Module 12 - Lecture 35

In this Lecture, we will continue our discussion of hurricanes. The picture below is of Hurricane Katrina making landfall on August 29, 2005 http://www.katrina.noaa.gov/satellite/satellite.html.

On average, hurricanes kill 20 people per year in the United States and cause about $5 billion worth of damage. As the table below indicates, there are exceptional years such as 2005 when the death and damage totals greatly exceed the average values (data are from www.economics.noaa.gov)

Year	Deaths	Total Damage (billion $)
2000	0	< 1
2001	24	6.5 B
2002	51	1.7 B
2003	14	2.3 B
2004	34	22.9 B
2005	1016	107.5 B
2006	0	< 1
2007	1	< 1
2008	11	7.9 B
2009	2	< 1
2010	0	< 1

Of course, 2005 was the year hurricane Katrina hit New Orleans. Three of the ten strongest hurricanes ever observed in the north Atlantic occurred in 2005. Wilma was the strongest and the new record holder, Rita was the fourth strongest and Katrina the sixth strongest. The deadliest hurricane in US history is the 1900 Galveston hurricane which caused 6000 - 12,000 deaths. The Great Hurricane of 1780 killed over 20,000 people in the Lesser Antilles. Historic rainfall amounts (75 inches perhaps in some locations) and flooding associated with Hurricane Mitch (1998) killed over 19,000 people in Honduras, Guatemala, and Nicaragua.

The Saffir Simpson Scale, which ranges from 1 to 5, is used to rate hurricane intensity in the same way that the Fujita Scale is used for tornadoes. A hurricane must have winds of 74 miles per hour or above to be considered a hurricane. Categories 3, 4, and 5 are considered "major hurricanes". In other parts of the world the term "super typhoon" is used for Category 4 or 5 typhoons.

SAFFIR SIMPSON SCALE

Category	Pressure (mb)	Winds (MPH)	Storm surge (ft.)
1	980 - 994	74 - 95	4 - 5
2	965 - 979	96 - 110	6 - 8
3	945 - 964	111 - 130	9 - 12
4	920 - 944	131 - 155	13 - 18
5	< 920	> 155	> 18

major hurricane

Here is an easy-to-remember version of the scale. The pressure decreases by 20 mb, wind speeds increase by 20 miles per hour, and the storm surge increases by 5 feet with every category change on the scale.

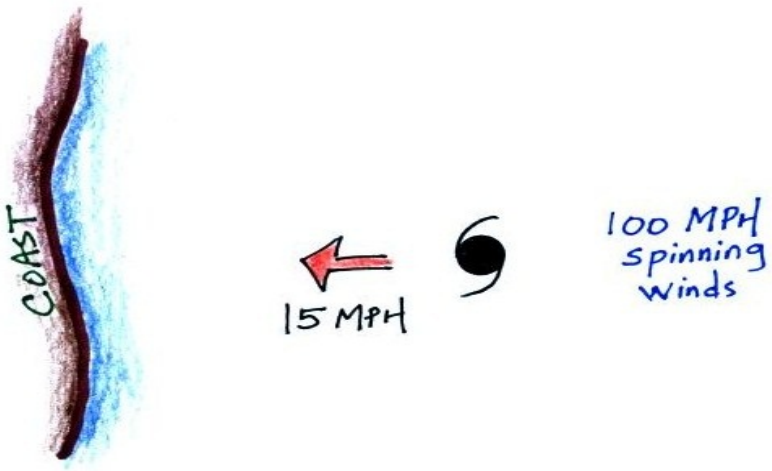
Simplified, easy-to-remember version

Category	Pressure (mb)	Winds (MPH)	Storm surge (ft.)
1	> 980	75 - 95	< 5
2	960 - 980	95 - 115	5 - 10
3	940 - 960	115 - 135	10 - 15
4	920 - 940	135 - 155	15 - 20
5	< 920	> 155	> 20

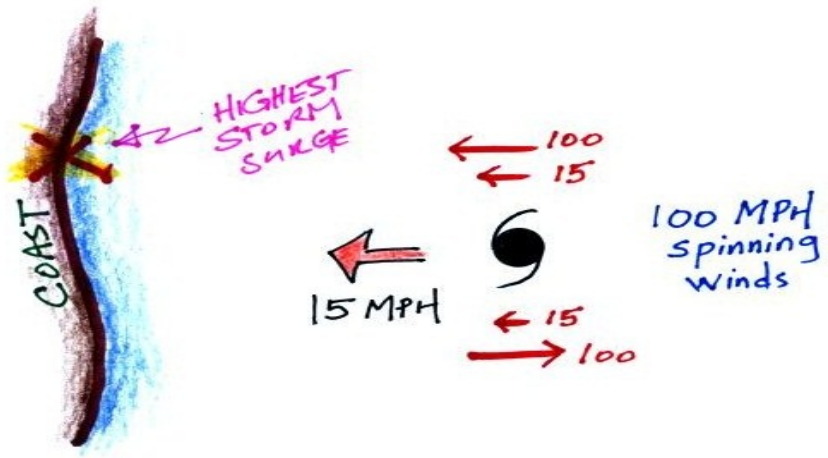
The storm surge is a rise in the ocean level when a hurricane makes landfall. It causes the most damage and the greatest number of fatalities near a coast. The converging surface winds associated with hurricanes sweep surface water in toward the center of a hurricane and cause the water to pile up. The water sinks and, in deeper water, returns to its point of origin. As the hurricane approaches the shore, the ocean becomes shallower and the piled up water becomes deeper. Return currents also become stronger.

The National Weather Service has developed the SLOSH computer model to predict the height and extant of a hurricane storm surge (SLOSH stands for Sea, Lake, and Overland Surges from Hurricanes). You can see some animations of SLOSH predictions for hurricanes of historical interest (including the Galveston 1900 hurricane) at the National Hurricane Center website http://www.nhc.noaa.gov/surge.

You will notice the highest surge is not where the center of the hurricane makes landfall. We can use the figure below to understand why this is true. A hurricane is approaching a north-south oriented coast from the east at 15 miles per hour. The winds are spinning in a counterclockwise direction at 100 miles per hour around the center of the hurricane.



Will the fastest winds be on the north, south, east or west side of the hurricane? The fastest winds will be on the north side, because the direction of motion and the direction of the winds are both in the same direction, so that the winds are blowing straight toward the coast at 115 miles per hour. On the south side, the winds are pointing opposite the direction of motion. Now you subtract the speed of motion from the wind speed. The winds are 85 miles per hour and are blowing away from the coast on the south side of the hurricane. Once a hurricane moves onshore the winds weaken rapidly. The greatest threat then becomes flooding from the tremendous amounts of rain that a hurricane can produce. Tornadoes are also a danger.



One of the reasons the 1900 Galveston hurricane was so deadly was that without radar and weather satellites, it was not possible to provide much advance warning of its approach. Meteorologists depended on surface observations of pressure, winds, and ocean waves. Now the National Hurricane Center can monitor the development, direction of motion, and strengthening as tropical storms move across the Atlantic and issue watches and warnings as needed. Watch and warning lead times of 36 and 24 hours were used prior to the 2010 hurricane season.

	Tropical Storm	**Hurricane**	**Comments**
Watch	Tropical storm conditions are possible within the specified coastal area within 48 hours	Hurricane conditions are possible within 48 hours. Issued 48 hours before the expected start of tropical storm strength winds	People in the watch area should obtain supplies, secure their homes and be prepared to evacuate
Warning	Tropical storm conditions are expected within 36 hours or less.	Hurricane conditions are expected within the specified coastal area. Issued 36 hours before the expected onset	

		of tropical storm strength winds.	

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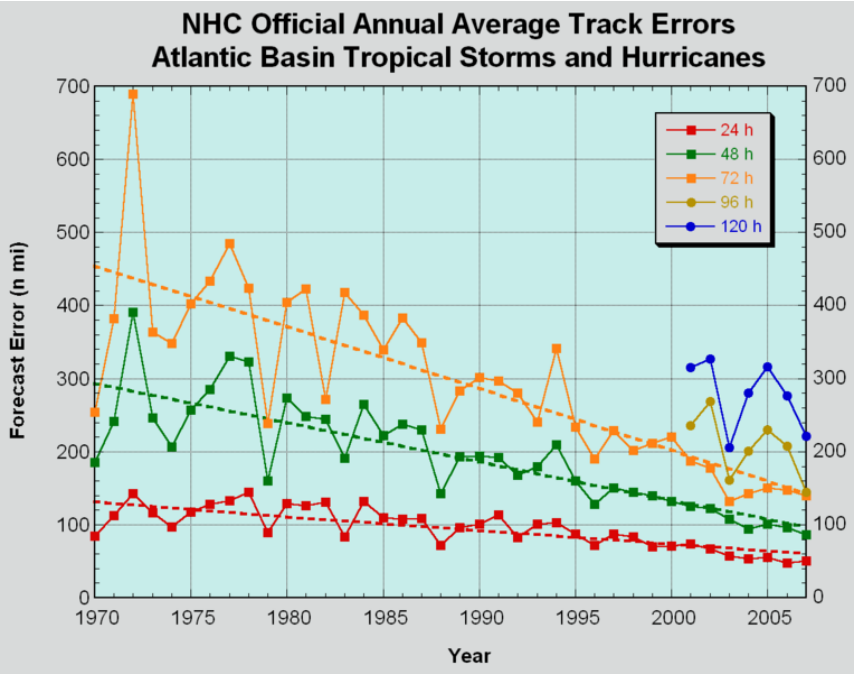
Predicting the future path of a hurricane is difficult because hurricane movement is affected by nearby weather systems and the ocean. This figure shows that there has been a considerable reduction in the forecast errors. Predicting changes in the intensity of a hurricane remains difficult.



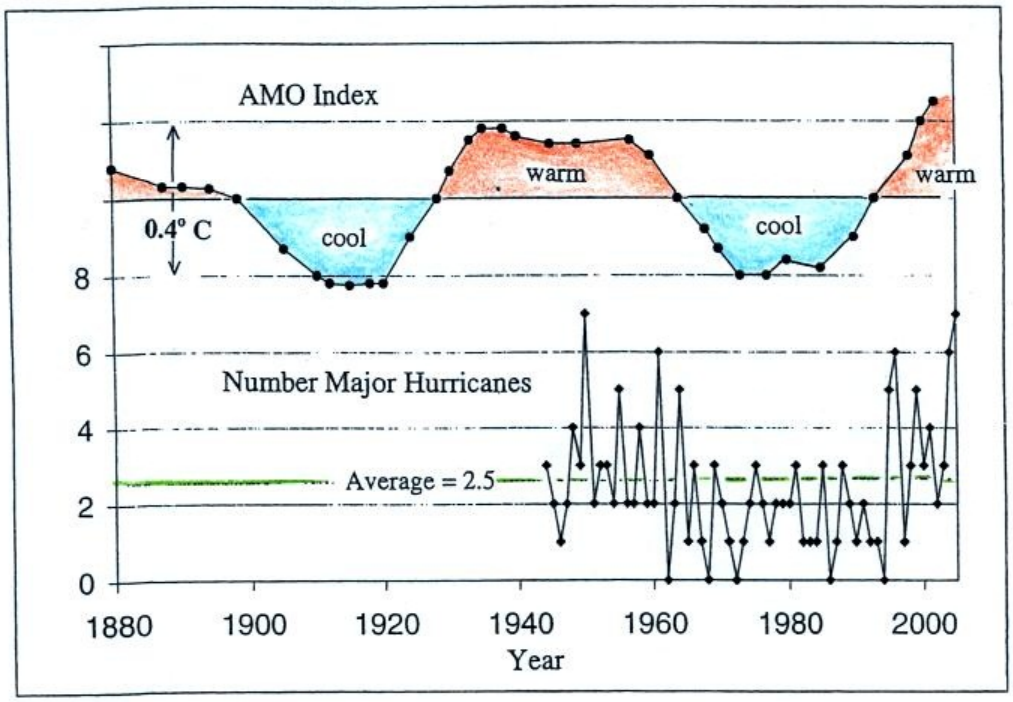
Some researchers also try to forecast how active the upcoming hurricane season will be. Probably the best known forecast of this type is issued by Dr. William Gray from Colorado State University. You can look at the latest predictions here.

We have mentioned that 2005 was a record breaking year for north Atlantic hurricanes. There were 28 named storms (tropical storms or hurricanes) which easily beat the old record of 21 named storms in a year. The pool of available names became exhausted and the last few hurricanes were named with Greek characters. The most intense north Atlantic hurricane ever (Wilma) occurred in 2005. Hurricane Katrina was the third most intense Atlantic hurricane to hit the US mainland. The 1935 Labor Day hurricane and Hurricane Camille (1969) are still the first and second most intense hurricanes on record. Hurricane Andrew (1992) is fourth. Hurricane Katrina became (easily) the most costly natural disaster in US history.

There is a tendency to blame an unusual year like 2005 on global warming. We have seen that there has been a small increase in global average surface temperatures over the past 150 years. The world's oceans also appear to have warmed. We know that hurricanes form over

warm ocean water, so it is reasonable to expect that warmer oceans might produce more frequent and more intense hurricanes.

In the Atlantic, there does seem to be a pretty good correlation between the Atlantic Multidecadal Oscillation (AMO) Index, which is a measure of sea surface temperature, and the frequency of major hurricanes. Greater than average numbers of major hurricanes tend to occur during warm periods of the AMO Index and vice versa. The correlation is not quite as apparent when the total number of hurricanes is plotted. We only have reliable hurricane frequency data for a limited period of time that satellites have been able to monitor hurricane development over the oceans. This is probably not enough data to know whether or not global warming will have an effect on hurricane frequency. Globally there are about 90 tropical cyclones per year and this number does not seem to have changed significantly over the past 40 to 50 years.



At one point, scientists thought that there might be a recent increase in hurricane intensity that could be tied to global warming. But more recently scientists have come to question that conclusion. One recent article suggests that climate change might decrease the global hurricane frequency. However, hurricanes that do form could be more intense and produce more rain. It seems clear that we will need several more decades of hurricane data before we can determine whether global warming has an effect on hurricane frequency or intensity.