Oceans – Powering Hurricanes

How do Hurricanes Form?

Storm Surge – What is it?

Reading: 8.17-8.24

Graphic: Cyclones Olaf (cat 5) and Nancy, in the vicinity of Samoa, February 22, 2005, courtesy of MODIS Rapid Response Team, NASA/GSFC.

Oceans – Breeding Ground for Hurricanes

Hurricanes get their energy from warm, humid air that forms over the warm waters of the tropical oceans

Hurricane season = summer to early fall

Graphic: (top) Atmospheric water vapor measured by satellite, red=high humidity. Garrison Fig. 8.24, (bottom) sea surface temperature, courtesy of NASA's Earth Observer.

Putting on Some Spin

- Earth rotation (via the Coriolis effect) initiates rotation in a developing hurricane
- Hurricanes can't form on or near the equator

Graphic: Garrison, Fig. 8.26.

Recipe for a Hurricane

Take:
- Sea surface temperatures ~80 deg F or warmer
- A warm, humid atmosphere

Add an atmospheric disturbance:
- example: due to clashes between warm air off the Sahara and cool air over the Atlantic ocean

Mix with rotating winds over the ocean

Less than 10% of disturbances develop into hurricanes in a typical year

Graphic: Tropical storms developing off the coast of Africa, courtesy of NOAA.

Impact of vertical wind shear

Gradients in vertical winds can weaken or destroy a hurricane, or prevent one from forming

Fueling the Beast – Evaporation and Energy

540 calories is needed to evaporate 1 gram of water

540 calories of energy are released when water vapor condenses to form liquid water

Graphic: Garrison Fig. 6.8.

A Hurricane's Energy

As hot, humid tropical air rises, it expands and cools… moisture condenses out and energy is released

Only about 1/400th of a hurricane's total energy is converted into the mechanical energy (wind)

Graphic: See Garrison Fig. 8.23.

How Much Energy Does a Strong Hurricane Have?

- Wind energy is equivalent to ~1/2 of the world's electrical generation capacity

- Total energy equivalent to 200 times the world's electrical generation capacity

- The heat energy of a strong hurricane is comparable to a 30 Megaton nuclear bomb exploding every hour

Graphics: Damage in Florida following Hurricane Andrew, courtesy of NOAA NWS.

Path of a Hurricane

Hurricanes move from the tropics toward the poles

While over warm ocean waters, they continuously draw energy from the air and sea

Their energy source is cut off when they move over land or colder ocean water, leading to gradual weakening

Graphic: Garrison Fig. 8.26, (bottom) Hurricane Ivan approaching the Gulf Shore, courtesy of NOAA.

The Effect of Ocean Temperatures on Hurricane Intensity

Graphic: Altimetry-derived tropical cyclone heat potential for August 28, 2005. The path of Hurricane Katrina is indicated with circles spaced every 3 hours. Credit: NASA/AVISO/AOML. courtesy of NOAA.

Potential Climate Changes

Primary effects:

- Warmer temperatures
- Sea level rise
- Water cycle impacts (reduced N.hemisphere snow)
- Reduced sea ice extent (Arctic)
- Changes in frequency, intensity of storms (notably hurricanes)

Types of changes:

- changes in average conditions
- changes in variability
- rapid changes
- "surprises"

Graphic: (top) Hurricane Floyd, Sept. 14, 1999. Courtesy of NASA (bottom) The record of Atlantic basin Hurricane intensity closely follows changes in tropical sst (From Emanuel, Nature, 2005).

Destructive Power of Hurricanes

- storm surge (causes largest loss of life and much property damage)
- high winds (causes most of the property damage)
- heavy rain
- tornadoes

Graphic: Sewell Park, Florida before (top) and after (bottom) Hurricane Andrew. Note the impact of storm surge. Photographs courtesy of NOAA/NWS.

Hurricanes and Storm Surge

Storm surge = a dome of high sea level associated with a strong storm

This dome is formed:

- by strong winds driving ocean water toward shore (wind-driven surge)
- in response to low atmospheric pressure near the hurricane's center (pressure surge)

Graphic: (top) Relative sizes of wind-driven and pressure surge, courtesy of NOAA National Hurricane Center, (bottom) pressure surge, Garrison Fig. 10.25.

Impacts of Storm Surge

- Storm surge is a hazard in the immediate vicinity of low-lying coastal areas

- Damage can be more intense if combined with high waves or if arrival of a storm surge corresponds with high tide

Graphic: Storm surge, courtesy of NOAA National Hurricane Center.

Storm Surge in Action

The height of a storm surge depends on:

- the intensity of the hurricane (wind speed and lowest pressure)

- the geometry of the continental shelf and slope (surges are higher on coasts near broad, gently sloping continental shelves)

Graphic: Storm surge for two different continental shelf/slope configurations. Courtesy of NOAA National Hurricane Center.

Forecasting Storm Surge

Storm surge forecasts can give residents time to secure their property and evacuate to safety

Storm surge forecasts are based on hurricane wind speed, central pressure, size, forward speed, path

Graphic: SLOSH computer model of storm surge from the National Hurricane Center.

Surge Due to Other Storms

Storm surge can also occur due to strong storms that are not hurricanes

Any storm that develops low enough pressure and high enough winds can cause potentially damaging storm surge

Graphic: Storm surge along the New England Coast, courtesy of NOAA.

Costs of Hurricanes and Storm Surge

Top Insured Losses (in 2003/2004 dollars):

Andrew (1992)	**~ $15-20 billion**
Charley (2004)	**~ $ 7 billion**
Jeanne (2004)	**~ $ 5-7 billion**
Hugo (1989)	**~ $ 4-6 billion**
Frances (2004)	**~ $ 4-5 billion**
Ivan (2004)	**~ $ 4-5 billion**
Georges (1998)	**~ $ 2-3 billion**
1995 season	**~ $ 100 billion**

Forecasts for the 2005 Atlantic Hurricane Season*

(as of December 2004)

	2005 Forecast	Average Year	2004 (Actual)
Named storms	11	9.6	15
Hurricanes	6	5.9	9
Intense Hurricanes	3	2.3	6

*Data from Gray, Klotzbach and Thorson, Colorado State University, http://hurricane.atmos.colostate.edu/Forecasts/2004/dec2004/

Graphics: (top) Coast Guard aircraft warning sponge fisherman of an approaching hurricane, 1938, courtesy of NOAA. (bottom) Hurricane Bonnie, 24 Aug 1998, image provided by the SeaWiFS Project, NASA/GSFC and ORBIMAGE.

Where Sea Meets Land - Coastlines and Beaches

Coasts

Beaches

Reading:

5th Ed., Ch 12 Secs 2-9, 11, 13-14, 16-19, 30-34

Ch 6 Sec 20

6th Ed. Sec. 10.1-10.7, 10.15-10.19, 12.1-12.20, 12.28-12.30

Graphic: Beachfront property along North Carolina's outer banks following a Noreaster. Photographer, R.B.Mieremet, NOAA Senior Advisor. Courtesy of NOAA.