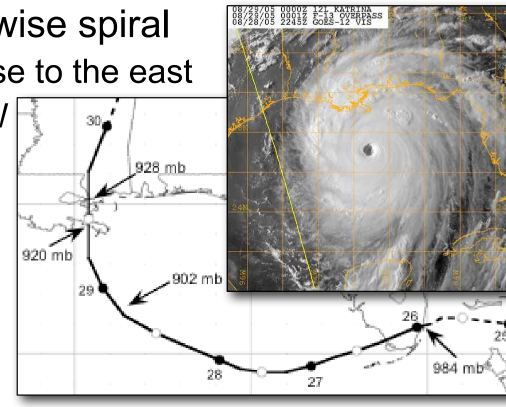
What Causes the Winds?

- Processes that cause air to start moving
- Processes that affect how the wind moves
- Two categories of wind
  - Prevailing Winds
  - Transient & storm winds
- Global patterns of prevailing winds
- Local/regional patterns of transient & storm winds
- Starting point: Katrina & hurricanes

Katrina as a Model

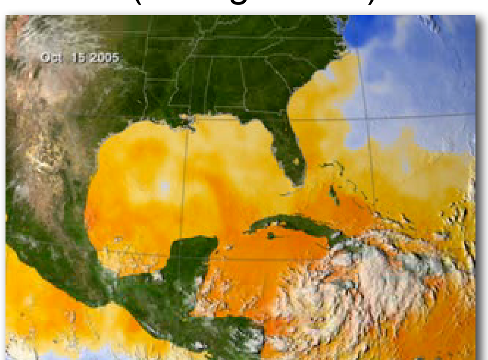
- Counterclockwise spiral
  - Damage worse to the east
  - Moves E to W
- Grows over the ocean
  - Pressure decreases
  - Winds increase
- Weakens over land



www.nhc.noaa.gov/pastall.shtml
www.nhc.noaa.gov/pdf/TCR-AL122005_Katrina.pdf
www.aoml.noaa.gov/hrd/Storm_pages/katrina2005/sat.html
www.nhc.noaa.gov/archive/2005/KATRINA.shtml?

Katrina a Classic Hurricane

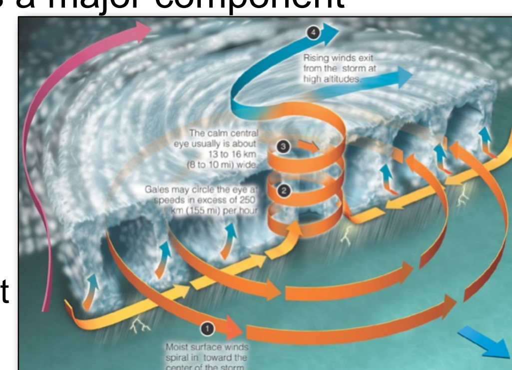
- Forms over warm water (Orange color)
  - Heat drives convection in the atmosphere
  - Air spirals from Earth's rotation
- Moves off to NE at higher latitudes
  - Wilma October 2005



www.srh.weather.gov/jetstream/tropics/tc.htm

Katrina & the Ocean

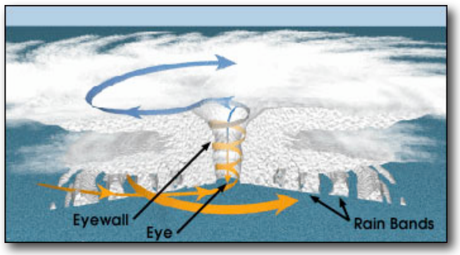
- Warn surface water intensifies the hurricane
- Evaporation is a major component
  - Water vapor less dense than air
  - Rises & cools
  - Moisture con-denses
  - Releases heat
  - Causes more air to rise



Garrison Fig. 8.23 p. 193

Cyclone Basics

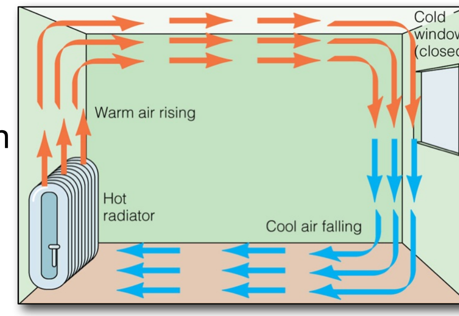
- An exaggerated case of a very common atmospheric phenomenon
  - Low-pressure system or *cyclone*
- Cyclones driven by air heated at the surface
  - Warm air rises
  - Air is drawn along the surface to replace rising air
  - Air spirals counter-clockwise because of Earth's rotation



http://earthobservatory.nasa.gov/Library/Hurricanes/

A Model for Global Winds

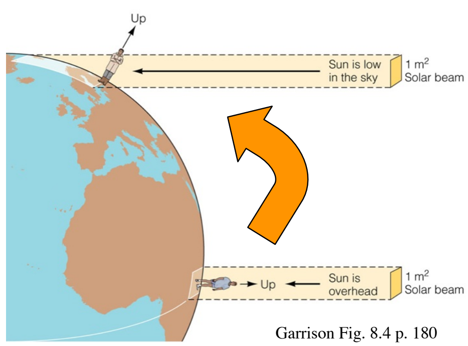
- ALL winds driven by surface heating
  - Warm air rises
  - Air drawn along the surface to replace rising air
    - Wind!
  - What goes up, must come down
    - Cooler air sinks somewhere
    - Uneven heating
    - Creates convection cells



Garrison Fig. 8.7 p. 182

Atmospheric Convection

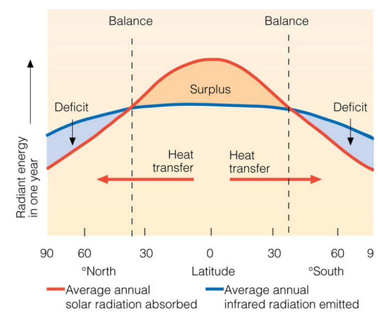
- Low latitudes are warmer than high latitudes
  - But temperature difference is not nearly as great as the difference in solar heating.
  - Heat is trans-ported from low latitudes to high latitudes.

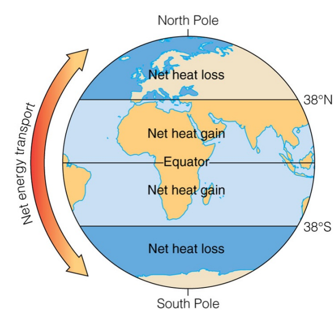


Garrison Fig. 8.4 p. 180

Atmospheric Convection

- Both ocean & atmosphere transport heat
  - Movement of air = convection & wind
    - Water vapor also transports heat
  - Movement of water = convection & currents





Atmospheric Convection

- At low latitudes the sea surface is heated
  - Tremendous evaporation from the oceans
  - Warm, moist air rises
  - The air cools as it rises
  - Cool air can hold less water vapor
  - So as the air rises, moisture condenses
  - Thus there is a belt of high precipitation (rain) near the equator

Atmospheric Convection

- Not all this moisture condenses over the equator, however.
  - Some of it rises and spreads north and south toward higher latitudes.
  - Eventually this air cools and sinks back to the surface.
  - As it does, more moisture condenses and causes rain (and snow) at these higher latitudes.

Atmospheric Convection

- Heat is thus transported by both the warm air and the latent heat of vaporization.
  - Energy required to convert water to vapor at same temperature
  - LHOV is transferred from water vapor to air when the moisture condenses again
  - Either over the equator or at higher latitudes.

Atmospheric Convection

- A simple model of the atmosphere
  - Assumes all ocean and not rotating
  - Large convection cells N & S of equator
  - Cooler, drier air sinks at poles
  - Returns to low latitudes along the surface
  - Replaces air that rises near the equator

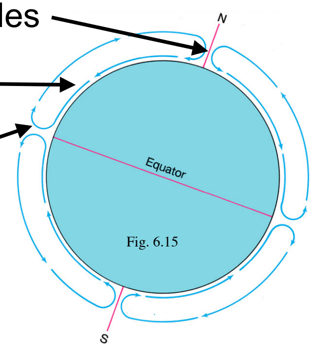


Fig. 6.15

Atmospheric Convection

- Actually 3 convection cells in each hemisphere.
  - Created by Earth's rotation
  - Air aloft sinks at about 30˚ N and 90˚ N
  - Surface air rises at about 60˚ N.

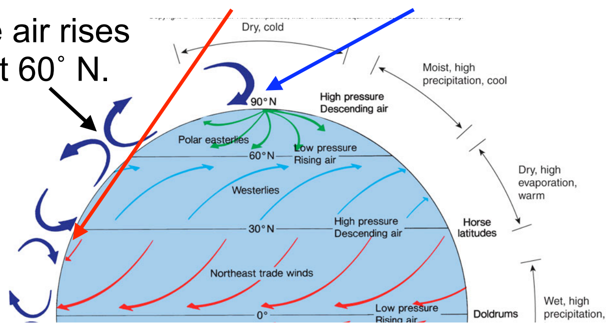


Fig. 6.19

Atmospheric Pressure

- Rising warm, moist air is less dense
  - Creates lower atmospheric pressure

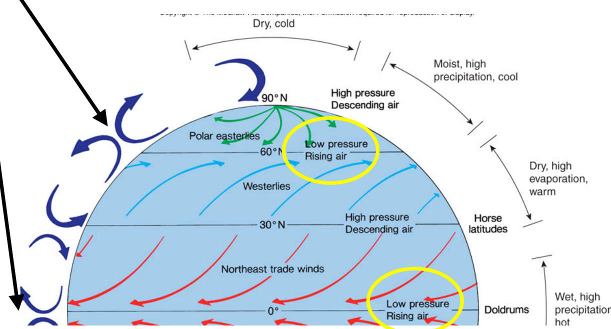
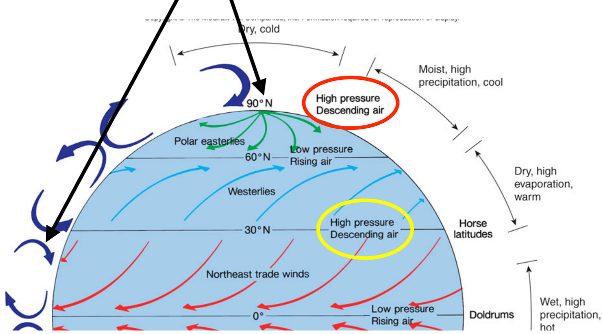


Fig. 6.19

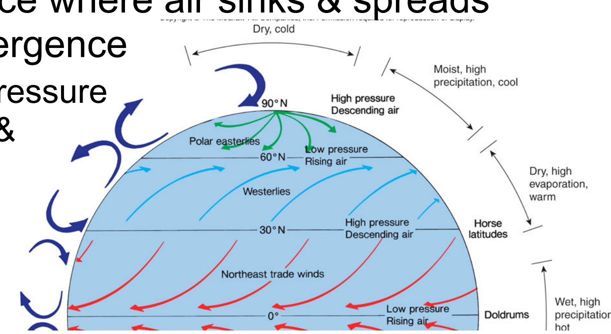
Atmospheric Pressure

- Sinking dry air is more dense
- Creates higher atmospheric pressure



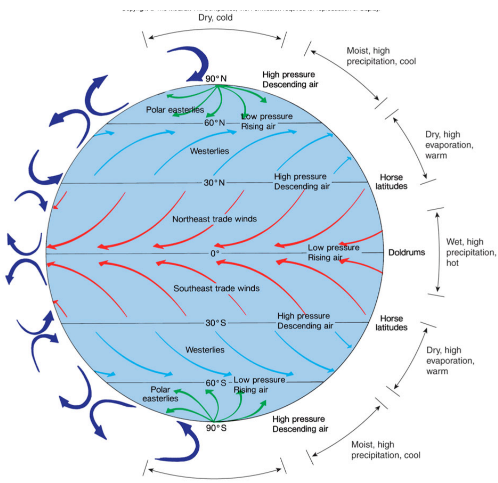
Convergence & divergence

- At surface where air along the surface comes together & rises: convergence.
  - Low pressure at 0˚ and 60˚ N
- At surface where air sinks & spreads out: divergence
  - High pressure at 30˚ & 90˚ N



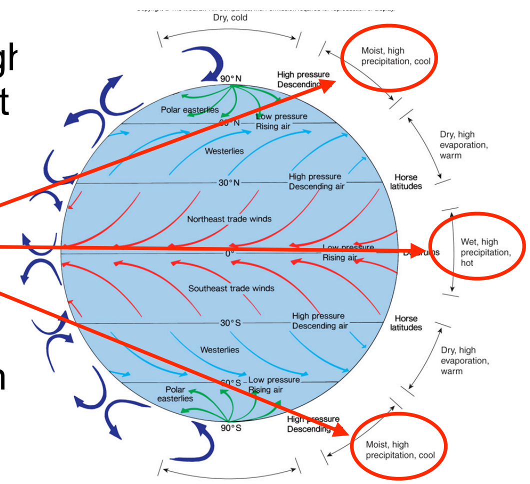
Atmospheric Symmetry

- Convection and high & low pressure patterns are symmetrical in Northern & Southern hemispheres



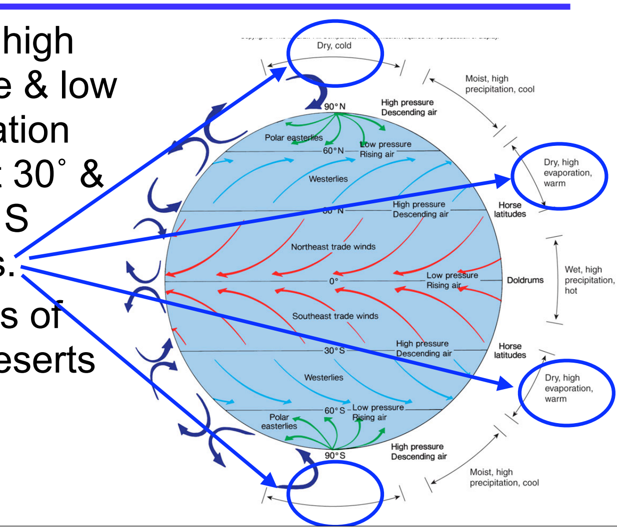
Atmospheric Symmetry

- Belts of low pressure & high precipitation at 0˚ and about 60˚N & S latitudes
- Latitudes of tropical and temperate rain forests



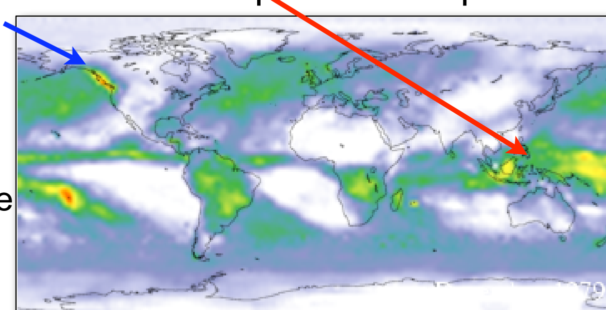
Atmospheric Symmetry

- Belts of high pressure & low precipitation at about 30˚ & 90˚ N & S latitudes.
- Latitudes of major deserts



A Model for Climate

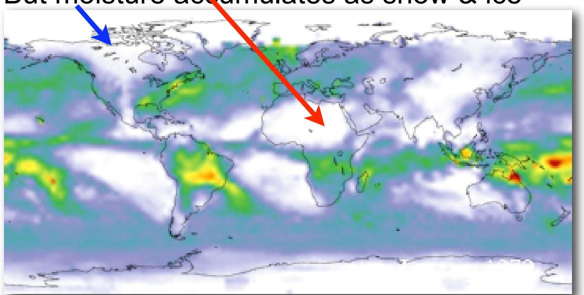
- Rising air in the tropics & condensation
  - Global belt of wet climate at tropical latitudes
- Another wet belt at temperate - subpolar latitudes
  - Seattle
  - Nov. 1979 average
  - Rain forests



http://earthobservatory.nasa.gov/Observatory/Datasets/rainfall.gpcp.html

A Model for Climate

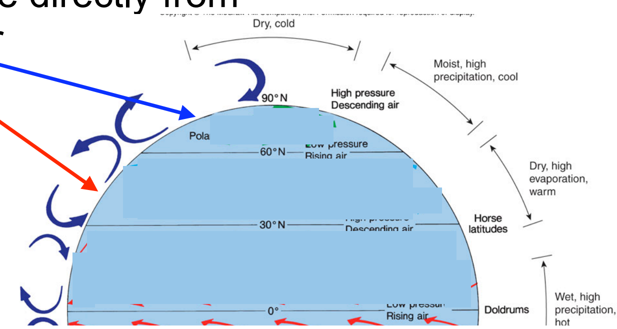
- Desert belts indicate sinking & drying air
  - Sahara, Kalahari, Gobi, Australian outback
  - Poles are deserts too!
    - But moisture accumulates as snow & ice



http://earthobservatory.nasa.gov/Observatory/Datasets/rainfall.gpcp.html

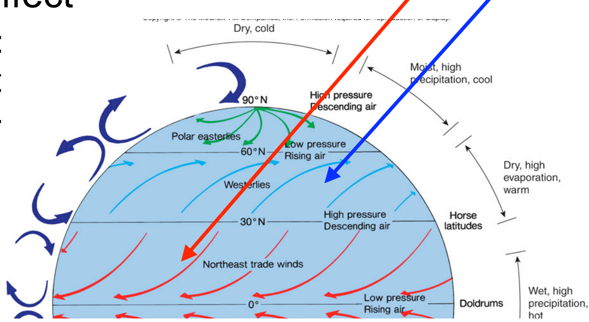
Winds

- Driven by differences in pressure
  - From High to Low pressure
- In this convection model, all winds would be directly from North or South



Winds

- Note: winds are named for the direction *from which* they blow
- Prevailing winds come mainly from E & W
- Coriolis Effect
  - Moving c turn right N. Hemi- sphere
  - Left in S. hemi- sphere



Coriolis Effect

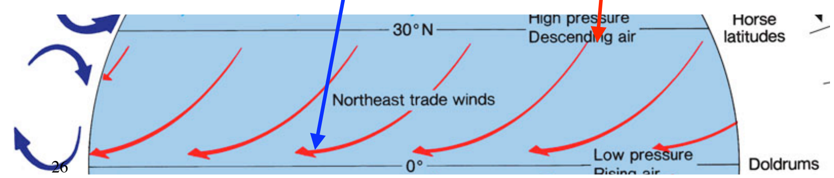
- Some people call it Coriolis "force."
  - As if it diverts moving objects from a straight line.
- It is not a real force.
  - Objects actually travel in a straight line.
  - It's the Earth that is turning.
  - It is simply an effect of being on a rotating body.

Formula for Coriolis

- Coriolis Effect f=2ω sin θ v.
- 2ω + rotation rate of the earth (a constant)
- sin θ = 0 to 1 depending on latitude
  - Coriolis Effect is zero at the equator and maximum at the poles
- V = speed of moving object
  - Greater effect at higher speeds

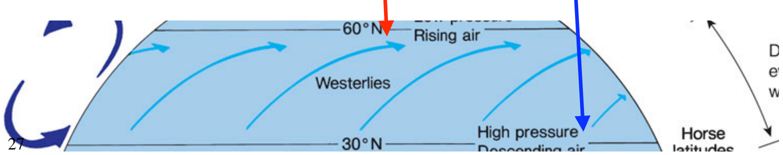
Atmospheric Zonal Circulation

- Coriolis effect + 3 convection cells
- Equator to 30˚ N
  - Surface air is moving *toward* south
  - So it turns right, *toward* the west
  - Forms a belt of easterly winds (*from* the east)
  - Trade Winds.



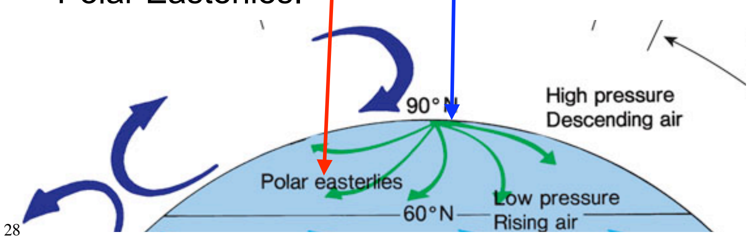
Atmospheric Zonal Circulation

- 30˚ N to 60˚ N
  - Surface air is moving *toward* north
  - So it turns right, *toward* the east
  - Forms a belt of westerly winds (*from* the west)
  - Prevailing Westerlies.



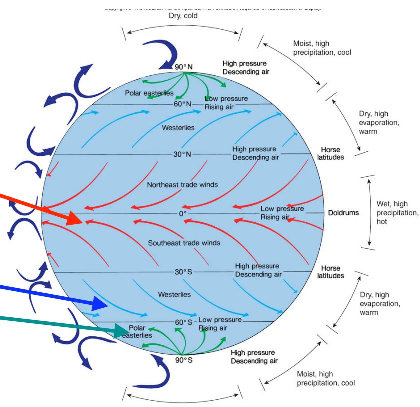
Atmospheric Zonal Circulation

- 60˚ N to 90˚ N
  - Surface air is moving *toward* south
  - So it turns right, *toward* the west
  - Forms a belt of easterly winds (*from* the east)
  - Polar Easterlies.



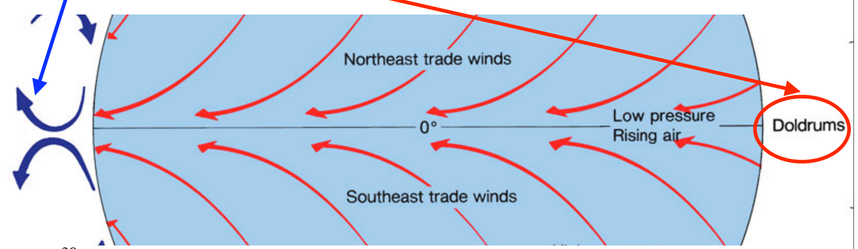
Atmospheric Zonal Circulation

- Direction of winds is symmetrical in S. Hemisphere
  - Coriolis is opposite to the left
- Trade Winds *from* the East
- Prevailing Westerlies
- Polar Easterlies



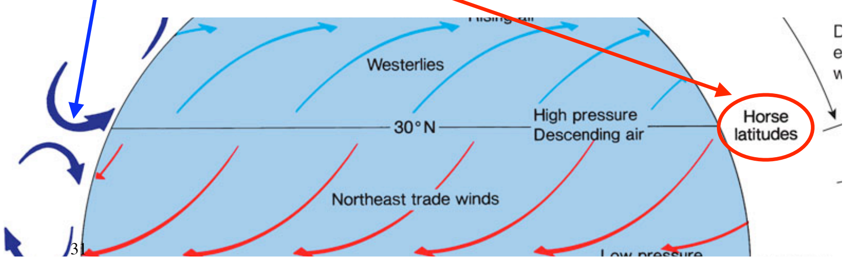
Atmospheric Zonal Circulation

- Equator is a transition zone
  - Air movement is vertical more than horizontal
  - Region of weak surface winds
  - Doldrums



Atmospheric Zonal Circulation

- 30˚ N & S also transition zones
  - Air movement is vertical more than horizontal
  - Region of weak surface winds
  - Horse Latitudes



Atmospheric Zonal Circulation

- 60˚ N & S are regions of strong winds
  - "The polar front" & jet stream
  - Strong temperature contrast between converging temperate and polar air masses
  - No such contrast at lower latitudes.