Natural Hazards and Disaster

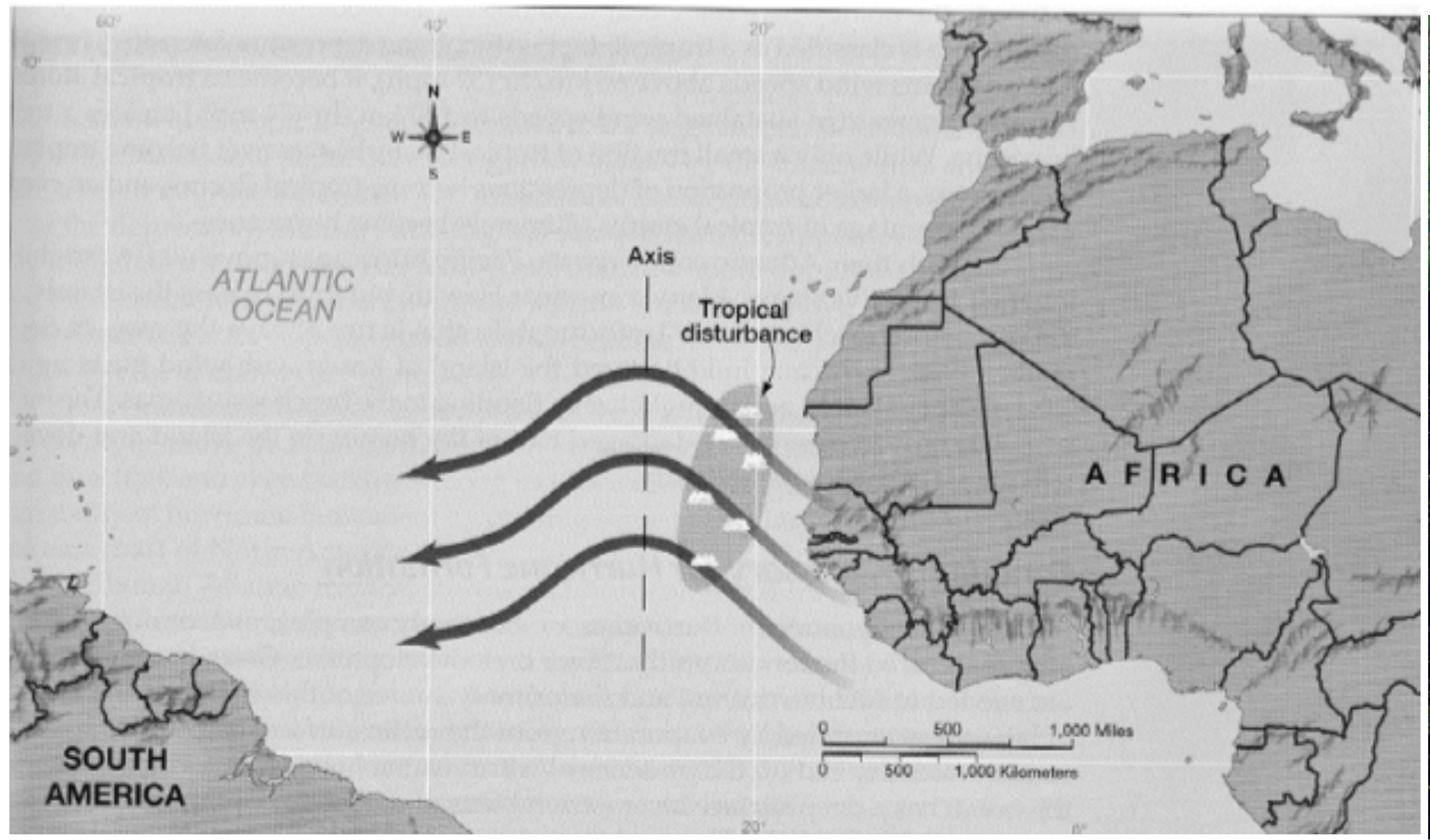
MITIGATION & ADAPTATION RESEARCH INSTITUTE MARI OLD DOMINION UNIVERSITY

Lab 9: Hurricanes, Typhoons, Cyclones

- Where is Sandy?
- Which was worst?
- Hurricane tracking
- Hurricane return period

Lab Hurricane, Typhoons, Cyclones

North Atlantic hurricanes and their southern Pacific Ocean equivalents, called typhoons, have often caused immense damage and significant loss of life. Hurricane prediction and tracking is therefore one of the most important aspects of weather forecasting, and hurricane preparedness is a critical factor for all residents of U.S. A.'s coastal communities. Hurricane formation begins with rising warm air over warm ocean water, which causes the atmospheric pressure in that region to fall and generates waves in the atmosphere, known as tropical waves. Winds are attracted into the low pressure centers, where Earth's Coriolis effect causes a counterclockwise wind circulation, called cyclonic circulation. Ocean water off the west coast of Africa is warmest in summer and autumn, and therefore the North Atlantic hurricane season officially begins on June 1 and ends on November 30, although hurricanes can and do occur well outside of that time range when seawater temperatures are warm enough.



Left : Tropical waves in the atmosphere are generated above warm ocean water off the African coast.
Right : Satellite view of Hurricane Fran off the Florida coast in September 1996.

A Tropical Disturbance occurs when systematically organized clouds form above a low pressure zone. The system is called a Tropical Depression when the wind speeds are below 65 km/h. When wind speeds reach, and are sustained, at 65 km/h or more, the cyclonic circulation is called a Tropical Storm. When sustained wind speeds exceed 118 km/h, the storm is officially called a hurricane and at this stage the clouds form the characteristic spiral hurricane structure.

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The intensity of a hurricane, sometimes referred to as its strength, is assessed from its lowest atmospheric pressure reached, measured in hPa (1 millibar = 1 hPa). The category ascribed to a hurricane is based on its maximum wind speeds, which must be sustained for at least one minute, using the Saffir-Simpson scale.

For some of the below exercises, the websites provide wind speeds in knots (kt, or also written as kn). One knot (1 kt) = 1.85 km/h = 1.15 mph

Most of the damage caused by hurricanes is not directly caused by the high winds themselves, but by the storm surge that the winds generate and, occasionally, from tornadoes that are spawned in the trailing edge of the storm system.

Saffir-Simpson Hurricane Wind Scale

Hurricane Category	Peak 1-min sustained Wind Speeds (mph)	Peak 1-min sustained Wind Speeds (km/h)	Damage
1	74-95	119-153	Minimal
2	96-110	154-177	Moderate
3	111-130	178-209	Extensive
4	131-155	210-249	Extreme
5	>155	>249	Catastrophic

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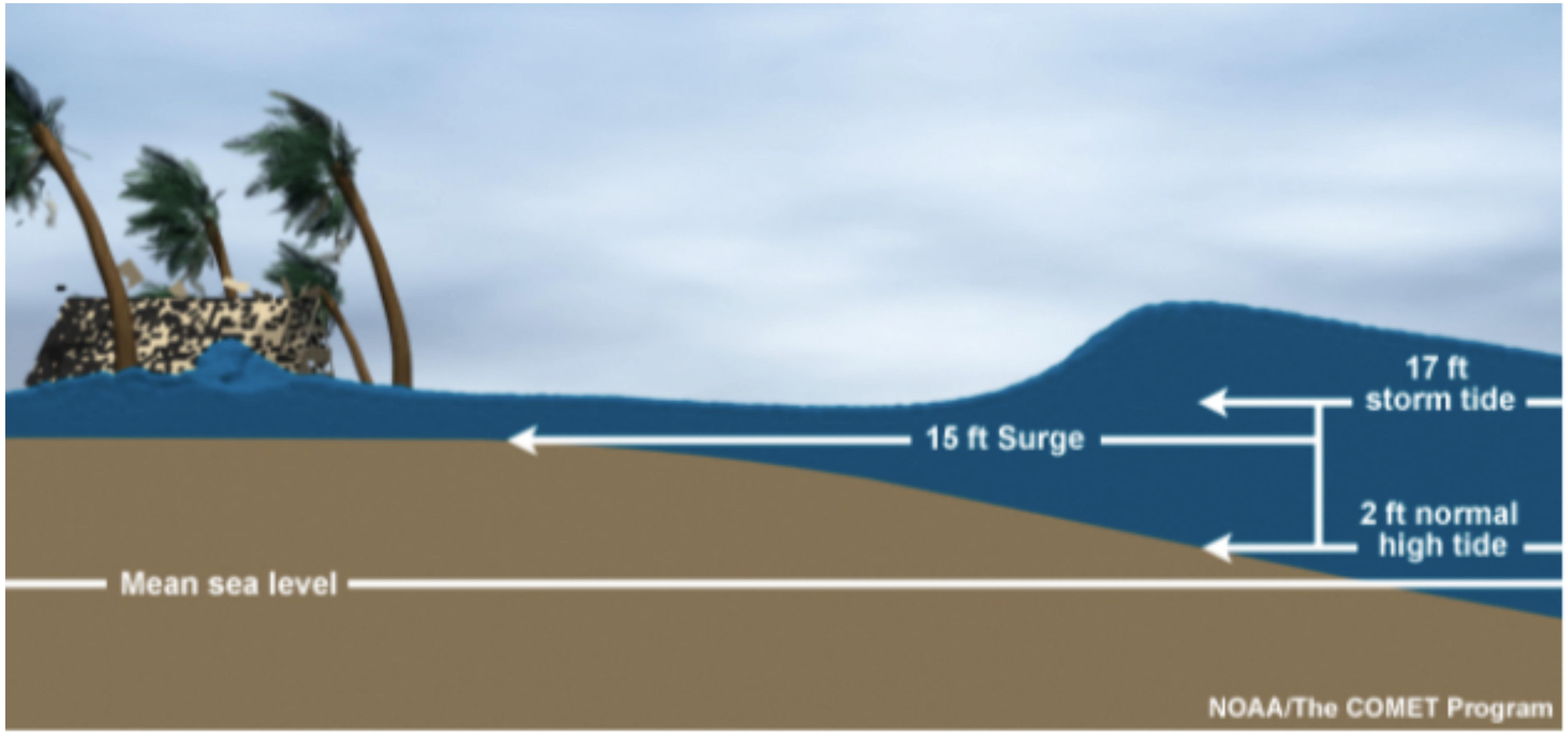
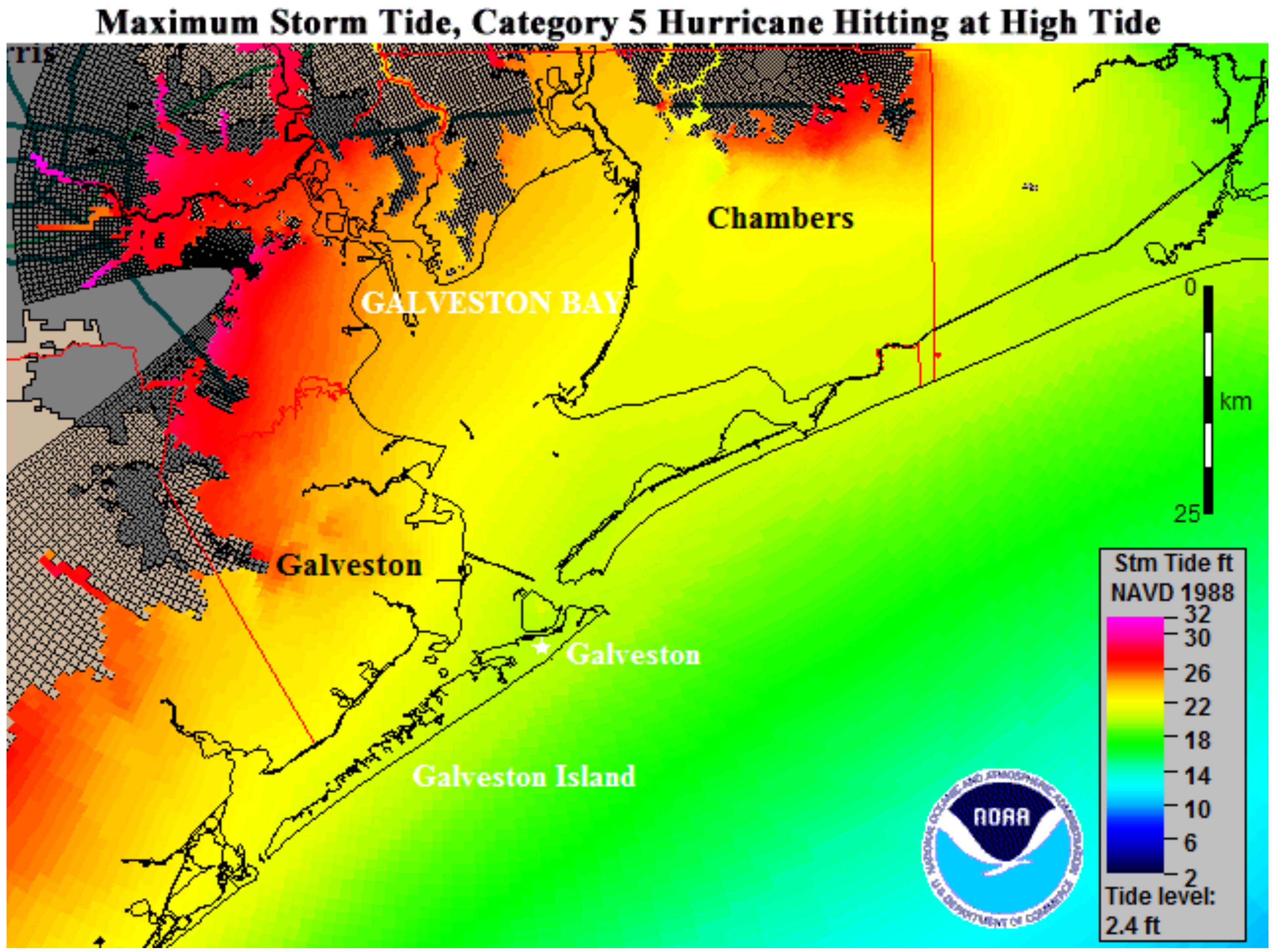
Storm surge is the rise in local coastal sea level caused by the storm's high winds. The storm's low atmospheric pressure center does contribute to the total rise in sea level, but only by a very small amount compared to the surge caused by the wind. Storm surge water can travel tens of km inland in low-lying coastal regions such as along the Texas, Louisiana, and Florida coasts.



Wind-driven storm surge and storm tide.



Computer model of "worst case" storm tide scenario of a category 5 hurricane hitting Galveston, TX at high tide. Not only the city of Galveston, but much of Houston's southeastern suburbs would be inundated by up to 30 ft (10 m) of storm tide water.

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Storm tides occur when the storm surge coincides with the astronomical high tide. Thus the worst possible situation for coastal communities is when a hurricane makes landfall at high tide. Unfortunately, there is no simple way to link storm surge with hurricane category.

- Hurricane Katrina (category 3 at landfall) generated an 8.5 m storm surge, which resulted in catastrophic damage when the levees of Lake Pontechrain were breached;
- Hurricane Ike (category 2 at landfall) produced a 6 m storm surge;
- Hurricane Charley (category 4 at landfall) produced a modest, although nonetheless damaging, 2 m storm surge.

Several factors affect the amount of storm surge that a hurricane will produce:

- Low or high tide at the time of landfall
- Slope of the ocean bottom at the position of landfall (shallow slope = greater surge)
- Speed of the storm's approach
- Wind strength on landfall (atmospheric pressure and/or category)
- Size (diameter) of the storm system
- Coastline shape
- Presence or absence of barrier islands
- Angle of storm's approach to the coastline (head-on or glancing angle)

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Lists of the top 20 hurricanes from 1880 to 2008, according to different ranking systems.

Rank	Cyclone name	Season	Peak 1-min sustained wind speeds	Minimum Central Pressure
	Top 20 Atlantic Hurricanes Ranked by Minimum Pressure			
1	Wilma	2005	295 km/h (185 mph)	882 hPa (26.05 inHg)
2	Gilbert	1988	295 km/h (185 mph)	888 hPa (26.22 inHg)
3	Labor Day	1935	295 km/h (185 mph)	892 hPa (26.34 inHg)
4	Rita	2005	285 km/h (180 mph)	895 hPa (26.43 inHg)
5	Allen	1980	305 km/h (190 mph)	899 hPa (26.55 inHg)
6	Camille	1969	280 km/h (175 mph)	900 hPa (26.58 inHg)
7	Katrina	2005	280 km/h (175 mph)	902 hPa (26.64 inHg)
8	Mitch	1998	285 km/h (180 mph)	905 hPa (26.72 inHg)
9	Dean	2007	280 km/h (175 mph)	905 hPa (26.72 inHg)
10	Ivan	2004	270 km/h (165 mph)	910 hPa (26.87 inHg)
11	Cuba	1924	270 km/h (165 mph)	910 hPa (26.87 inHg)
12	Janet	1955	280 km/h (175 mph)	914 hPa (26.99 inHg)
13	Isabel	2003	270 km/h (165 mph)	915 hPa (27.02 inHg)
14	Cuba	1932	280 km/h (175 mph)	915 hPa (27.02 inHg)
15	Opal	1995	240 km/h (150 mph)	916 hPa (27.05 inHg)
16	Hugo	1989	260 km/h (160 mph)	918 hPa (27.11 inHg)
17	Gloria	1985	230 km/h (145 mph)	919 hPa (27.14 inHg)
18	Hattie	1961	260 km/h (160 mph)	920 hPa (27.17 inHg)
19	Floyd	1999	250 km/h (155 mph)	921 hPa (27.20 inHg)
20	Andrew	1992	280 km/h (175 mph)	922 hPa (27.23 inHg)

Notes:

a) Hurricane categories are given for the time of landfall. Hurricane peak wind speeds are the storm's maximum and not necessarily the same as at the time of landfall.

b) The current naming of hurricanes, using alternating male and female names, did not begin until 1953. Prior to 1953, storms were named for the time of year, state, or specific location that suffered the most severe damage.

c) Fatality numbers for events (see next slide) between 1875 and 1930 are considered underestimates.

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Lists of the top 20 hurricanes from 1880 to 2008, according to different ranking systems.

Top 20 Atlantic Hurricanes Ranked by Damages in U.S. $

Rank	Cyclone name	Season	Category	Damage estimate (billions $)
1	Katrina	2005	3	108
2	Ike	2008	2	29.5
3	Andrew	1992	5	26.5
4	Wilma	2005	3	21.0
5	Ivan	2004	3	18.8
6	Charley	2004	4	15.1
7	Rita	2005	3	12.0
8	Frances	2004	2	9.5
9	Allison	2001	0 (T.S.)	9.0
10	Jeanne	2004	3	7.7
11	Hugo	1989	4	7.0
12	Floyd	1999	2	6.9
13	Isabel	2003	2	5.4
14	Opal	1995	3	5.1
15	Gustav	2008	2	4.6
16	Fran	1996	3	4.1
17	Georges	1998	2	2.8
18	Dennis	2005	3	2.5
19	Frederic	1979	3	2.3
20	Agnes	1972	1	2.1

Top 20 Atlantic Hurricanes Ranked by Fatalities

Rank	Cyclone name	Season	Category	Fatalities
1	Galveston, TX	1900	4	8,000
2	Lake Okeechobee, FL	1928	4	2,500
3	Katrina	2005	3	1,200
4	Cheniere Caminanda, LA	1893	4	1,100
5	Sea Islands, GA/SC	1893	3	1,000
6	unnamed GA/SC	1881	2	700
7	Audrey	1957	4	416
8	Florida Keys	1935	5	408
9	Last Island, LA	1856	4	400
10	Miama. FL	1926	4	372
11	Grand Isle, LA	1909	3	350
12	Florida Keys & TX	1919	4	287
13	New Orleans	1915	3	275
14	Galveston, TX	1915	4	275
15	unnamed New England	1938	3	256
16	Camille	1969	5	256
17	Diane	1955	1	184
18	unnamed GA, NC, NC	1898	4	179
19	unnamed TX	1875	3	176
20	unnamed SE FL	1906	3	164

EXERCISE 1: Where is Sandy?

Hurricane Sandy, which had a devastating effect on the New Jersey and New York coast in 2012, is not on any of these charts because they only go to 2008.

A. Indicate clearly on each of the three lists above where Sandy would be placed. You can use the document provided by the National Hurricane Center at http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf or do an internet search as needed to find the relevant data.

B. Add the information that you find to each list in its appropriate position.

20 Points

EXERCISE 2: Which was the worst? (working in teams of 3 or 4 is recommended)

Review the three data tables above and answer the following questions:

A. Describe the relationship, if any, between a hurricane's strength and the damage and/or deaths that it caused.

B. Since 1950, which have been the top three seasons (in ranked order) for hurricane disasters in terms of total damages?
1. Season __________ combined total damages = _________ billions US dollars
2. Season __________ combined total damages = _________ billions US dollars
3. Season __________ combined total damages = _________ billions US dollars

C. Discuss the correlation, if any, between your answers in B and the most fatalities caused in each of the same 3 years.

D. What factors could produce more damage and/or deaths from a "weaker" or lower category storm?

E. What are some of the reasons why the estimates of fatalities and damages in the older records may be less accurate than for the more recent events?

50 Points

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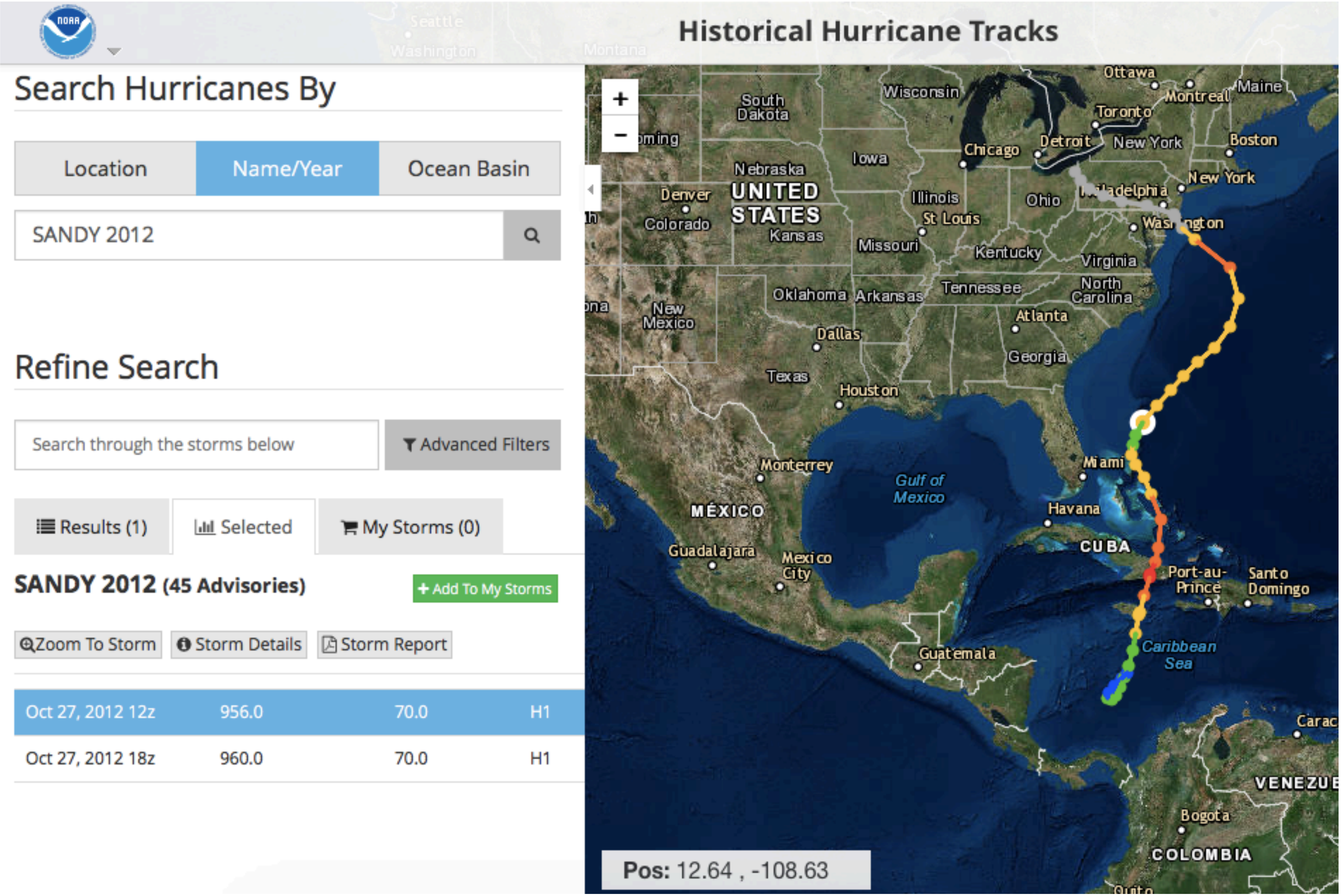

EXERCISE 3: Hurricane Tracking (working in pairs is recommended)

A. Load the NOAA hurricane website http://coast.noaa.gov/hurricanes/. Type Sandy 2012 into the Search by Name/Year window. You should see a window similar to the one in the previous slide. Hover the mouse over the hurricane tracks; observe that the data for each position is shown on the left half of the window.

i. How many hours apart are the positions on the storm's track for the majority of its progress? __________hours apart

ii. What was the highest category reached by Sandy, and where was it at the time?
Category ___ Position (lat; lon) _________ Nearest geographic locality_______

iii. What was the Sandy's wind speed in km/h when it made landfall in Atlantic City? Wind speed = ________km/h

iv. Use the "Search by Location" window to search for Norfok, Va, and reduce the search area to 15 km. How many severe storms are listed? __________storms

v. How many of the listed storms for this area were at hurricane strength? _________ hurricanes

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EXERCISE 3: Hurricane Tracking (continued)

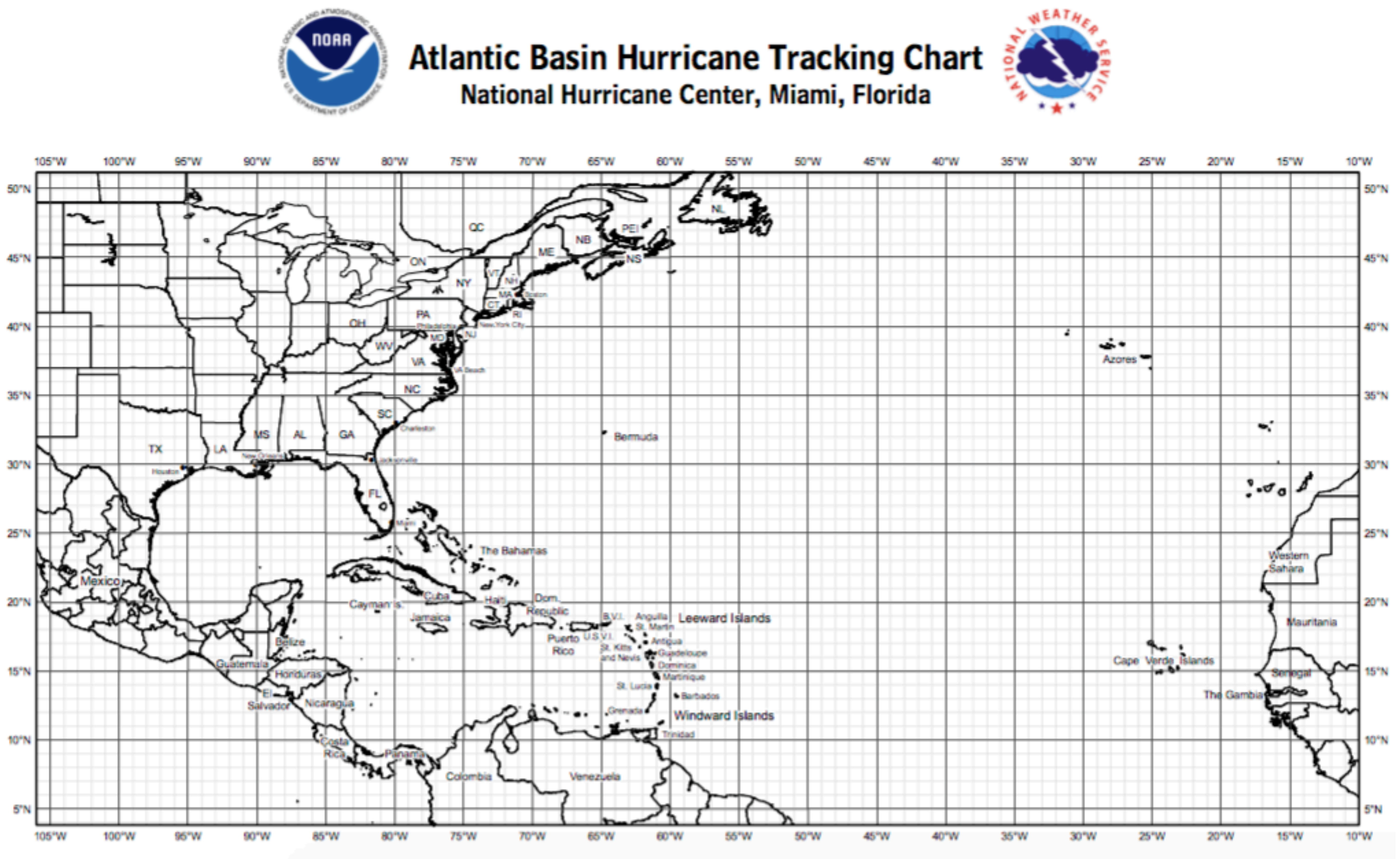
B. Search the NOAA hurricane website http://coast.noaa.gov/hurricanes/ for the hurricane Isabel 2003. Use the hurricane tracking chart below and the data provided on the website to plot the track of Isabel's eye at noon each day, from September 11, 2003 to September 19, 2003. Label each point with its date (9/11, 9/12, etc.).

i. Over which 24 hour period did the storm move forward the fastest? _________

ii. Over which 24 hour period was the hurricane's wind speed at its maximum?_______

iii. If the answers to (i) and (ii) are not the same, explain why they differ.

iv. Hurricane Isabel passed well to the south of Norfolk, and yet it caused extreme flooding and power outages throughout this region. Why? (hint: think about the storm's rotation and the wind direction before, during and after landfall).



50 Points

EXERCISE 4: Hurricane return periods

NOAA's National Hurricane Center has assembled records of all major storms that have impacted coastal U.S.A. since the late 1800's. From these records they have determined the average return period (also known as the recurrence interval) for the different categories of hurricanes. On the next slide are two of these charts, each made in 2011, for Category 1 and Category 3 hurricanes, respectively. Numbers inside the

A. Locate and label the cities of Galveston, New Orleans, and Norfolk on each of the maps. You may use GoogleEarth or any map application – or even an atlas (!) – if you are not certain of the exact location.
i. What is the estimated return period for a Category 1 hurricane for the City of Galveston? ___________ years
ii. What is the estimated return period for a Category 3 hurricane for the City of New Orleans? _____________years

B. Why are the regions with green circles around the Gulf Coast considered less likely to have a hurricane landfall than the regions with red circles?

C. How frequently can the citizens of Norfolk expect to see:
i. A Category 1 hurricane? on average every ___________ years
ii. A Category 3 hurricane? on average every ___________ years

40 Points

D. Discuss what the citizens of Hampton Roads might do to prepare for the next hurricane.

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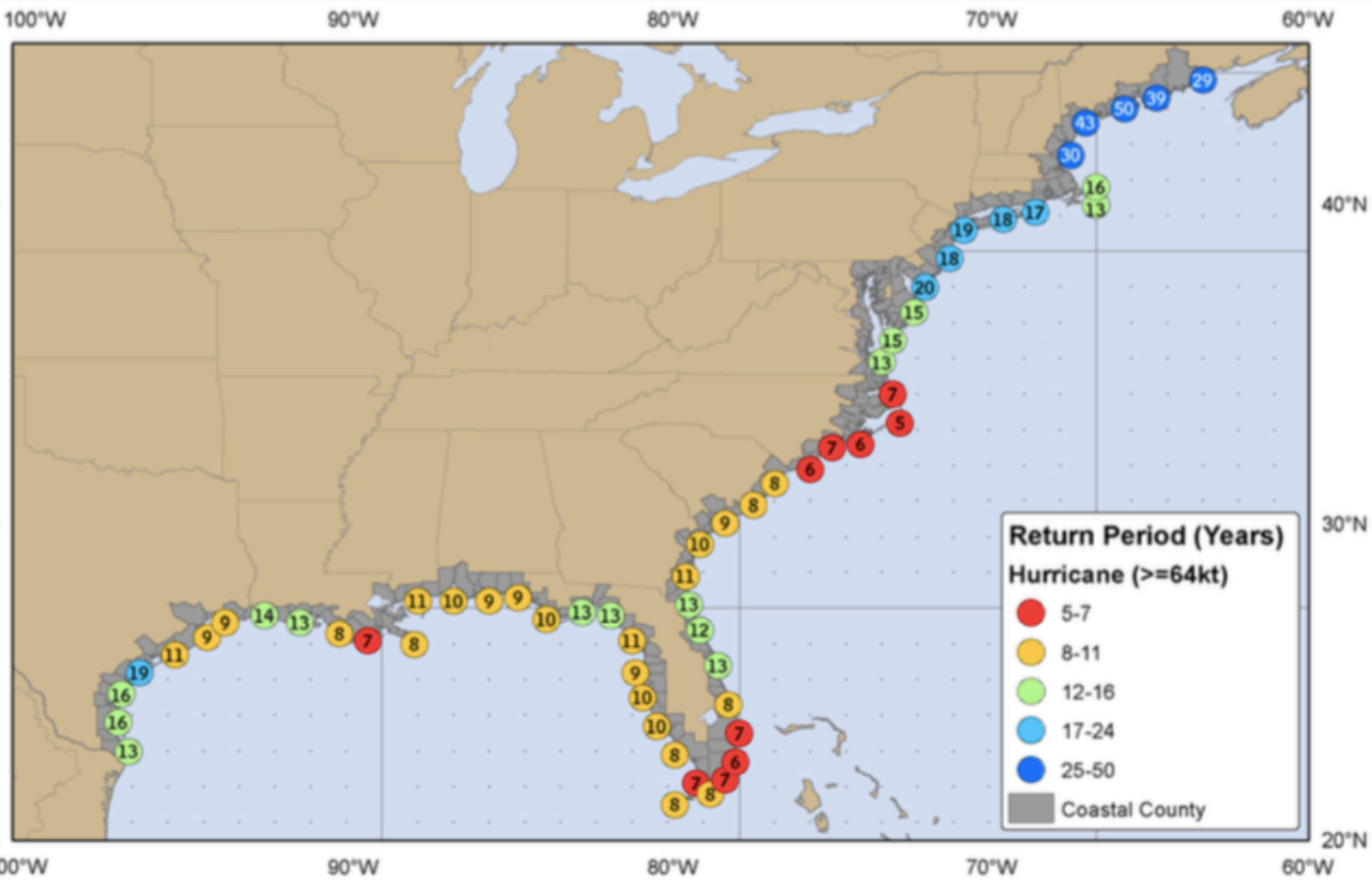
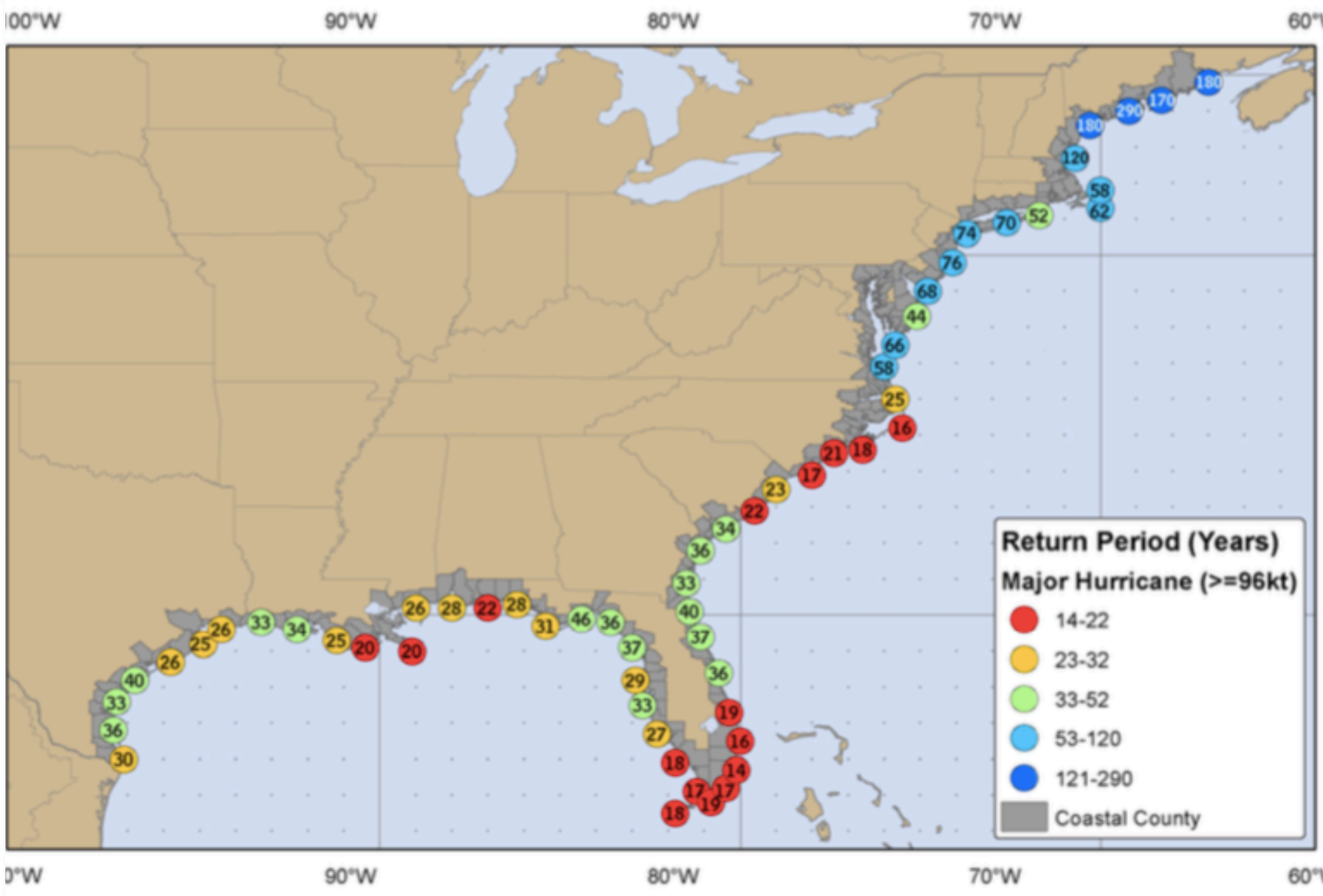


Category 1



Category 3