Preparing for New York City's Katrina:

Storm Surge Barriers to Protect the New York Metropolitan Region

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Stony Brook University

New York City Department of Environmental Protection

HydroQual, Inc.

New York Sea Grant

Eppley Foundation

Marine Sciences Research Center

Stony Brook Storm Surge Research Group

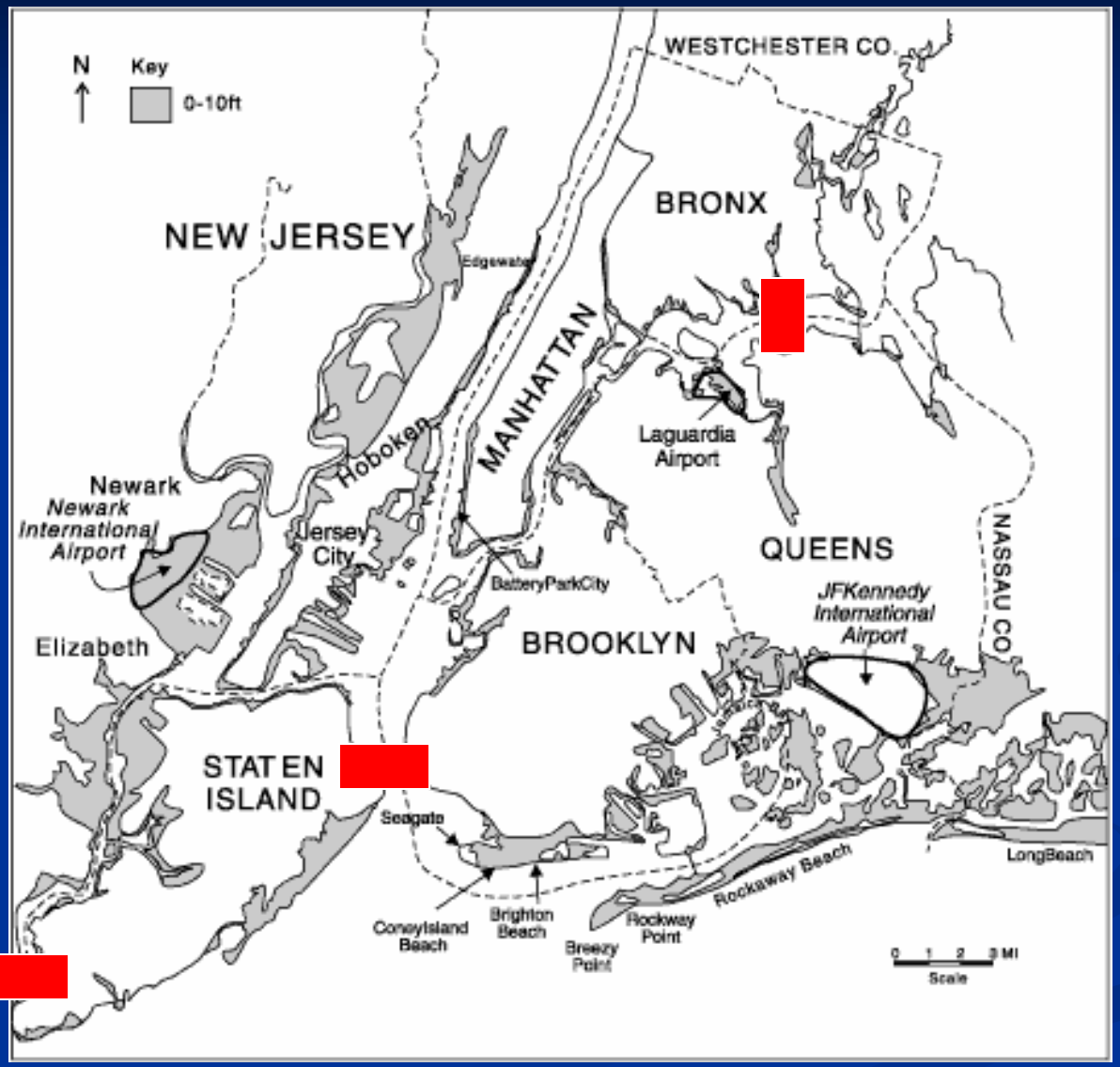
- Malcolm Bowman, Professor, P.I: physical oceanography
- Frank Buonaiuto, Asst Prof: ADCIRC modeling, river runoff
- Brian Colle, Asst. Professor, atmospheric sciences
- Roger Flood, Professor: high resolution topography, bathymetry
- Douglas Hill, PhD., P.C: storm induced precipitation effects
- Robert Wilson, Assoc. Professor: physical oceanography, modeling
- Peng Cheng & Jindong Wang, PhD students: ADCIRC modeling
- Yi Sheng, MS student: FVCOM modeling
- Kevin Bilyk, Robert Hunter, Kit Mirchel, undergraduate students

Outline

1. The Threat of Coastal Flooding
2. Existing Storm Surge Barriers in the USA & Europe
3. The Stony Brook Integrated Storm Surge Model
4. Bathymetric/Topographic Database for New York
5. Test Runs on Historical Storm Events
6. Coastal Early Warning System
7. Rainfall Runoff Flooding
8. Further Work and Conclusions

1. The Threat of Coastal Flooding

Proposed Barrier Locations



The 100-year flood at present mean sea level (from Gornitz, 2001)

- **Q.** When do you plan for a flood?
- **A.** Too late.

A severe storm in November 1950 caused extensive flooding of La Guardia airport (Bloomfield, 1999)

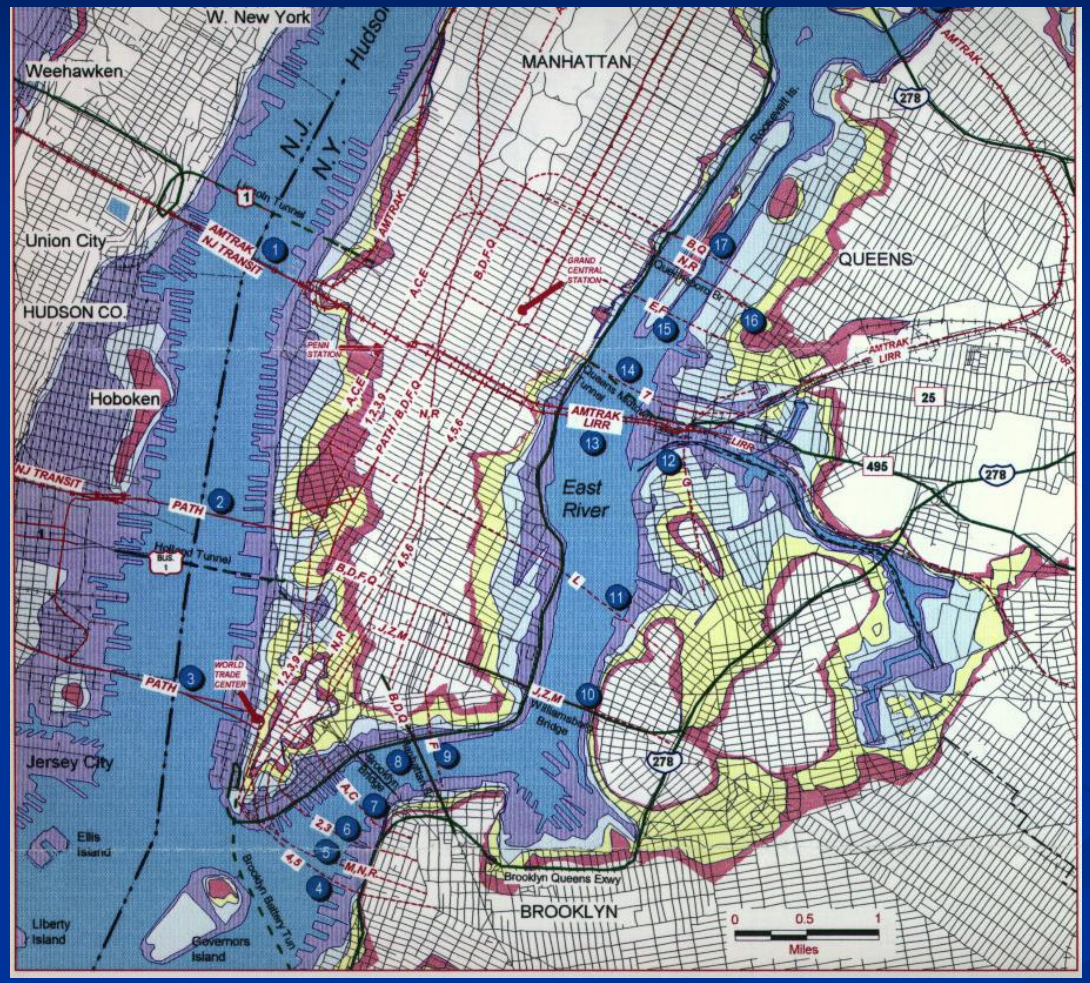
FDR Drive during the December 1992 nor'easter (Bloomfield, 1999)

Ref: Bloomfield, J., M. Smith and N. Thompson, 1999. *Hot Nights in the City*. Environmental Defense Fund, New York.

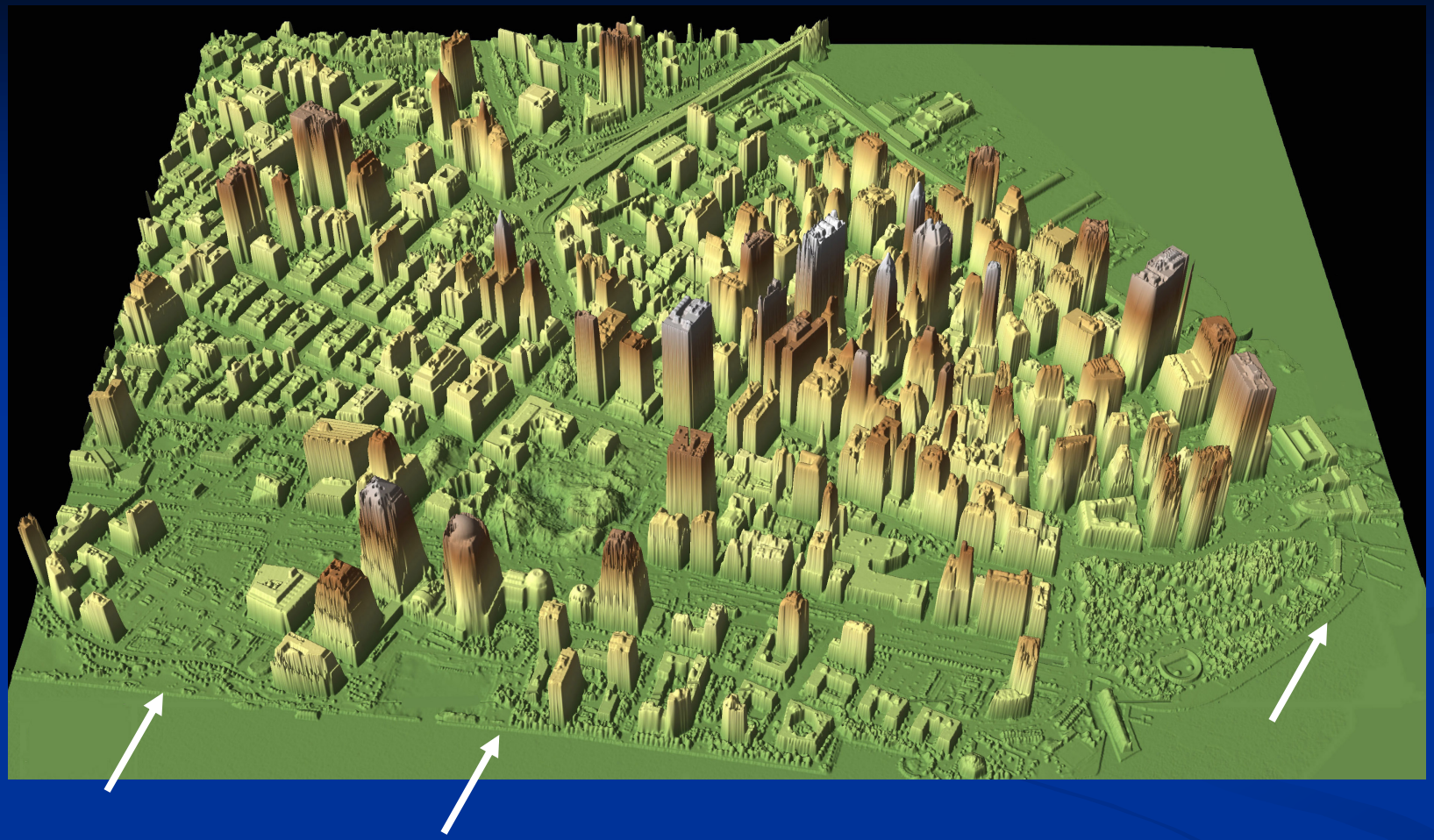
1992 Nor'easter Flooding

Source: Metro New York Hurricane Transportation Study, 1995

New York City Flooding

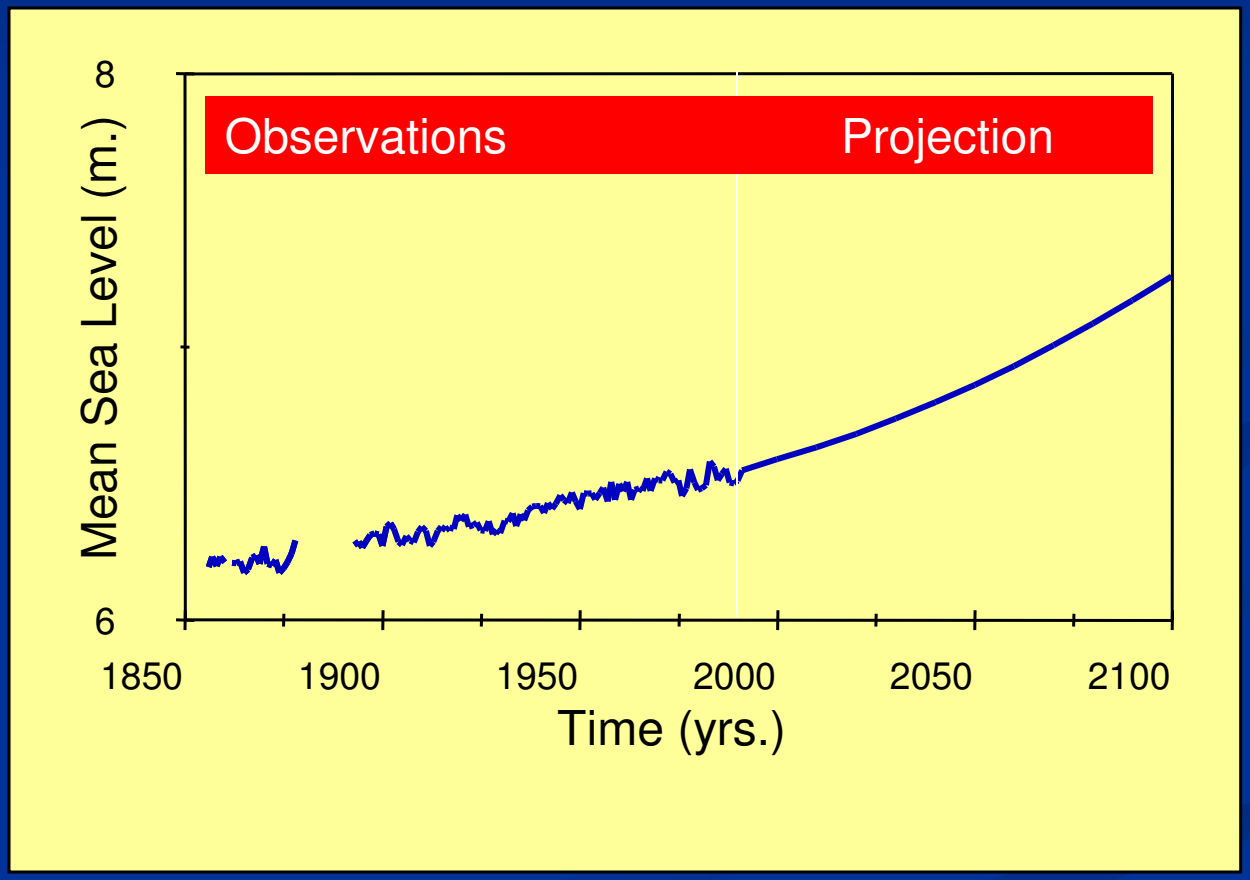


Source: Metro New York Hurricane Transportation Study, 1995



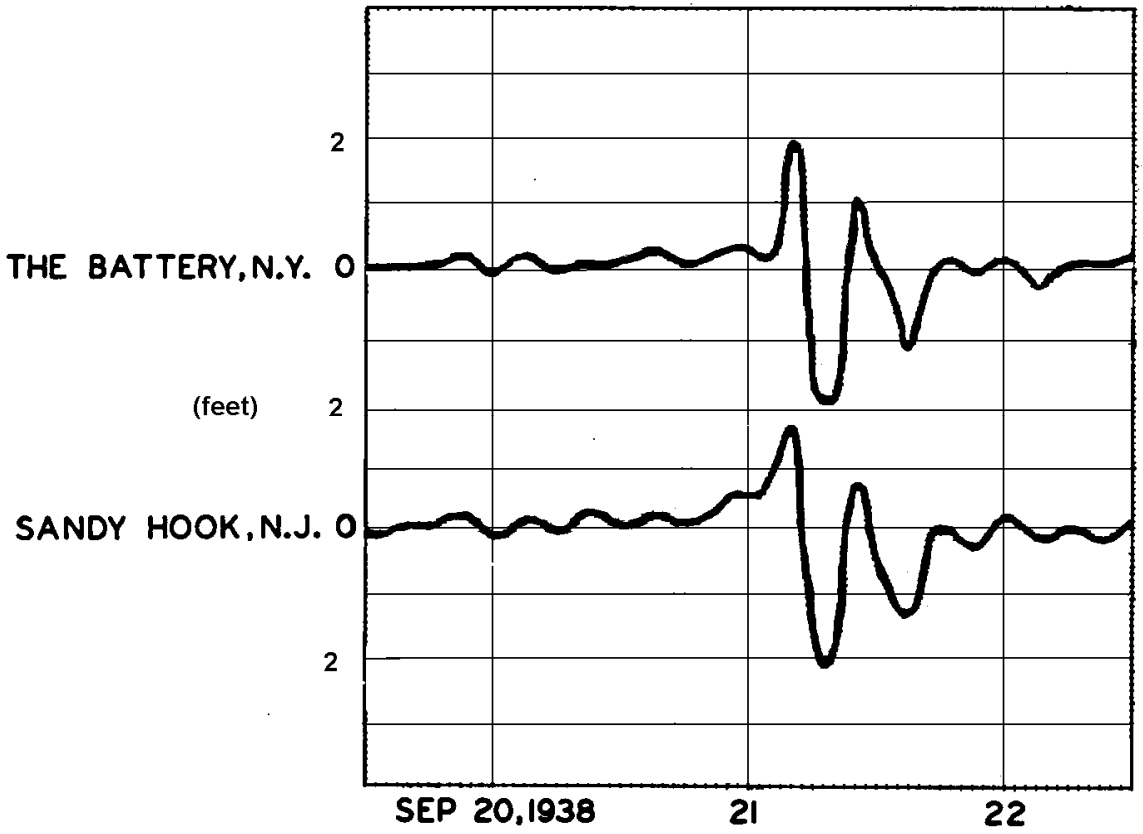
Lidar image of business district of Manhattan showing seawall locations and elevation (arrows). The imager is flying above the Hudson River looking east.

NYC Rise in Sea Level



(courtesy Robert J. Nicholls)

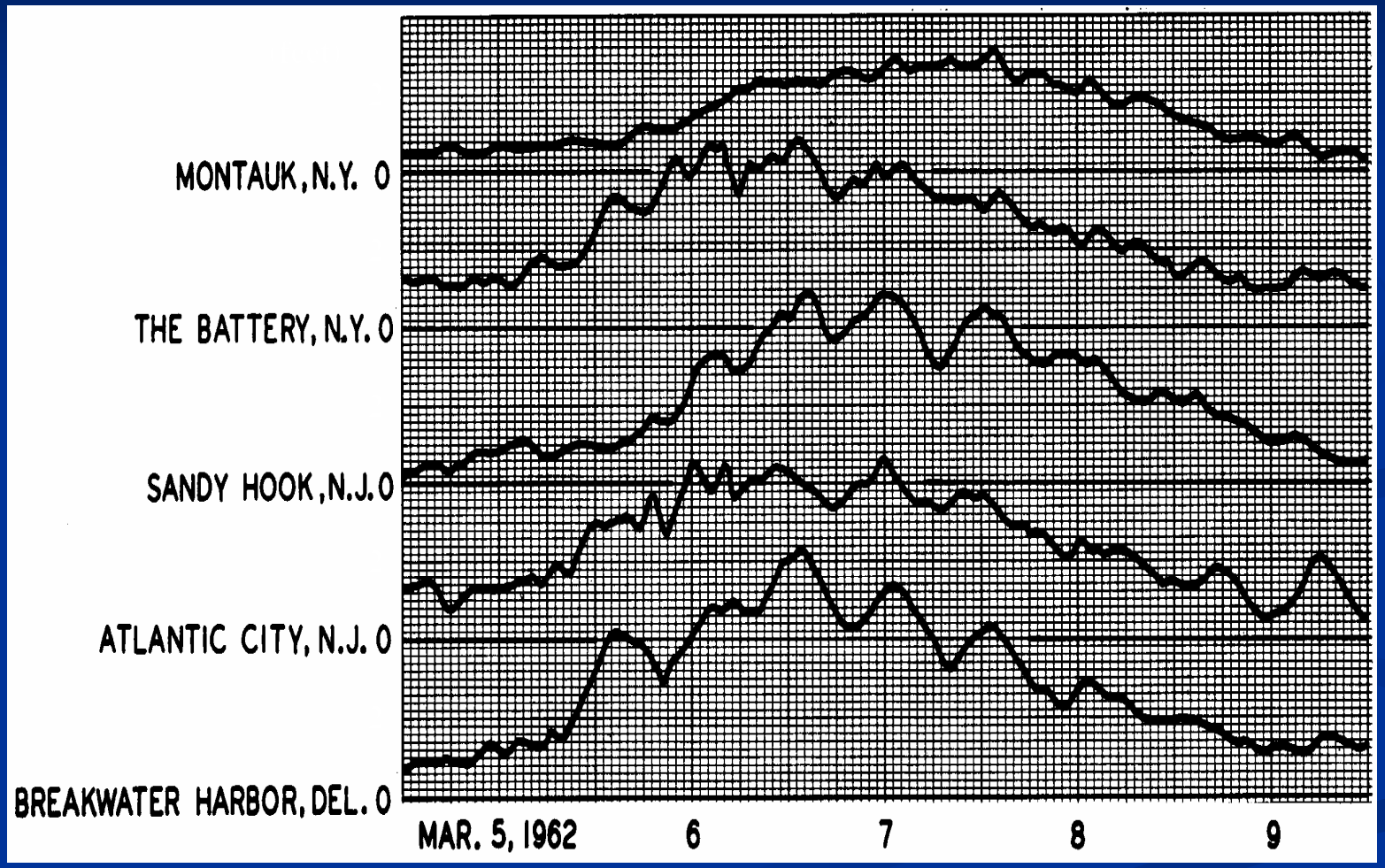
Hurricane Storm Surge



21-22 September 1938 hurricane

Source: N.A. Pore and C.S. Barrientos, Storm Surge, 1976

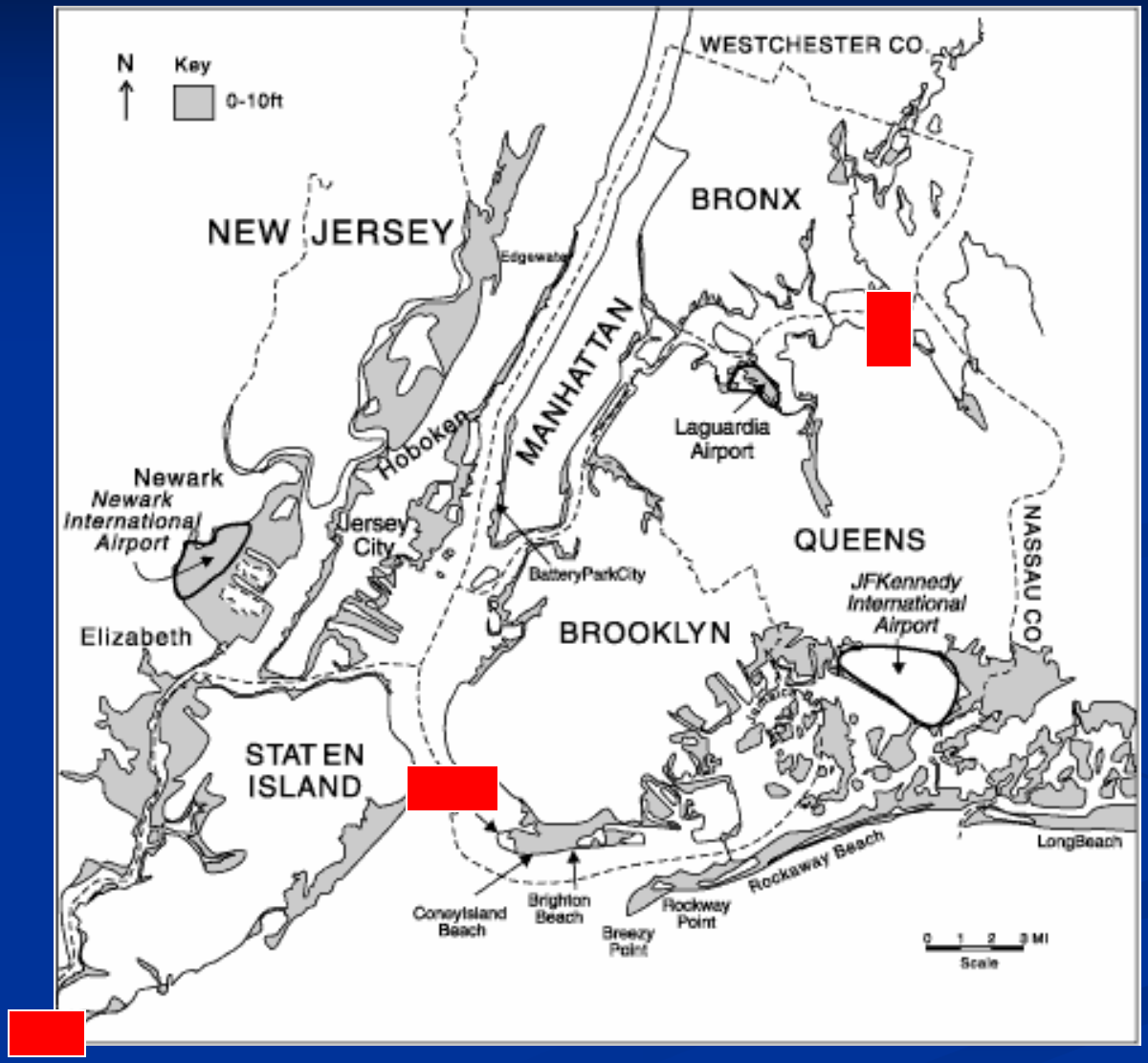
Nor'easter Storm Surge



5-8 March 1962 storm

Source: N.A. Pore and C.S Barrientos, Storm Surge, 1976.

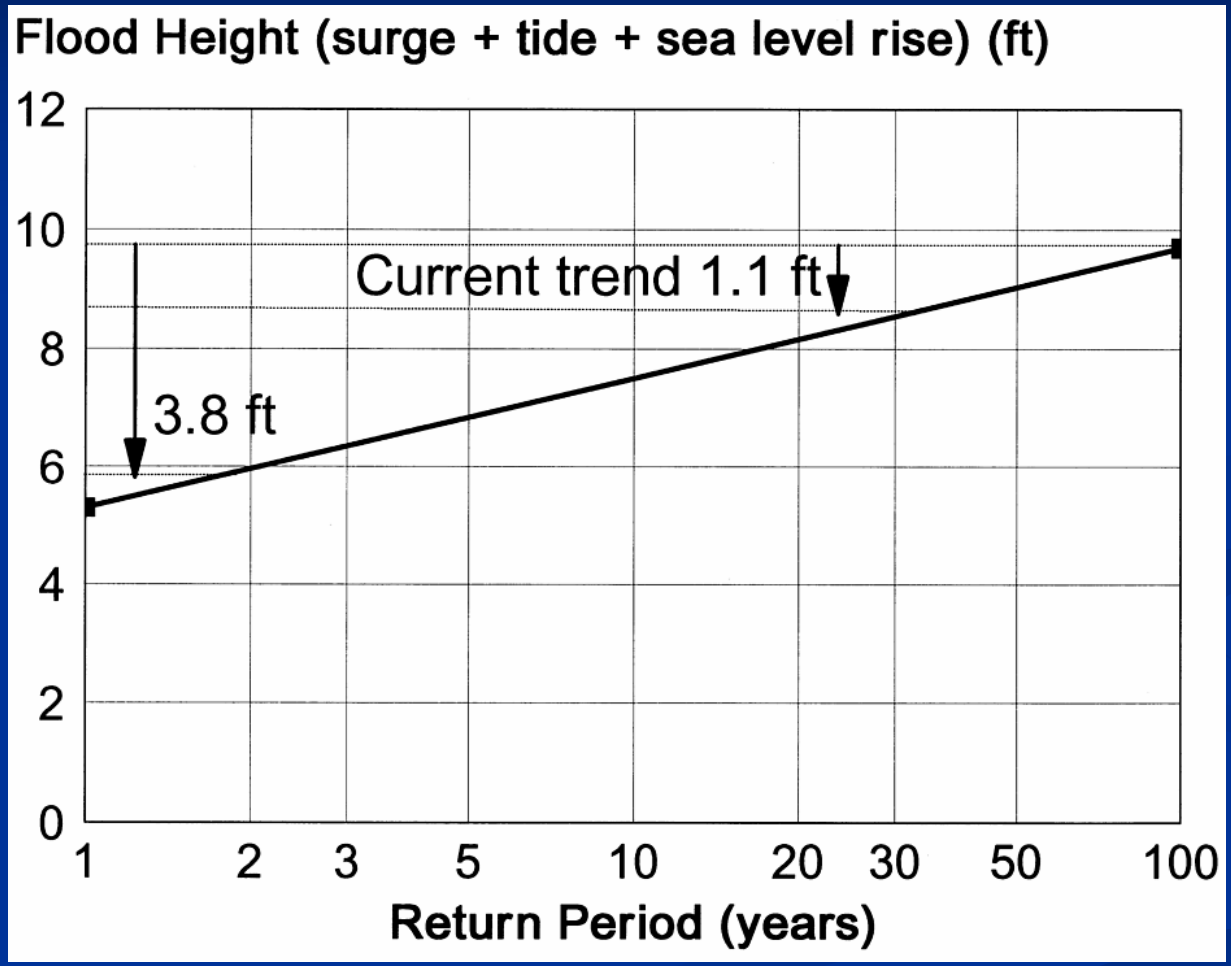
Proposed Barrier Locations



The 100-year flood at present mean sea level (from Gornitz, 2001)

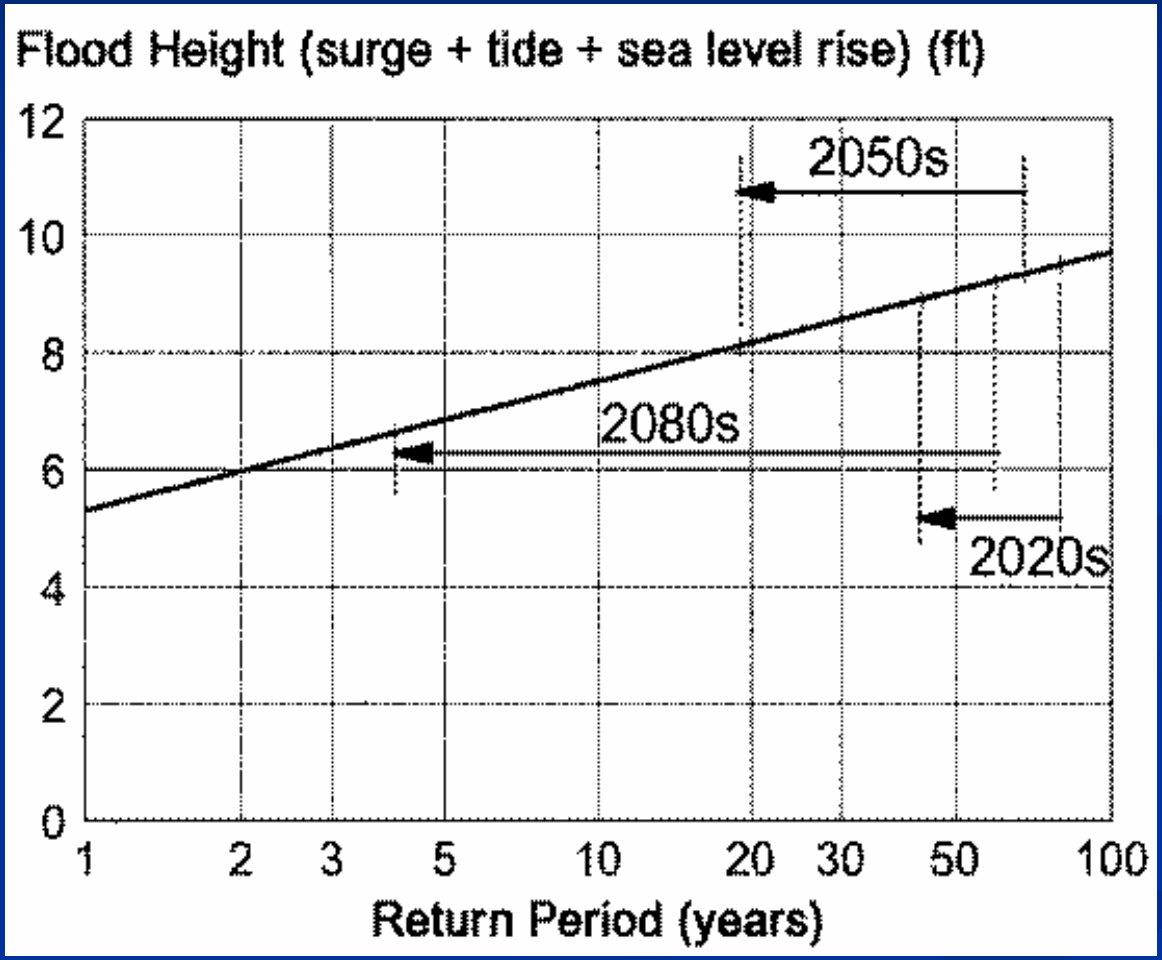
Flood Height vs. Return Period

(by 2090s)



Source: V.M. Gornitz, Climate Change and a Global City, 2000

Flood Height vs. Return Period 2020s, 2050s, 2080s



(from V.M. Gornitz, Climate Change and a Global City, 2000)

2. Existing Storm Surge Barriers in the USA and Europe

Providence, Rhode Island. Built 1966

Gates in open position

Boat steaming through the open gate

Providence, Rhode Island Taintor Gates

New Bedford MA, 1966

New Bedford MA

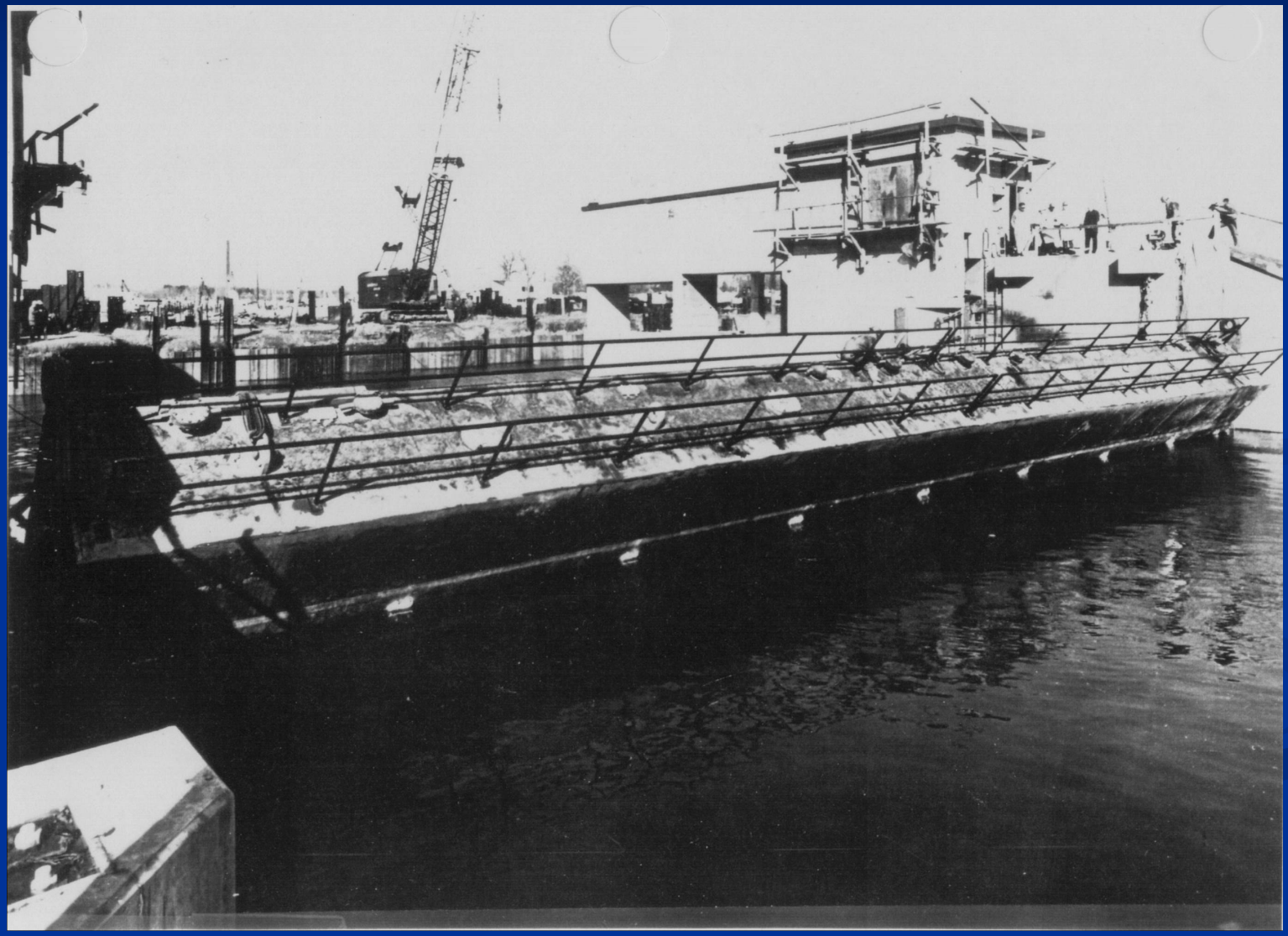
A high seawall stretches across the entrance to the harbor

Details of seawall/barrier construction

Rotateable flood gates across gap in seawall

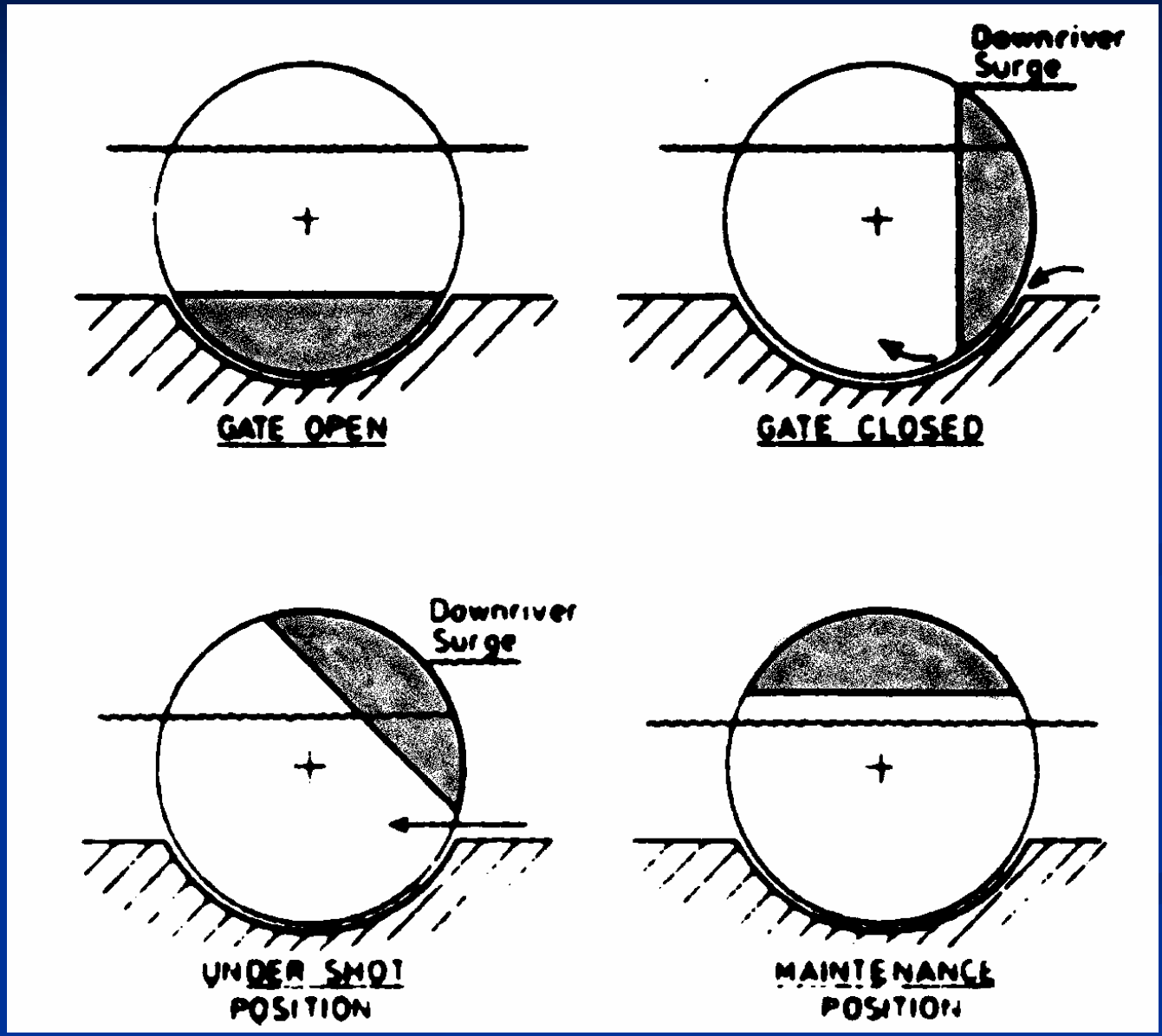
Stamford CT, 1968

Stamford Barrier



Thames River Tidal Barrier, England, 1982

Thames Barrier rotating gates - Operation

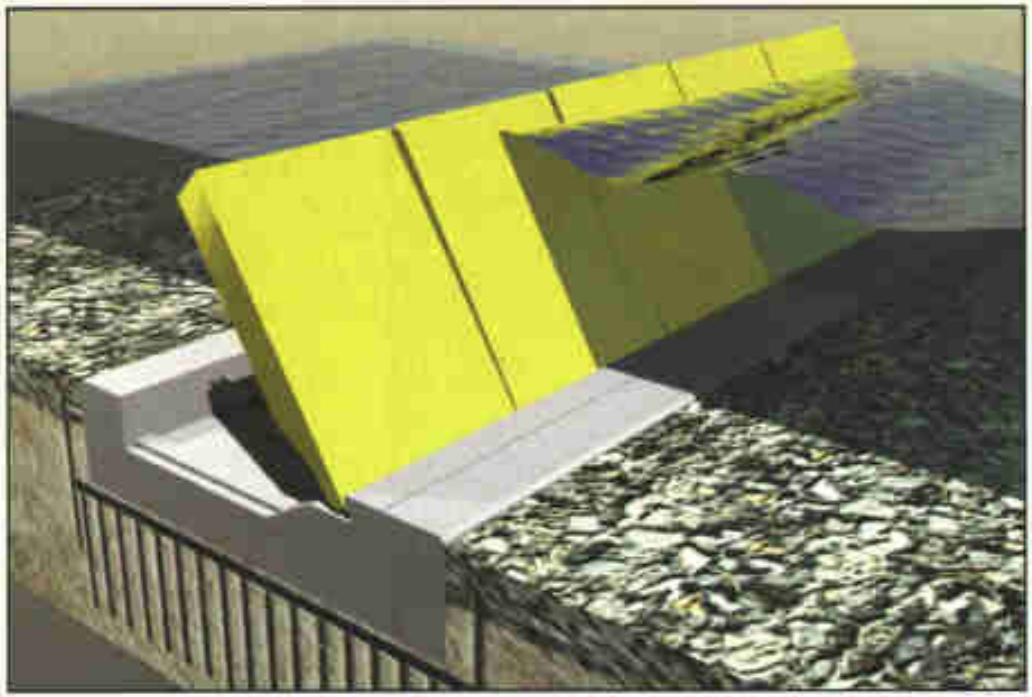


Hollandse Ijssel, the Netherlands, 1958

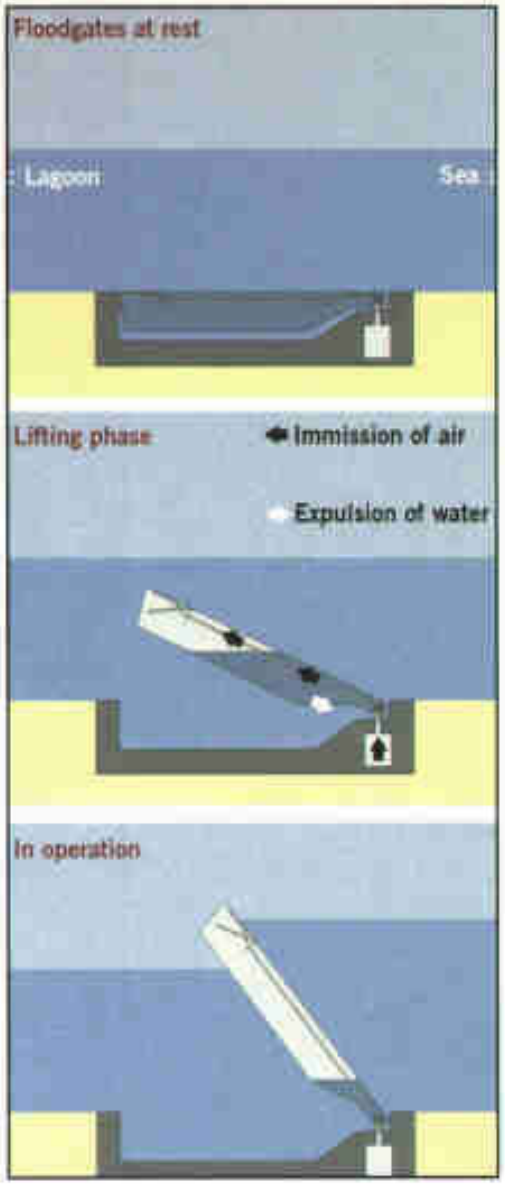
Eastern Scheldt, the Netherlands, 1986

New Waterway, the Netherlands, 1997

Venice Lagoon Design, 2010



THE GATES *fill with water under normal tidal conditions and rest on the inlet canal bed. When tides reach 100 cm, the gates will be filled with compressed air and rise to isolate the lagoon from the sea.*



Delays

Barrier	Flood	Completed	Delay
New England	1938	1966, 1968	28-30 years
Thames River	1953	1982	29
Holland	1953	1958, 1986, 1997	5, 33, 44
Venice	1966	(2010)	44

3. The Stony Brook Integrated Storm Surge Model

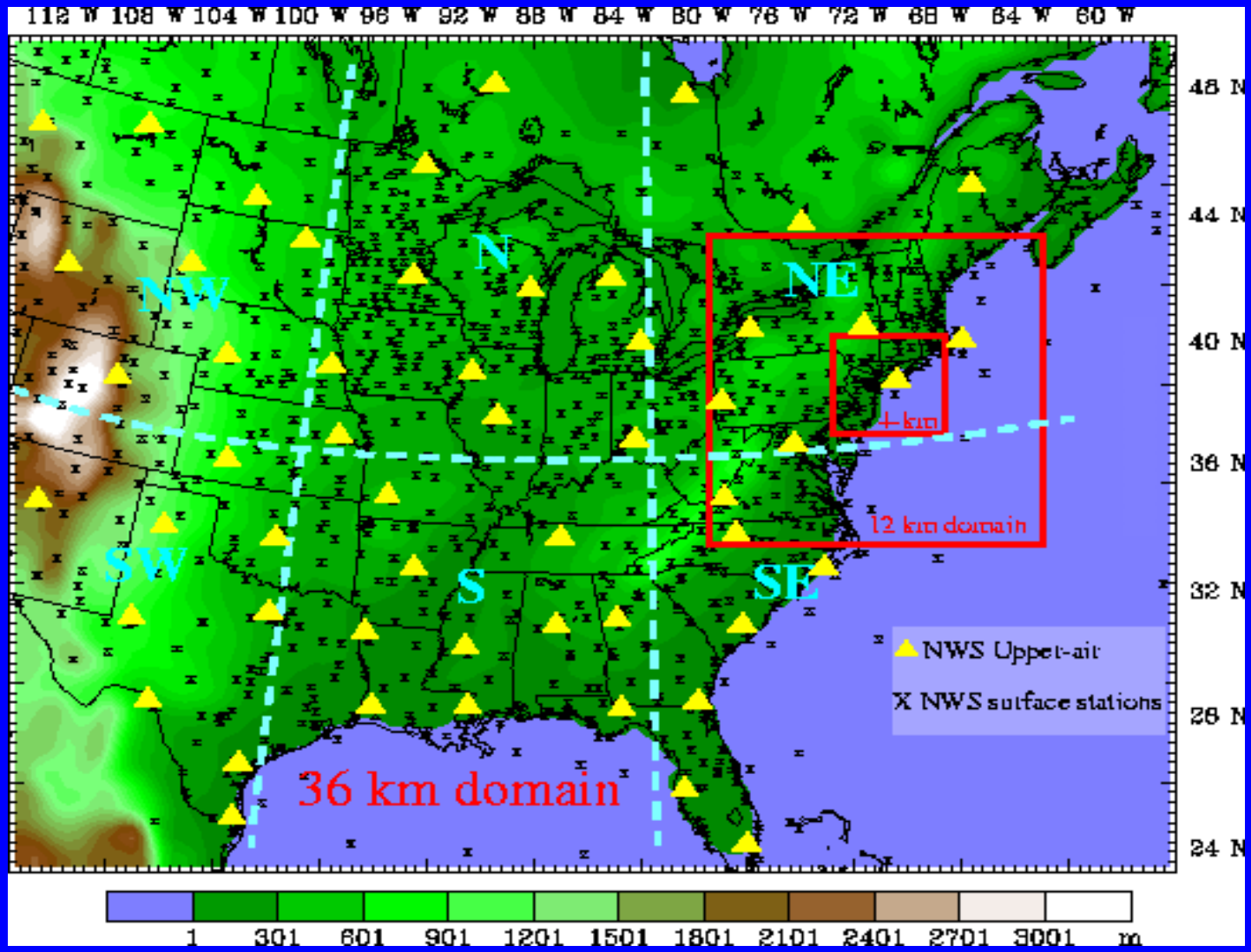


Fig. 9. MM5 36 km,12 km and 4 km nested model domains.

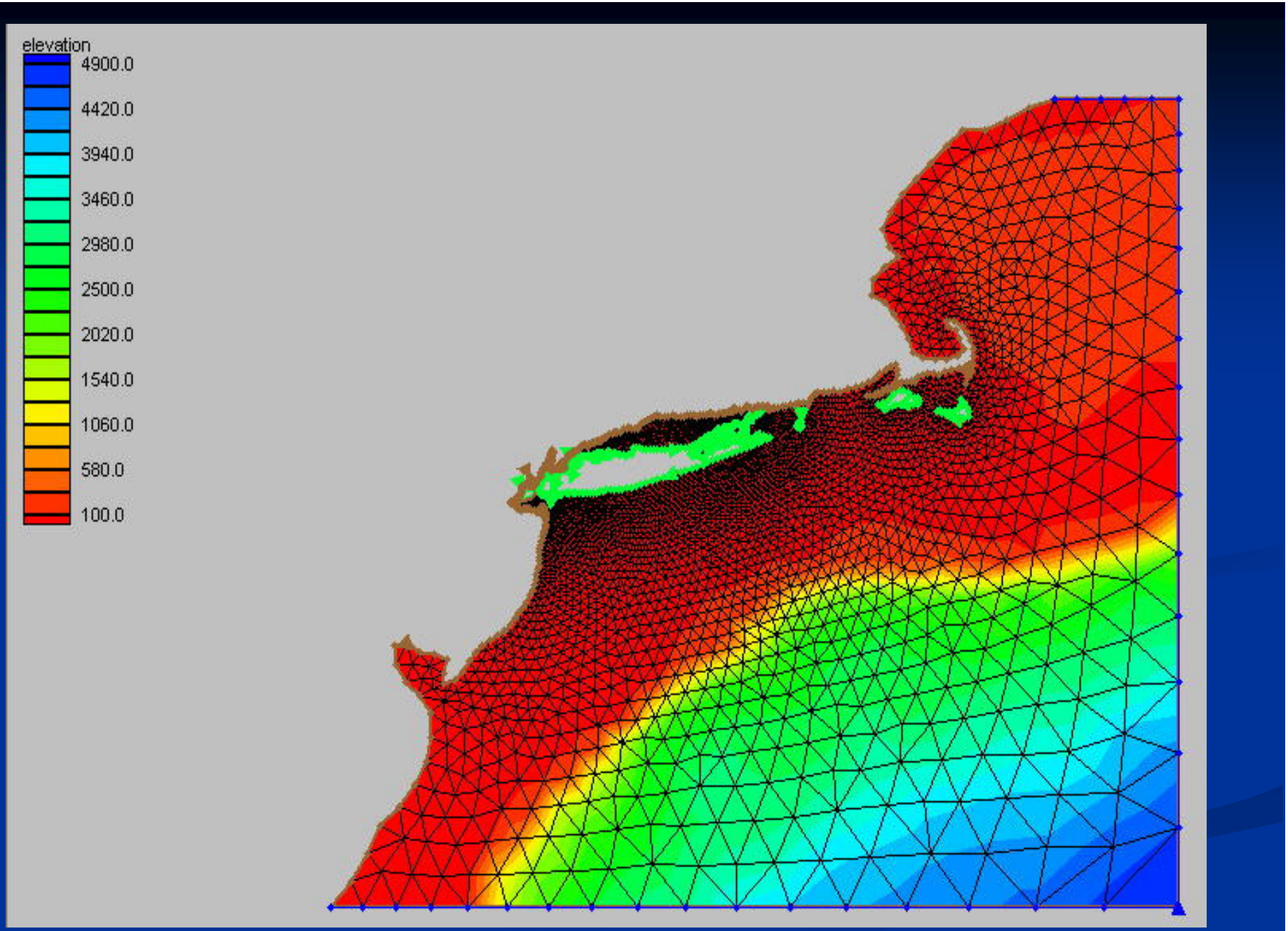
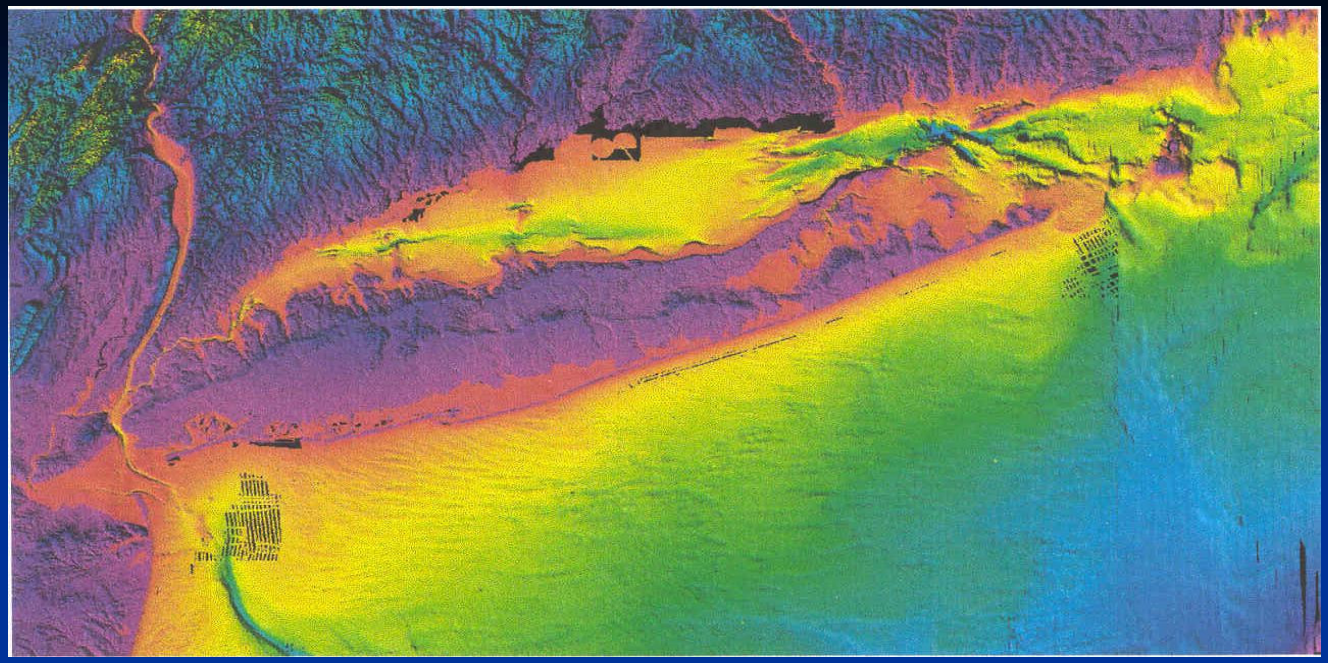
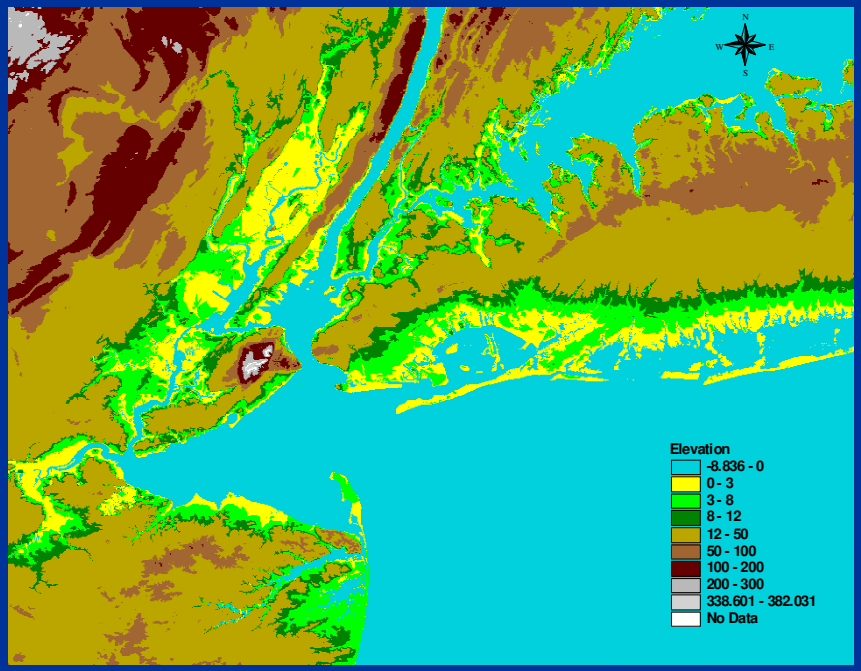


Figure 4. ADCIRC and MM5 (4 km) model domain.

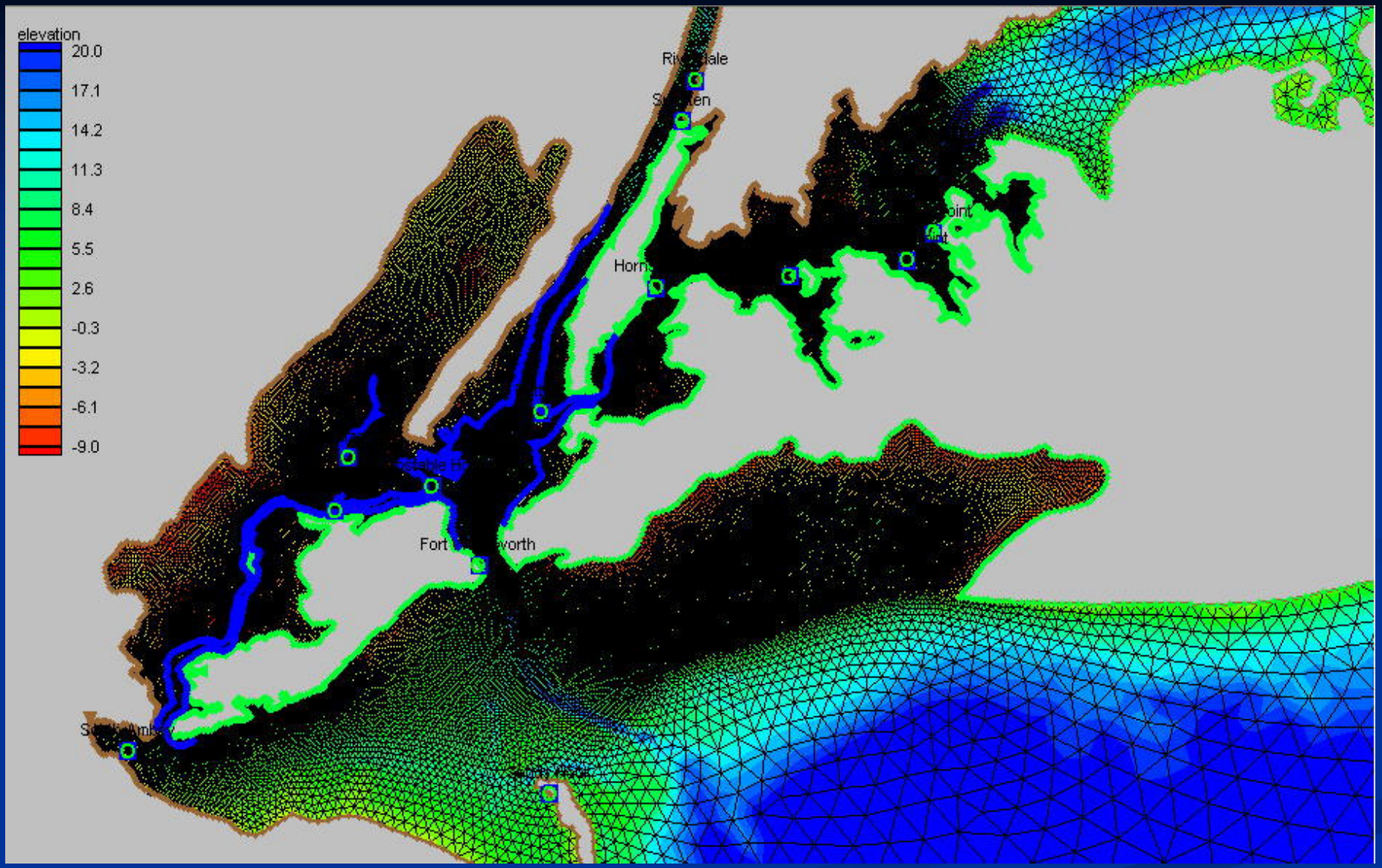
4. Bathymetric/Topographic Database for the New York Coastal Region



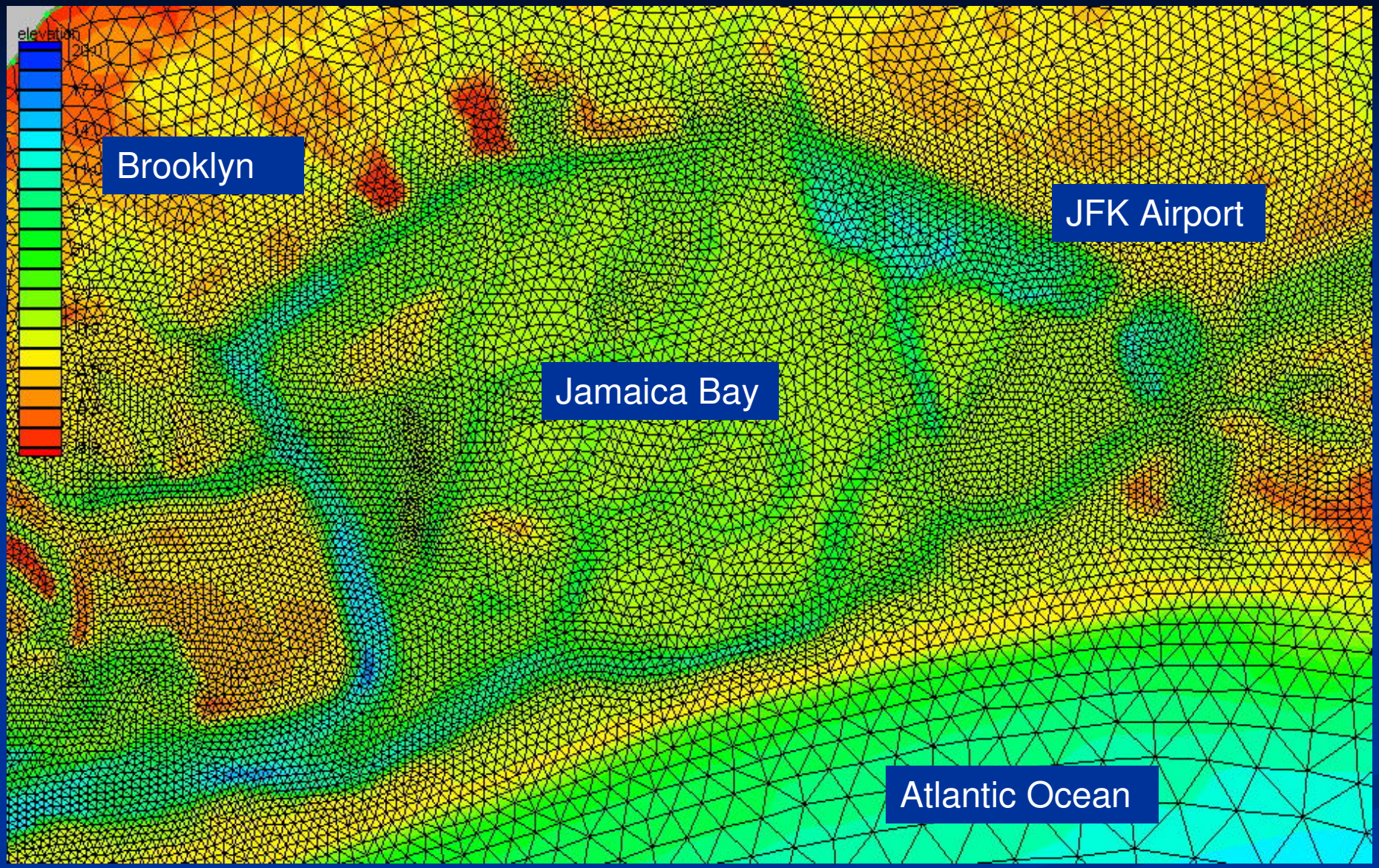
Map of merged high-resolution bathymetric & topographic data for the New York coastal area.



Topographic contour map (m) for the greater Metropolitan region. The dark green-brown color boundary is the 8 m above msl contour.



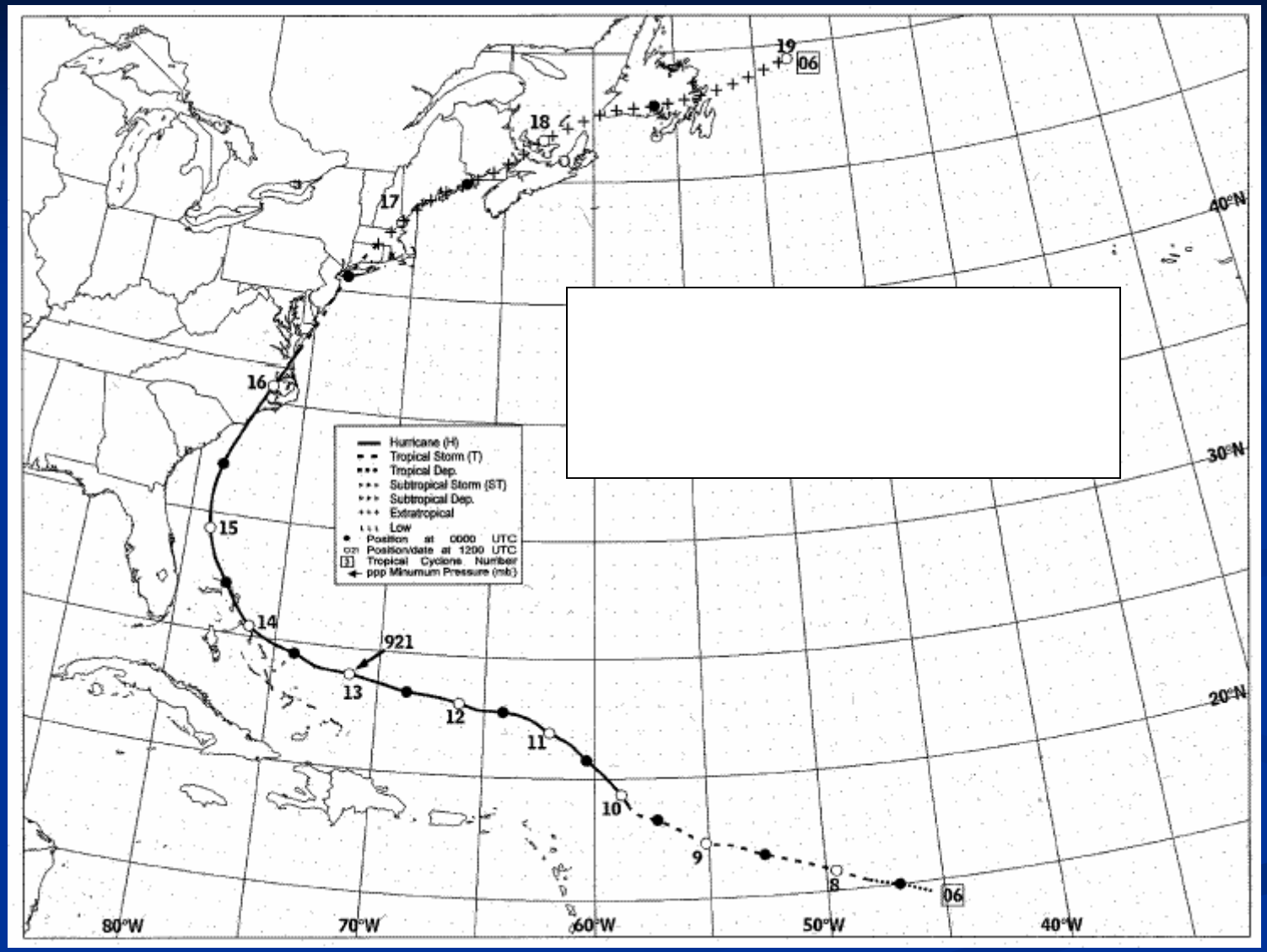
Detail of ADCIRC grid. Blue contours delineate regions where weirs (seawalls) have been inserted; green line is the +8 m contour.

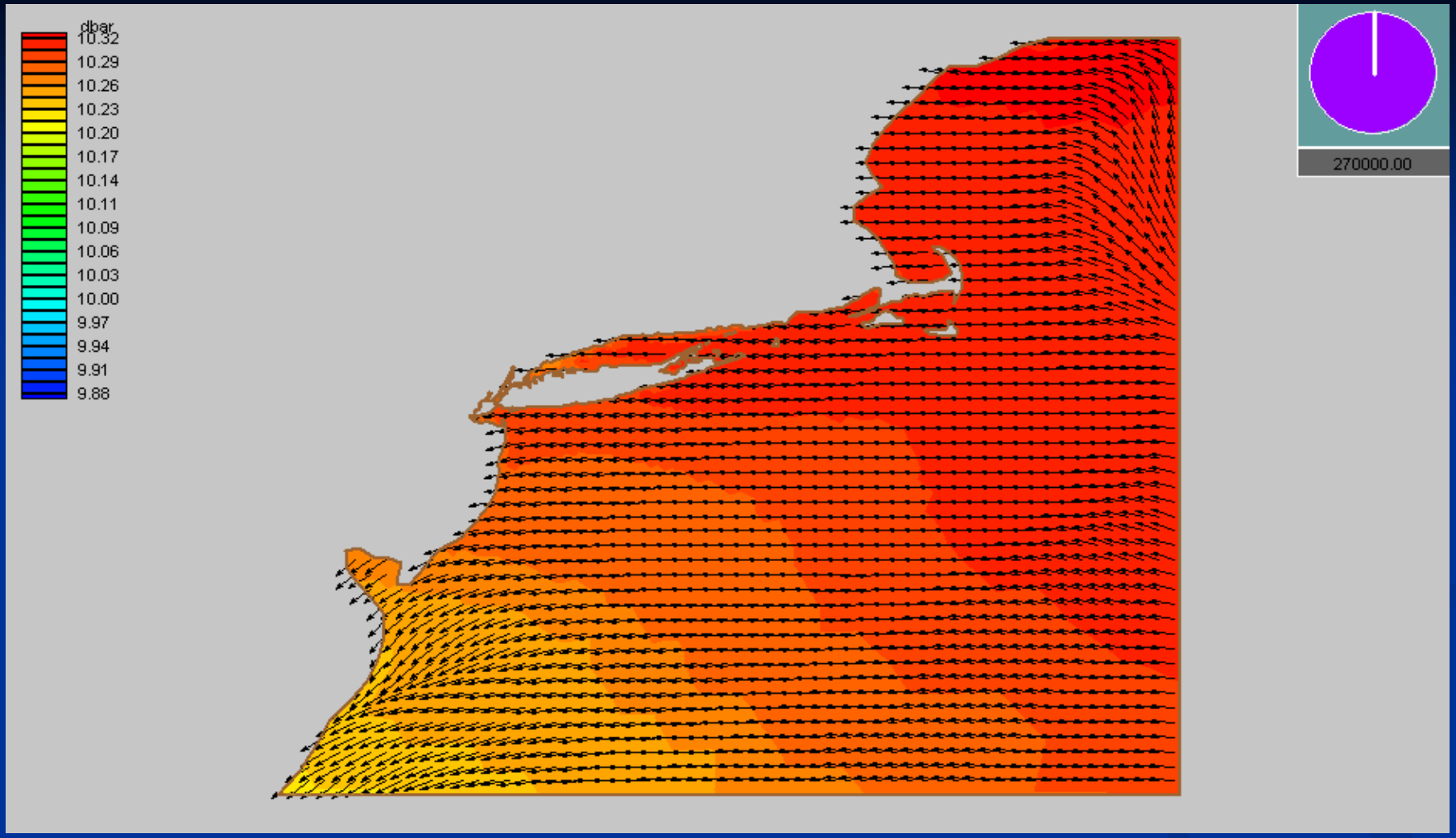


Detail of gridding of Jamaica Bay up to +8 m contour.

5. Test runs on Historical Storm Events

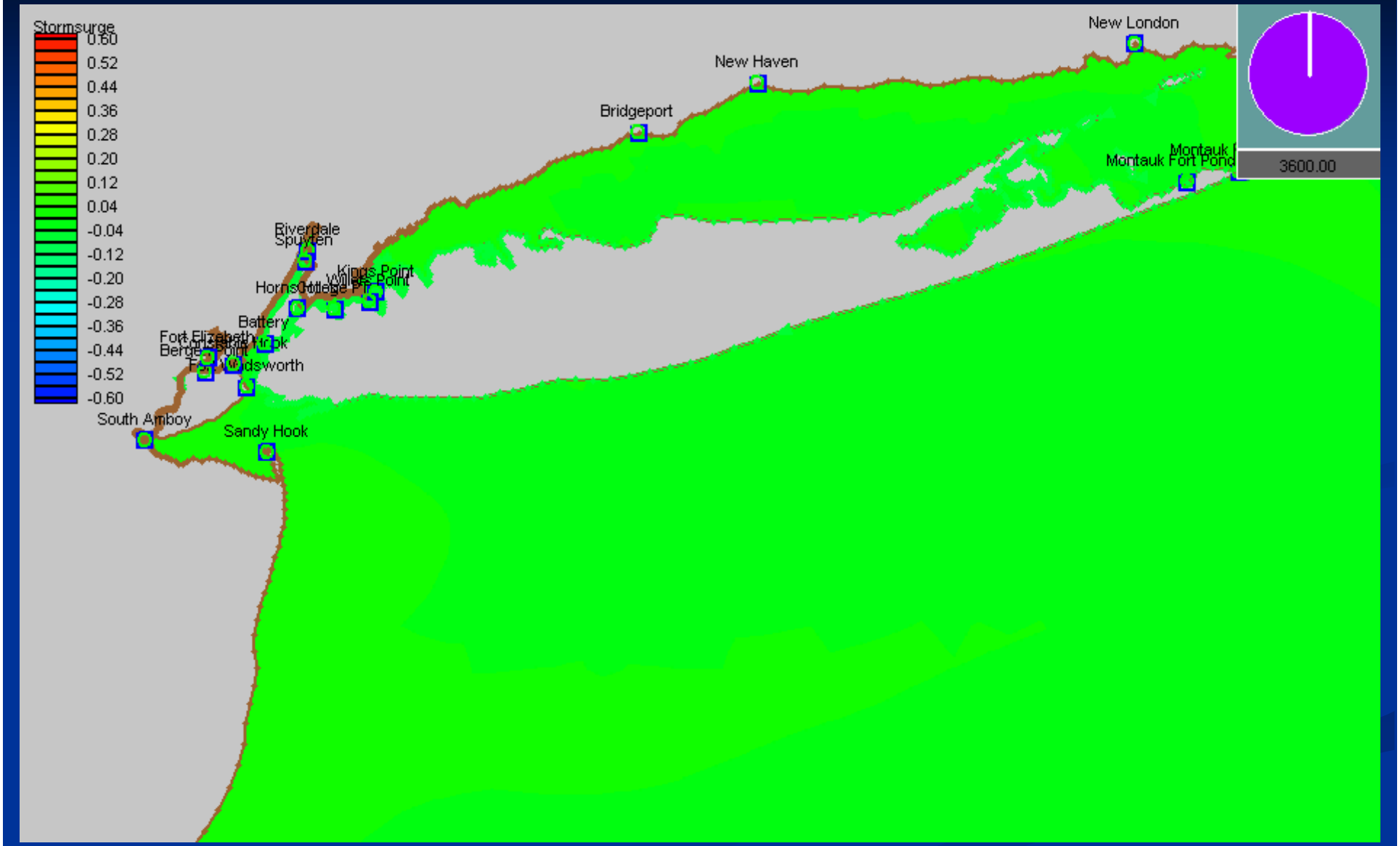
- Hurricane Floyd (Sept 1999)
- Super Floyd
- December 2002 Nor'easter

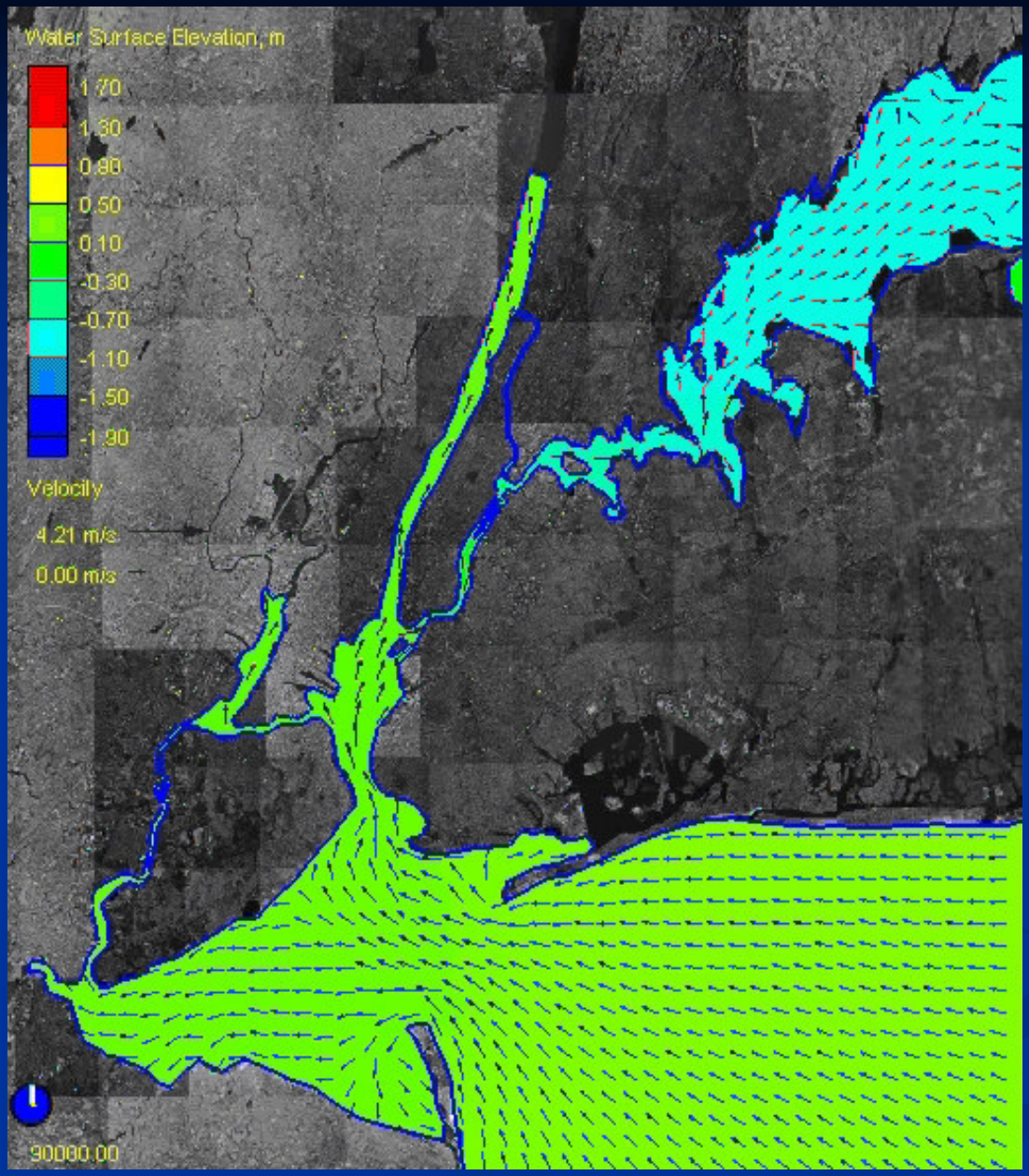

Hurricane (H)
Tropical Storm (T)
Tropical Dep.
Subtropical Storm (ST)
Subtropical Dep.
Extratropical
Low
Position at 0000 UTC
Position/date at 1200 UTC
Tropical Cyclone Number
ppp Minumum Pressure (mb)
921
40°N
30°N
20°N
80°W
70°W
60°W
50°W
40°W

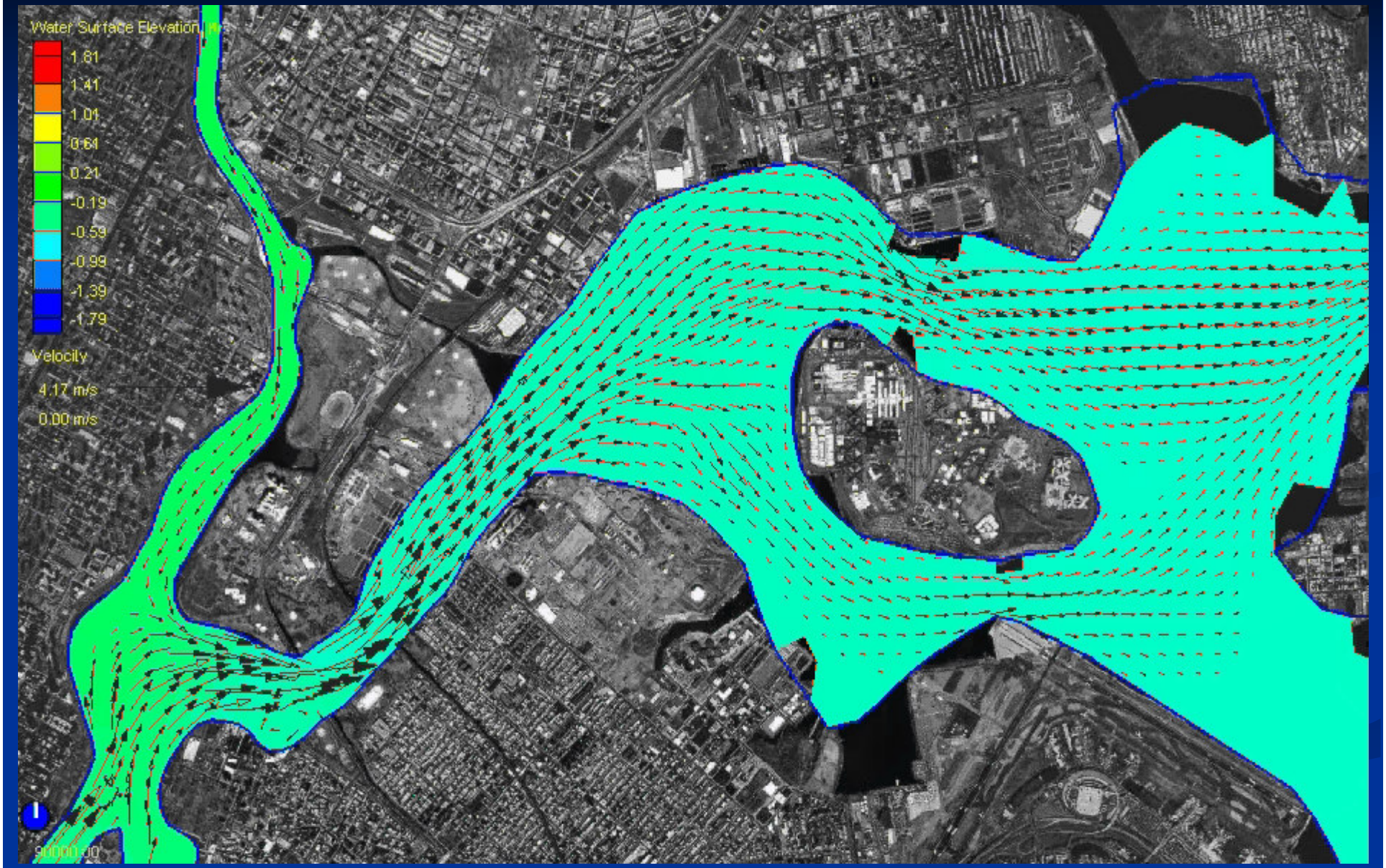


Winds and sea level pressure during Hurricane Floyd (16-19 Sept 1999)

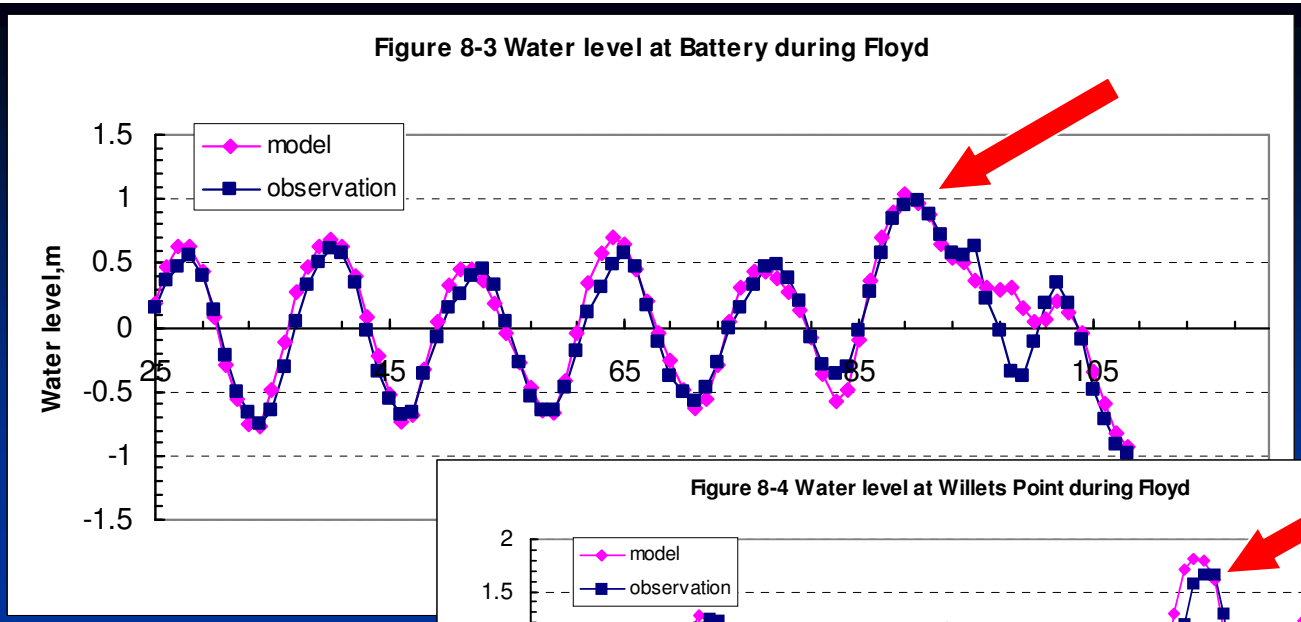
Storm surge (m) during Hurricane Floyd 16-19 Sept 1999

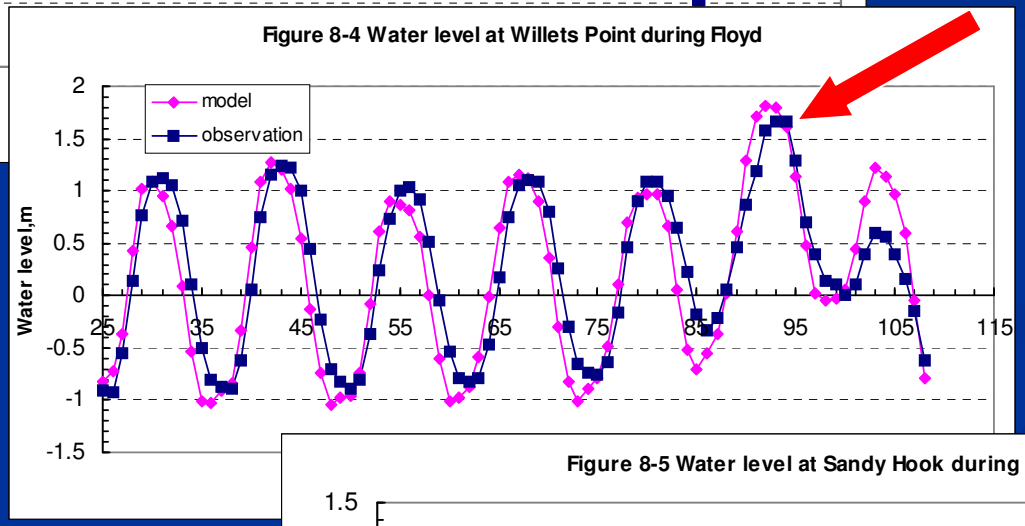


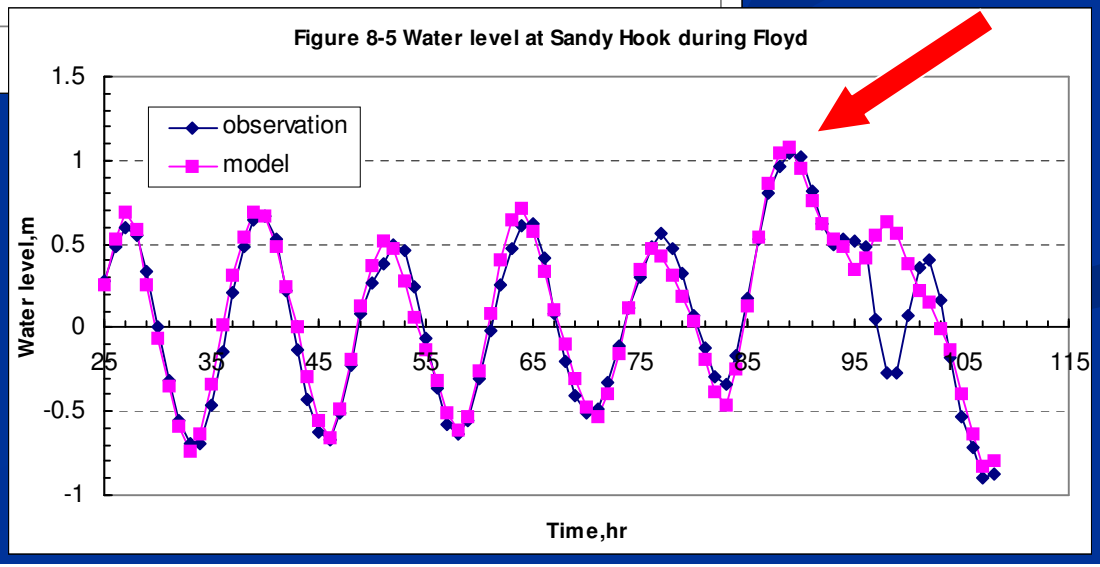

Water Surface Elevation, m
1.70
1.30
0.90
0.50
0.10
-0.30
-0.70
-1.10
-1.50
-1.90
Velocity
4.21 m/s
0.00 m/s
90000.00

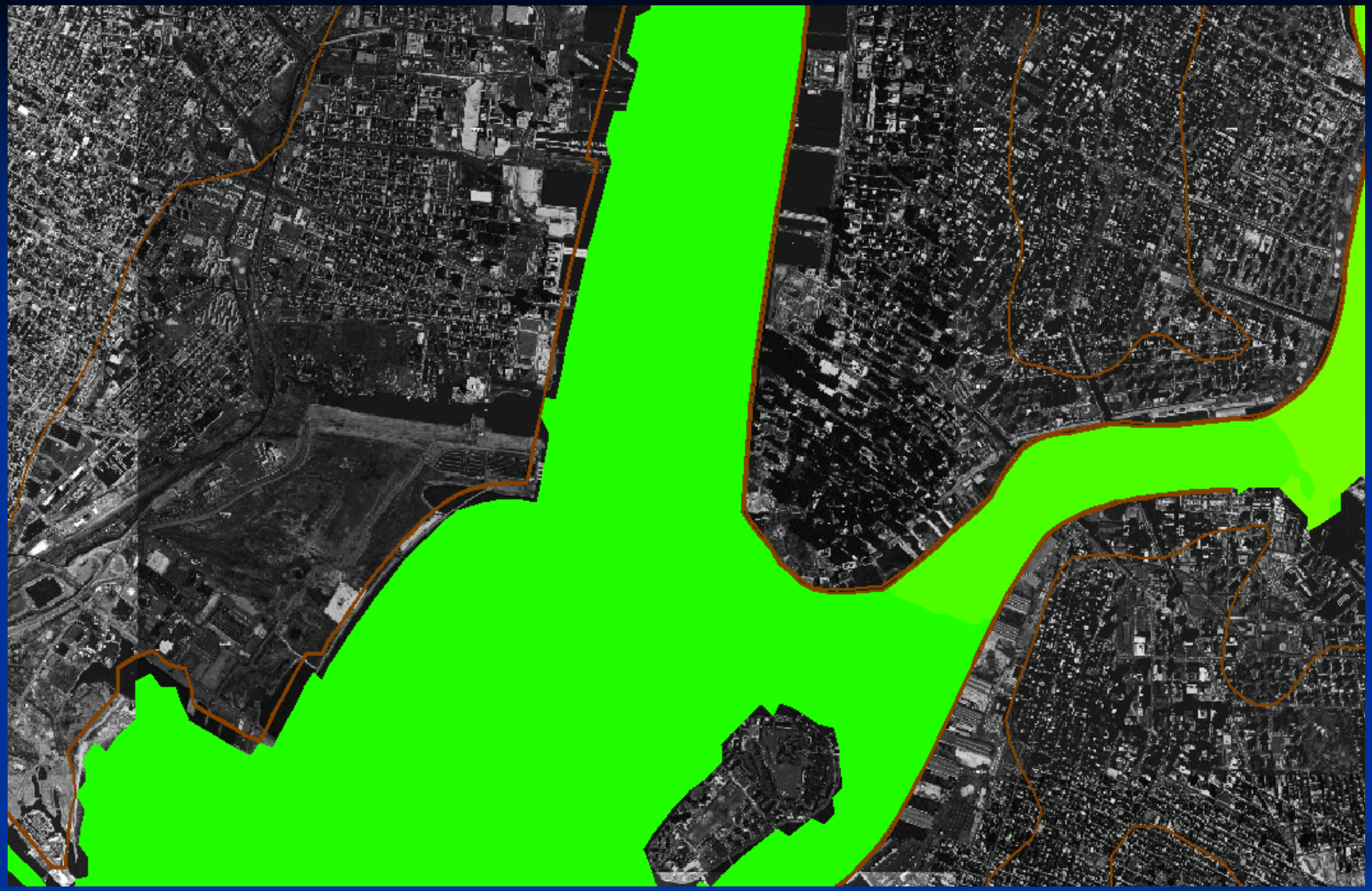

Water Surface Elevation
1.81
1.41
1.01
0.61
0.21
-0.19
-0.59
-0.99
-1.39
-1.79
Velocity
4.17 m/s
0.00 m/s

Comparison of observations and modeling of sea level during Floyd

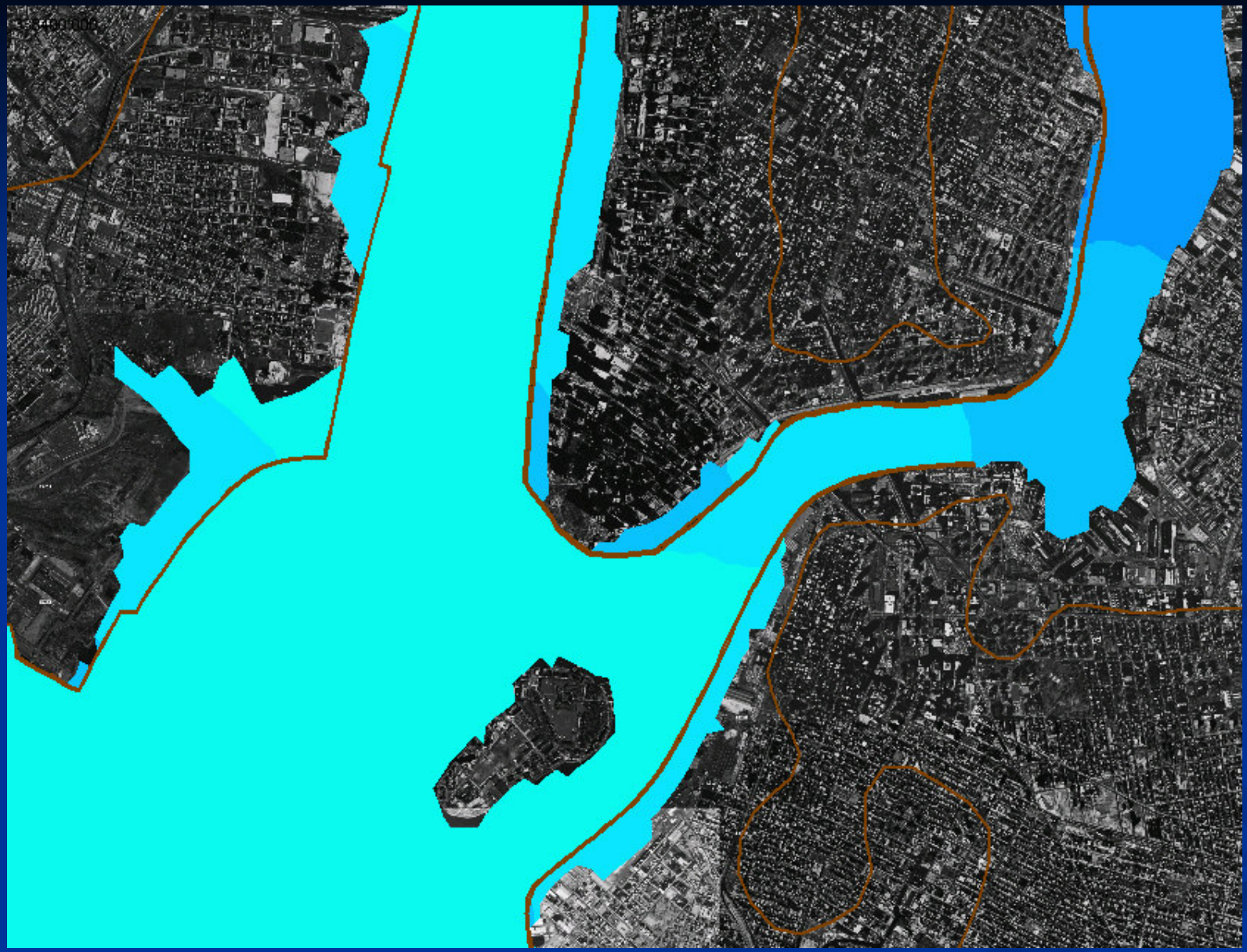


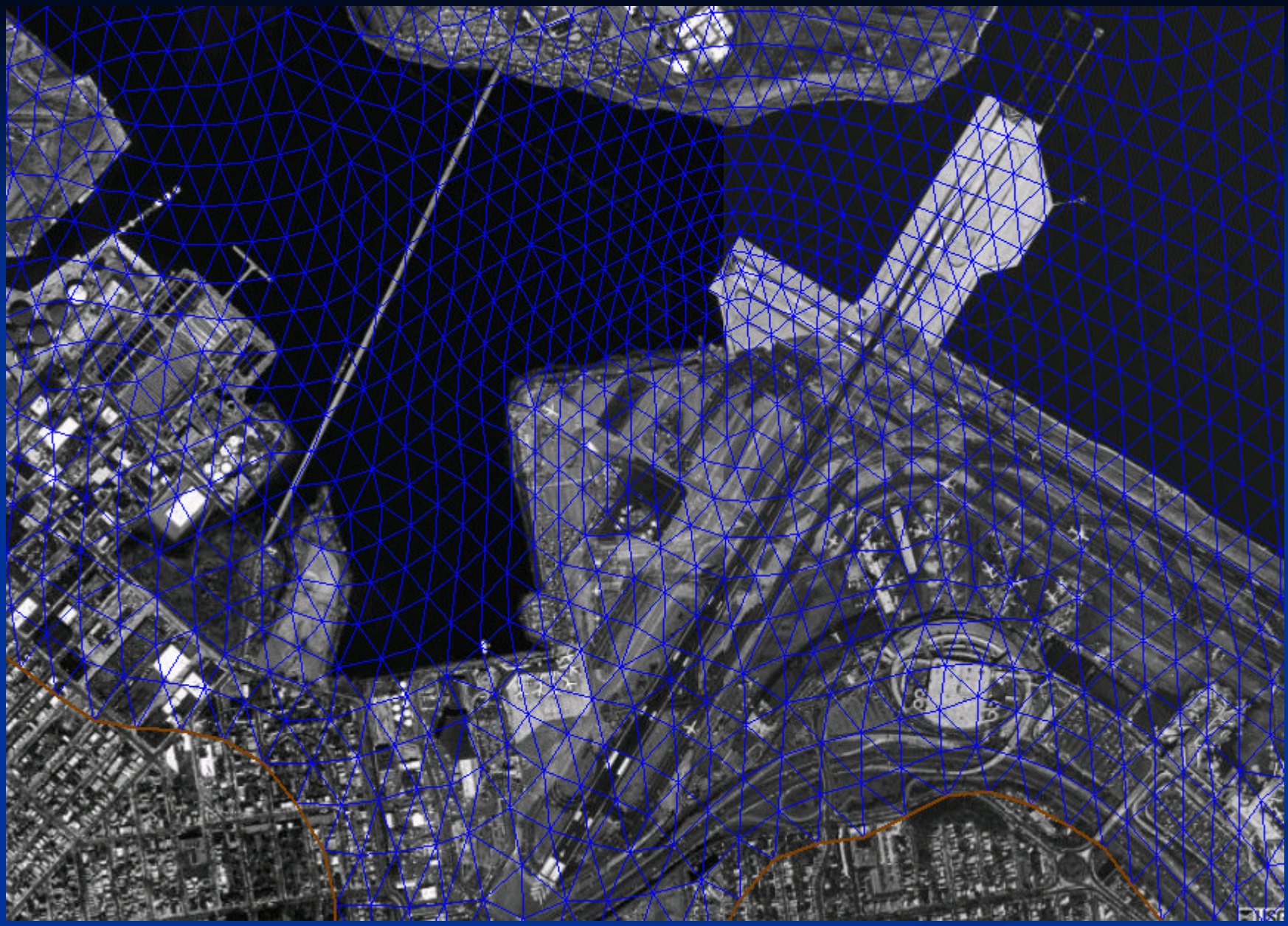




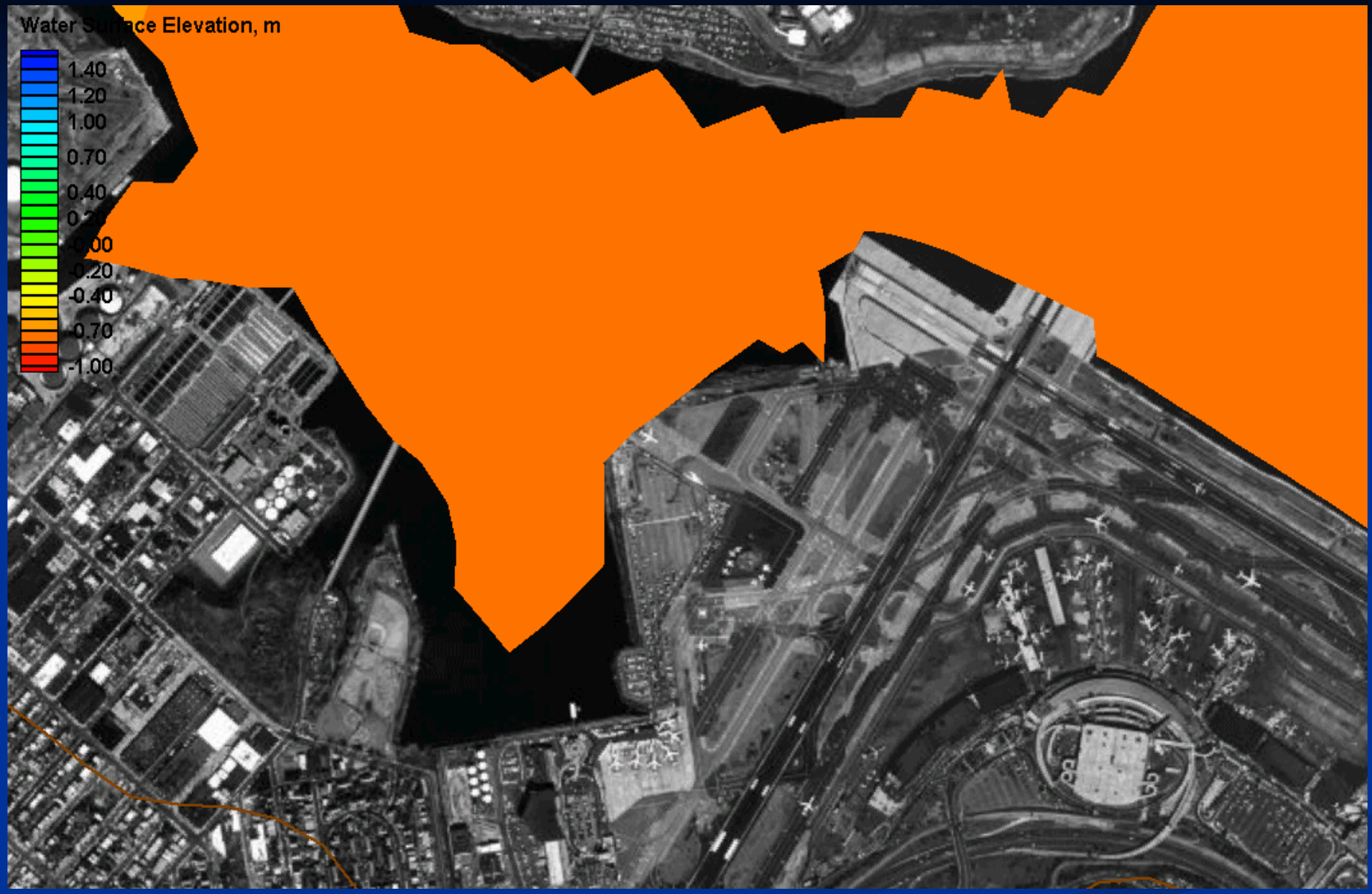


Water level elevations superimposed on aerial photo showing flooding during Super Floyd.

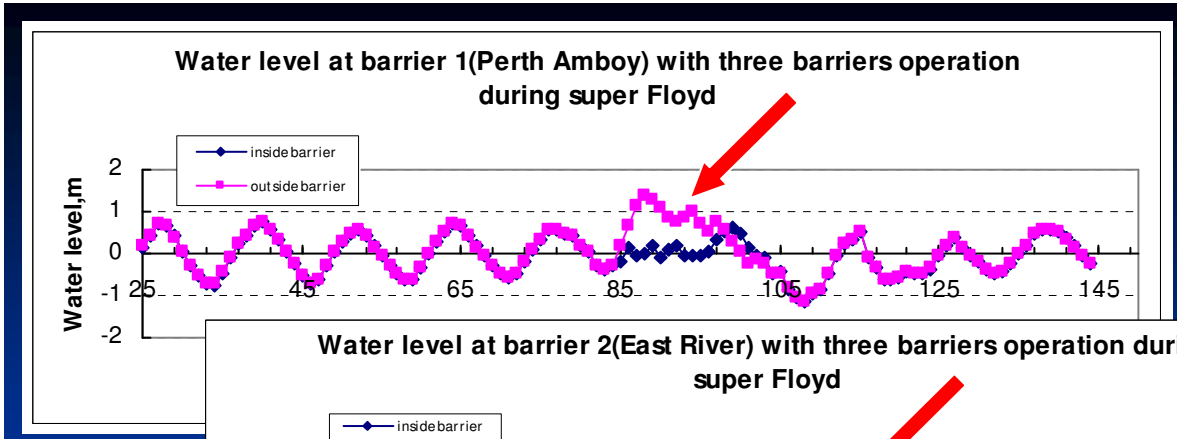




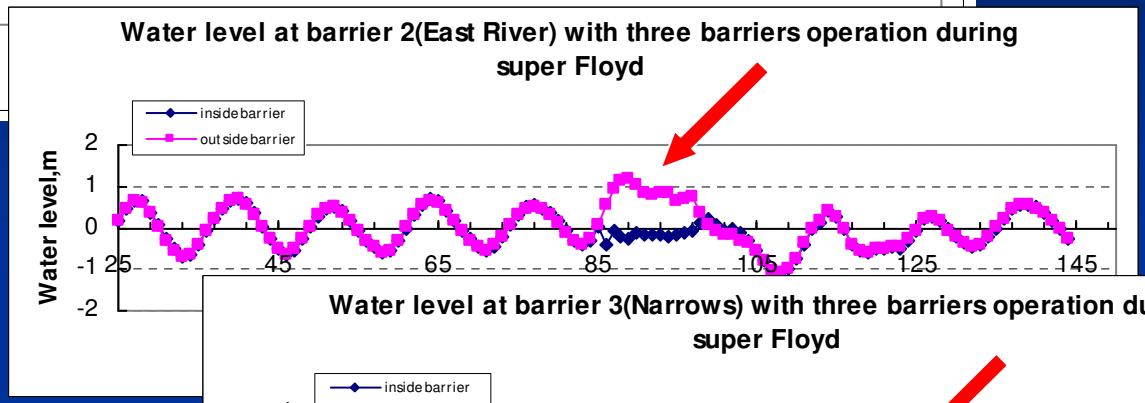
Detail of gridding around La Guardia Airport



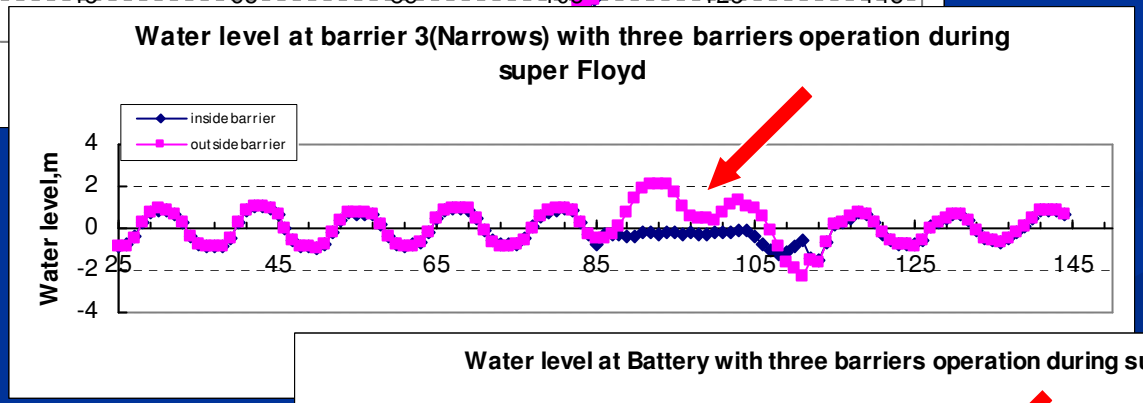
Flooding at La Guardia airport during Super Floyd (no dikes)



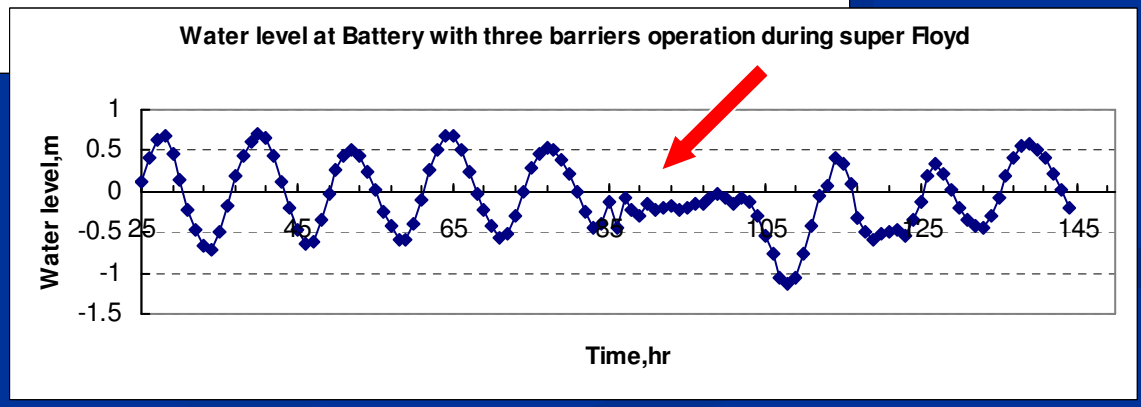
Perth Amboy



East River

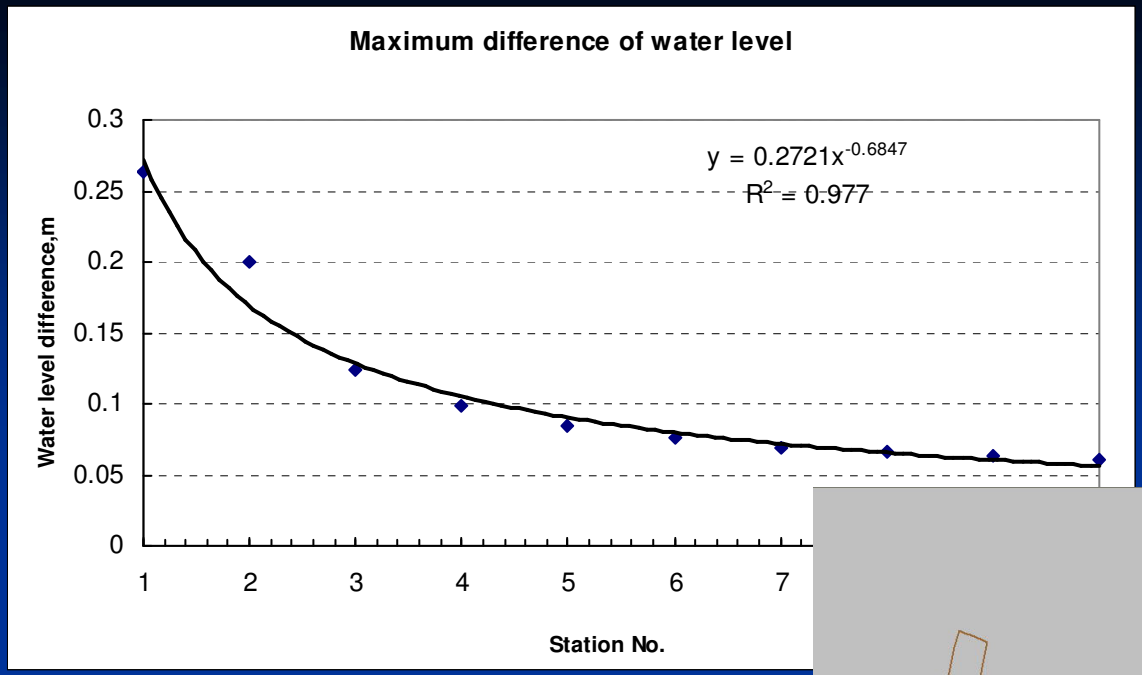


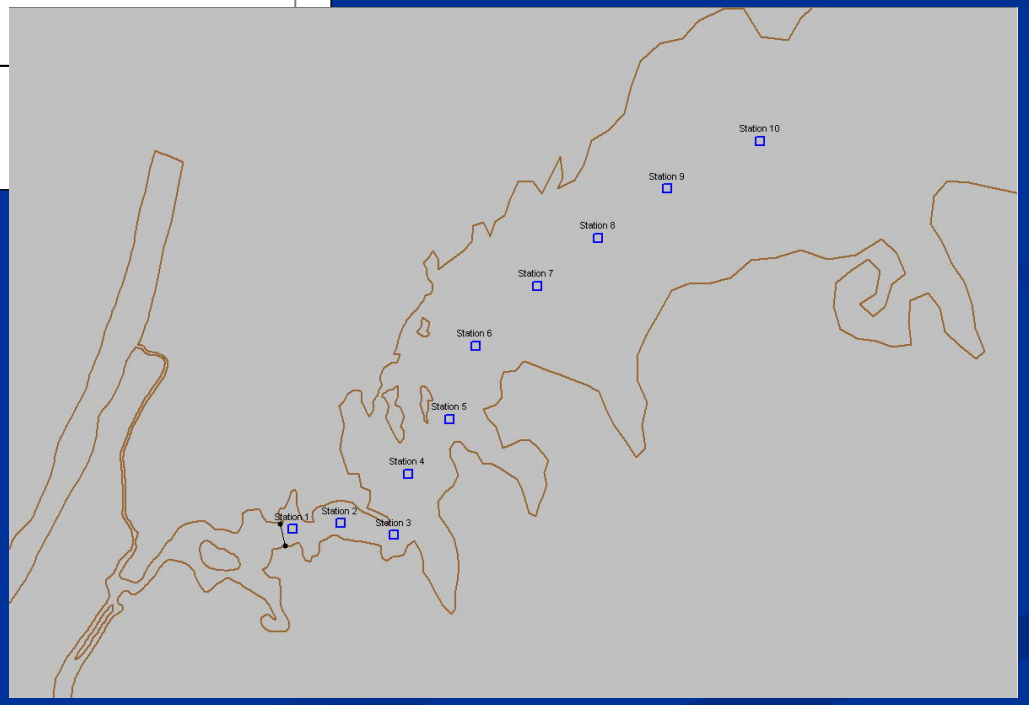
The Narrows



The Battery

Barriers deployed during Super Floyd eliminate NY Harbor surge





Incremental rise in water level east of closed East River barrier during Dec 2002 nor'easter.

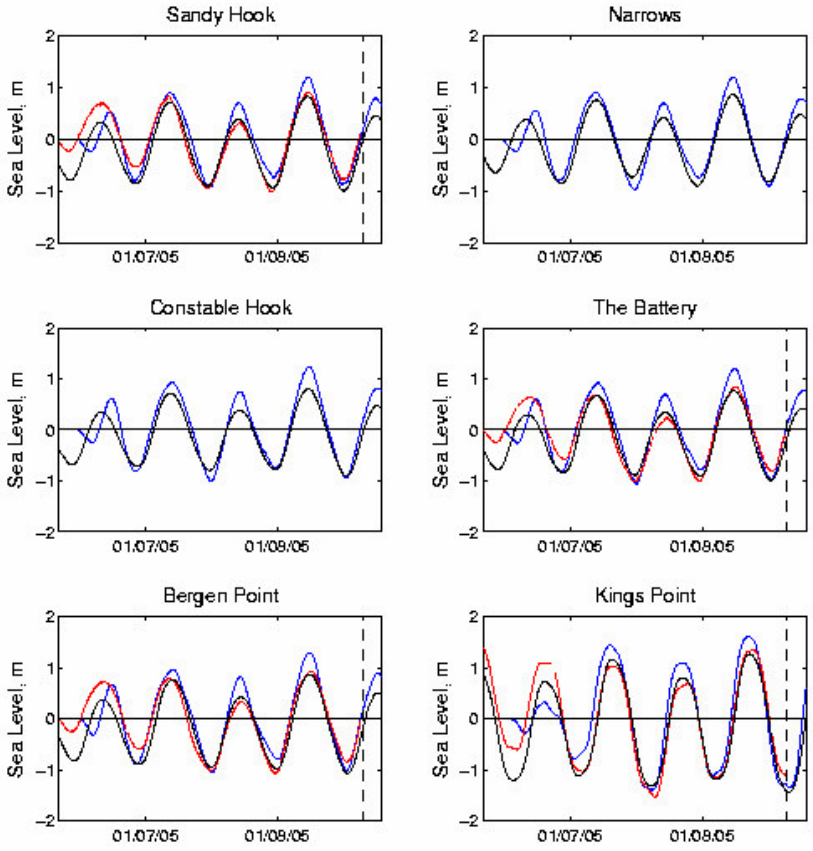
6. Coastal Early Warning System

Stony Brook Storm Surge Research Group

Water level predictions from coupled MM5-ADCIRC models running at 12 km and reduced-resolution, respectively. The Stony Brook MM5 model, a mesoscale weather forecasting model, produces 60 hour predictions in about 120 minutes, twice a day. Wind speed and sea-level pressure predictions are then used to drive the ADCIRC storm surge ocean model over the same 60 hour period. The routine repeats every 12 hours, updating the forecasts.

Times shown are Greenwich Mean Time, which is 5 hours ahead of Eastern Standard Time.

Click on graphs for enlargement



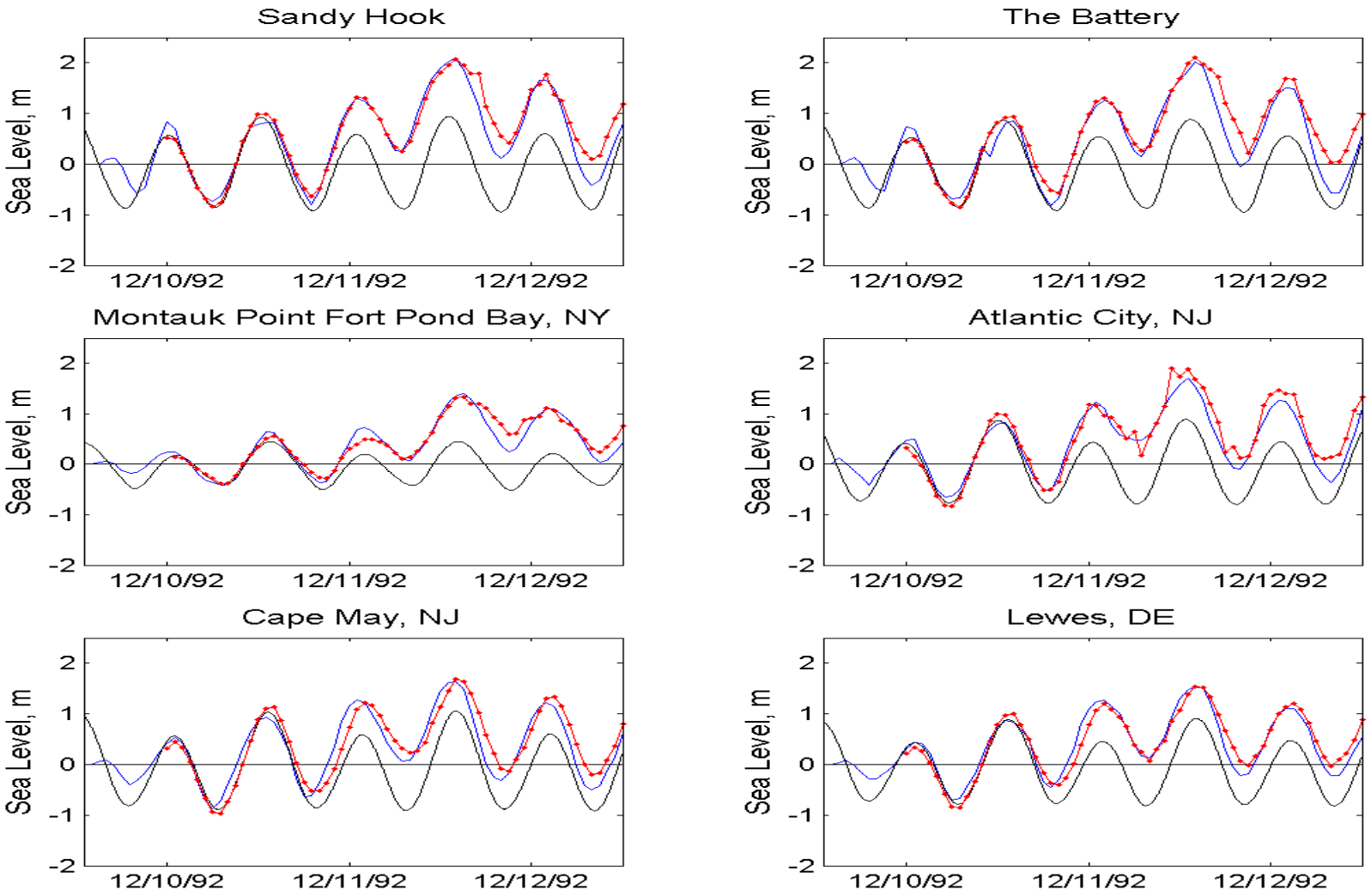
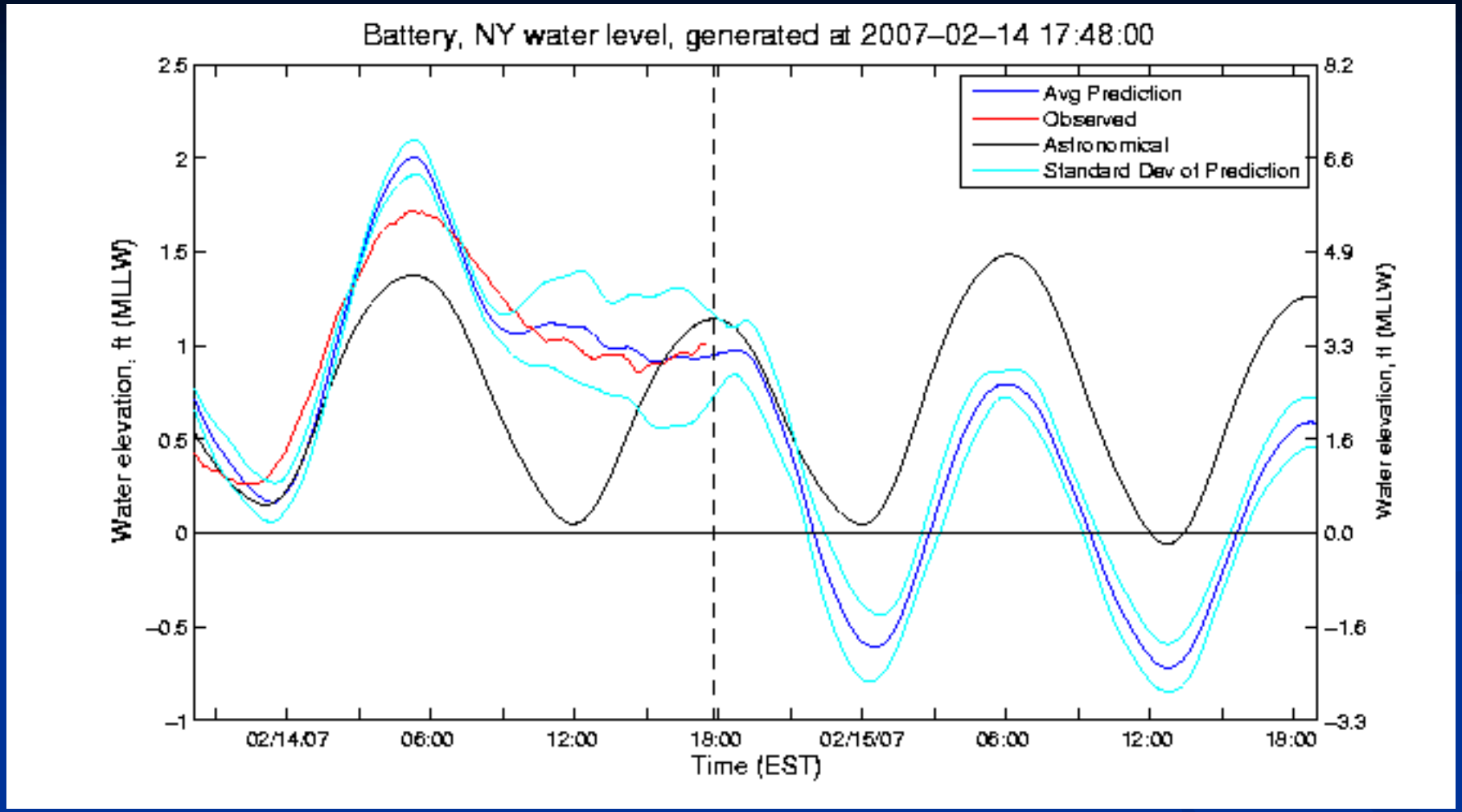
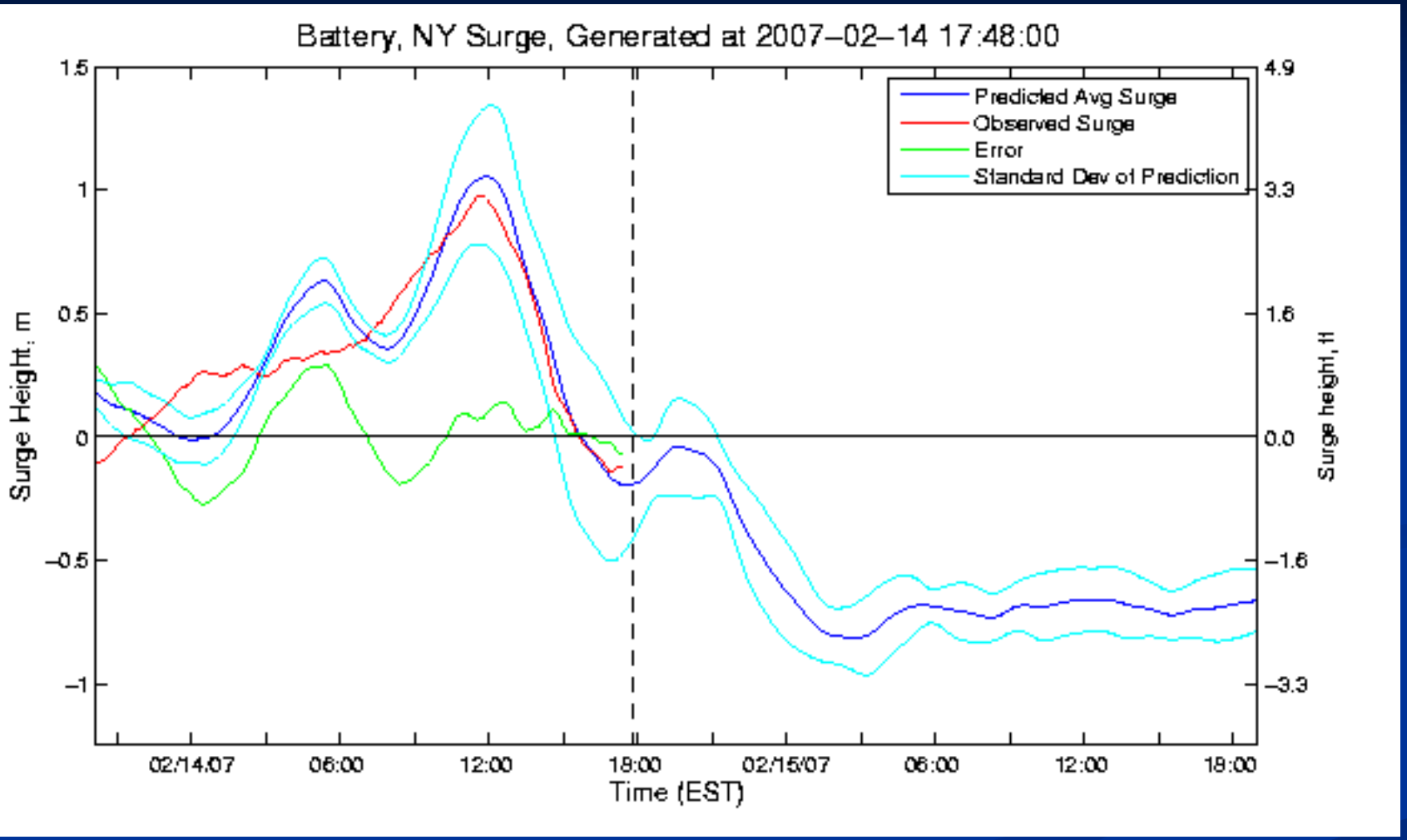


Fig. 3: Storm surge hindcast for 10-12 December 1992 nor'easter for various stations (13K grid). Observations (red), predictions (blue), astronomical tide (black).



Tide and surge forecast for 14 Feb 2007 nor'easter for the Battery NY (13K grid).



Surge forecast for 14 Feb 2007 nor'easter for the Battery NY (13K grid).

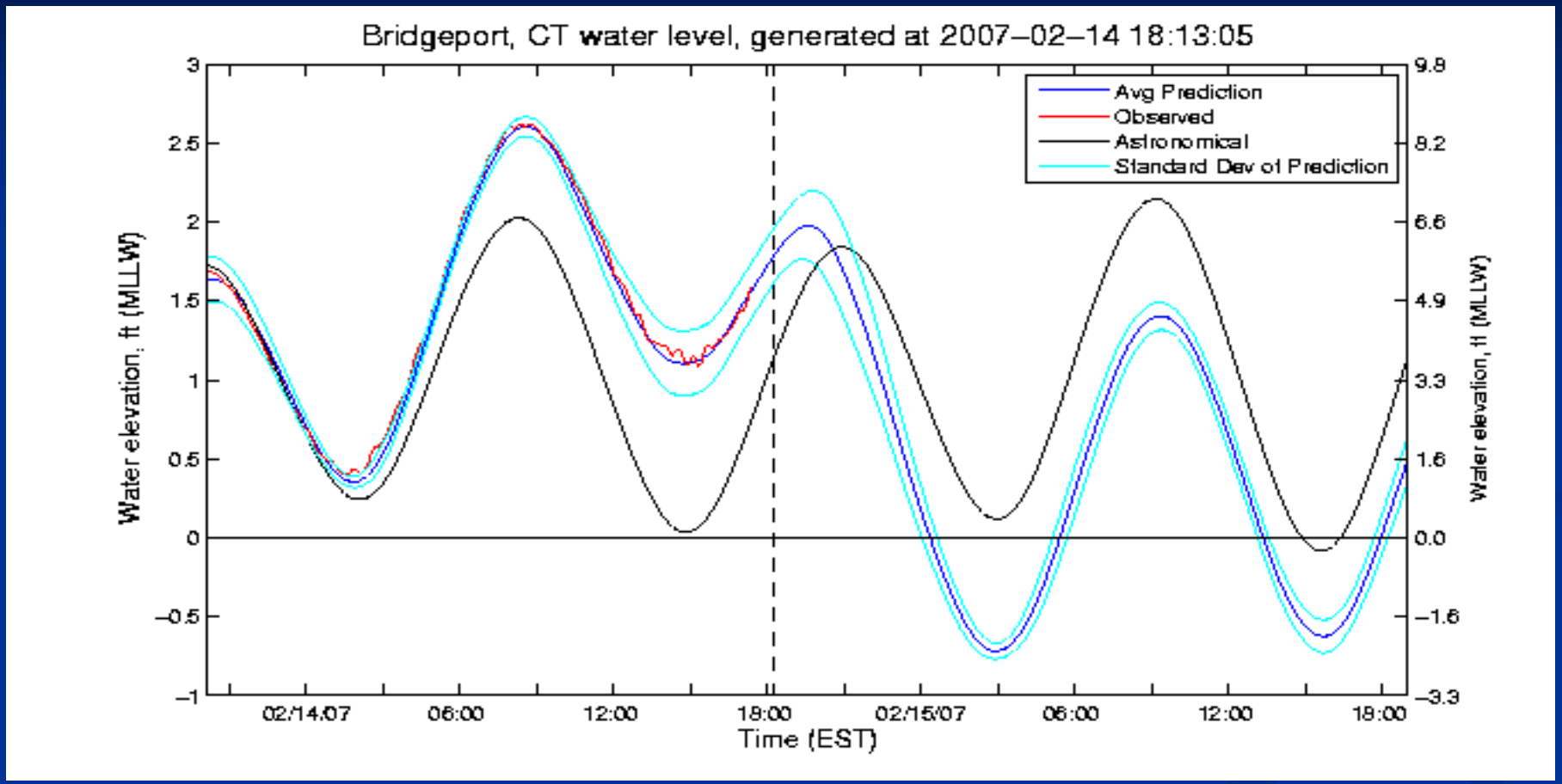


Fig. 8: Surge and tide observations (red), predictions (blue) and standard deviation (cyan) for Bridgeport CT 14 Feb 2007. Left of the vertical dashed line records the past predictions and observations, to the right of the line is the surge prediction into the future.

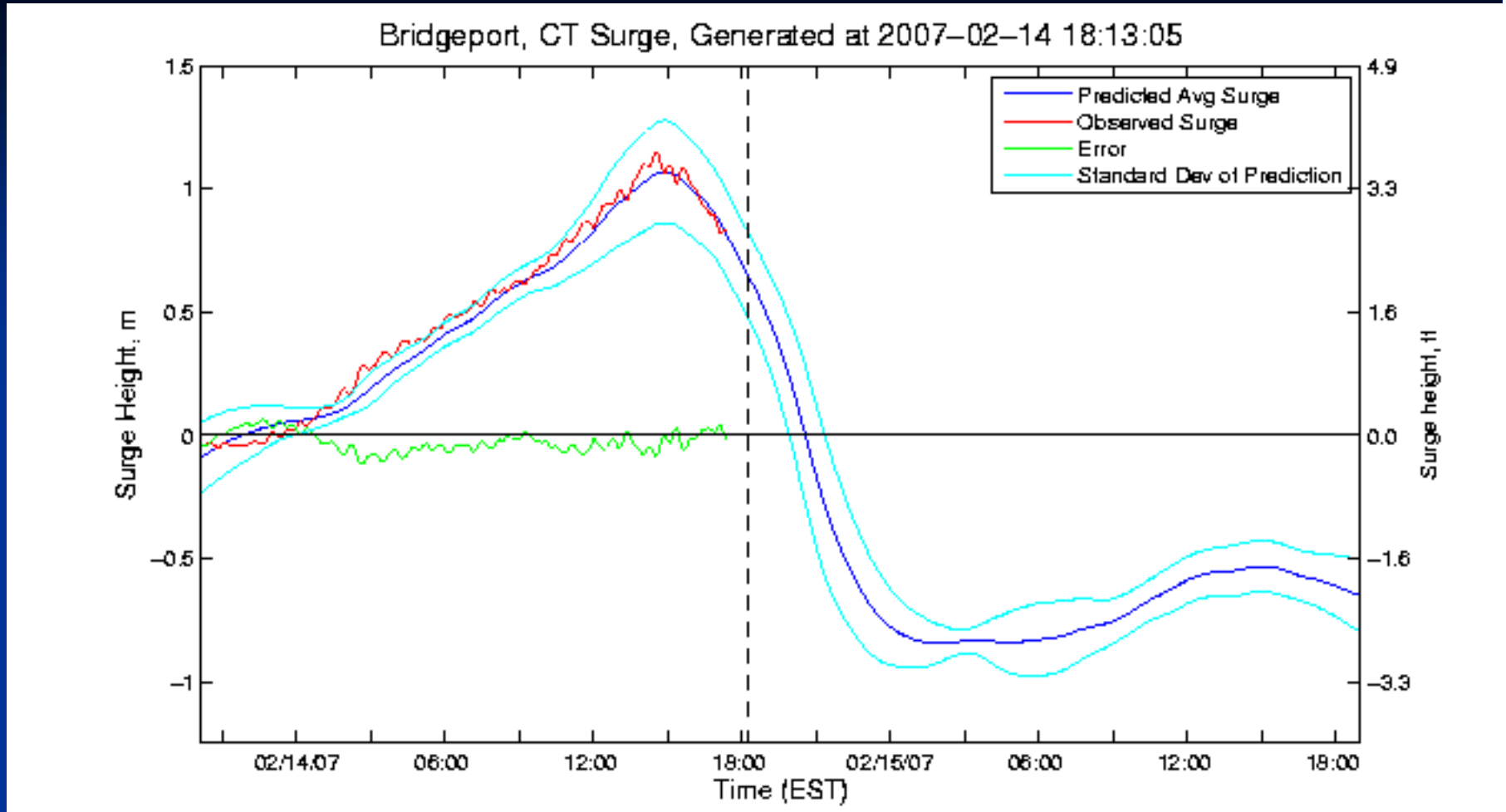
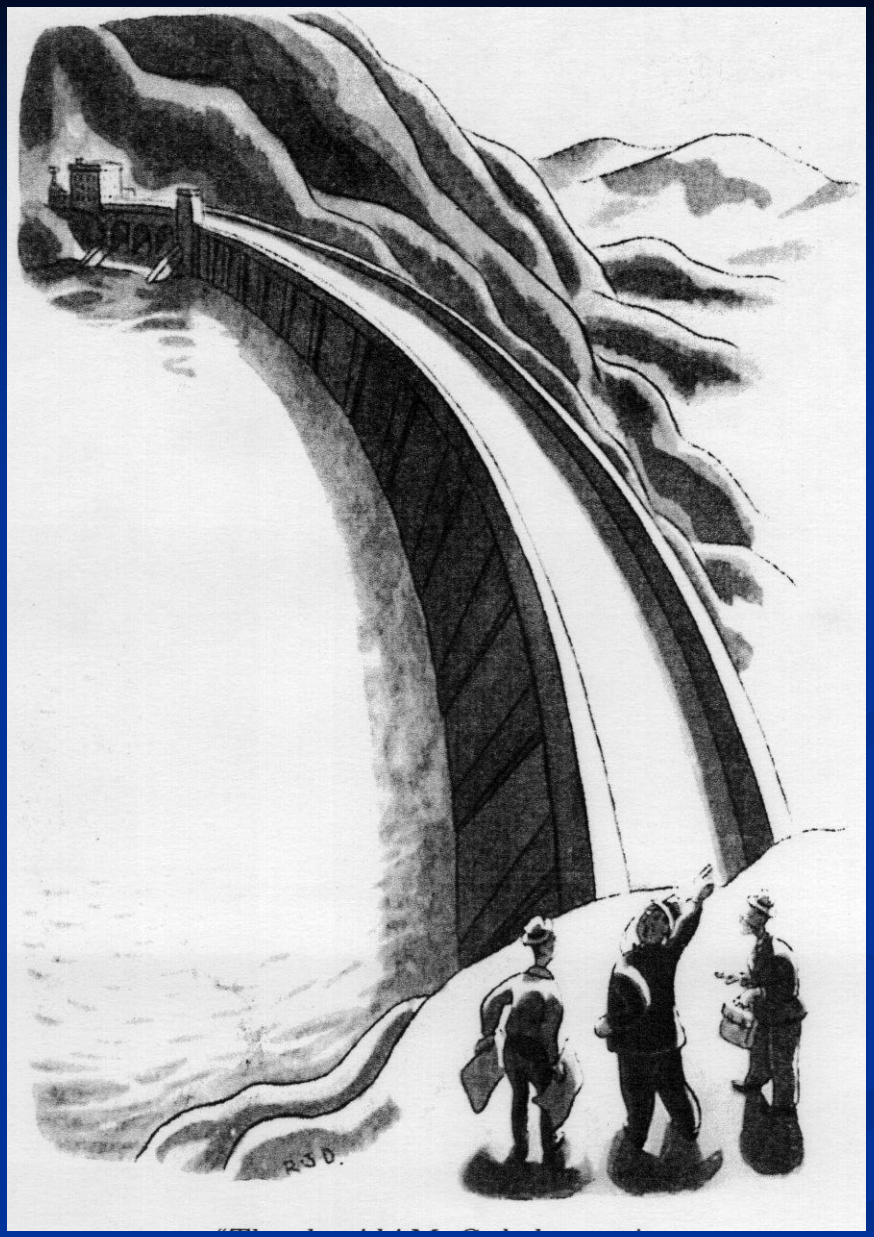
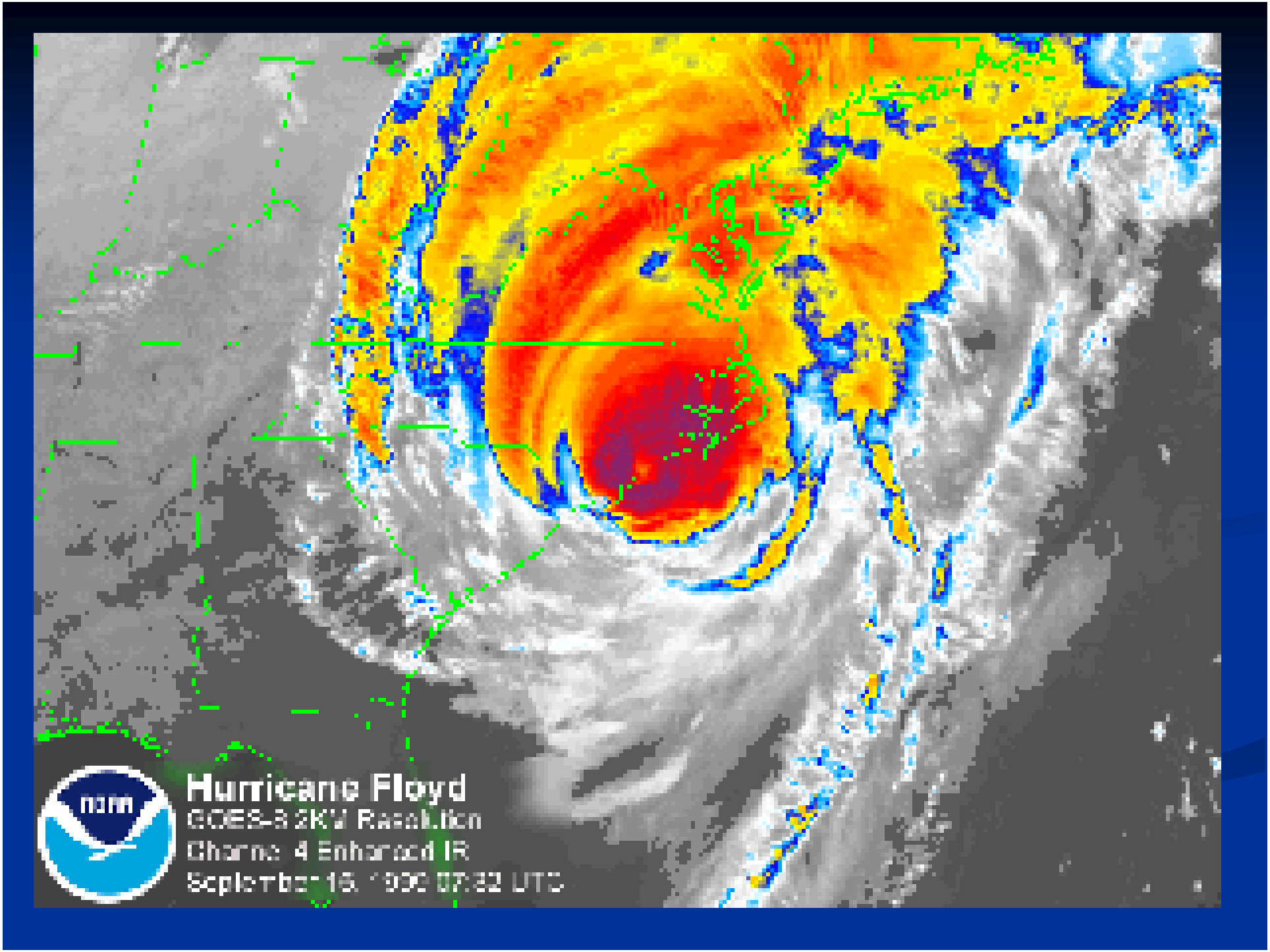


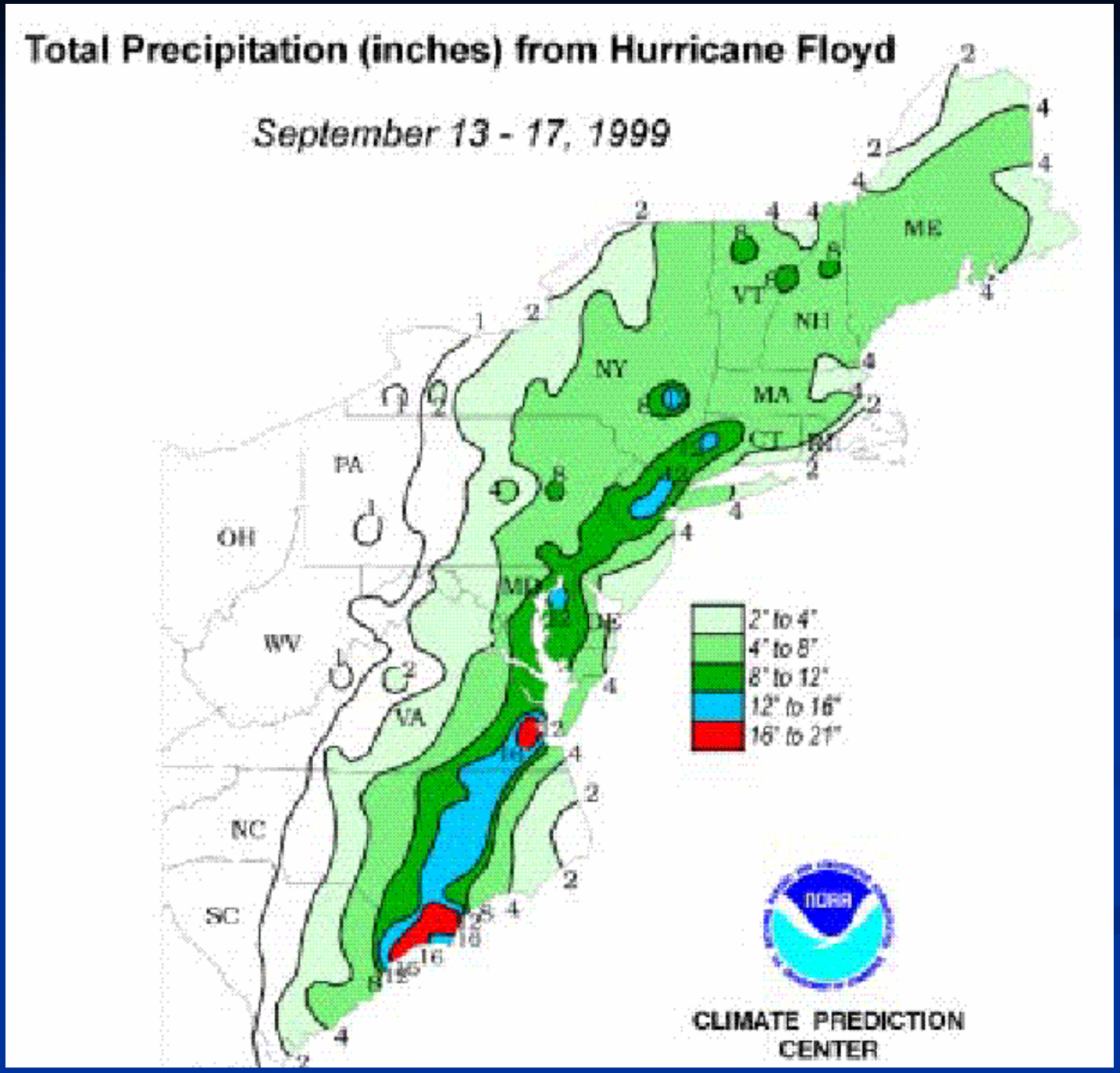
Fig. 5: Storm surge forecast for Bridgeport CT for 14 Feb 2007 nor'easter (13K grid).

7. Rainfall Runoff Flooding

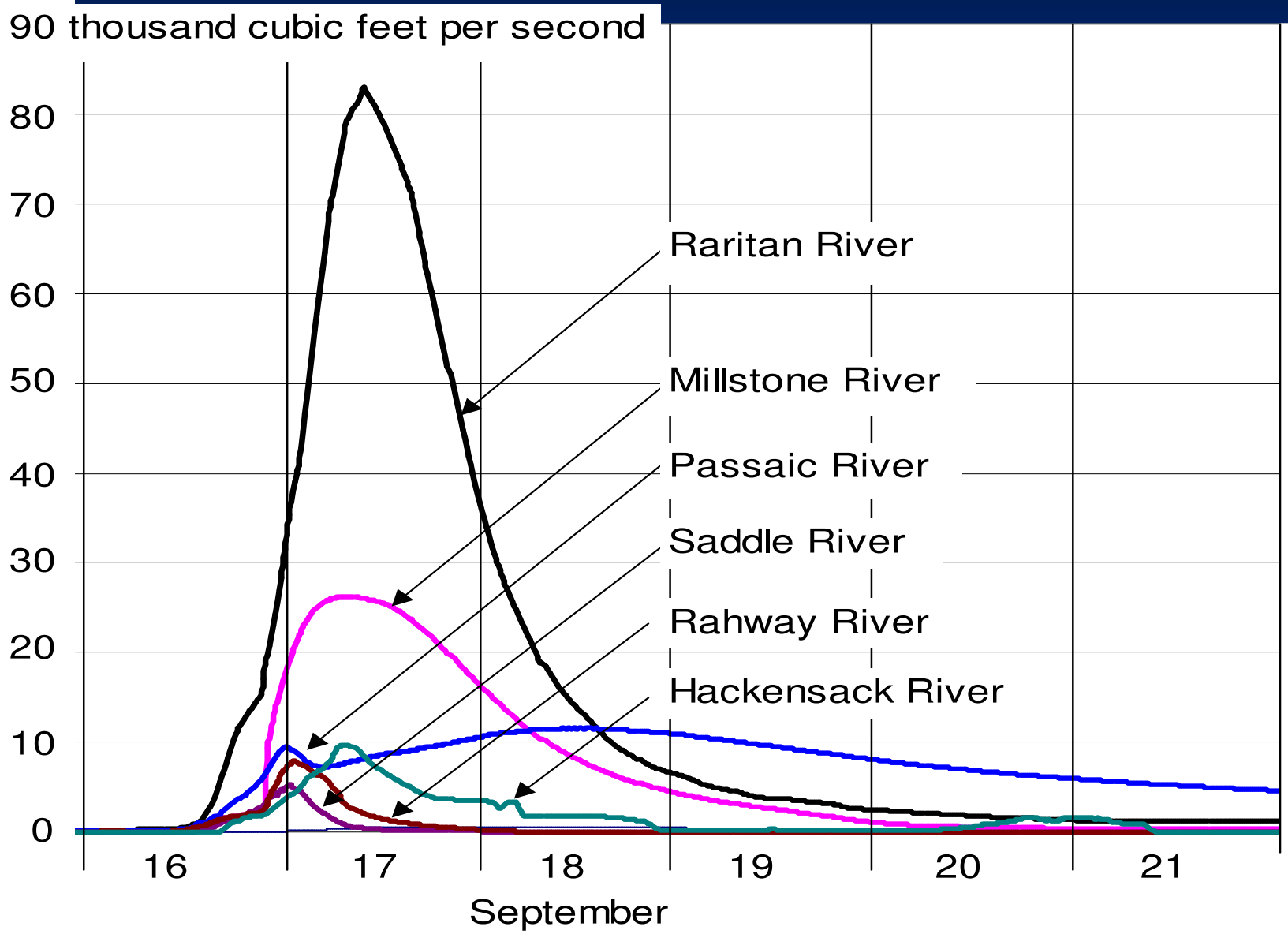


"The other side. My God, the water's supposed to be on the other side."

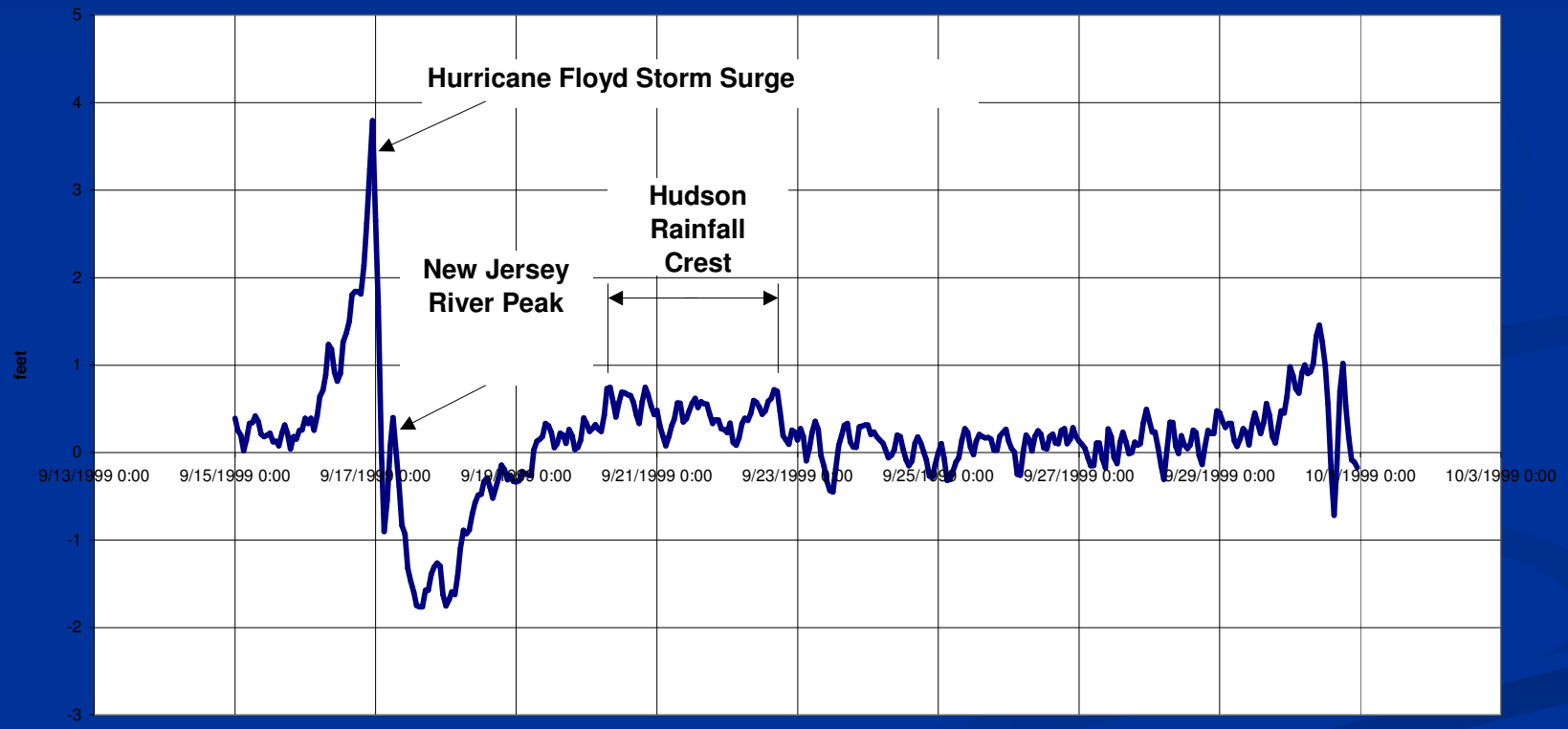

Hurricane Floyd
GOES-8 2KM Resolution
Channel 4 Enhanced IR
September 15, 1999 07:32 UTC

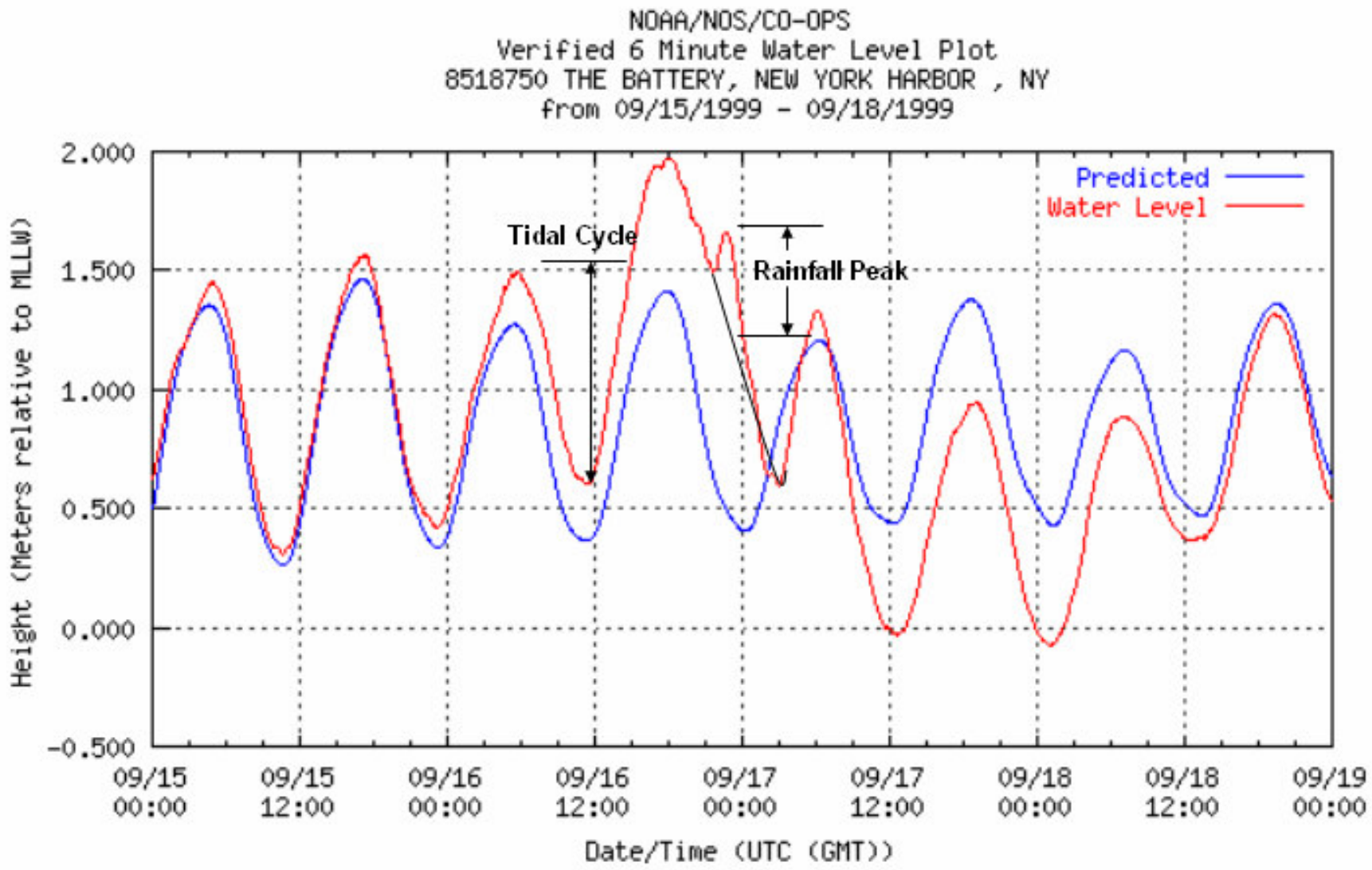

Total Precipitation (inches) from Hurricane Floyd
September 13 - 17, 1999
ME
VT
NH
NY
MA
CT
RI
PA
OH
WV
VA
NC
SC
2" to 4"
4" to 8"
8" to 12"
12" to 16"
16" to 21"
NOAA
CLIMATE PREDICTION CENTER

New Jersey River Streamflows

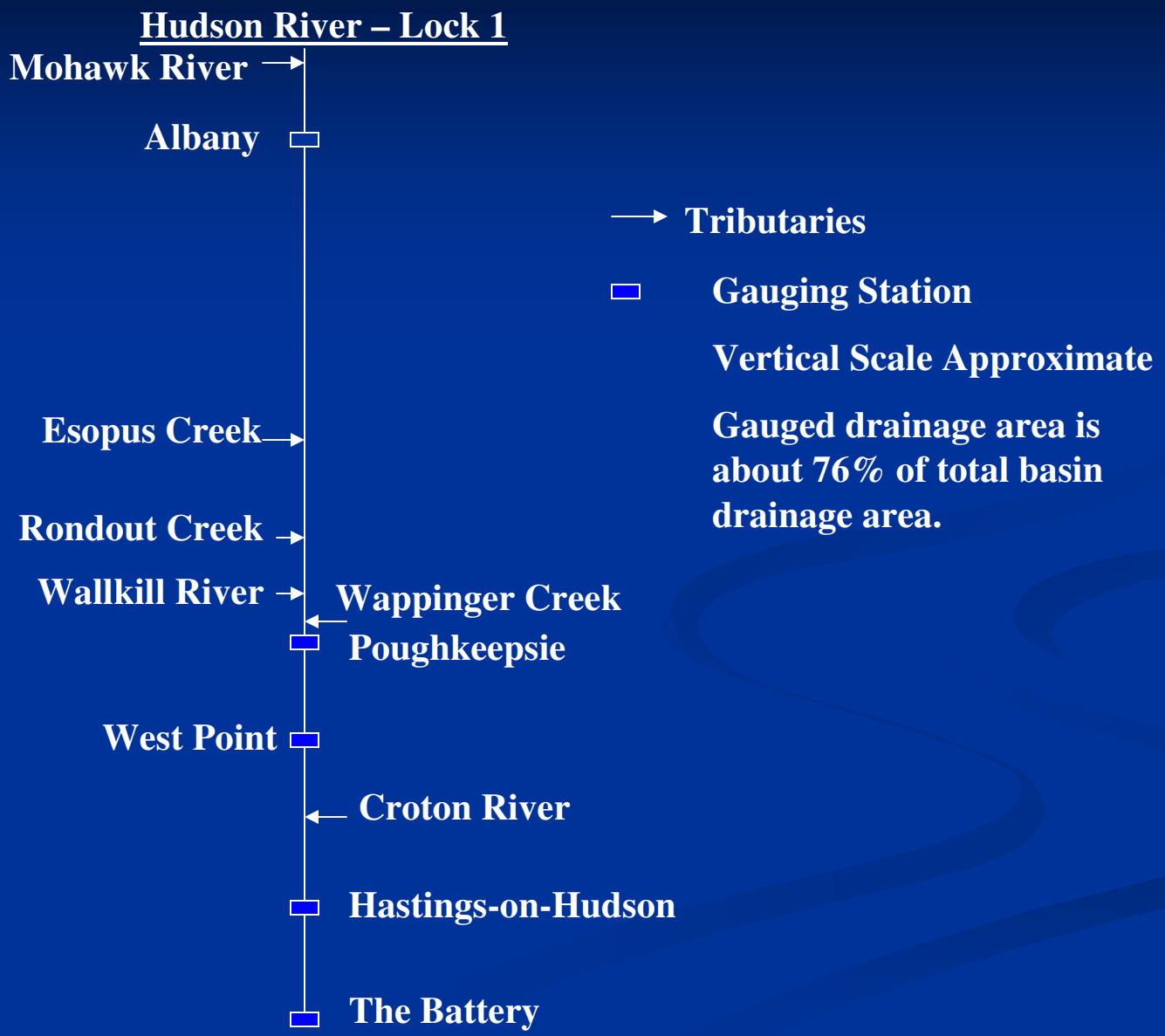


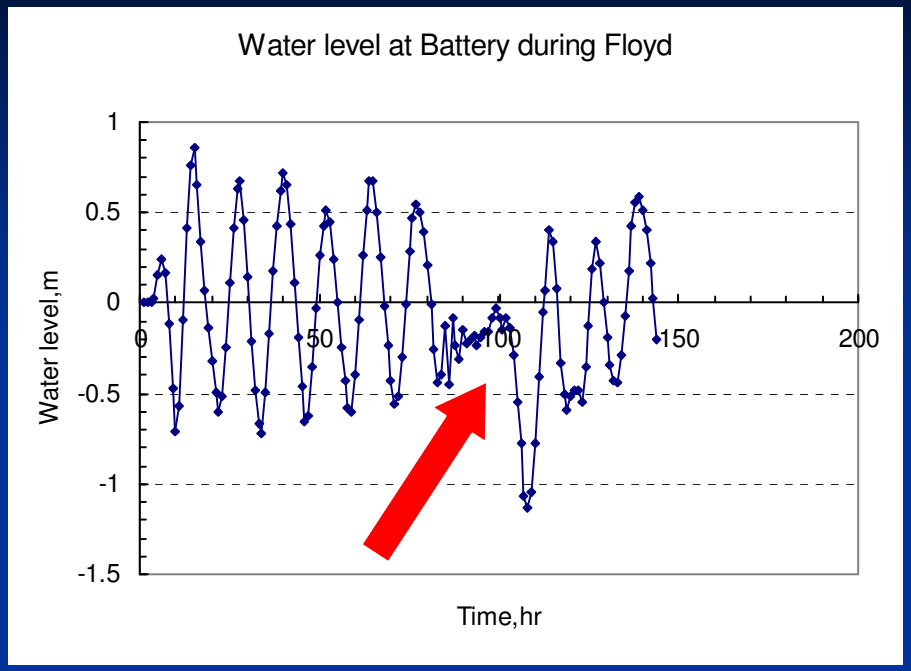
Deviations from Normal Water Level at the Battery

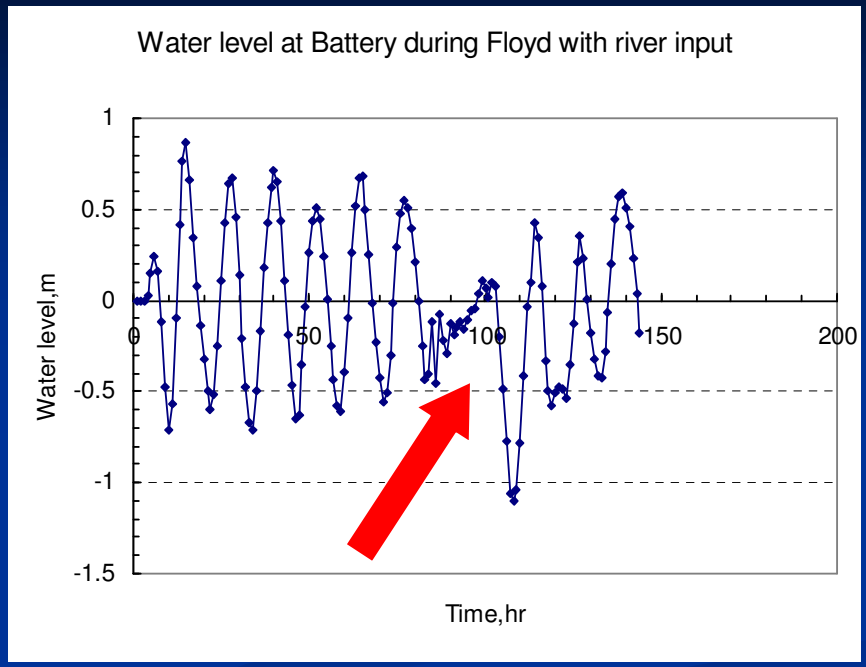



NOAA/NOS/CO-OPS
Verified 6 Minute Water Level Plot
8518750 THE BATTERY, NEW YORK HARBOR , NY
from 09/15/1999 - 09/18/1999
Predicted
Water Level
Tidal Cycle
Rainfall Peak
Height (Meters relative to MLLW)
2.000
1.500
1.000
0.500
0.000
-0.500
09/15 00:00
09/15 12:00
09/16 00:00
09/16 12:00
09/17 00:00
09/17 12:00
09/18 00:00
09/18 12:00
09/19 00:00
Date/Time (UTC (GMT))

Hudson River Watershed

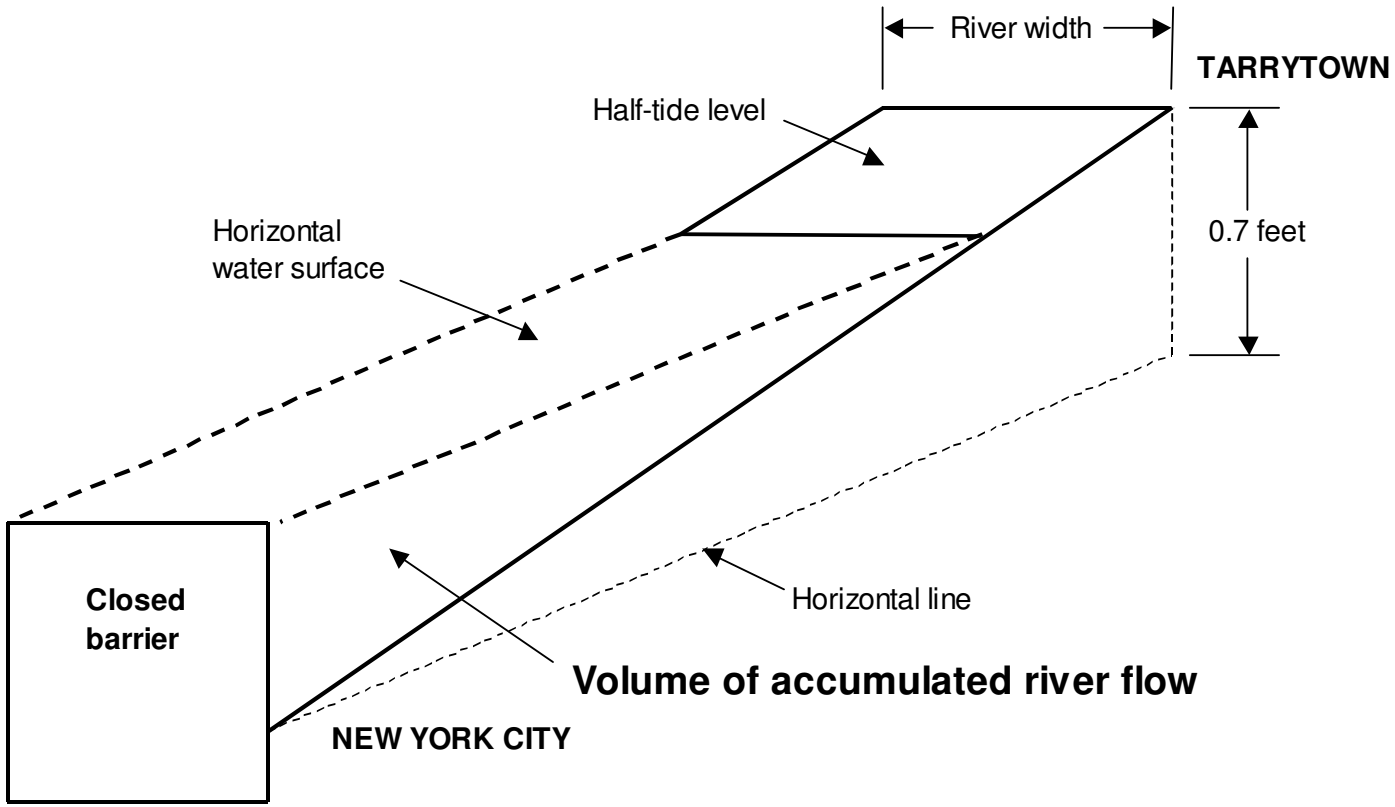




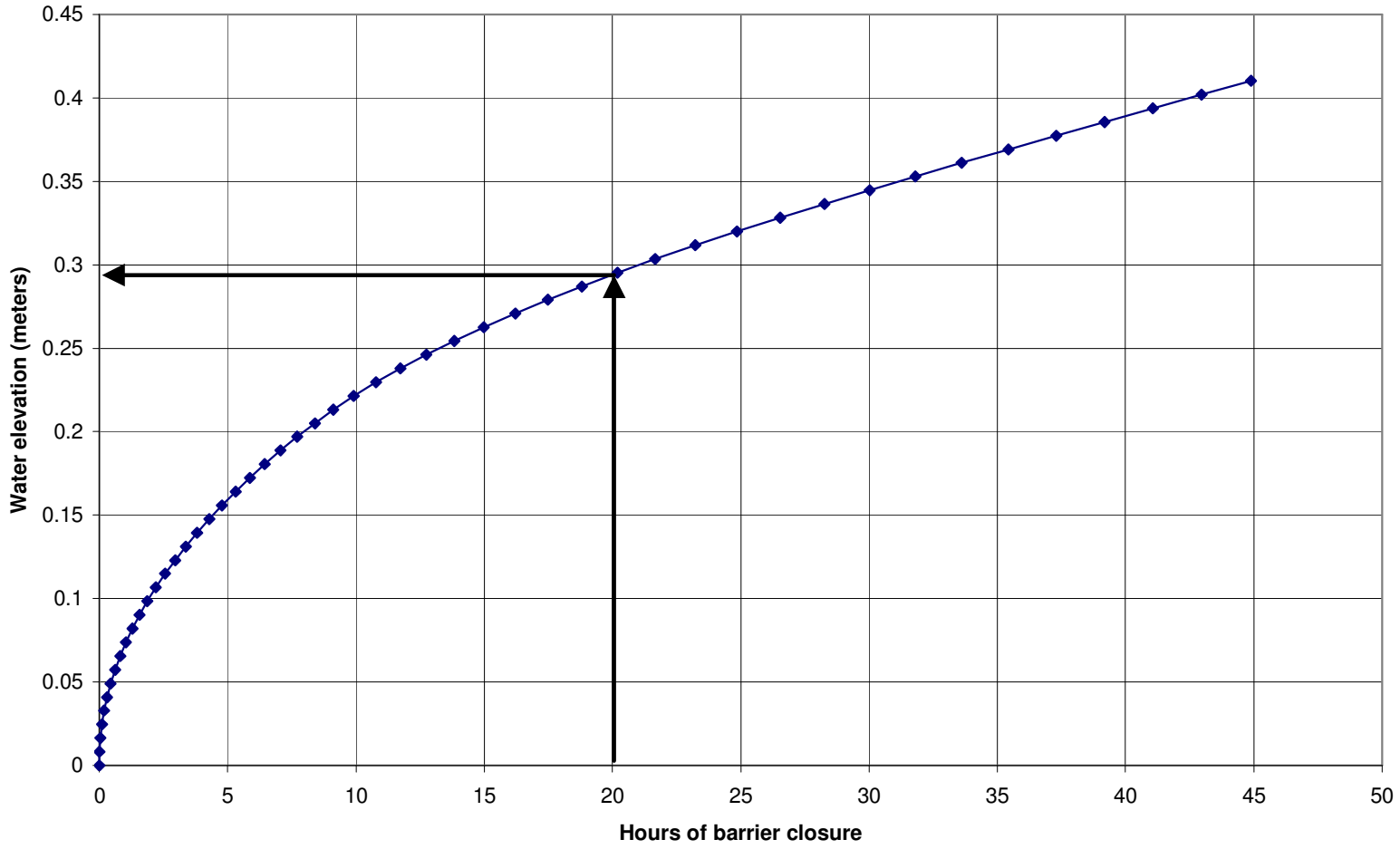


Left: Water level inside barriers without runoff.

Right: Water levels with runoff.


River width
TARRYTOWN
Half-tide level
Horizontal
water surface
0.7 feet
Closed
barrier
Horizontal line
Volume of accumulated river flow
NEW YORK CITY

Water level at the Battery vs. hours of barrier closure



Conclusions

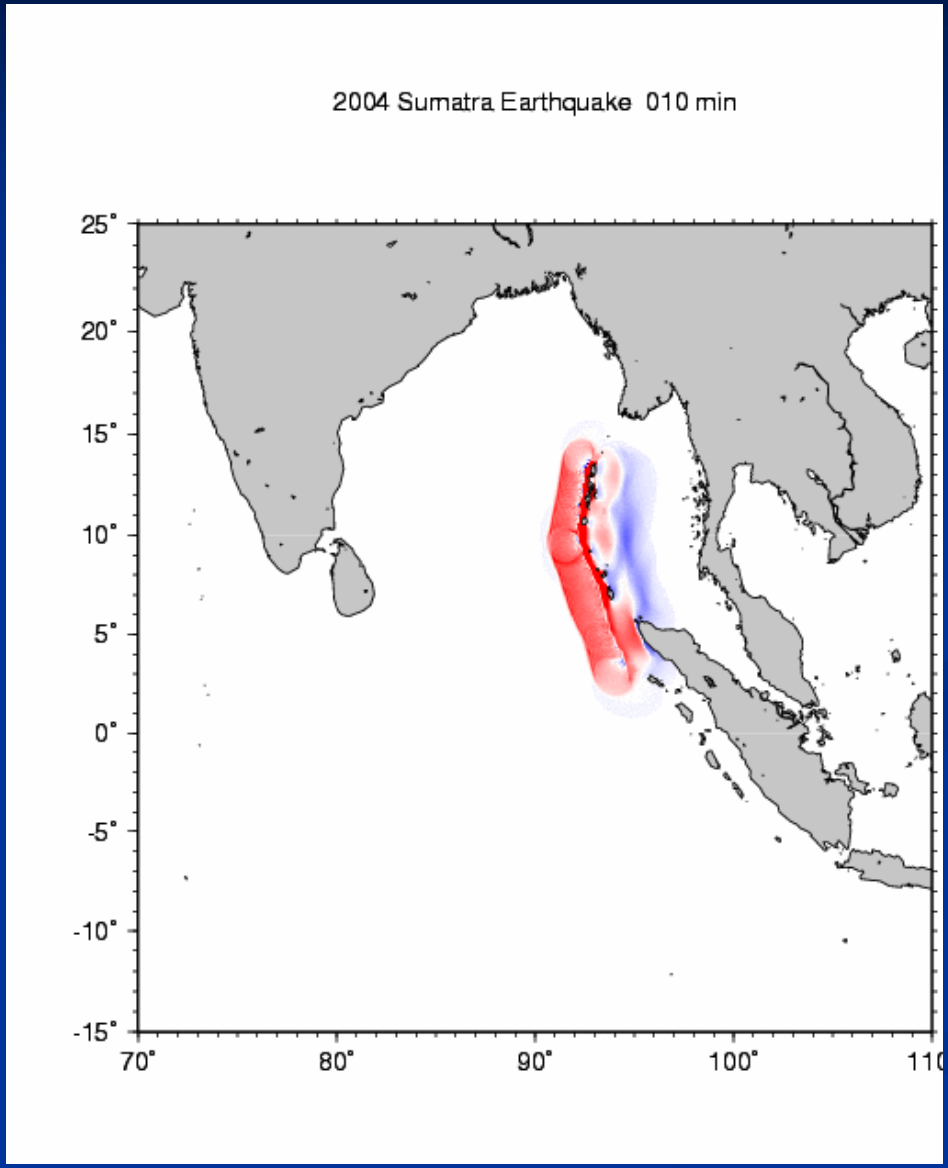
- Storm surge barriers would work
- All 3 barriers required
- Rainfall runoff flooding not a problem
- East River location controversial
- Engineering feasibility study needed

8. Work in Progress

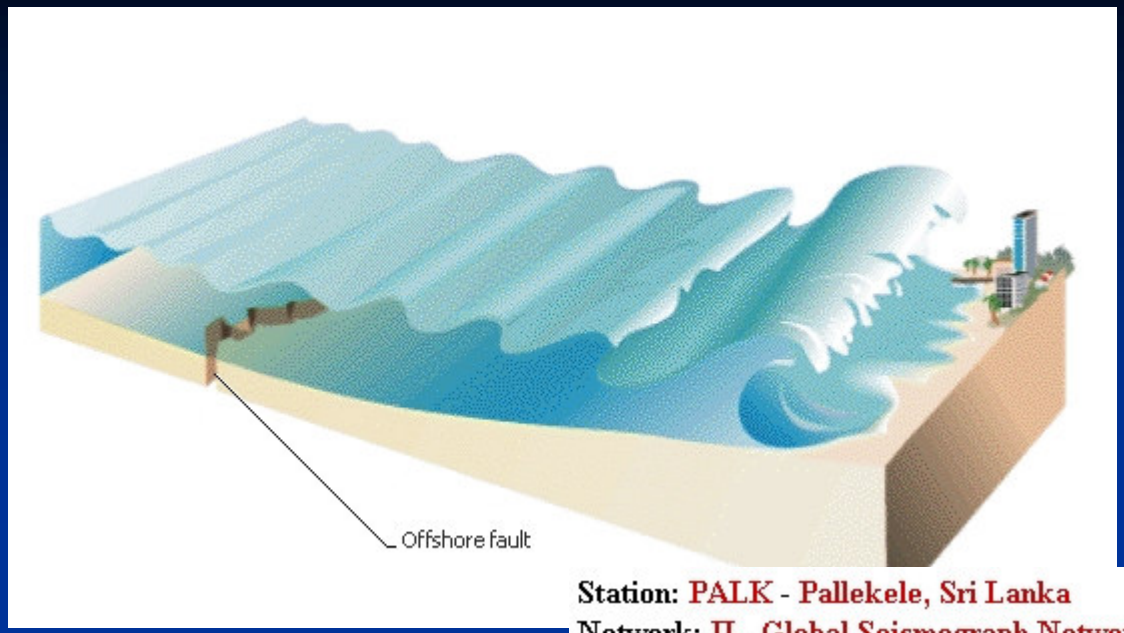
- Develop Coastal Early Warning System
  - near-real-time forecasts on the Web
- Add Long Island's south shore to domain
- Upgrade from 2D → 3D storm surge model
- Upgrade MM5 → WRP meteorological model
- Extend model up Hudson & NJ Rivers to gauging stations
- Promote barrier solution to engineers & scientists in and out of government

- **Q.** When do you plan for a flood?
- **A.** Too late.

Tsunami Threats

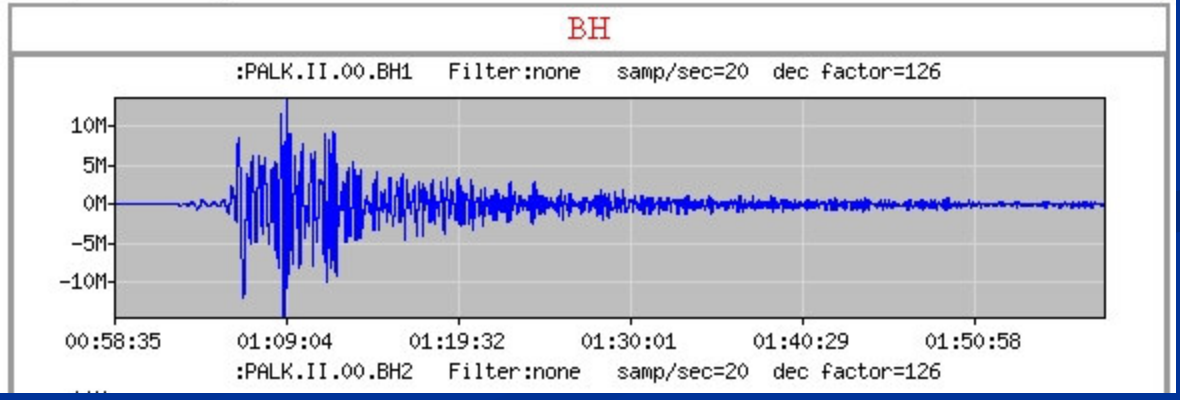


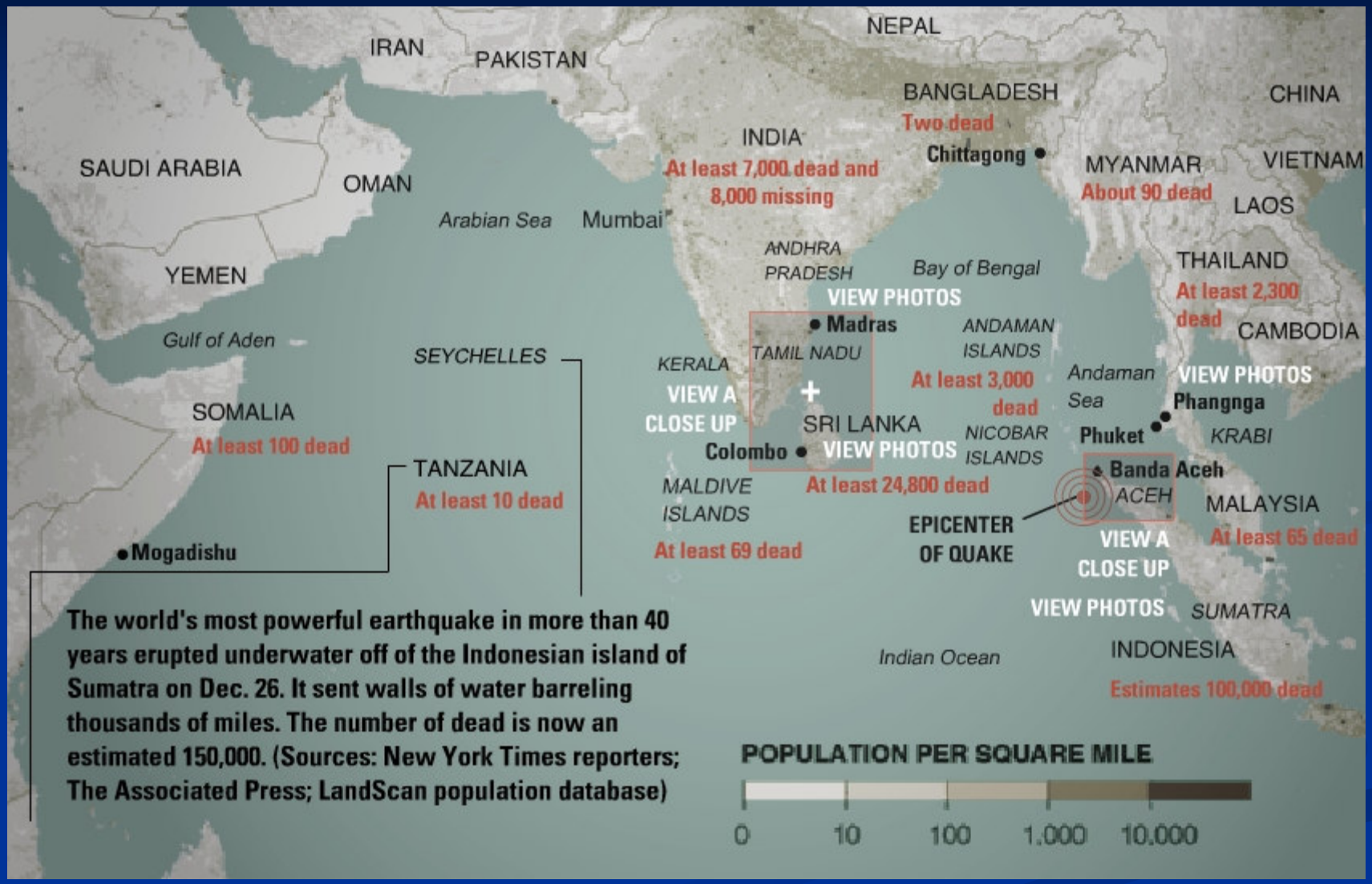
Tsunamis are shallow water waves that spread away from the epicenter at speeds ~ 450 mph



Station: PALK - Pallekele, Sri Lanka
Network: II - Global Seismograph Network (GSN - IRIS/IDA)
Lat: 7.27 Lon: 80.70 Elev: 460.00
Event Name: 20041226_005850.7.spyder
Available Channels: BH1,BH2,BHE,BHN,BHZ,BLE,BLN,BLZ,LH1,LH2,LHZ
Available Locations: 00,10

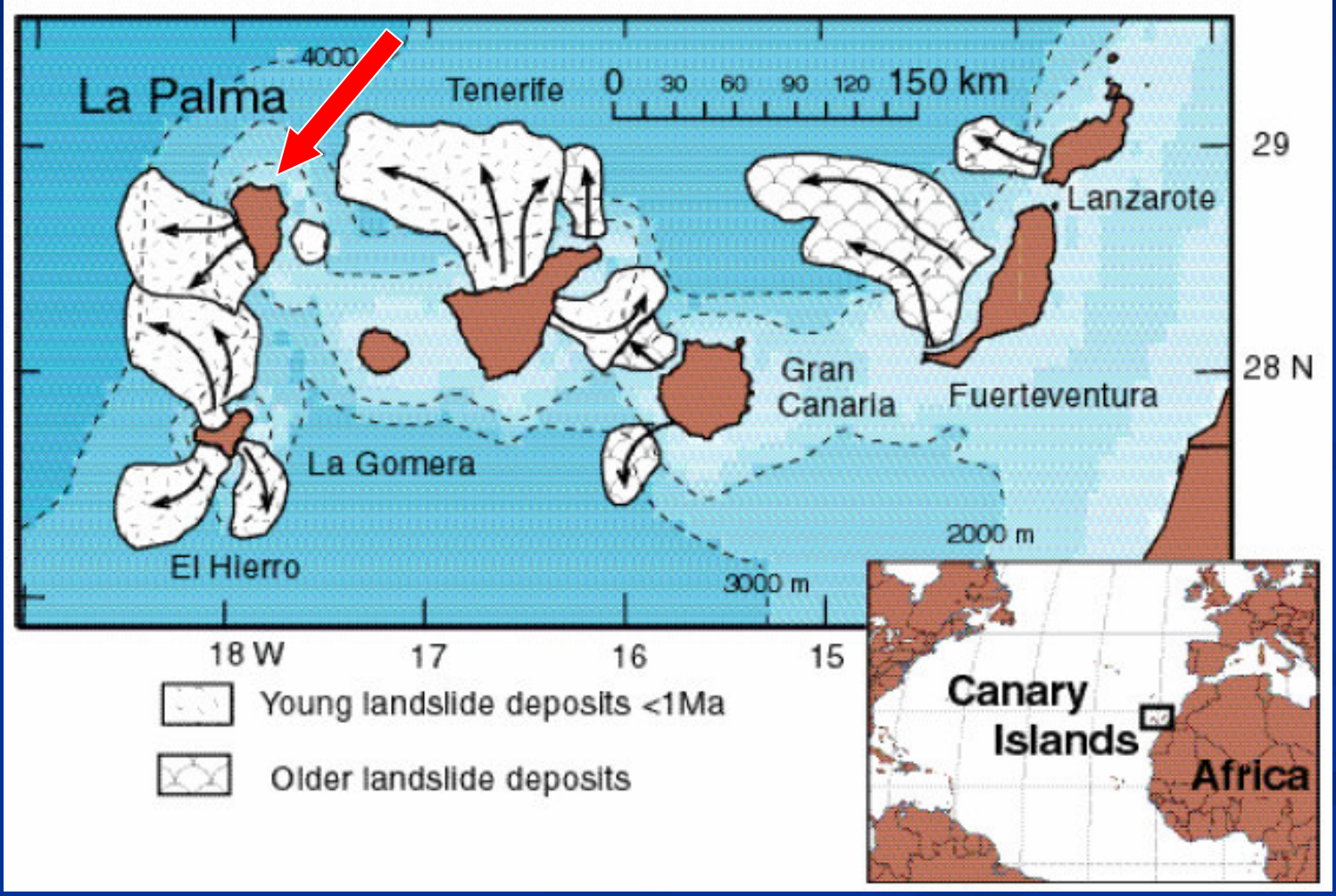
Sample Seismograms



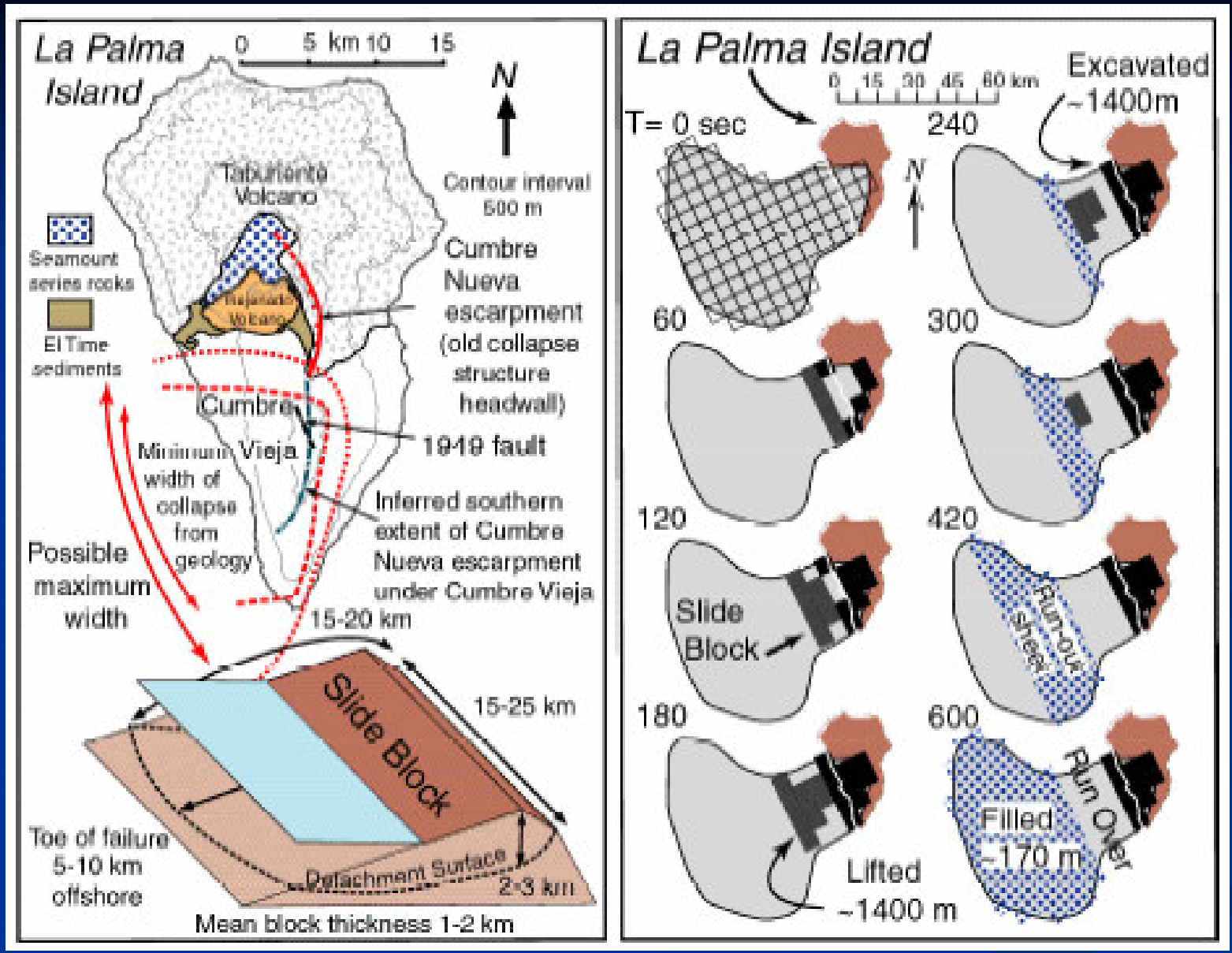


The world's most powerful earthquake in more than 40 years erupted underwater off of the Indonesian island of Sumatra on Dec. 26. It sent walls of water barreling thousands of miles. The number of dead is now an estimated 150,000. (Sources: New York Times reporters; The Associated Press; LandScan population database)

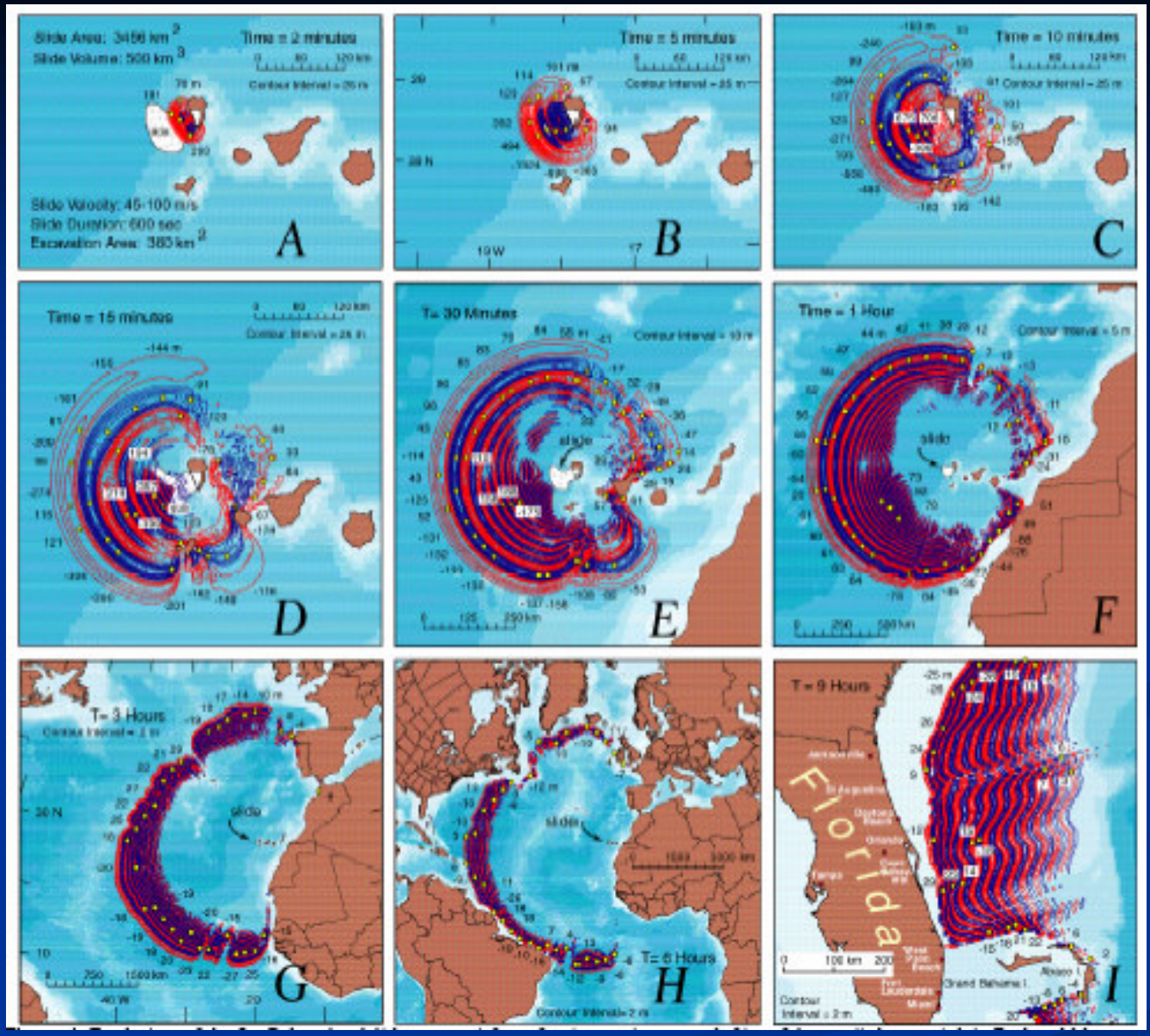
Cumbre Vieja Volcano Represents a Potential Site of Collapse and Giant Tsunami Generation



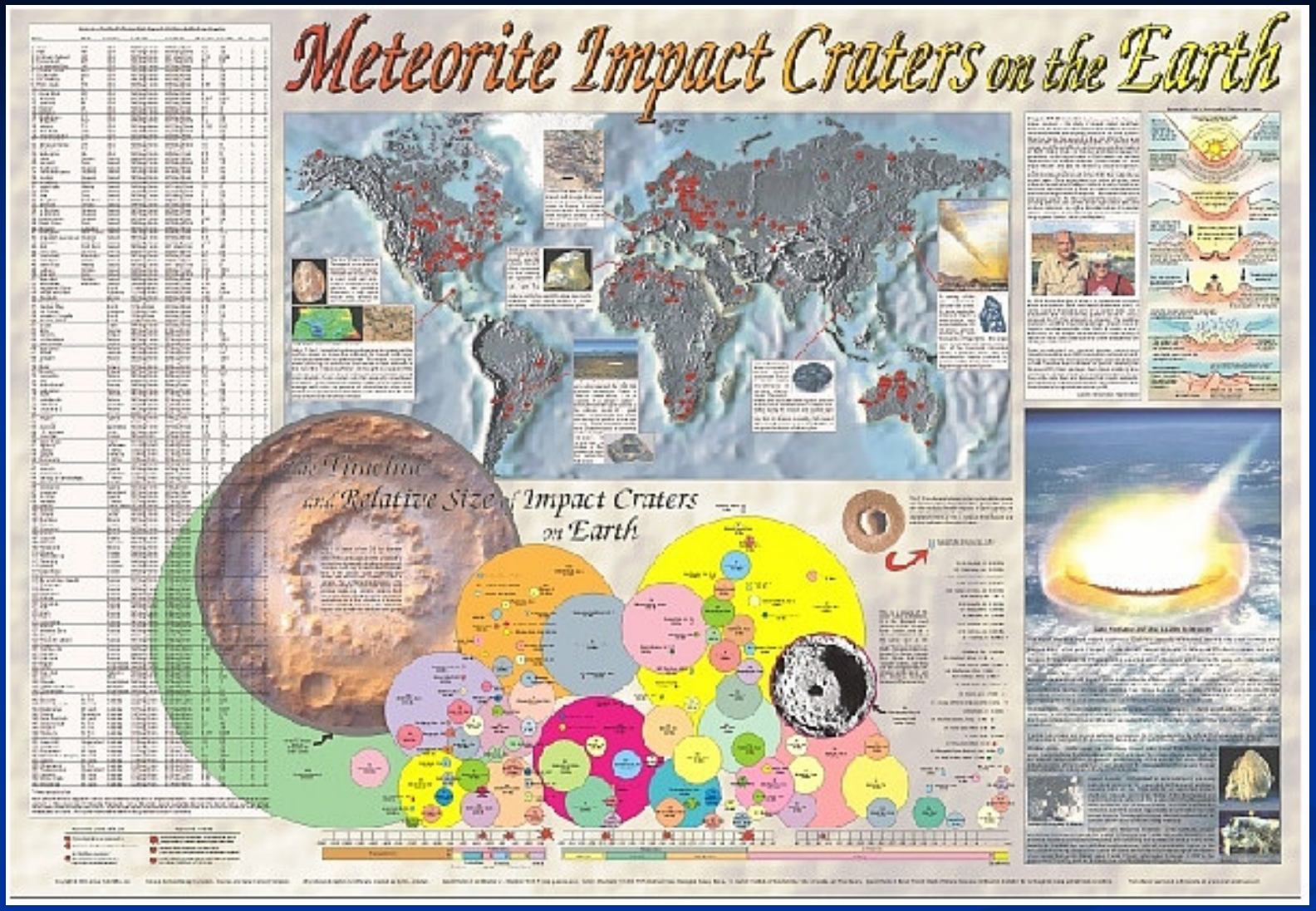
Ward, S.N., and S. Day. Geophys. Res. Lett. 17: 3397-3400 (2001)



Ward & Day (2001) estimate that a landslide of the western flank of the island could send 150-500 km^3 rock sliding into the sea, creating a wall of water up to 500 m high.



A giant tsunami would race across the Atlantic Ocean, reaching New York in about 9 hr with a height of 3-25 m.



What is the probability of a 1 km dia. meteorite plunging into the Atlantic Ocean in the next 50 years?

http://store1.yimg.com/I/scimall-usa_1809_11024099