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

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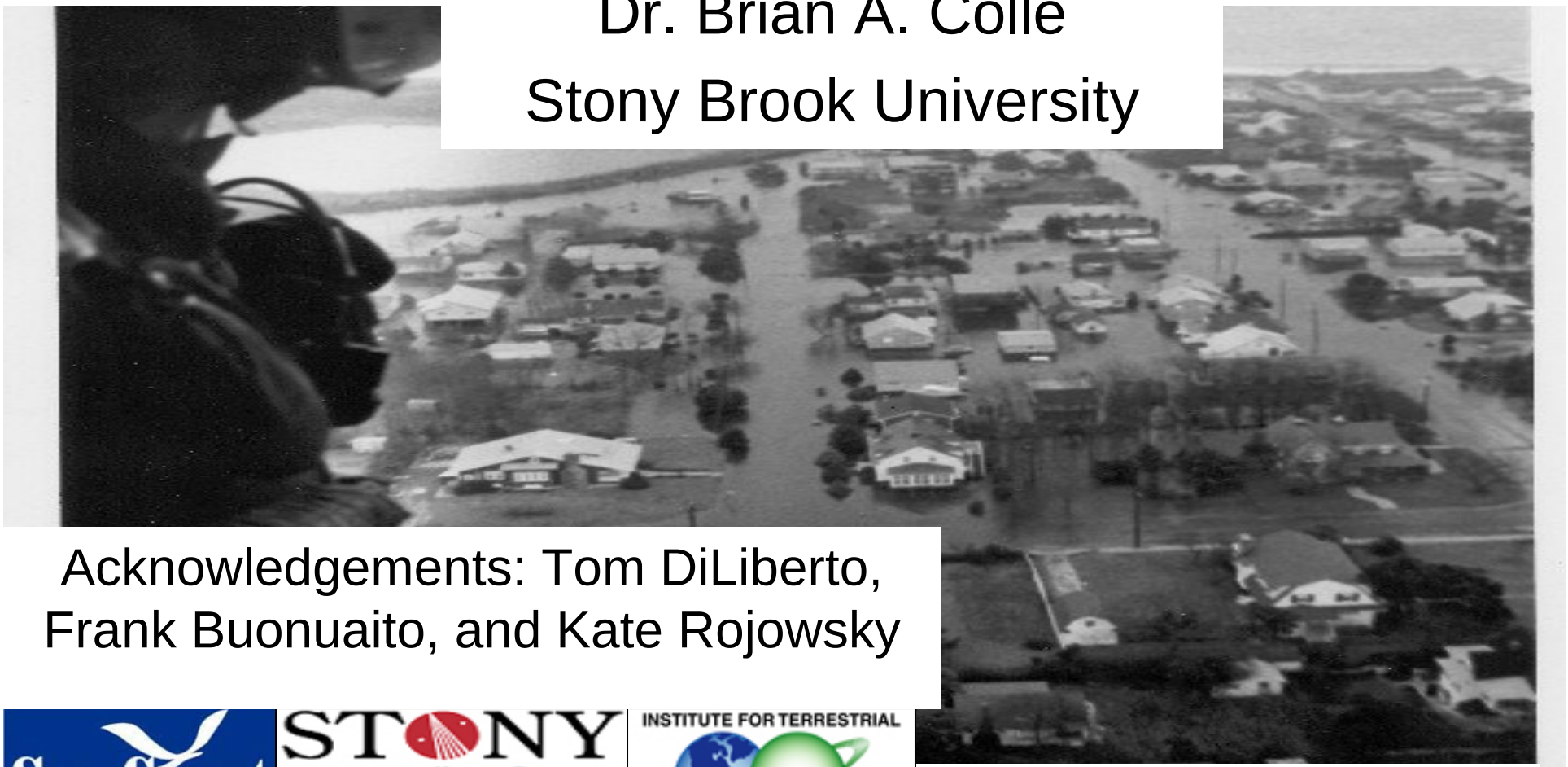
Stony Brook University



United States Coast Guard 1985

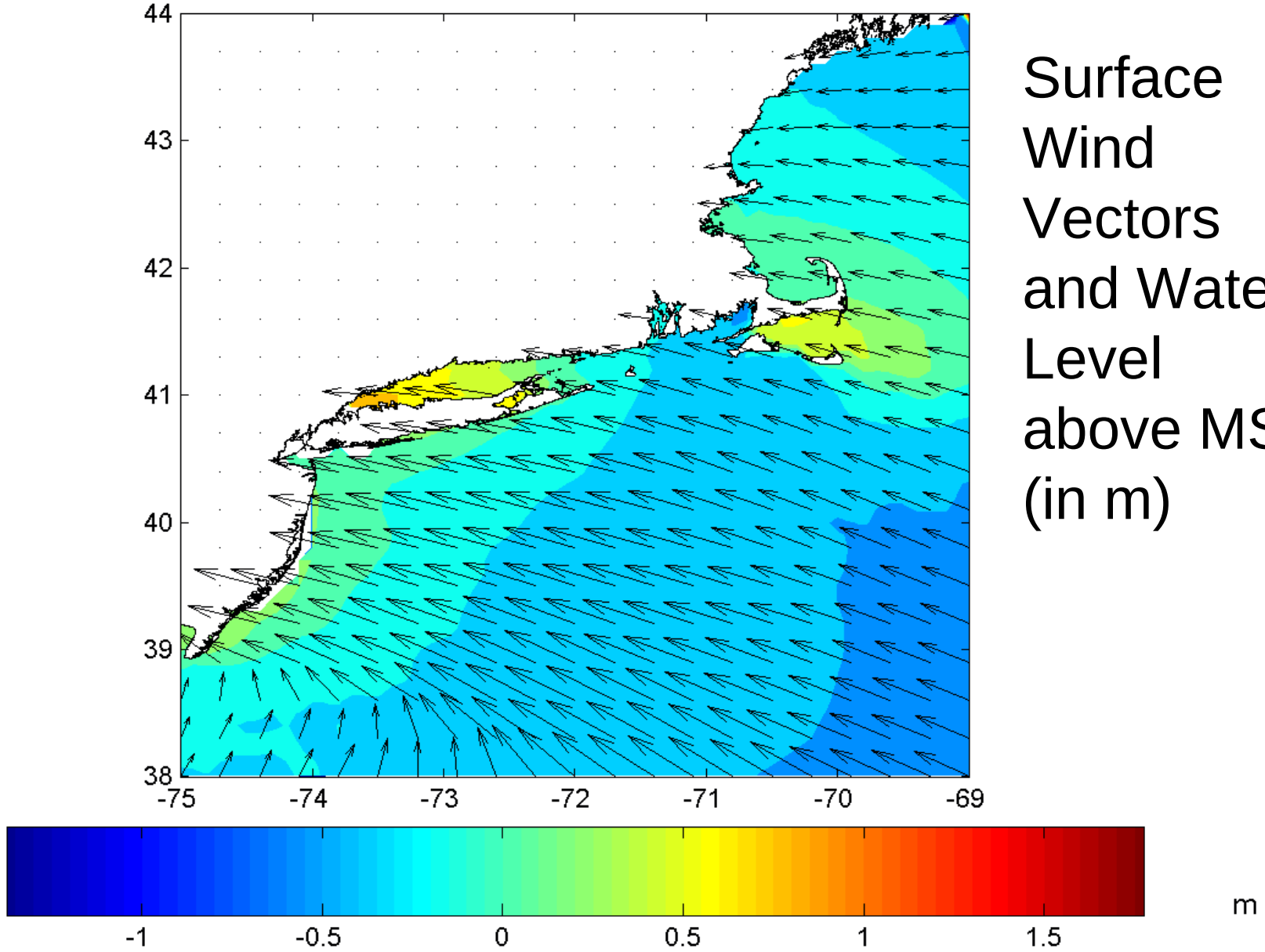
Acknowledgements: Tom DiLiberto, Frank Buonuaito, and Kate Rojowsky

Sea Grant New York

STONY BROOK UNIVERSITY

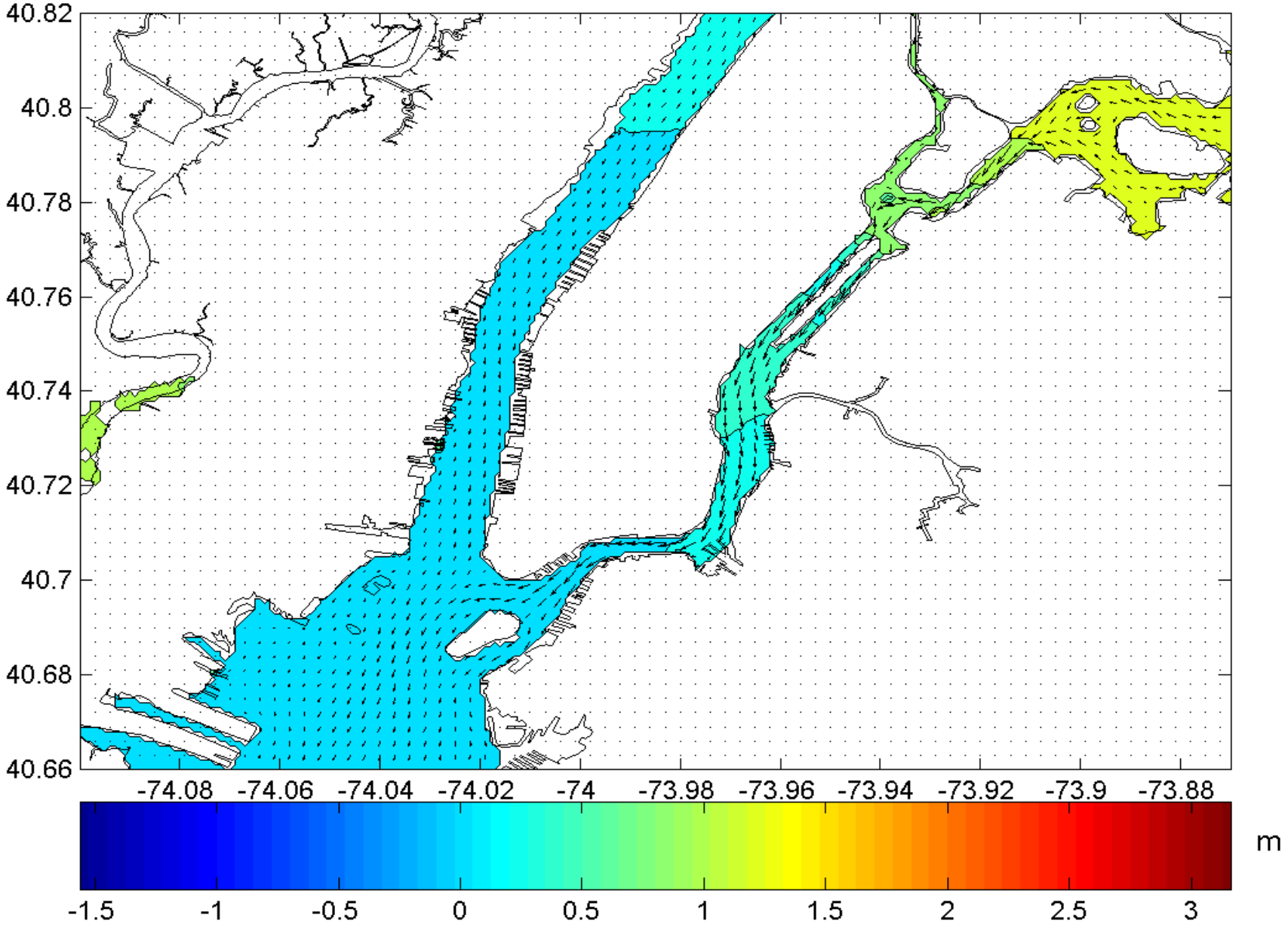
INSTITUTE FOR TERRESTRIAL AND PLANETARY ATMOSPHERES

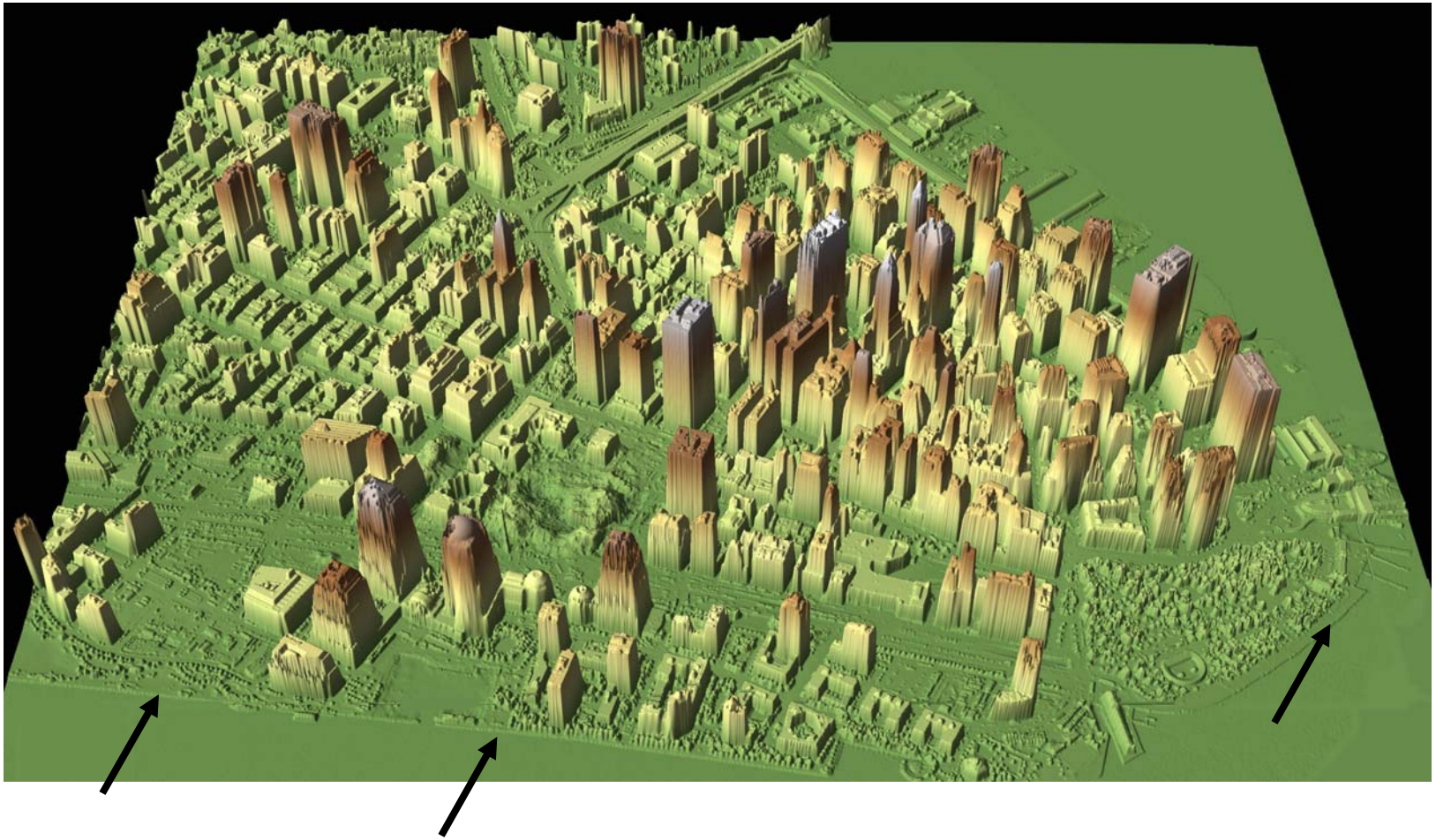
Storm Surge Modeling for the New York City Region



Surface Wind Vectors and Water Level above MSL (in m)

ADCIRC Simulation of NYC Flooding



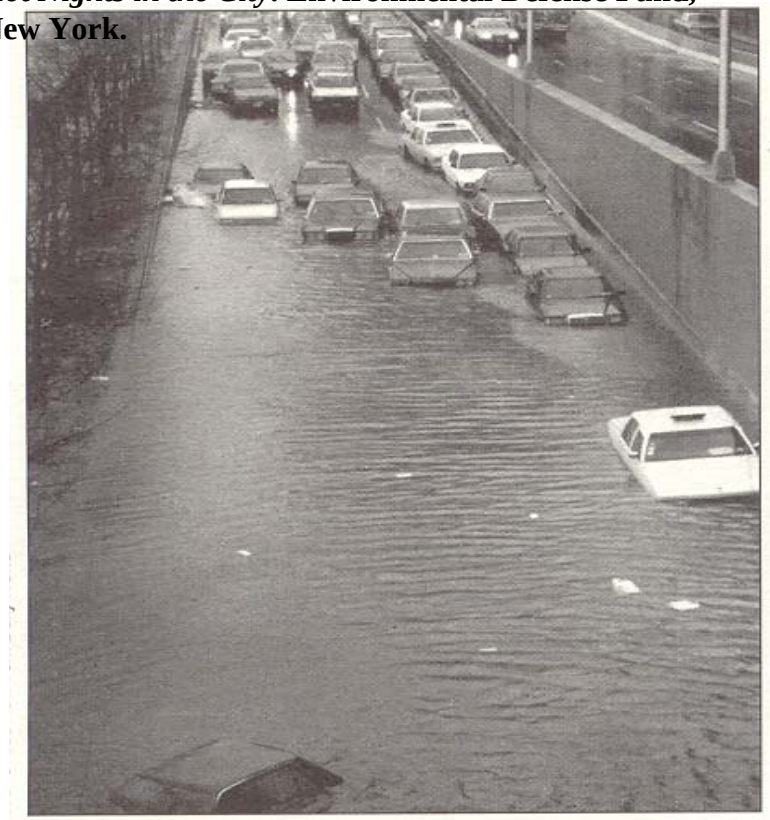


Lidar image of business district of Manhattan showing seawall locations and elevation (arrows). The imager is flying above the Hudson River looking east.

1992 Nor’easter Flooding

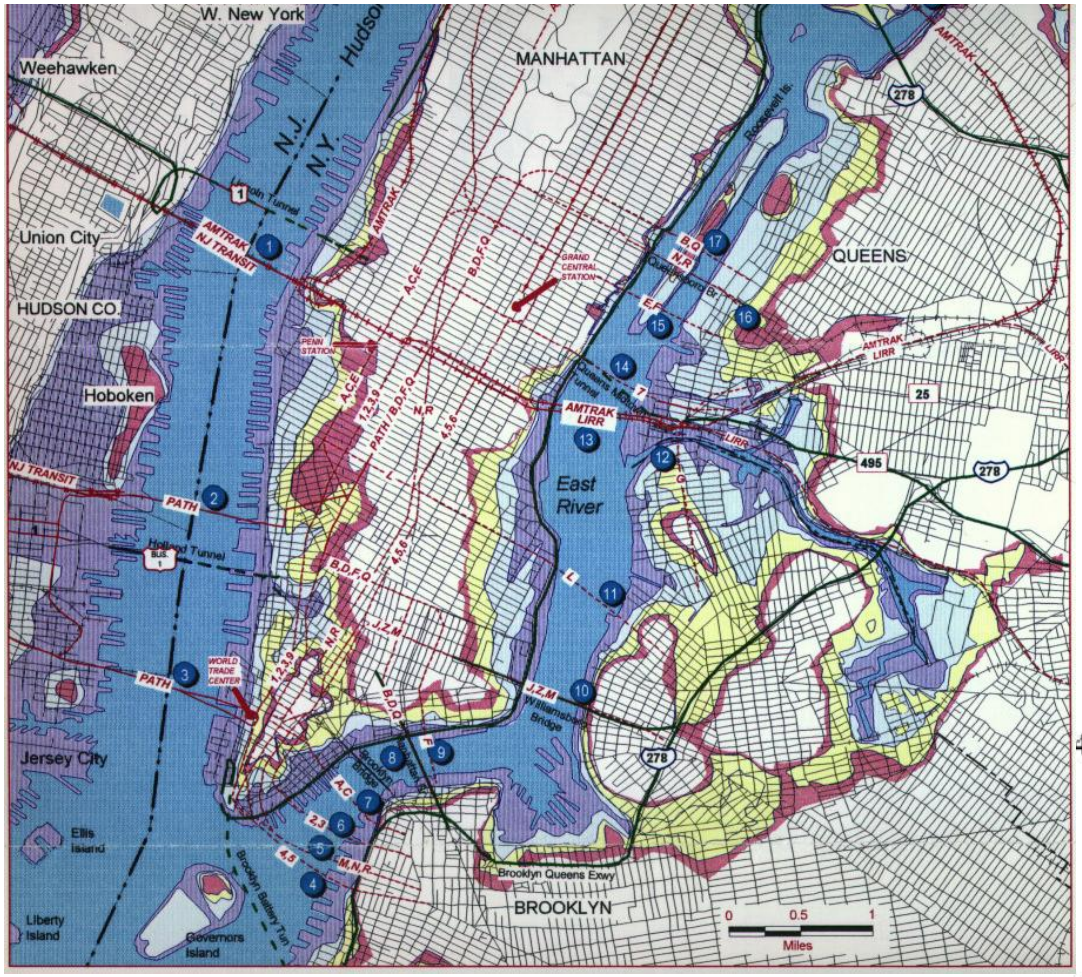
Source: Metro New York Hurricane Transportation Study, 1995

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



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

1950 Flooding of La Guardia airport and lower E side (Bloomfield, 1999 and NYC OEM)



Hurricane Flooding for NYC (Metro NY Hurricane Transportation Study 1995)

Flood areas
for hurricane:

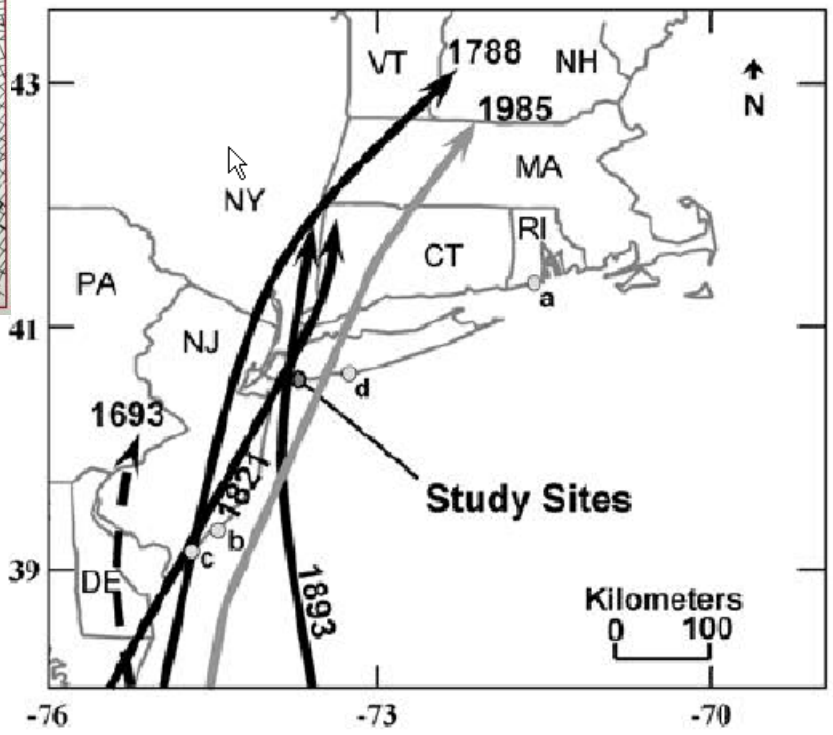
CAT 1

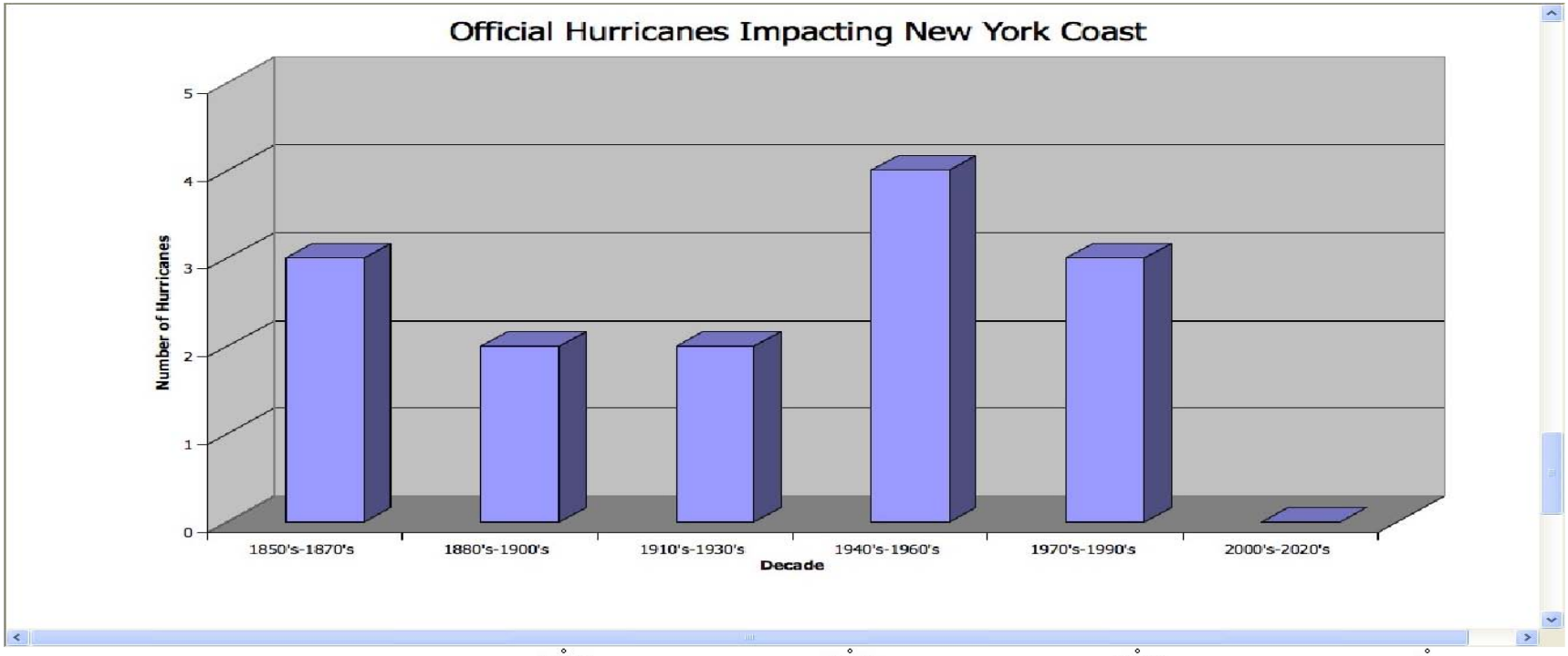
CAT 2

CAT 3

CAT 4

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





Tropical Storm Tracks: 1851-2005

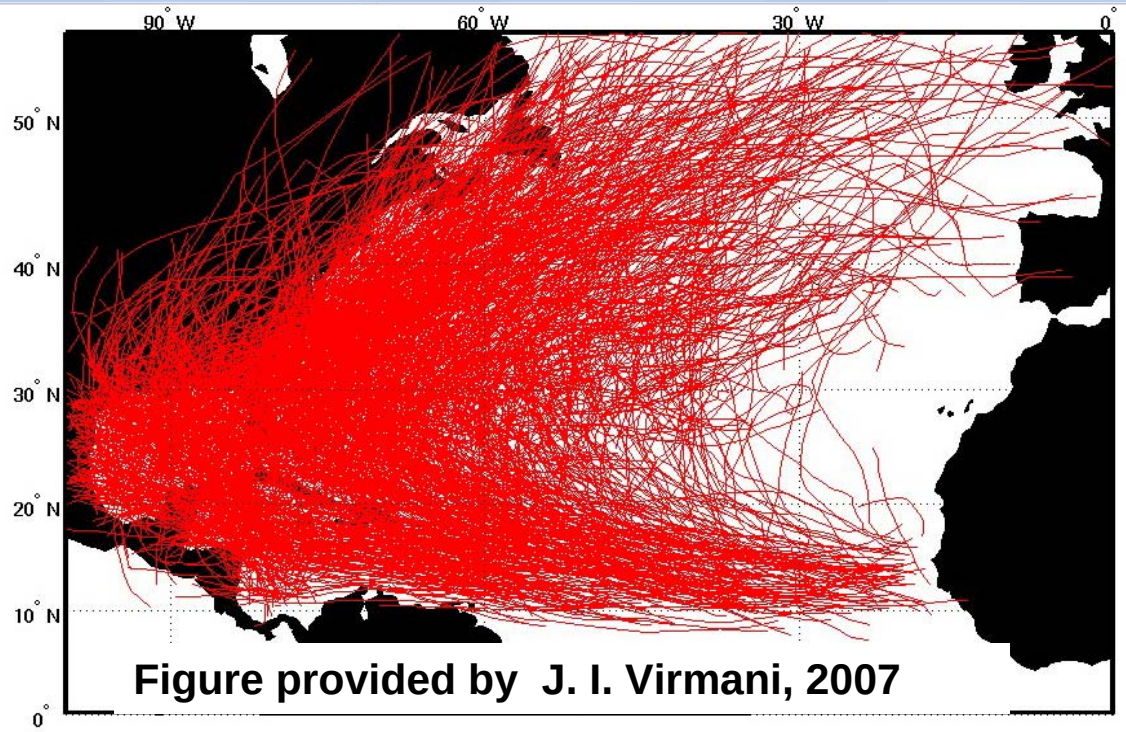
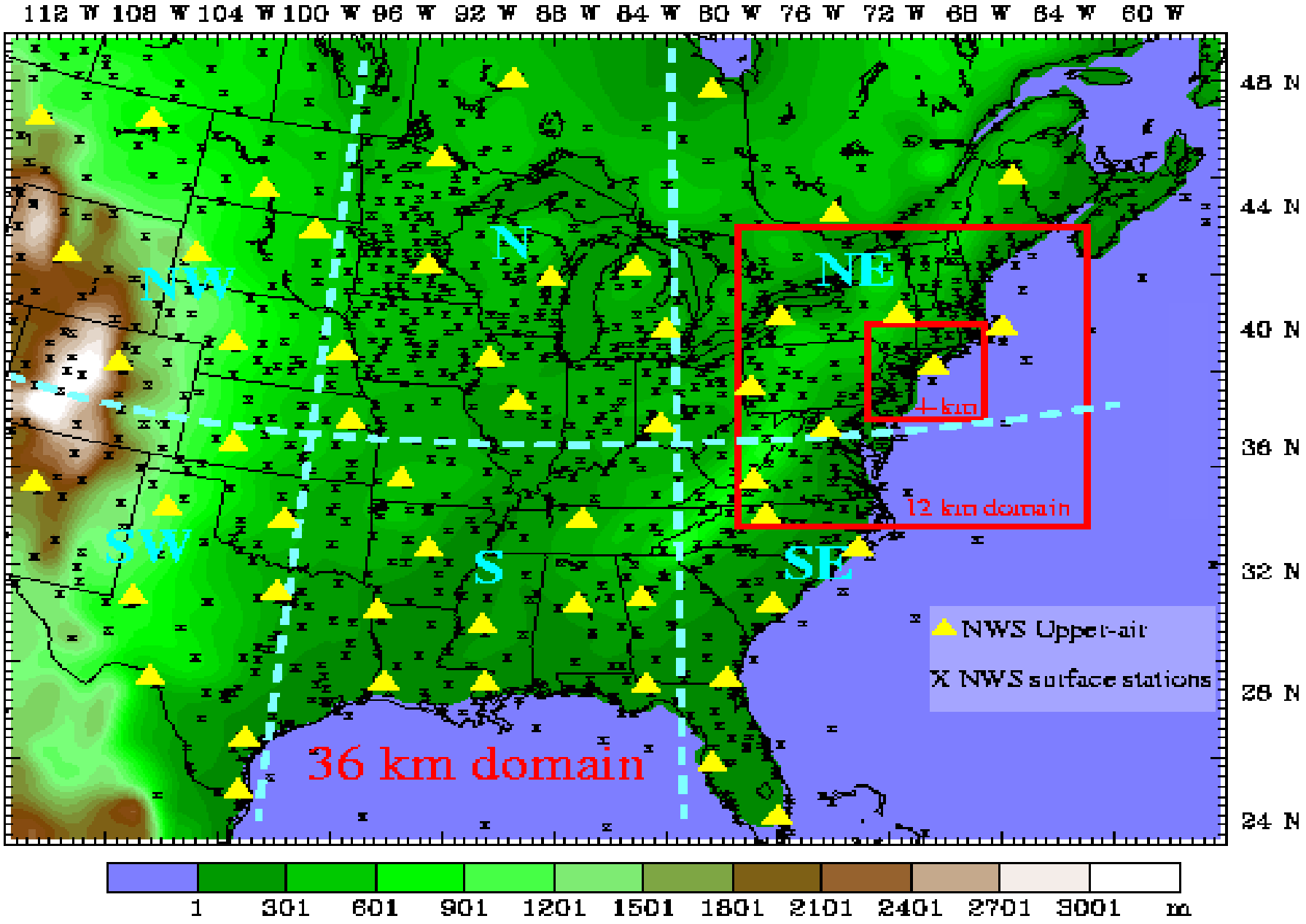


Figure provided by J. I. Virmani, 2007

Outline

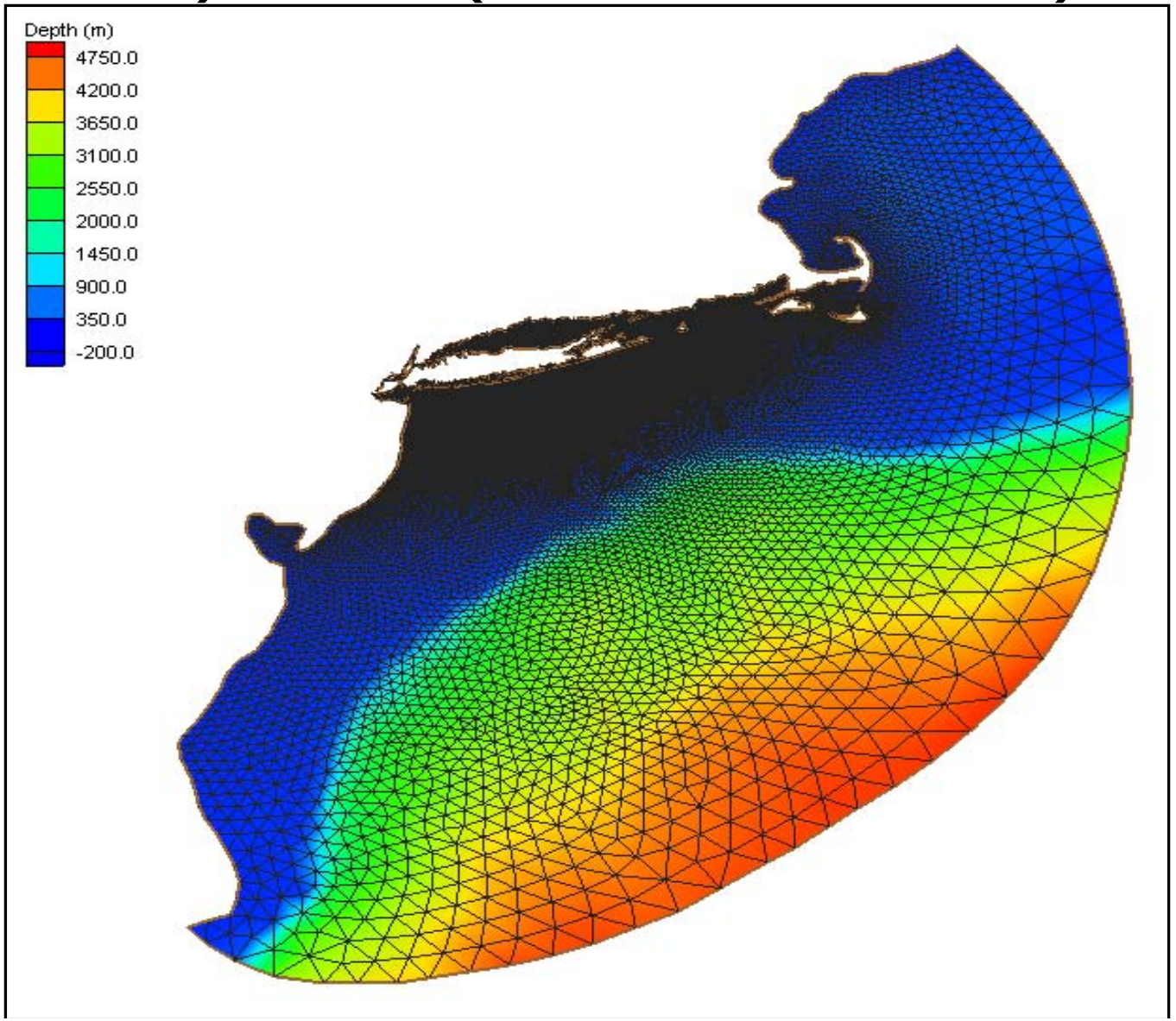
- How well can a coupled atmospheric (WRF) and ocean (ADCIRC) modeling system predict storm surge for nor-easters and landfalling hurricanes around NYC?
- How sensitive are the simulated water levels to relatively small changes in the track and timing of hurricanes?
- What is the climatology of storm surges and associated storm tracks for the NYC area in last 50 years? How will the climatology change as sea level rises?

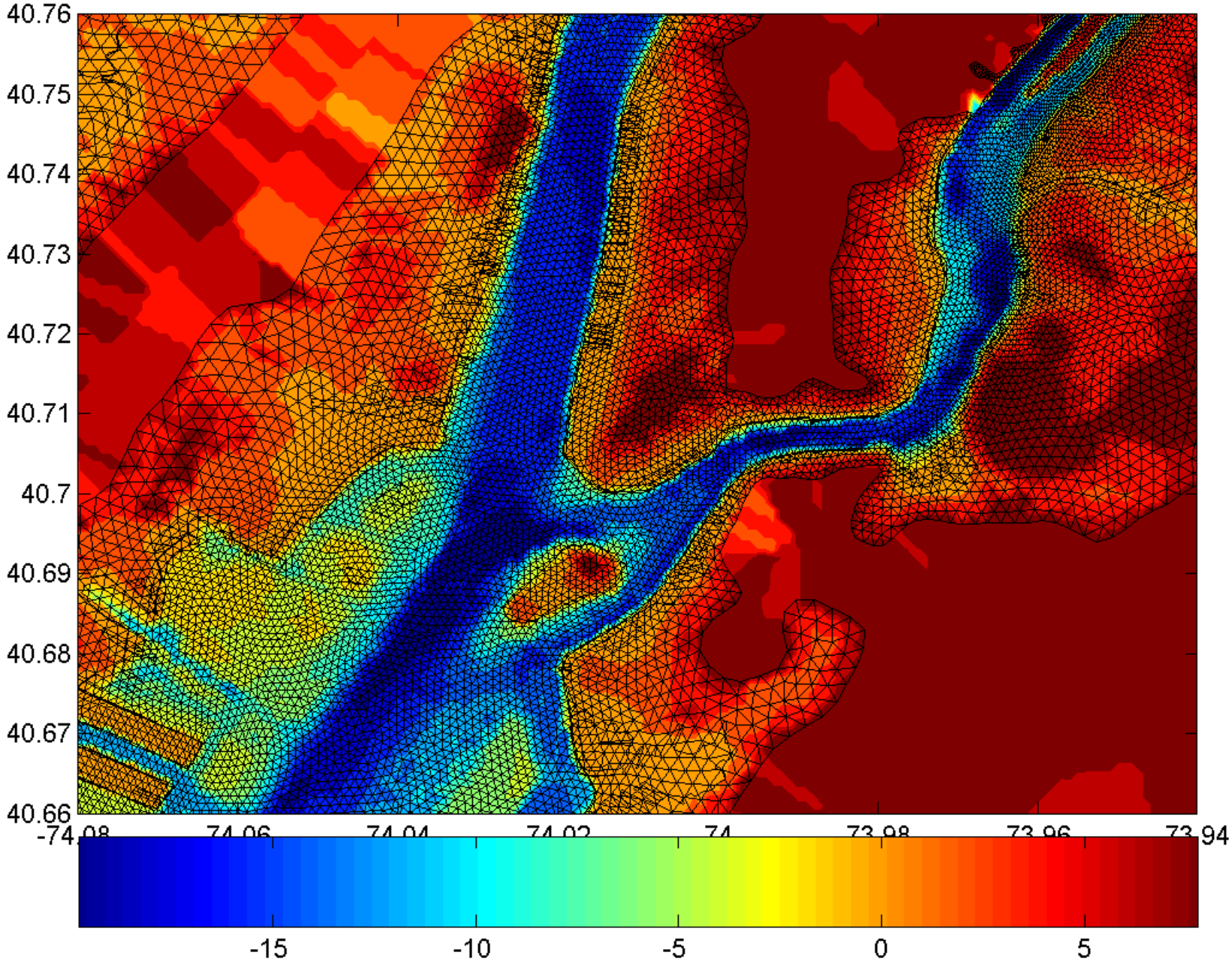
Stony Brook Weather Research and Forecasting Model (WRF) Domains



Advanced Circulation Ocean Model (ADCIRC) Grid (~108 K nodes)

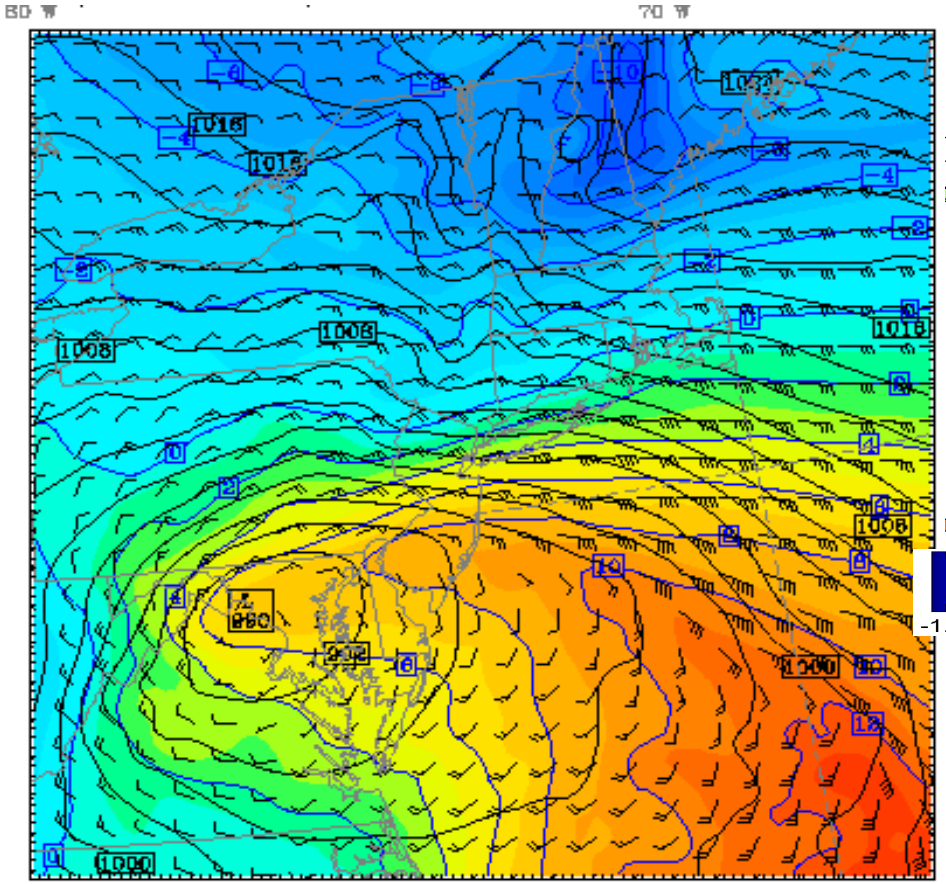
- Run in barotropic mode (1-layer in vertical)
- Use hourly MM5/WRF winds and surface pressures to force model
- Tidal forcing at boundaries
- No wave forcing (yet)



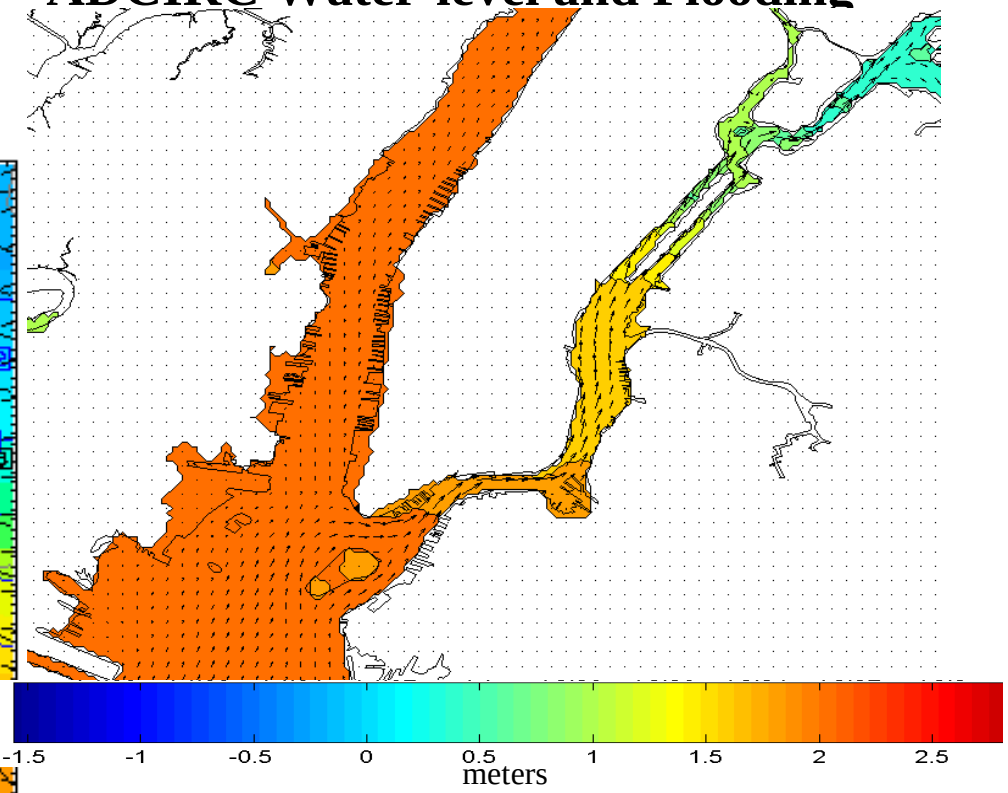


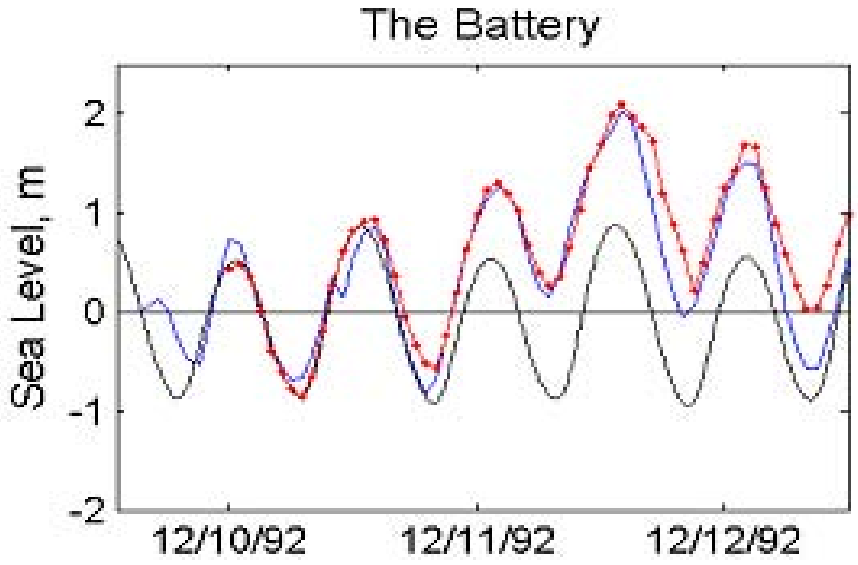
Detail of gridding in lower Manhattan up to +8 m contour

12-km MM5 Forecast 1200 UTC 11 December 1992



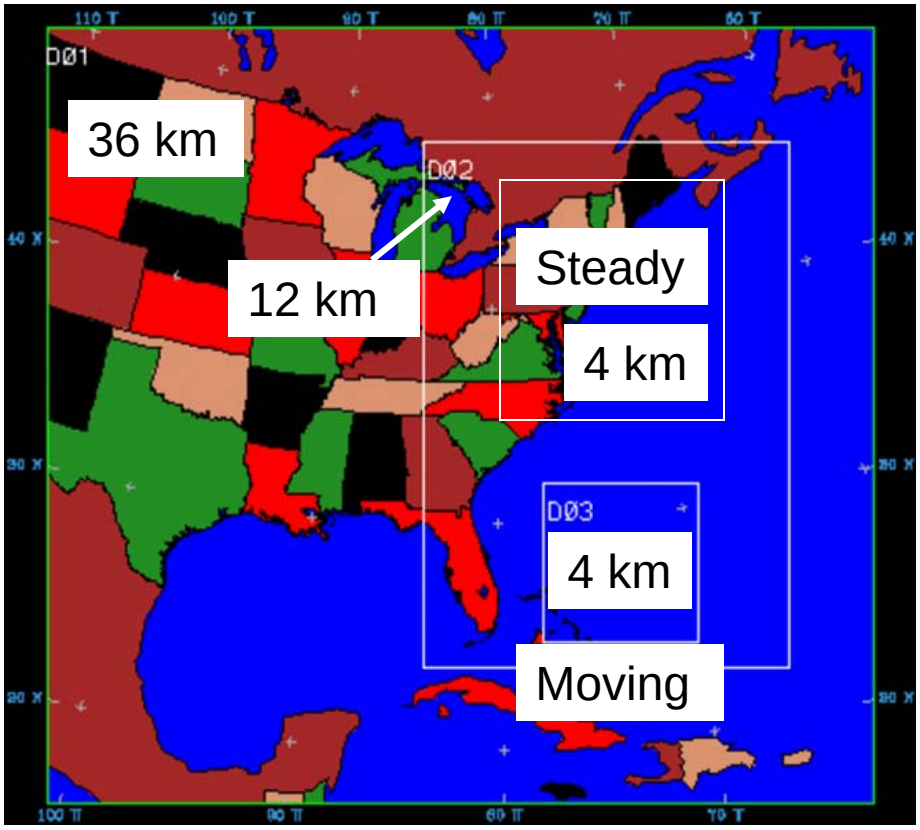
ADCIRC Water-level and Flooding

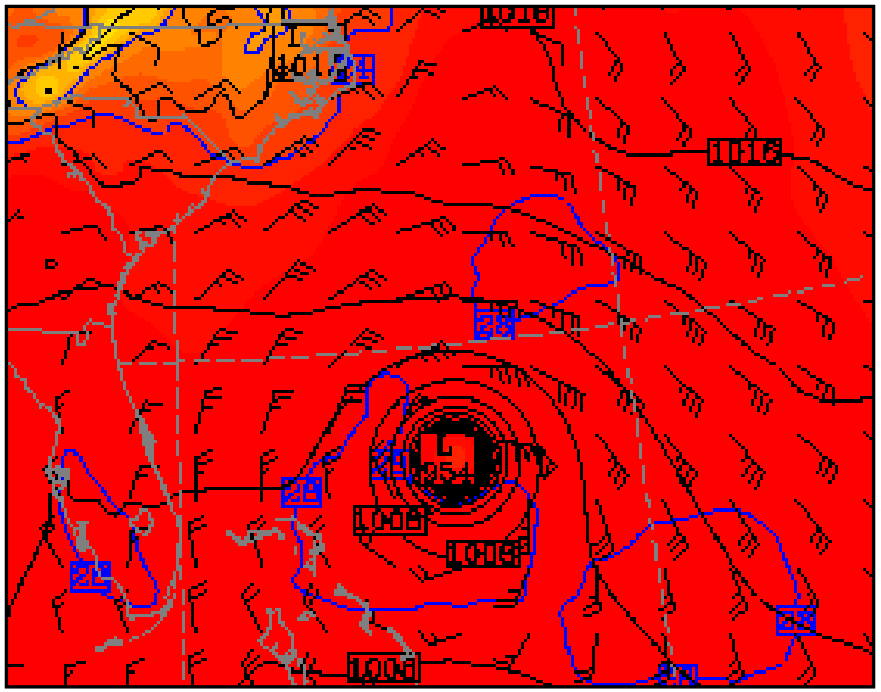


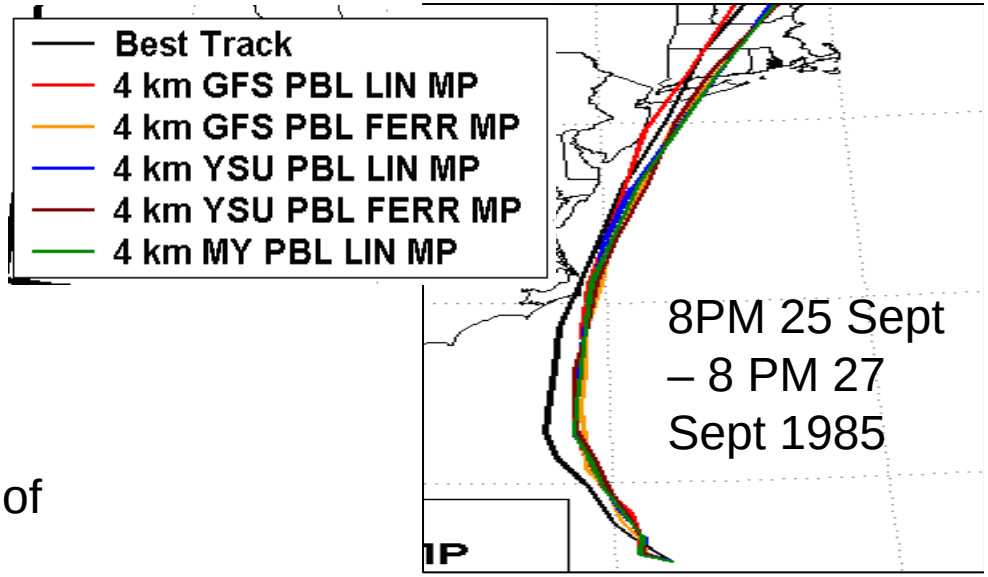


Colle, B. A., F. Buonaiuto, M. J. Bowman, R. E. Wilson, et al., 2008: Simulations of past cyclone events to explore New York City's vulnerability to coastal flooding and storm surge model capabilities , *Bull. Amer. Meteor. Soc.*

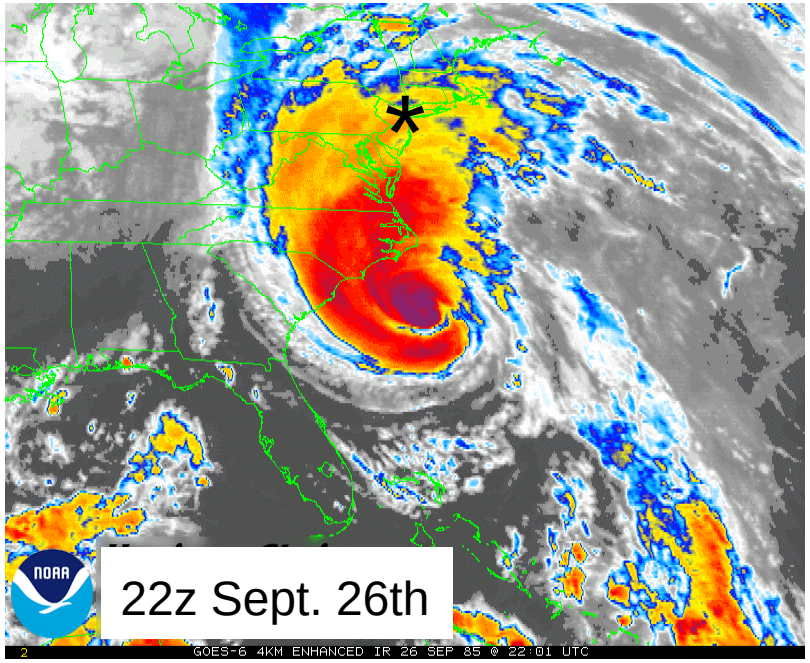
48-h WRF Hindcast of Hurricane Gloria

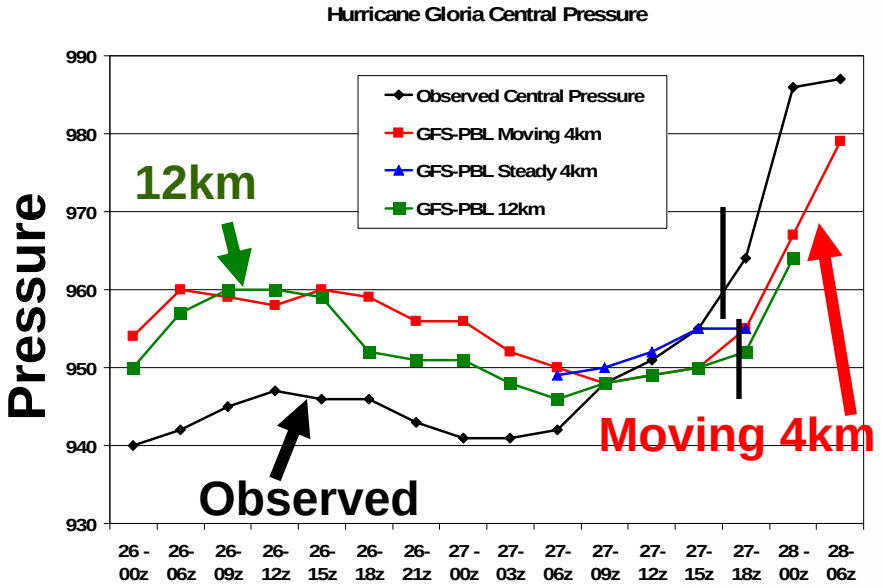




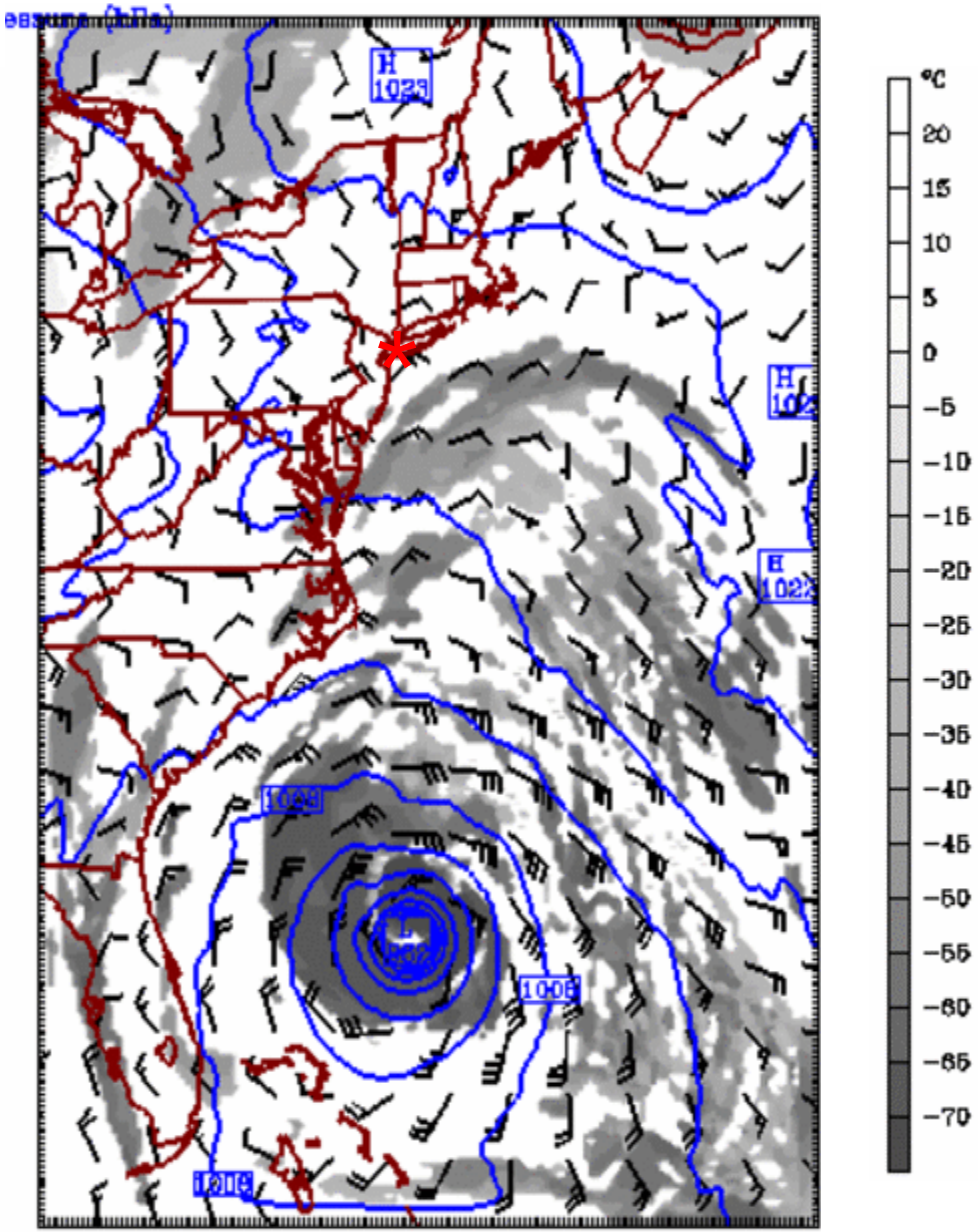


- Insert Cyclone Using NCAR-AFWA Method:
  - Davis and Low-Nam (2001)
  - Specify Radius of Maximum Wind Maximum Wind Speed m/s, Radius of storm, and Wind profile



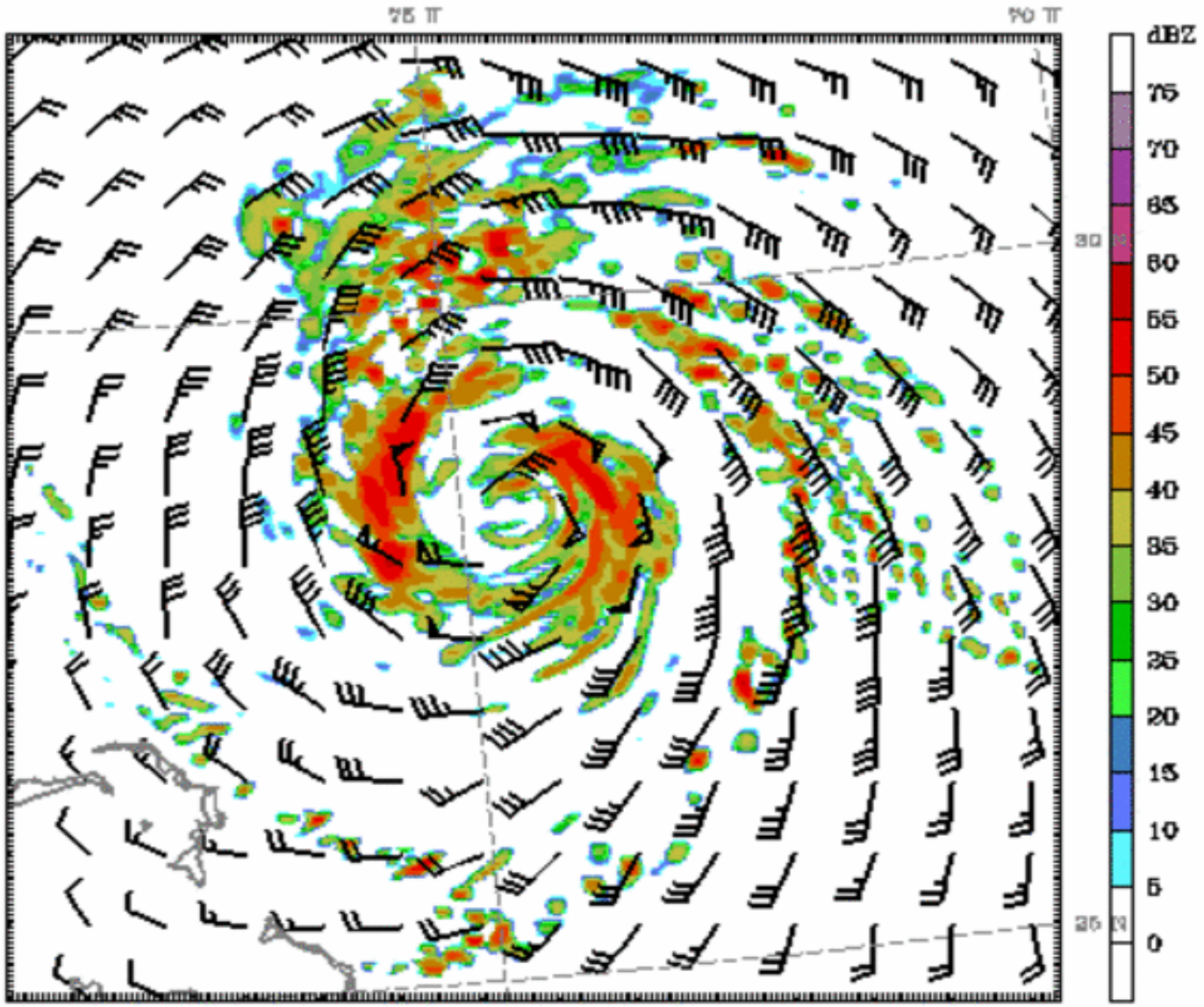


12-km WRF (GFS-PBL) Cloud Top Temperatures (°C)

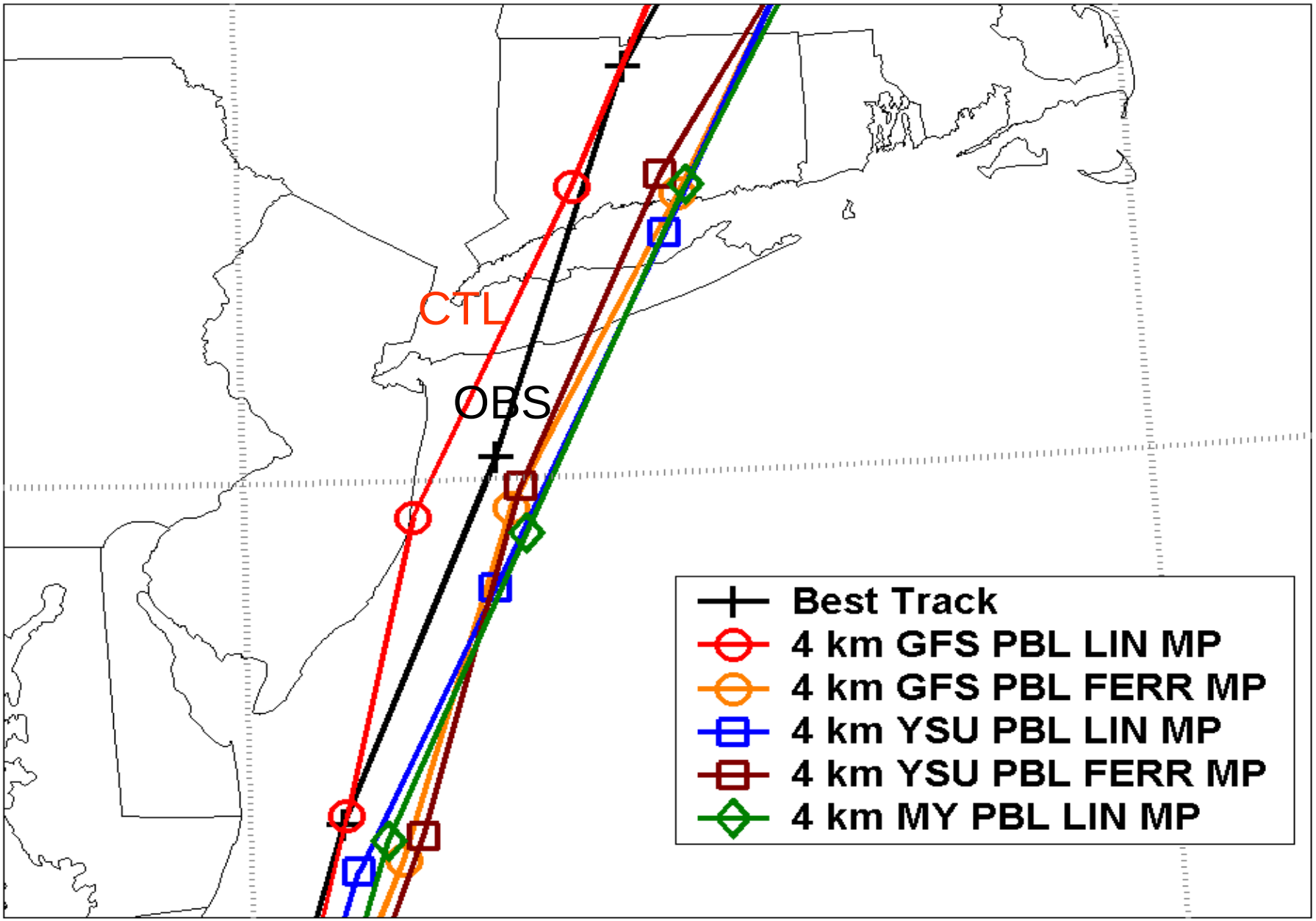


06z Sept 26th – 12z Sept 28th

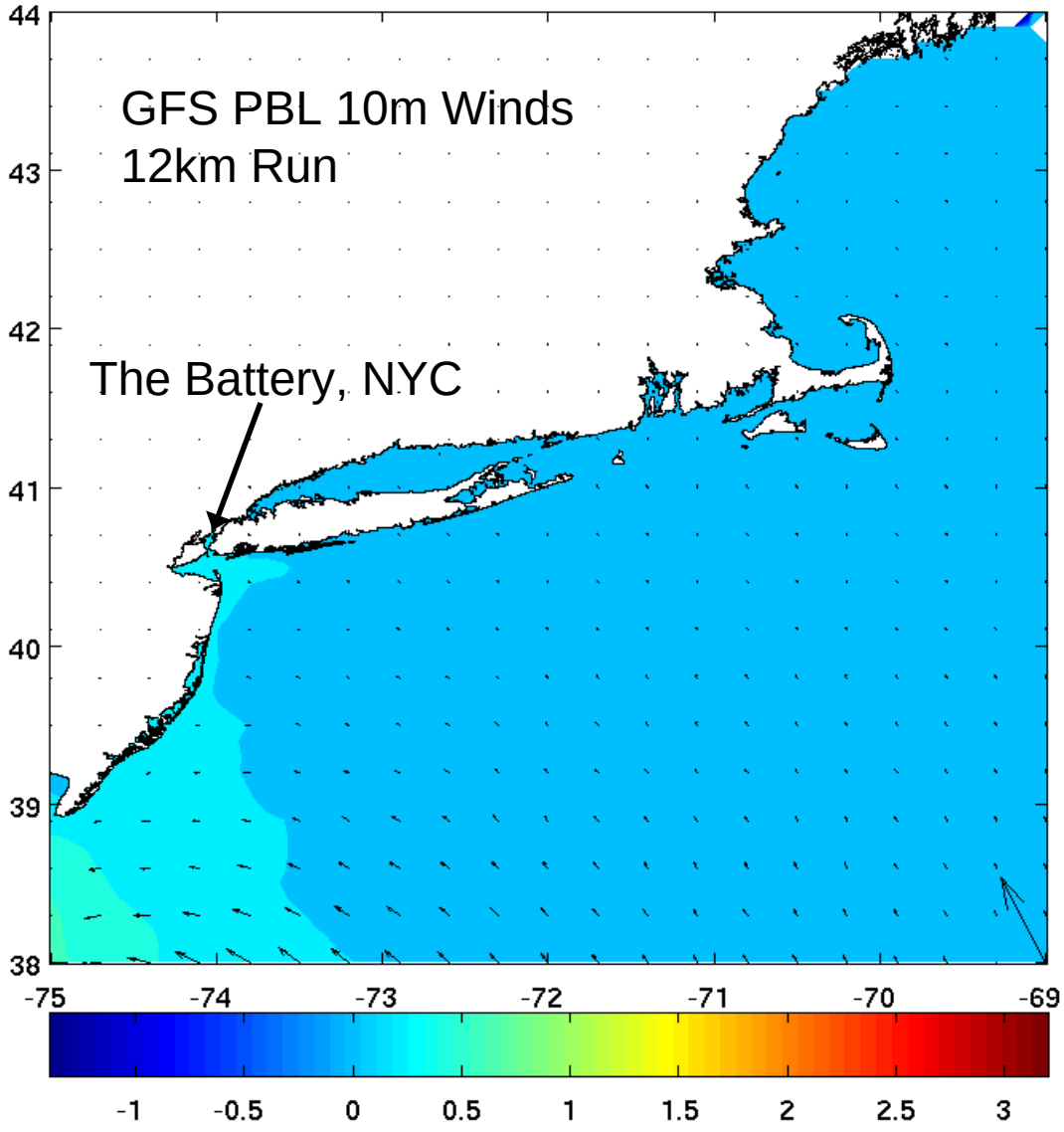
4-km WRF: surface reflectivity (rain intensity)
and 10-m winds (full barb = 10 kts)



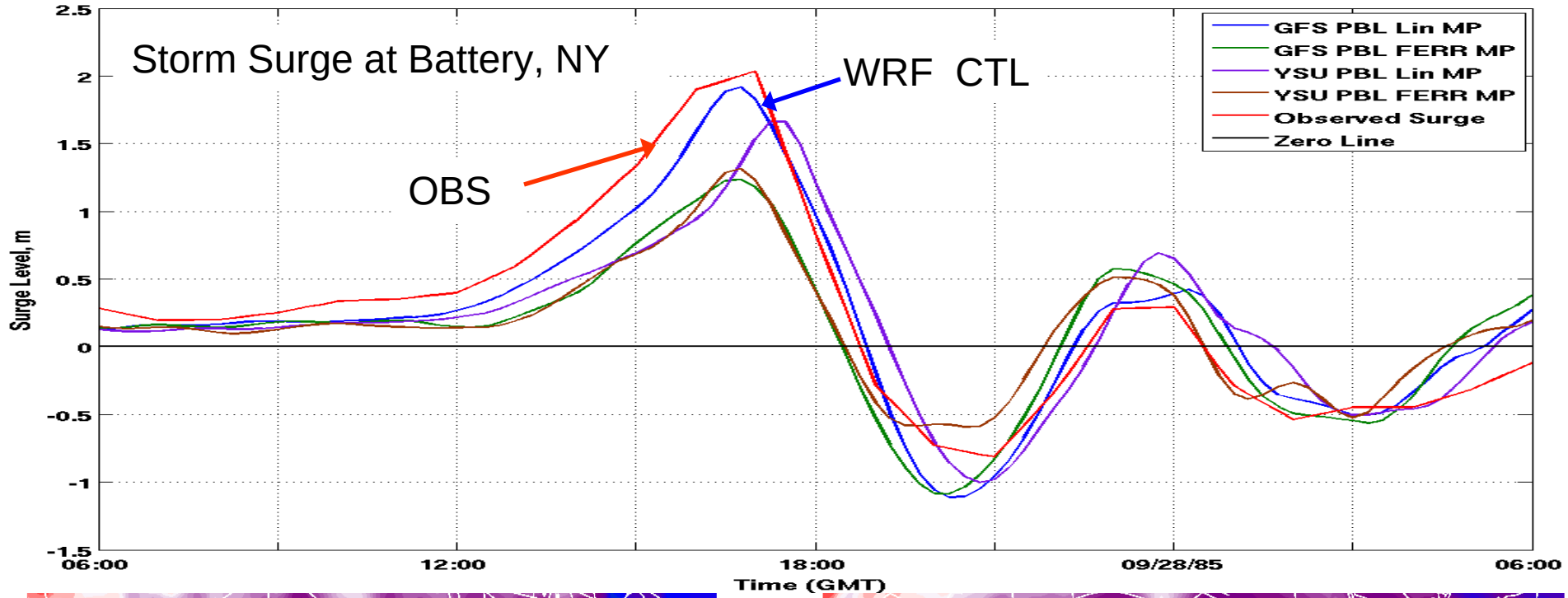
4-km WRF Tracks for Gloria

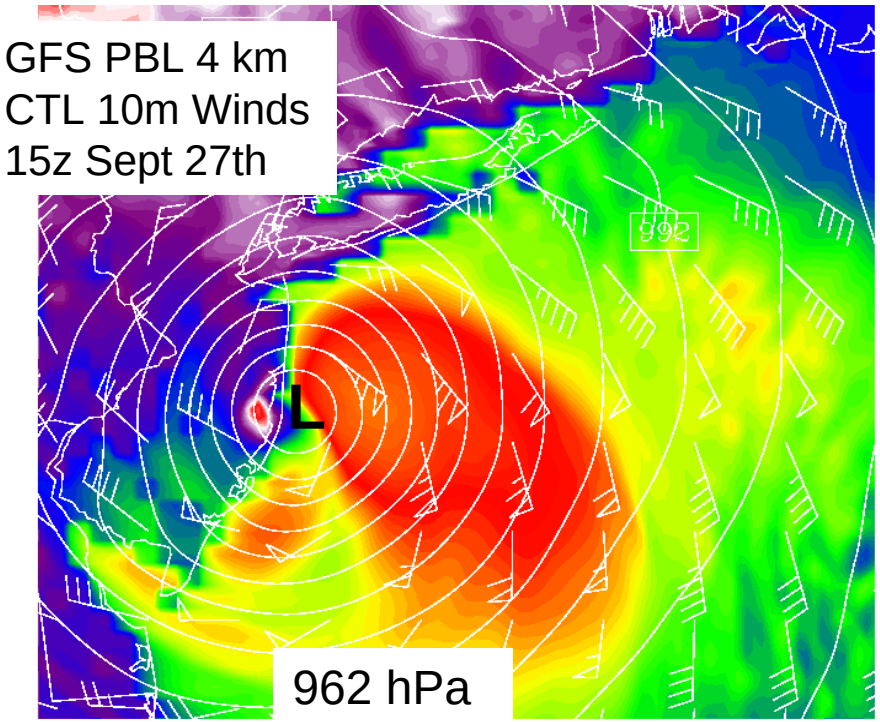


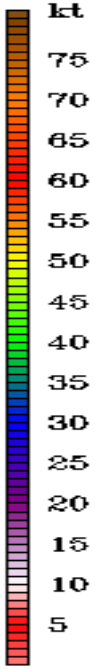
Modeled Hurricane Gloria Storm Surge

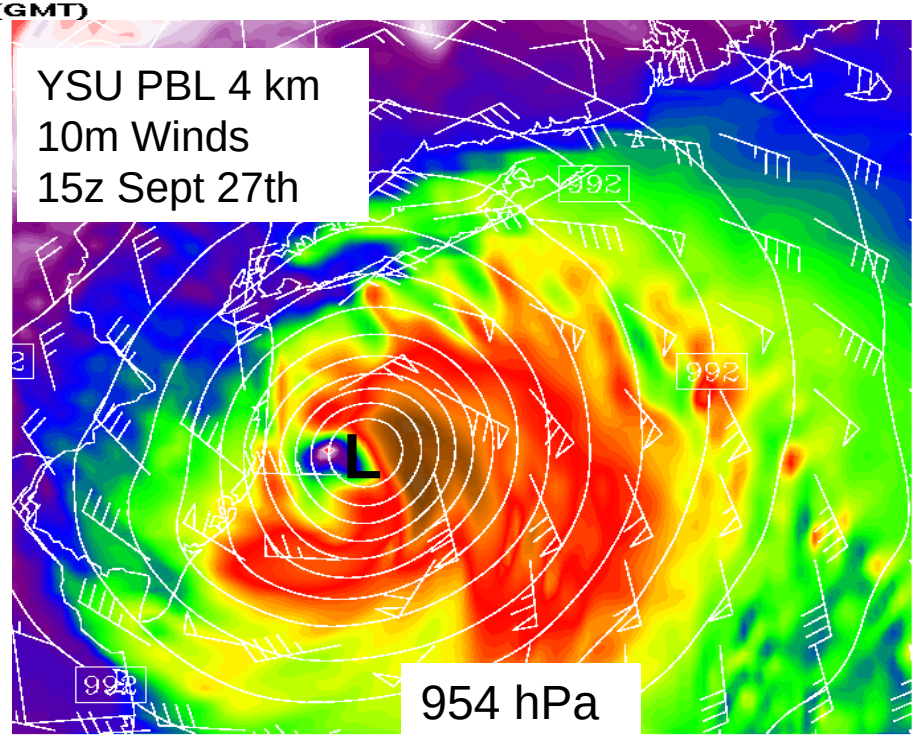


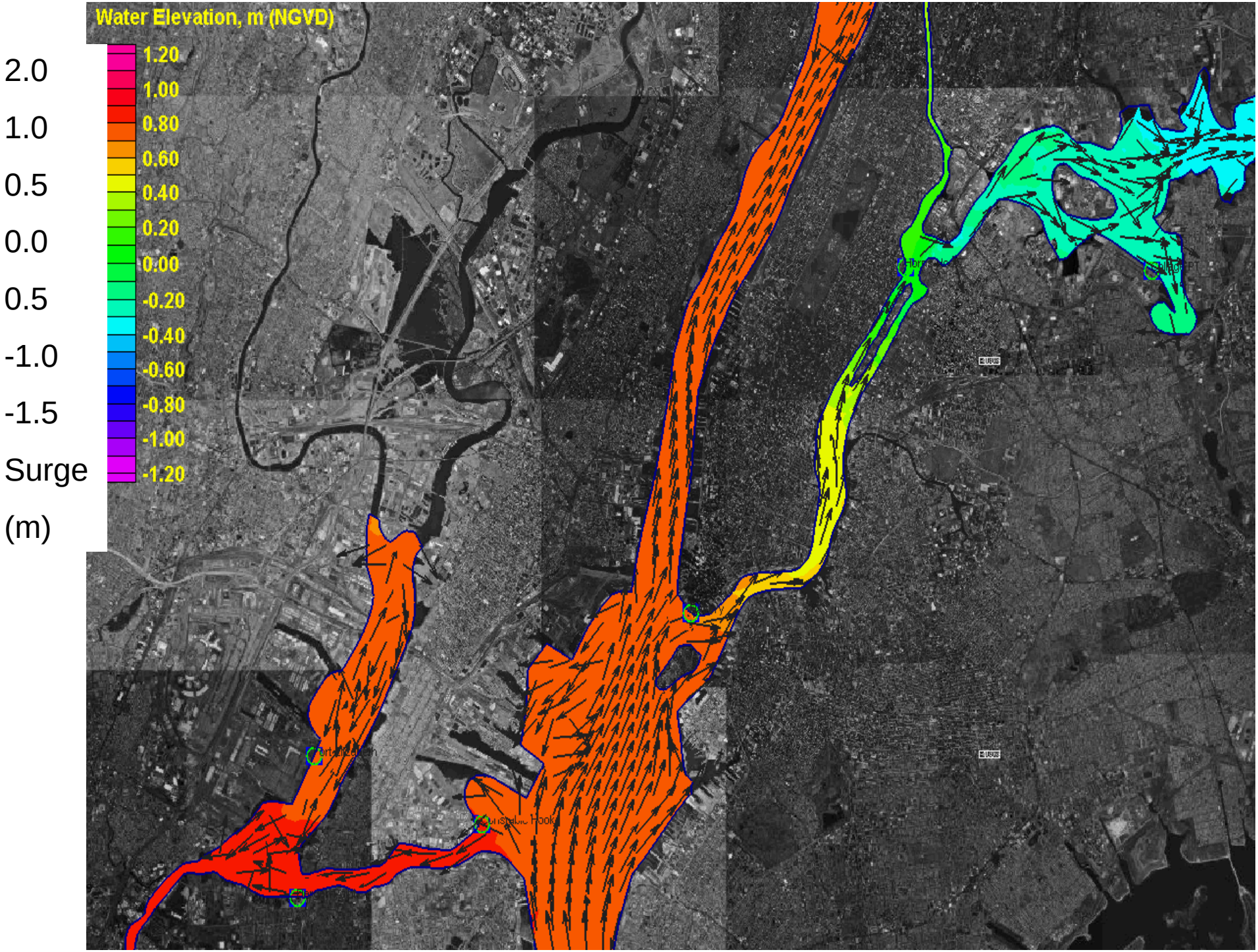
09z Sept. 27th – 00z Sept 28th


Storm Surge at Battery, NY
WRF CTL
OBS
GFS PBL Lin MP
GFS PBL FERR MP
YSU PBL Lin MP
YSU PBL FERR MP
Observed Surge
Zero Line
Surge Level, m
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
06:00
12:00
18:00
09/28/85
06:00
Time (GMT)

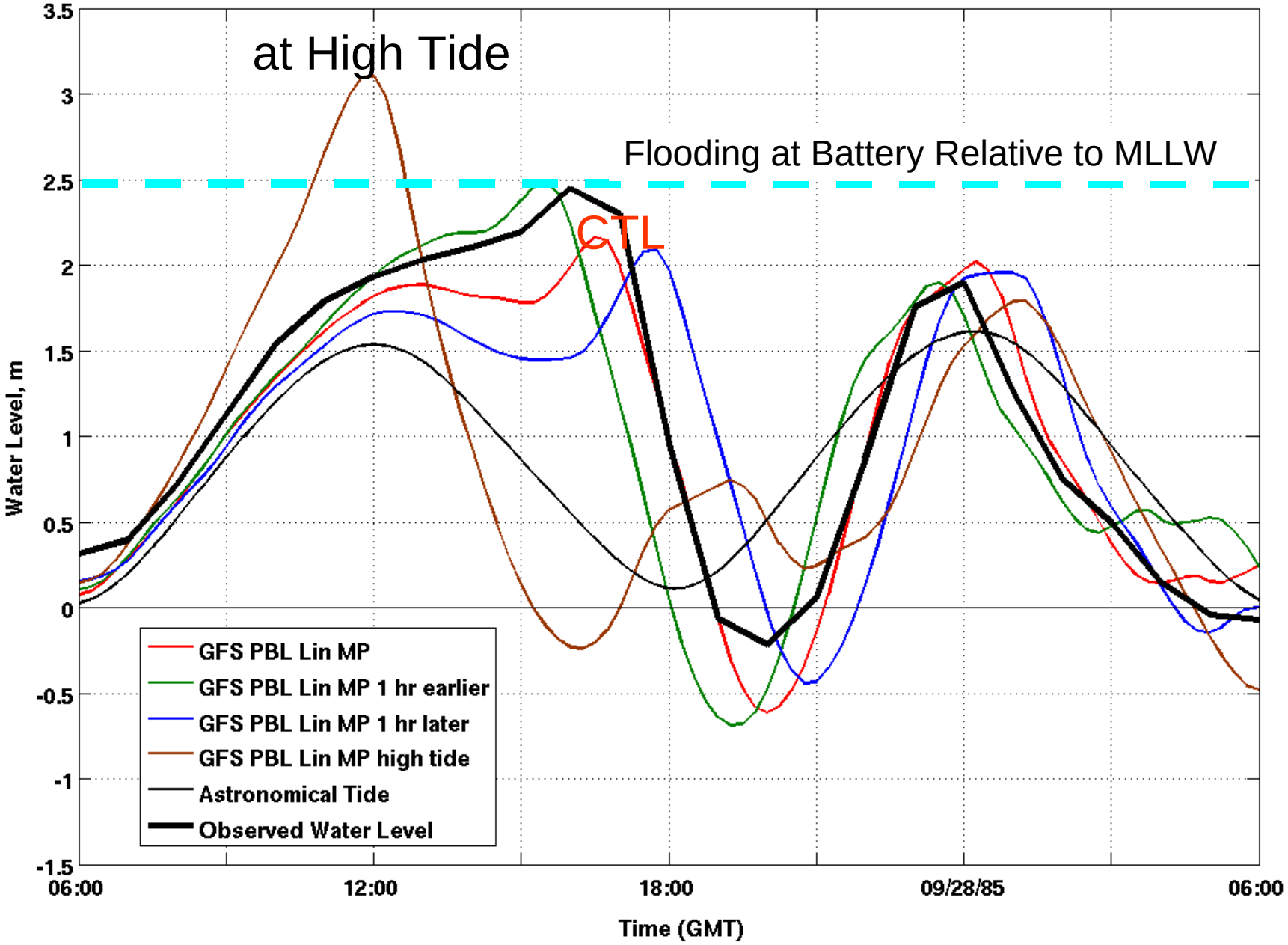

GFS PBL 4 km
CTL 10m Winds
15z Sept 27th
992
L
962 hPa


kt
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5

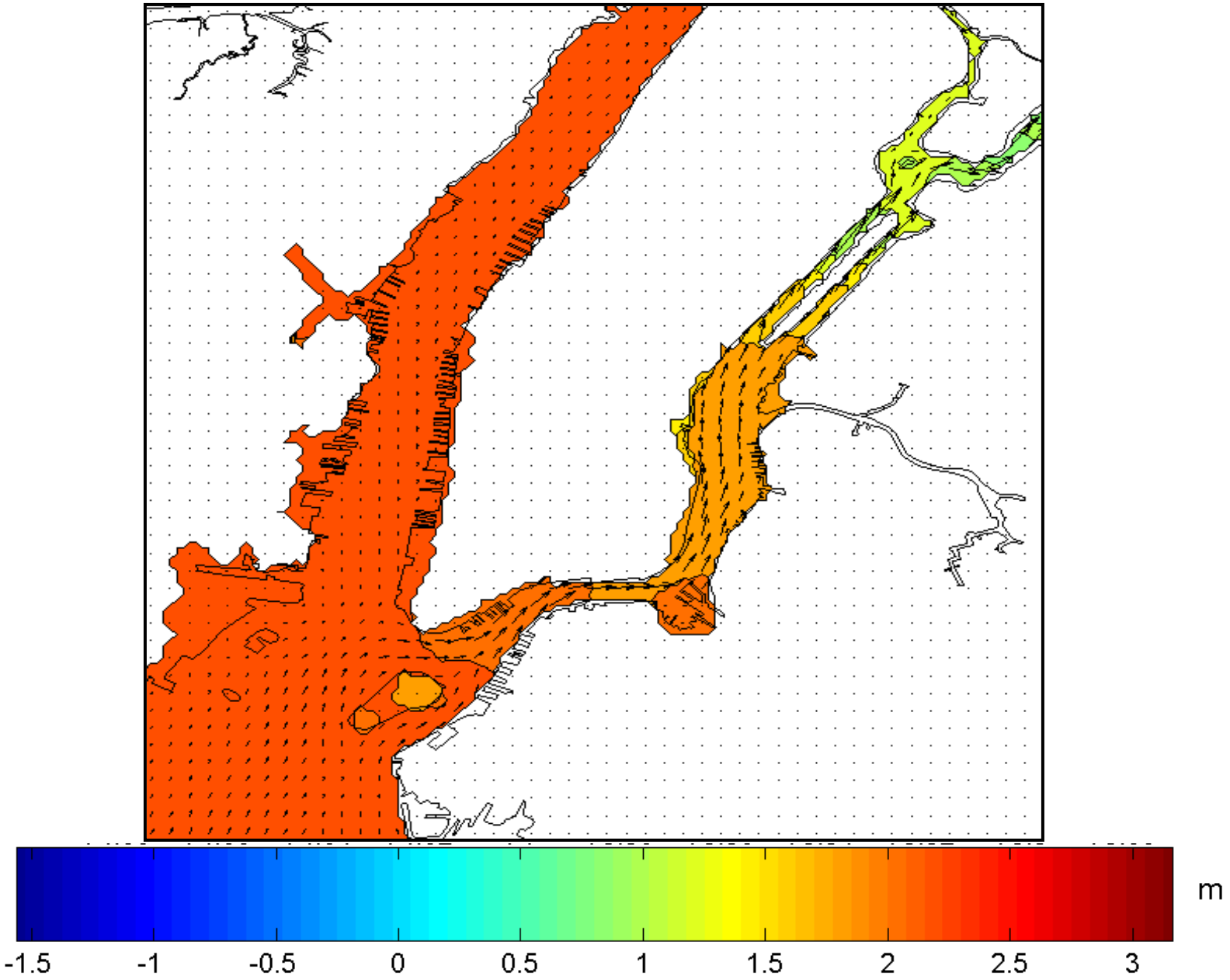

YSU PBL 4 km
10m Winds
15z Sept 27th
992
992
L
954 hPa

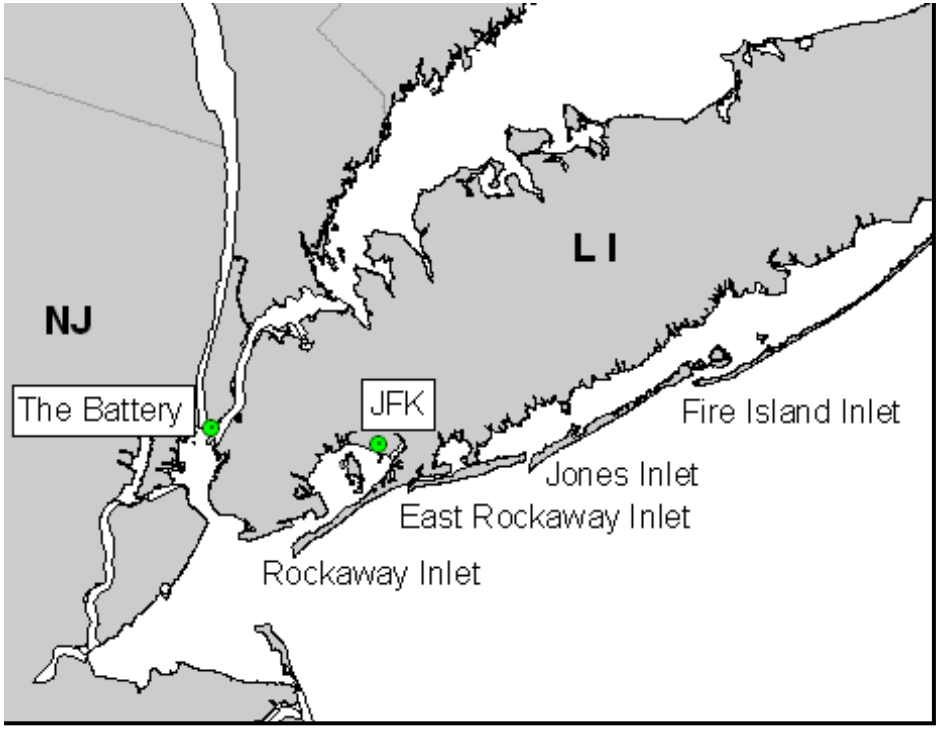

Water Elevation, m (NGVD)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
-1.20
2.0
1.0
0.5
0.0
0.5
-1.0
-1.5
Surge
(m)

Landfall Timing Impact on Water Levels



Gloria (1985) Water Level (MSL) at High Tide





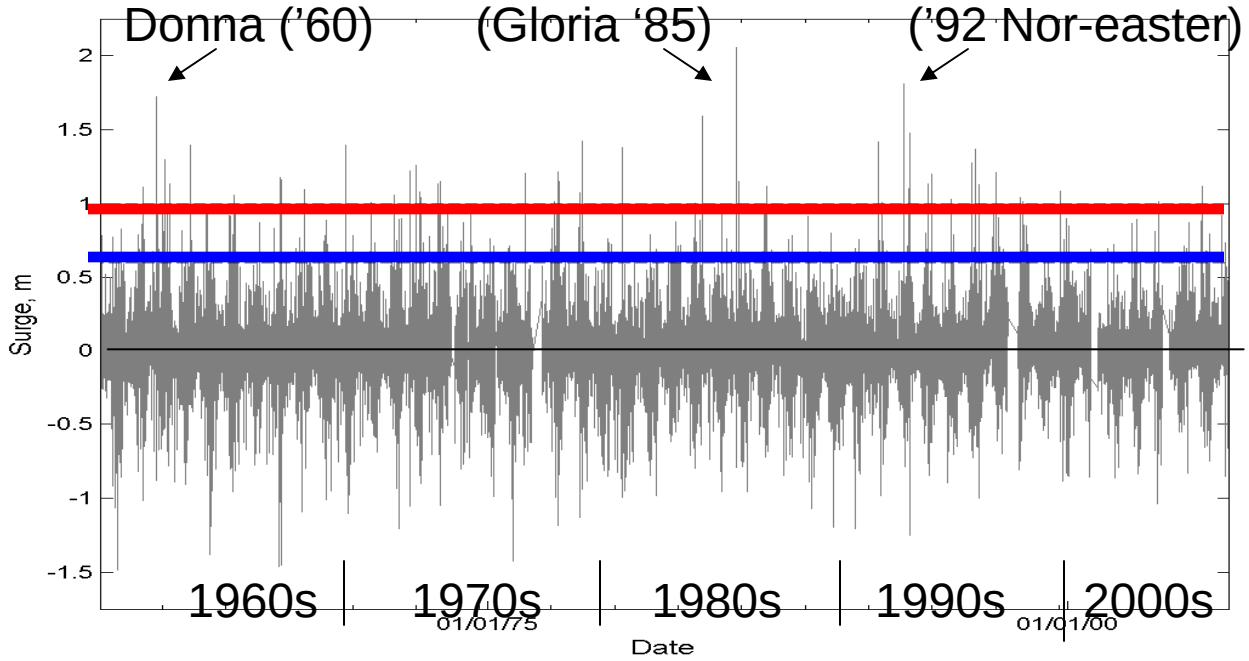
Climatological Analysis of NYC Surges

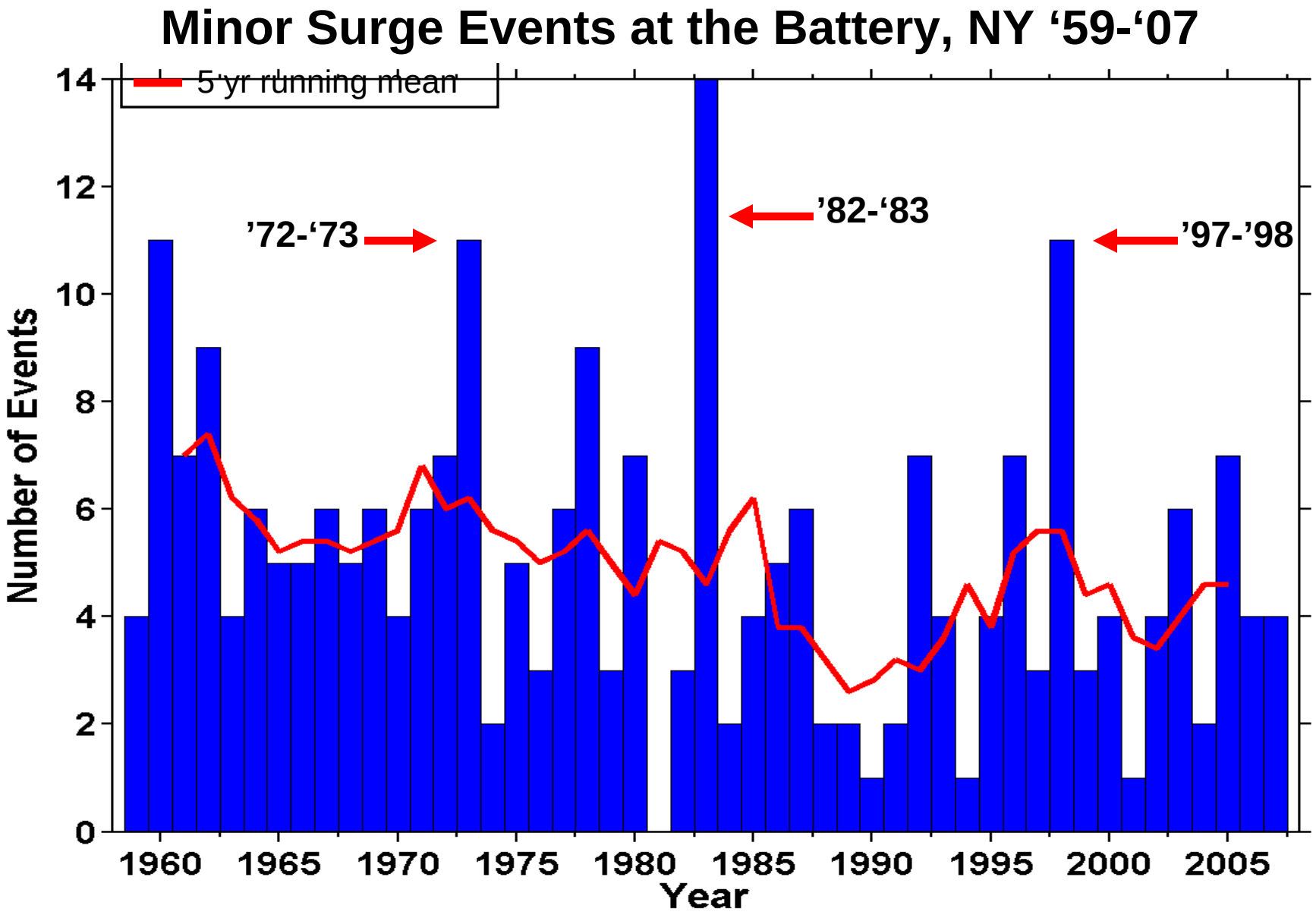
A minor and moderate surge at the Battery would result in a coastal flood advisory and warning, respectively, by the NWS during a high tide (mean high water).

Minor: 0.60-1.00 m above MHW

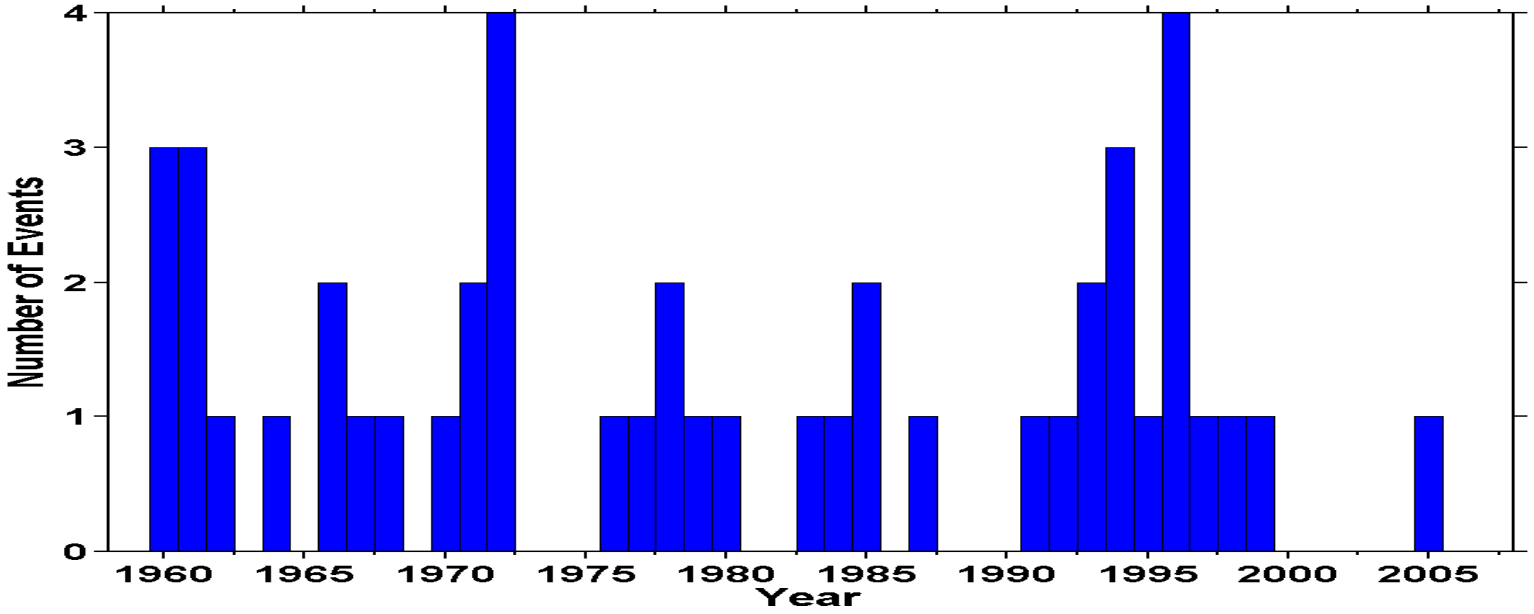
Moderate: >1.00 m above MHW

Maximum daily surge at the Battery, NYC (1959 - 2007)

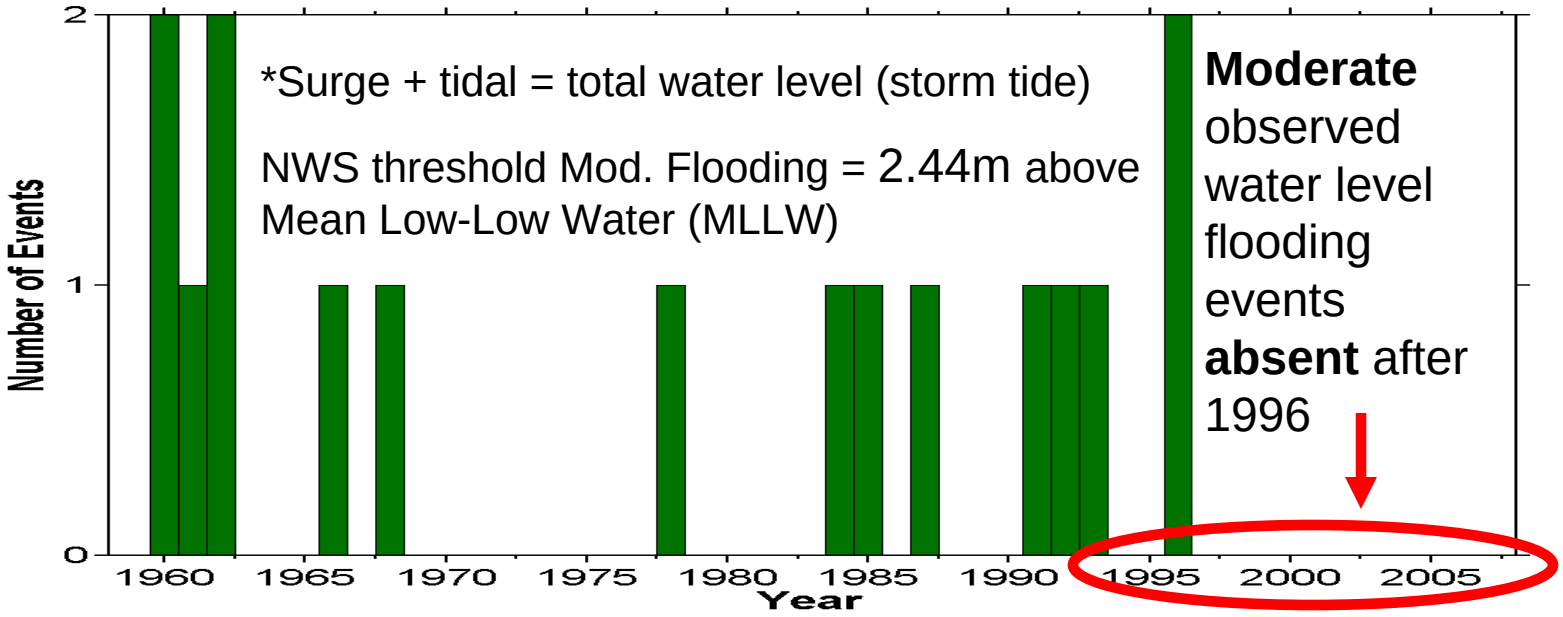



Minor Surge Events at the Battery, NY '59-'07
5 yr running mean
'72-'73
'82-'83
'97-'98
Number of Events
Year
0
2
4
6
8
10
12
14
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

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

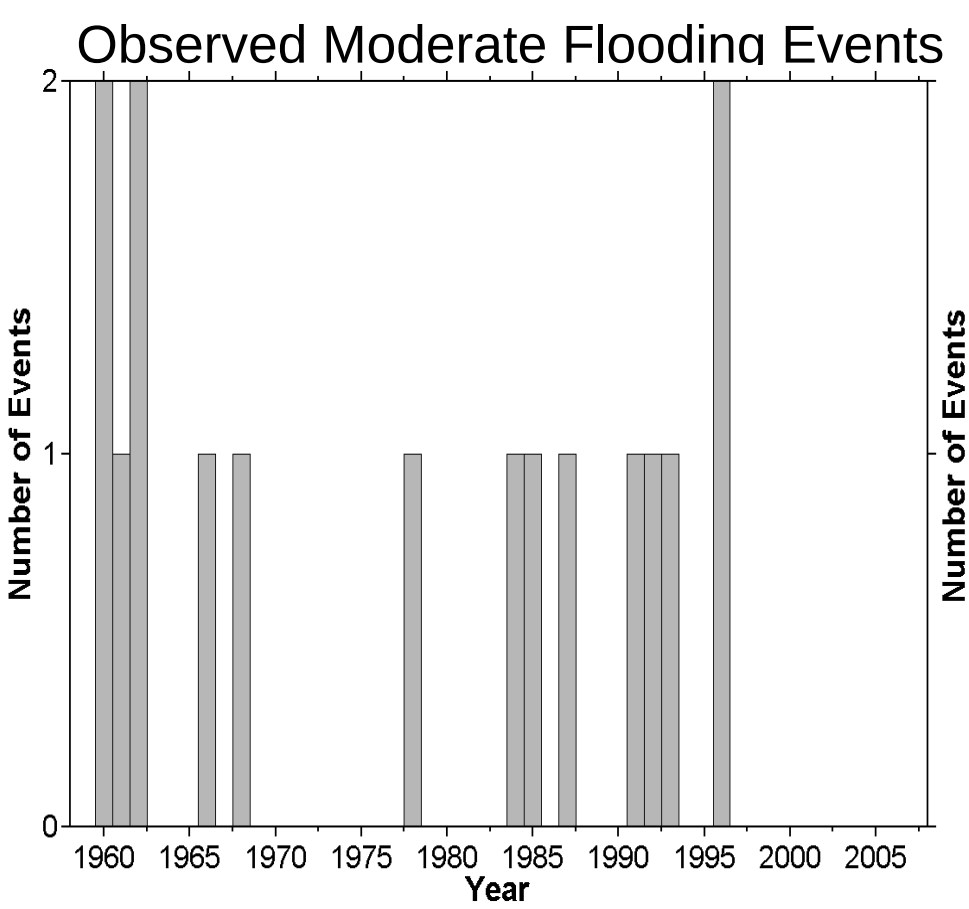


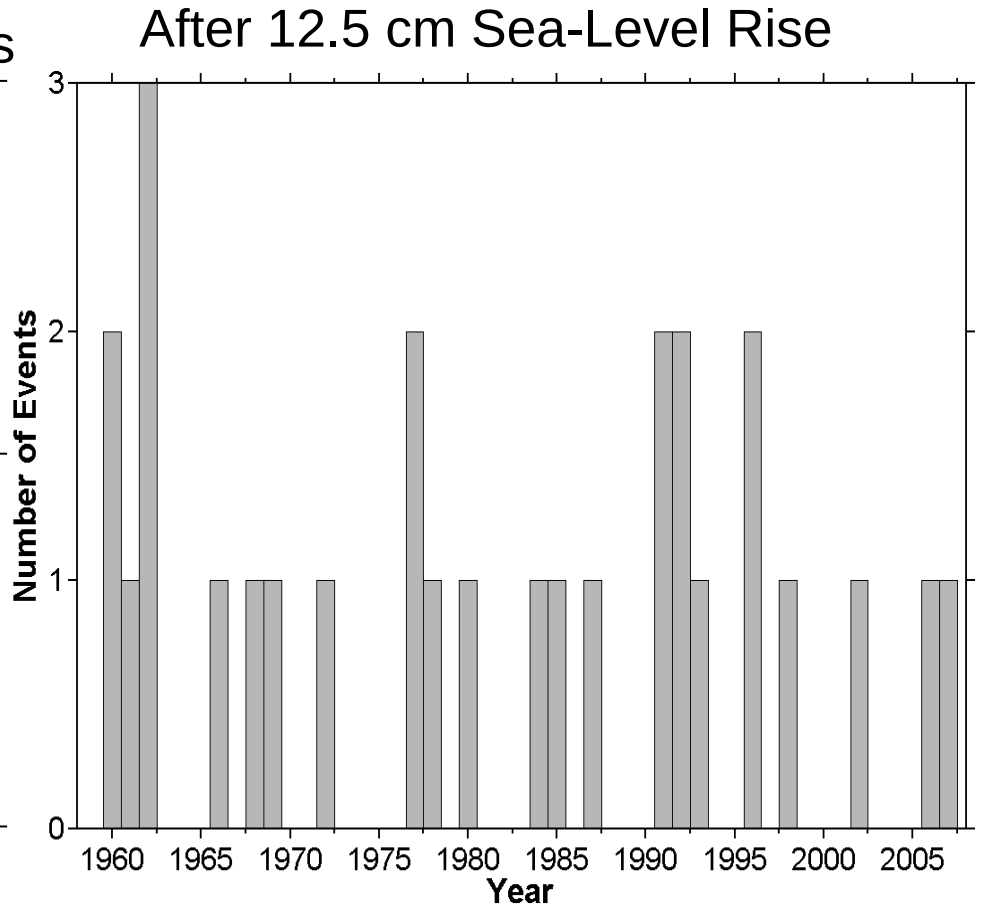
Annual Observed Moderate Flooding Events at the Battery, NY ‘59-‘07



Impact of Sea-Level Rise on NYC Flood Events

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

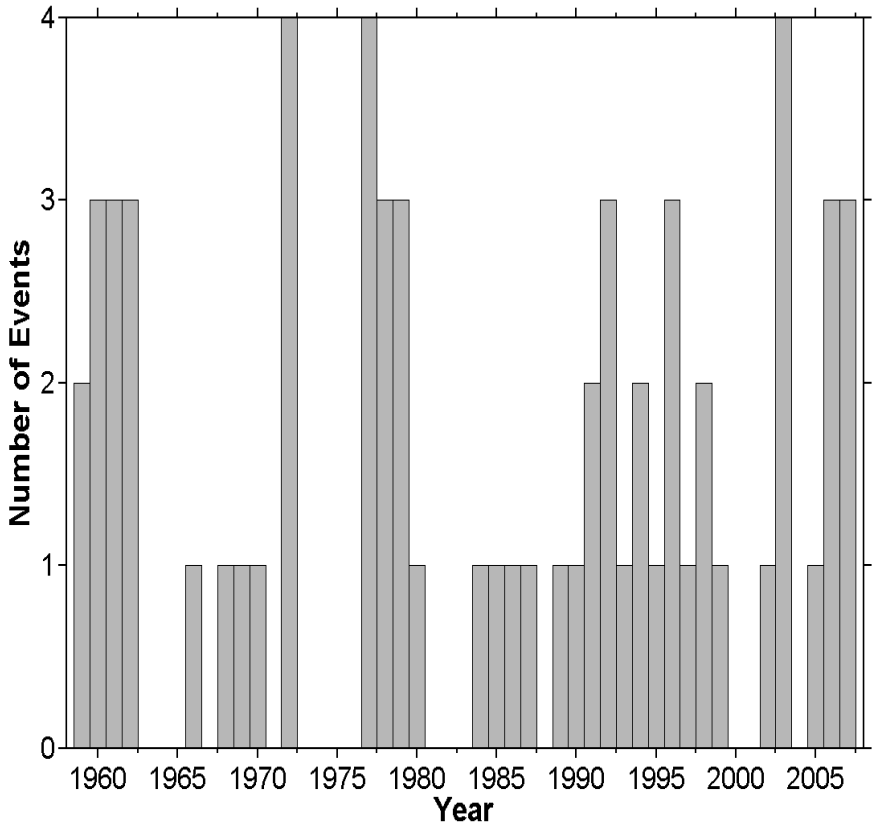




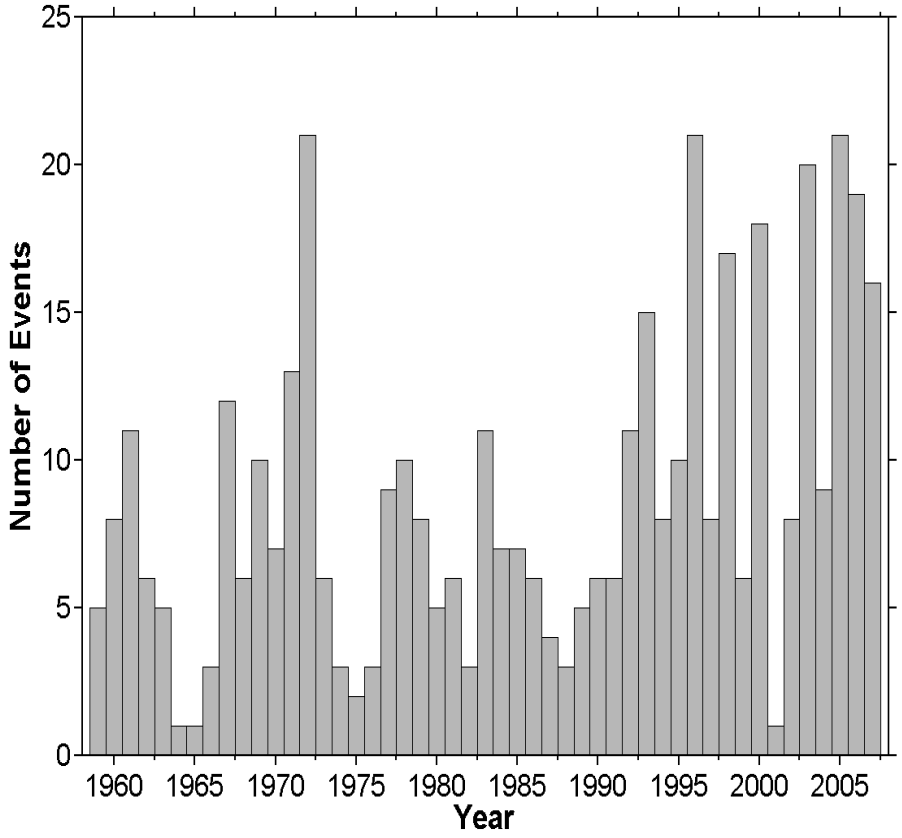
Impact of Sea-Level Rise on NYC Flood Events

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

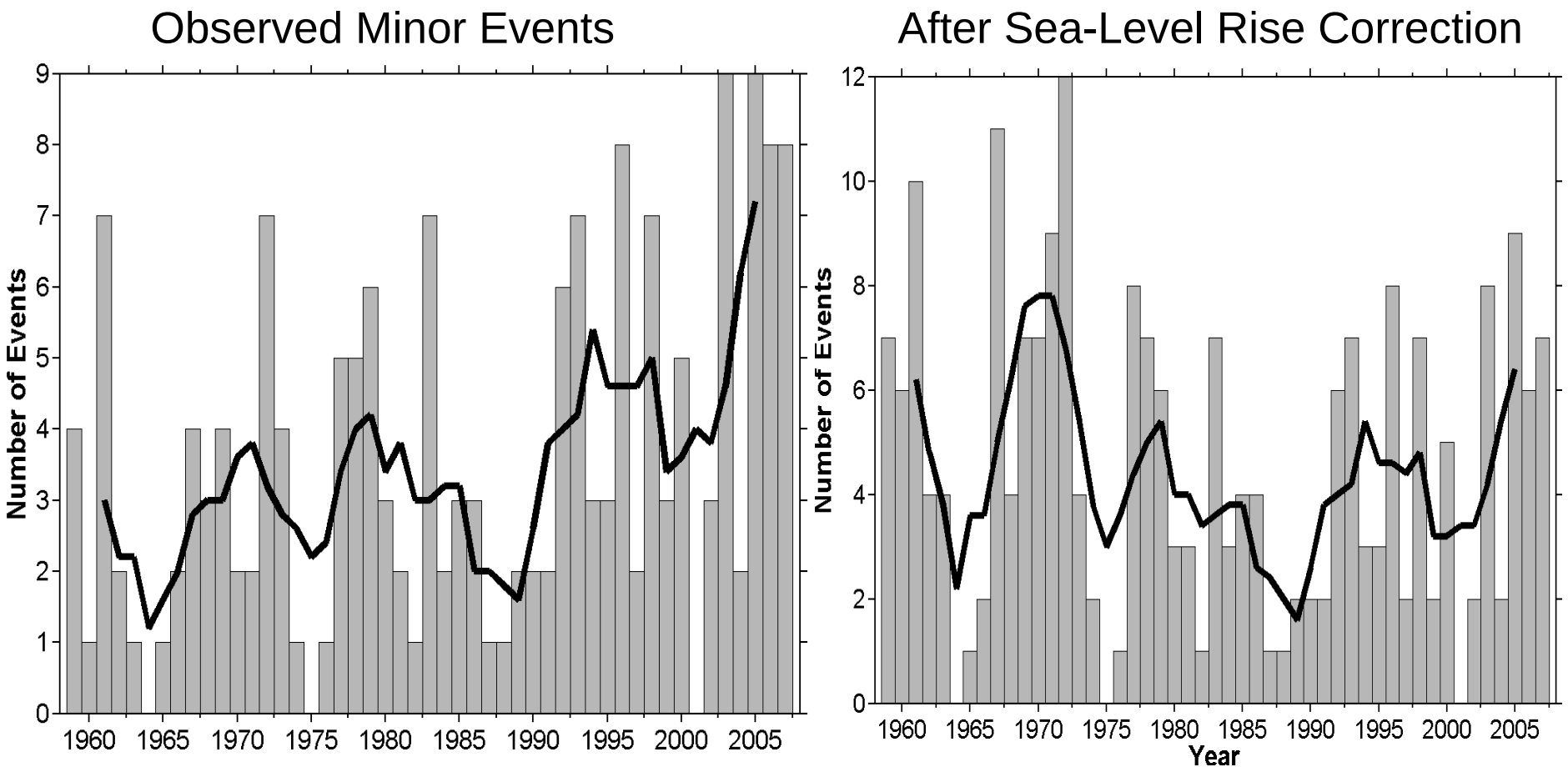
After 25 cm Sea-Level Rise



After 50 cm Sea-Level Rise

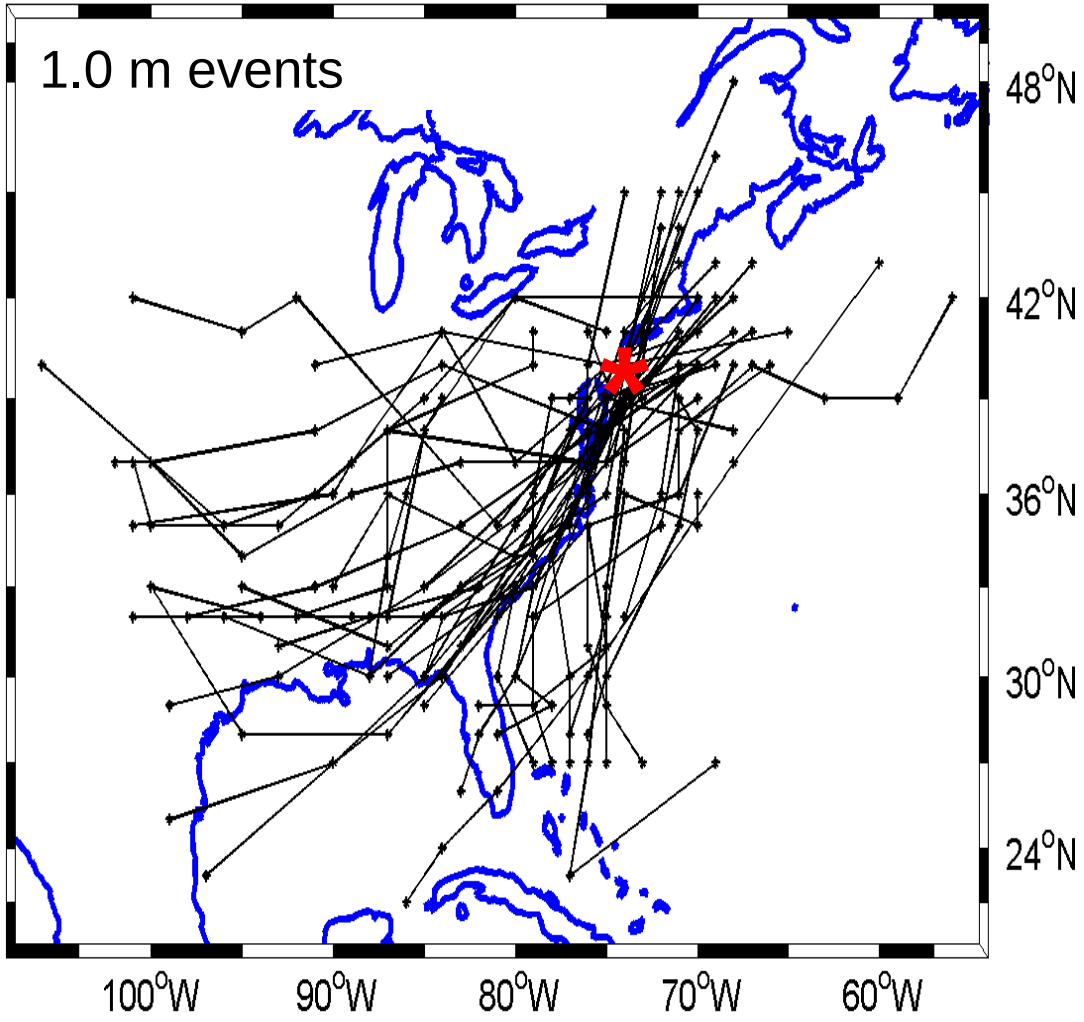


Impact of Sea-Level Rise on Minor Storm-Tide Events (> 2.04 MLLW) (rise ~2.77 mm/yr at Battery--10-15 cm over 50 yrs)

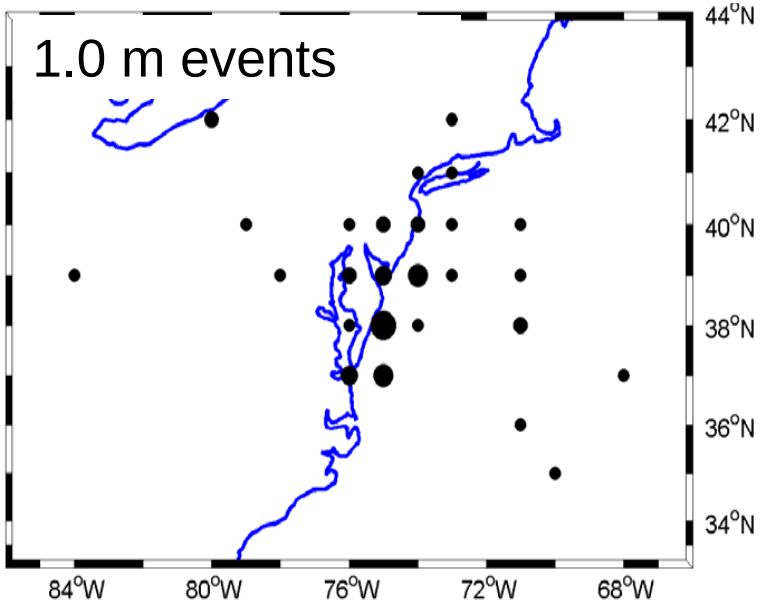


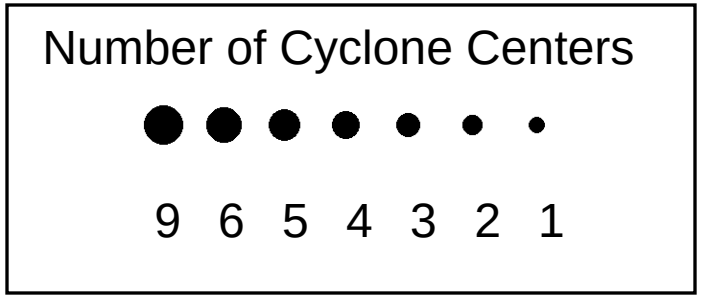
Moderate Surge Cyclone Tracks -48/+12h

Cyclone Tracks

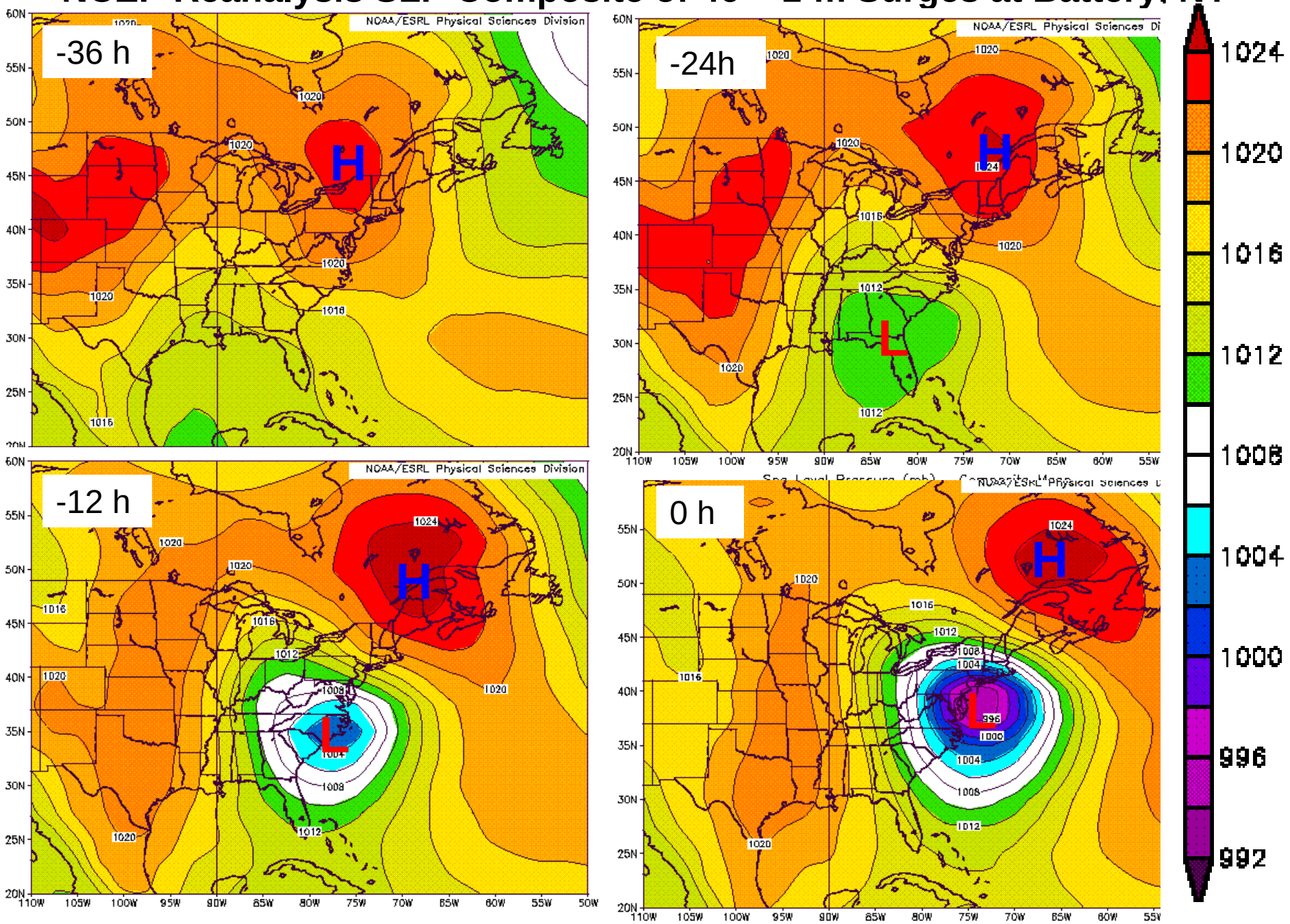


Position at Time of Max Surge

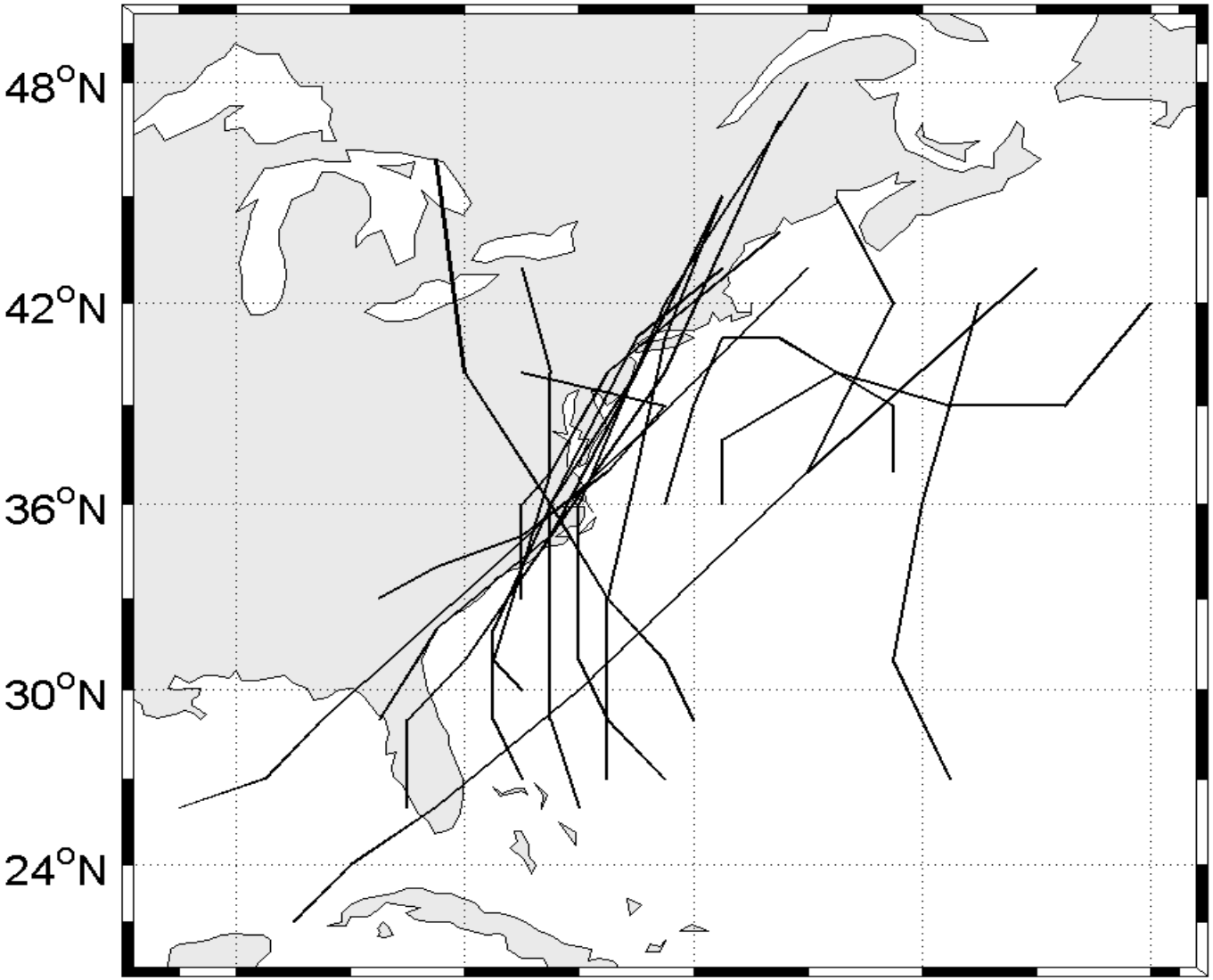




NCEP Reanalysis SLP Composite of 46 > 1-m Surges at Battery, NY

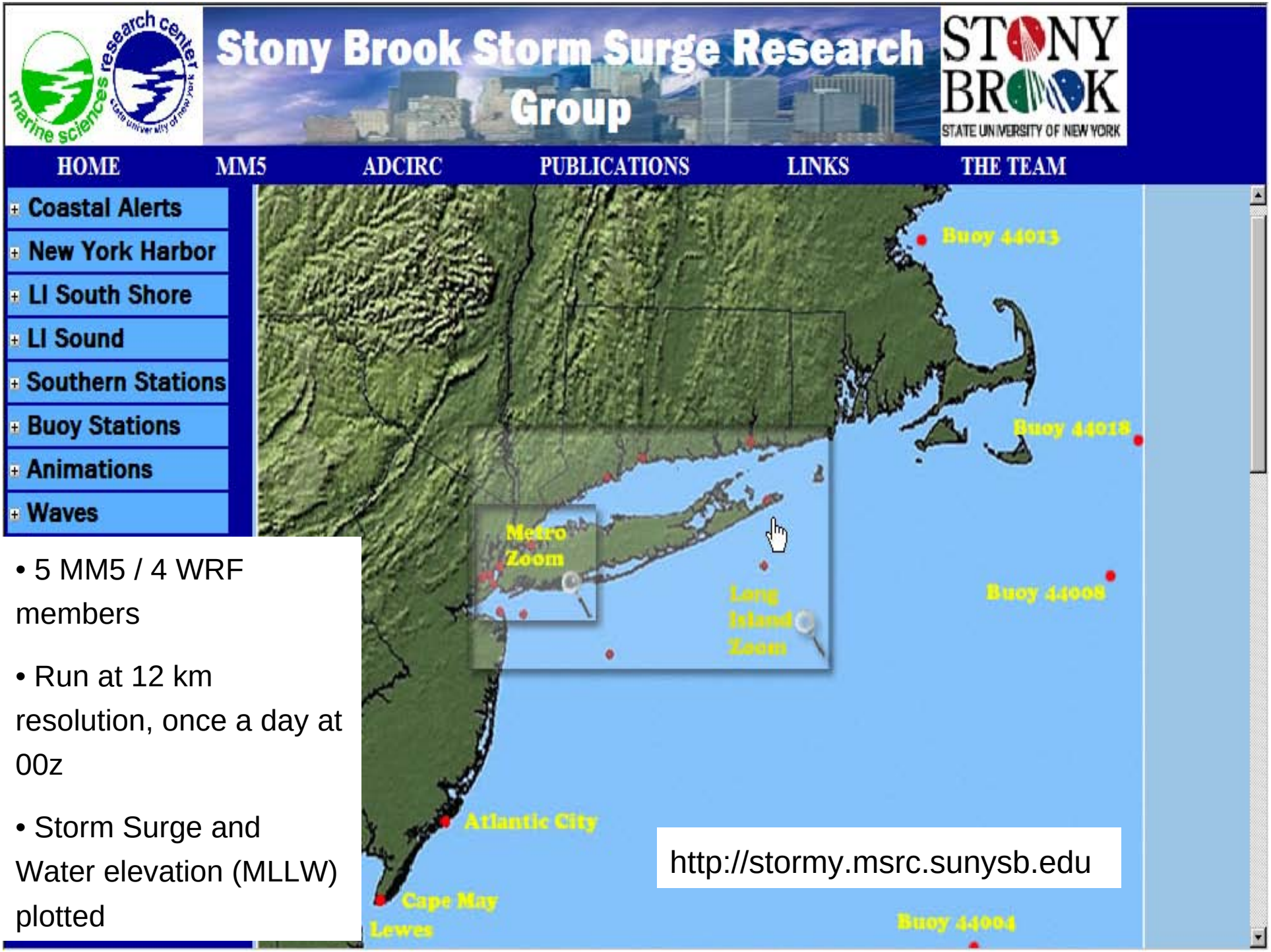


Tropical Storm Surge Tracks (1959-2007)



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.

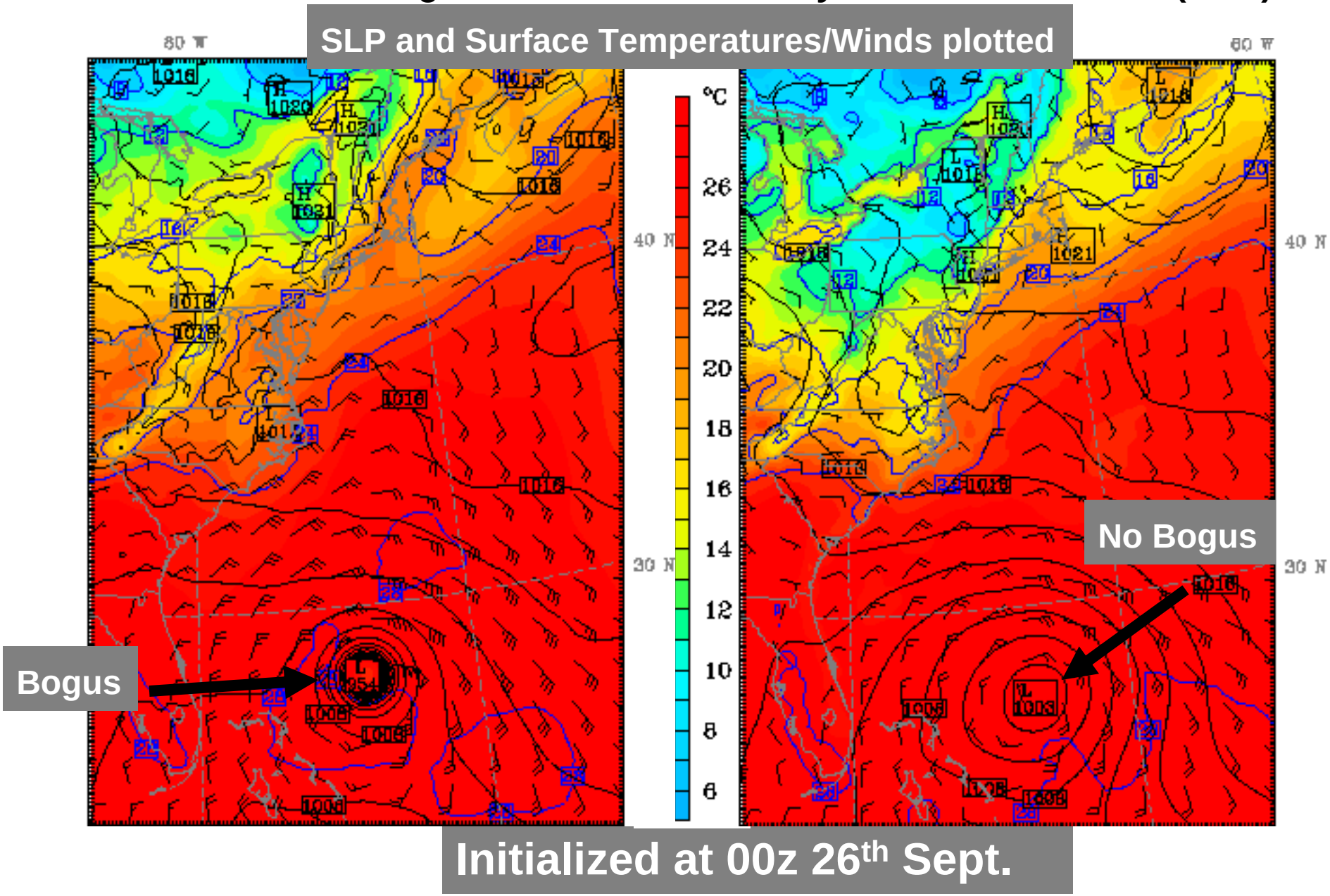


- 5 MM5 / 4 WRF members
- Run at 12 km resolution, once a day at 00z
- Storm Surge and Water elevation (MLLW) plotted

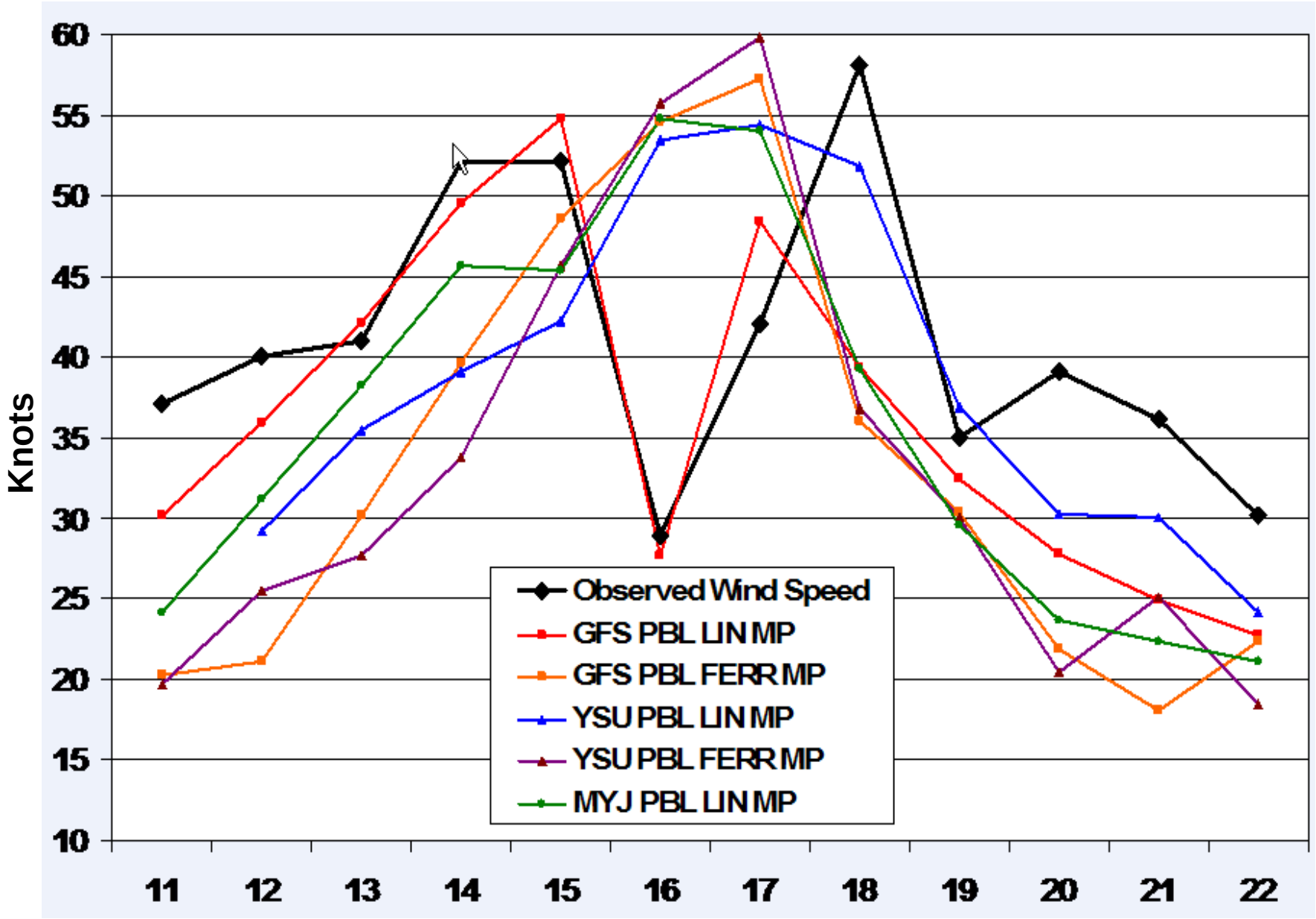
EXTRA SLIDES

Hurricane Gloria Initialization

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

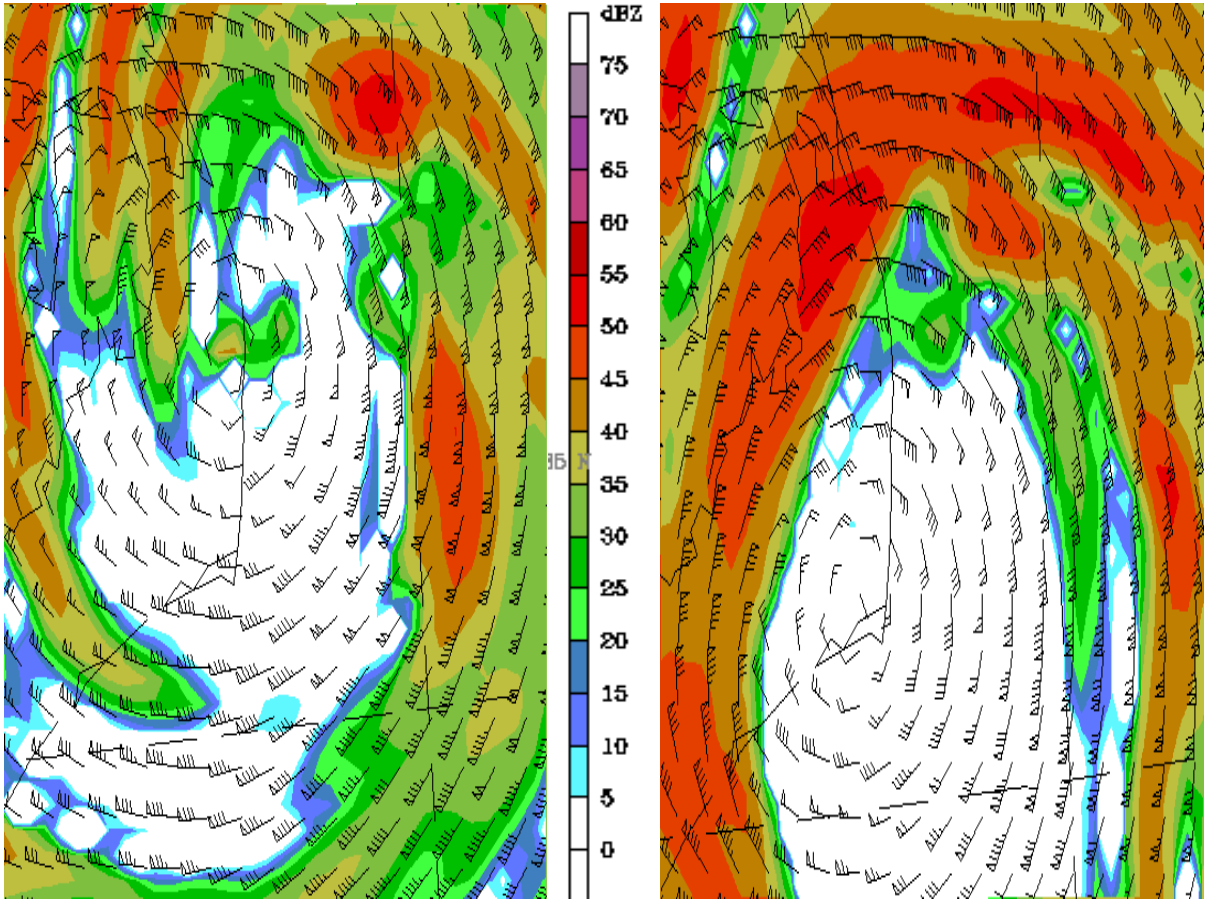


Ambrose Tower Winds



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

06z Sept 27th



Central Pressure - 943 mb

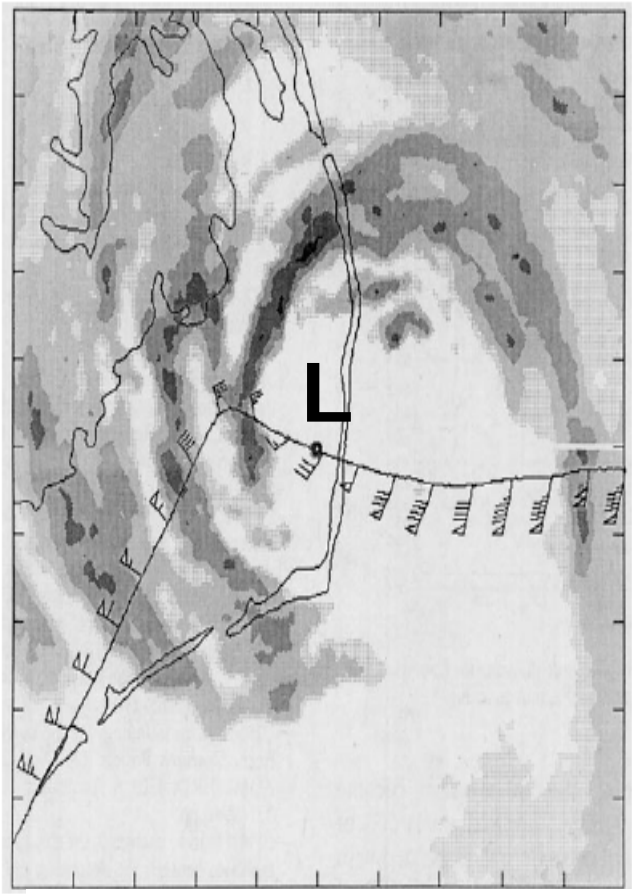
Moving 4km

GFS-PBL

Reflectivity at 2.7-km with 2.7-km winds

(full barb = 5 m/s , flag = 25 m/s)

538z Sept 27th



Central Pressure - 942 mb

Franklin, Lord and Marks Jr. (MWR May, 1988)

Flight Level Winds (full barb = 5 m/s , flag = 25 m/s)

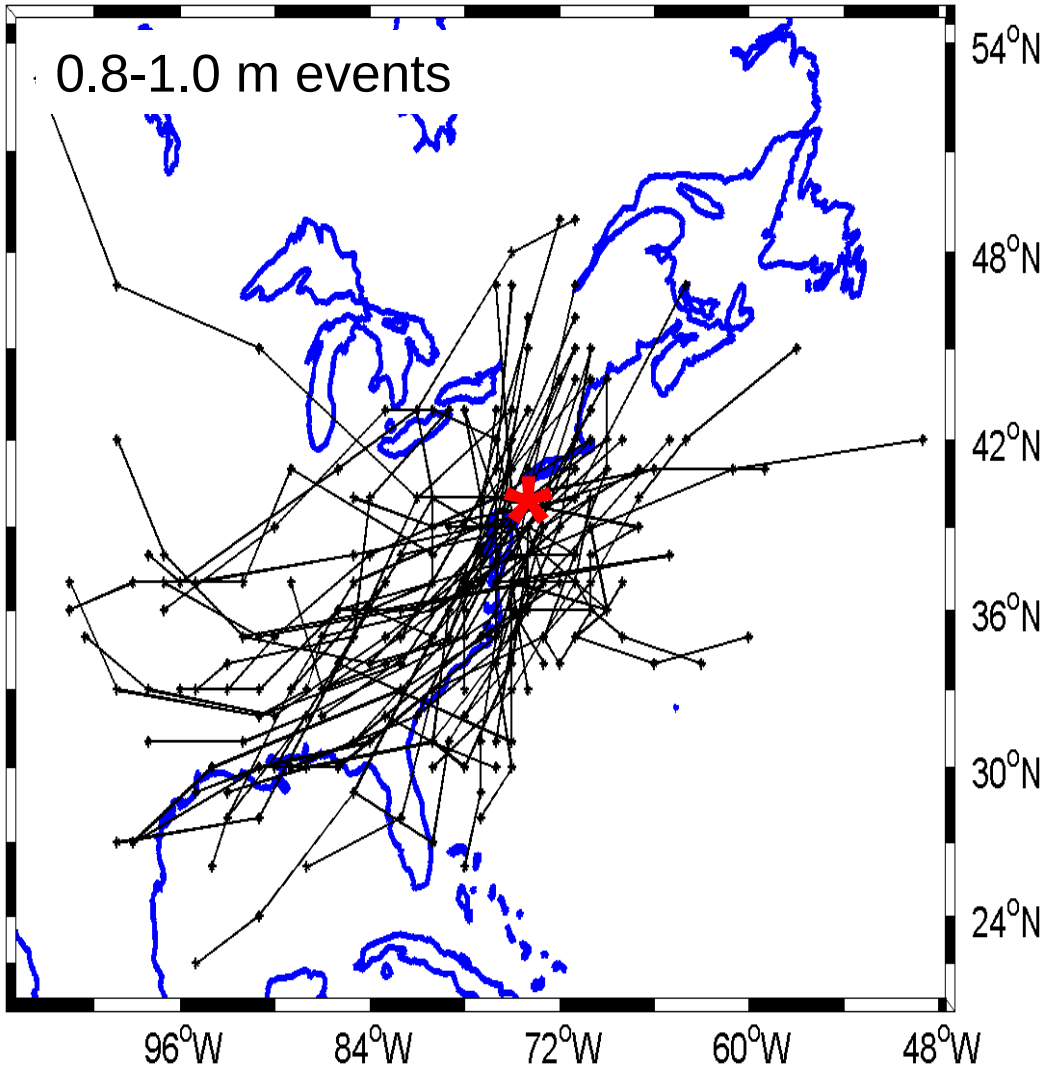
Reflectivity sweep taken at 2.7 km, 21-38dbz = gray scale

Central Pressure - 950 mb

Steady 4km

Minor Surge Cyclone Tracks -48/+12h

Cyclone Tracks



Position at Time of Max Surge