

## **Atmospheric Circulation: Key Ideas**

- **Different amounts of solar energy are absorbed at different latitudes.**
- **Interaction of the ocean and atmosphere moderates surface temperature, shapes Earth's weather and climates, and creates waves and currents.**
- **Earth's rotation causes the Coriolis effect, the apparent curvature of the path of moving air.**

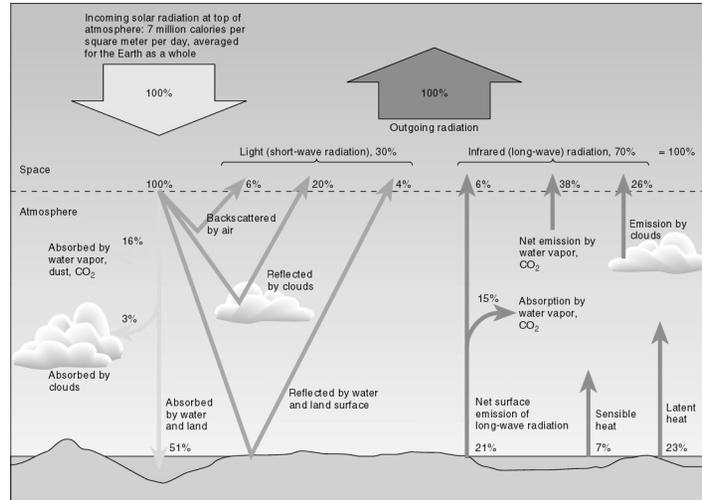
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## **Composition and Properties of the Atmosphere**

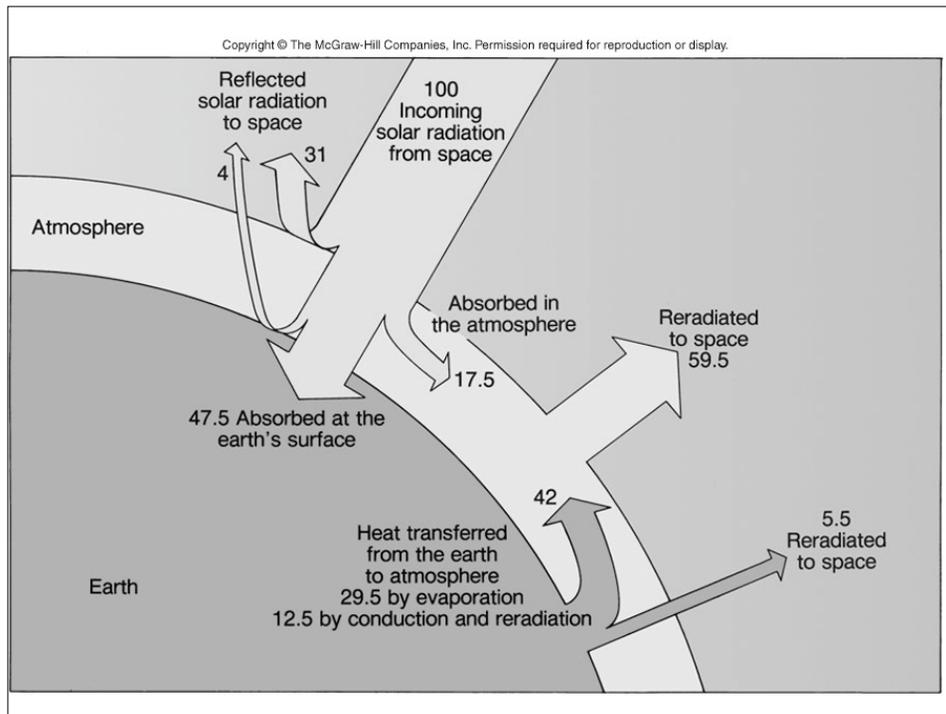
- **The lower atmosphere is a fairly homogeneous mixture of gases comprised mostly of  $N_2$  and  $O_2$ .**
- **Water vapor may comprise up to 4% of the volume of the atmosphere.**
- **The density of air is affected primarily by temperature.**

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# Heat Budget of Earth

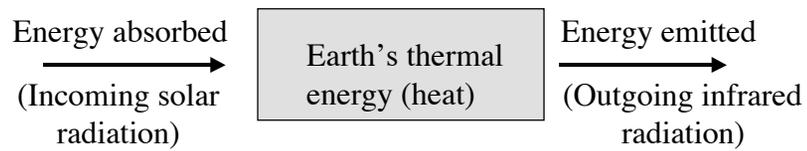


Atmospheric circulation is powered by sunlight. Since Earth is in thermal equilibrium, what assumption can be made about the input and output of heat on Earth?



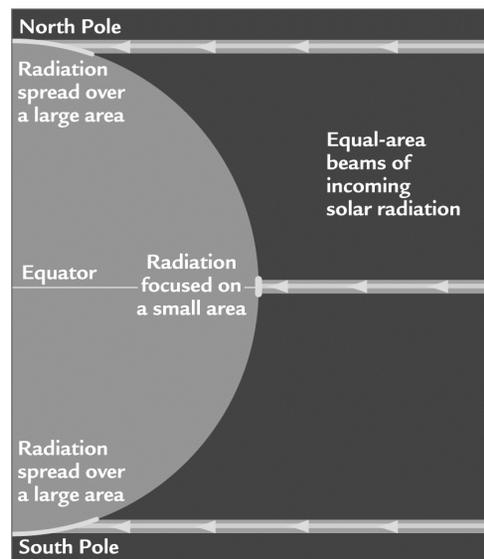
# Earth's Energy Balance

- Energy emitted = energy absorbed
- Energy absorbed = incident radiation - reflected sunlight



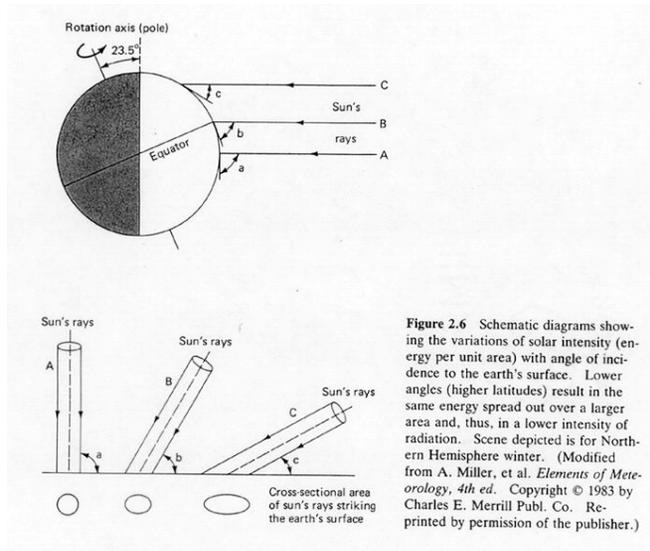
If emitted and absorbed are not equal, then Earth will become warmer or cooler until these become equal again

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Unequal distribution of solar radiation

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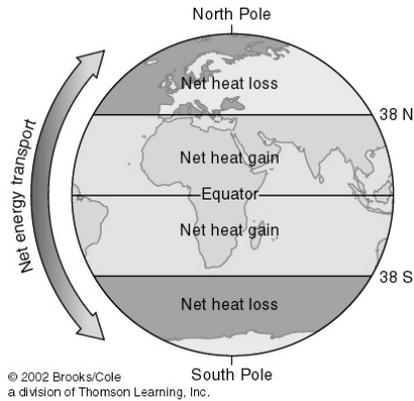
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## Factors Governing Global Air Circulation

- Uneven solar heating
- The Coriolis effect

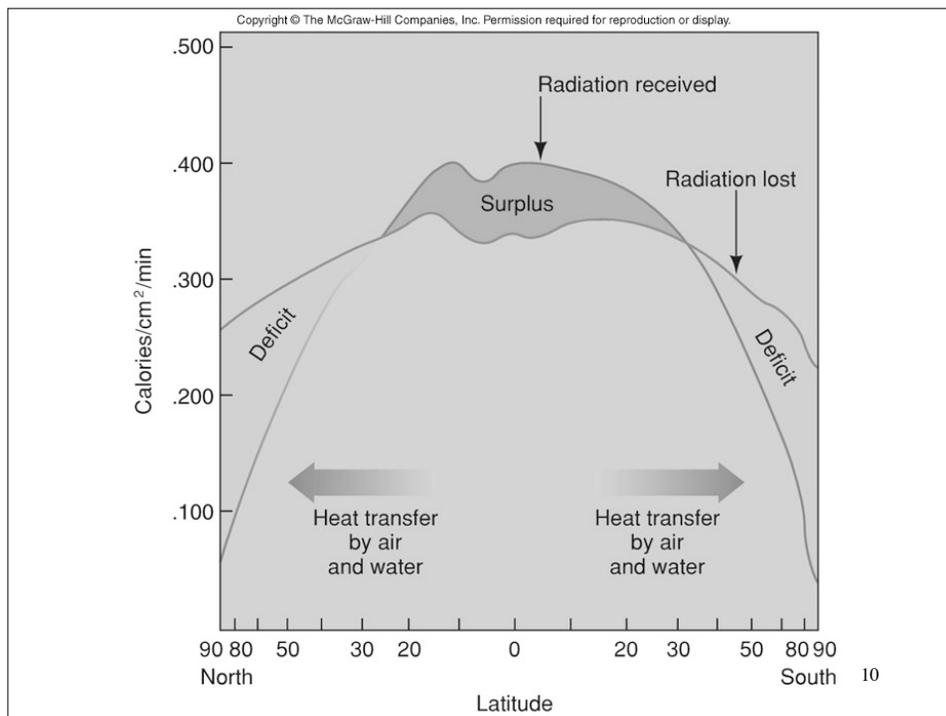
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# Uneven Solar Heating and Latitude



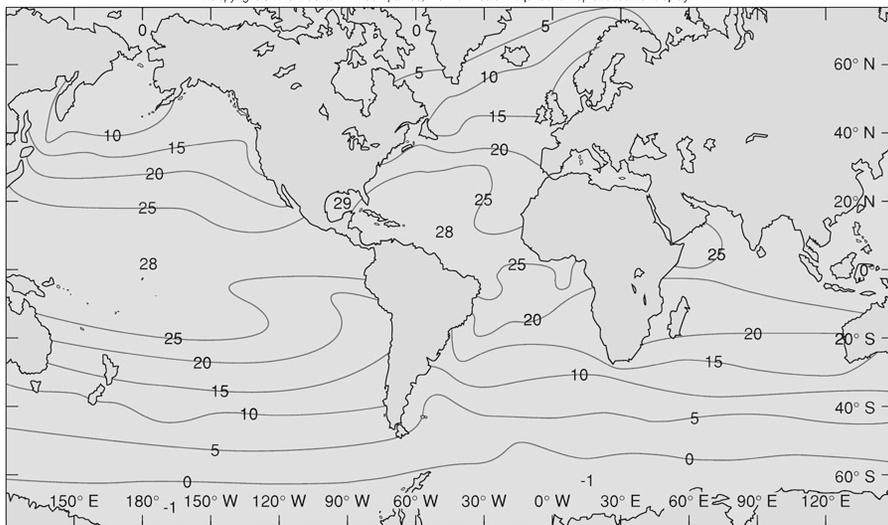
Earth as a whole is in thermal equilibrium, but different latitudes are not. Moving masses of air and ocean currents transport energy from locations with a surplus to those with a deficit.

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## Summer sea surface temperatures

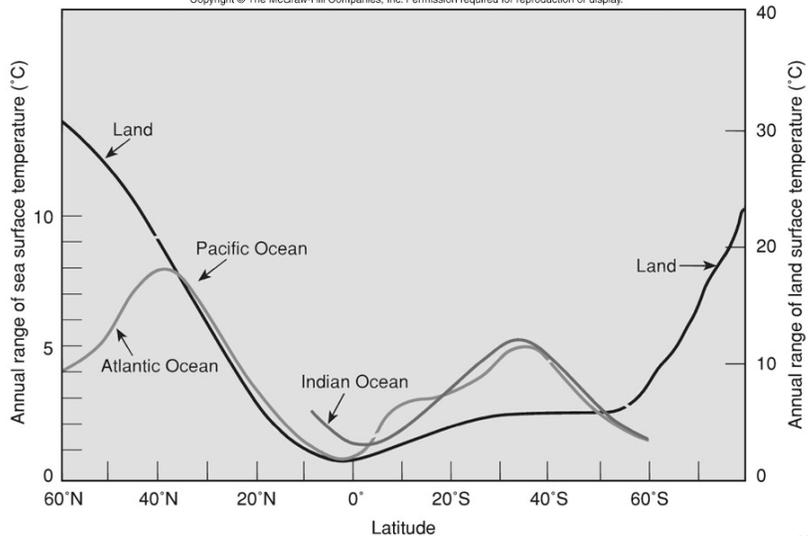
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## Surface Temperature Ranges at Different Latitudes

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## Density of Air

- Decreases with:
  - Increasing T
  - Increasing humidity
  - Increasing altitude

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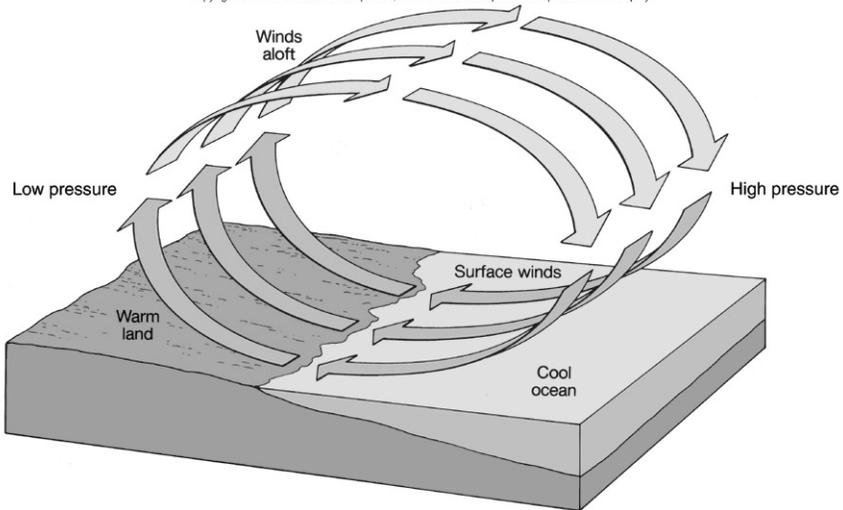
## Air Density: Affected by Temperature, Pressure and Moisture Content

- Warm air is less dense than cold air and moist air is less dense than dry air.
- Air pressure is the weight of the air from Earth's surface to the top of the atmosphere and equals  $1.04\text{kg/cm}^2$  (standard air pressure, one atmosphere) at sea level.
- Low pressure zone is where air density is lower than in surrounding areas because the air is warmer or has a higher moisture content.
- High pressure zone is where air pressure is higher than in surrounding area because of cooling or lower moisture content.

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# Air Circulation

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## Monsoons, Sea Breezes and Land Breezes

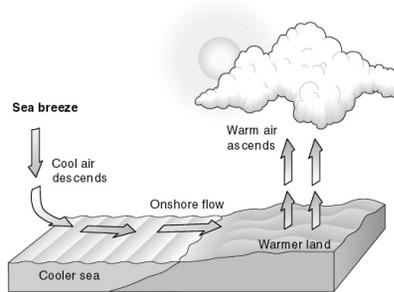
- Monsoons are patterns of wind circulation that change with the season. Areas with monsoons generally have dry winters and wet summers.
- Sea breeze is cool air from over the water moving toward land. Sea breezes occur after sunrise.
- Land breezes occur after sunset when air warmed by the land blows toward the water.

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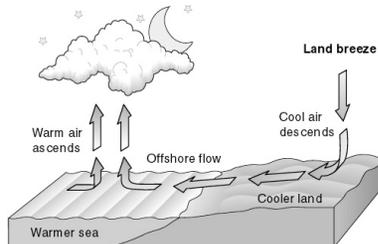
# Sea Breezes And Land Breezes

Top: Sea breeze

Bottom: Land breeze



a

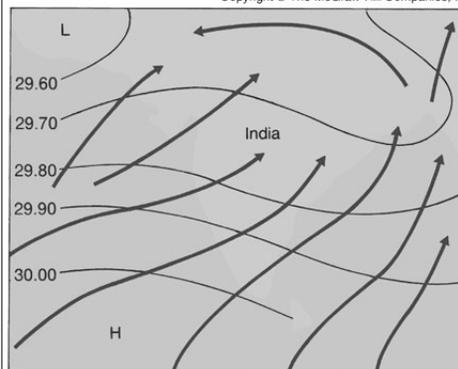


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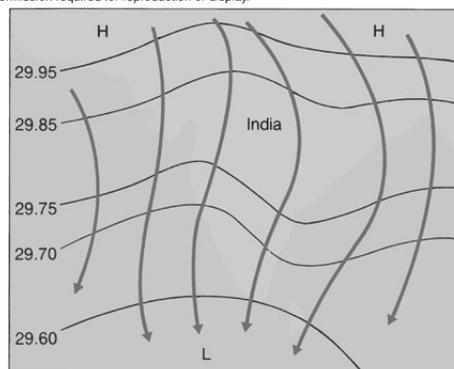
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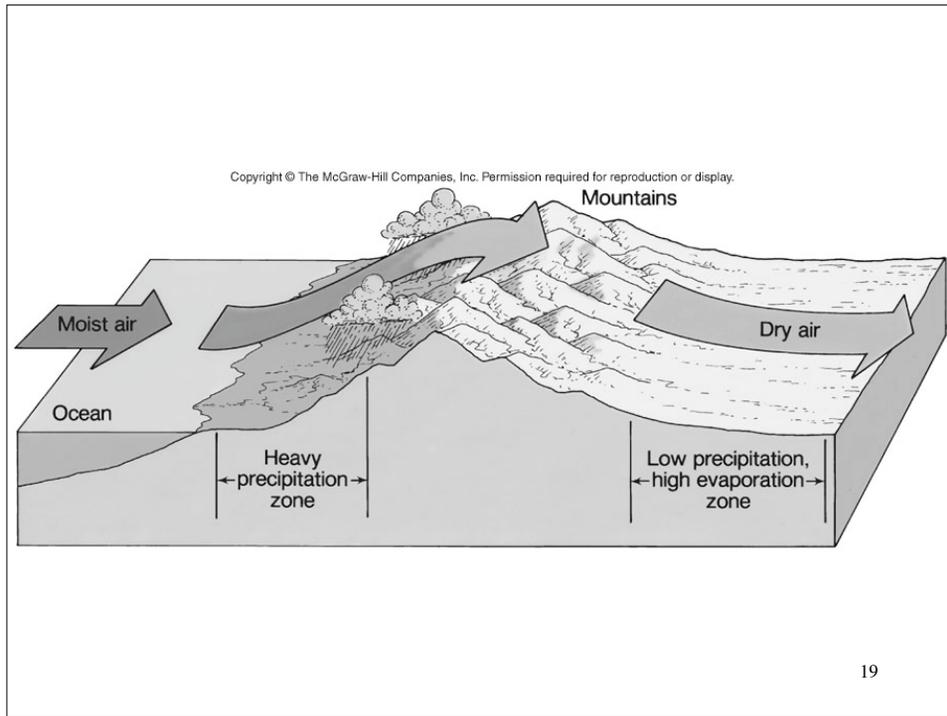


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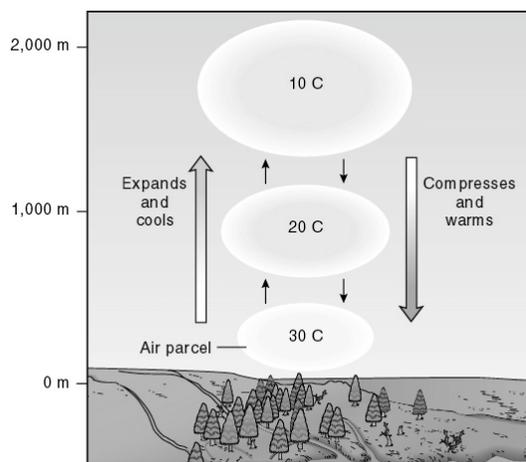
(b)

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## Temperature of Rising and Falling Air

Ascending air cools as it expands. Cooler air can hold less water, so water vapor condenses into clouds. Descending air warms as it compresses and the clouds evaporate.

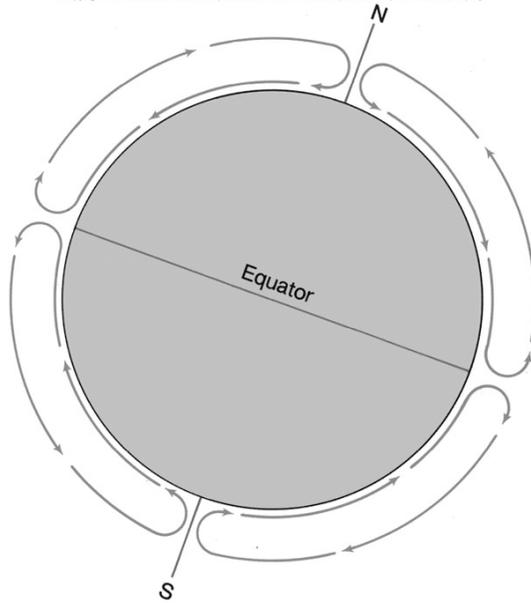


(a)

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## Simple air circulation on a non-rotating Earth

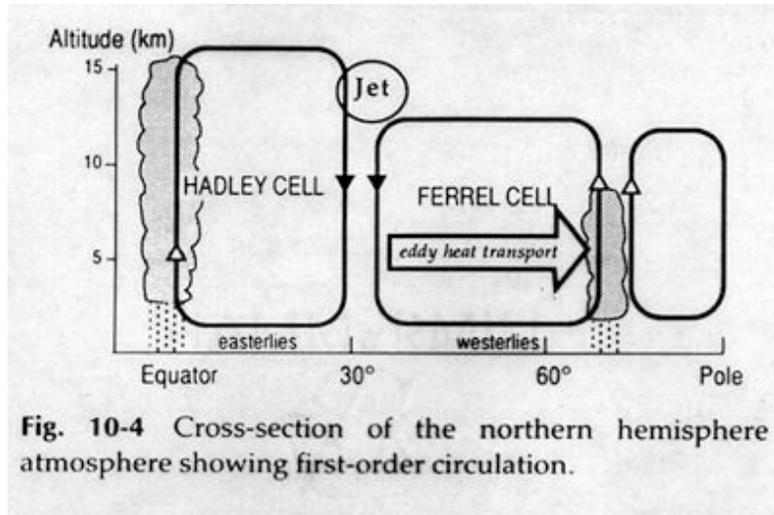
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## Atmospheric Circulation Cells

A large circuit of air is called an atmospheric circulation cell. Three cells exist in each hemisphere.

- Hadley cells are tropical cells found on each side of the equator.
- Ferrel cells are found at the mid-latitudes.
- Polar cells are found near the poles.

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**Fig. 10-4** Cross-section of the northern hemisphere atmosphere showing first-order circulation.

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## Three Major Convection Cells in Each Hemisphere

- The Hadley cell extends from the Equator to about 30° latitude.
- The Ferrel Cell extends from 30° to about 50° latitude.
- The Polar Cell extends from 90° to about 50° latitude.
- The Coriolis effect causes wind in these cells to bend to the east or west to form the westerlies, easterlies, and the trade winds.

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## Fluid Motion

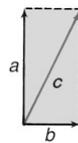
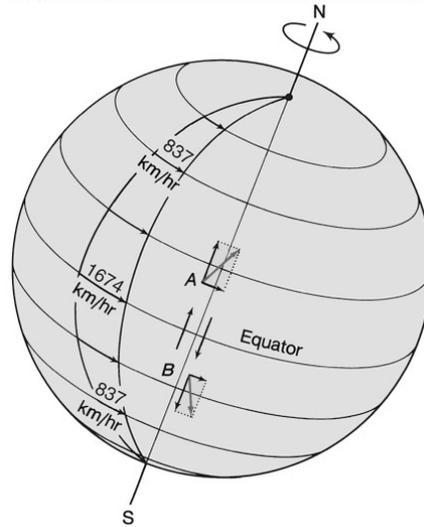
- Fluids (air and water) flow from areas of high pressure to areas of low pressure.
- Change in pressure across a horizontal distance is a pressure gradient.
- Movement of air across a pressure gradient parallel to Earth's surface is called a wind
- Winds are named for the direction from which they come.

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## Rotation of the Earth Influences Winds

- Global winds blow in response to variation in pressure related to uneven solar heating (insolation) of Earth's surface.
- Coriolis deflection is the apparent deflection of objects moving across Earth's surface to the right of direction of travel in the northern hemisphere and to the left of direction of travel in the southern hemisphere.

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- $a$  = Initial north or south wind velocity of poleward moving air
- $b$  = Initial eastward velocity minus the eastward velocity of the Earth at a higher latitude
- $c$  = Resultant velocity of the wind

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## The Coriolis Effect

**The Coriolis effect is the observed deflection of a moving object, caused by the moving frame of reference on the spinning Earth.**

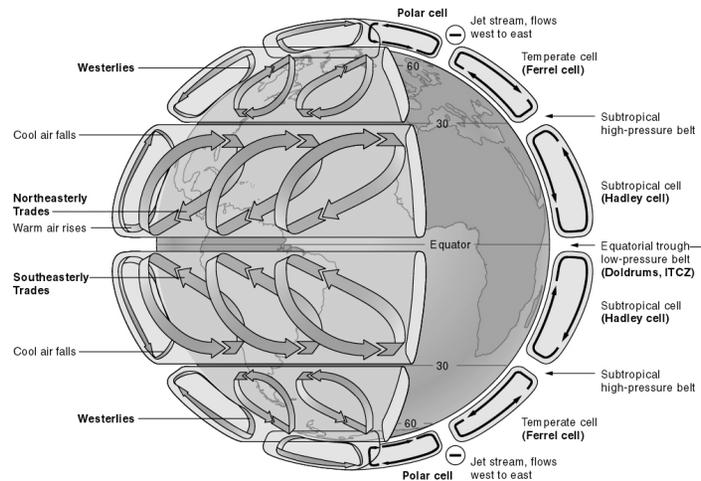
As air warms, expands, and rises at the equator, it moves toward the pole, but instead of traveling in a straight path, the air is deflected eastward.

In the Northern Hemisphere air turns to the right.

In the Southern Hemisphere air turns to the left.

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# The Coriolis Effect



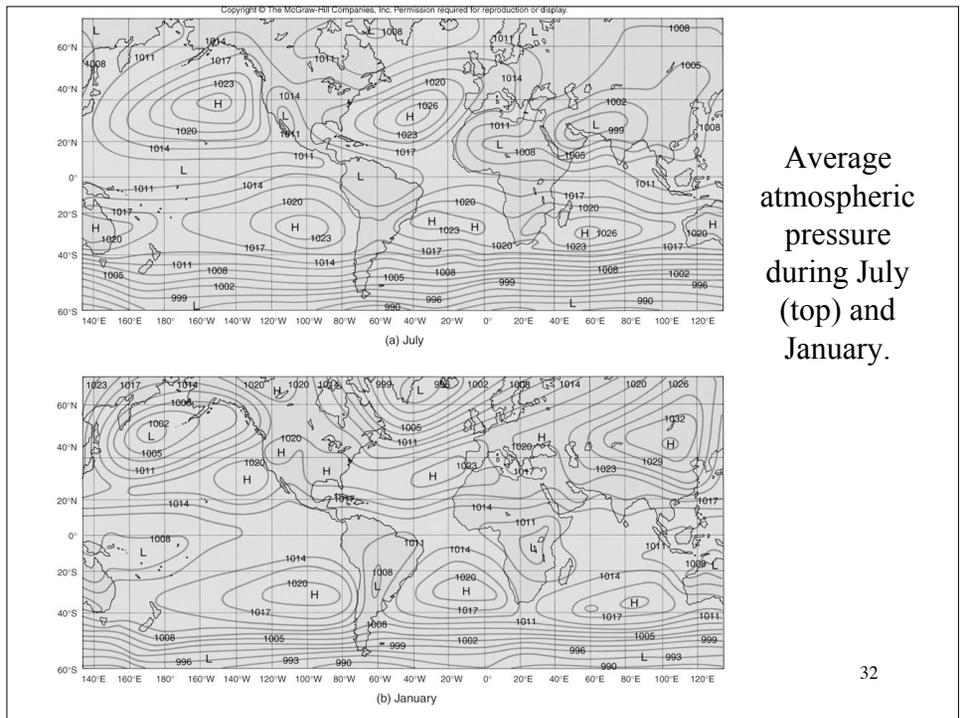
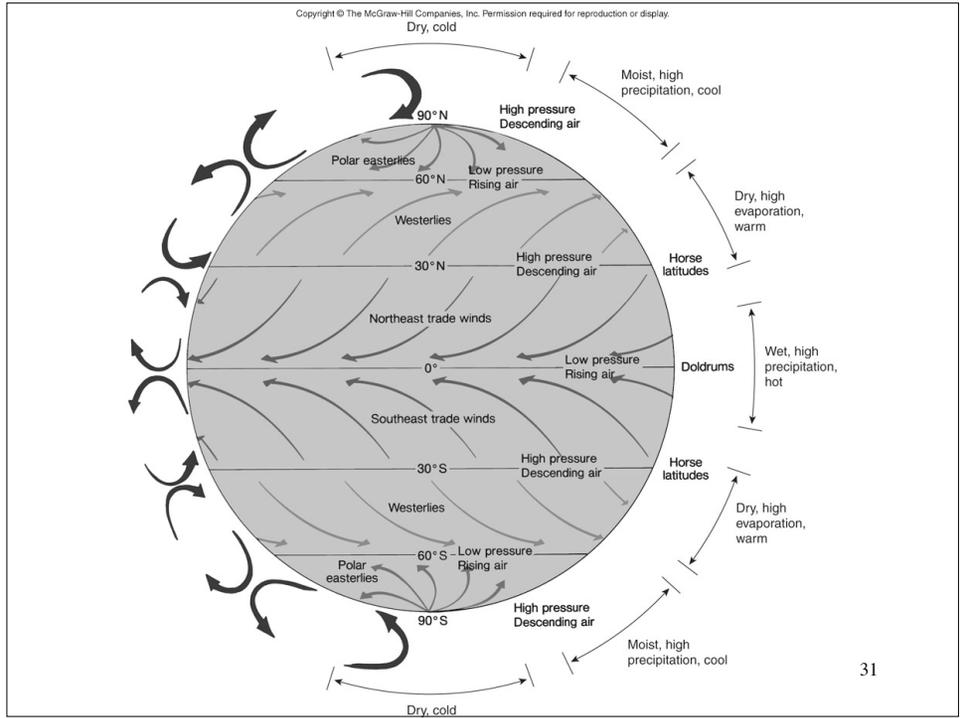
Air moves in cells, influenced by the Coriolis effect.

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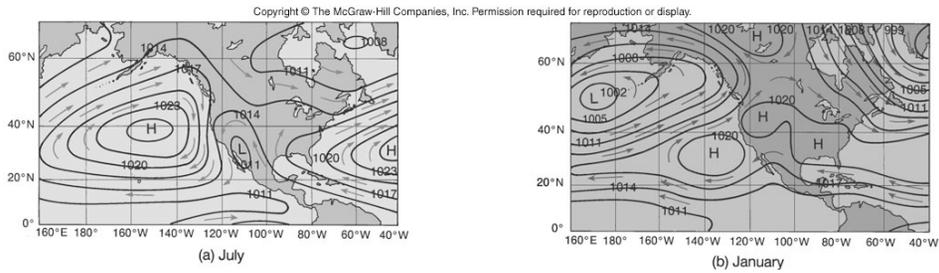
# Wind Patterns

- The doldrums are calm equatorial areas where two Hadley cells converge
- The horse latitudes are areas between Hadley and Ferrel cells. There is little surface wind in this area.
- The trade winds are surface winds of Hadley cells.
- The westerlies are surface winds of Ferrel cells.

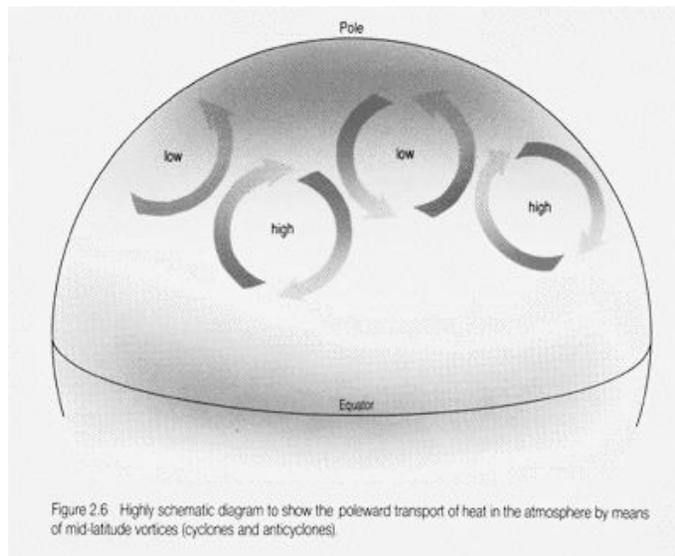
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**Summer (left) and winter prevailing winds controlled by pressure cells.**



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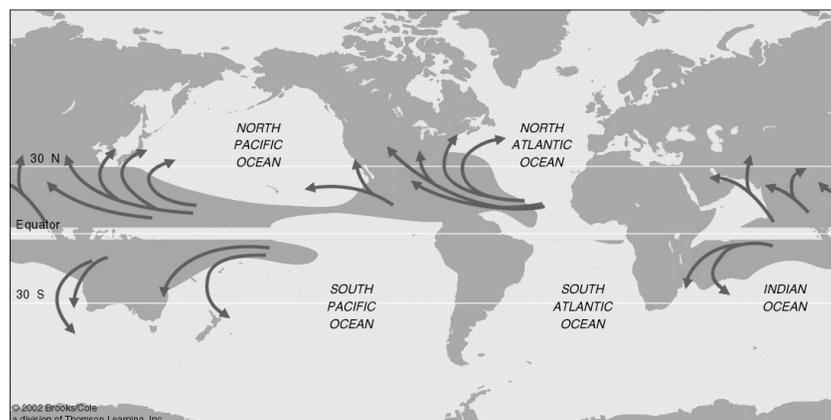
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# Storms

- Storms are regional atmospheric disturbances. Storms have high winds and most have precipitation.
- Tropical cyclones occur in tropical regions. These storms can cause millions of dollars worth of damage and endanger life.
- Extratropical cyclones occur in Ferrel cells, and are winter weather disturbances. These storms can also cause extensive damage.
- Both types of storms are cyclones, or rotating masses of low-pressure air.

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# Storms



The orange shaded areas and arrows designate the location and movement of most hurricanes.

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