Chapter 15: Hurricanes

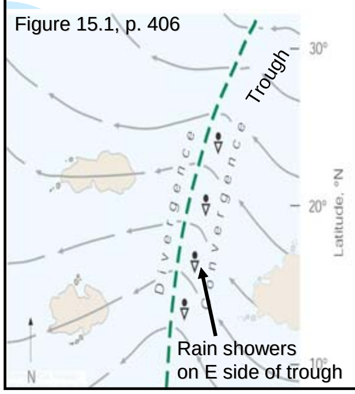
Tropical weather & easterly waves
Structure of a hurricane
Hurricane formation theories
  Organized convection
  Heat engine driven by warm ocean
Stages of development
Hurricane formation and movement
Watches and warnings
5 point Saffir-Simpson scale for hurricane strength
For more information, see the Web site for the National Hurricane Center, www.nhc.noaa.gov

Tropical Weather (p. 406)

- Tropics: region between Tropic of Cancer (23.5°N) and Tropic of Capricorn (23.5°S).
- In tropics, temperature changes little during year, so no winter, spring, etc.
- Seasons marked mainly by differences in rainfall, so rainy season(s) and dry season(s)
- Near the equator, typically two rainy seasons & two dry seasons per year. Near Tropics of Cancer and Capricorn, one rainy season & one dry season per year. (Reason for this will be covered in chapter 3.)
- Winds are typically from the east (also from NE & SE)

Tropical Easterly Waves, p. 406

Figure 15.1, p. 406



•Tropical wave: slow moving (10-20 kts) trough of low pressure from east.
•Low-level con-vergence is on east side of trough, so air rises, producing showers and thunderstorms.
•Only a few (< 20%) of easterly waves produce hurricanes

Hurricane Anatomy, pp. 406- 409

Tropical cyclone: general name for hurricane, typhoon, etc., with winds > 64 knots = 74 mph.
In photo, note:
•Eye: fairly clear, 10-30 miles across.
•Eye wall: intense thunderstorms & fastest winds.
•Spiral rain bands
•Total diameter of hurricane: several hundred miles.

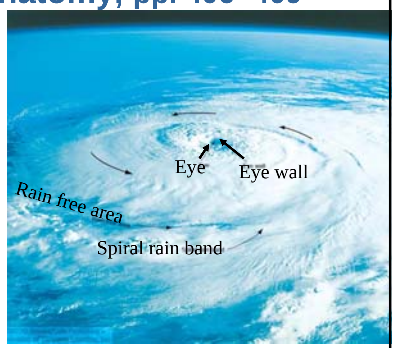
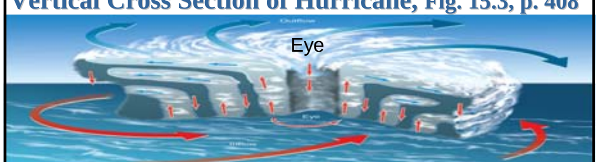


Figure 15.2, p. 407: Hurricane Elena in Gulf of Mexico (1985)

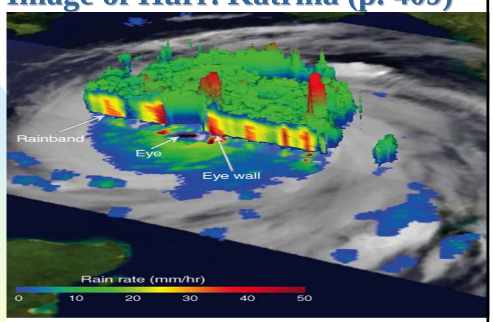
Vertical Cross Section of Hurricane, Fig. 15.3, p. 408



Eye: sinking air; a few clouds; lowest surface pressure.
Eye wall: intense thunderstorms around eye.
  Thunderstorms further out are not as strong.
Low-level air spirals inward (CCW in N Hem),
  picking up moisture & heat from warm sea surface.
Air converges, particularly at eye wall, rises, causing
  clouds & rain. Latent heat released. Air diverges
  outward at top, rotating CW in N Hem, sinks between
  thunderstorms, and warms.

Radar Image of Hurr. Katrina (p. 409)

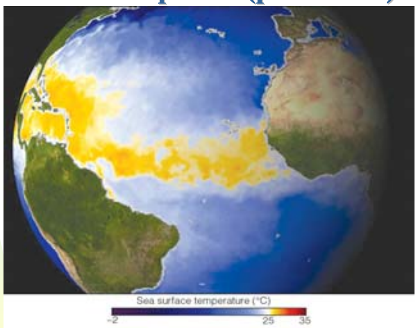
Fig. 15.5, p. 409: 3-D view done by radar scanning several levels 28 Aug 2005



Note: Clear eye (no rain); fastest rainfall rate in eye wall; spiral rain bands & rain free areas between; top of thunderstorm overshooting into stratosphere.

Hurr. Formation & Dissipation (p. 410-412)

Fig. 15.7, p. 410: Sea surface temperature in May 2002 sensed by satellite. Yellow shows areas above 28 C (82 F)



Hurricane formation requires warm tropical waters, lights winds, & thick layer of humid air. In Northern Hemisphere, most common in June - November.

Hurricane Formation (cont., p. 410)

- Latitude range for hurricane formation: 5 to 20 degrees from equator
- Absence of formation close to equator indicates role of Coriolis force involving Earth's rotation.
- Hurricanes do not form spontaneously. They must be triggered by some weather disturbance, often a tropical wave. (See beginning of chapter.)
- Low-level convergence needed to concentrate humidity for rain. Upper-level winds should not be too fast; otherwise, the tops of thunderstorms will be sheared off.
- Atmosphere should not be too stable, i.e., not too much warm air aloft. More thunderstorms occur if warm near surface and cold aloft, so warm air rises.

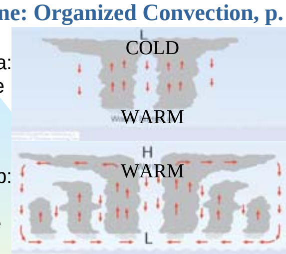
Seasonal Forecasting of Hurricanes (p. 410)

- Started in 1984 by now retired ("emeritus") professor William Gray of Colorado State University
- Based on factors listed on p. 410, although Gray dropped West African rainfall by 2004
- See http://typhoon.atmos.colostate.edu/
- Seasonal forecasting does not have much skill. Last year someone pointed out that you could beat Dr. Gray's forecasts by forecasting this year will have average number form last 10 years.
- Dr. K.-Y. Kim, recently of FSU, is doing better.
- See http://www.marshall.org/pdf/materials/409.pdf for "Hurricanes: A Primer on Formation, Structure, Intensity Change and Frequency" by Prof. Robert Hart of FSU

Hurricane: Organized Convection, p. 442 of 7th edition

Fig. 16.5a: Hurricane formation

Fig. 16.5b: Mature hurricane



Cold air aloft & warm at surface initially makes for vertical instability, enhancing thunderstorm growth. By maturity, release of latent heat by condensation warms upper levels.

Theory due to Jule Charney (American) and Arnt Eliassen (Norwegian) in 1949: Large scale flow feeds warm moist air into thunderstorms through spiral rain bands, organizing them into a more powerful unit. Condensation in thunder-storms releases latent heat, warming air which is ducted up. At tropopause, risen air diverges outward.

Newer Formation Theory: Air-Sea Inter-action as a "Heat Engine," p. 411, 8th ed.

•Newer theory of hurricane formation due to Kerry Emanuel in late 1980's (Jule Charney's last Ph.D. student): Warm sea surface heats and moistens air. Latent heat released when water condenses.
•Difference between input temperature (sea surface temperature) and output temperature (temperature in the upper troposphere) determines amount of energy put into winds.
•Clearly both organized convection (Charney) and warm ocean (Emanuel) are important, so issue is relative importance of the two factors. Theories are checked by their mathematical predictions.

Stages of Hurricane Development (p. 412)

Fig. 15.9, p. 412: Tropical disturbance up to mature hurricane (max. organization), finally weakening

1. Tropical Disturbance

2. Tropical depression (winds > 20 kts)

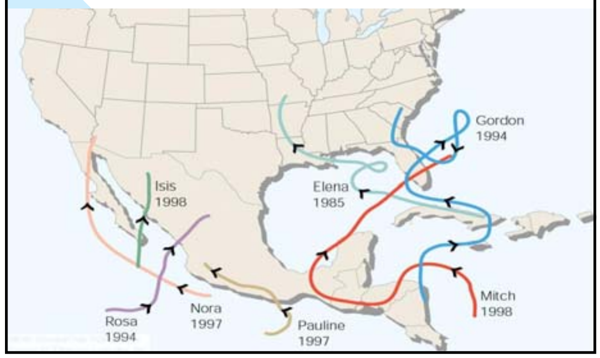
3., 5. Tropical storm (winds > 35 kts)

4. Hurricane (winds > 64 kts)

Hurricane Formation & Typical Paths, Fig. 15.10, p. 414

Pink regions: areas of hurricane formation in tropics over warm ocean, not on equator.
Red arrows: Typical directions of motion, curving toward mid-latitudes over western oceans around large regions of high pressure, e.g., Bermuda High in Atlantic and Pacific High.

But Some Hurricanes Take Erratic Paths, Fig. 15.11, p. 414



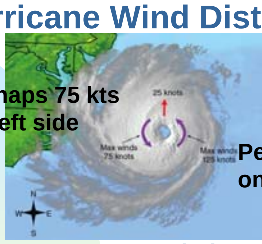
Hurricane Statistics

- Tropical cyclones at same latitude survive longer over Atlantic than Pacific because of warmer Atlantic waters (p. 416).
- Hurricane centers typically move at 10-50 knots (p. 414) but may stall near or over land and cause destructive flooding. At least in US, more damage occurs from flooding (storm surge and rain) than from winds (p. 417).
- Avg of 1-2 hurricanes/year make landfall at US.
- About ¼ of hurricanes that hit US produce tornadoes, usually in right front quadrant where winds and rain are most intense. (p. 418, col. 1)

Death of Hurricanes (p. 443 of 7th ed)

- Because hurricanes derive their energy from warm surface water and release of latent heat, they die when they move over cold water or onto land (no warm water surface plus friction).
- When hurricanes travel from tropics to mid-latitudes, they can change into midlatitude storms with fronts.
- Life usually < 1 week.

Hurricane Wind Distribution (pp. 416-417)



Perhaps 75 kts on left side

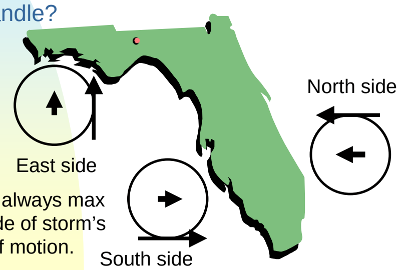
Suppose center of hurricane is moving N at 25 kts

Perhaps 125 kts on right side

Fig. 15.16: Fastest winds on RIGHT side of direction of motion, where forward speed combines with speed of winds around storm. Example: 75 kt winds around low with 25 kt forward motion gives 100 kts from SSW on right, 50 kts from NNE on left. At landfall, right side also has highest storm surge, rainfall, and maybe tornadoes.

Where would winds be fastest if a hurricane hits Florida?

- Apply the reasoning from the previous slide: Where would the winds be fastest for a hurricane hitting Florida's east coast? West coast? Panhandle?



Winds are always max on right side of storm's direction of motion.

Storm Surge (p. 418)

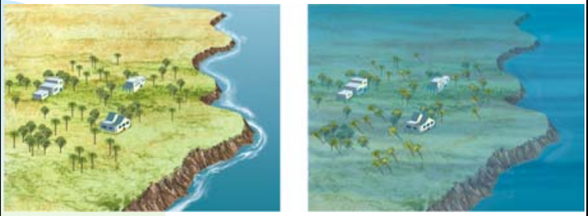
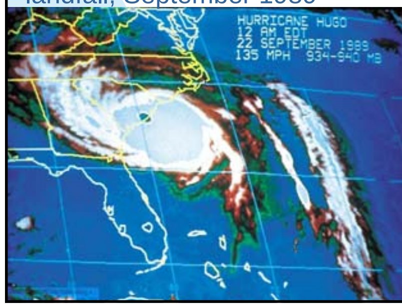


Figure 15.27, p. 418: Storm surge, i.e., high water level at coast due to wind pushing water onshore, low atmospheric pressure (like water up a drinking straw). Worst at high tide.

Example of storm surge damage: Hurricane Hugo

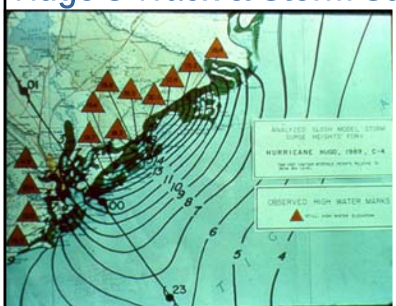
Figure 15.18, p. 421: Hurricane Hugo at landfall, September 1989



Where was the worst storm surge?

Answer: 20 ft surge at Bull's Bay, NE of eye

Hugo's Track & Storm Surge



Track of center of Hugo's eye is straight line from bottom center to upper left. Labeled lines are storm surge height in feet. Note max to right of Hugo's track.

From http://wchs.csc.noaa.gov/images/hhugo050.jpg

Damage of Hugo's 12 ft storm surge at Folly Beach, SW of worst surge at Bull's Bay

Before Hugo After Hugo
(Fig. 16.13, p. 452 of 7th ed.)

Hurricane Watches & Warnings (p. 418)

- Issued by National Hurricane Center in Miami, Florida, and Pacific Hurricane Center in Honolulu, Hawaii.
- HURRICANE WATCH: possible in 24 to 48 hrs.
- HURRICANE WARNING: likely strike within 24 hours.
- For east coast of US, hurricane warning includes probability of center passing within 105 km (65 mi)

Hurricane Andrew (pp. 421-422)

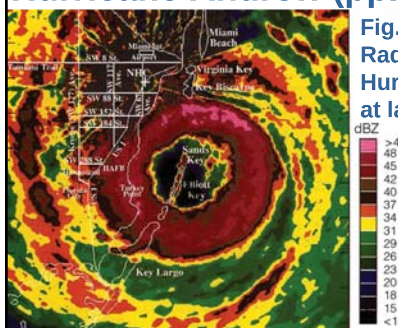


Fig. 15.19 (p. 422): Radar image of Hurr. Andrew (1992) at landfall

The scale in dBz indicates how strong the radar echo is

Note: 1) clear eye, 2) intense rainfall in eye wall, and 3) spiral rain bands

Saffir-Simpson Scale for Hurricane Strength, pp. 424-425

•Hurricanes ranked by 1-minute avg wind speed at 10m: category 1 (64-82 kts) to category 5 (>135 knots). (Tops of tall buildings have faster winds than at 10m.)
•"Major" hurricane: category 3 or higher.
•Example: Hugo (1989) category 5 at peak, cat. 4 at landfall. Nearly $7 billion in damages in US. Killed 76-82 in Caribbean and US.

No. of Landfalling Hurricanes for Atl & Gulf Coast between 1900 & 1999 (pp. 424)

Category 1 hurr. & other less intense tropical storms may bring needed rainfall or flooding.
Three cat 5 storms hit US in 1900's:
•1935 Labor Day (FL Keys)
•1969 Camille (LA)
•1992 Andrew (FL)

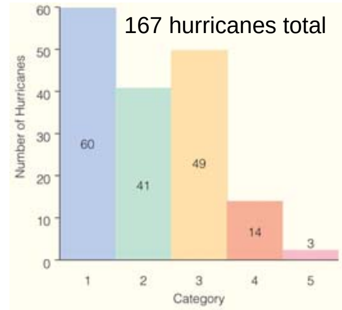


Fig. 15.24, p. 424

Hurricane Names (p. 426)

•Names cycle through 6 years of alphabetical lists of English, Spanish, & French male and female names for Atlantic and Pacific storms.
•Name retired if storm is especially damaging. 67 names retired from 1953 through 2005.
• Examples: Andrew (1992), Camille (1969)
•Retired from 2005: Dennis, Katrina, Rita, Stan, and Wilma

Hurricane Modification (pp. 425-426)

•From mid 1960's to early 1980's, Project Stormfury looked at possibility of hurricane modification. See http://www.aoml.noaa.gov/hrd/hrd_sub/modification.html
•Quoting this Web Site: The American Meteorological Society policy statement on planned and inadvertent weather modification, dated October 2, 1998, indicates, "There is no sound physical hypothesis for the modification of hurricanes, tornadoes, or damaging winds in general, and no related scientific experimentation has been conducted in the past 20 years." In the absence of a sound hypothesis, no Federal agencies are presently doing, or planning, research on hurricane modification.