

The Relationship between the Weather & Climate

Chapter 5 (etc.)

What is weather?

- Weather is a local area's short-term physical conditions such as temperature and precipitation; The state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity, and barometric pressure.
 - Short-term could refer to a weather pattern that lasts for an afternoon or up to several days.

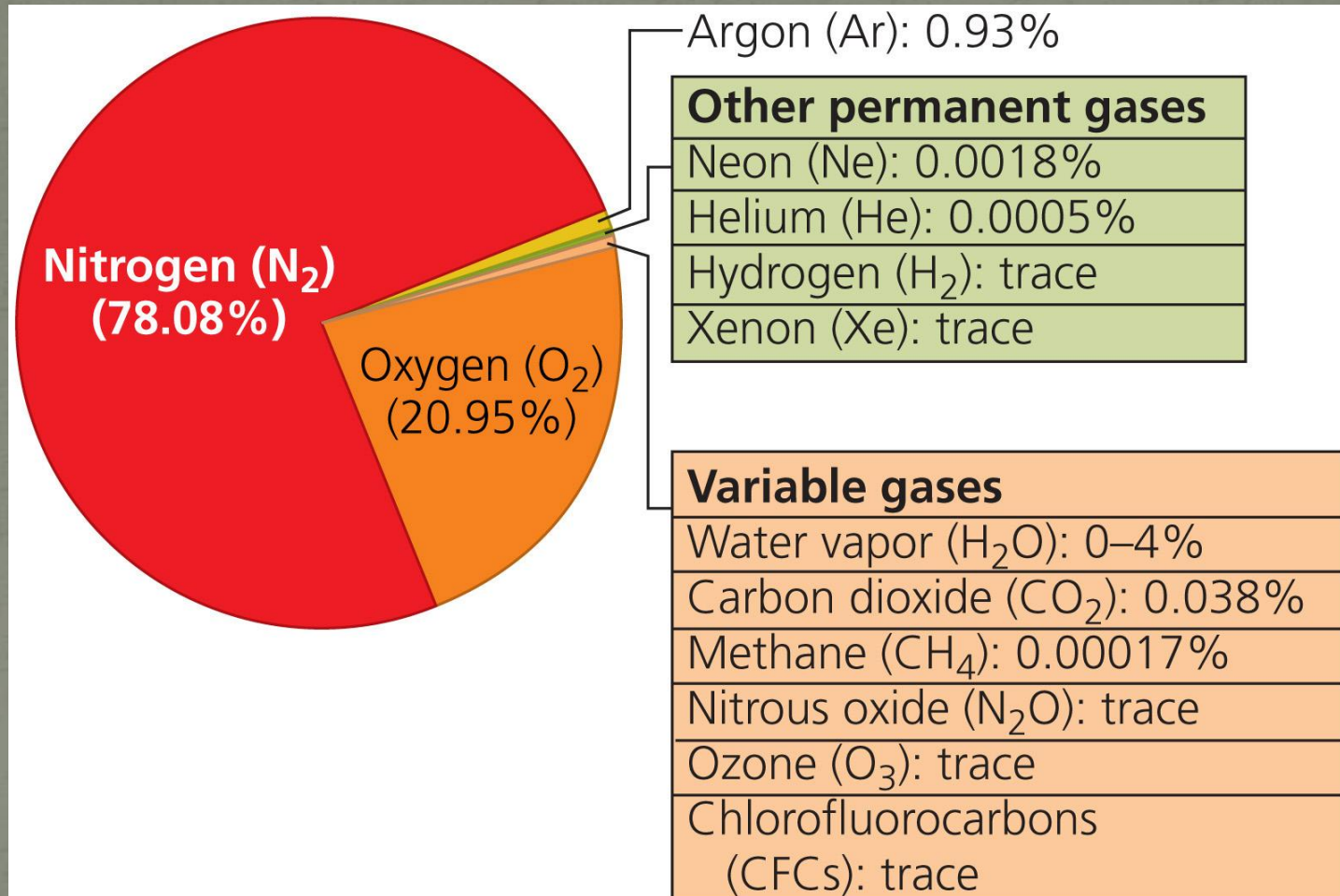
Where does weather take place?

- Weather takes place in the troposphere, the lowest portion of our Earth's atmosphere.

The atmosphere

- **Atmosphere** = the thin layer of gases that surrounds Earth
 - Absorbs radiation and moderates climate
 - Transports and recycles water and nutrients
 - 78% nitrogen gas, 21% oxygen gas, 1% other gases
 - Its four layers differ in temperature, density and composition
- Minute concentrations of **permanent** (remain at stable concentrations) and **variable gases** (varying concentrations)
- Human activity is changing the amounts of some gases

The atmosphere's composition



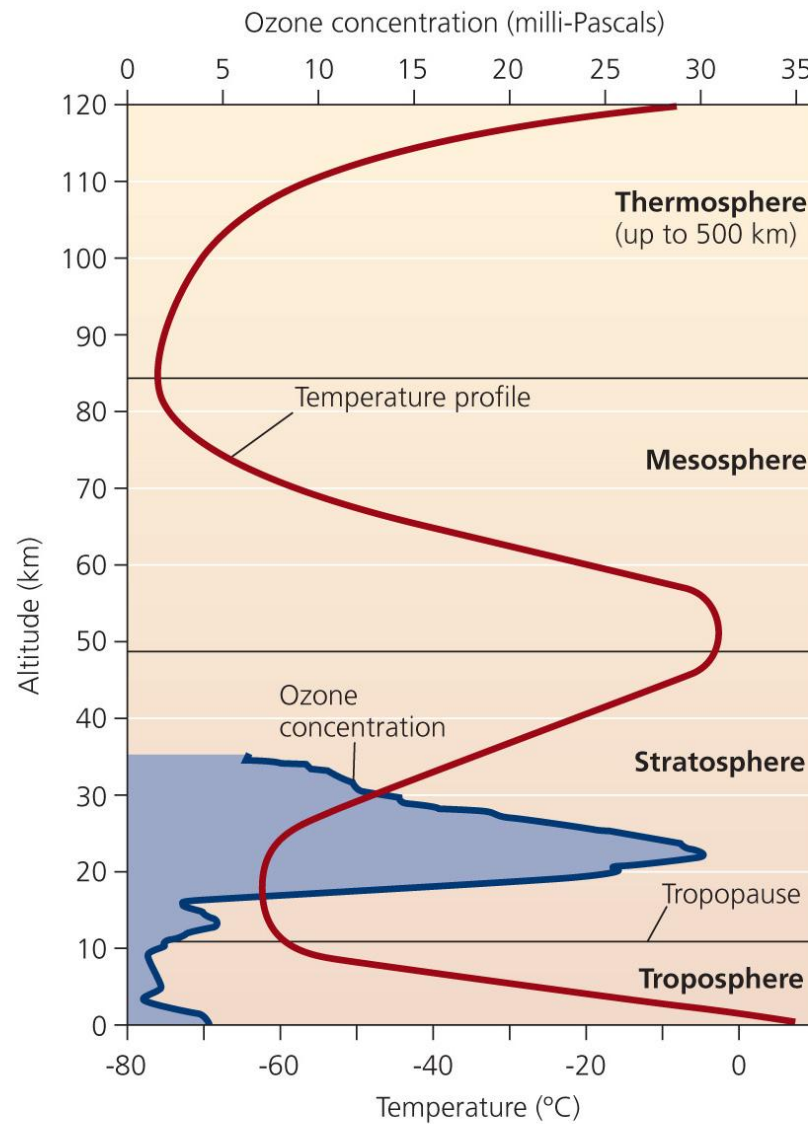
The first two layers of the atmosphere

- **Troposphere** = bottommost layer
 - Air for breathing, weather
 - Temperature declines with altitude
 - **Tropopause** = limits mixing between troposphere and the layer above it
- **Stratosphere** = 11-50 km (7-31 mi) above sea level
 - Drier and less dense, with little vertical mixing
 - Colder in its lower regions
 - Contains UV radiation-blocking ozone, 17-30 km (10-19 mi) above sea level

The two highest levels of the atmosphere

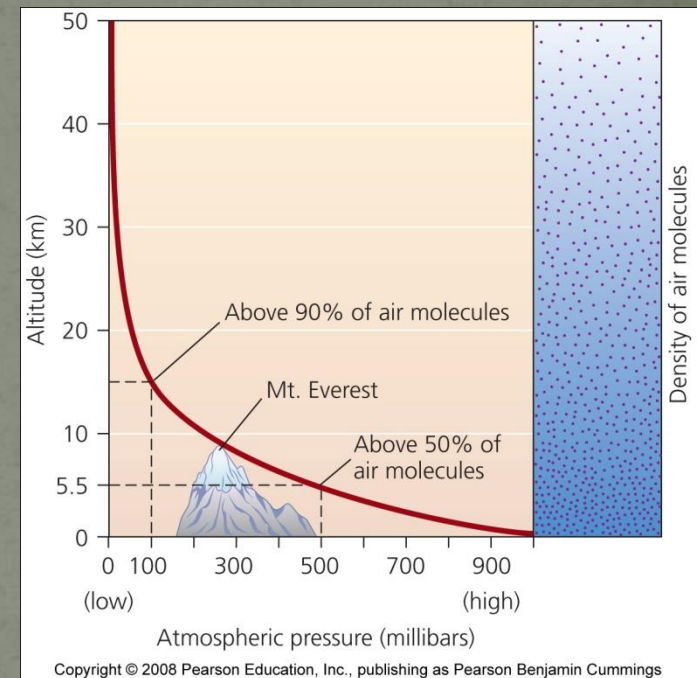
- **Mesosphere** = 50-80 km (31-56 mi) above sea level
 - Extremely low air pressure
 - Temperatures decrease with altitude
- **Thermosphere** = atmosphere's top layer
 - Extends upward to 500 m (300 mi)

The atmosphere's four layers



Atmospheric properties

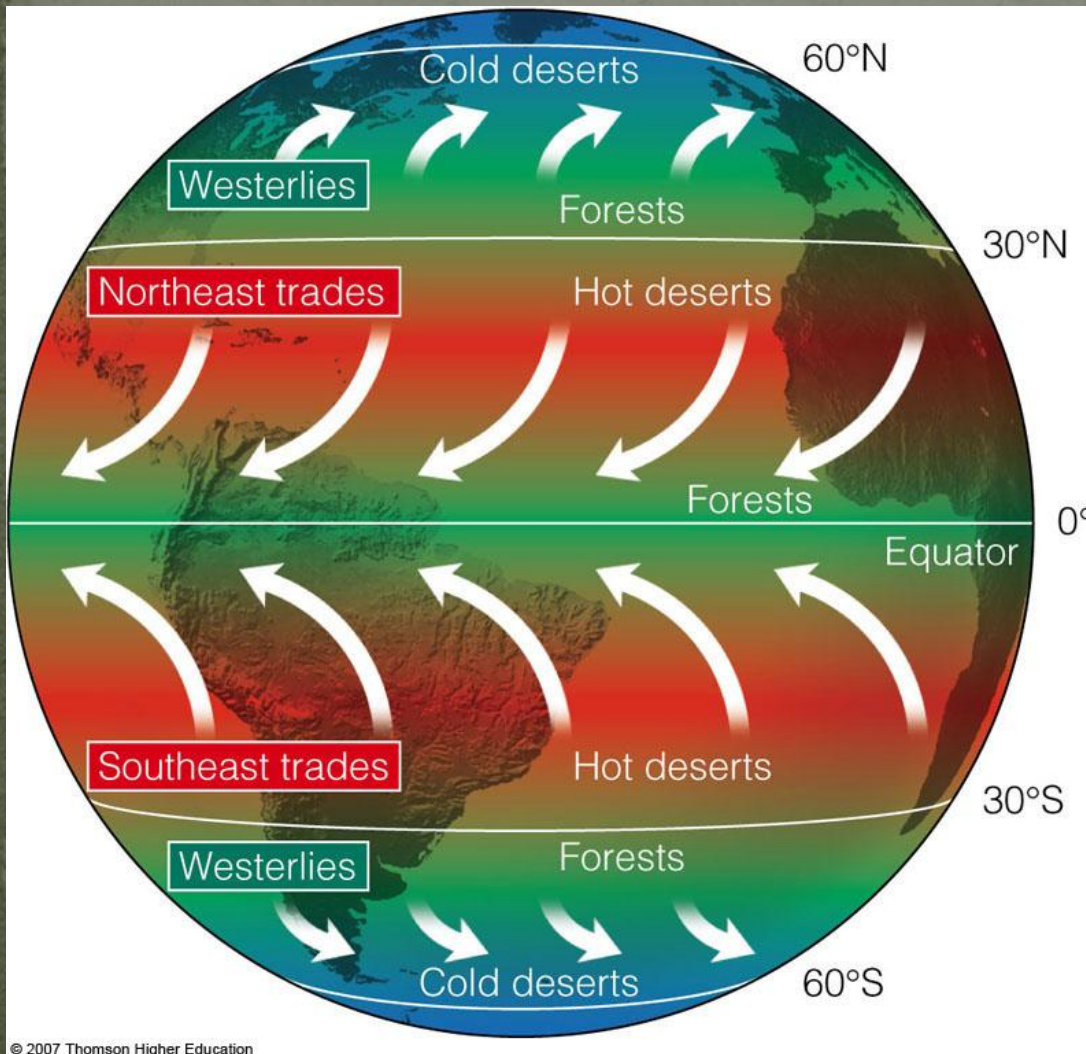
- **Atmospheric pressure** = measures the force per unit area produced by a column of air
 - Decreases with altitude
- **Relative humidity** = the ratio of water vapor a given volume of air contains to the amount it could contain at a given temperature
- **Temperature** = varies with location and time



Dew Point

- The dew point is the temperature to which a given parcel of air must be cooled, at constant barometric pressure for water vapor to condense into water.
- (English version: The dew point is a temperature at which the air becomes saturated and condensation begins. When it is accompanied by cool temperatures, this causes frost!)

Coriolis Effect

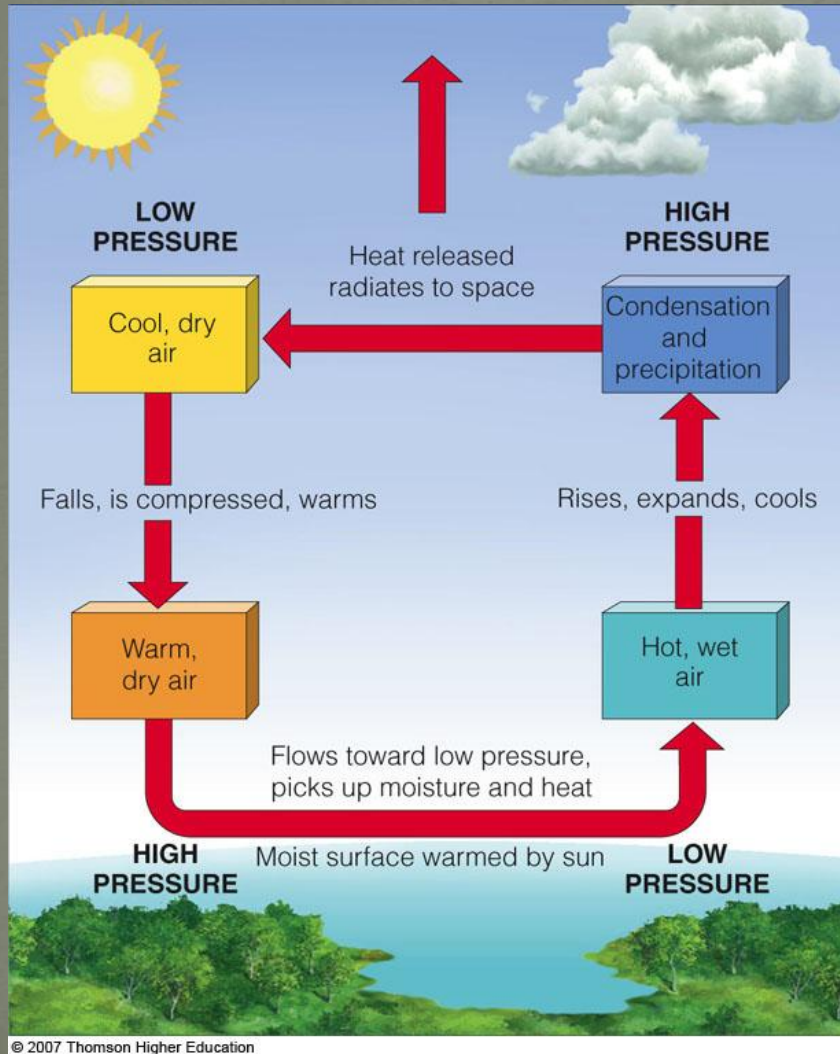


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- Global air circulation is affected by the rotation of the earth on its axis.

Figure 5-4

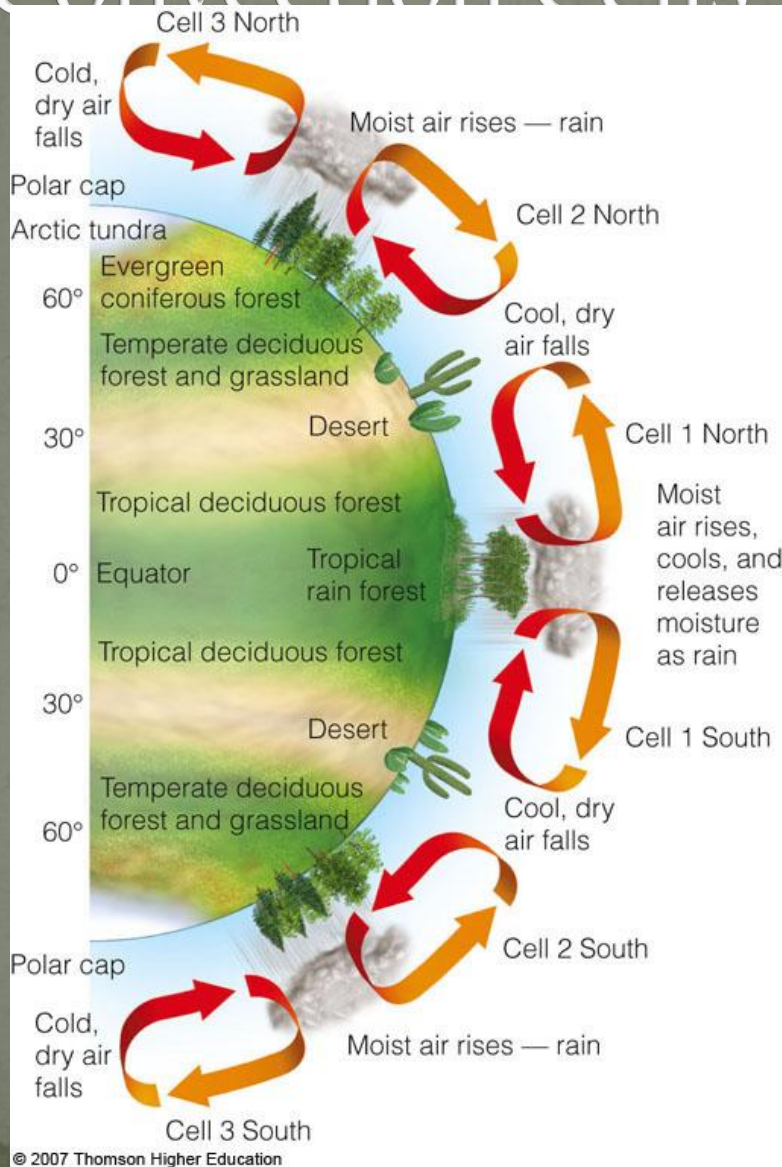
Convection Currents



- Global air circulation is affected by the properties of air water, and land.

Figure 5-5

Convection Cells

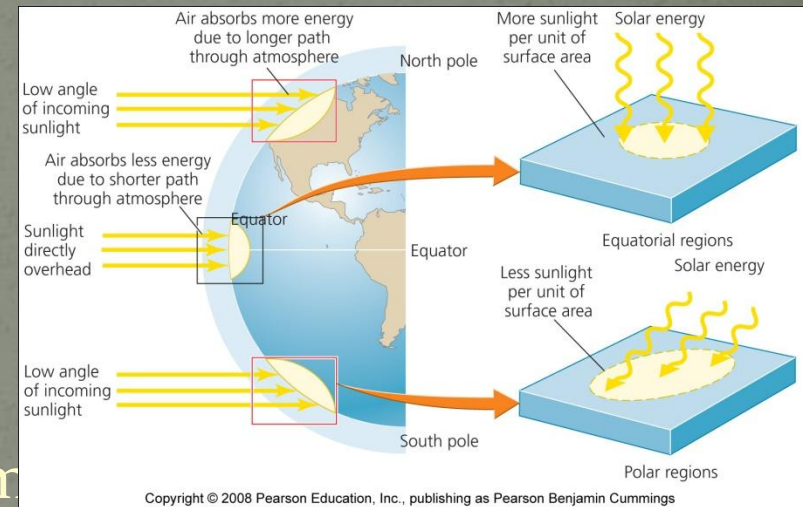


- Heat and moisture are distributed over the earth's surface by vertical currents, which form six giant convection cells at different latitudes.

Figure 5-6

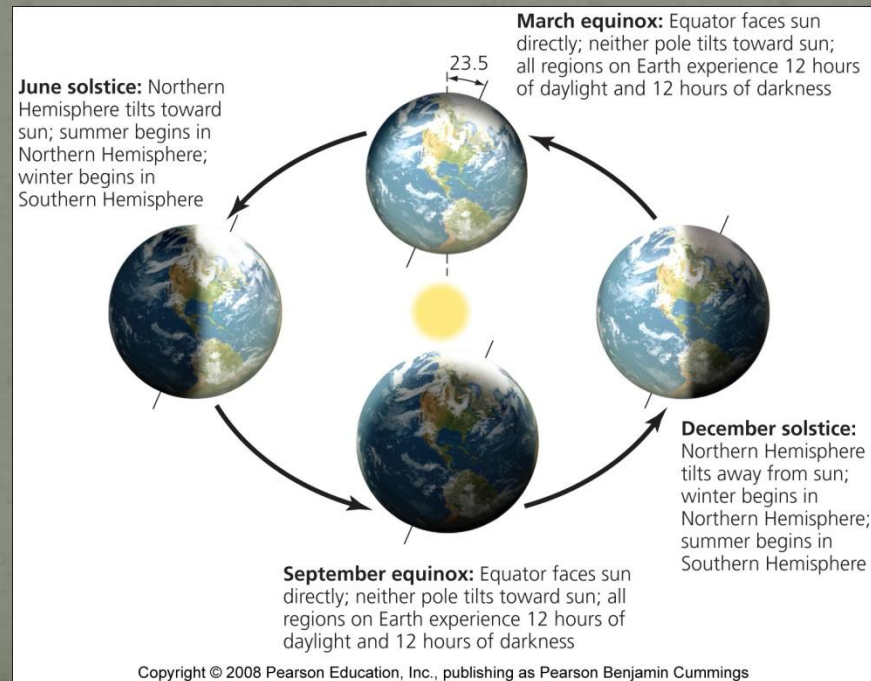
Solar energy heats the atmosphere

- The spatial relationship between the Earth and sun determines the amount of solar energy striking the Earth
- Energy from the sun
 - Heats air
 - Moves air
 - Creates seasons
 - Influences weather and climate
- Solar radiation is highest near the equator

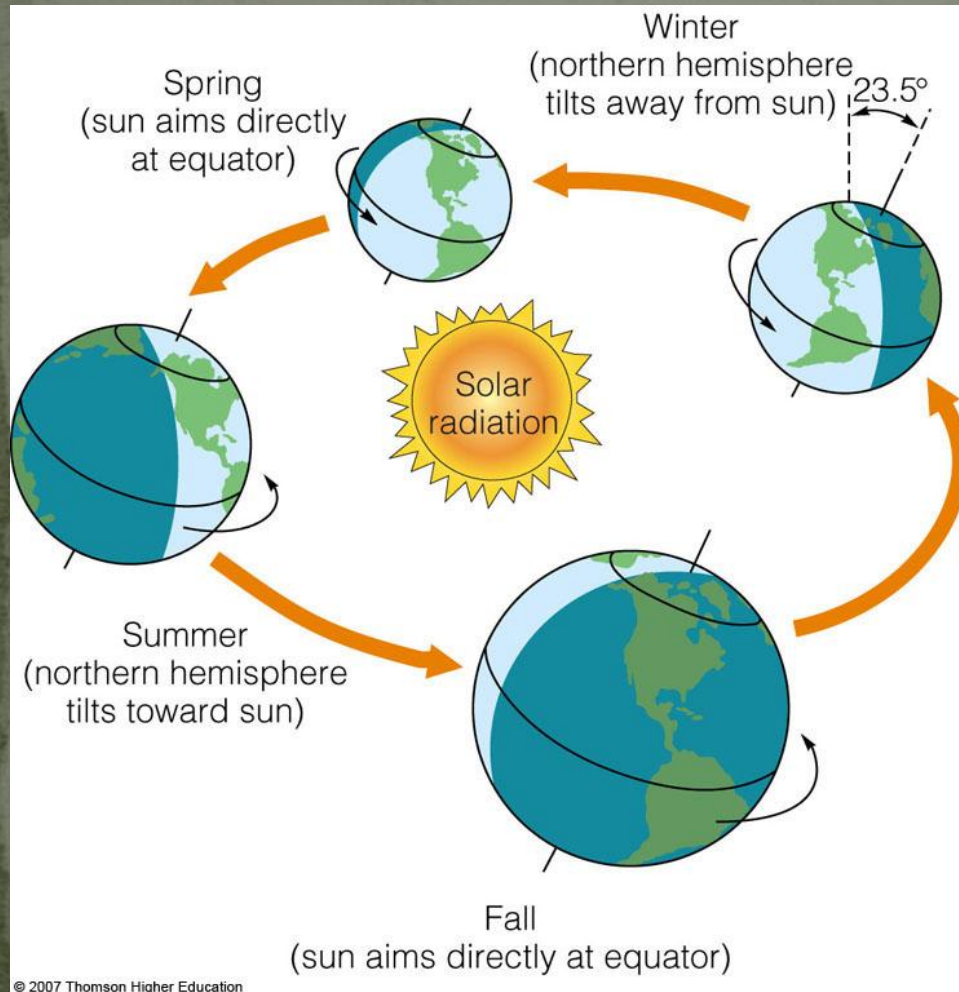


• Solar energy creates seasons

- Because the Earth is tilted
 - Each hemisphere tilts toward the sun for half the year
 - Results in a change of seasons
 - Equatorial regions are unaffected by this tilt, so days average 12 hours through the year



Solar Energy and Global Air Circulation: Distributing Heat

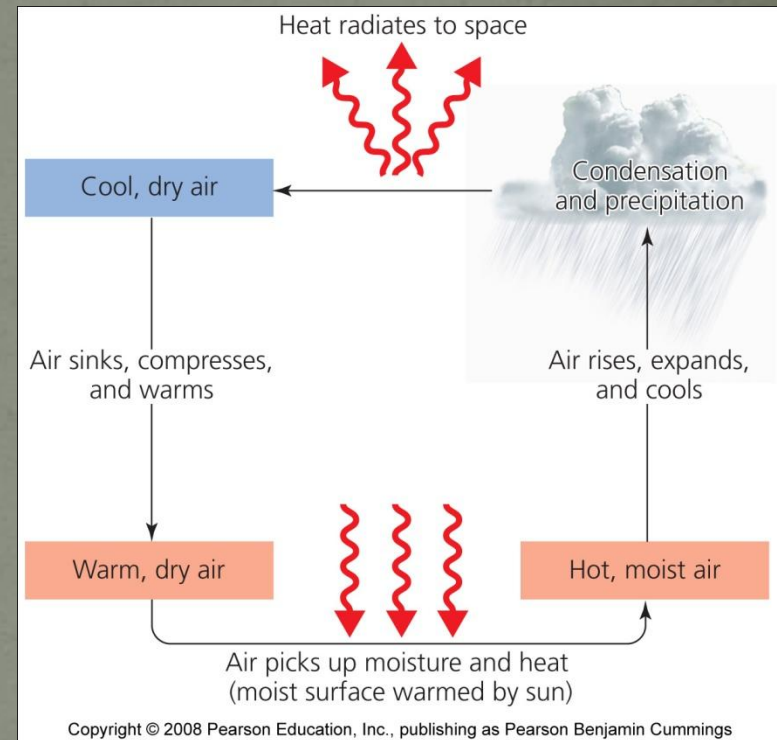


- Global air circulation is affected by the uneven heating of the earth's surface by solar energy, seasonal changes in temperature and precipitation.

Figure 5-3

Solar energy causes air to circulate

- Air near Earth's surface is warmer and moister than air at higher latitudes
- **Convective circulation** = less dense, warmer air rises and creates vertical currents
 - Rising air expands and cools
 - Cool air descends and becomes denser, replacing warm air
 - Influences both weather and climate

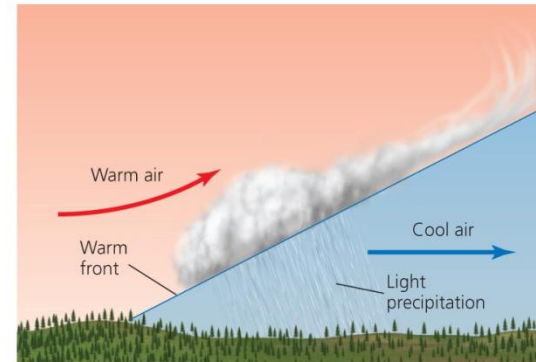


climate

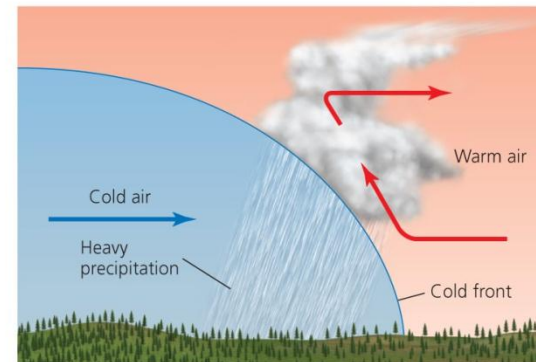
- **Weather** = specifies atmospheric conditions over short time periods and within a small geographic areas
- **Climate** = describes patterns of atmospheric conditions across large geographic regions over long periods of time
- Mark Twain said “Climate is what we expect; weather is what we get”

Air masses produce weather

- **Front** = the boundary between air masses that differ in temperature, moisture, and density
- **Warm Front** = the boundary where warm moist air replaces colder, drier air
- **Cold Front** = the boundary where colder, drier air displaces warmer, moister air



(a) Warm front

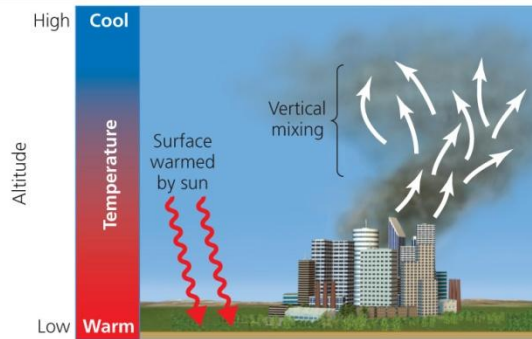


(b) Cold front

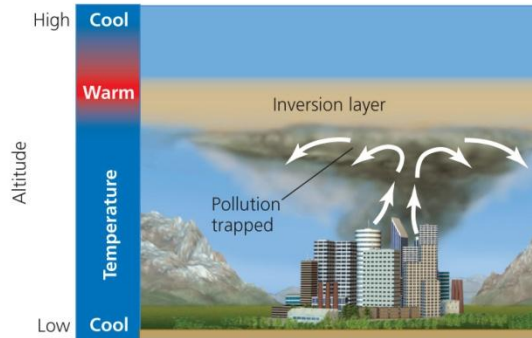
Air masses have different atmospheric pressures

- **High-pressure system** = air that moves away from a center of high pressure as it descends
 - Brings fair weather
- **Low-pressure system** = air moves toward the low atmospheric pressure at the center of the system and spirals upward
 - Clouds and precipitation

Thermal inversion



(a) Normal conditions



(b) Thermal inversion

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Usually, tropospheric air temperature decreases as altitude increases

- Warm air rises, causing vertical mixing

Thermal inversion = a layer of cool air occurs beneath a layer of warmer air

- **Inversion layer** = the band of air in which temperature rises with altitude
- Denser, cooler air at the bottom of the layer resists mixing

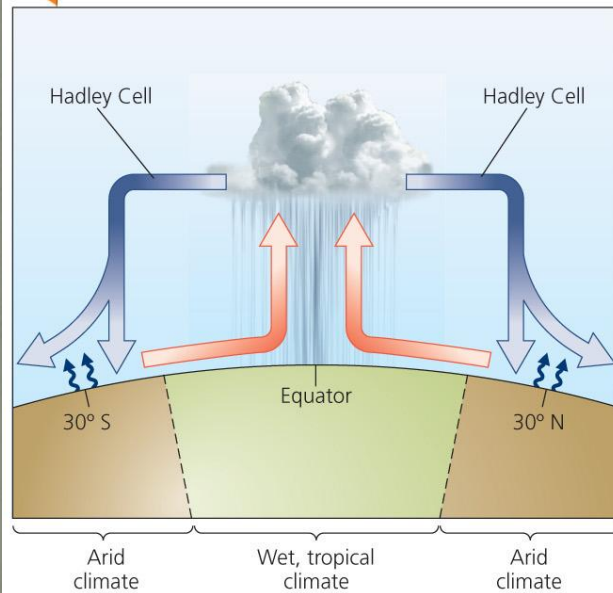
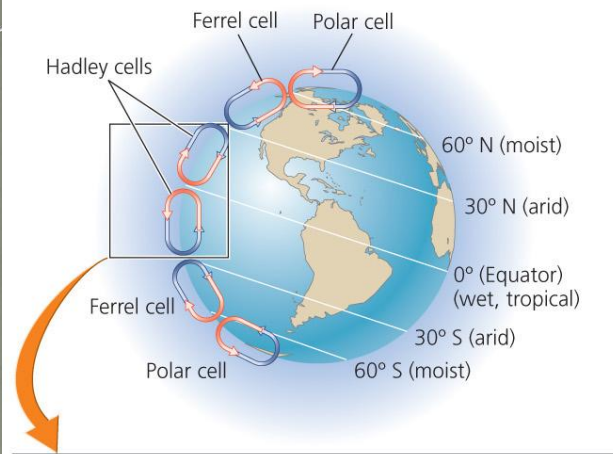
The atmosphere

- Convective currents contribute to climatic patterns and affect moisture distribution
- **Hadley cells** = near the equator, surface air warms, rises, and expands
 - Releases moisture and heavy rainfall near the equator
- **Ferrel cells and polar cells** = lift air
 - Creates precipitation at 60 degrees latitude north and south
 - Causes air to descend at 30 degrees latitude

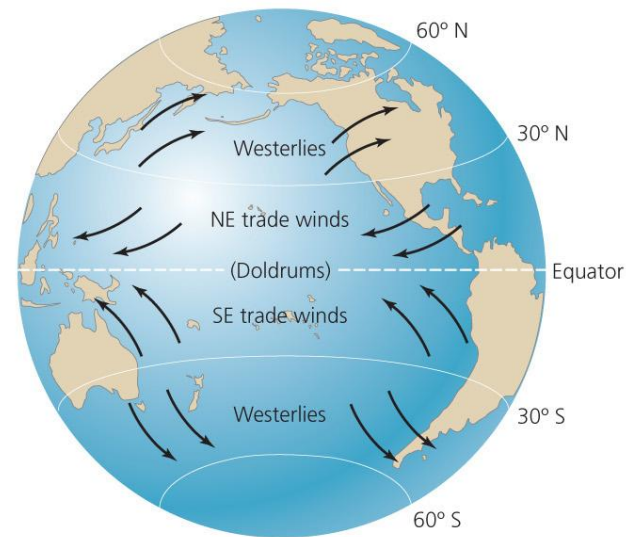
Global wind patterns

- The atmospheric cells interact with Earth's rotation to produce global wind patterns
 - As Earth rotates, equatorial regions spin faster
- **Coriolis effect** = the north-south air currents of the convective cells appear to be deflected from a straight path
 - Results in curving global wind patterns

Climate patterns and moisture distribution

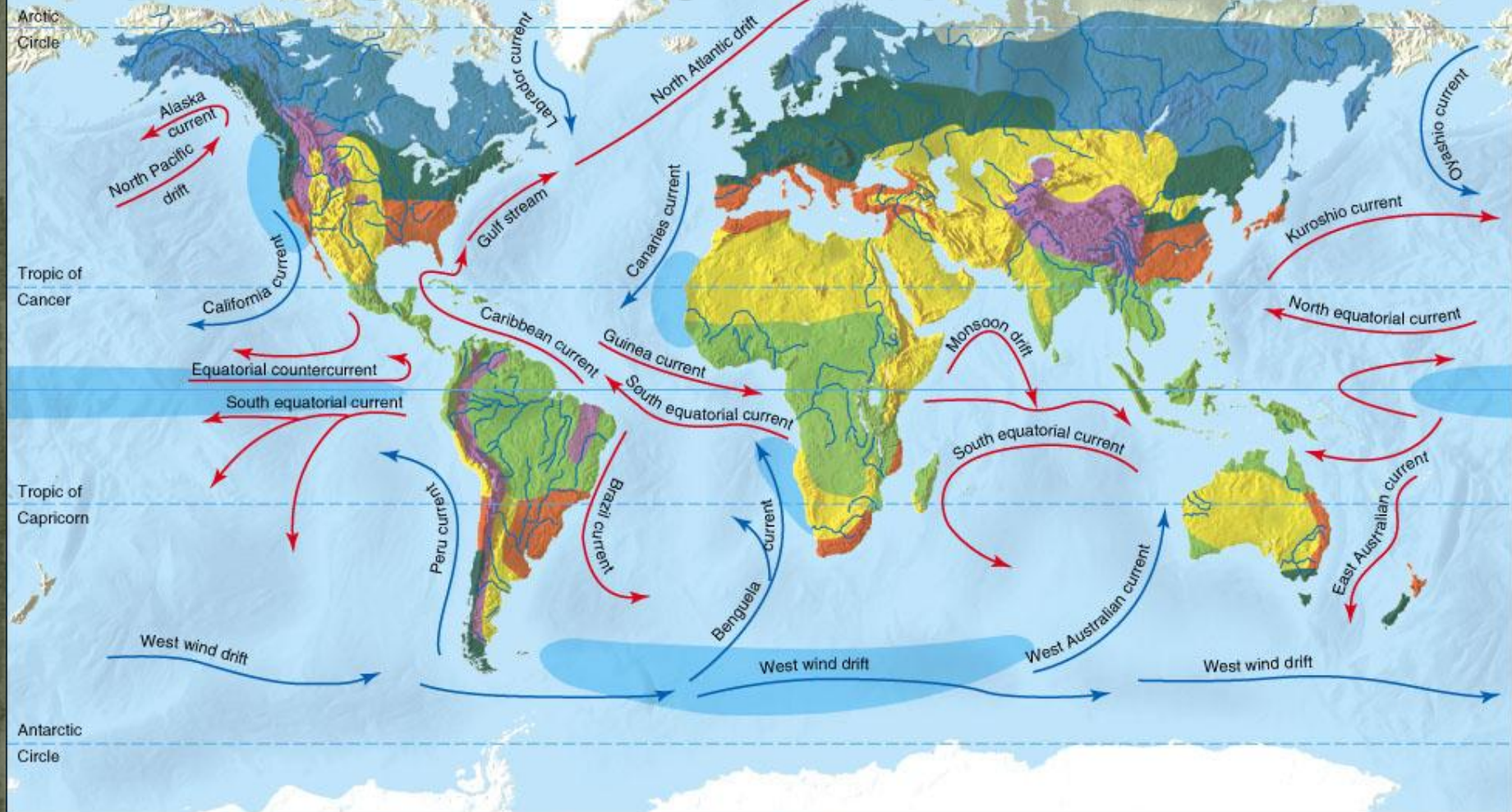


(a) Convection currents



(b) Global wind patterns

Earth's Current Climate Zones

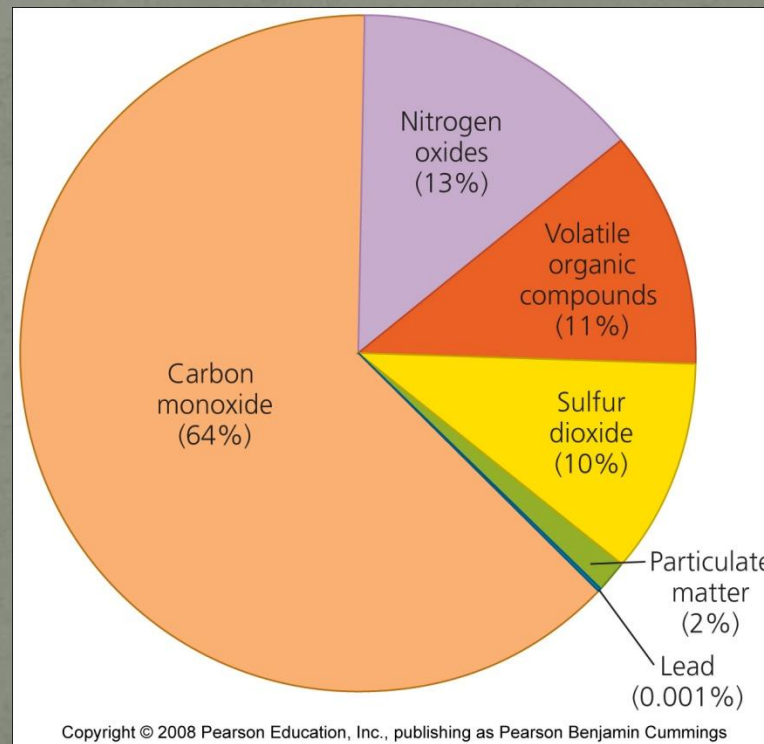


Wind patterns

- **Doldrums** = near the equator
 - Few winds
- **Trade winds** = between the equator and 30 degrees latitude
 - Blow from east to west
- **Westerlies** = from 30 to 60 degrees latitude
 - Originate from the west and blow east
- People used these winds to sail their ships across the ocean

U.S. air pollution: The reason that air flow is important.

In 2006, the U.S. emitted 137 million tons of the six major pollutants



Impact of Weather

- Severe weather can impact the environment . . . How?
 - Hurricanes, tornados, floods, drought, lightening storms, high wind, snow, hail

Can you predict the future?

- Weather forecasters use historical data and current conditions to “predict” what weather patterns are coming
 - [National Oceanographic and Atmospheric Administration](#)
- You can look at historical data from your area
 - [Welcome to Weather Underground : Weather Underground](#)

The difference in Weather and Climate

- Climate is a region's average weather conditions over a long period of time.
 - Latitude and elevation help determine climate.
 - Unseasonable weather does not indicate a change in the climate

Our dynamic climate

- Climate influences everything around us
- The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) made it clear that:
 - Climate is changing, we are the cause, and this change is already exerting impacts that will become increasingly severe
- Al Gore's movie *An Inconvenient Truth* has been seen by millions
- Climate change is the fastest-moving area of environmental science today

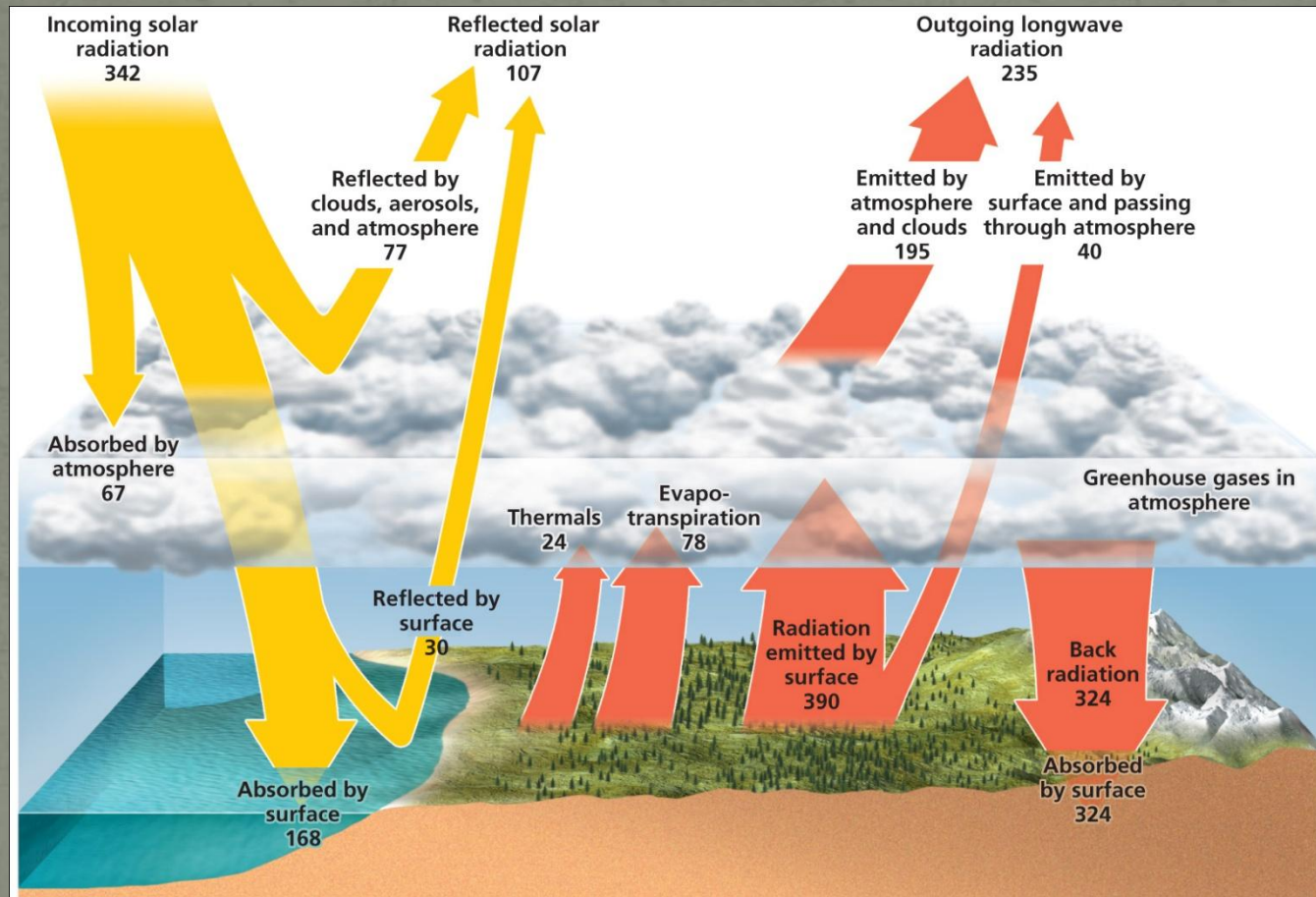
What is climate change?

- **Climate** = an area's long-term atmospheric conditions
 - Temperature, moisture content, wind, precipitation, etc.
- **Weather** = conditions at localized sites over hours or days
- **Global climate change** = describes trends and variations in Earth's climate
 - Temperature, precipitation, storm frequency
- **Global warming** = an increase in Earth's average temperature
 - Earth's climate has varied naturally through time
 - The rapid climatic changes taking place now are due to human activity: fossil fuels, combustion, and deforestation

The Sun and atmosphere keep the Earth warm

- Three factors exert more influence on climate than all others
- The Sun = without it, the Earth would be dark and frozen
 - Also supplies most of our planet's energy
- The atmosphere = without it, the Earth's temperature would be much colder
 - Earth's atmosphere, clouds, land, ice, and water absorb 70% of incoming solar radiation
- The oceans = shape climate by storing and transporting heat and moisture

The fate of solar radiation



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Greenhouse gases warm the lower atmosphere

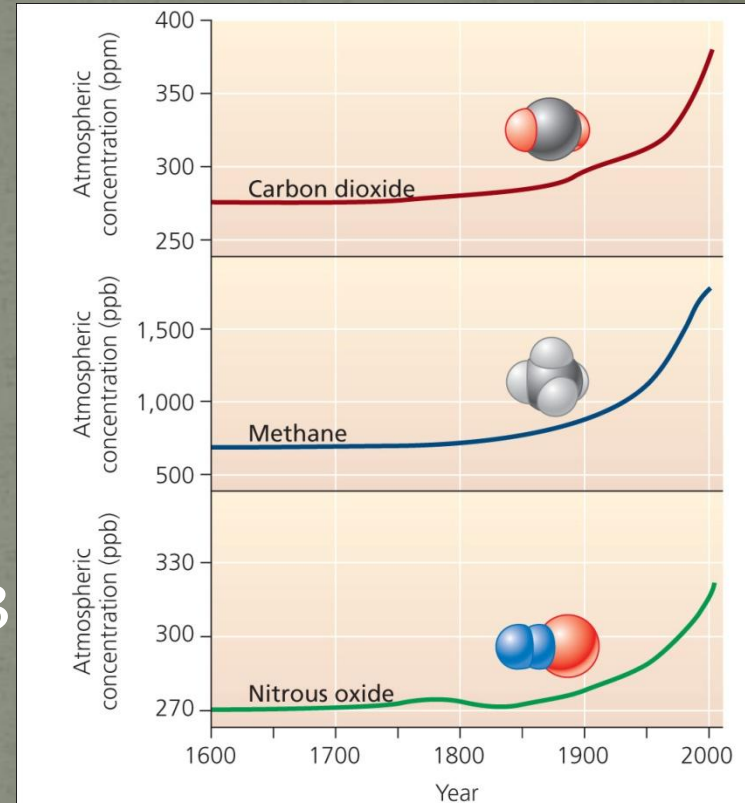
- As Earth's surface absorbs solar radiation, the surface increases in temperature and emits infrared radiation
- **Greenhouse gases** = atmospheric gases that absorb infrared radiation
 - The most abundant are water vapor, ozone, carbon dioxide, nitrous oxide, methane.
 - Additional gases are from industry and include Hydrofluorocarbons (HFCs) , Perfluorocarbons (PFCs), and Sulfur hexafluoride (SF₆)
 - Greenhouse gases differ in their ability to warm the troposphere and surface

The greenhouse effect

- After absorbing radiation, greenhouse gases re-emit infrared energy
 - Some energy is lost to space
 - **Greenhouse effect** = some energy travels back downward, warming the atmosphere and planet's surface
- **Global potential** = the relative ability of one molecule of a given greenhouse gas to contribute to warming
 - Expressed in relation to carbon dioxide (potential = 1)
 - Hydrochlorofluorocarbons are 12,000 times as potent as carbon dioxide

Carbon dioxide is of primary concern

- Not the most potent greenhouse gas, but it is extremely abundant
 - The major contributor to global warming
- a) Human activities have boosted atmospheric concentrations from 280 parts per million (ppm) to 383 ppm
 - To their highest levels in more than 650,000 years



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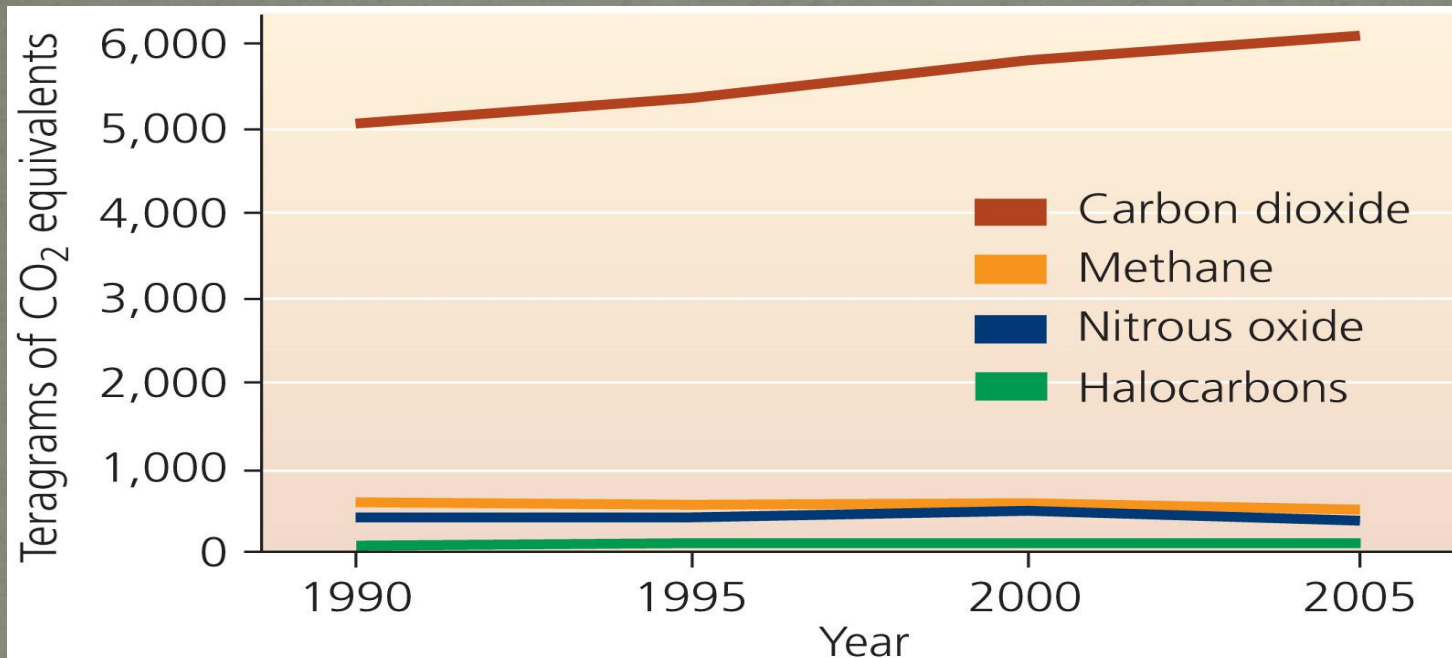
What caused levels of CO₂ to increase?

- Burned fossil fuels in our homes, factories, and automobiles
 - Transferred large amounts of carbon dioxide from lithospheric reservoirs into the atmosphere
 - The main reason atmospheric carbon dioxide concentrations have increased so dramatically
- a) Deforestation has contributed to rising atmospheric CO₂ concentration
 - Forests serve as sinks for recently active carbon
 - Their removal reduces the biosphere's ability to absorb carbon dioxide from the atmosphere

Other greenhouse gases add to warming

- Methane = fossil fuel deposits, livestock, landfills, and crops such as rice
- Nitrous oxide = feedlots, chemical manufacturing plants, auto emissions, and synthetic nitrogen fertilizers
- Ozone = risen due to photochemical smog
- Halocarbon gases (CFCs) = are declining due to the Montreal Protocol
- Water vapor = the most abundant greenhouse gas and contributes most to the greenhouse effect
 - a) Could increase cloudiness, which might slow global warming by reflecting more solar radiation back into space

U.S. emissions of major greenhouse gases

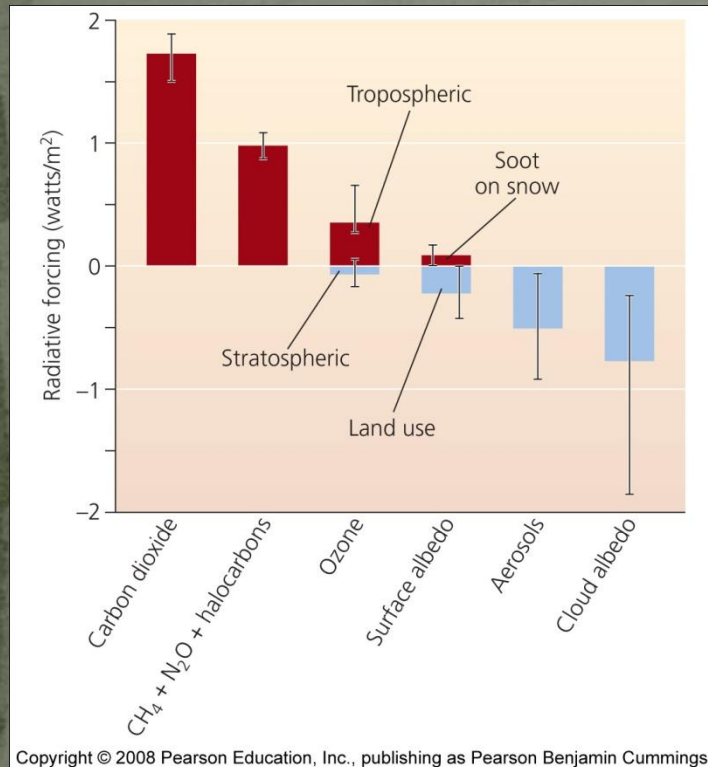


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Aerosols may exert a cooling effect

- **Aerosols** = microscopic droplets and particles that have either a warming or cooling effect
- Soot, or black carbon aerosols, cause warming by absorbing solar energy
 - But, most tropospheric aerosols cool the atmosphere by reflecting the Sun's rays
- a) Sulfate aerosols produced by fossil fuel combustion may slow global warming, at least in the short term
 - Volcanic eruptions reduce sunlight reaching the earth and cool the Earth

Radiative forcing expresses change in energy

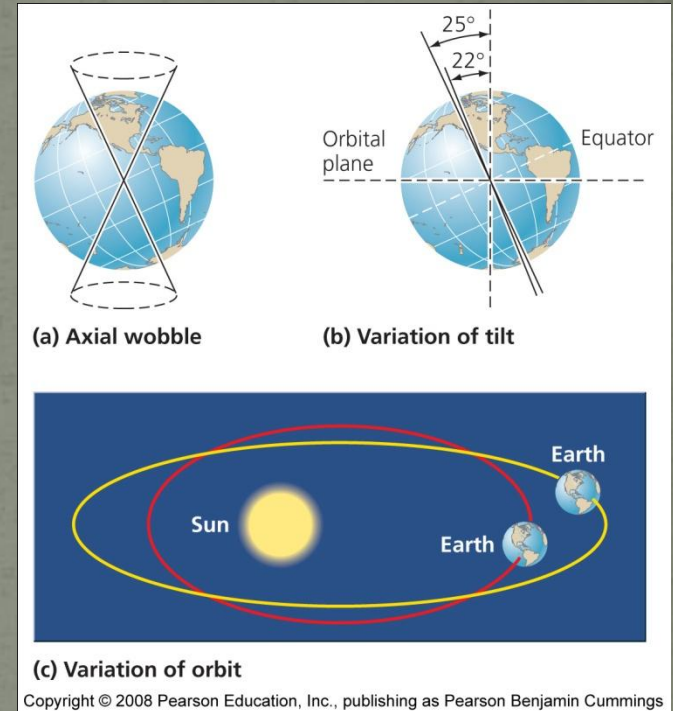


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- Scientists estimate the influence of factors over Earth's energy balance
- **Radiative forcing** = the amount of change in energy that a given factor causes
 - Positive forcing warms the surface; negative forcing cools it
- a) Compared with the pre-industrial Earth, Earth is experiencing radiative forcing of 1.6 watts/m²
 - Enough to alter the climate

Milankovitch cycles influence climate

- **Milankovitch cycles** = periodic changes in Earth's rotation and orbit around the Sun
 - Alter the way solar radiation is distributed over Earth's surface
 - By modifying patterns of atmospheric heating, these cycles trigger long-term climate variation such as periodic glaciation



Solar output and ocean absorption influence climate

- **Solar output** = drives temperature change on Earth's surface
 - The Sun varies in the radiation it emits
 - Variation in solar energy (i.e., solar flares) has not been great enough to change Earth's temperature
- **Ocean absorption** = the ocean holds 50 times more carbon than the atmosphere and absorbs it from the atmosphere
 - Carbon absorption by the oceans is slowing global warming but not preventing it
 - Warmer oceans absorb less CO₂ because gases are less soluble in warmer water – a positive feedback effect that accelerates warming

Ocean Currents: Distributing Heat and Nutrients

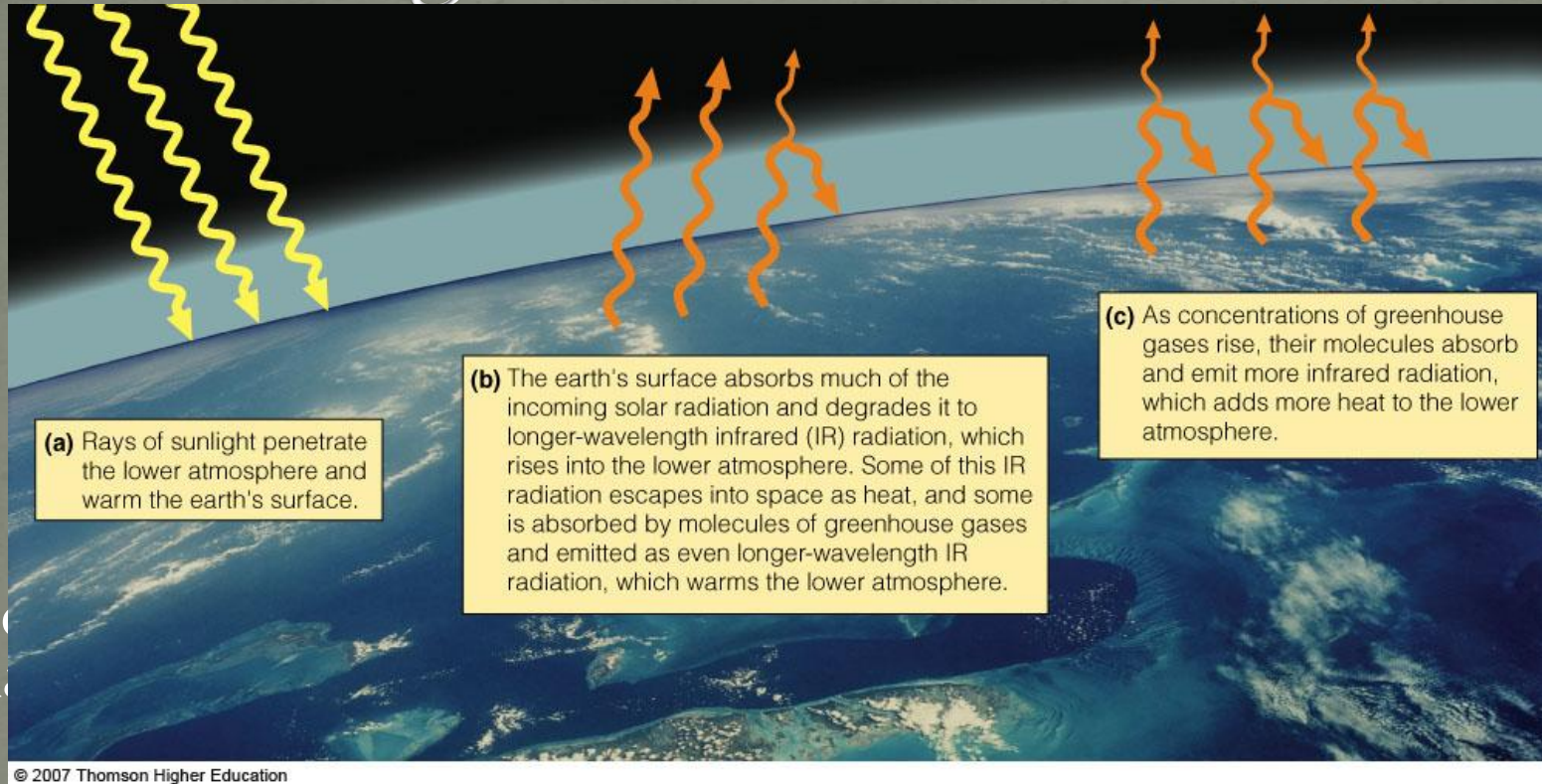


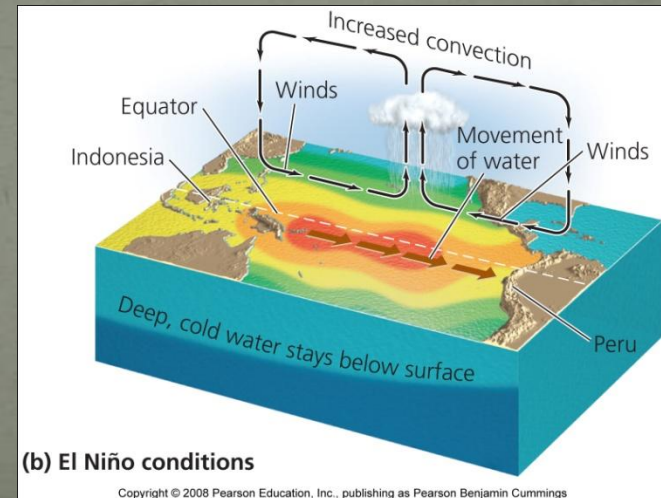
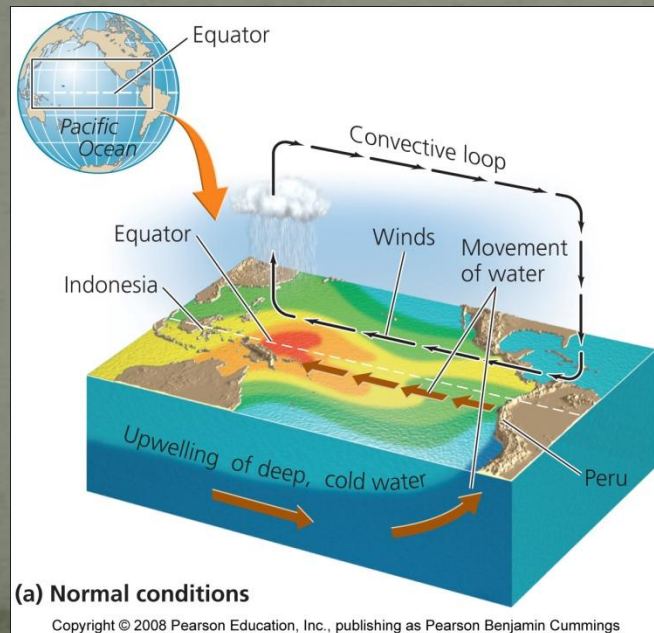
Figure 5-7

Ocean Currents: Distributing Heat and Nutrients

- Global warming:
 - Considerable scientific evidence and climate models indicate that large inputs of greenhouse gases from anthropogenic activities into the troposphere can enhance the natural greenhouse effect and change the earth's climate in your lifetime.

Ocean circulation and ENSO influence climate

- **Ocean circulation** = ocean water exchanges tremendous amounts of heat with the atmosphere, and ocean currents move energy from place to place
- a) **El Niño-southern oscillation (ENSO)** = a systematic shift in atmospheric pressure, sea surface temperature, and ocean circulation in the tropical Pacific



- **El Niño** Normally, winds blow from east to west along the equator, from high to low pressure
- Westward-moving surface waters allow nutrient-rich upwelling along the coast of Peru
- ENSO occurs when air pressure increases in the western Pacific and decreases in the eastern Pacific, causing the equatorial winds to weaken
- Water flows eastward, suppressing upwellings, shutting down delivery of nutrients that support aquatic life
- Coastal industries are devastated, global weather is changed

La Niña events

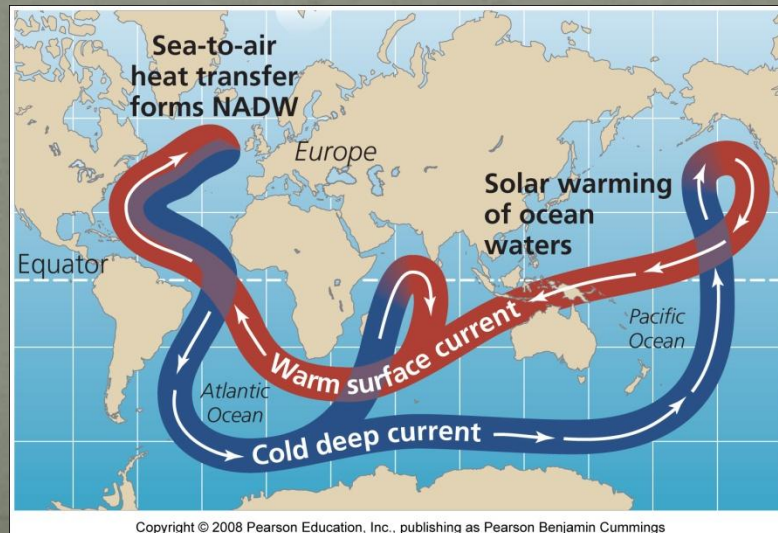
- The opposite of El Niño events
 - Cold surface waters extend far westward in the equatorial Pacific and weather patterns are affected in opposite ways
- ENSO cycles are periodic, occurring every 2-8 years
 - Globally warming air and sea temperatures may be increasing their frequency and strength

Thermohaline circulation

• Thermohaline circulation = a worldwide current system in which warmer, fresher water moves along the surface; and colder, saltier water moves deep beneath the surface

- Warm surface water carries heat to Europe
- **North American Deep Water (NADW)** = the deep portion of the thermohaline circulation, consisting of dense, cool water that sinks
- Interrupting the thermohaline circulation could trigger rapid climate change

- **NADW is vulnerable**
 - If Greenland's ice melts, freshwater runoff would dilute ocean waters, making them less dense, and stopping NADW
 - Some data suggest thermohaline circulation is slowing
- Europe would rapidly cool, as shown in *The Day After Tomorrow*, a movie which exaggerated the impacts



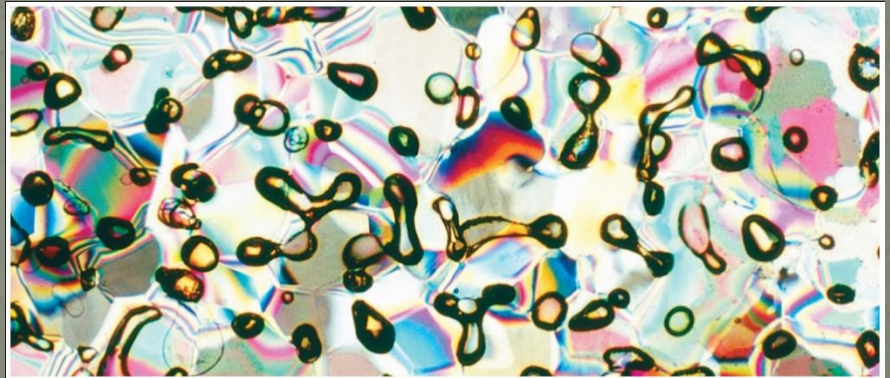
Proxy indicators tell us about the past

- **Proxy indicators** = types of indirect evidence that serve as substitutes for direct measurements
 - Shed light on past climate
 - Ice caps, ice sheets, and glaciers hold clues to Earth's climate
 - Trapped bubbles in ice cores show atmospheric composition, greenhouse gas concentration, temperature trends, snowfall, solar activity, and frequency of fires



(a) Ice core

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(b) Micrograph of ice core

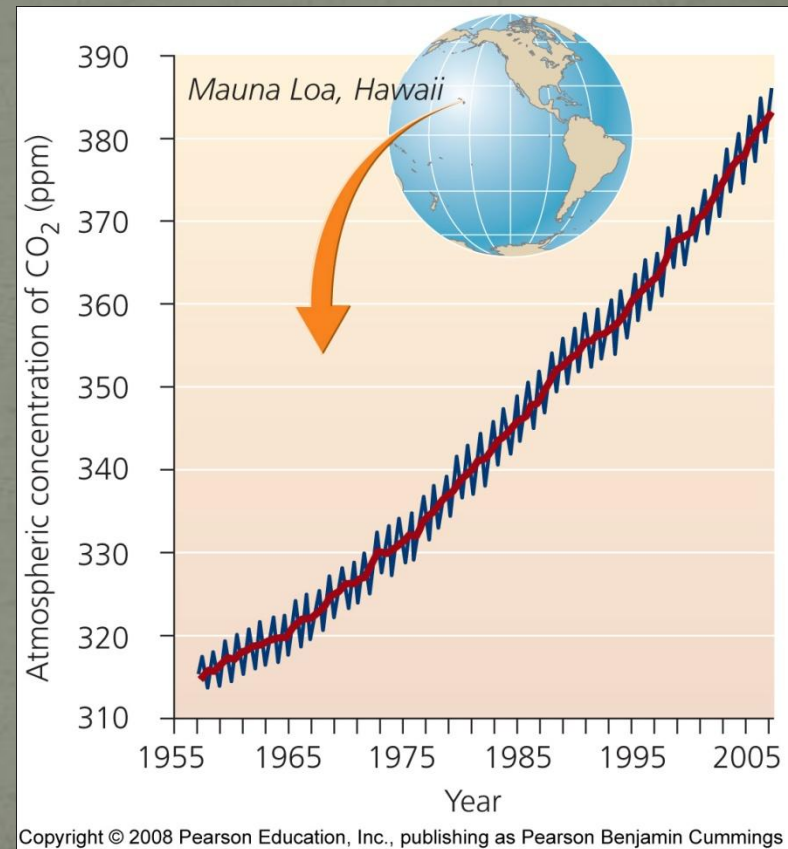
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More proxy indicators

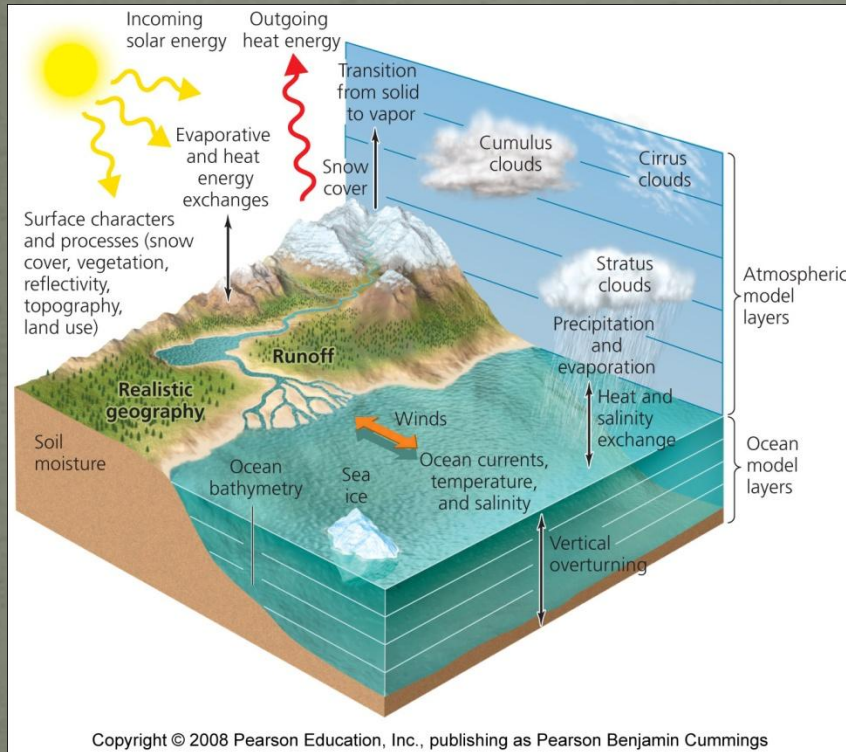
- Cores in sediment beds preserve pollen grains and other plant remnants
- Tree rings indicate age, wetness of the season, droughts, and seasonal growth
- Researchers also gather data on past ocean conditions from coral reefs
- Scientists need to combine multiple records to get a global perspective

Direct atmospheric sampling tells us about the present

Trends in atmospheric concentrations of carbon dioxide show that concentrations have increased from 315 ppm to 383 ppm



Models help us understand climate



Coupled general circulation model (climate models) = programs that combine what is known about atmospheric circulation, ocean circulation, atmosphere-ocean interactions, and feedback mechanisms to simulate climate processes

- These models are becoming more reliable in predicting climate change