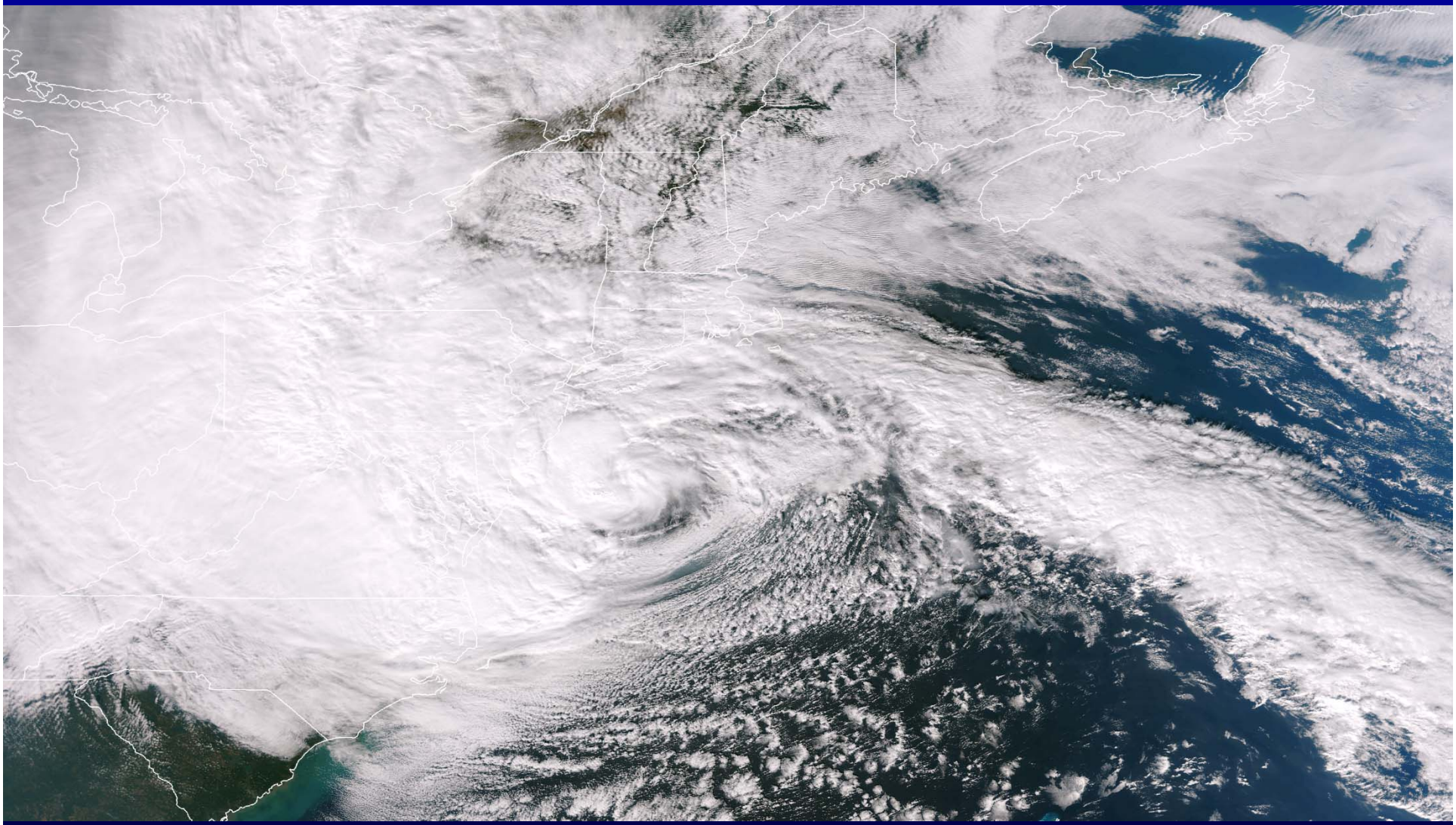
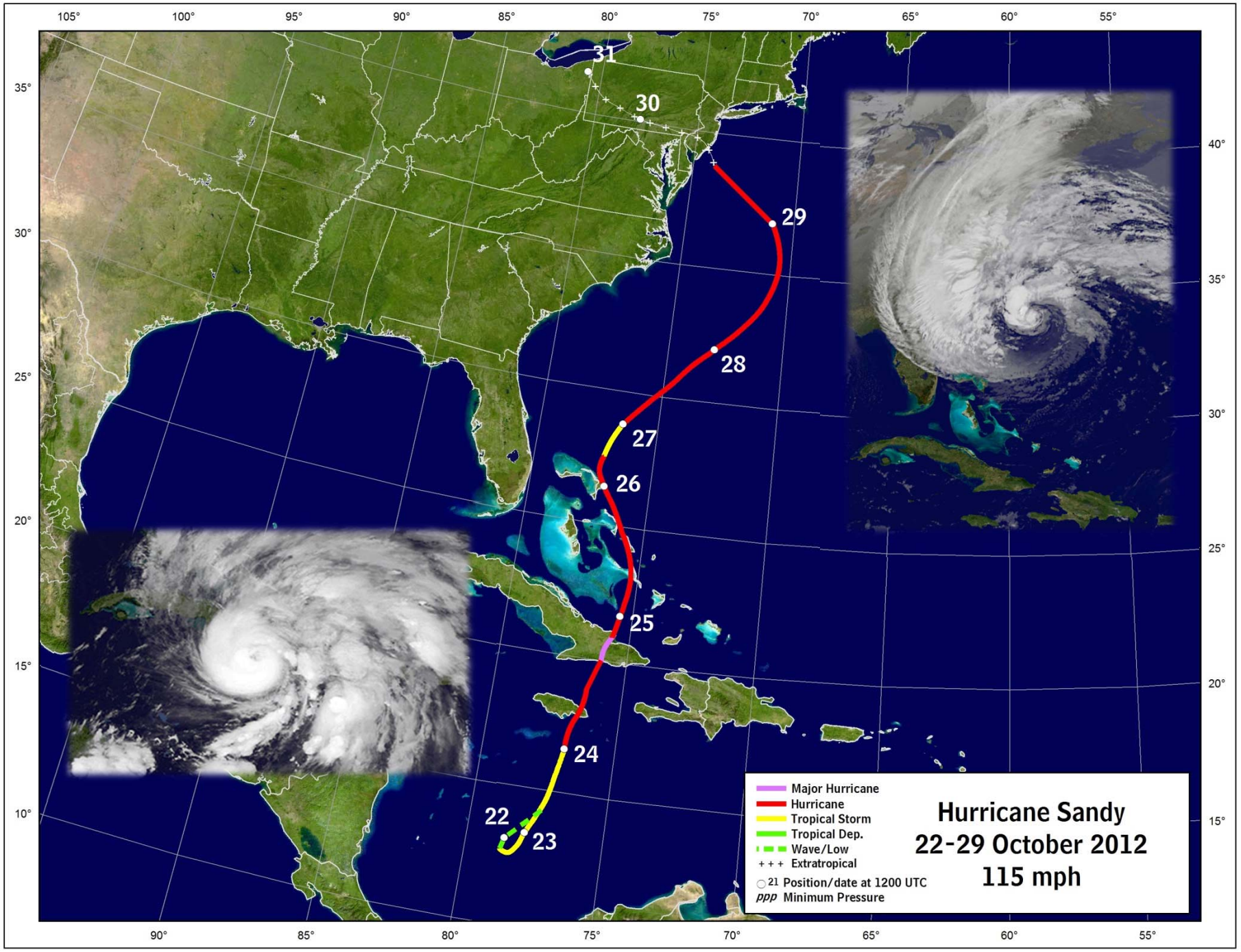
Hurricane Sandy

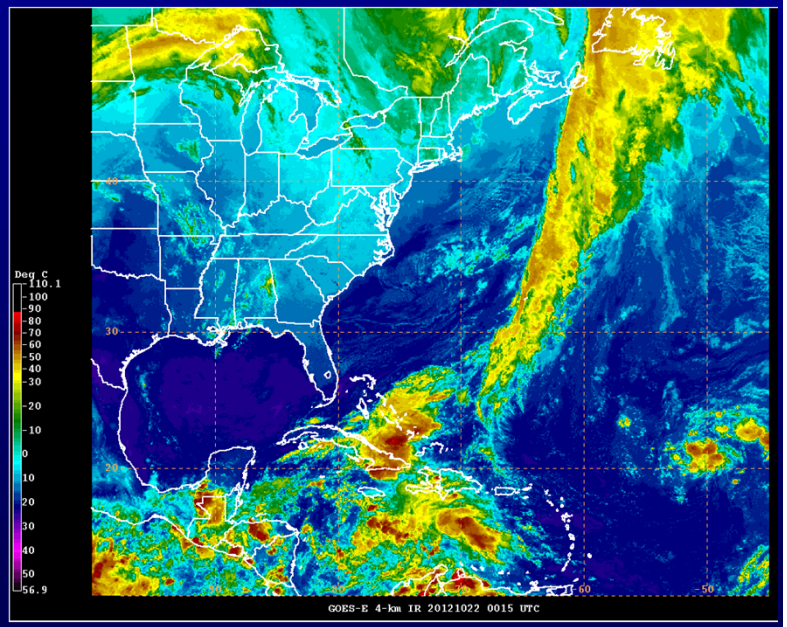


Eric Blake, 3/28/13
National Hurricane Center


105°
100°
95°
90°
85°
80°
75°
70°
65°
60°
55°
35°
30°
25°
20°
15°
10°
40°
31
30
29
28
27
26
25
24
22
23
Major Hurricane
Hurricane
Tropical Storm
Tropical Dep.
Wave/Low
+ + + Extratropical
21 Position/date at 1200 UTC
ppp Minimum Pressure
Hurricane Sandy
22-29 October 2012
115 mph

Sandy's history

- Became a hurricane before hitting Jamaica and a major hurricane just before hitting eastern Cuba.
- Weakened due to shear over the southeastern and central Bahamas.
- Interacted with an upper-level trough and surface front near the northwestern Bahamas and underwent a partial extratropical transition.
- Regained some of its tropical character as it moved northeastward off the southeastern United States.
- Interacted with a second upper-level trough and strengthened as it turned northwestward on a rare track toward the northeastern United States.
- Became extratropical just before landfall in New Jersey.



Sandy's Impacts

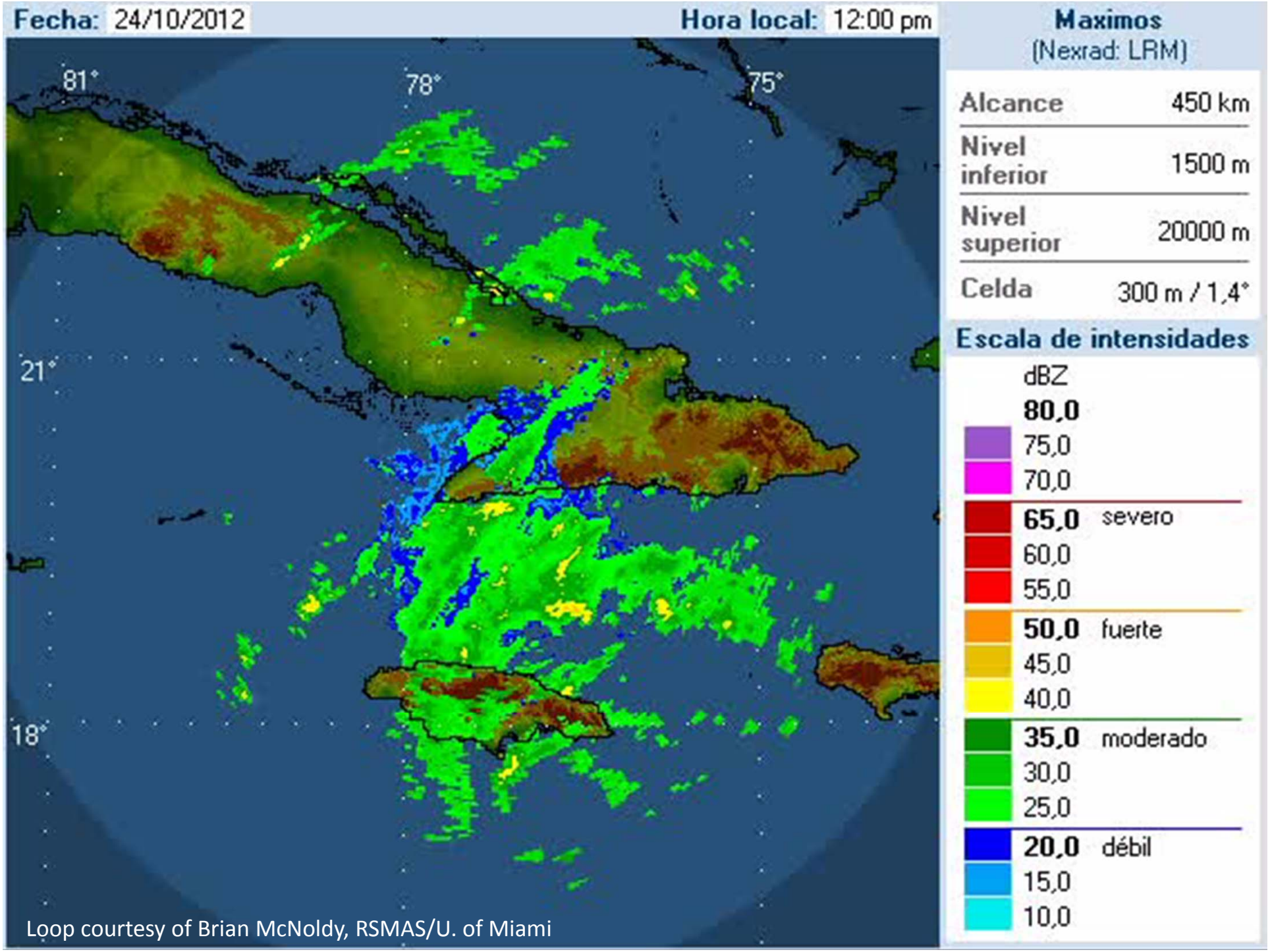
- Death tolls: U. S. – 72, Haiti – 54, Cuba – 11, Dominican Republic – 3, Bahamas – 2, Maritime – 2, Canada, Jamaica, Puerto Rico – 1
- Hurricane conditions in eastern Jamaica, eastern Cuba, Bahamas, and small area of eastern NY
- Tropical storm/gale conditions over the U. S. Mid-Atlantic and New England States
- Gale-force winds gusts as far west as the western Great Lakes
- Major to record storm surge with extensive damage along large portions of the New Jersey, Ney York, Connecticut, Rhode Island, and Massachusetts coasts
- Widespread heavy rains along the track, with heavy snow in the Appalachian Mountains
- $50 billion property damage in the U.S.



Mayarí, Holguín (courtesy Cuban Met. Service)



Manhattan, NY (courtesy of Twitter/nycarecs)


Fecha: 24/10/2012
Hora local: 12:00 pm
81°
78°
75°
21°
18°
Maximos
(Nexrad: LRM)
Alcance 450 km
Nivel inferior 1500 m
Nivel superior 20000 m
Celda 300 m / 1,4°
Escala de intensidades
dBZ
80,0
75,0
70,0
65,0 severo
60,0
55,0
50,0 fuerte
45,0
40,0
35,0 moderado
30,0
25,0
20,0 débil
15,0
10,0
Loop courtesy of Brian McNoldy, RSMAS/U. of Miami



Kingston, Jamaica (Collin Reid/AP)



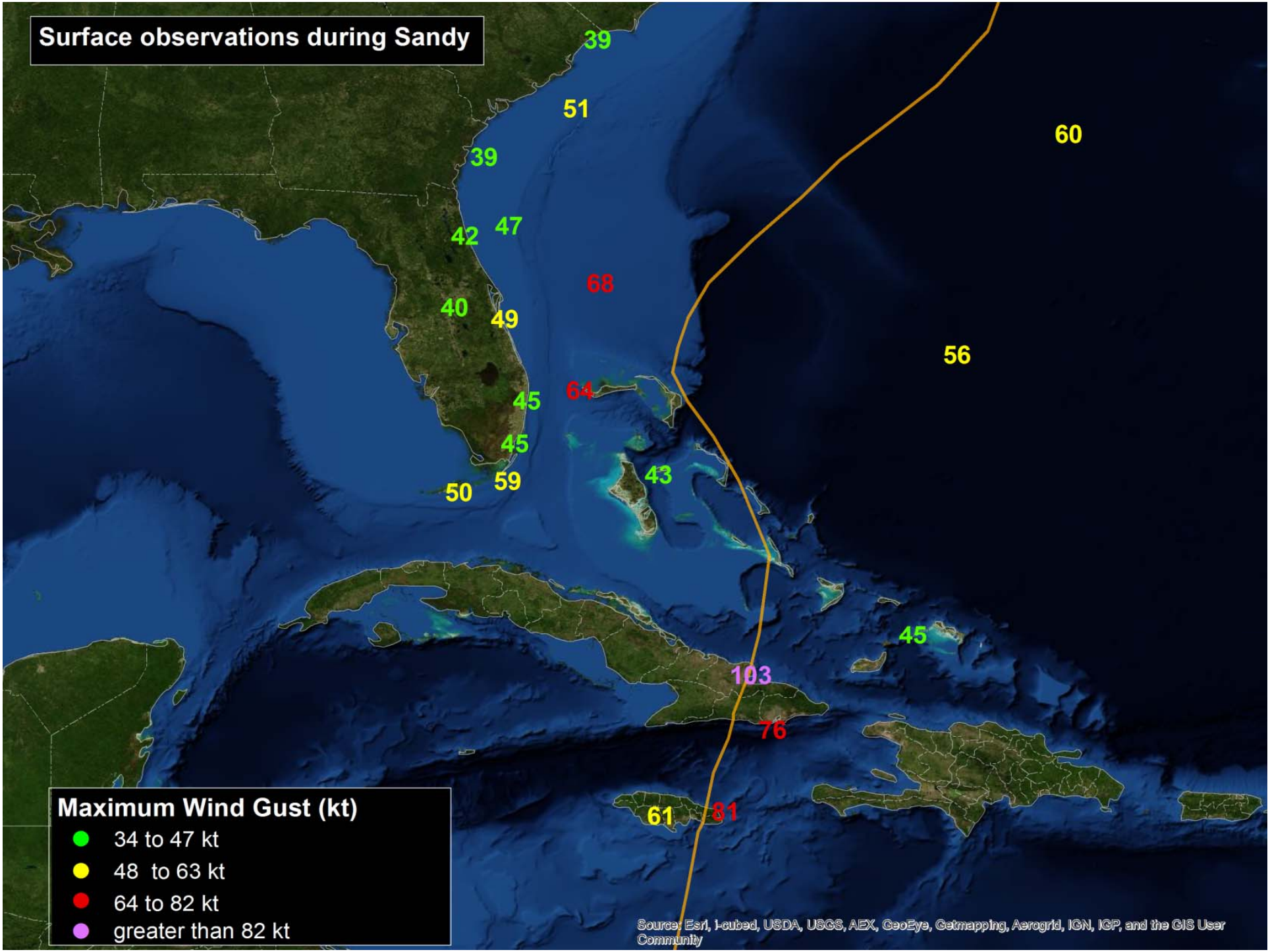
Santiago de Cuba, Cuba (Reuters)



Haiti (Logan Abassi/MINUSTAH)



Santo Domingo, Dominican Republic (Ricardo Rojas/Reuters)


Surface observations during Sandy
39
51
39
60
47
42
68
40
49
56
64
45
45
43
59
50
45
103
76
61
81
Maximum Wind Gust (kt)
34 to 47 kt
48 to 63 kt
64 to 82 kt
greater than 82 kt
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community



Freeport, Bahamas (Simon Lewis/BIS)



Nassau, Bahamas (Tony Grant, Jr.)



Ft. Lauderdale Beach, FL (WeatherUnderground)



Deerfield Beach, FL (WeatherUnderground)

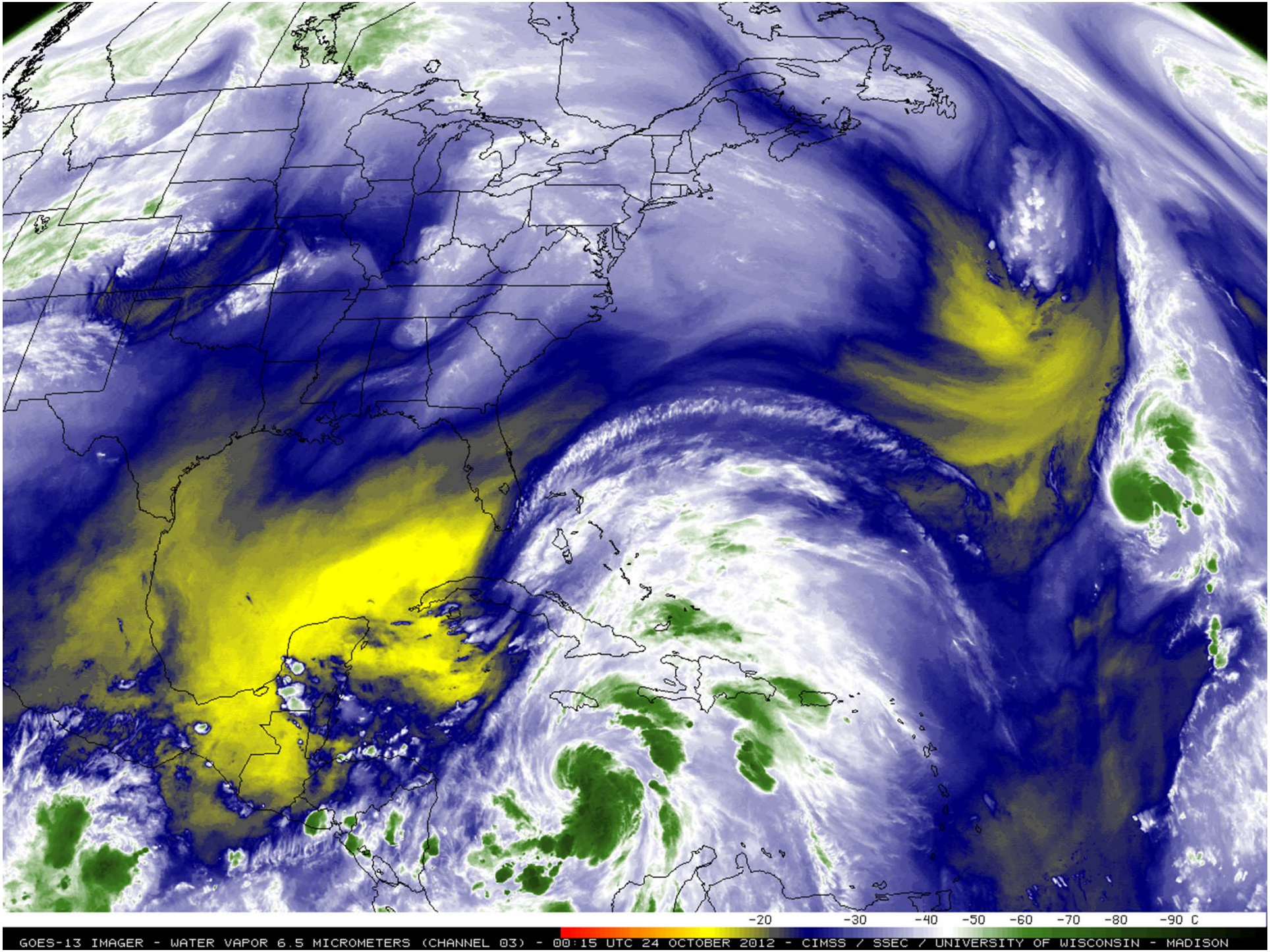


NC 12, Rodanthe, NC (AP Photo/The Virginian-Pilot, Steve Earley)

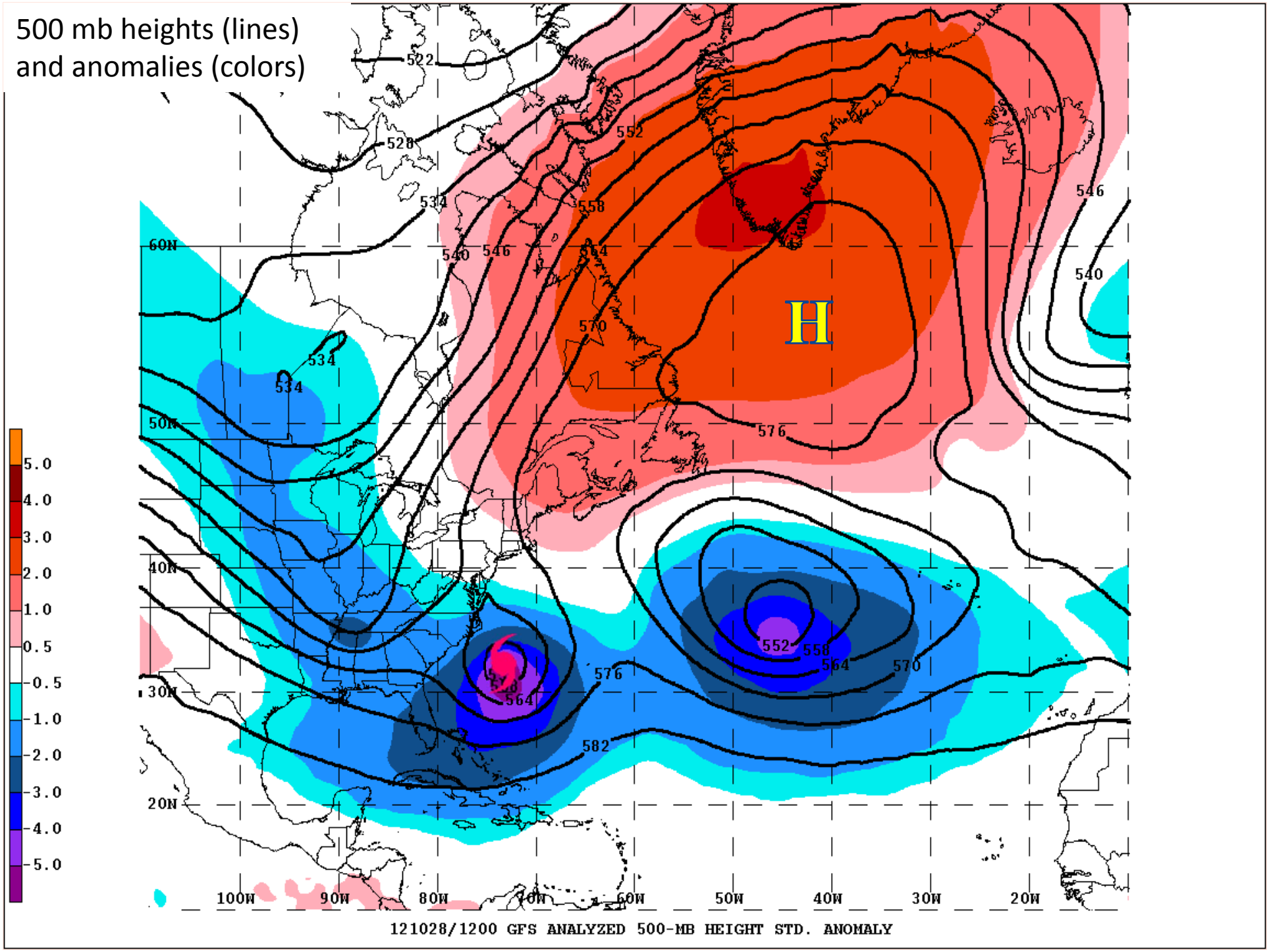

Norfolk, VA (Twitter/@MartinMMC)


Ocean City, MD (DMVFollowers.com)

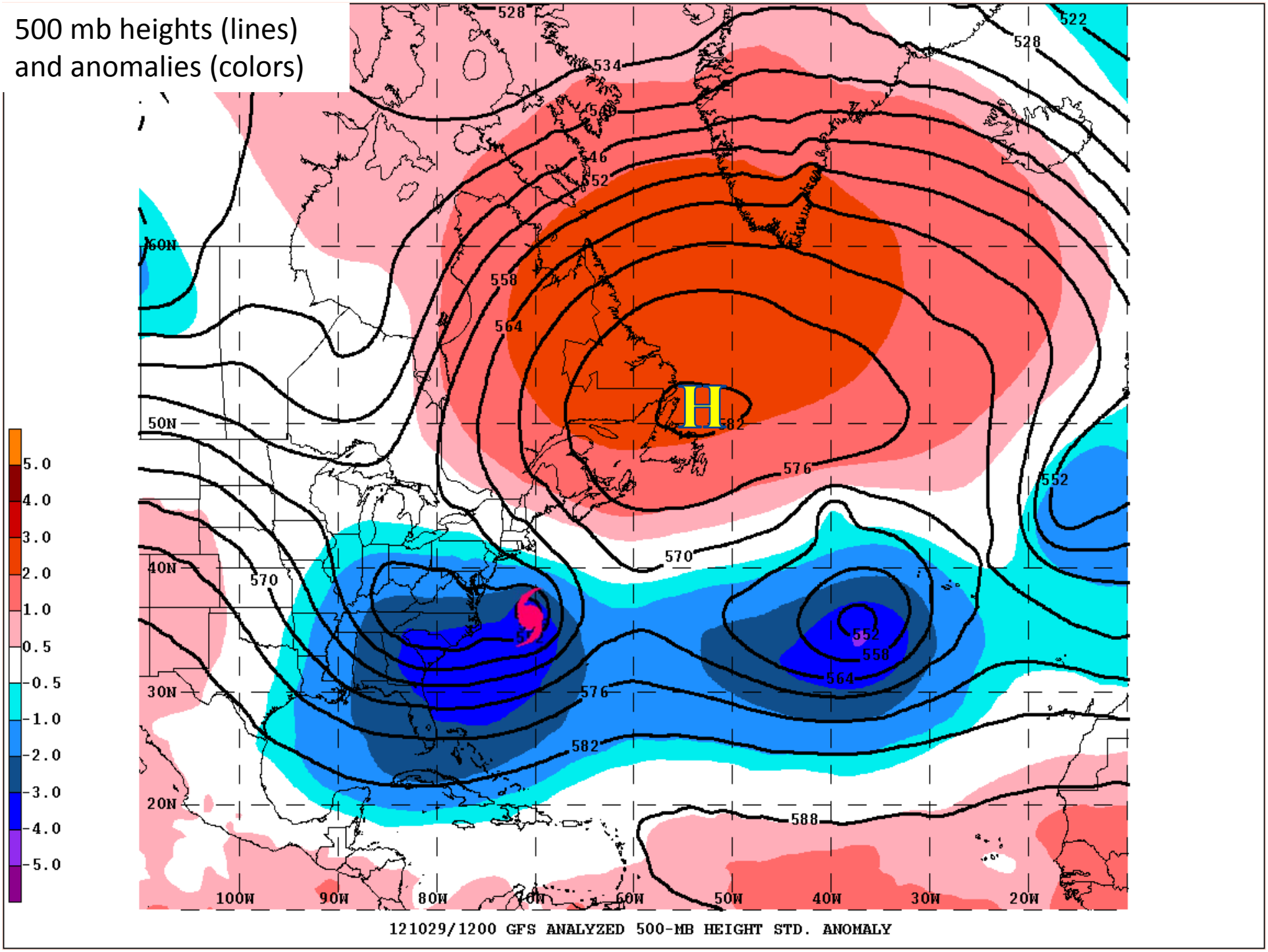

Sussex County, DE (Jeremy Tucker/Delaware EC)


-20 -30 -40 -50 -60 -70 -80 -90 C
GOES-13 IMAGER - WATER VAPOR 6.5 MICROMETERS (CHANNEL 03) - 00:15 UTC 24 OCTOBER 2012 - CIMSS / SSEC / UNIVERSITY OF WISCONSIN - MADISON

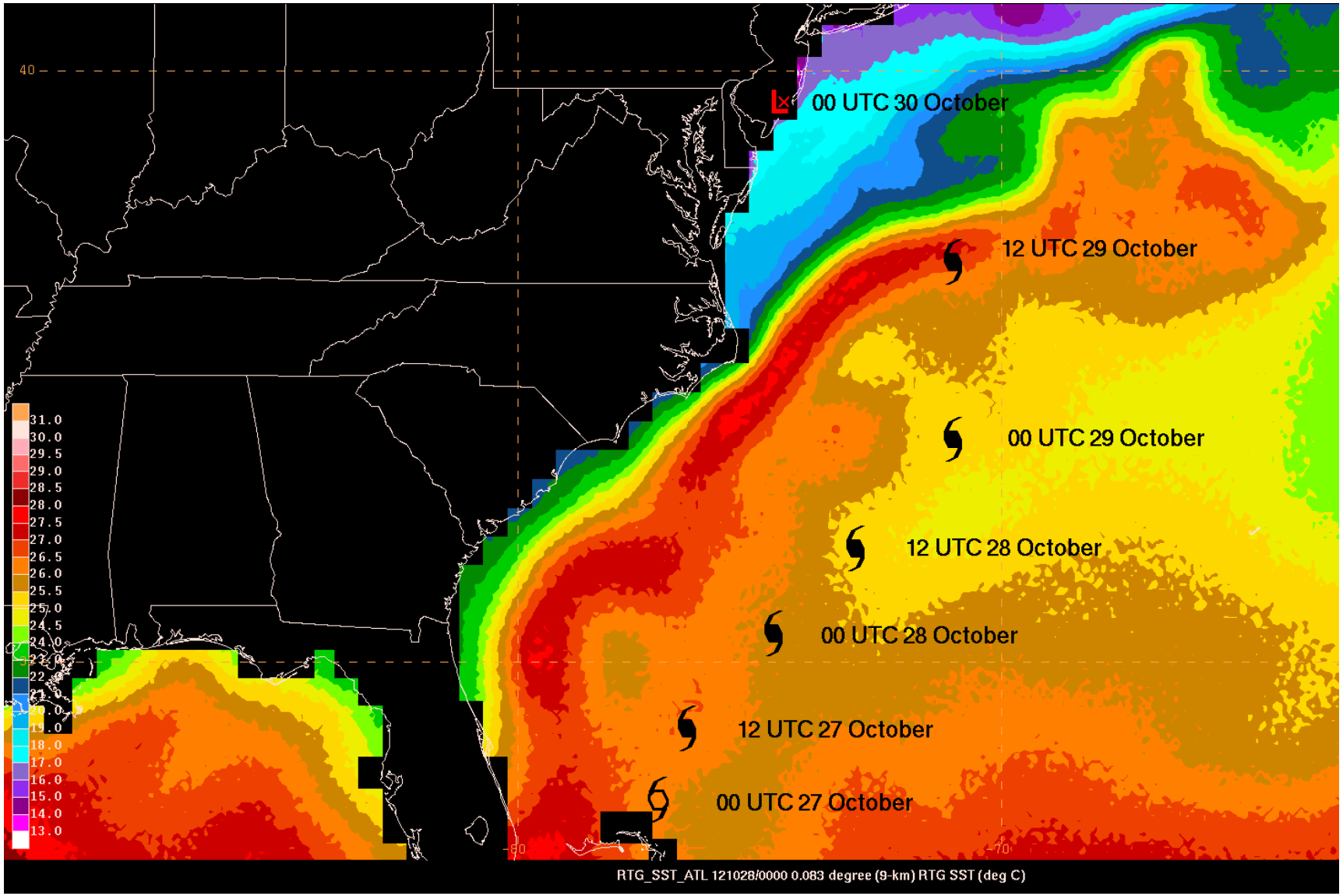
500 mb heights (lines)
and anomalies (colors)



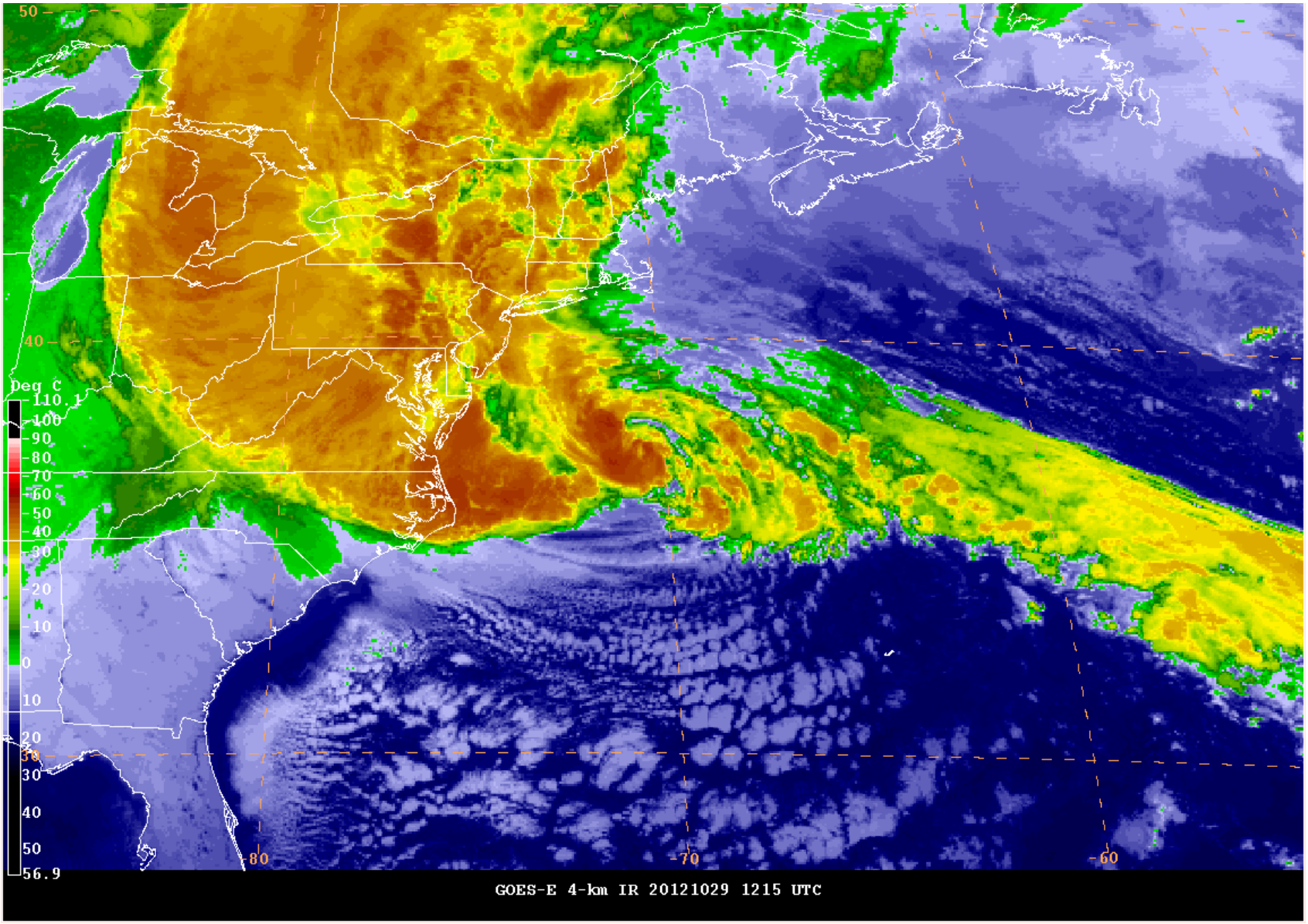
500 mb heights (lines)
and anomalies (colors)

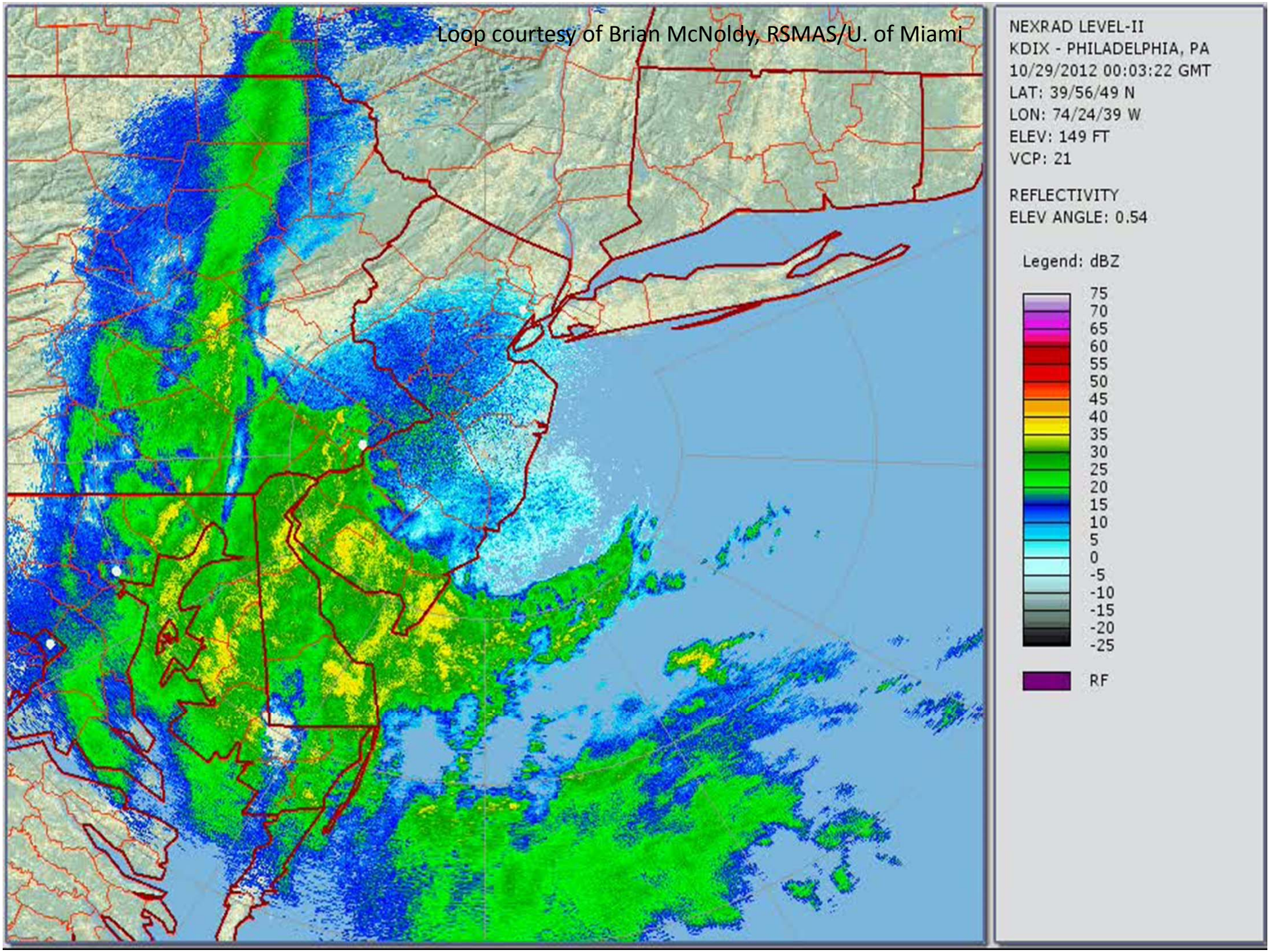


Sea-surface temperatures along Sandy's path



About 11 hours before landfall, a faint eye is still present on satellite




Loop courtesy of Brian McNoldy, RSMAS/U. of Miami
NEXRAD LEVEL-II
KDIX - PHILADELPHIA, PA
10/29/2012 00:03:22 GMT
LAT: 39/56/49 N
LON: 74/24/39 W
ELEV: 149 FT
VCP: 21
REFLECTIVITY
ELEV ANGLE: 0.54
Legend: dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
RF

Hurricane Sandy damage in southern New Jersey





8th St./Ave. C, Manhattan, NY
(YouTube/Kevin Barnett)



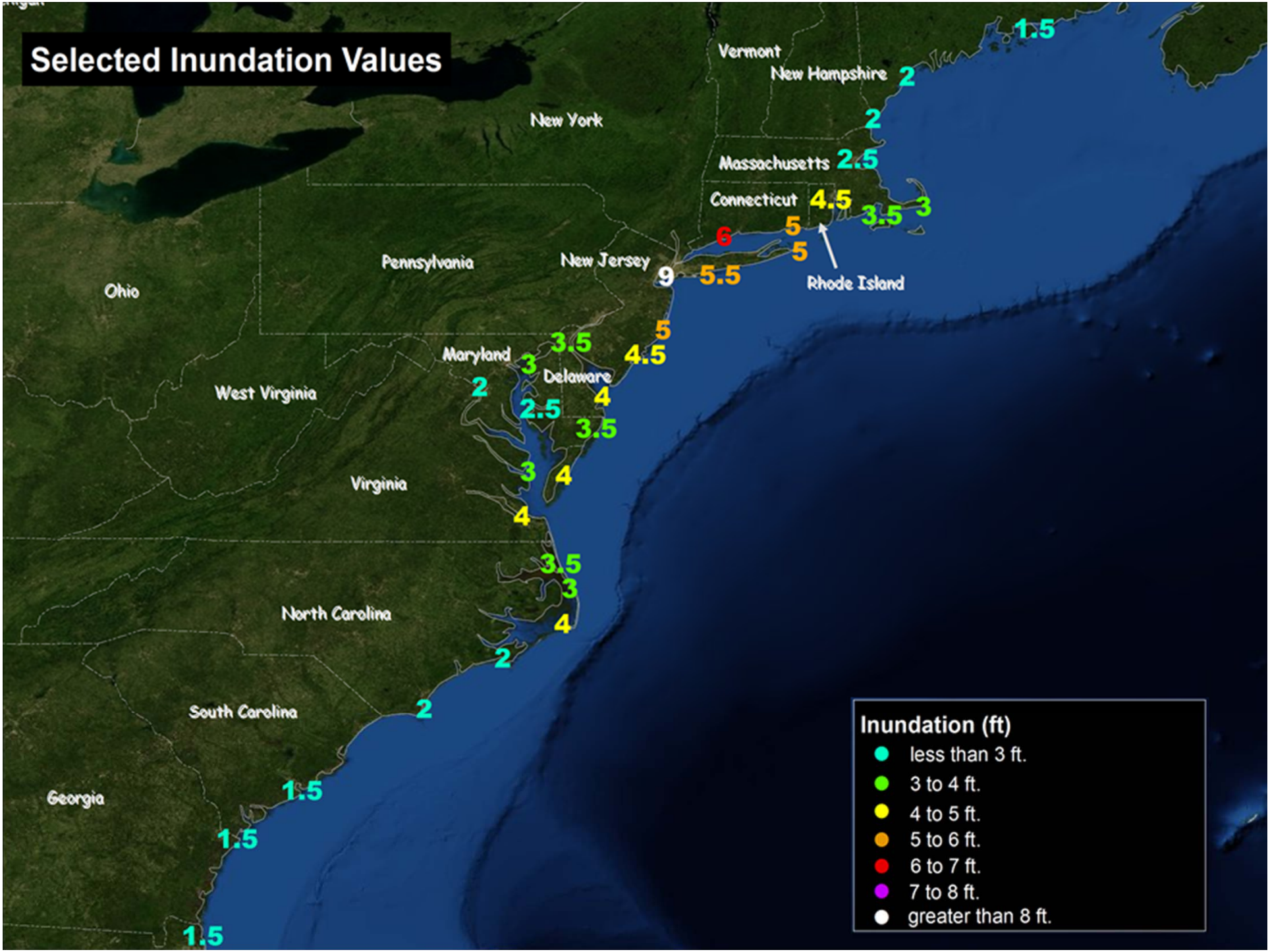
Midland Beach, Staten Island, NY
(YouTube/Pablo Pintor)

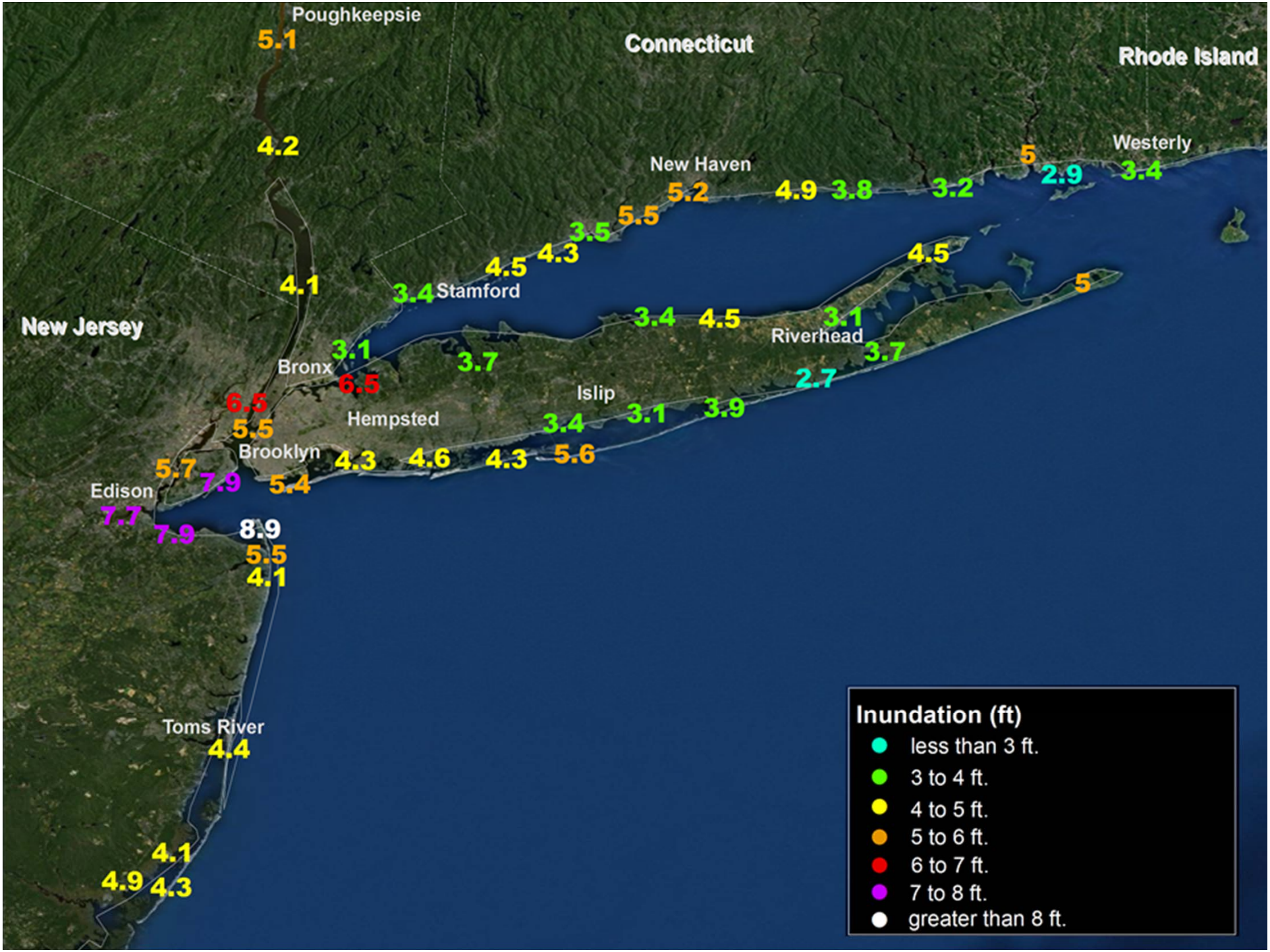


Jersey City, NJ (YouTube/echtjbm)



Long Beach, NY (YouTube/105Florida)


Selected Inundation Values
Vermont
New Hampshire
New York
Massachusetts
Connecticut
Rhode Island
Pennsylvania
New Jersey
Ohio
Maryland
Delaware
West Virginia
Virginia
North Carolina
South Carolina
Georgia
1.5
2
2
2.5
4.5
3.5
3
6
5
5
9
5.5
5
3.5
3
4.5
2
2.5
4
3.5
3
4
4
3.5
3
4
2
2
1.5
1.5
1.5
Inundation (ft)
less than 3 ft.
3 to 4 ft.
4 to 5 ft.
5 to 6 ft.
6 to 7 ft.
7 to 8 ft.
greater than 8 ft.


Poughkeepsie
5.1
Connecticut
Rhode Island
4.2
New Haven
5.2
4.9
3.8
3.2
5
2.9
Westerly
3.4
5.5
3.5
4.3
4.5
4.5
4.1
3.4
Stamford
New Jersey
3.4
4.5
3.1
Riverhead
5
3.1
Bronx
3.7
3.7
6.5
2.7
Islip
6.5
Hempsted
3.4
3.1
3.9
5.5
Brooklyn
4.3
4.6
4.3
5.6
5.7
7.9
5.4
Edison
7.7
7.9
8.9
5.5
4.1
Toms River
4.4
4.1
4.9
4.3
Inundation (ft)
less than 3 ft.
3 to 4 ft.
4 to 5 ft.
5 to 6 ft.
6 to 7 ft.
7 to 8 ft.
greater than 8 ft.

USGS High-Water Marks



USCG Station, Sandy Hook, NJ
8.9 ft above ground level



Staten Island, NY
7.9 ft above ground level

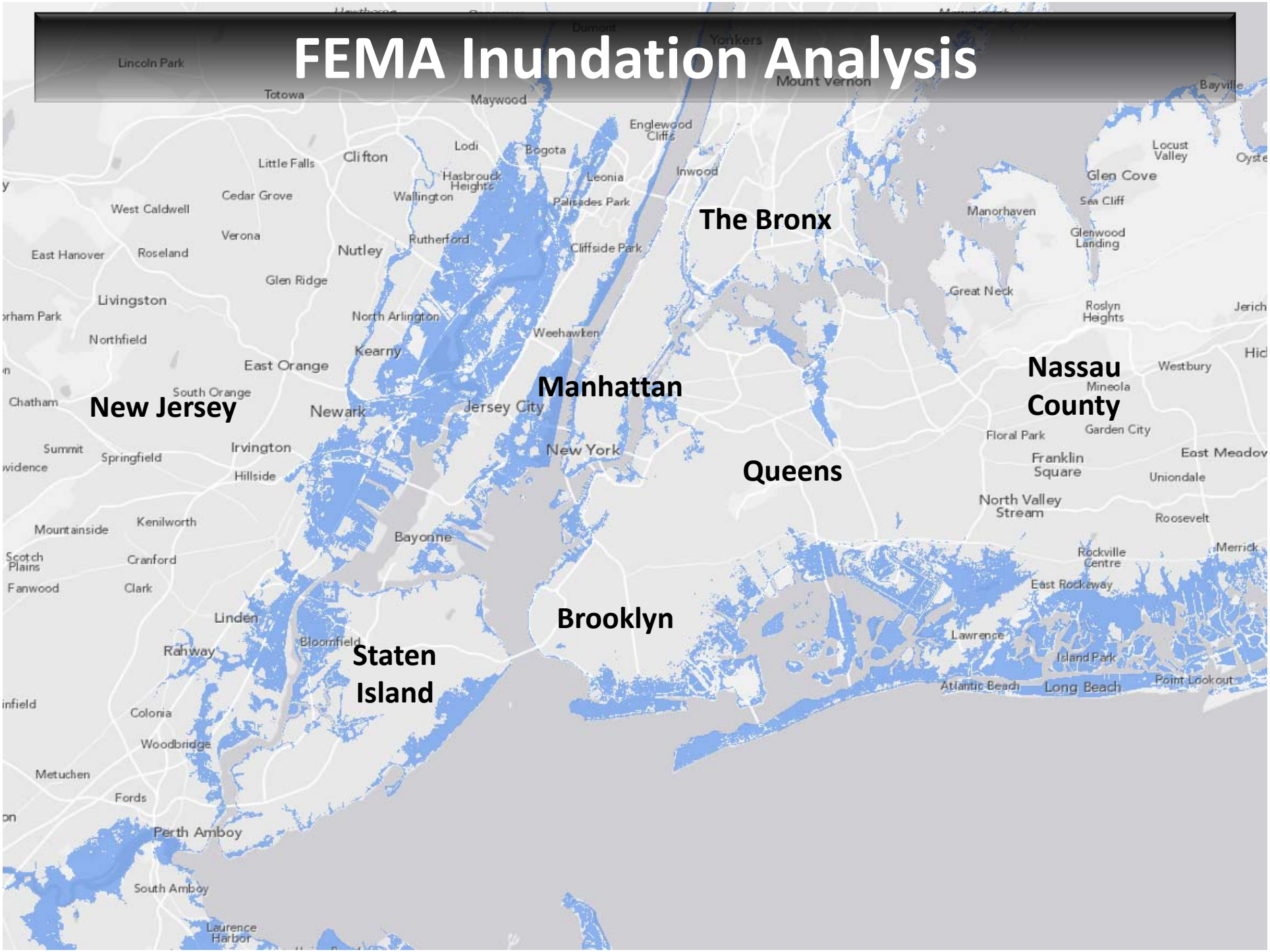


Fire Island, NY
5.6 ft above ground level

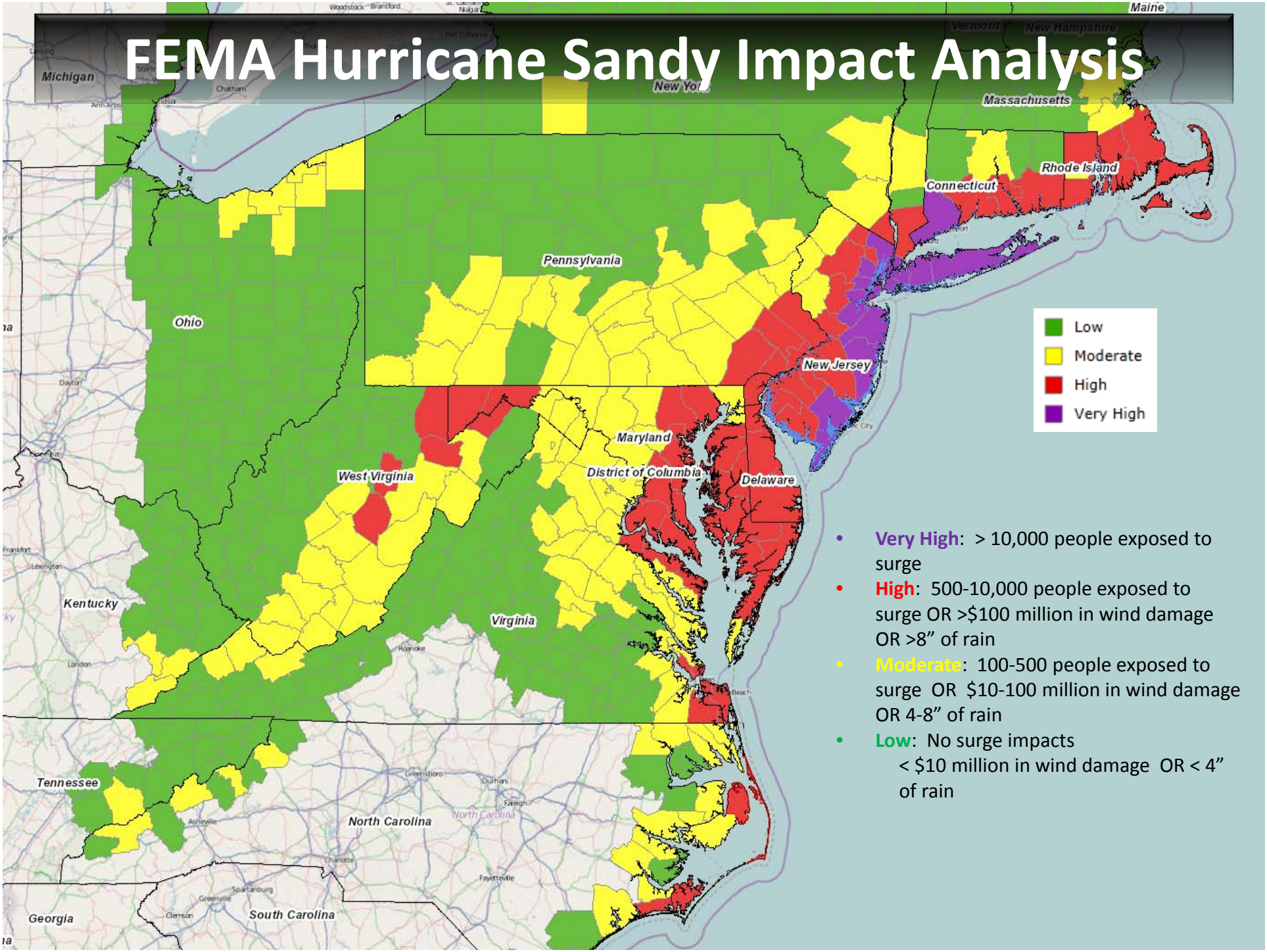


Weehawken, NJ
6.5 ft above ground level

FEMA Inundation Analysis



FEMA Hurricane Sandy Impact Analysis



- **Very High**: > 10,000 people exposed to surge
- **High**: 500-10,000 people exposed to surge OR >$100 million in wind damage OR >8” of rain
- **Moderate**: 100-500 people exposed to surge OR $10-100 million in wind damage OR 4-8” of rain
- **Low**: No surge impacts
  < $10 million in wind damage OR < 4” of rain



PATH station, Hoboken, NJ
AFP PHOTO / The Port Authority of New York & New Jersey



Harvey Cedars, Long Beach Island, New Jersey
(AP Photo/The Philadelphia Inquirer, Clem Murray)



Atlantic City, NJ (Tom Mihalek/Reuters)



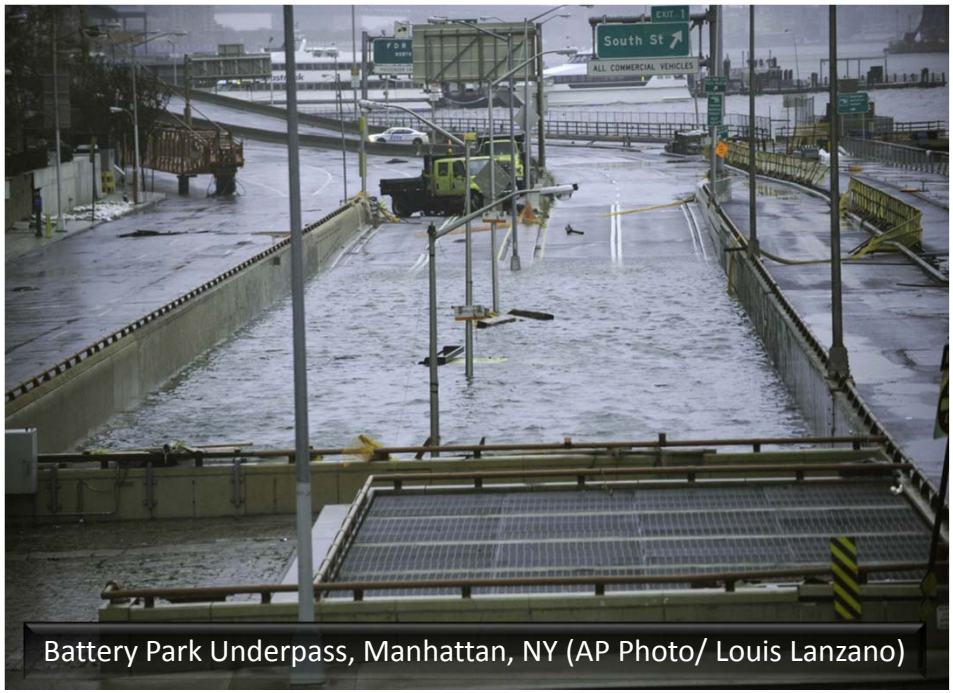
Union Beach, NJ (blog, Spleeness)



Dumbo, Brooklyn, NY (AP Photo/Bebeto Matthews)



Bellport, NY (Lucas Jackson/Reuters)



Battery Park Underpass, Manhattan, NY (AP Photo/ Louis Lanzano)



Lindenhurst, NY (AP Photo/Jason DeCrow)



East Haven, CT (AP Photo/Jessica Hill)



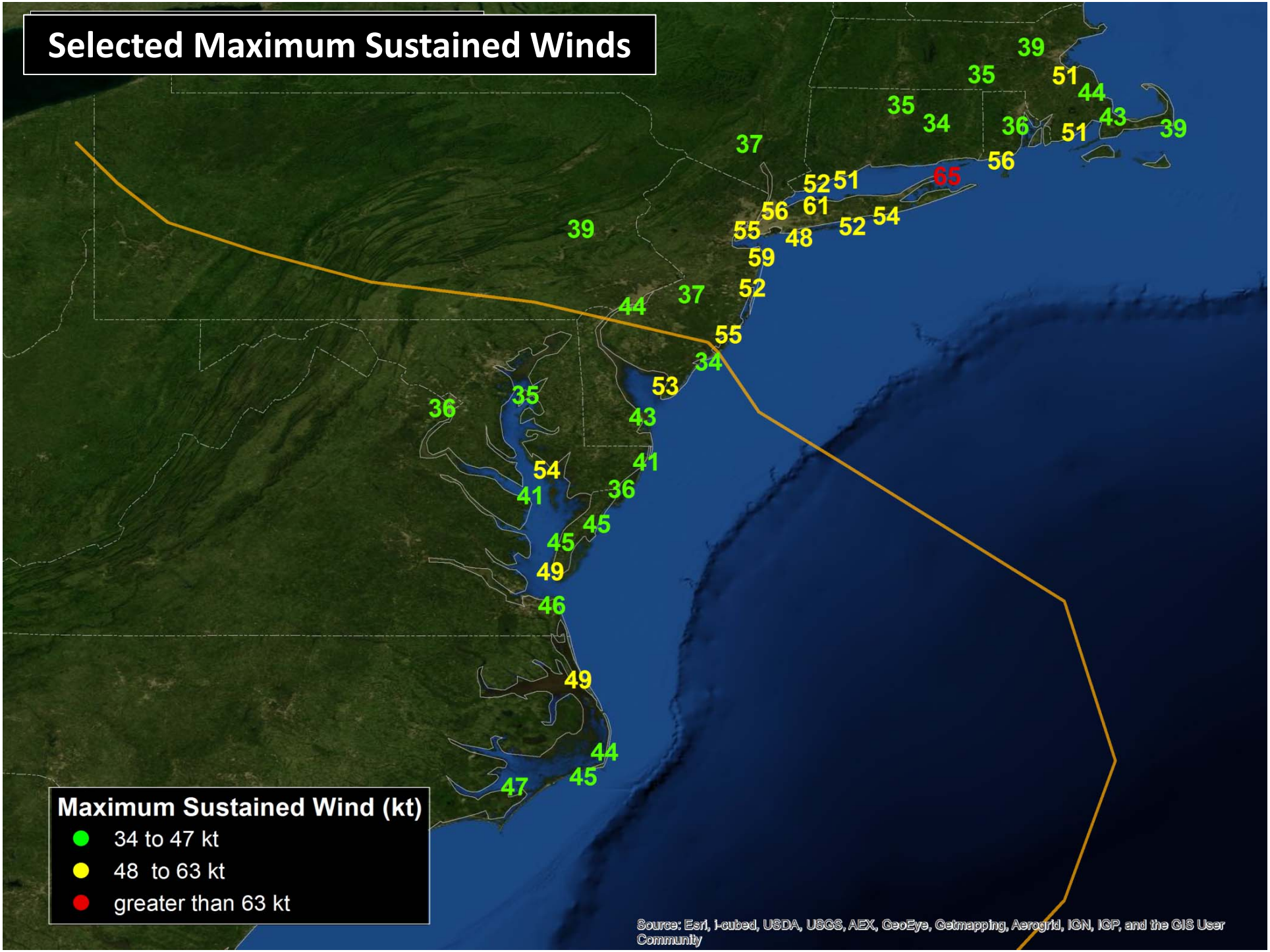
Stratford, CT (Ned Gerard)

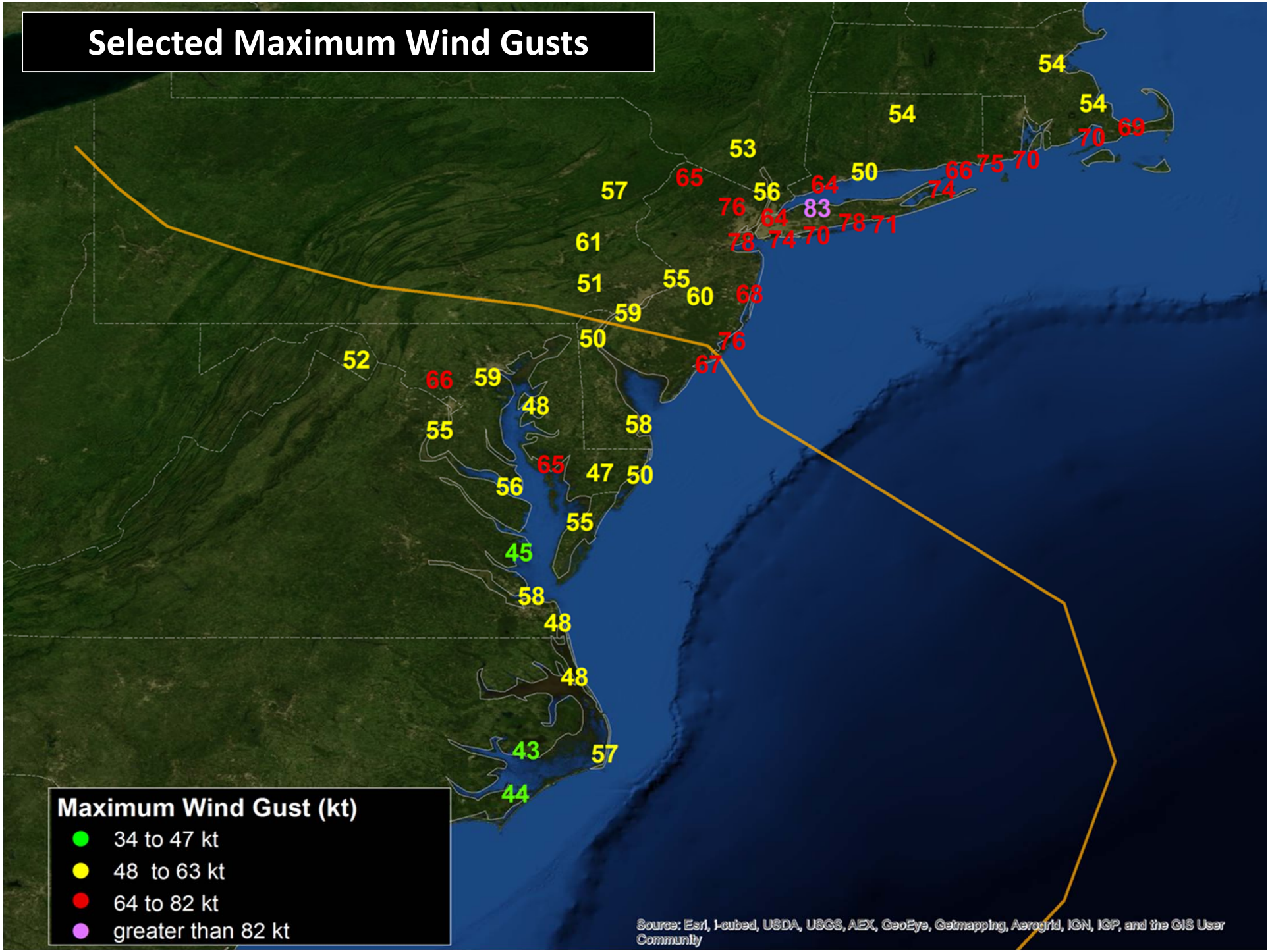


South Kingstown, RI (AP Photo/Steven Senne)

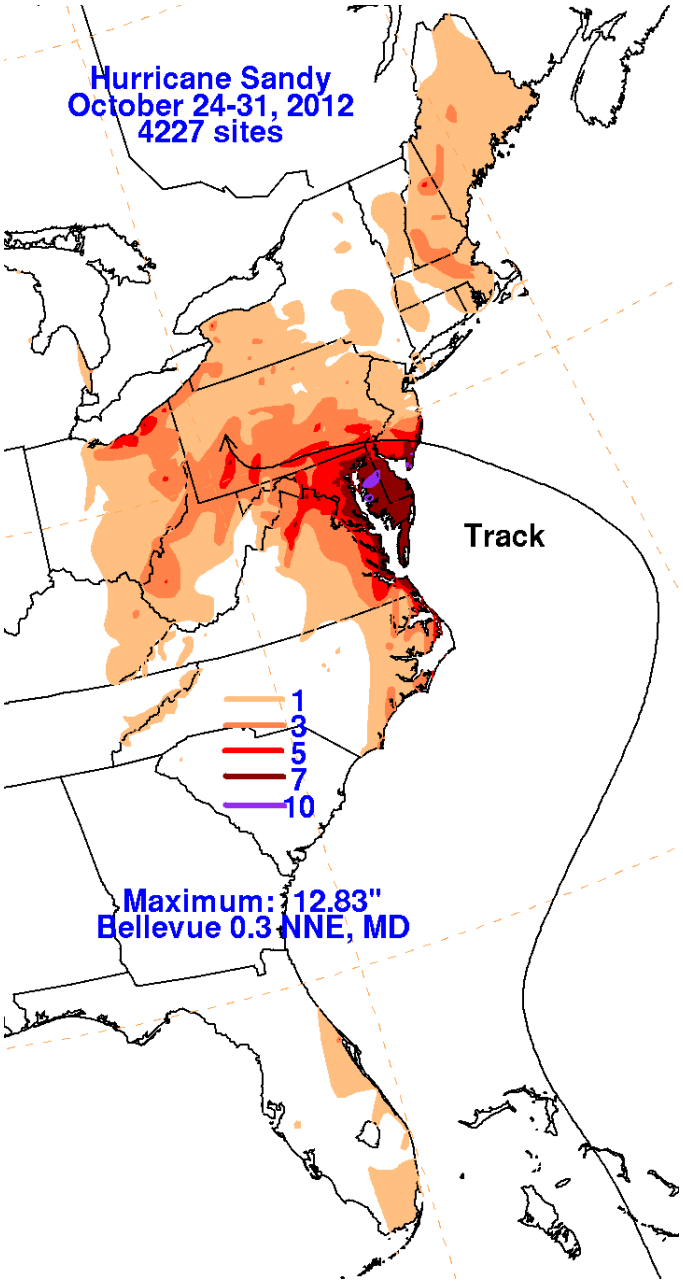


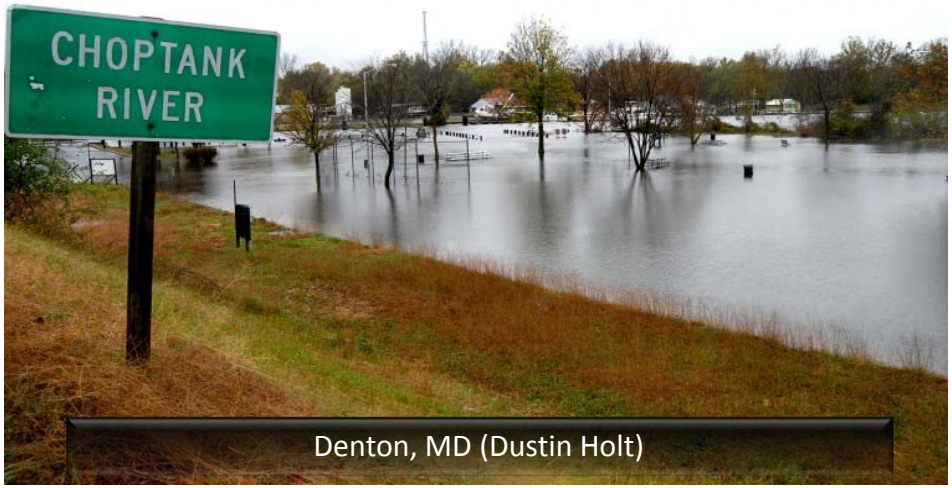
Scituate, MA (David L Ryan/Boston Globe)


Selected Maximum Sustained Winds
39
35
51
44
35
34
36
51
43
39
37
56
65
52
51
56
61
54
52
55
48
39
59
52
37
44
55
34
53
35
36
43
54
41
41
36
45
45
49
46
49
44
45
47
Maximum Sustained Wind (kt)
34 to 47 kt
48 to 63 kt
greater than 63 kt
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community


Selected Maximum Wind Gusts
54
54
54
70
69
53
65
57
56
64
50
66
75
70
74
76
64
83
78
71
78
74
70
61
51
55
60
68
59
50
76
67
52
66
59
48
55
58
65
47
50
56
55
45
58
48
48
43
57
44
Maximum Wind Gust (kt)
34 to 47 kt
48 to 63 kt
64 to 82 kt
greater than 82 kt
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

Sandy Rainfall/Flooding

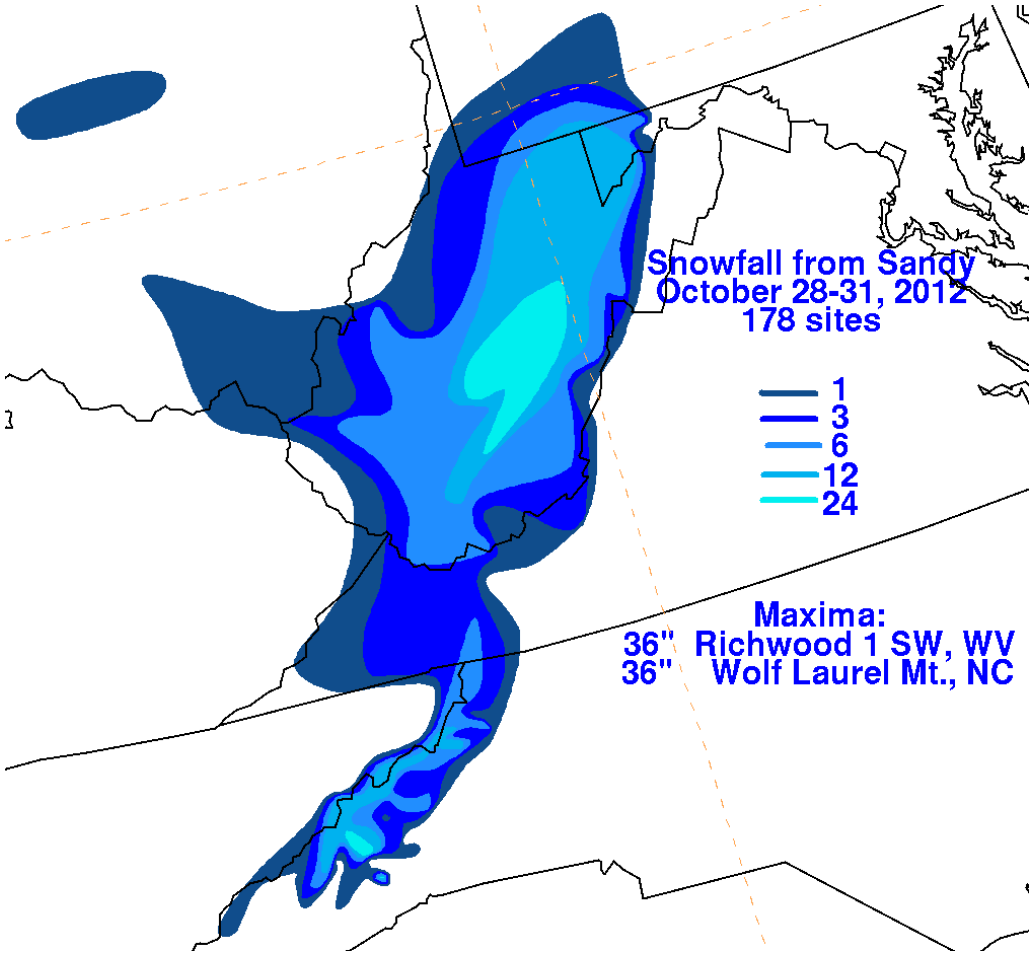




Denton, MD (Dustin Holt)


Lancaster, PA (WHTM)

Sandy Snowfall

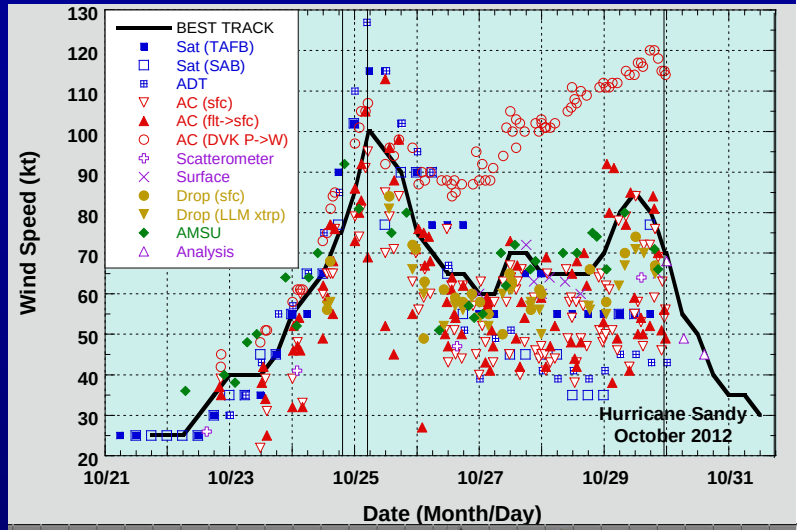


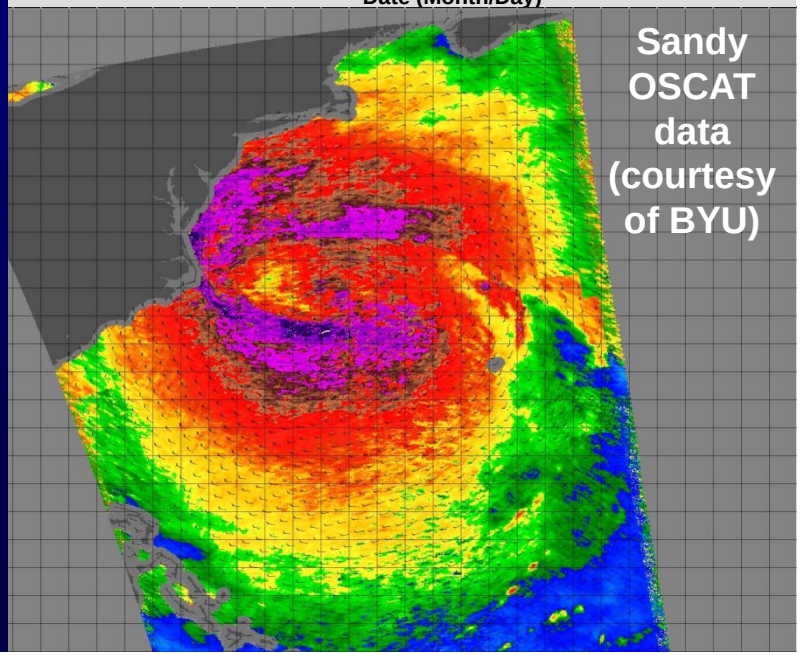




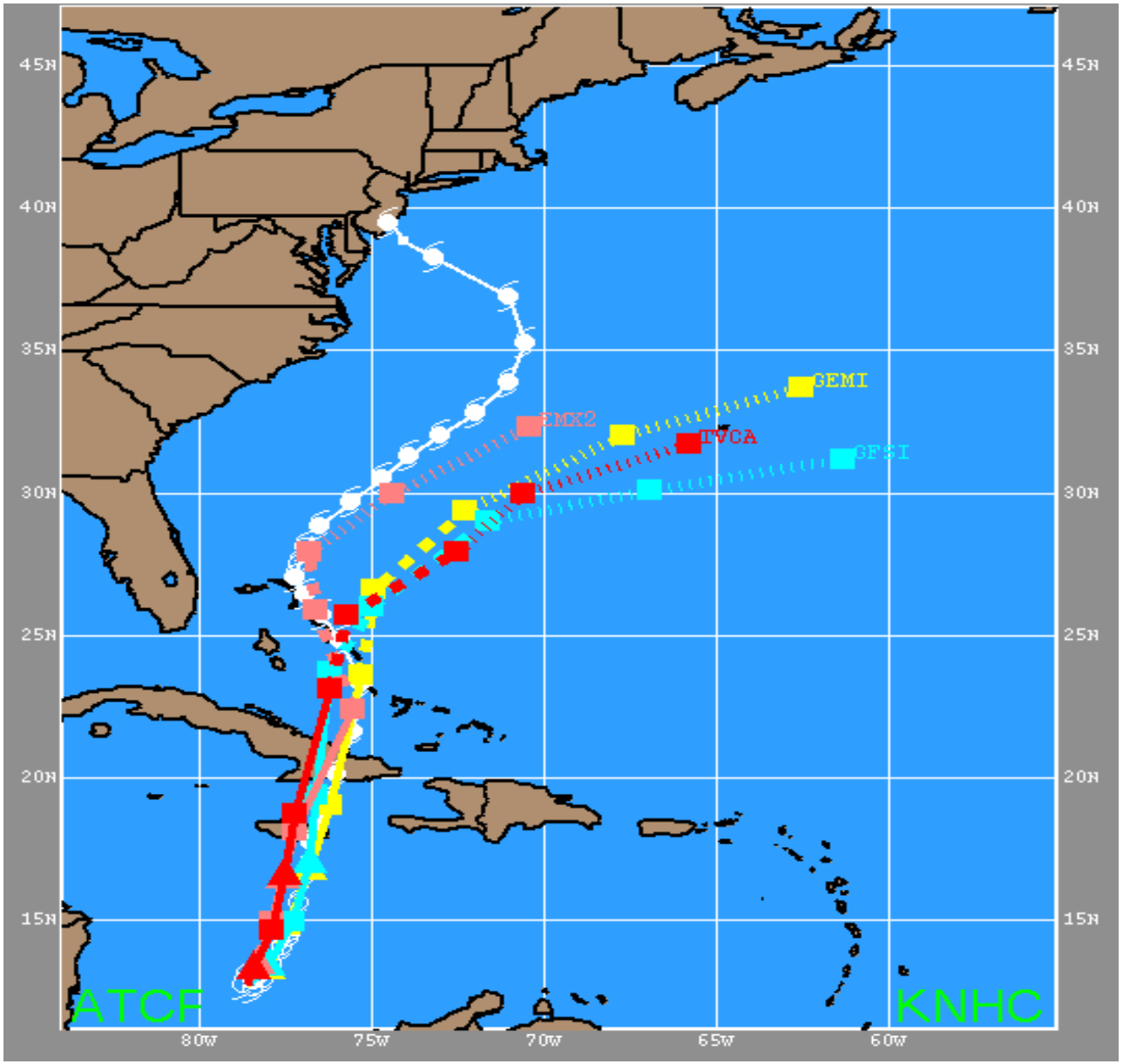
Forecast Challenges During Sandy

- No dropsondes were available on the aircraft that was in Sandy near peak intensity – issue for determining the peak.
- Satellite intensity estimates were useless once Sandy lost some tropical characteristics.
- Normal wind-pressure relationships didn't work.
- Wind structure posed a sampling problem for aircraft – the strongest winds were sometimes outside of the flight path!





Model Guidance for Sandy– 7 days before landfall



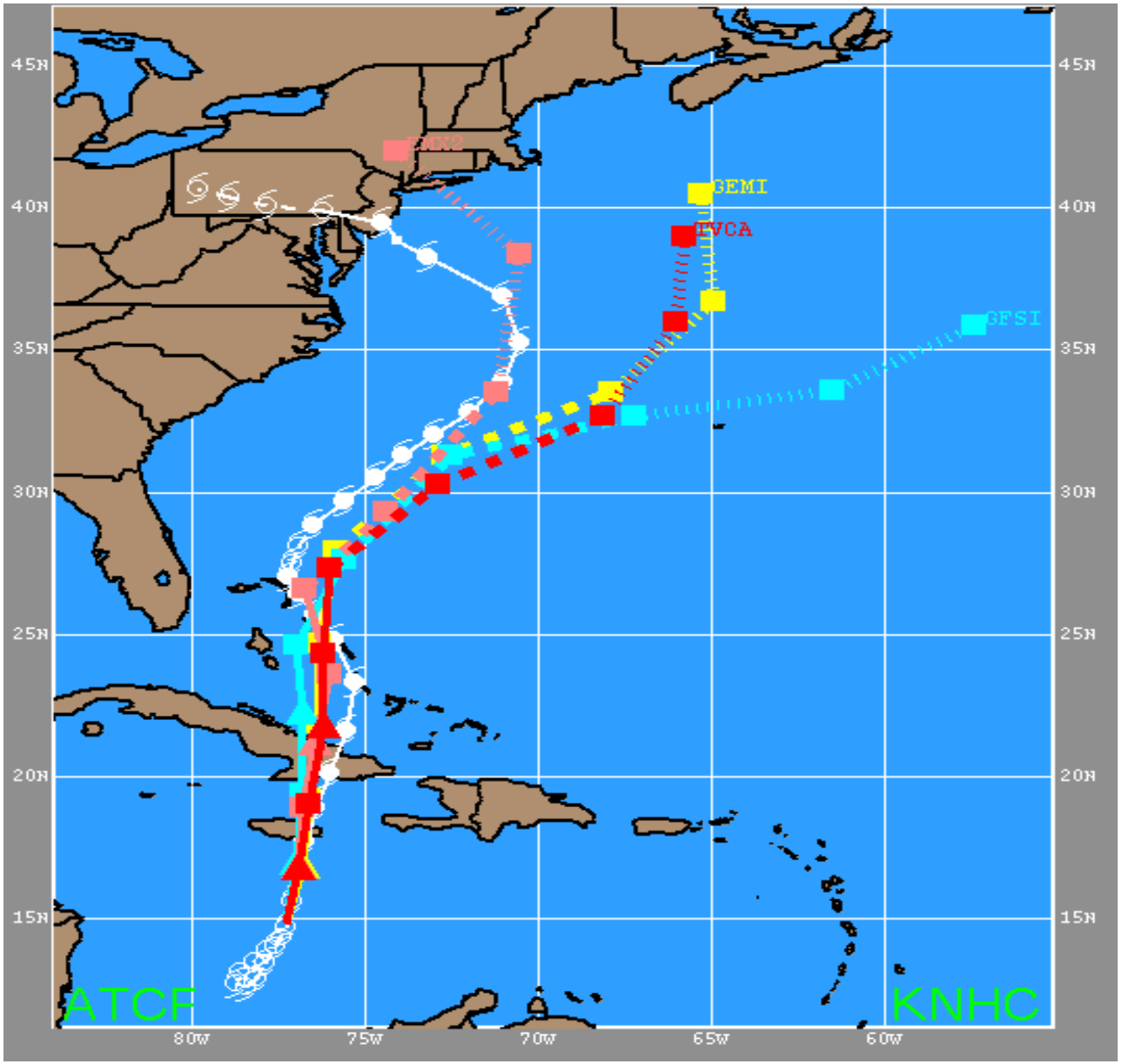
ECMWF

GFS

GFS Ensemble

Consensus

Model Guidance for Sandy– 6 days before landfall



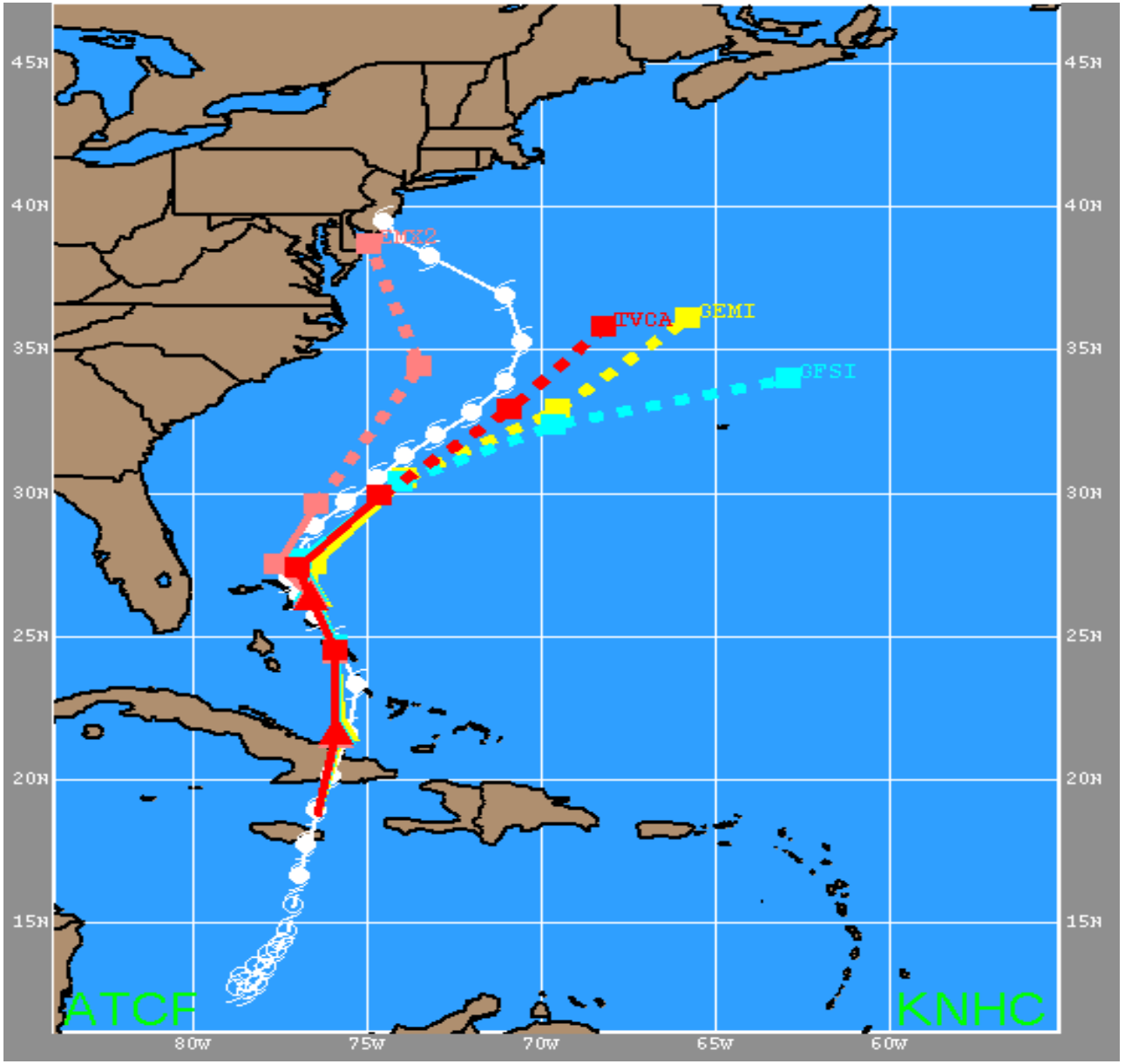
ECMWF

GFS

GFS Ensemble

Consensus

Model Guidance for Sandy– 5 days before landfall



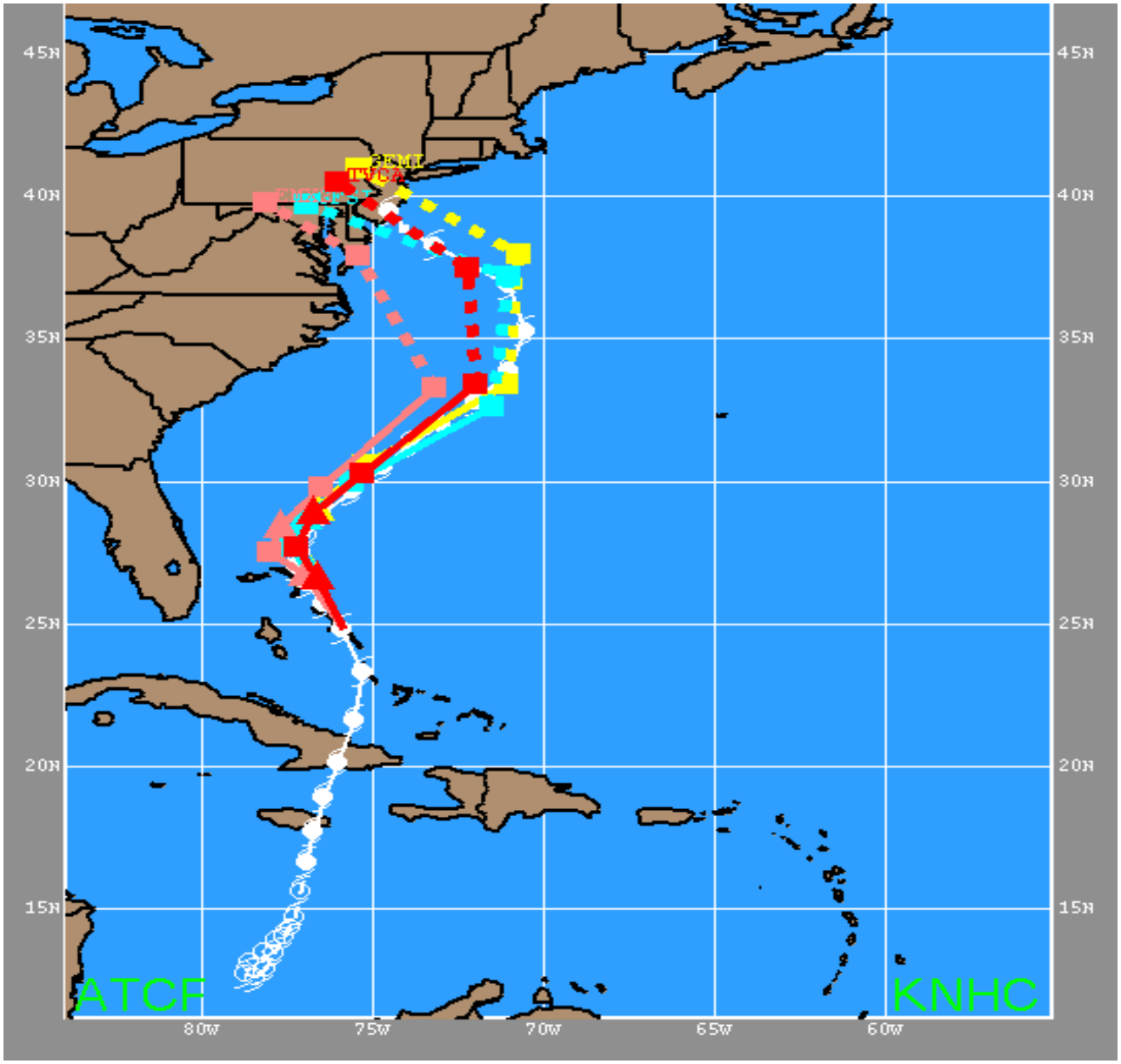
ECMWF

GFS

GFS Ensemble

Consensus

Model Guidance for Sandy– 4 days before landfall

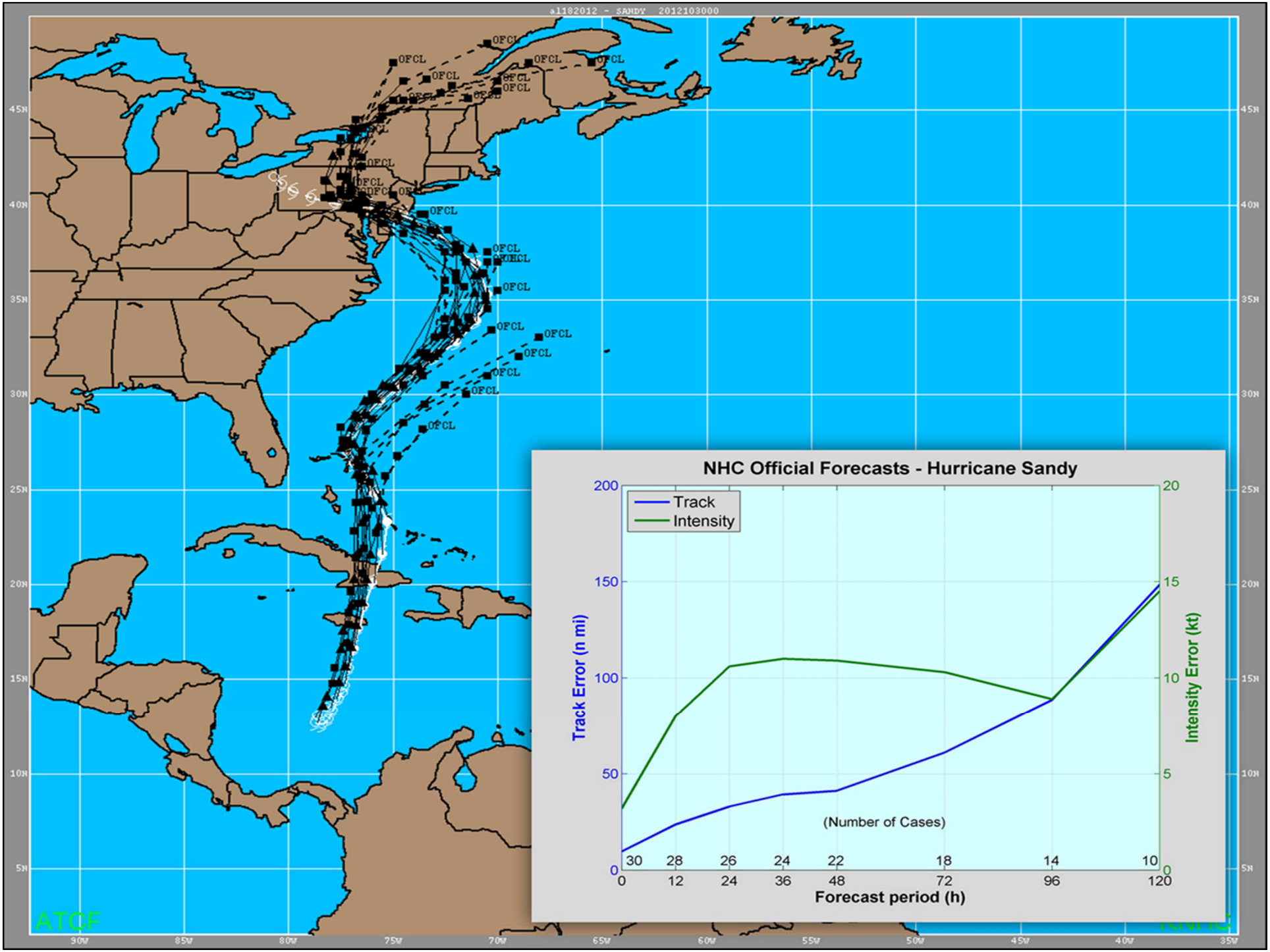


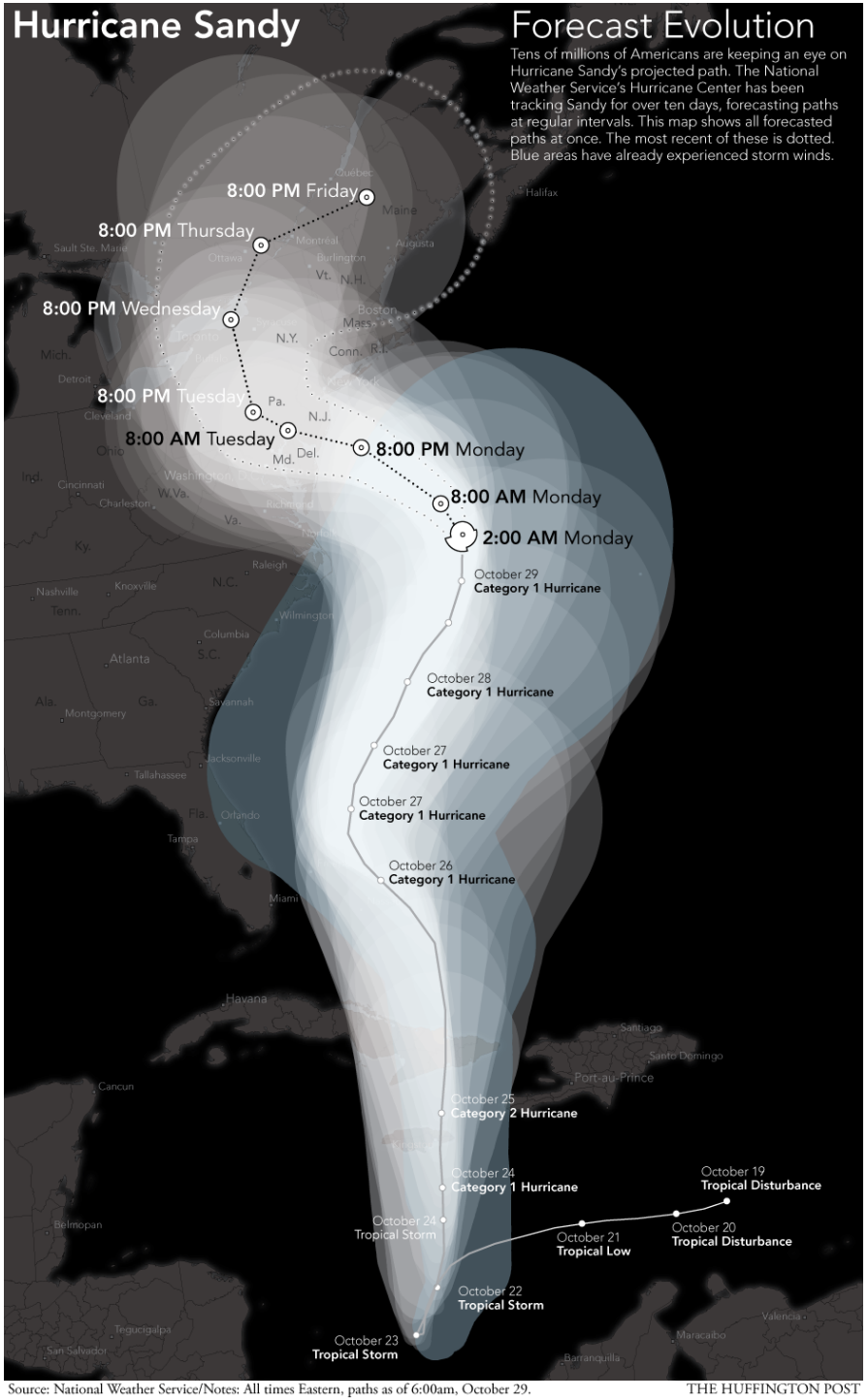
ECMWF

GFS

GFS Ensemble

Consensus


al182012 - SANDY 2012103000
OFCL
ATCF
NHC Official Forecasts - Hurricane Sandy
Track
Intensity
Track Error (n mi)
Intensity Error (kt)
(Number of Cases)
30 28 26 24 22 18 14 10
0 12 24 36 48 72 96 120
Forecast period (h)

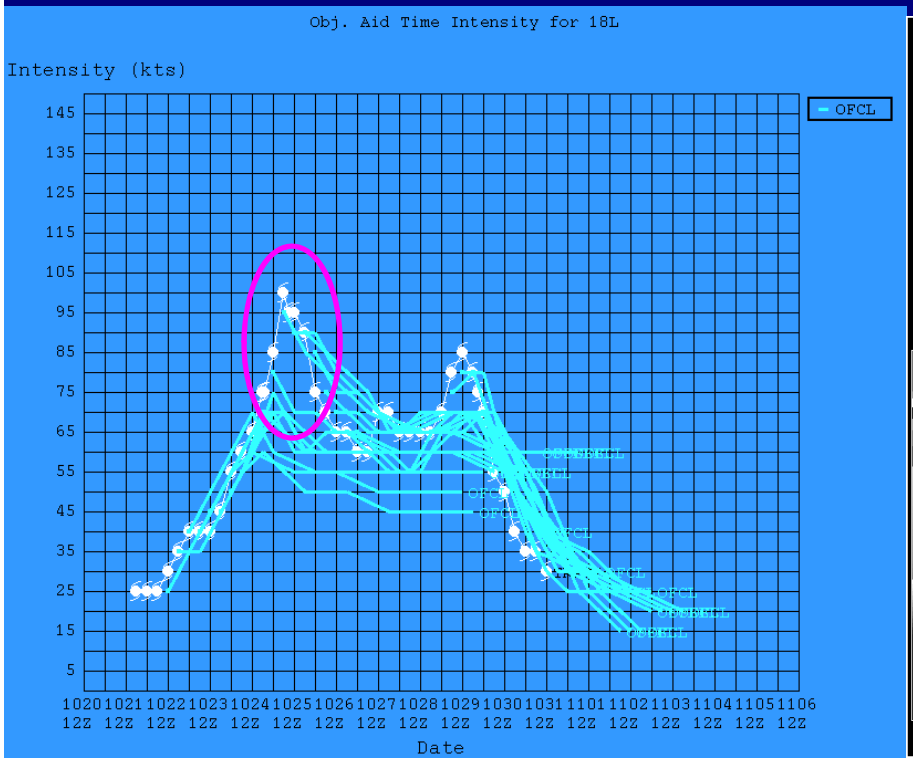


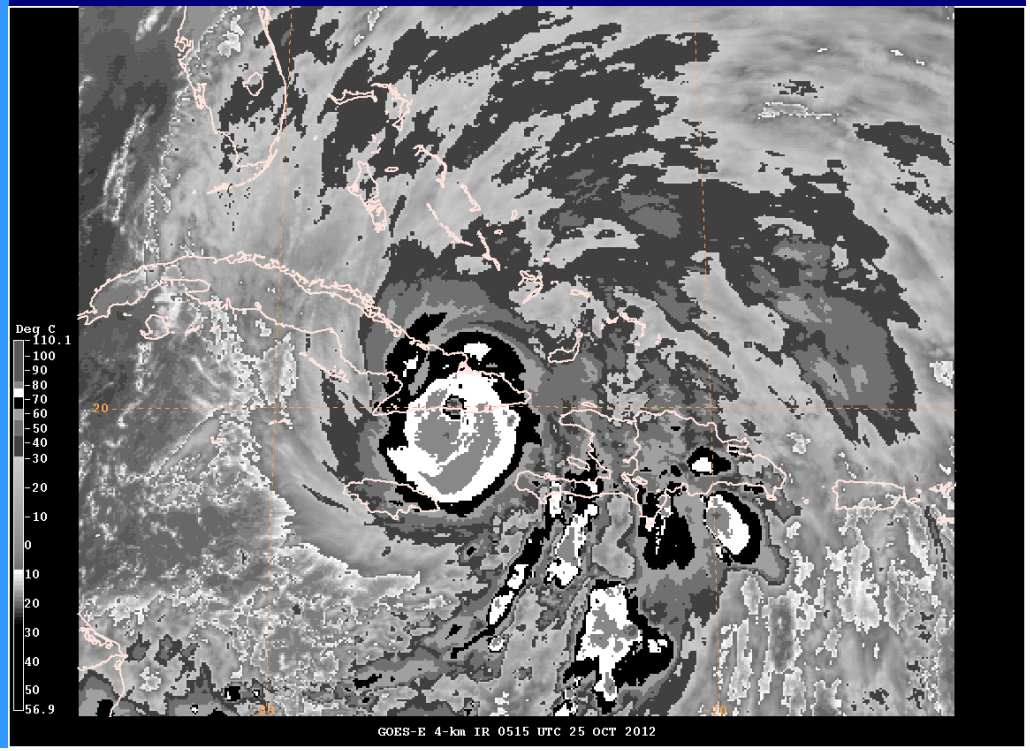
Source: National Weather Service/Notes: All times Eastern, paths as of 6:00am, October 29.

THE HUFFINGTON POST

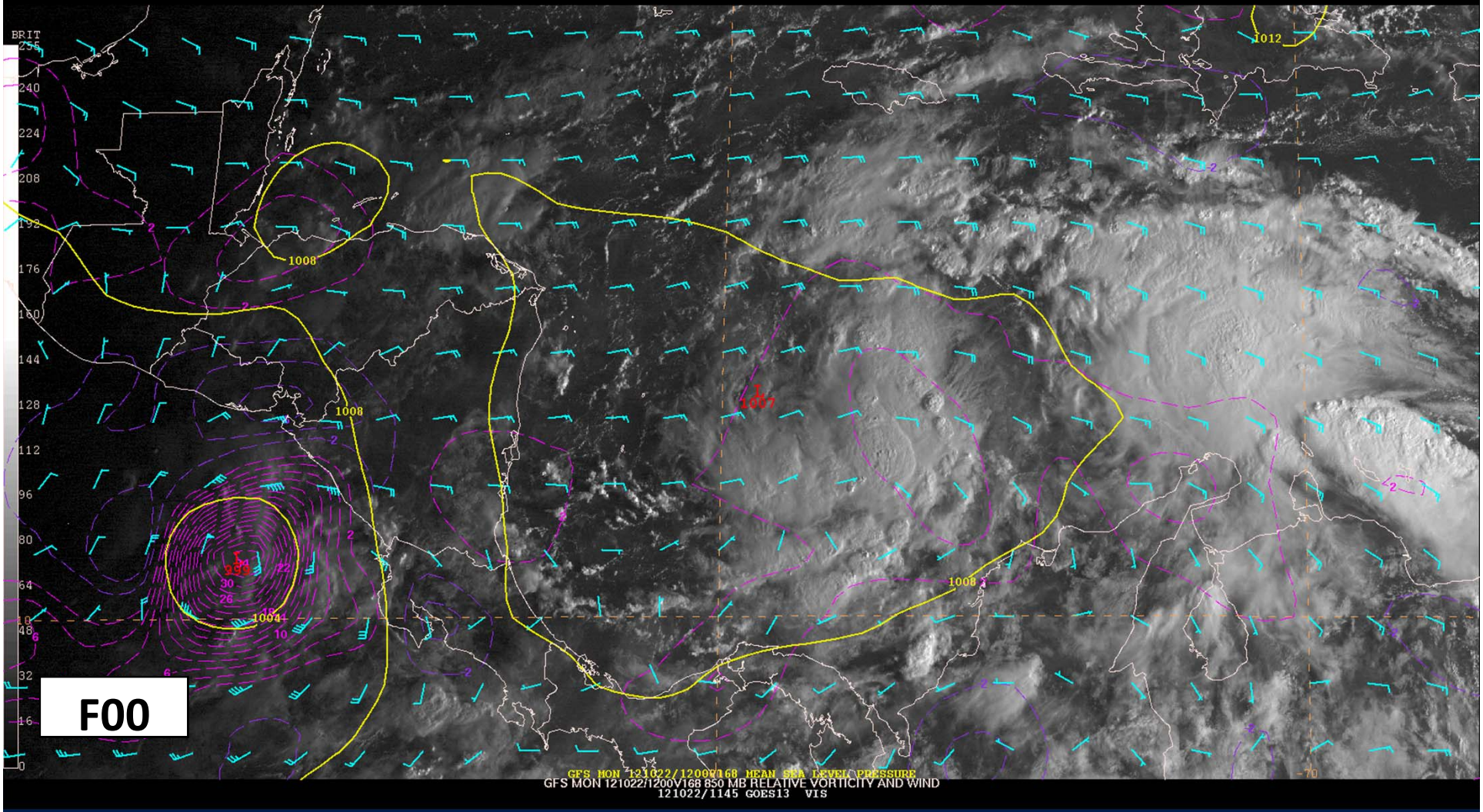
Rapid Intensification: A Recurring Challenge

- Sandy intensified rapidly between Jamaica and Cuba, and this was poorly forecast.
- Despite ongoing efforts (e.g. the Hurricane Forecast Improvement Program), forecasting rapid intensification remains a major problem.





Sandy – GFS Forecasts Valid 12Z 22 October 2012



At genesis Sandy had winds of 30 kt and a central pressure of 1002 mb

Challenge – Warnings for Sandy

- Cyclone type and the associated transitions are ‘shades of grey’ or continuum issues.
- Operational handling of cyclone types is a ‘black and white’ or ‘yes or no’ response – tropical cyclone (TC) warnings or non-tropical gale/storm warnings.
- This situation can lead to issues and inconsistencies in the warning process, response, and climatology.
- But, if *you* get hit by 75 mph winds, 10 ft above normal tides, and/or 12 in of rain, does the nature of the system really matter?

