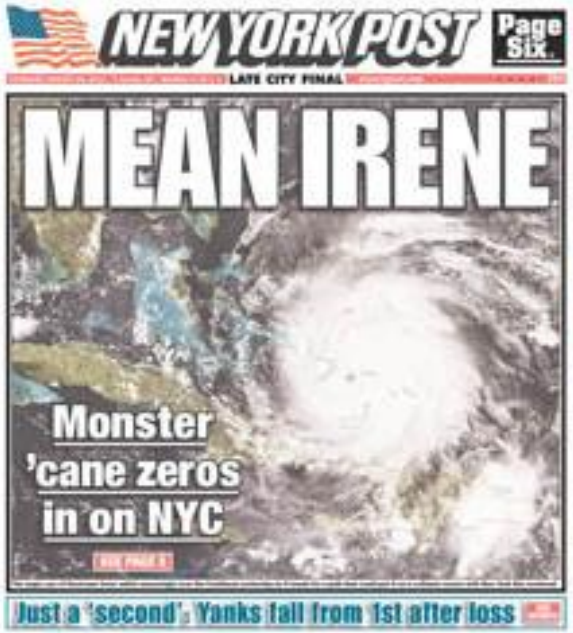
Modeling a Hurricane: Superstorm Sandy

Aaron Byrd, Ph.D., P.E.

US Army Corps of Engineers.

ERDC

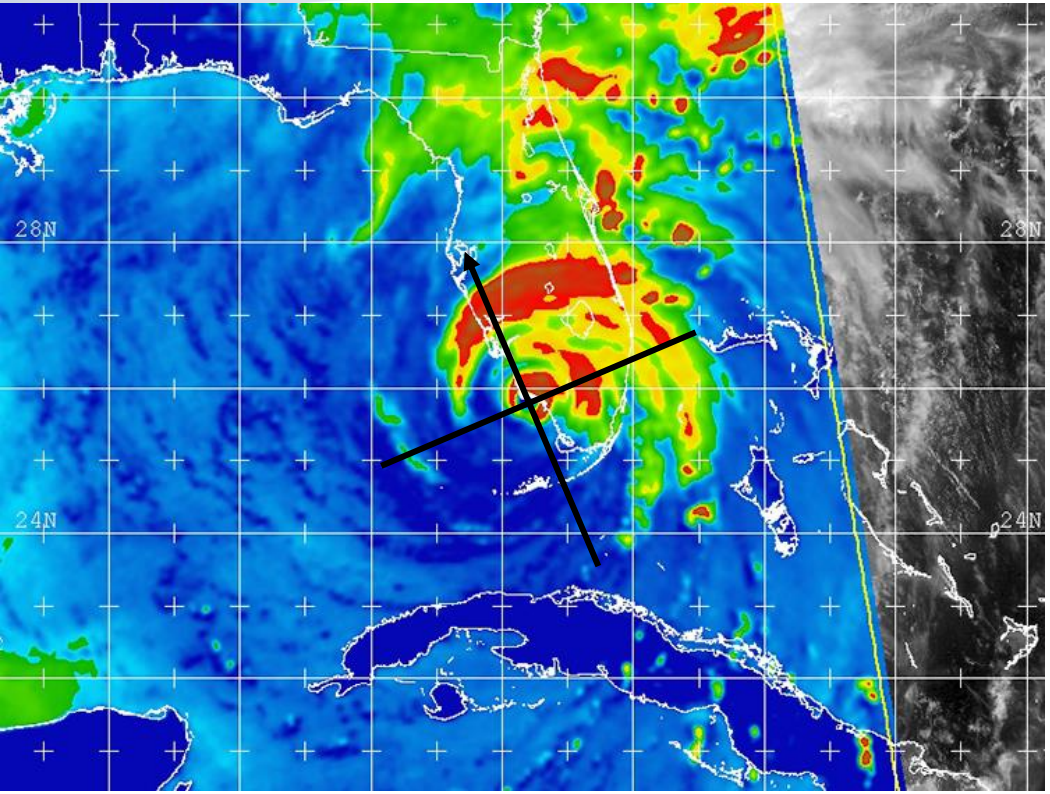


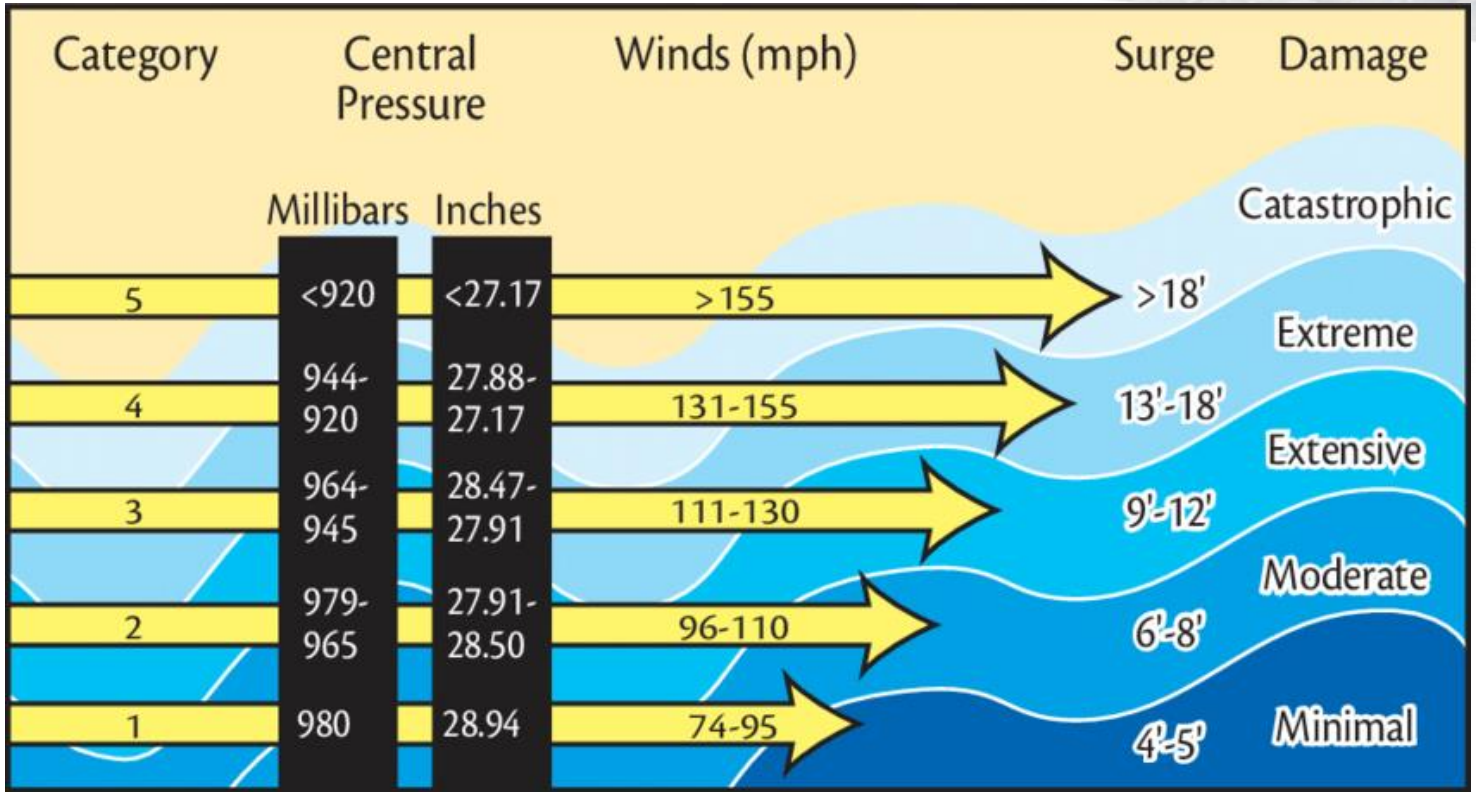
2011: Hurricane Irene

US Army Corps of Engineers.

ERDC

Under the Hood of a Hurricane



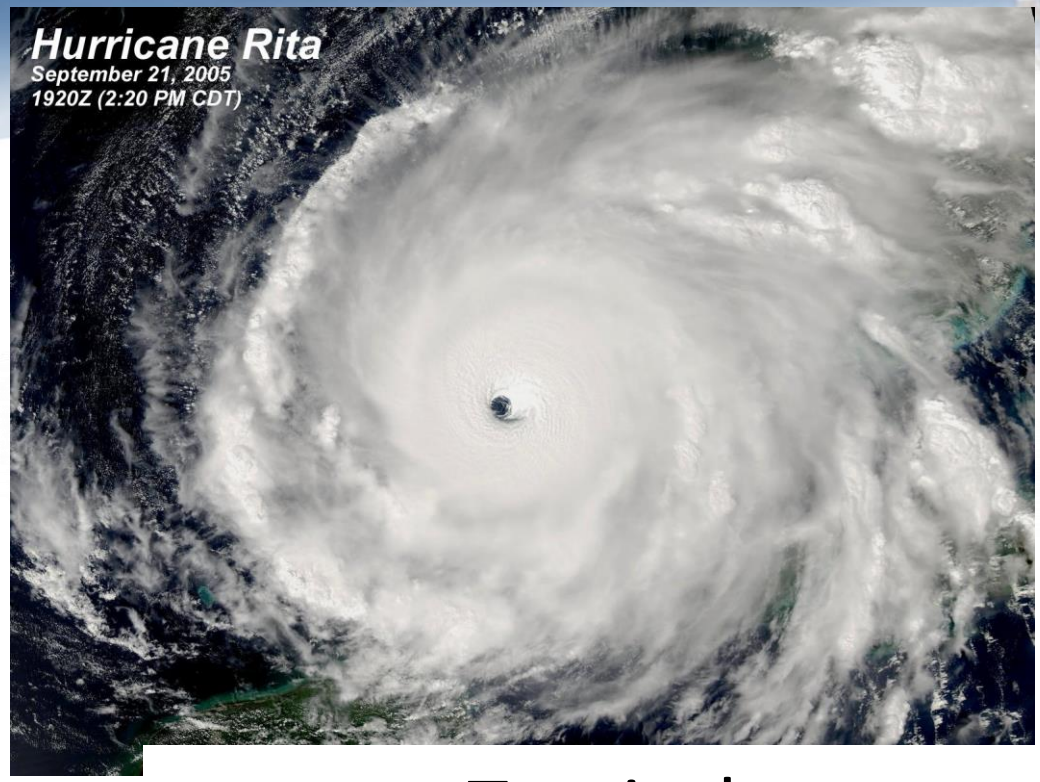


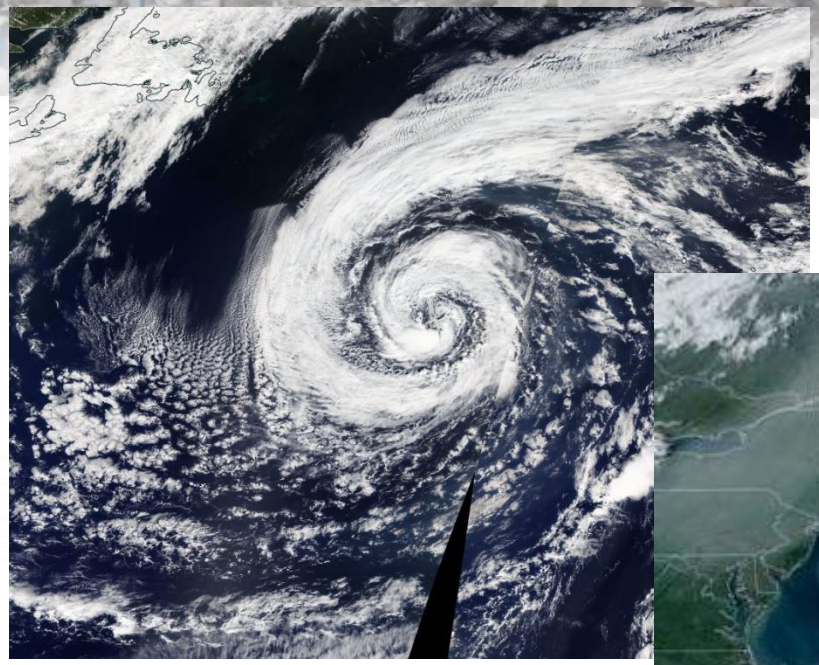
Walker, Nan & Haag, Alaric & Balasubramanian, Shreekanth & Leben, Robert & van Heerden, Ivor & Kemp, Paul & Mashriqui, Hassan. (2006). Hurricane Prediction: A Century of Advances. Oceanography. 19. 24-36. 10.5670/oceanog.2006.60.

US Army Corps of Engineers.

ERDC

Tropical vs Post-Tropical Storm Shape





Tropical

Usually Symmetrically Shaped

Warm-core, No fronts

Inflow bands tend to be from the south

Rainfall tends to be concentrated in bands around the center

Post-Tropical / Extratropical

Usually “Comma Shaped”

Cold-core, has fronts

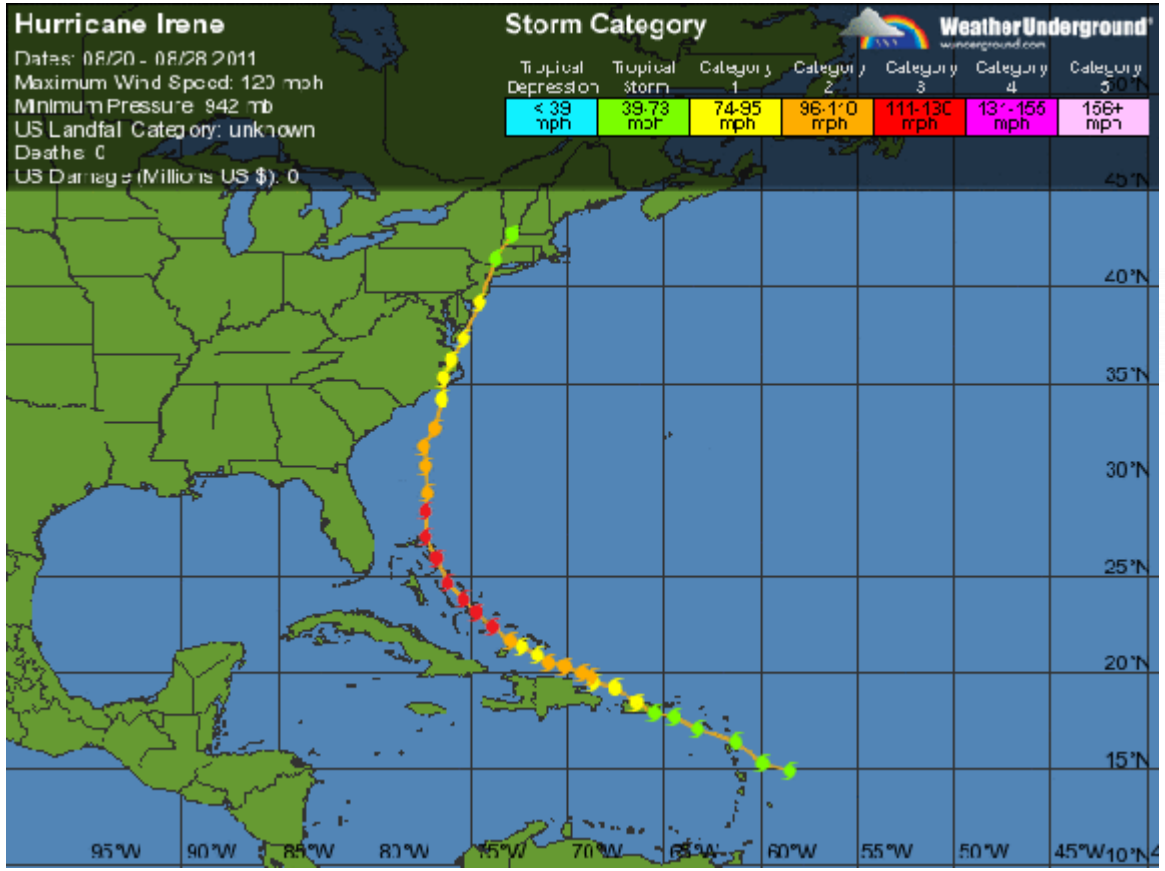
Inflow and outflow bands tend to be from the north

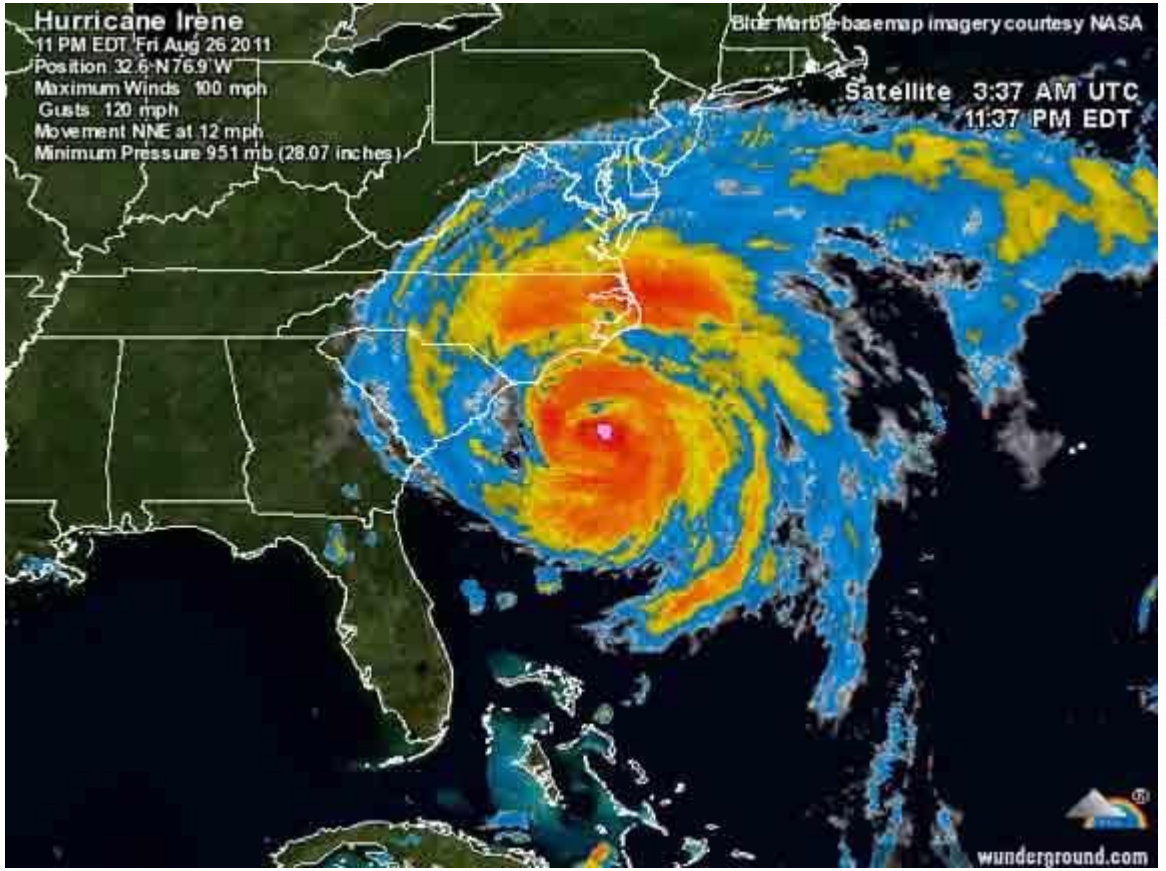
Rainfall tends to be spread out across 100’s of miles

US Army of Engine

ERDC

Hurricane Irene

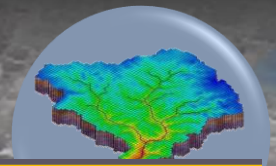




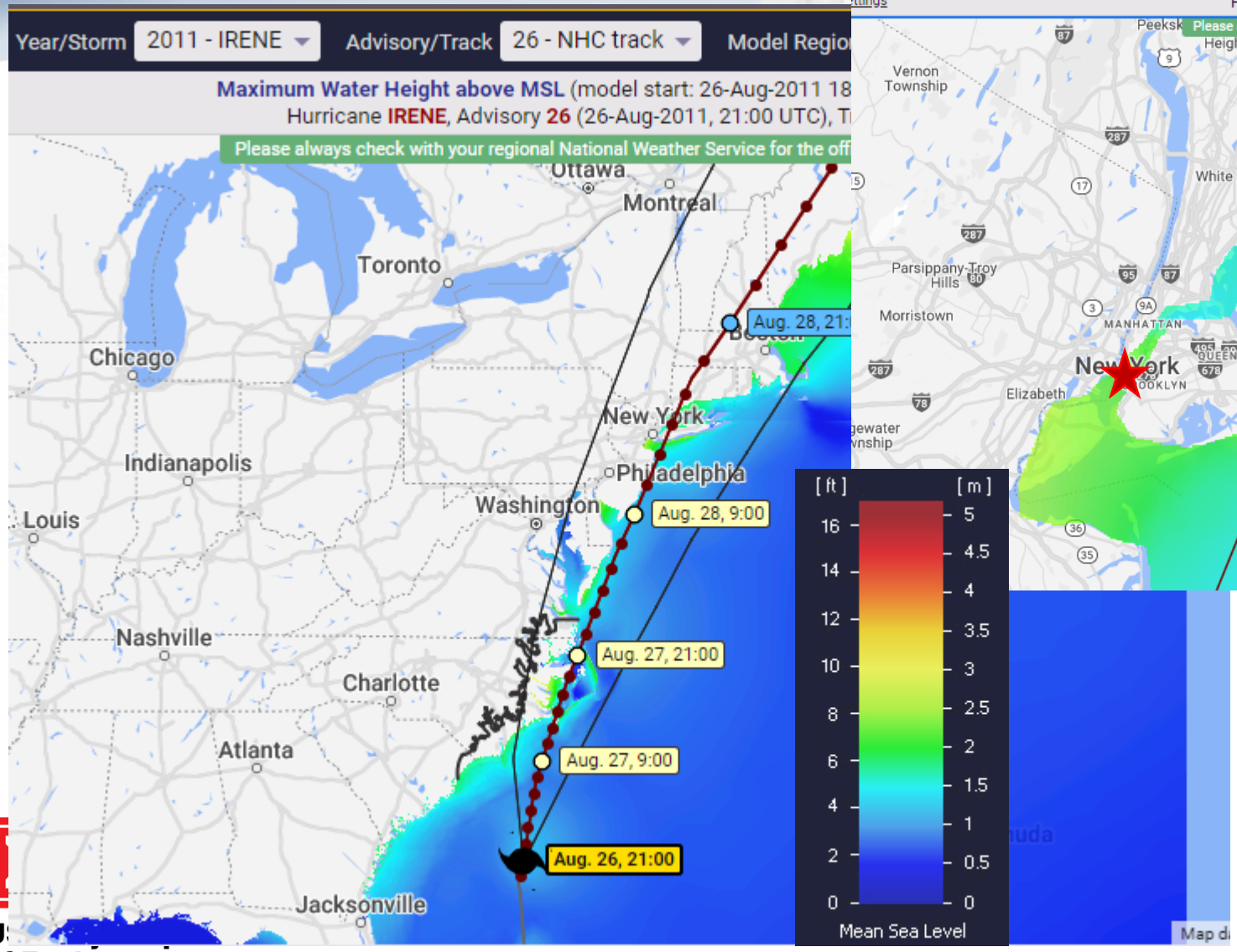
US Army Corps of Engineers.

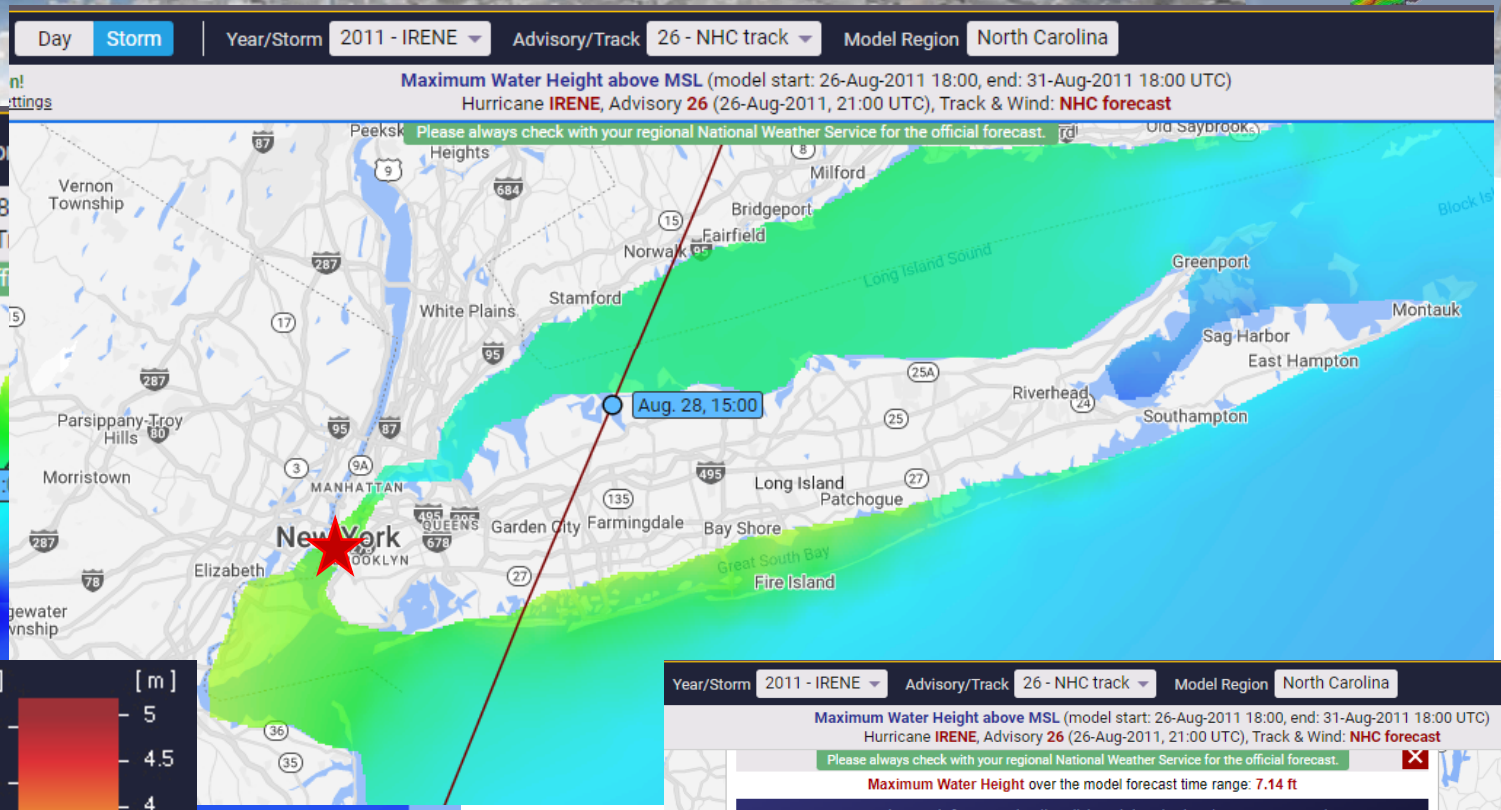
ERDC

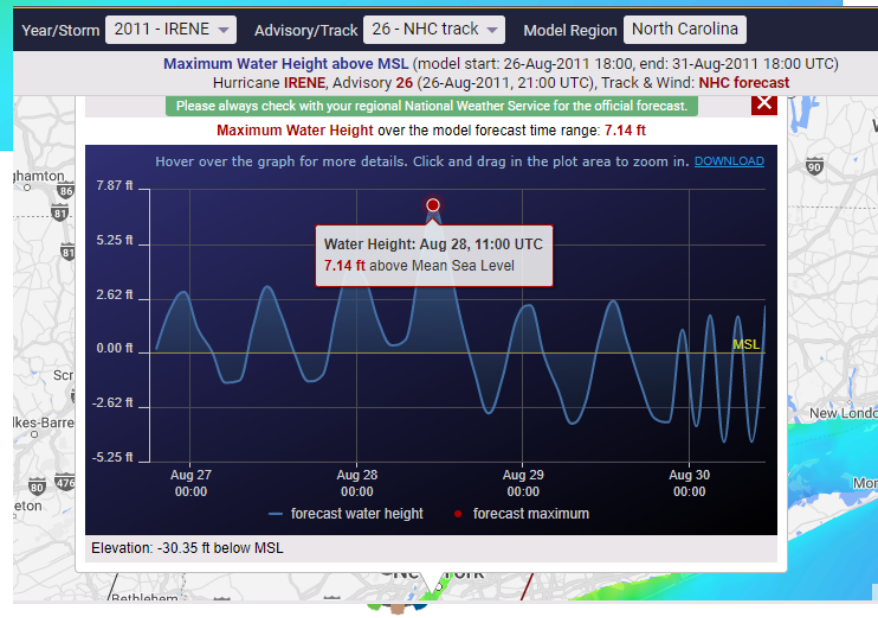
Hurricane Irene Forecast Storm Surge



36 hours before New York







of Engineers.

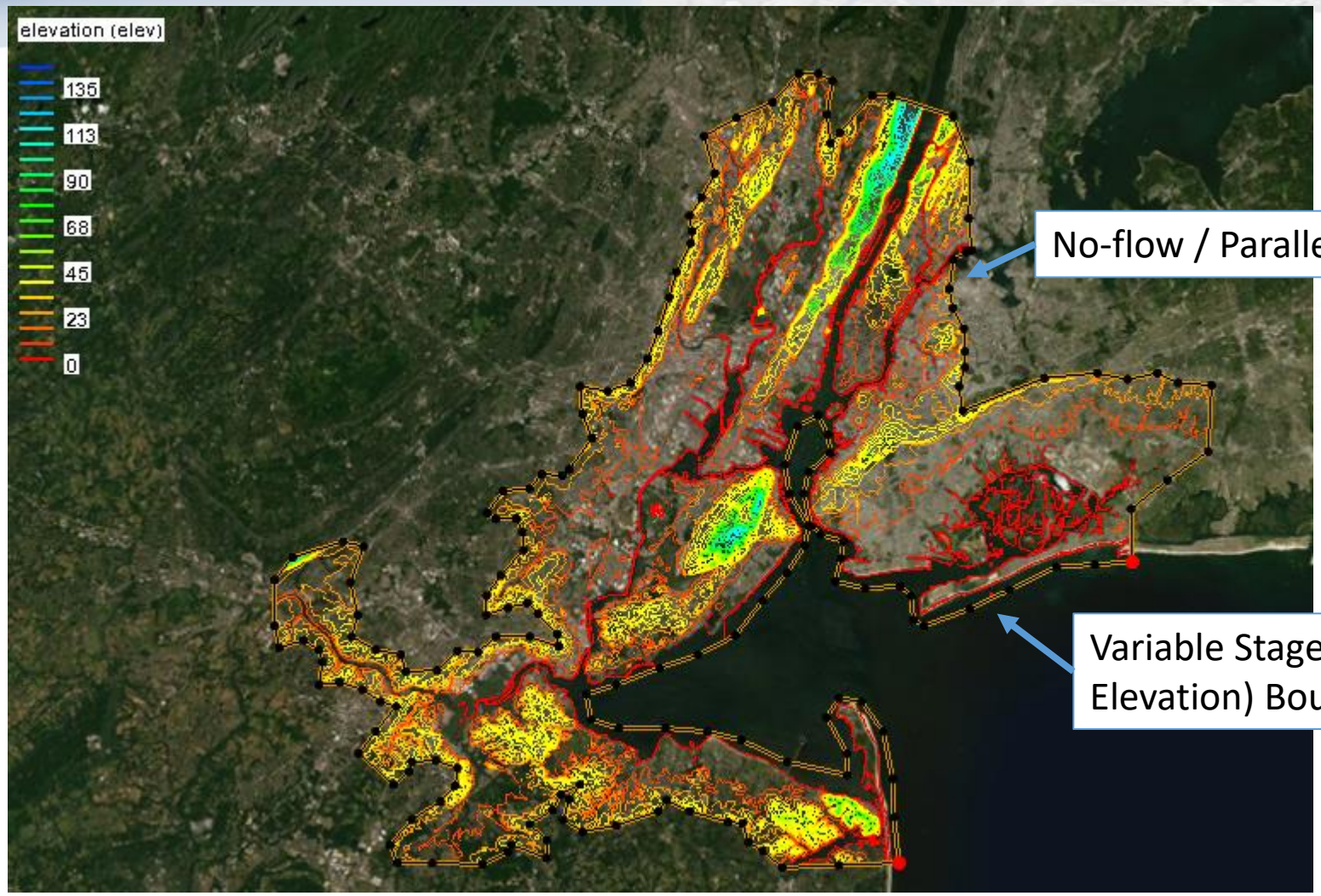
GSSHA New York Models

- GSSHA 2D Overland Flow Model used to predict inland flood inundation
  - Use time-varying specified head condition for storm surge
- 2 Models:
  - Central NY Model @75m (right)
  - Long Island Model @150m
- Rainfall estimated from NWS plots
- Storm surge from ADCIRC

US Army Corps of Engineers.

ERDC

Hurricane Irene: Model Design



- 75m cell size chosen to be as fine as possible while running in under 3 hours.
- Uniform Manning's n of 0.3 used (urban-ish)

US Army Corps of Engineers.

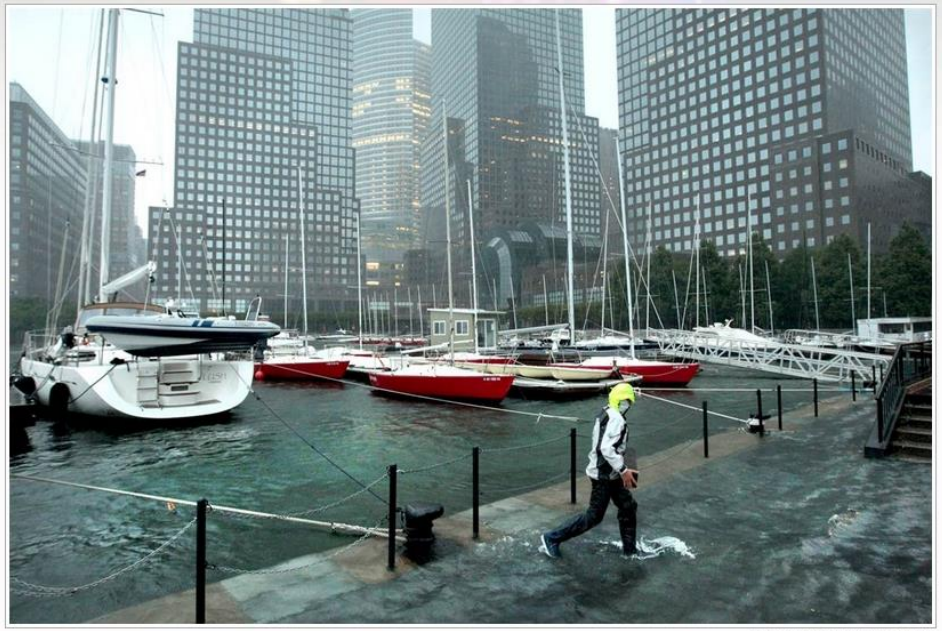
ERDC

Restaurant Felix @ Grand and West Broadway

US Army Corps of Engineers.

ERDC

North Cove Marina



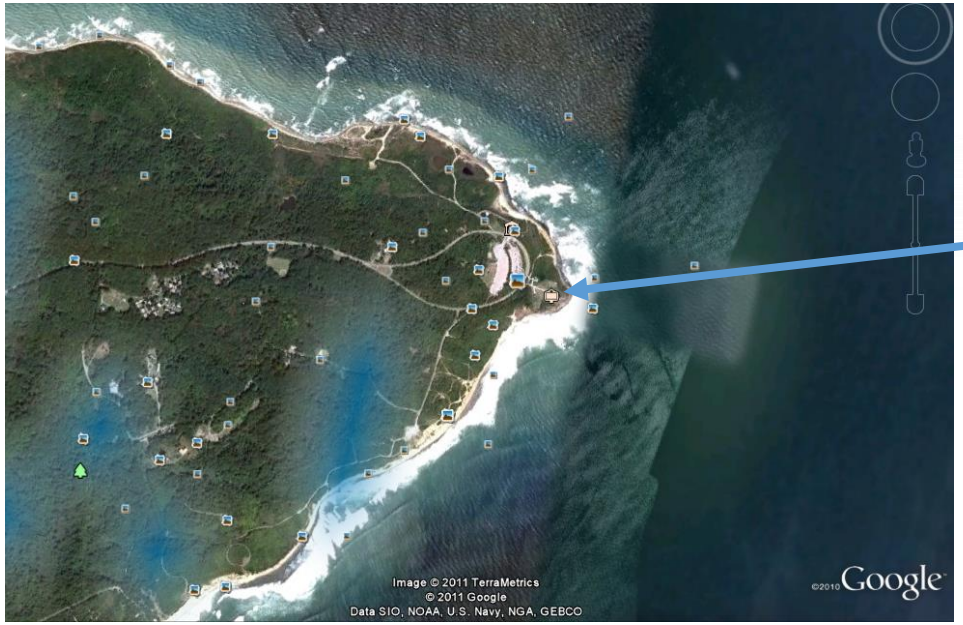
Hurricane Irene's wind and rain pour down as North Cove Marina employees work to secure gangways, docks and boats as seawater comes over the marina's low walls just before high tide in the World Financial Center Plaza on Aug. 28 in New York City.

Chip Somodevilla / Getty Images

US Army Corps of Engineers.

ERDC

Montauk Point Lighthouse



A lighthouse-shaped building is battered by storm surge and winds from Hurricane Irene in Montauk, New York on Aug. 28.

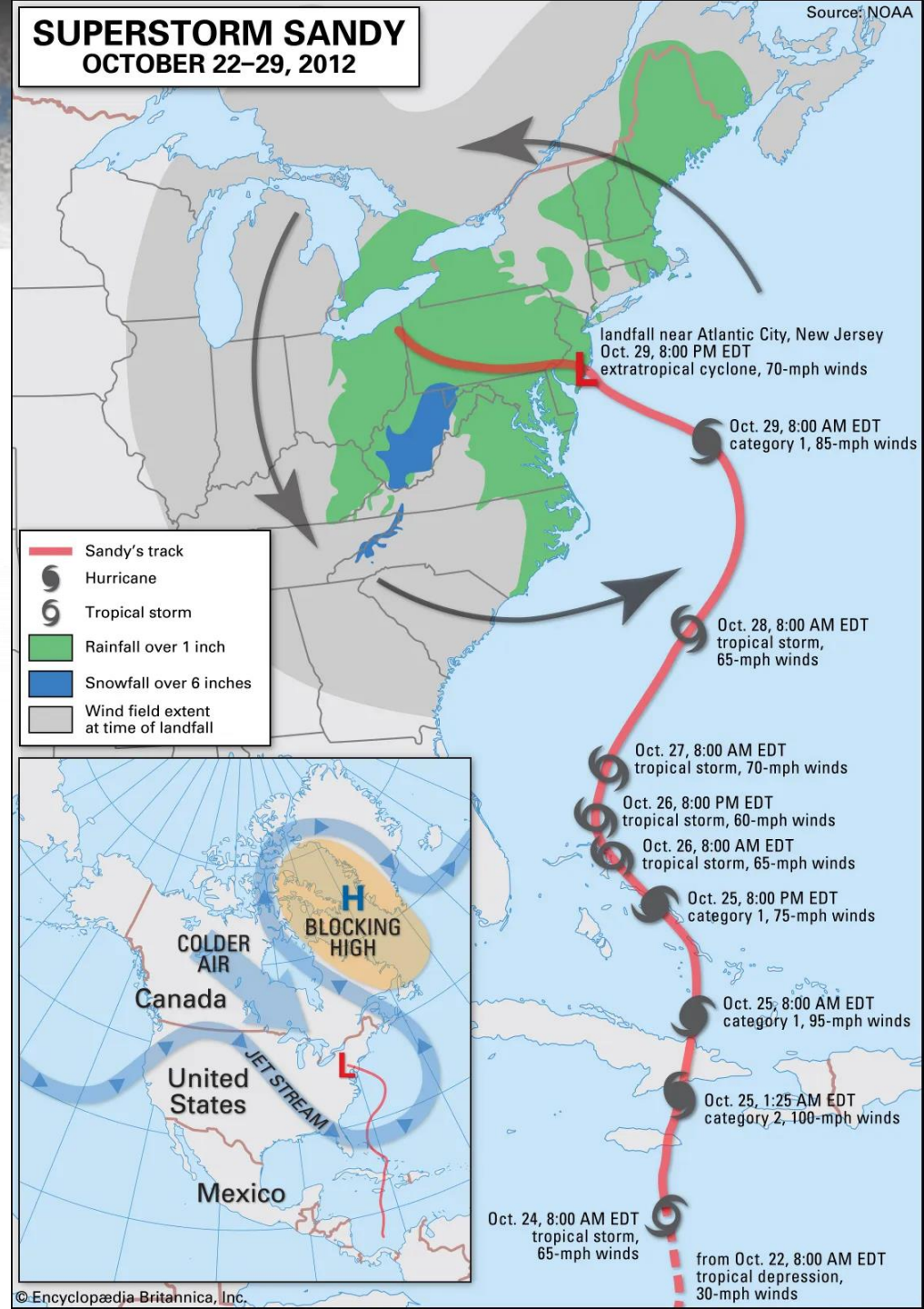
Lucas Jackson / Reuters

US Army Corps of Engineers.

ERDC

Superstorm Sandy

Superstorm Sandy

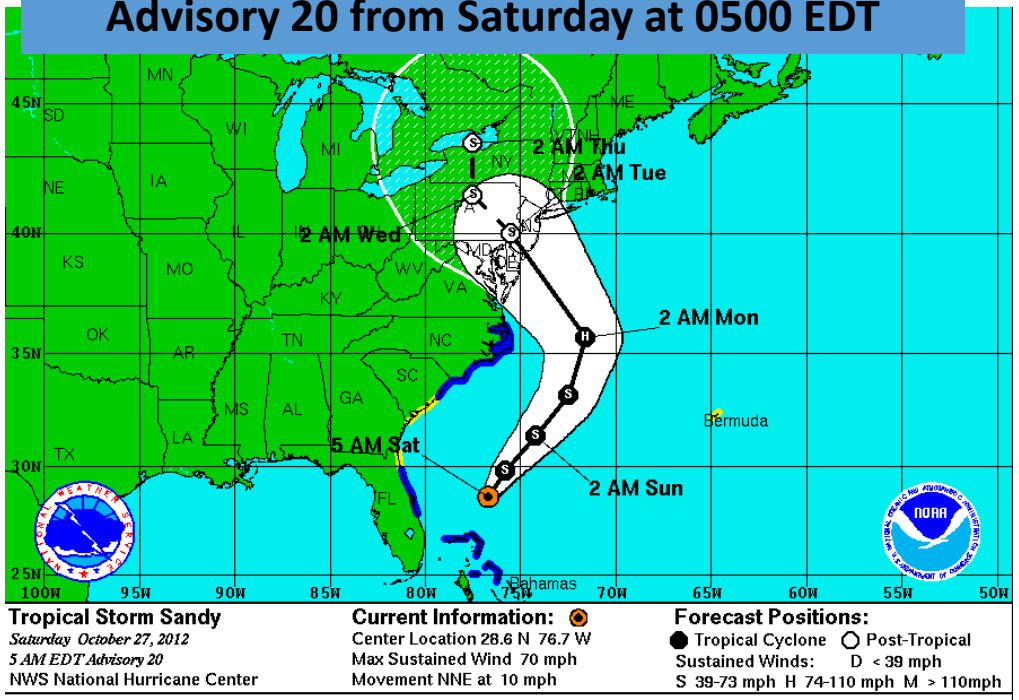


US Army Corps
of Engineers.

CHL's Modeling Efforts

- On Saturday Oct. 27, 2012, ERDC CHL was asked by the New York District (NAN) through the UROC to provide estimates to potential flooding in the New York City area before 1200 EDT on Monday October, 29, 2012.
- Provide potential coastal storm surge estimates using the hydrodynamic model **ADCIRC**
- Provide potential inland flooding estimates using the overland flow model **GSSHA**

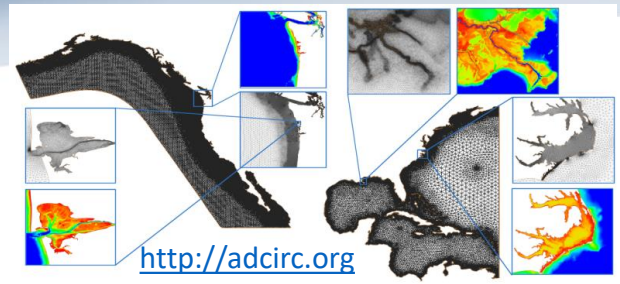
Advisory 20 from Saturday at 0500 EDT



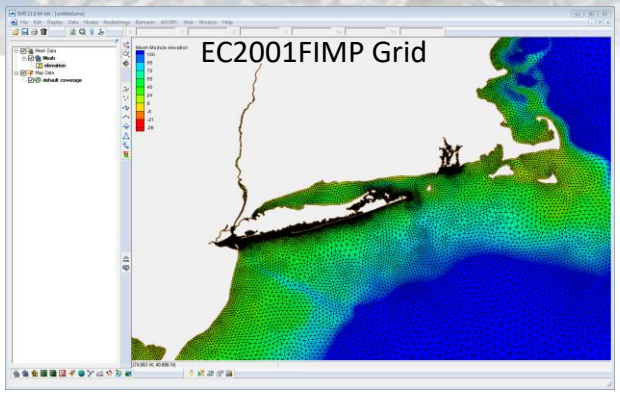
US Army Corps of Engineers.

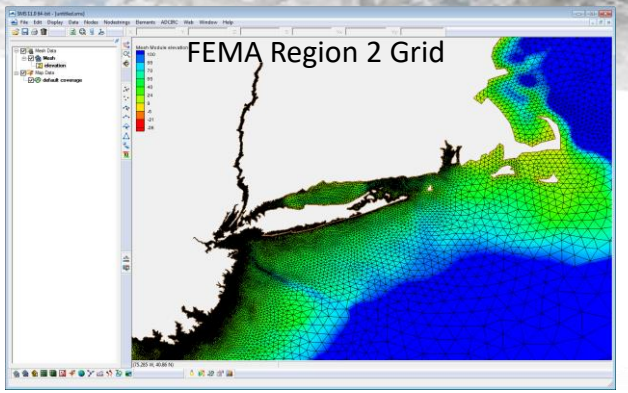
ERDC

ADCIRC Coastal Circulation and Storm Surge Model



- An unstructured finite element hydrodynamics model
- 2D and 3D simulations
- Wetting/Drying algorithm allows for storm surge inundation over previously dry land
- Highly portable code
- A part of ERDC's Coastal Storm Modeling System





Surge Modeling for Sandy

- Used two meshes
  - EC2001FIMP Grid
  - FEMA Region 2 Grid
- Used tidal forcing and the imbedded asymmetric vortex Holland wind/pressure model
- Wind model inputs derived from the NHC forecast using the ASGS in collaboration with Dr. Jason Fleming and Dr. Rick Luettich
- Advisories 22 – 31 were simulated
- Advisory 26 results sent to NAN.

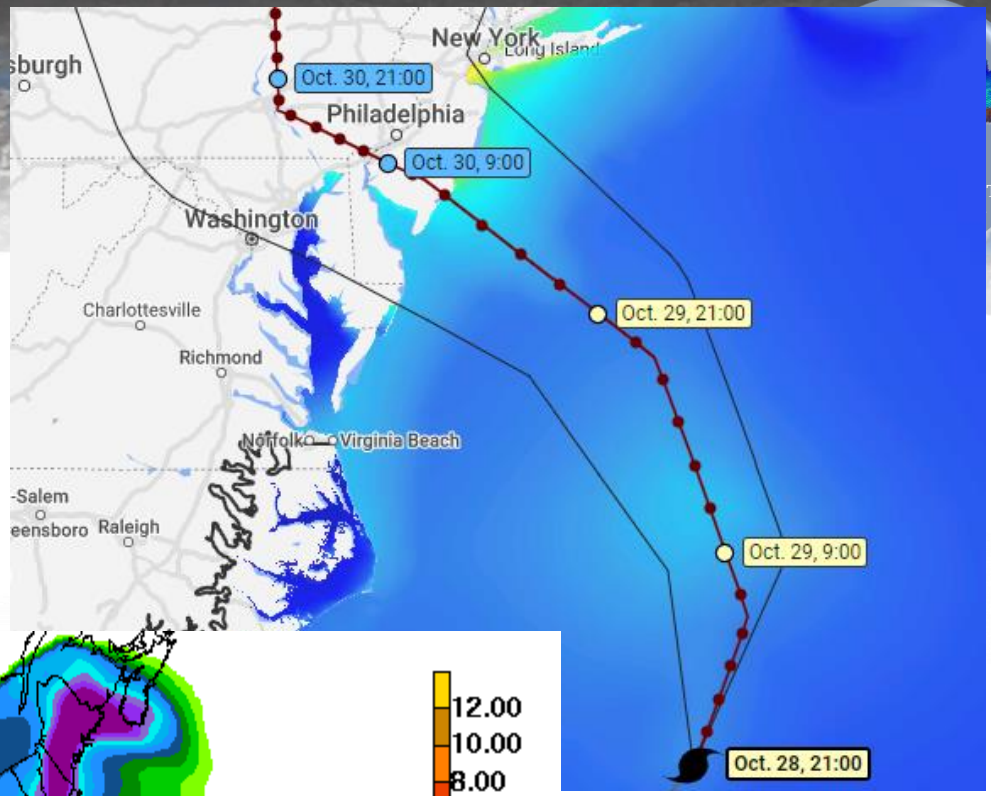
US Army Corps of Engineers.

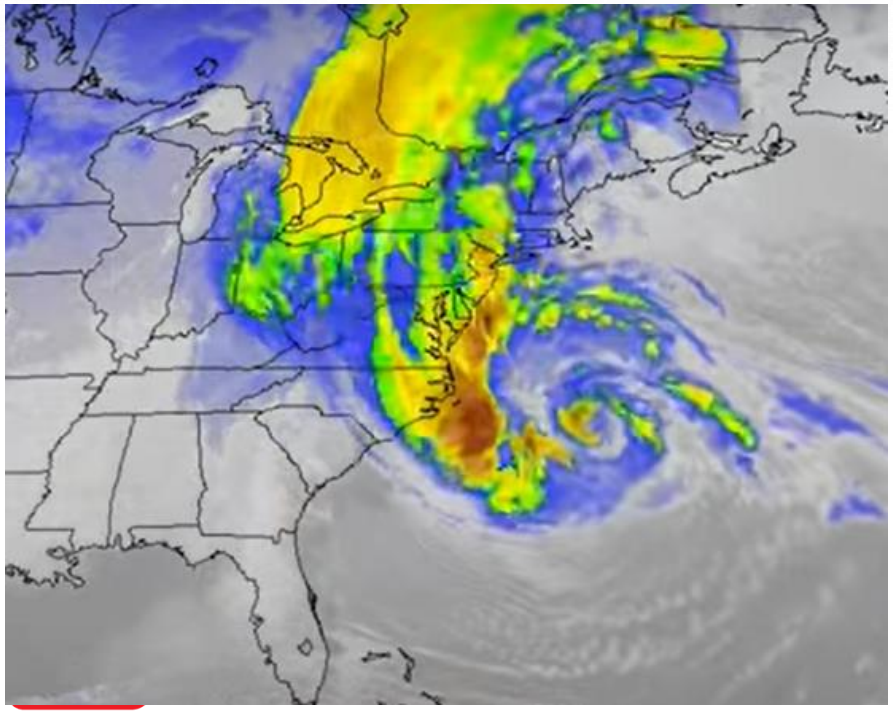
CSTORM-MS COASTAL STORM MODELING SYSTEM

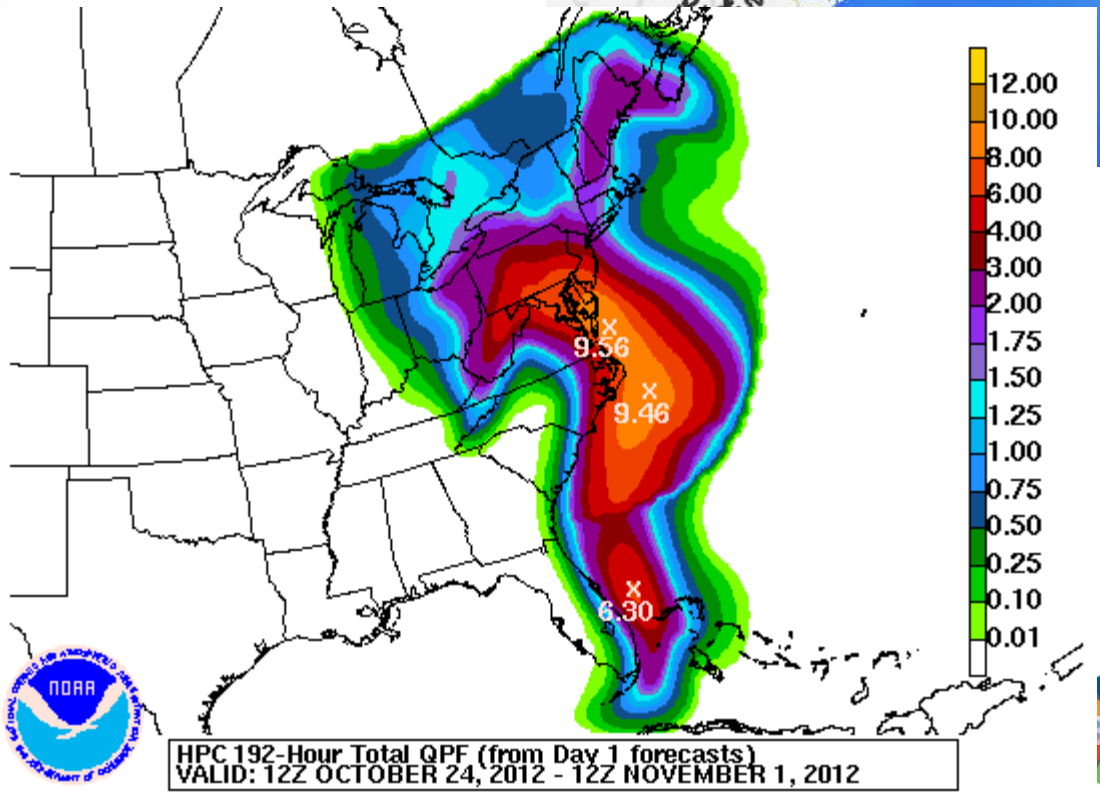
ERDC

NHC Sandy Advisory 26

IN ADDITION...**HURRICANE-FORCE WINDS ARE EXPECTED** ALONG PORTIONS OF THE COAST BETWEEN CHINCOTEAGUE VIRGINIA AND CHATHAM MASSACHUSETTS. THIS INCLUDES THE TIDAL POTOMAC FROM COBB ISLAND TO SMITH POINT...THE MIDDLE AND UPPER CHESAPEAKE BAY...DELAWARE BAY...AND THE COASTS OF THE NORTHERN DELMARVA PENINSULA...**NEW JERSEY...THE NEW YORK CITY AREA...LONG ISLAND**...CONNECTICUT...AND RHODE ISLAND.



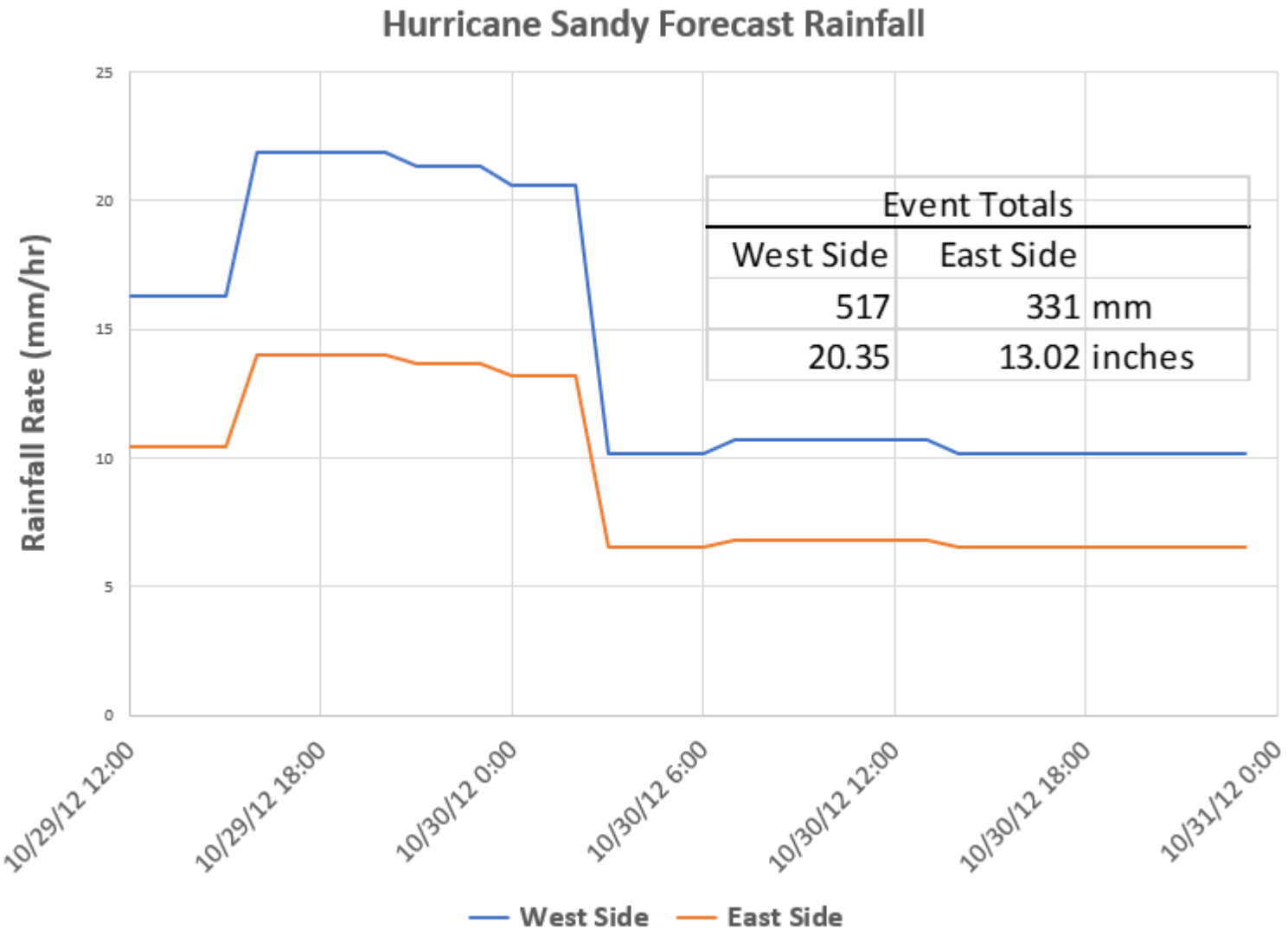




https://www.youtube.com/watch?v=5KVwI5Ltf5w

ERDC

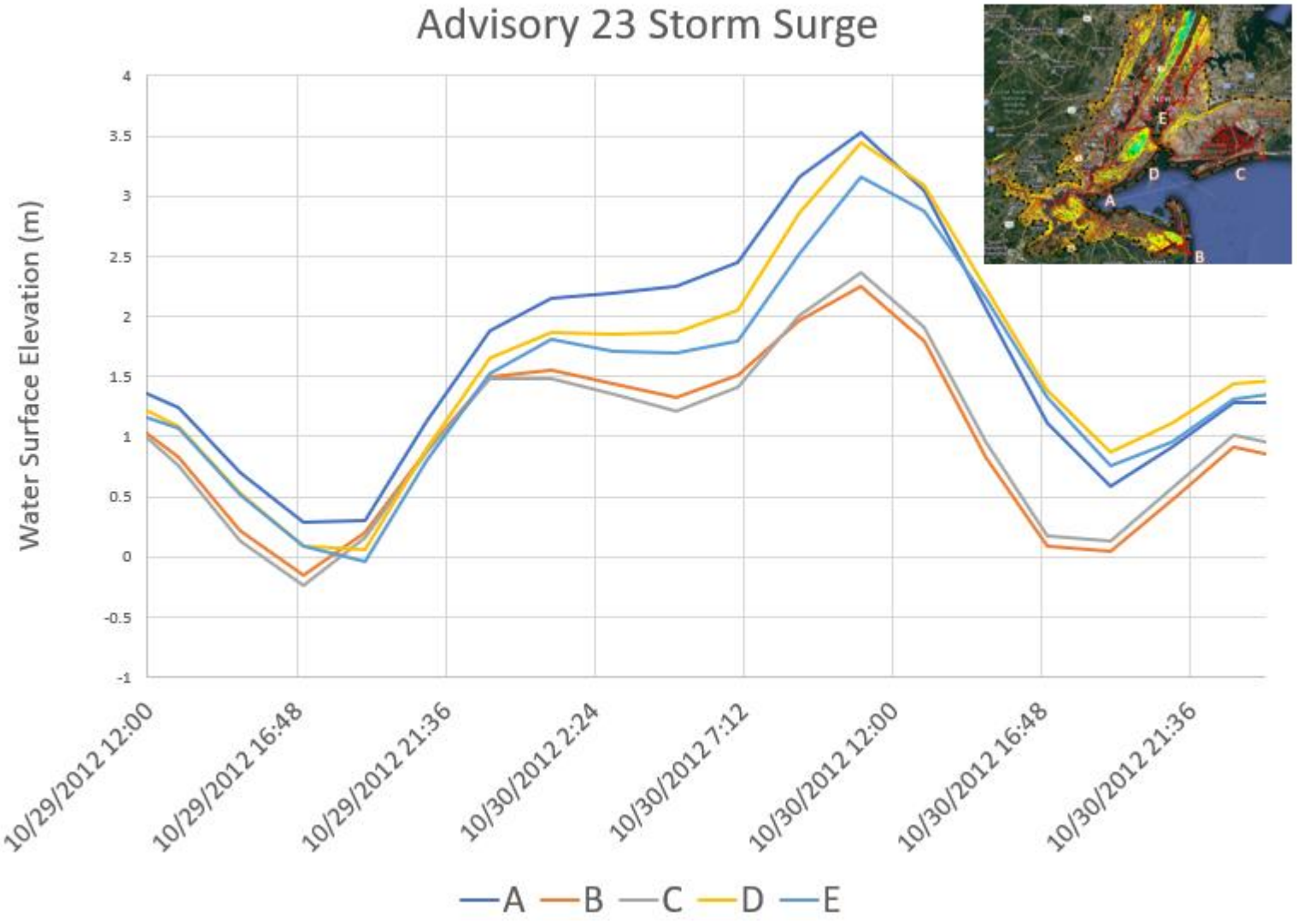
Forecast Rainfall



US Army Corps of Engineers.

ERDC

Storm Surge

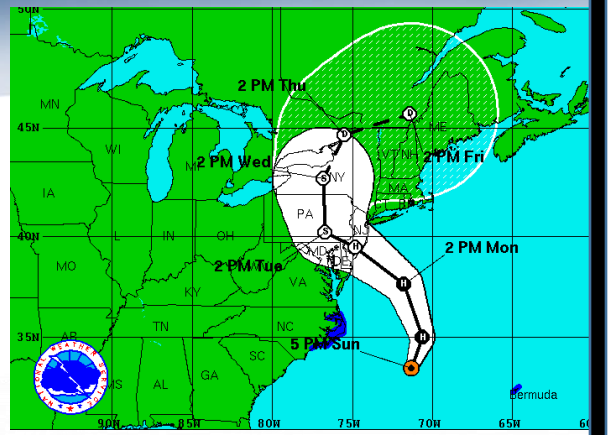


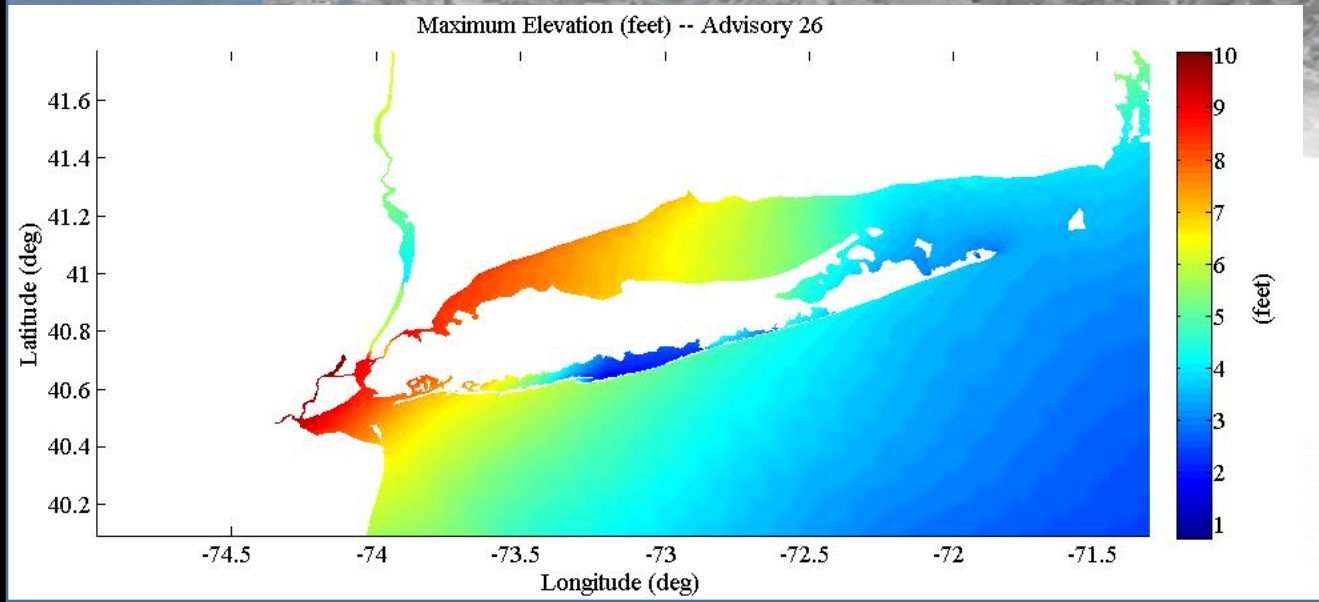
US Army Corps of Engineers.

ERDC

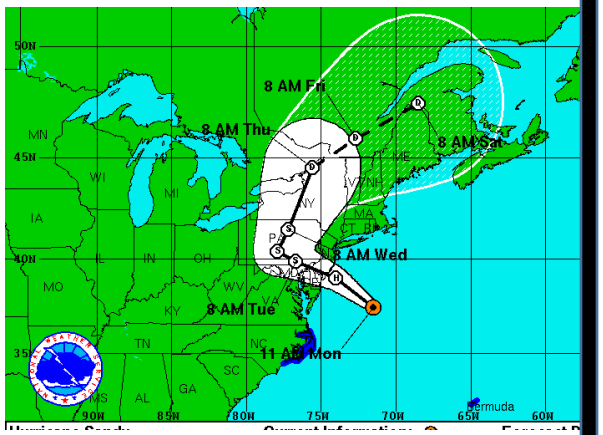
Max Elevation (ft MSL)

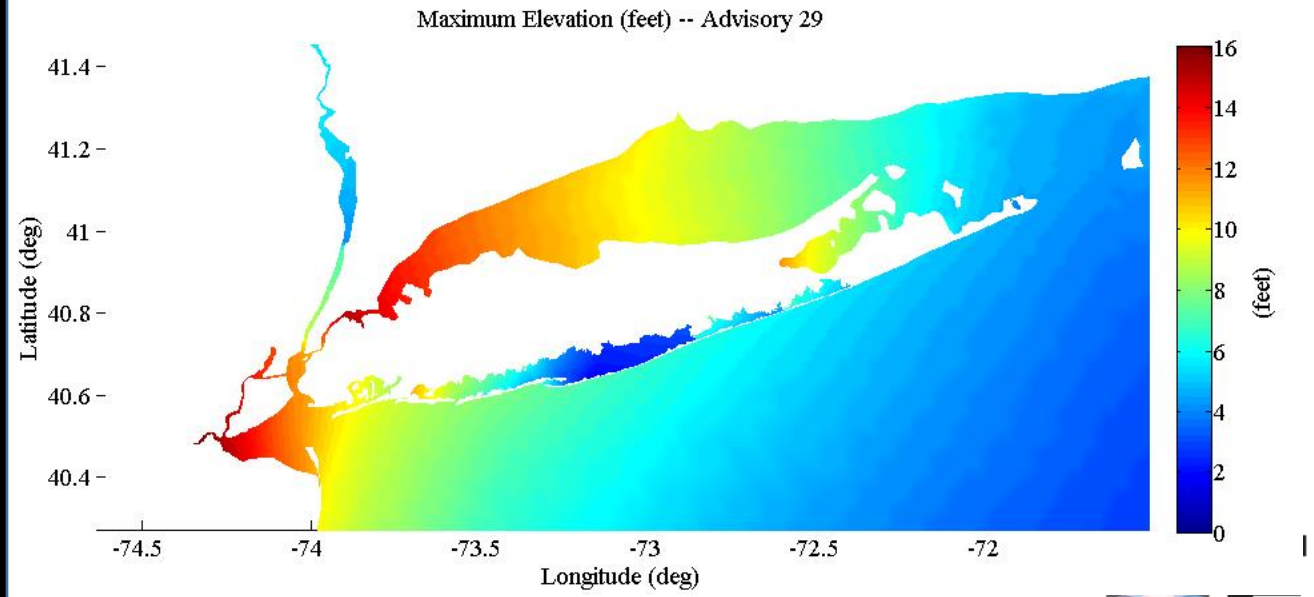
Advisory 26





Advisory 29





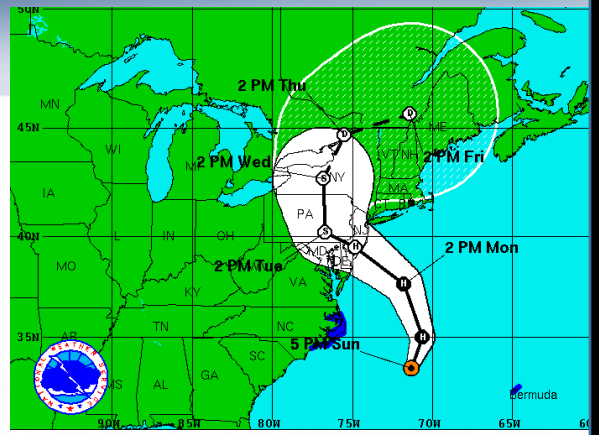
US Army Corps of Engineers.

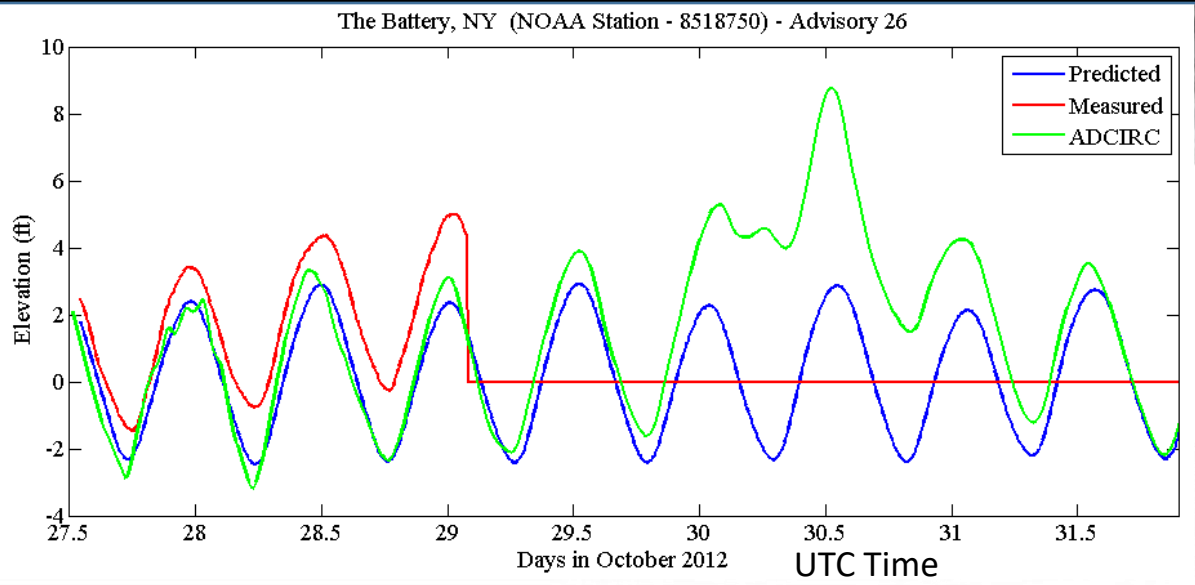
EC2001FIMP Grid

ERDC

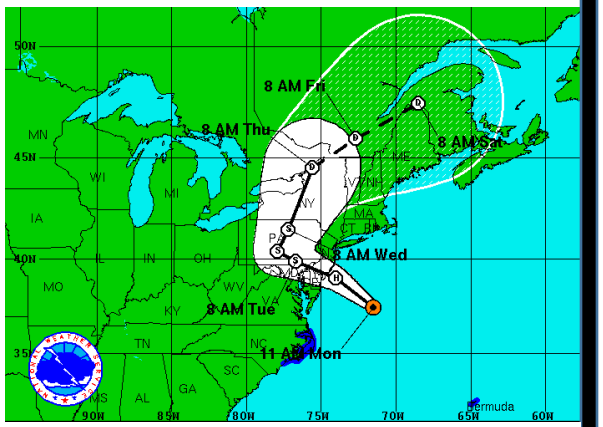
The Battery, NY Elevation (ft MSL)

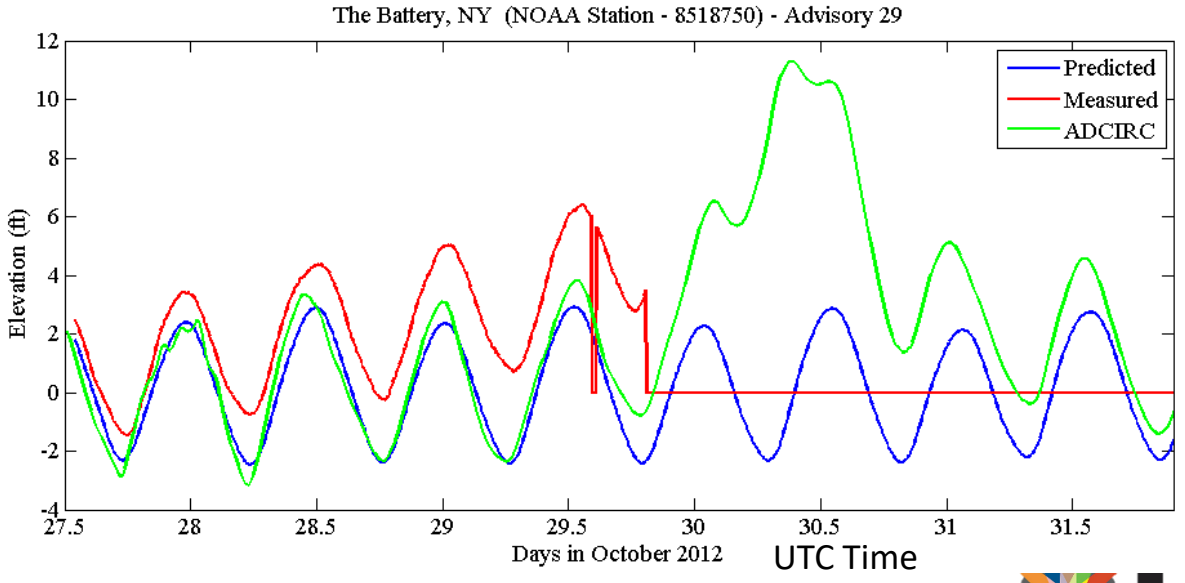
Advisory 26





Advisory 29





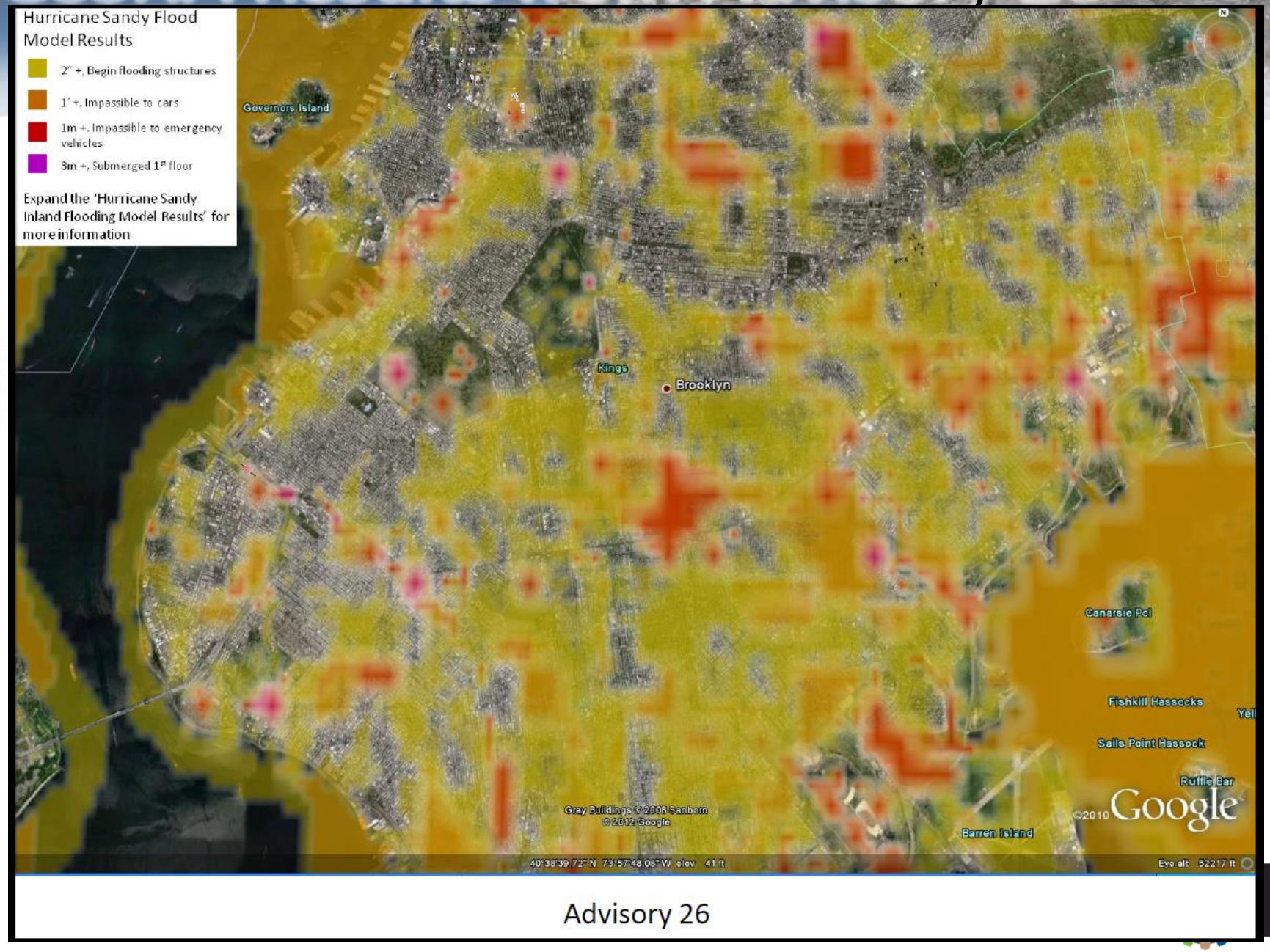
Datum Conversions at this Location
MSL to NAVD88 subtract 0.21 ft
MSL to MLLW add 2.57 ft

EC2001FIMP Grid

US Army Corps of Engineers.

ERDC

GSSHA Results from Advisory 26

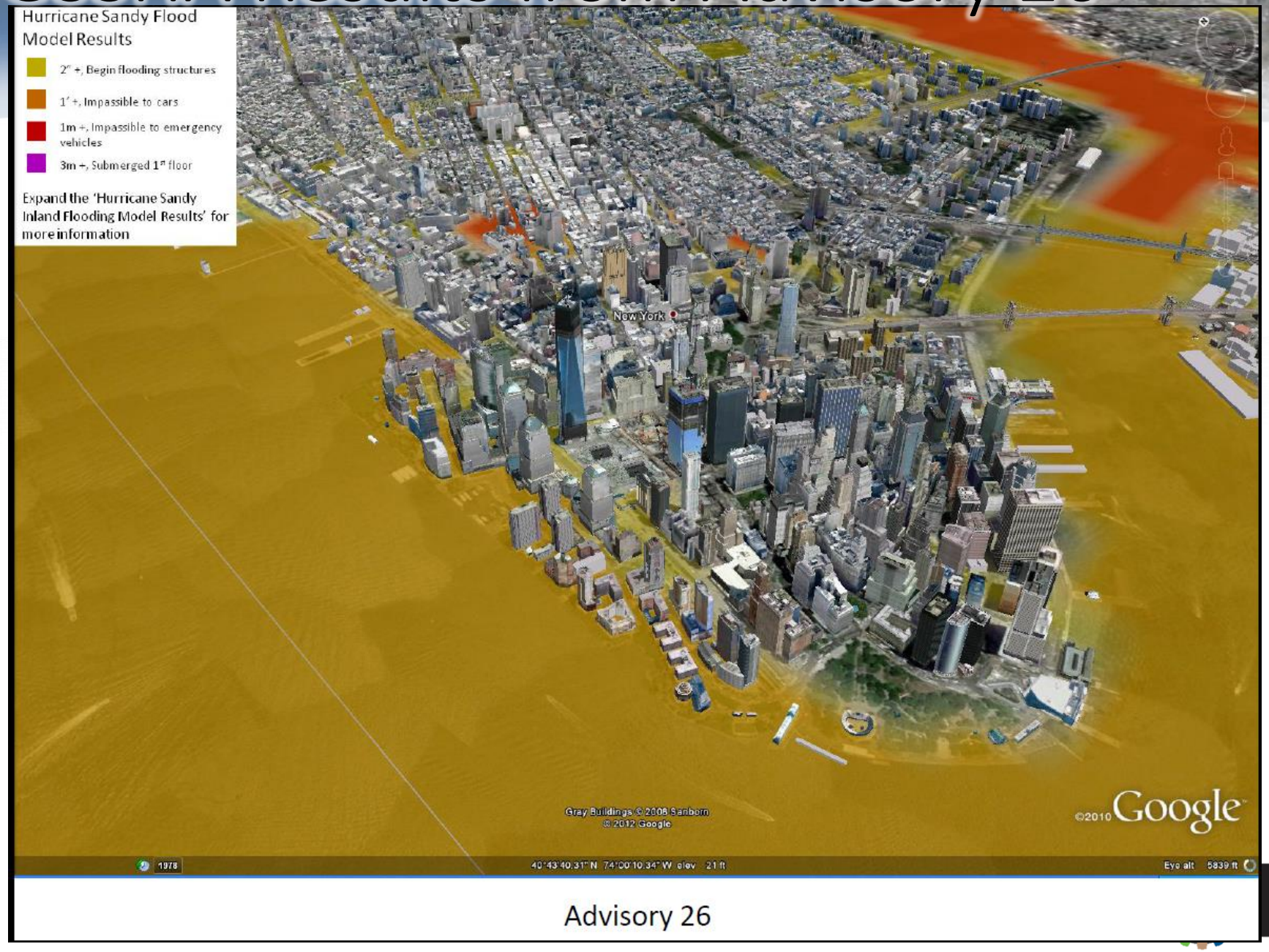


Advisory 26

US Army Corps of Engineers.

ERDC

GSSHA Results from Advisory 26



Advisory 26

US Army Corps of Engineers.

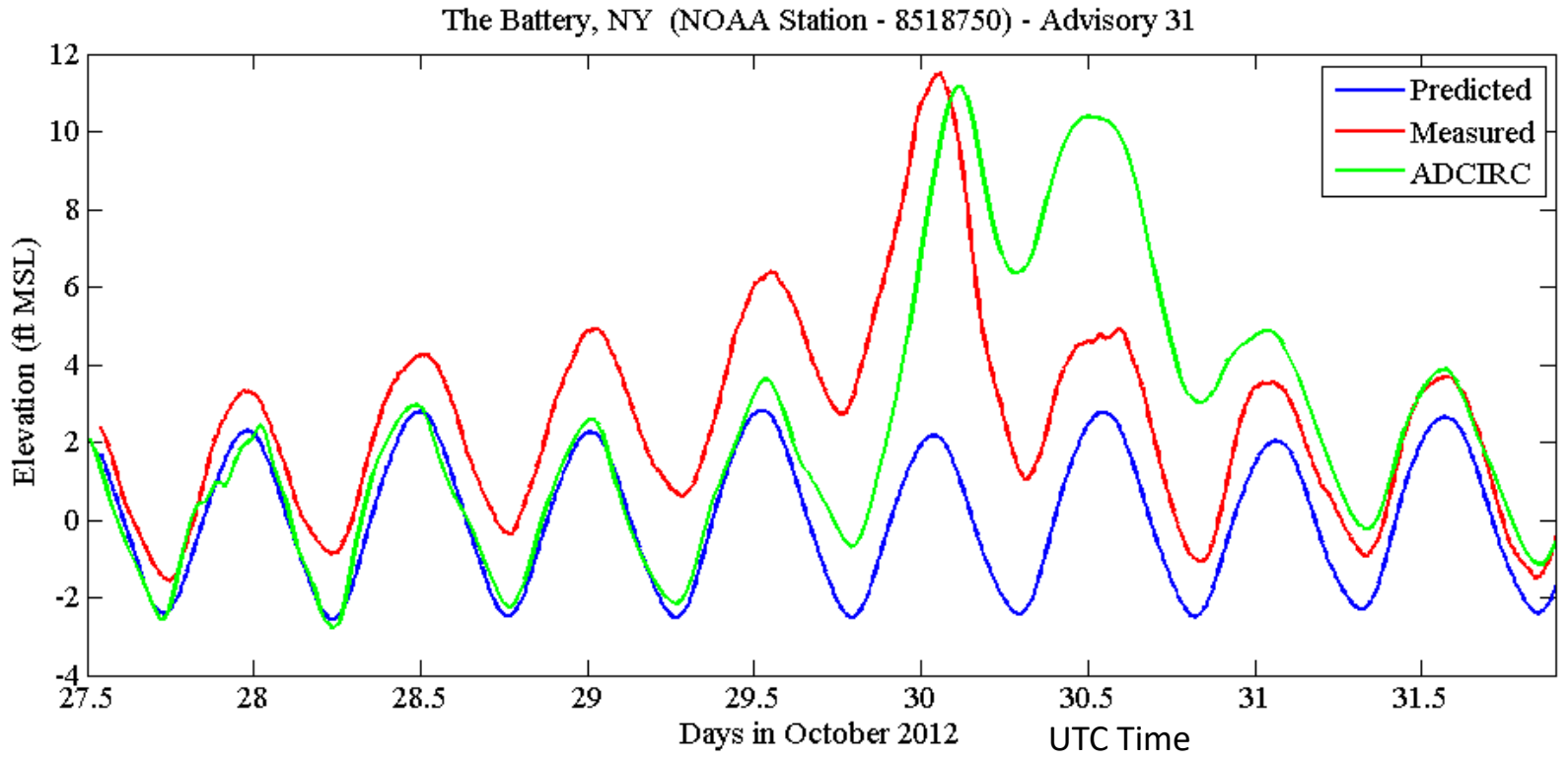
ERDC

GSSHA Sandy Results

US Army Corps of Engineers.

ERDC

Comparison of Hurricane Sandy Water Elevations (ft MSL) at the NOAA Gauge at the Battery, NY



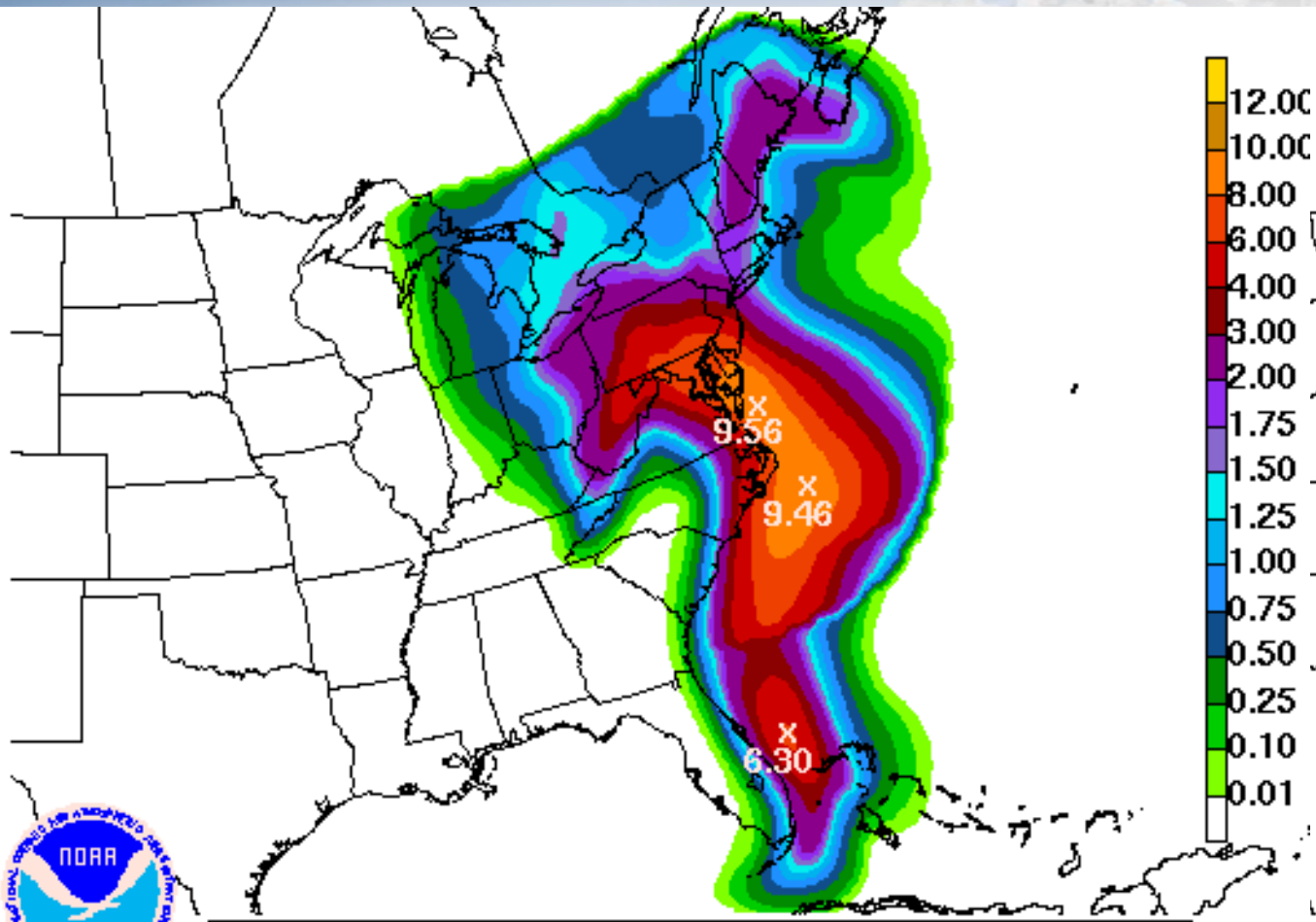
Datum Conversions at this Location
MSL to NAVD88 subtract 0.21 ft
MSL to MLLW add 2.57 ft

US Army Corps of Engineers.

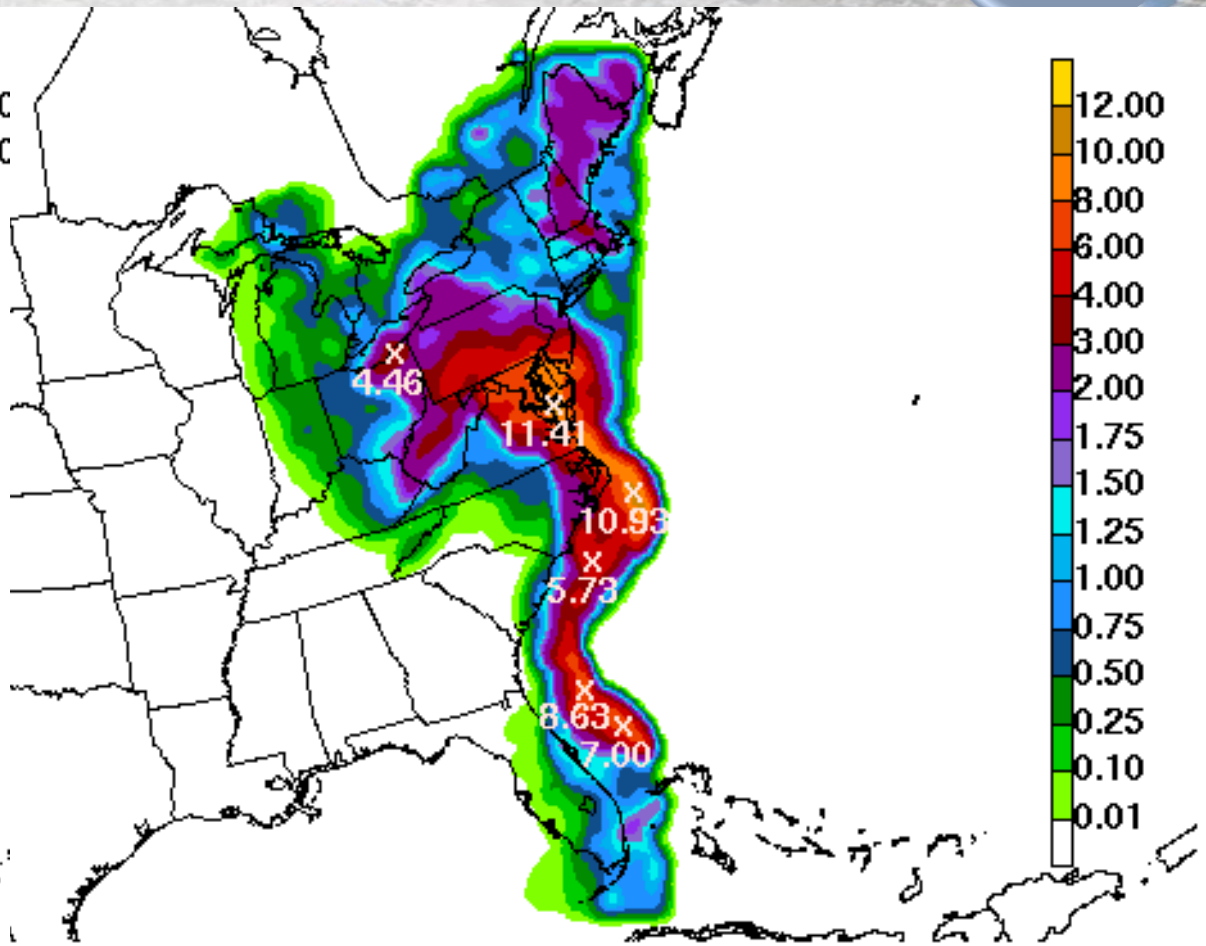
ERDC

Sandy Rainfall

GSSHA™



HPC 192-Hour Total QPF (from Day 1 forecasts)
VALID: 12Z OCTOBER 24, 2012 - 12Z NOVEMBER 1, 2012



STAGEIV 192-Hour Total QPE
VALID: 12Z OCTOBER 24, 2012 - 12Z NOVEMBER 1, 2012

US Army Corps of Engineers.

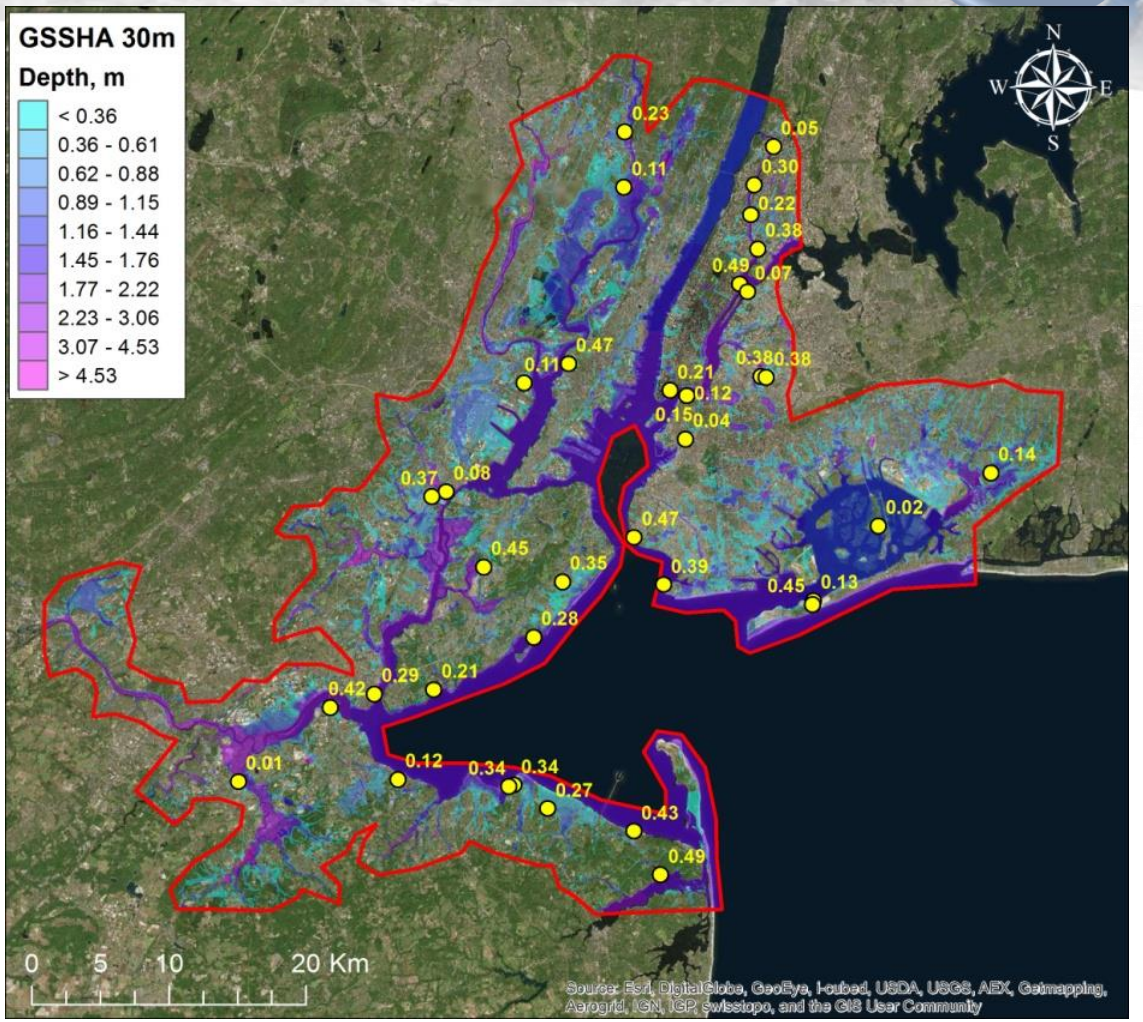
ERDC

GSSHA Post Assessment

Comparison to 180 USGS high water marks

Absolute Error (AE), m	75m	30m	Cumulative Difference
AE ≤ 0.50	42	37	-5
0.50 < AE ≤ 1.00	43	55	7
1.00 < AE ≤ 2.00	81	78	4
AE > 2.00	14	10	8

Statistic	Grid Resolution	
	75m	30m
Mean Absolute Error, m	1.20	1.11
RMSE, m	1.83	1.56



Examined grid resolution, grid rotation, adding bathymetry, cell flow obstructions, and variable depth manning's roughness.

US Army Corps of Engineers.

ERDC

Where to Get Data

US Army Corps of Engineers.

ERDC

Historical Hurricane Data

Historical Descriptions and Data

Home | Mobile Site | Text Version | RSS | Local Forecast | Enter City,St or ZIP code | Go

NATIONAL HURRICANE CENTER and
CENTRAL PACIFIC HURRICANE CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

ANALYSES & FORECASTS | DATA & TOOLS | EDUCATIONAL RESOURCES | ARCHIVES | ABOUT | SEARCH

NHC Data Archive

Data Archive | Publications

Contents

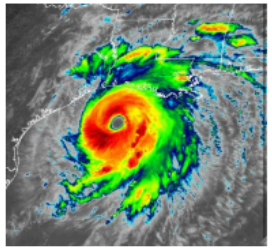
- Tropical Cyclone Reports
- Tropical Cyclone Advisories
- Graphical Tropical Weather Outlook (GTWO)
- Marine & Advisory Text Products
- Marine Graphical Products
- Best Track Data (HURDAT2)
- Past Track Seasonal Maps
- Past Track Maps of Major U.S. Landfalls
- Tropical Cyclone GIS Data
- Storm Wallet Scanning Project
- Tropical Cyclone Monthly Summaries
- Tropical Cyclone Annual Summaries (Atlantic)
- Tropical Cyclone Seasonal Outlooks
- Tropical Cyclone Climatology
- Tropical Cyclone Forecast Verification
- Aircraft Reconnaissance Archive
- Deadliest, Costliest, Most Intense Atlantic Storms
- Central Pacific Hurricane History

https://www.nhc.noaa.gov/data/

Historical Descriptions and Data

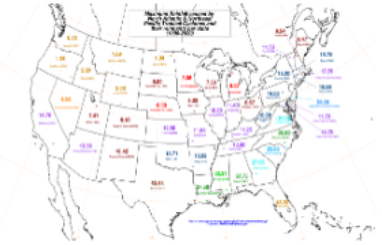
Tropical Cyclone Rainfall

This set of pages remains in flux, with new information added from time to time.
Data is available for impactful tropical and subtropical cyclones that impacted the U.S. from 1900 onward to the present, and Mexico between 1982 and 2003.



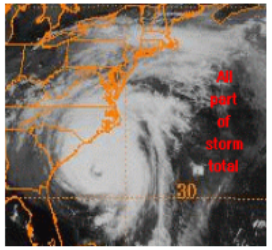
Storms Available

By Name
By Year
By Region Of Impact
By Point Of Entry
Point Maxima in reverse chronological order
Pre-1956 U.S. T.C. Rainfall Publication
Rainfall analogs to current storms



Derived Information

Maxima Per U. S. State
Maxima Per U. S. County
(autodownloading related .csv file)
Maxima Per Mexican State
T.C. Rainfall Averages & Maxima per Duration



Background Information

Methodology for climatology
Acknowledgments
Milestones
T.C. Rainfall Forecasting
T.C. Rainfall Powerpoint Slideshow

https://www.wpc.ncep.noaa.gov/tropical/rain/tcrainfall.html

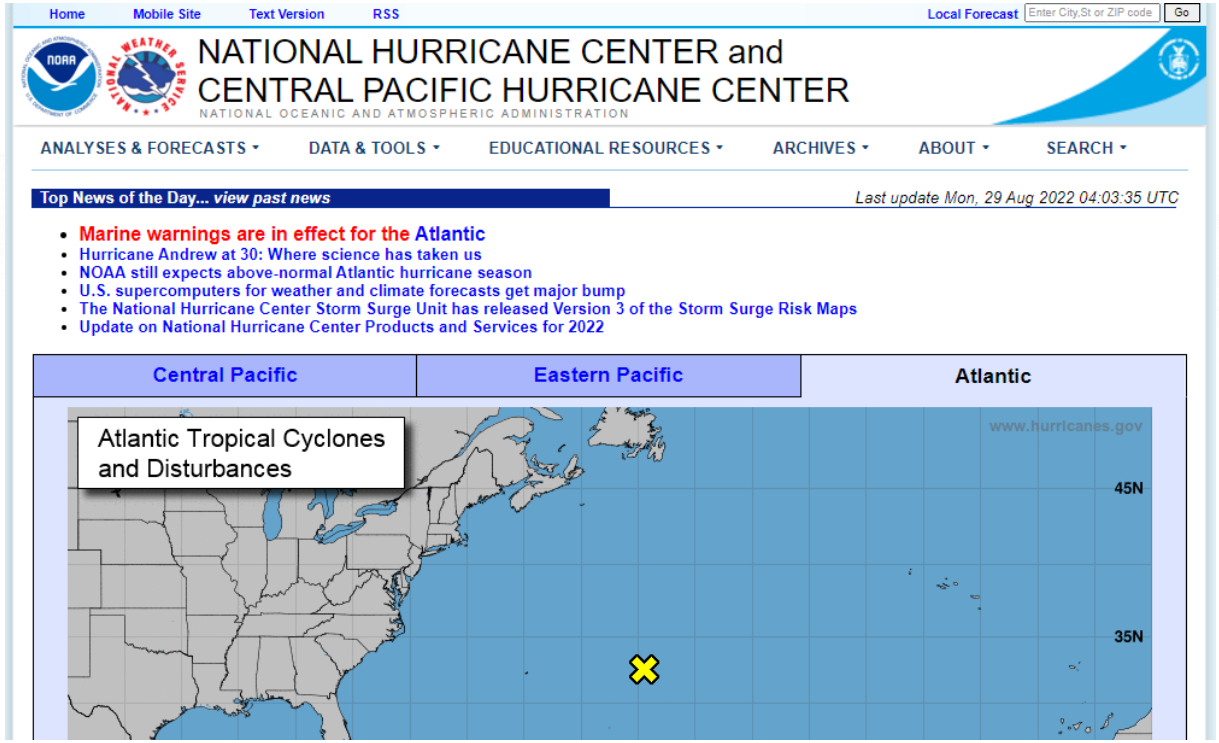
US Army Corps of Engineers.

ERDC

Current Hurricane Data

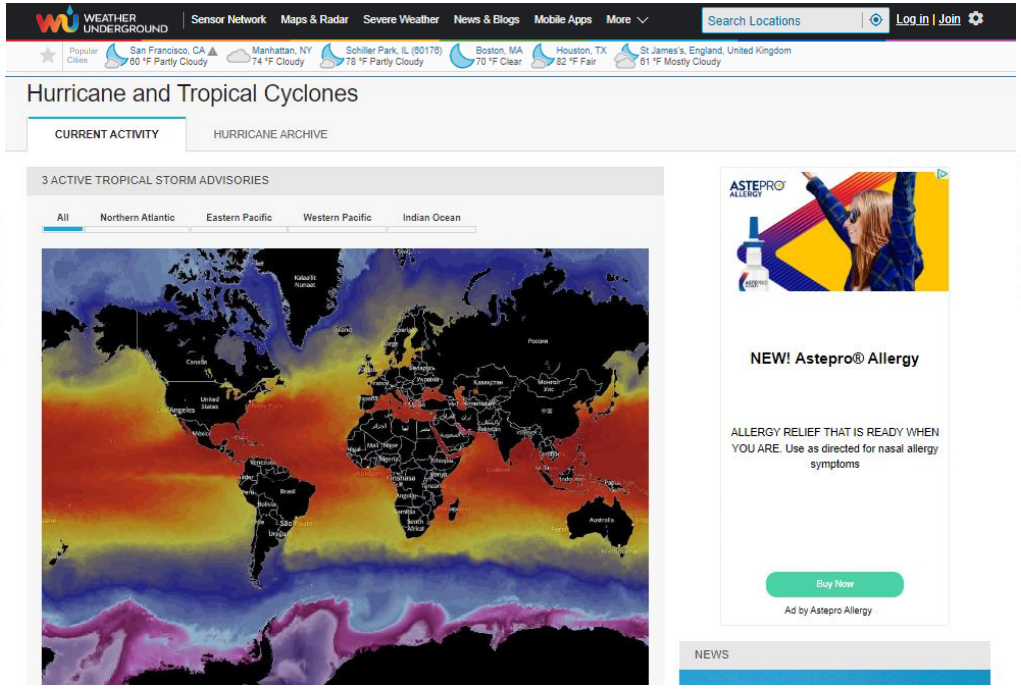
GSSHA™

National Hurricane Center



https://www.nhc.noaa.gov/

Weather Underground



https://www.wunderground.com/hurricane

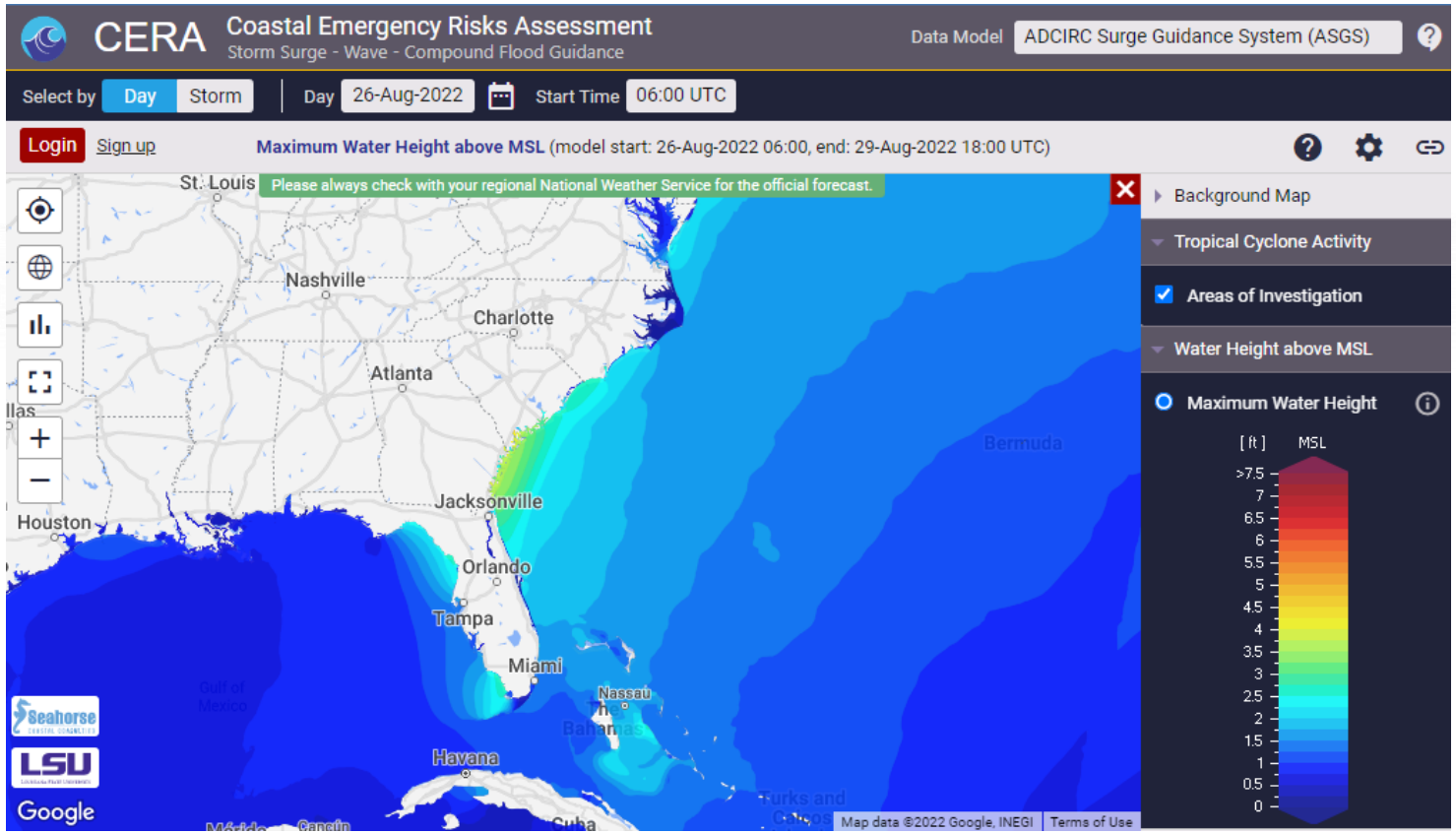
US Army Corps of Engineers.

ERDC

ADCIRC Storm Surge Data

GSSHA™

Historical and Current Modeled Storm Surge



https://cera.coastalrisk.live/cerarisk/

US Army Corps of Engineers.

ERDC