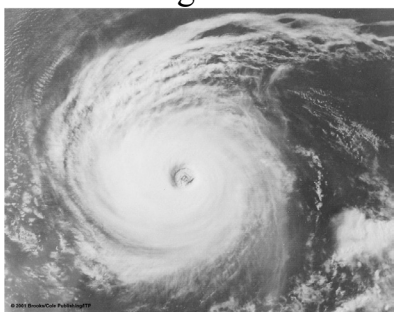
Chapter 16, Part 1

Hurricane Structure and Formation

What are hurricanes?

- Hurricanes are tropical cyclones which have peak winds about the central core (eye) that exceed 64 knots (74 mph).
- Other names:
  - Typhoon (western N. Pacific)
  - Baguio (Philippines)
  - Cyclone (India and Australia)
  - Tropical Cyclone (official name)

Satellite Image of a Hurricane



- Hurricane John in Pacific. Central pressure is 965mb with sustained winds of 100 knots near eye.

Structure of a Hurricane

- Eye – winds light, clouds mainly broken, surface air pressure is very low (here 965mb); diameter = 20-50 km typically
- Clouds align into spiraling bands (spiral rain bands)
- Surface winds increase in speed as they blow counterclockwise and inward toward the center.
- Wind and precipitation is most intense at the eye wall.

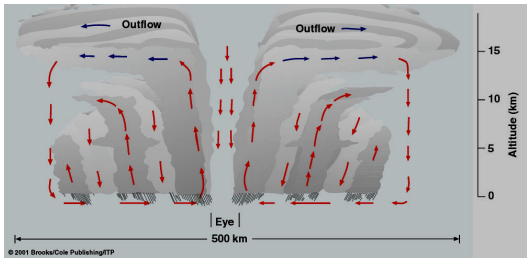
1. Weather in a Hurricane

- Going from west to east:
- Sky becomes overcast.
- Pressure drops slowly, then more rapidly.
- Winds blow from North or Northwest with increasing speed.
- High winds generate huge waves (10m) and are accompanied by heavy rain showers.

2. Weather in a Hurricane

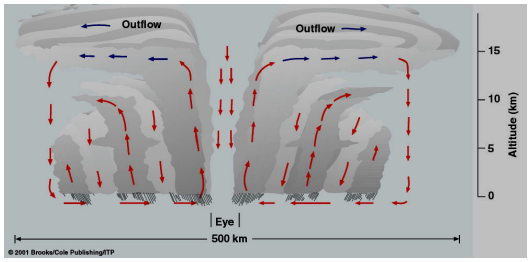
- As we move into the eye, the air temperature rises, winds slacken, rainfall ceases, and the sky brightens (fewer clouds). The barometer is now at its lowest.
- Enter eastern side of eye wall. Heavy rain and strong southerly winds.
- Moving away from the eye wall, pressure rises, winds diminish, rain diminishes, … as the process reverses.

1. Model of a Hurricane



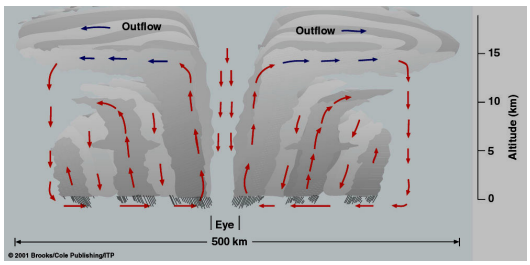
- Organized mass of thunderstorms.
- Moist tropical air flows in to hurricane's center.
- Near eye, air rises & condenses into thunderstorms.

2. Model of a Hurricane



- Near top of thunderstorms, dryer air flows outward from the center (actually flows clockwise).
- At the storm's edge, this air begins to sink and warm, inducing clear skies.

3. Model of a Hurricane



- In the thunderstorms of the eye wall, the air warms leading to higher pressures aloft and downflow in eye.
- Subsiding air warms by compression accounting for the warm air and absence of thunderstorms in the eye.

1. Hurricane Formation

- Hurricanes form over tropical waters where
  - Winds are light
  - Humidity high in a deep layer
  - Surface water temperature is warm (80°F).
- Occurs in topical N. Atlantic and N. Pacific in summer and early fall.
- Hurricane season normally runs from June through November.

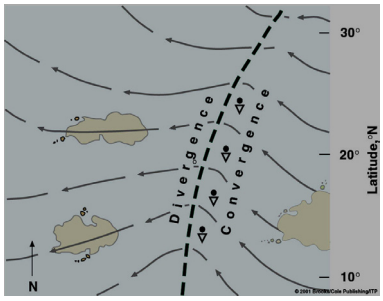
2. Hurricane Formation

- In the tropics (between 23.5^{o}N and 23.5^{o}S) the noon sun is always high in sky.
- Coupled with high humidity this frequently leads to development of cumulus clouds and thunderstorms.
- In some cases the thunderstorms may become organized and form a hurricane.
- For that one needs convergence.

3. Hurricane Formation

- <u>Sources of convergence</u>:
- Intertropical convergence zone (ITCZ) – an area of low pressure may develop along a wave in the ITCZ.
- Topical waves – converging and diverging region in easterly winds in the tropics (common for Atlantic hurricanes).
- Front that moves into the tropics.

Tropical Wave



Streamlines showing wind flow.

- Thunderstorms form in converging region.
- Typical wavelength 2500km and speed 10-20 knots.

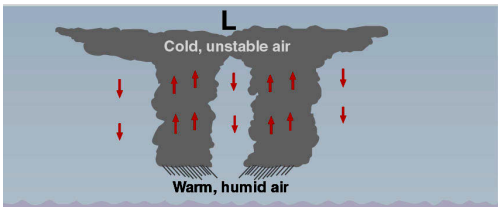
4. Hurricane Formation

- The converging air begins to spin counterclockwise because of the Coriolis force.
- Can not happen right at the equator where Coriolis force is zero.
- Two thirds of all hurricanes form between 10° and 20° latitude.

5. Hurricane Formation

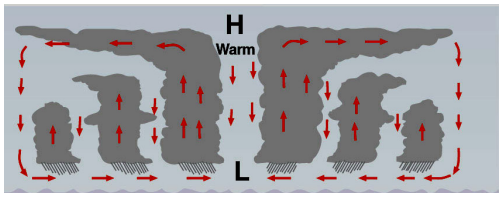
- Need upper-level winds to diverge and leave more quickly than surface air is converging (upper level air support).
- Trade wind inversion near 20° is caused by sinking due to subtropical high (prevents).
- Hurricanes do not form when upper level winds are strong and can disrupt the organization of the storm (occurs over Atlantic more frequently in El Nino event).

1. Organized Convection Theory



- Suppose air aloft is unstable, e.g. colder.
- Large clouds are generated.

2. Organized Convection Theory



- Release of latent heat warms the upper level air creating an upper level high.
- Upper-level winds move outward away from the high enhancing surface low.

3. Organized Convection Theory

- Chain reaction (feedback mechanism):
  - Rising air releases more heat
  - Increases surface low & upper level high
  - Stronger surface winds
  - More waves and friction
- Controlling factors are the temperature of the water and the release of latent heat.
- When storm is full of thunderstorms, it has used up all available energy.

Heat Engine Theory

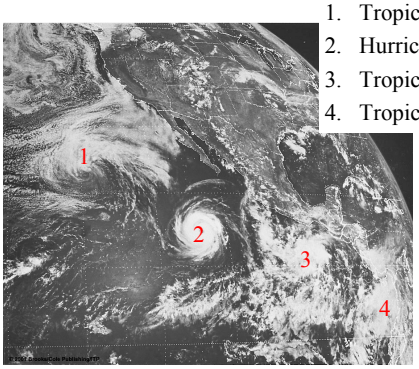
- Heat engine - heat is taken in at a high temperature, converted into work, and then ejected at a lower temperature.
- For hurricanes source of heat is sensible heat at surface and latent heat of condensation.
- Heat taken in at ocean surface, converted to kinetic energy of wind motion, and lost at top due to radiation cooling.
- Not clear at present which theory (or both) drives hurricanes.

Stages of Hurricane Development

- Tropical Disturbance – thunderstorms with only slight wind circulation
- Tropical Depression – winds increase to between 20 and 34 knots. Several closed isobars appear.
- Tropical Storm – winds are between 35 and 64 knots.
- Hurricane – winds exceed 64 knots (74 mph).

Visible Satellite Image

1. Tropical Storm
2. Hurricane
3. Tropical Depression
4. Tropical Disturbance



Comparison of Hurricanes & Middle Latitude Cyclones

Hurricanes	Middle Latitude Cyclones
Counterclockwise air flow	Counterclockwise air flow
Surface low	Surface low
Energy from warm water & latent heat of condensation.	Energy from horizontal temperature contrasts.
Weakens with height	Winds strengthen with height
Eye	Rising air in center
Warm air from surface up	Cold upper level L to west

Relationship with Other Storms

- Some polar lows that develop over (relatively warm) polar waters in the winter may have
  - a symmetrical band of thunderstorms
  - a cloud-free eye
  - a warmer core of low pressure
  - strong winds near the center.
- Some northeasters may have a cloud-free eye, very strong winds, and a warm inner core.

Summary

- Hurricanes are tropical cyclones composed of organized thunderstorms with winds about the eye exceeding 64 knots (74 mph).
- They derive their energy from warm tropical water and latent heat of condensation.
- They form in a region of surface convergence and upper level divergence.