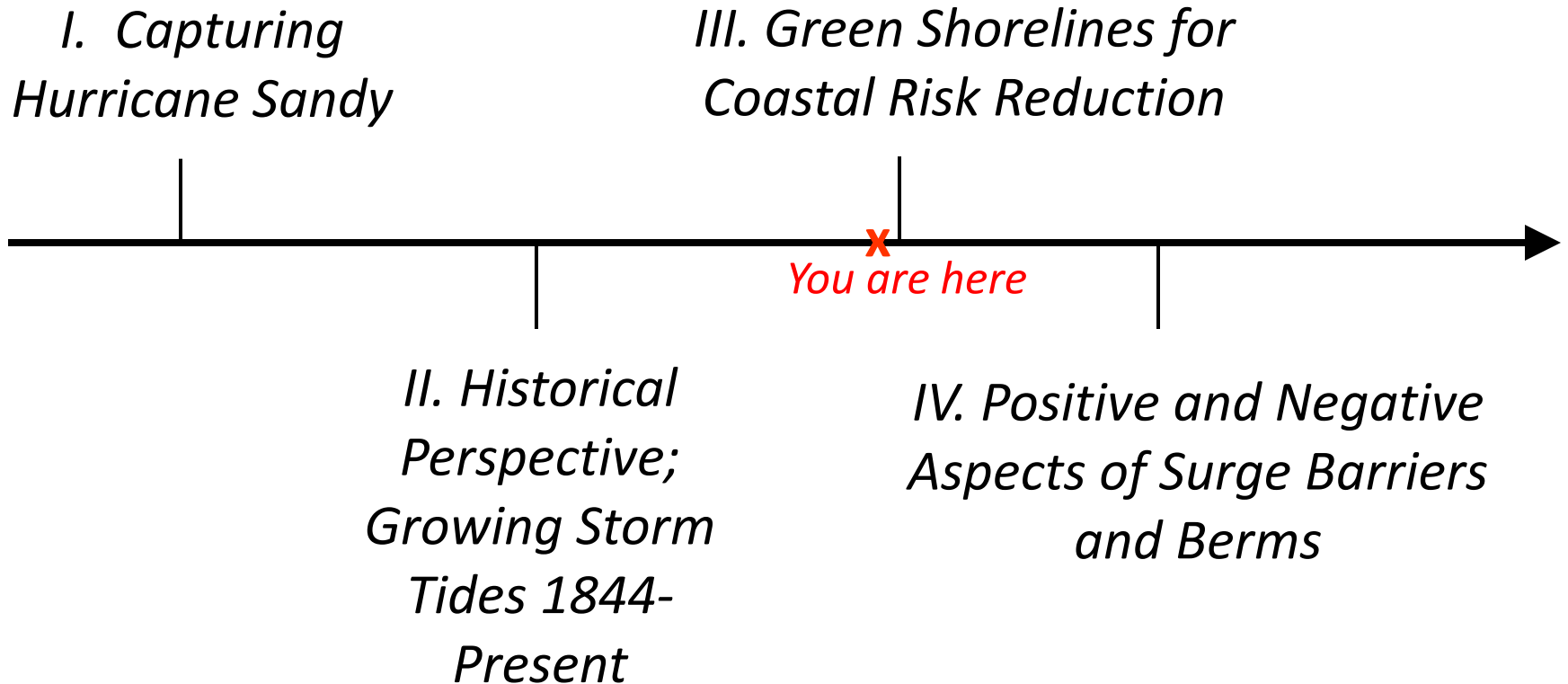


Possible reasons:

- Climate variability (emergence from Little Ice Age)
- Climate change
- Human changes made to the harbor (e.g. elimination of wetlands, dredging channels)

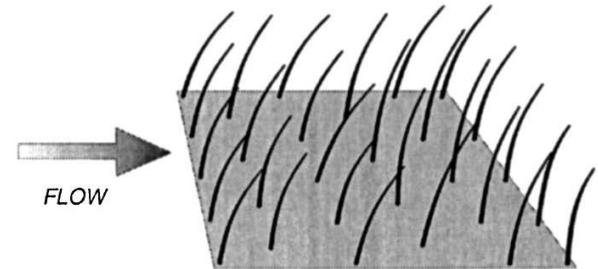


Timeline



Adaptation Option 1: Bathymetric Restoration and Wetlands (or “green engineering”)

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



Elders East Island, Jamaica Bay, NYC, 2010

Elders East Island, Jamaica Bay, NYC, 2006

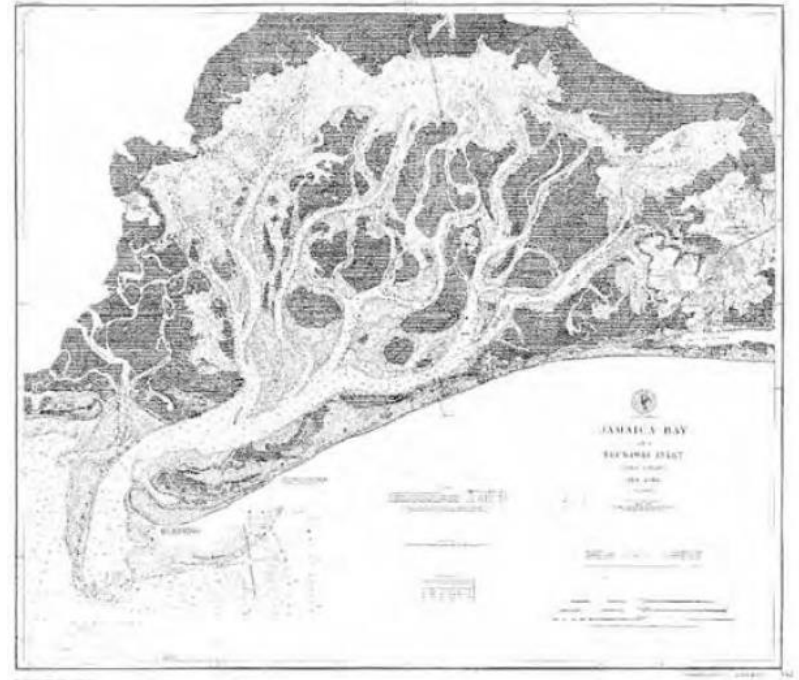


Photo credits: US Army Corps of Engineers

Historic Depth Changes in Jamaica Bay

Jamaica Bay is “...so full of marshes and islands as to render its navigation utterly impossible except to very light-draft vessels with local pilots on board. No intelligible description can be given of the islets and numerous channels among them.”

U.S. Coast Pilot Coast and Geodetic Survey,
1904

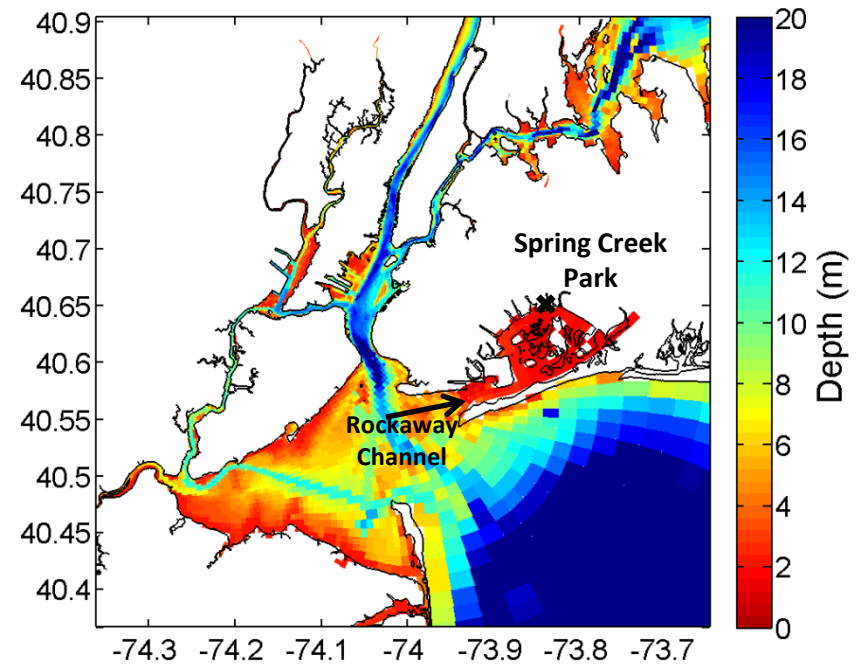
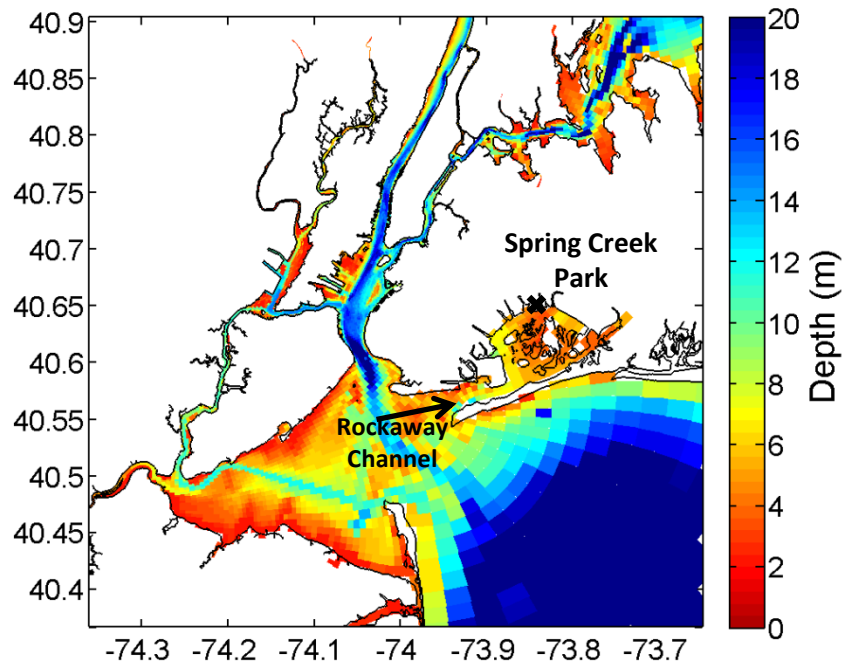


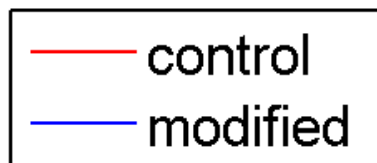
Volume of the Bay has increased 350% and average depth has gone from 1m to 5m since the late 1800s.

NYC DEP, 2007;

- Tide ranges in the bay have increased ~0.5 m (25-45%)
- High water levels have increased ~0.10 to 0.25 m (Swanson and Wilson, 2008)

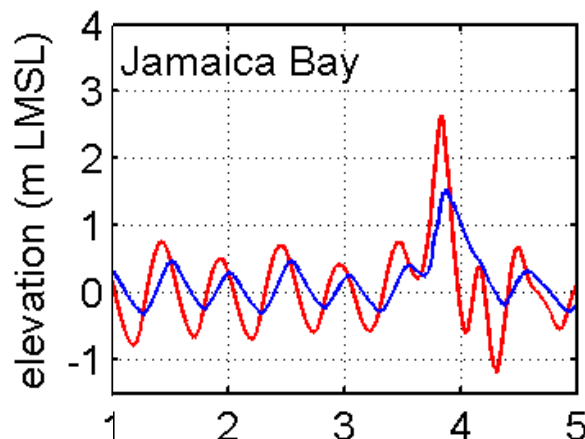
Bathymetric Change Experiment – Shallowing Jamaica Bay by 67%



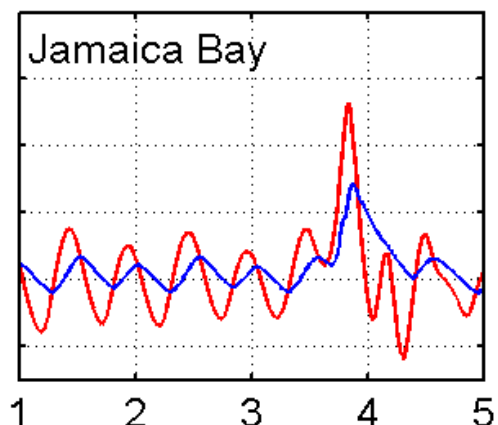


1821
Category 3
Hurricane

Shallowing Only



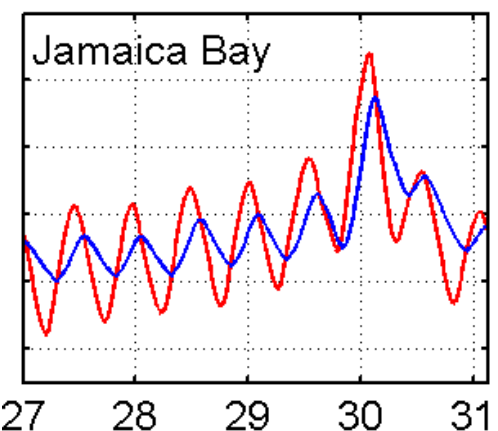
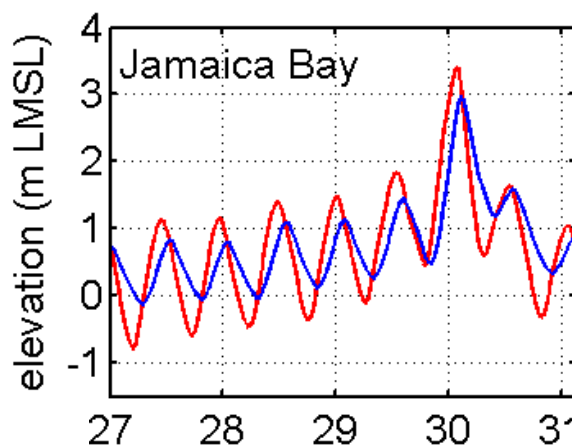
Shallowing
AND wetlands



Date in September, 1821

1.45 ft of
reduction
(0.44 m)
and 2.1 ft
(0.65 m)

2012
Hurricane
Sandy



Date in October, 2012



A STRONGER, MORE RESILIENT NEW YORK



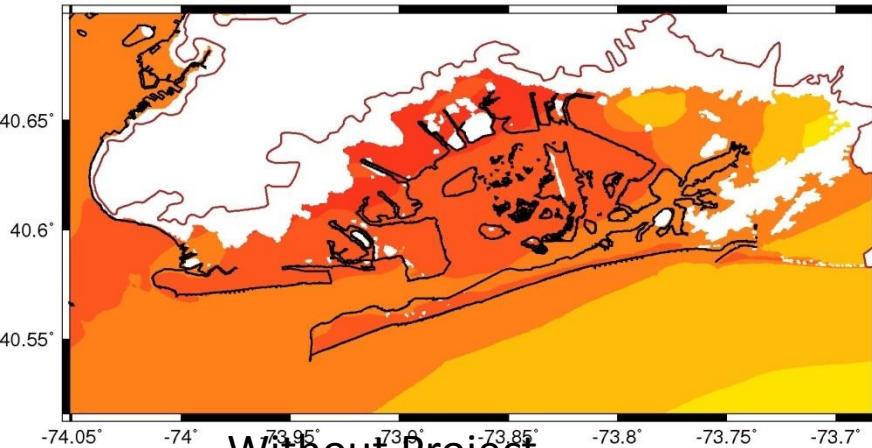
The City of New York
Mayor Michael R. Bloomberg

Map of Adaptation – J-Bay Wetlands and Rockaway dune



Jamaica Bay Wetlands & Rockaways Bern Storm Tide/Still Water Levels

Max Surge Height: P00 Sandy 2050



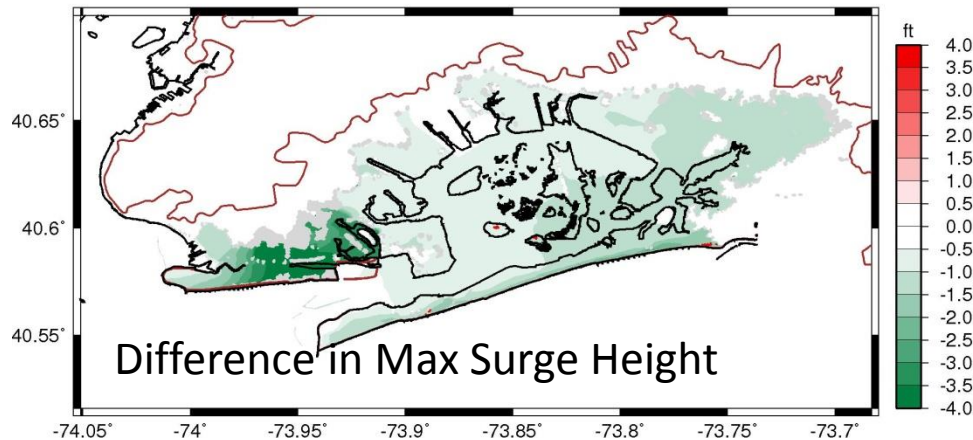
Without Project

Max Surge Height: P05P06P07P11 Sandy 2050



With Project

Surge Height Difference: P05P06P07P11 Sandy 2050



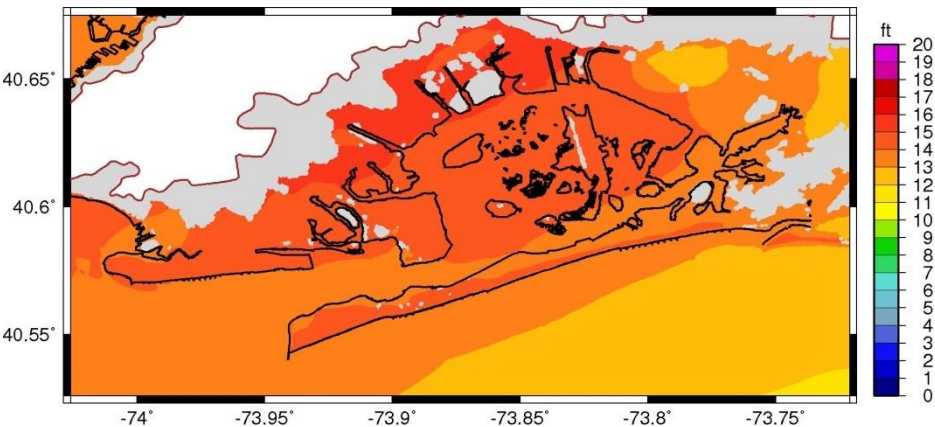
Difference in Max Surge Height

Collaborative
work done for
NYC SIRR study
with Arcadis
and others

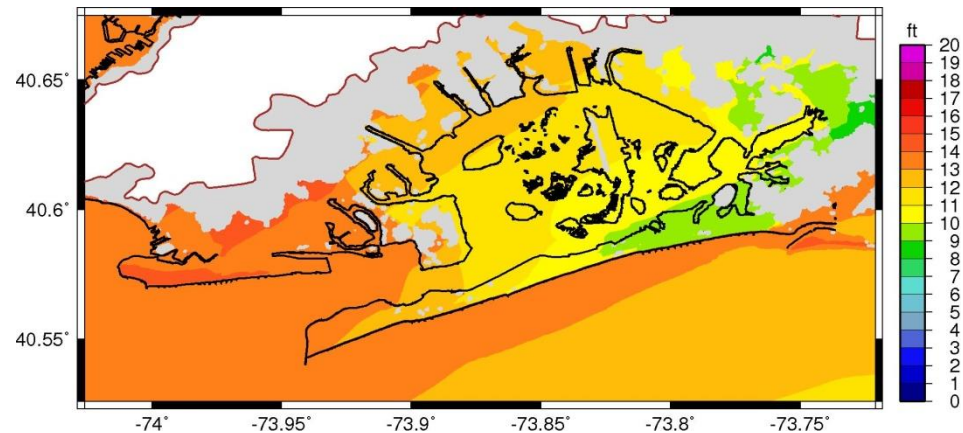
Map of Adaptation – J-Bay wetlands, shallowing and Rockaway dune



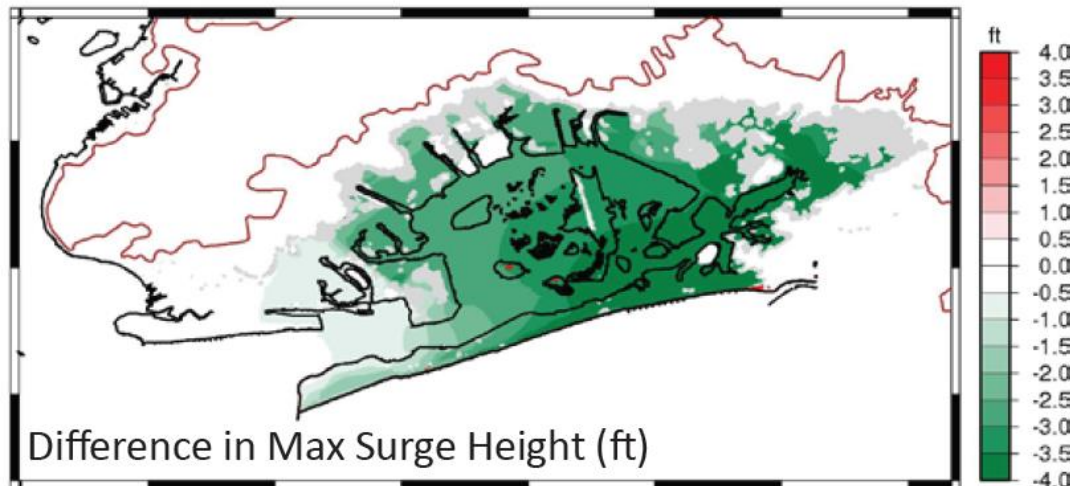
Jamaica Bay Wetlands, Shallowing, Berm Storm Tide/Still Water Levels



Without Project



With Project



Difference in Max Surge Height (ft)

Collaborative
work done for
NYC SIRR study
with Arcadis
and others

Adaptation Option 2: Storm Surge Barriers

Barriers have been successful for The Netherlands, Providence, Stamford (CT), New Bedford (CT), the Thames (London), and new ones are in action in St. Petersburg and Venice.

Oosterschelde

Maeslant



Thames



Benefits of Storm Surge Barriers

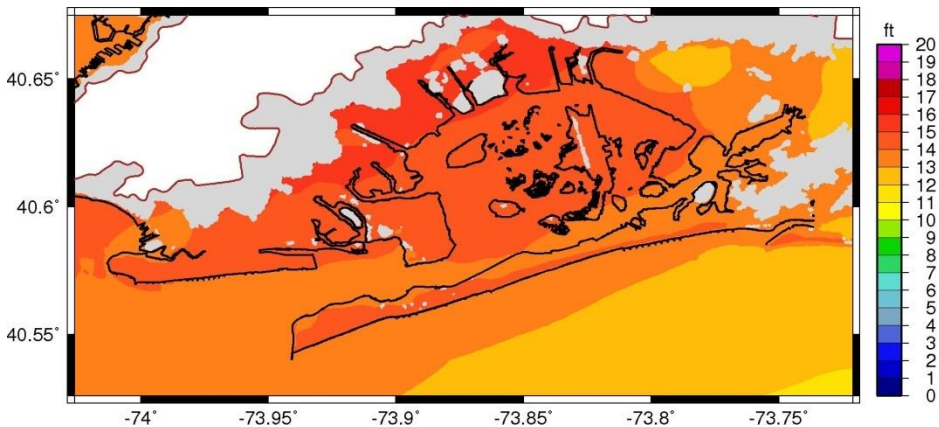
- Efficiency- reduce length of shoreline that must be protected (e.g. Jamaica Bay)
- Our cities are our “greenest” developments, preventing sprawl, so we should protect them at all costs
- We could have the big one – Hill et al. claim 30-foot storm surges crashing over Brooklyn and Queens (Doug Hill, J. Coastal Res. editorial, 2012)

Map of Adaptation – J-Bay surge barrier

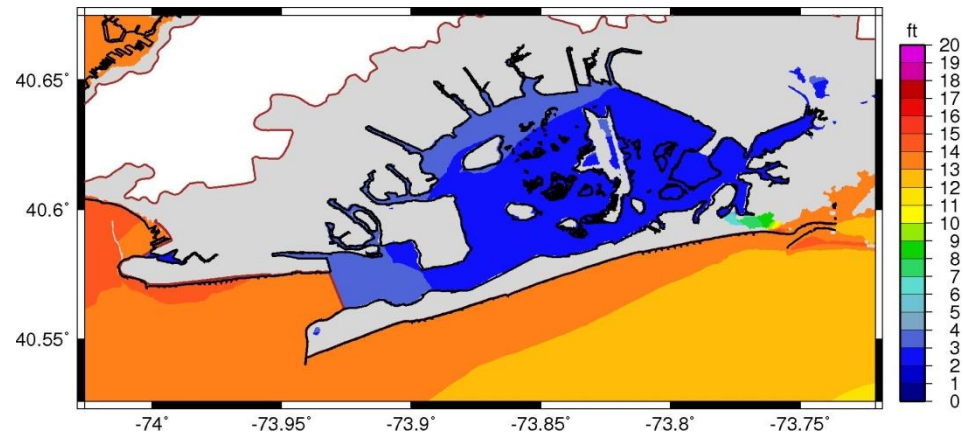


Jamaica Bay Barrier + Berm

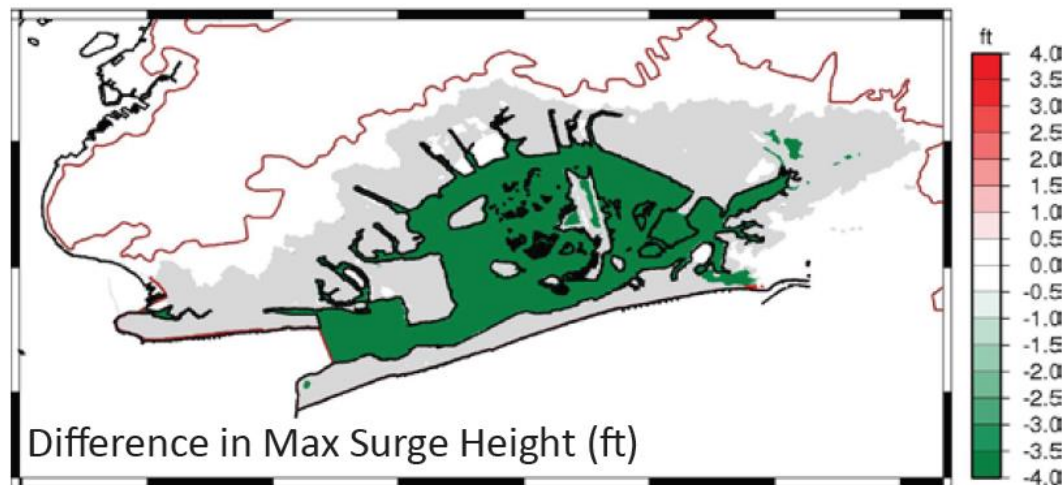
Storm Tide/Still Water Levels



Without Project



With Project

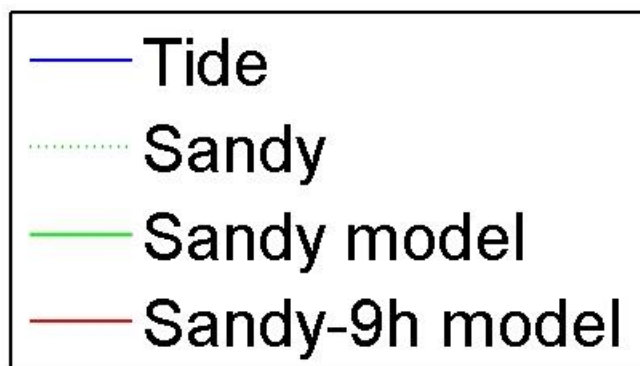
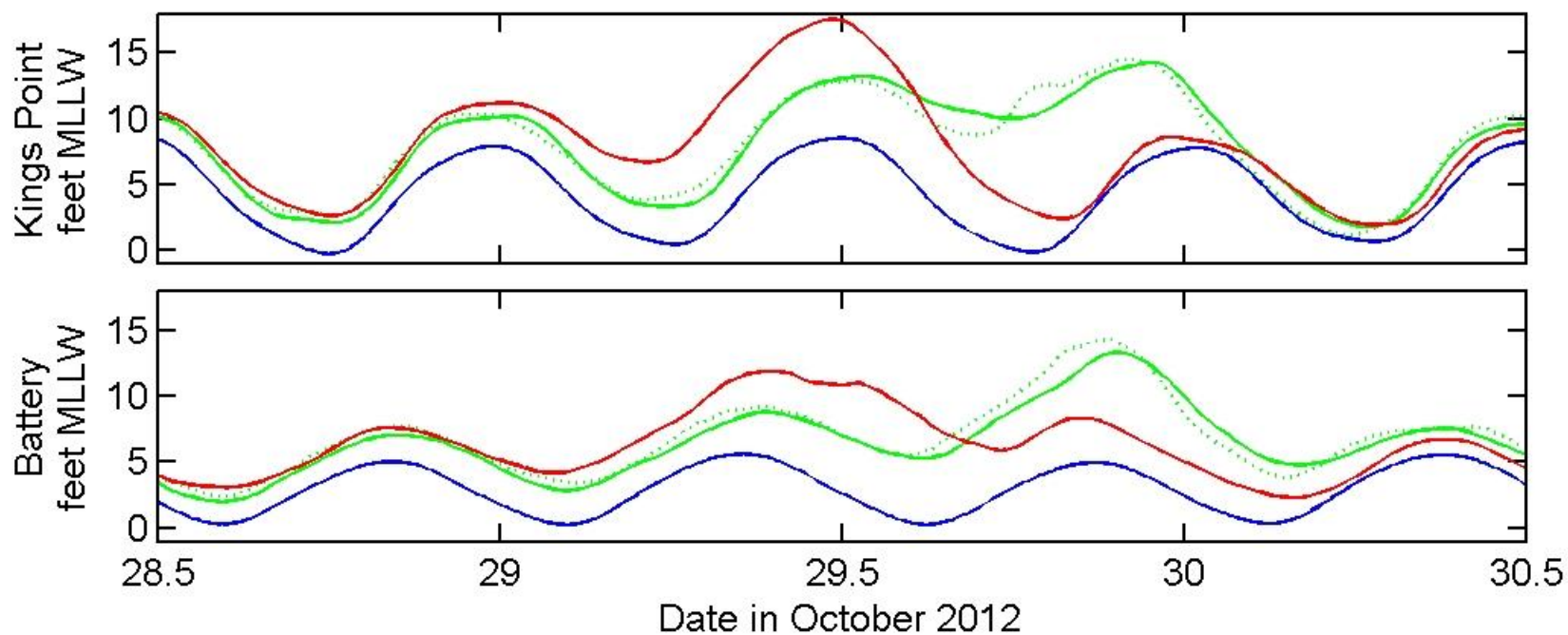


Difference in Max Surge Height (ft)

Collaborative
work done for
NYC SIRR study
with Arcadis
and others

Do The Sandy-Shift – Does Stamford Sink?

- To evaluate the alternative scenario of Long Island Sound / East River flooding for NYC, we shifted Sandy landfall timing
- Superposition of the observed storm surge on top of Oct 29th high tide exceeds the design elevation of the Stamford surge barrier by 38cm
- The hydrodynamic model results (-9h shift) suggest that the waters would have risen to within 8cm of the barrier design height



What Happens When Protections are Overtopped?

WNYC News

Deadly Topography: The Staten Island Neighborhood Where 11 Died During Sandy

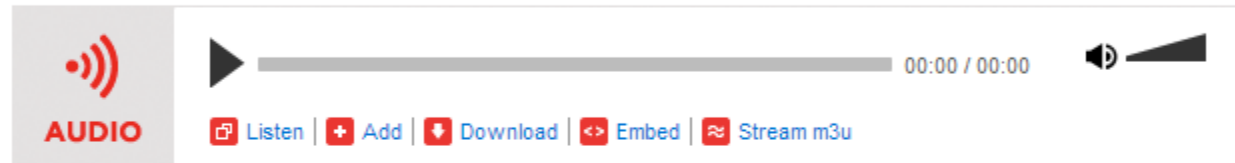
Monday, February 25, 2013

By [Matthew Schuerman](#) : Editor, WNYC

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Life After Sandy

Stories from the storm recovery

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The stories that people tell about fleeing from Sandy's surge in one section of Staten Island's Eastern Shore all sound alike: the water came all at once, and gave little advance notice.

"It happened so fast that we just had to get up the stairs and tell everybody else that we were flooding, because they didn't even know," said Kristina Zakarya, who was getting ready to watch a movie on the ground floor of her mother's house in Midland Beach.

A friend who was with her, Nick Duggan, added: "I had a sweatshirt, my shoes and my wallet and my phone, and I only grabbed my wallet and my phone."

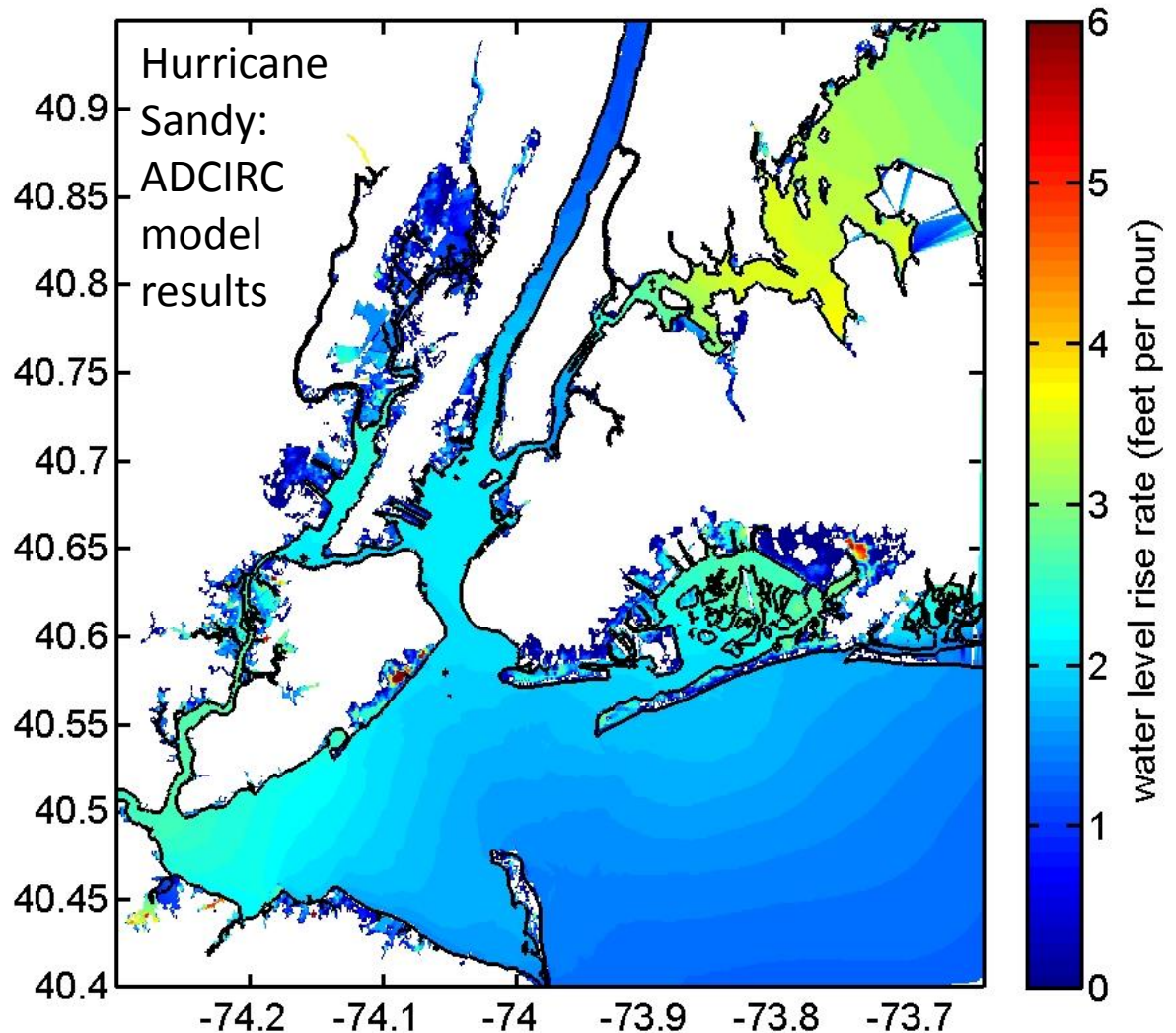
A few blocks away, on Quincy Street in an adjoining neighborhood known as Ocean Breeze, Mike Taurozzi got a phone call from a neighbor warning him to move his car to higher ground.

"By the time I came back down," he recalled, "it was already a foot and a half, just from moving the car."

What Happens When Protections are Overtopped?

Protections have a design height – we need to also study what happens when they fail.

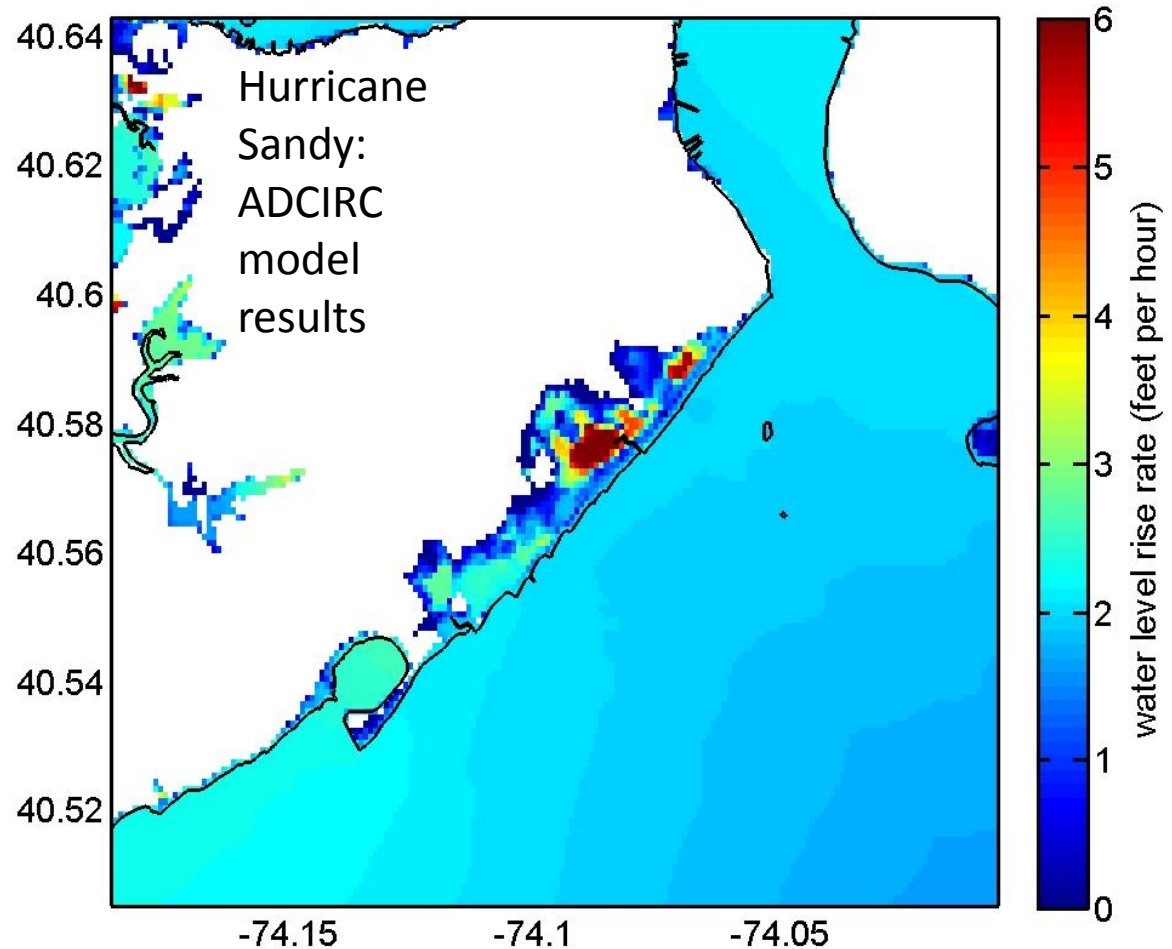
Case study: Did Staten Island's waterfront berm that was raised in the 1950s cause a more deadly flood?



Barriers/Berms can act as Risk-Multipliers

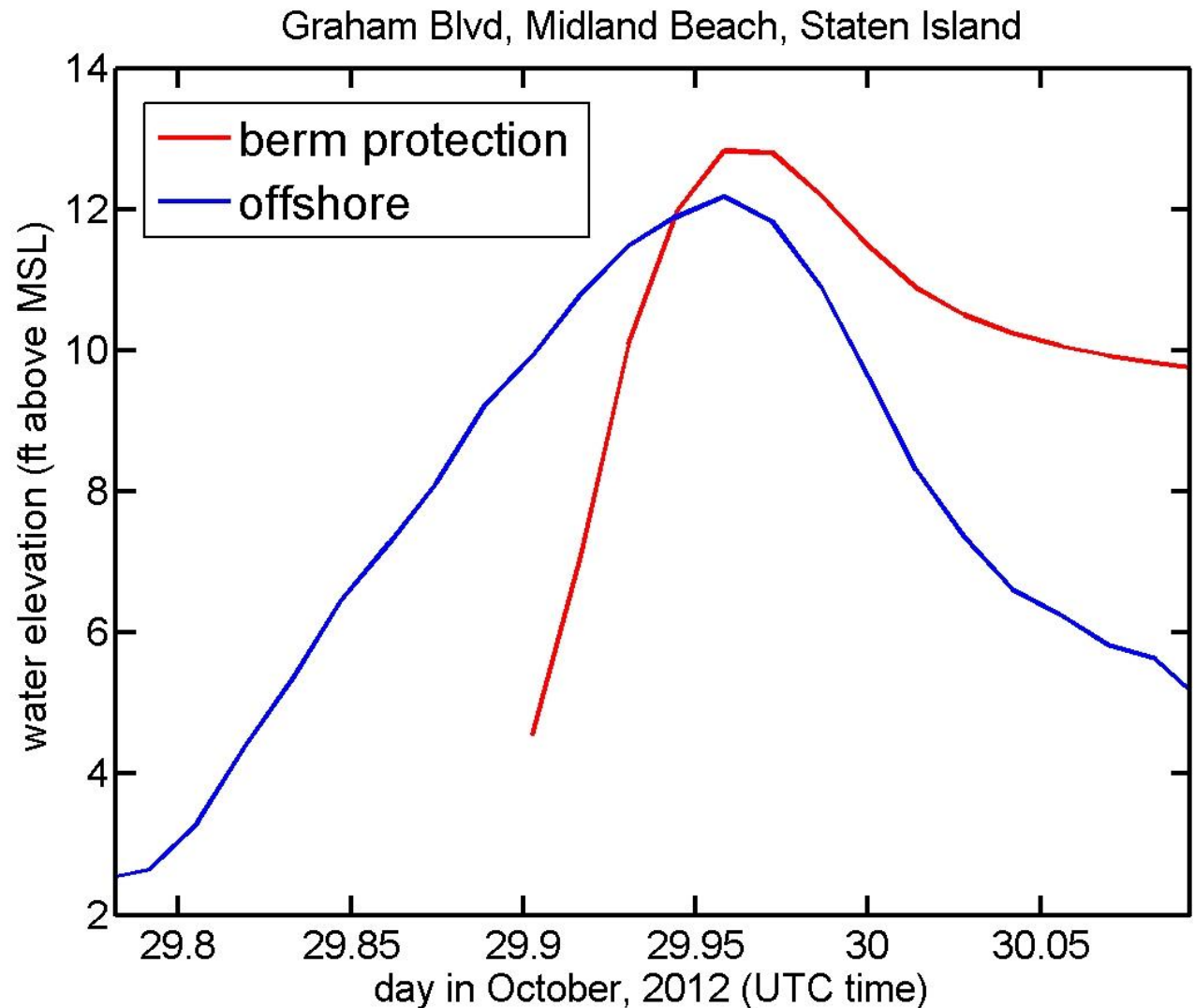
The larger red area is centered on Midland Beach – model results back up and help identify reasons for witness observations.

The region with the highest drowning rate was the region with the highest water rise rate.



Modeled Water Level Rise Rate- Worsened by “Protection” or “Risk-Reduction” Measure

- Rise rate in harbor was ~2 feet per hour
- Rise was abrupt in Midland Beach, and >6 feet/hour



Barriers and Natural Flood Protection

- Storm surge barriers and levees/berms
 - can protect the city center from storm surge flooding
 - however, they can also slightly worsen flooding outside the barriers
 - not always “risk reduction measures” – should plan better evacuations or raise land, not create deadly topography
- Massive wetland restoration alone in Jamaica Bay only reduces “Sandy plus sea level rise” flood levels by inches
 - however, they likely have wave/erosion reduction benefits in smaller storm events
- Wetland restoration plus channel depth reductions to 2m maximum depth reduces Sandy’s water elevations for Jamaica Bay substantially

Modeling & Quantifying Coastal Protection

REBUILD
BY
DESIGN

THE SHALLOWS

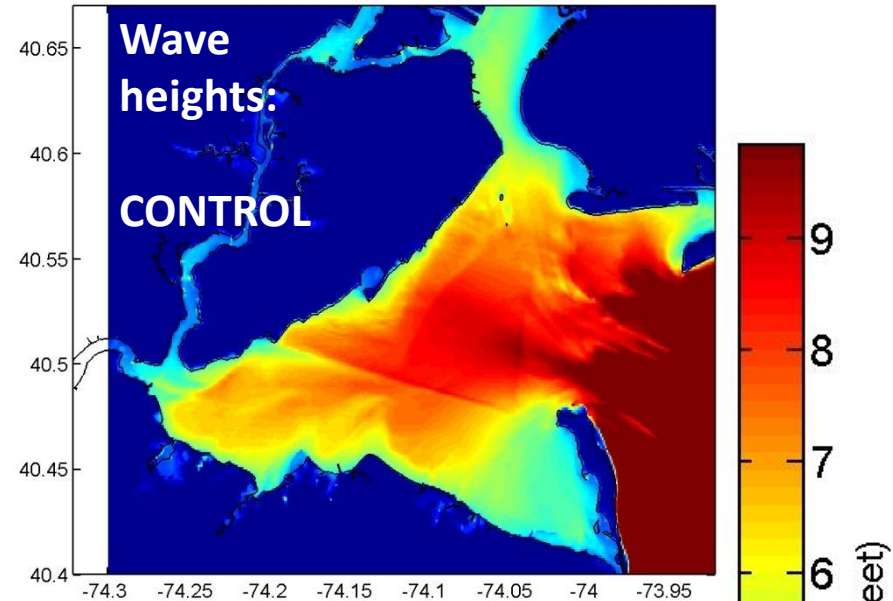
BAY LANDSCAPES AS ECOLOGICAL INFRASTRUCTURE

Focus project:
Living, Growing
Breakwaters,
Staten Island and
Raritan Bay

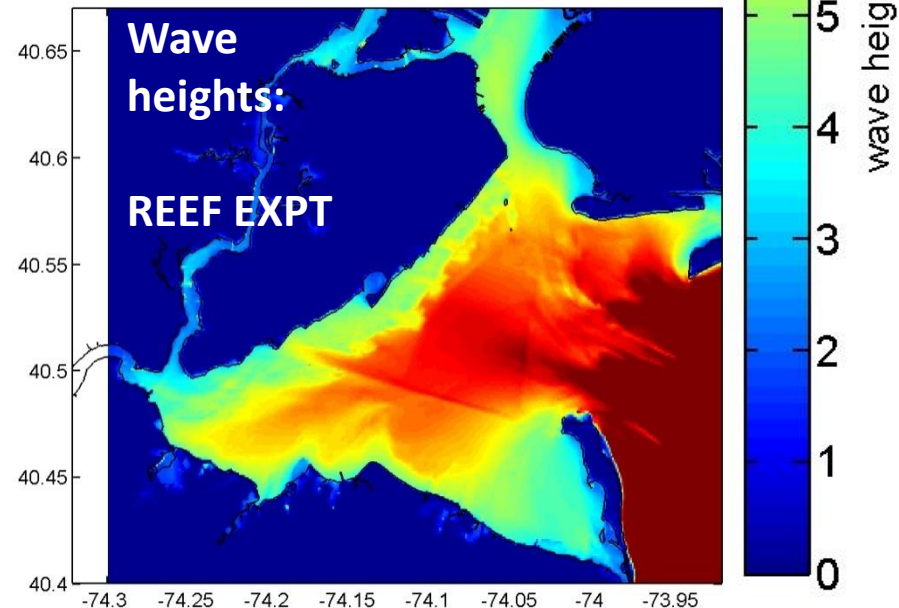
SCAPE / LANDSCAPE
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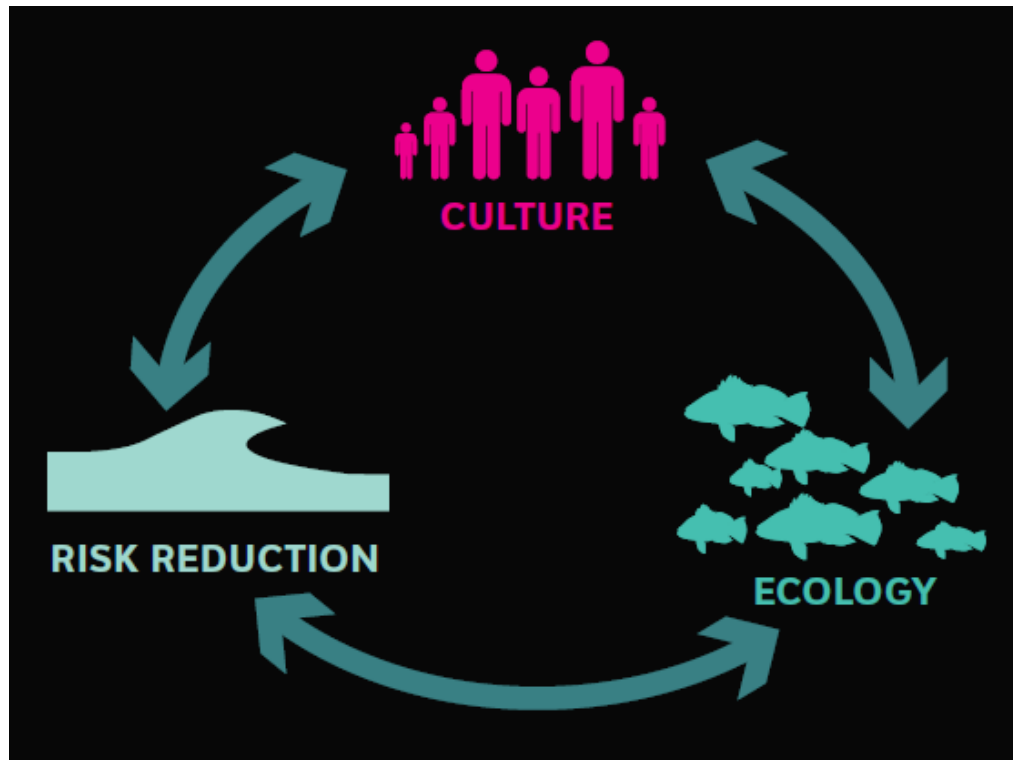
Donna 1960



Donna 1960



Scape Team RBD Resilience Philosophy: The Layered Approach



Final Conclusions

- We have successfully simulated Hurricane Sandy storm tides with a typical RMS error of 0.15 m
 - Sandy “captured” ... available for experimentation
- Storm tides in NY/NJ Harbor have worsened since the 1800s and first half of the 1900s
- Storm surge barriers and levees can be efficient means of protection, but are not always “risk reduction measures”
 - They create bowl-shaped neighborhoods, so may not be an appropriate solution in an era of accelerating sea level rise
- Shallowing unused deep dredged channels could be an effective long-term “green” strategy for reducing flooding



Modeling NY/NJ Harbor Storm Surge Flooding and Influences of Barriers and Natural Systems

Philip Orton

Much help from Nickitas Georgas, Sergey Vinogradov, Alan Blumberg
Davidson Laboratory, Stevens Institute of Technology



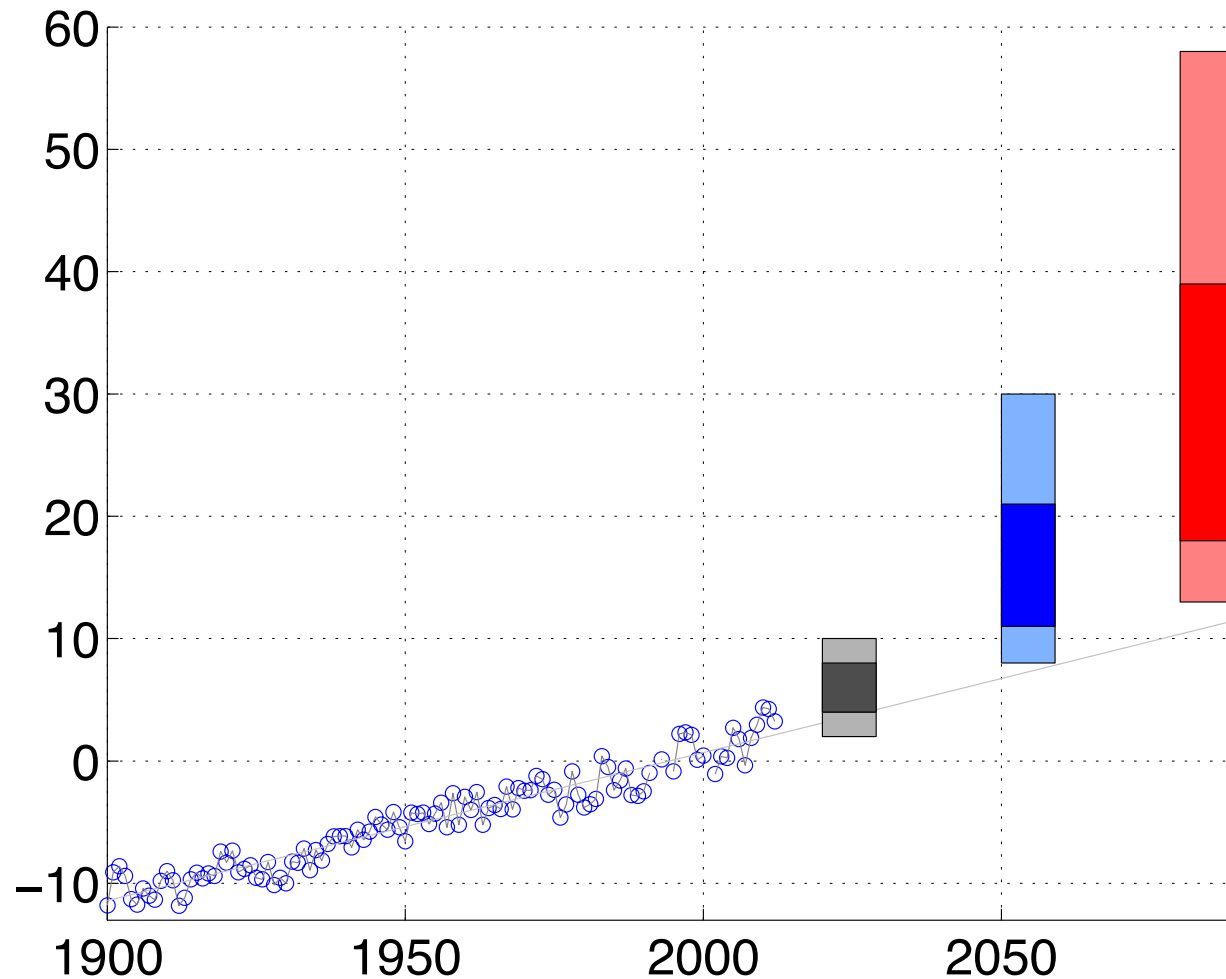
Funding from the NOAA RISA Program (Rosenzweig et al.) project:
“Consortium for Climate Risk in the Urban Northeast (CCRUN)”
and a NASA project for research supporting the Nat’l Climate Assessment
Thanks also to the CUNY High Performance Computing Center



Climate Change Impacts on Flooding

- We’ve already had about 8” of anthropogenic (human-caused) sea level rise since 1900 → sea level rise is already making floods worse, and this will worsen
- Sandy may have been influenced by altered jet stream patterns (debated)
- Globally: IPCC-SREX 2012 says
 - “Average tropical cyclone maximum wind speed is *likely* to increase”
 - “It is *likely* that the global frequency of tropical cyclones will either decrease or remain essentially unchanged”
- In our region: North Atlantic storms have been frequent and more powerful in the past few decades
 - However, many scientists agree that we do not have enough historical data to determine if this is natural or human-induced variability

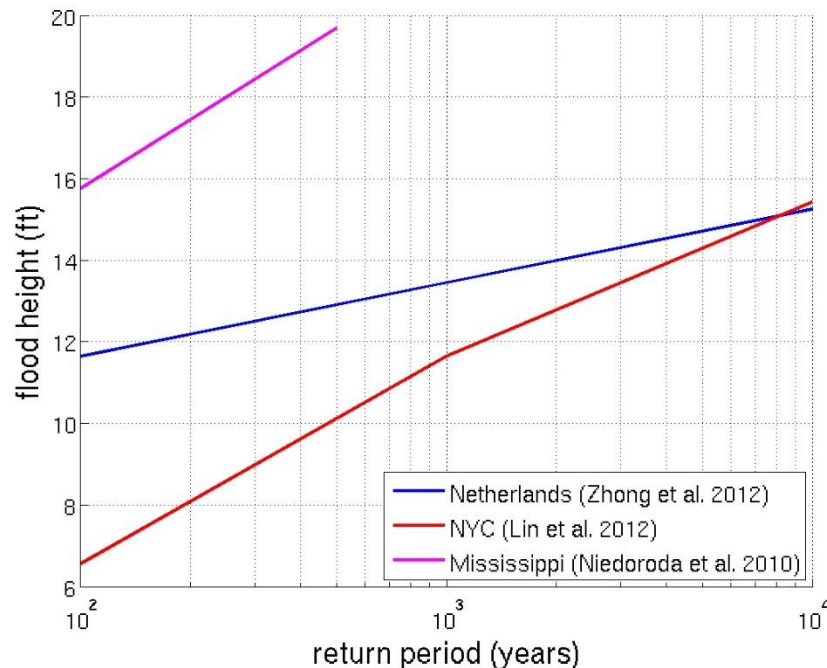
NYC Panel on Climate Change Draft Predictions



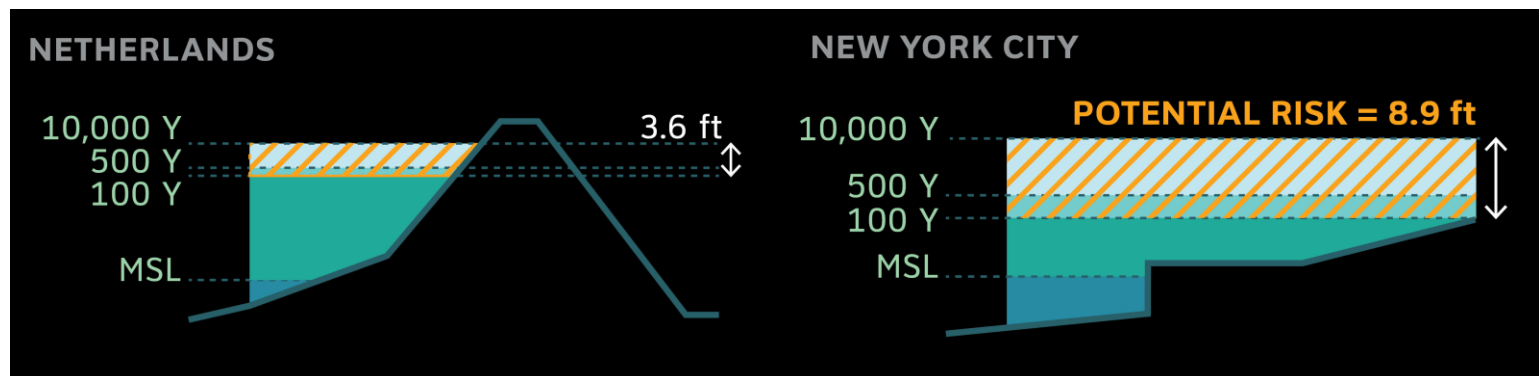
Horton, R., and many others. A Framework for Rapid Assessment of Climate Hazards in NYC Post-Hurricane Sandy: Part 1, Atmospheric Variables and Part 2, Sea Level Rise. (in prep.)

Methods follow: Kopp, R.E., and many others. Probabilistic 21st century sea-level rise projections at a global network of tide gauge sites. (submitted to *Earth's Future*)

NYC is not The Netherlands – Different Hazard Profile, More High Ground

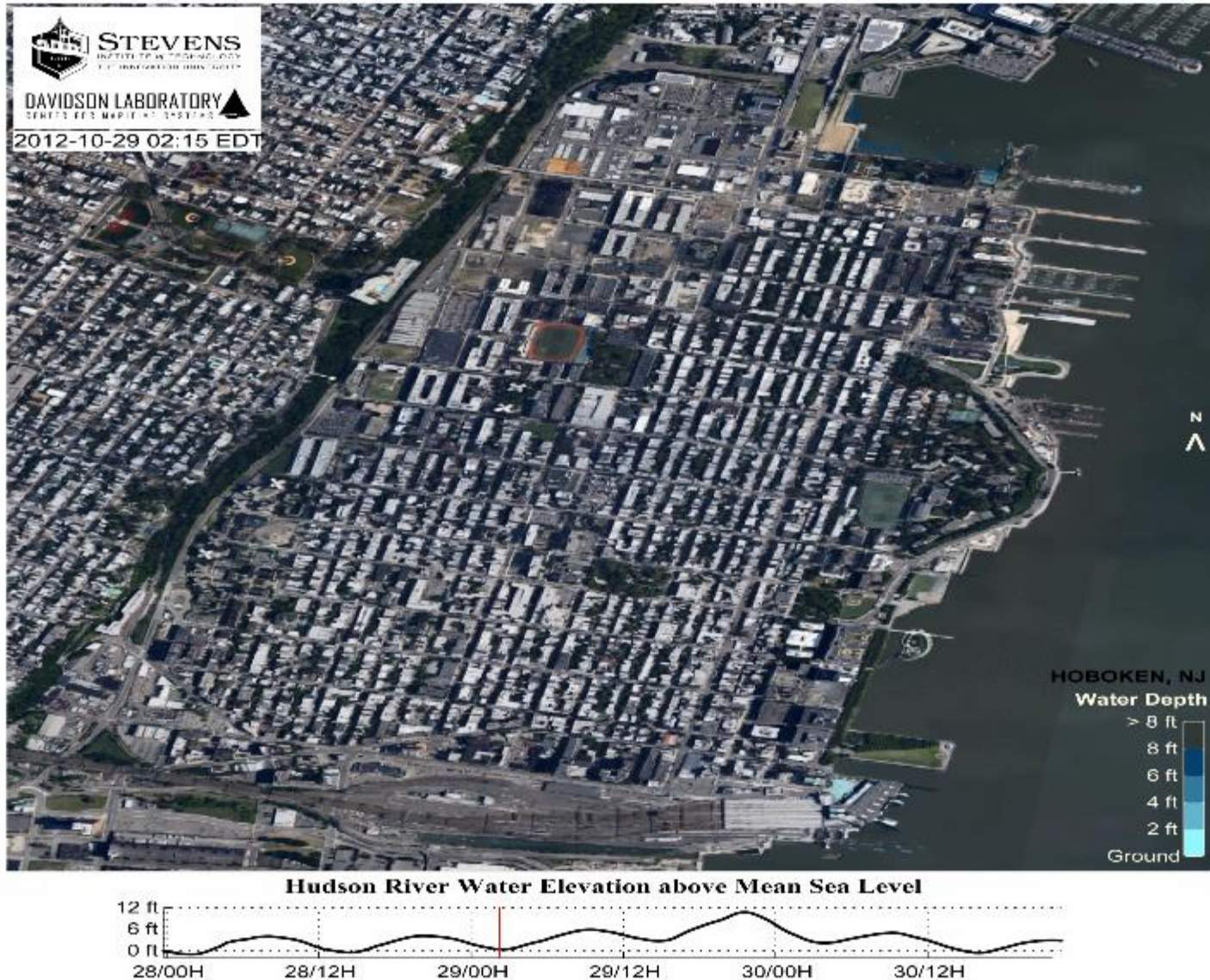


- Physically, NYC has very little in common with The Netherlands
 - Our hazard curve is steep-sloped, meaning we have “surprise” large events
 - They have 28% of their land below average sea level --> evacuation distances can be very long
 - We have 0% below average sea level
 - We have 0% of our neighborhoods below typical high tide levels (rounded off), for that matter

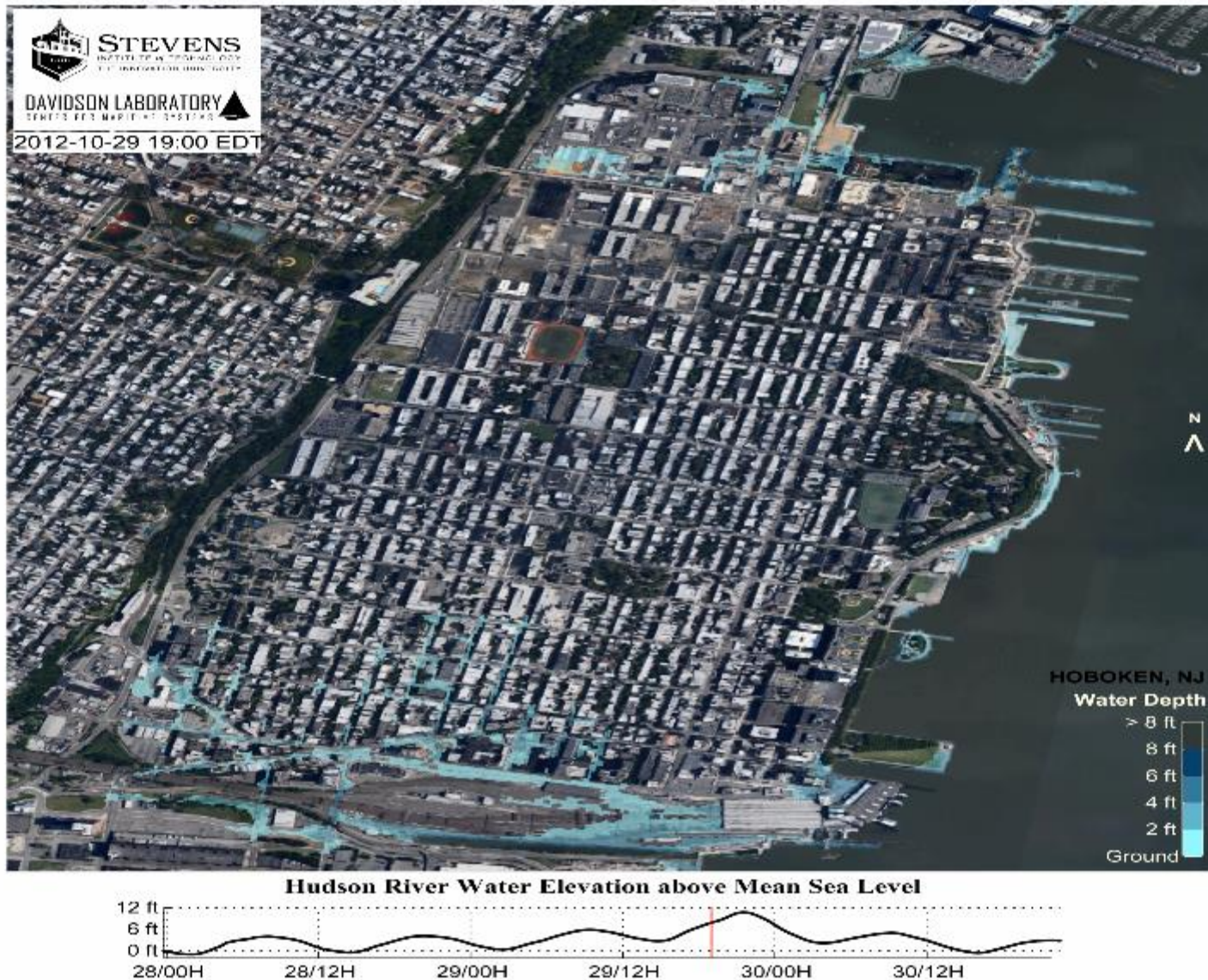


Stills of Animations

Sandy: Hoboken Flooding Sub-model



Sandy: Hoboken Flooding Sub-model



Sandy: Hoboken Flooding Sub-model

