

- **The Atmosphere of Earth**



- The probability of a storm can be predicted, but nothing can be done to stop or slow a storm. Understanding the atmosphere may help in predicting weather changes, but it is doubtful that weather will ever be controlled on a large scale.

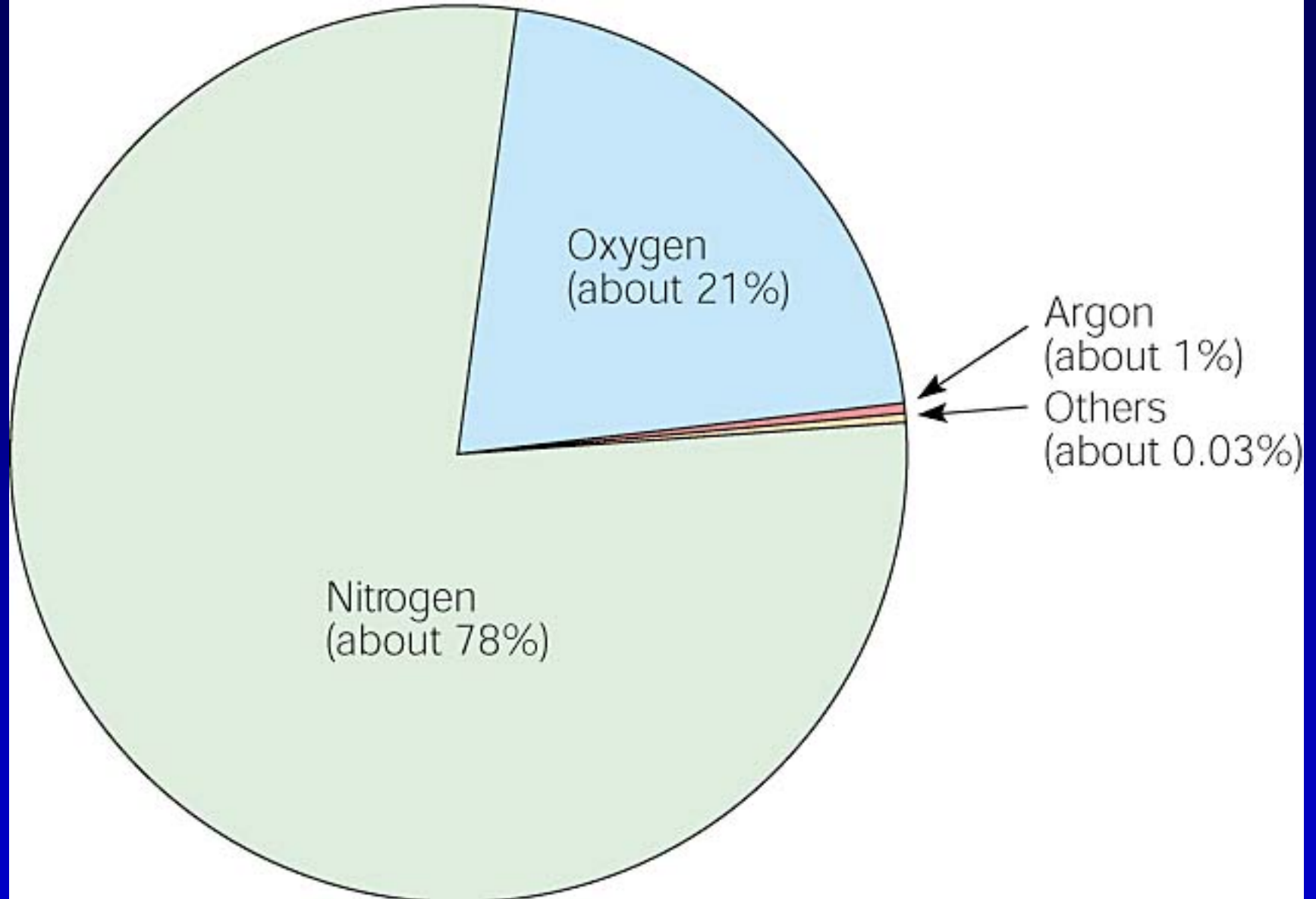
- **The Atmosphere**

- **Composition of the Atmosphere**

- **Nitrogen** (N_2) is the most abundant gas in the Earth's atmosphere making up about 78 %.
- **Oxygen** is the second most abundant making up about 21 %.
- Nitrogen cycles in the atmosphere through the Nitrogen Cycle as it is removed from the atmosphere by bacteria and lightening
 - These nitrogen compounds are then taken up by plants and utilized in growth and development.

- Oxygen (O_2) also cycles in the atmosphere
 - Living organisms are used as food sources and oxygen is utilized in most organisms that digest other organisms
 - Chemical weathering of rocks can cause oxides to form, locking up the oxygen with minerals.
 - Oxygen is released into the atmosphere by plants as they photosynthesize.

- **Water** in the atmosphere varies considerably and also cycles in the Hydrologic Cycle.
 - This is the cycle of evaporation and condensation that results almost daily.
- **Carbon Dioxide** (CO_2) makes up approximately 0.03 % of the Earth's atmospheric gases.
- Carbon dioxide concentrations in the atmosphere is regulated by:
 - Removal of CO_2 from the atmosphere as green plants fix the CO_2 into carbohydrates
 - Exchanges of CO_2 between the atmosphere and the oceans
 - Chemical reactions between the atmosphere and limestone

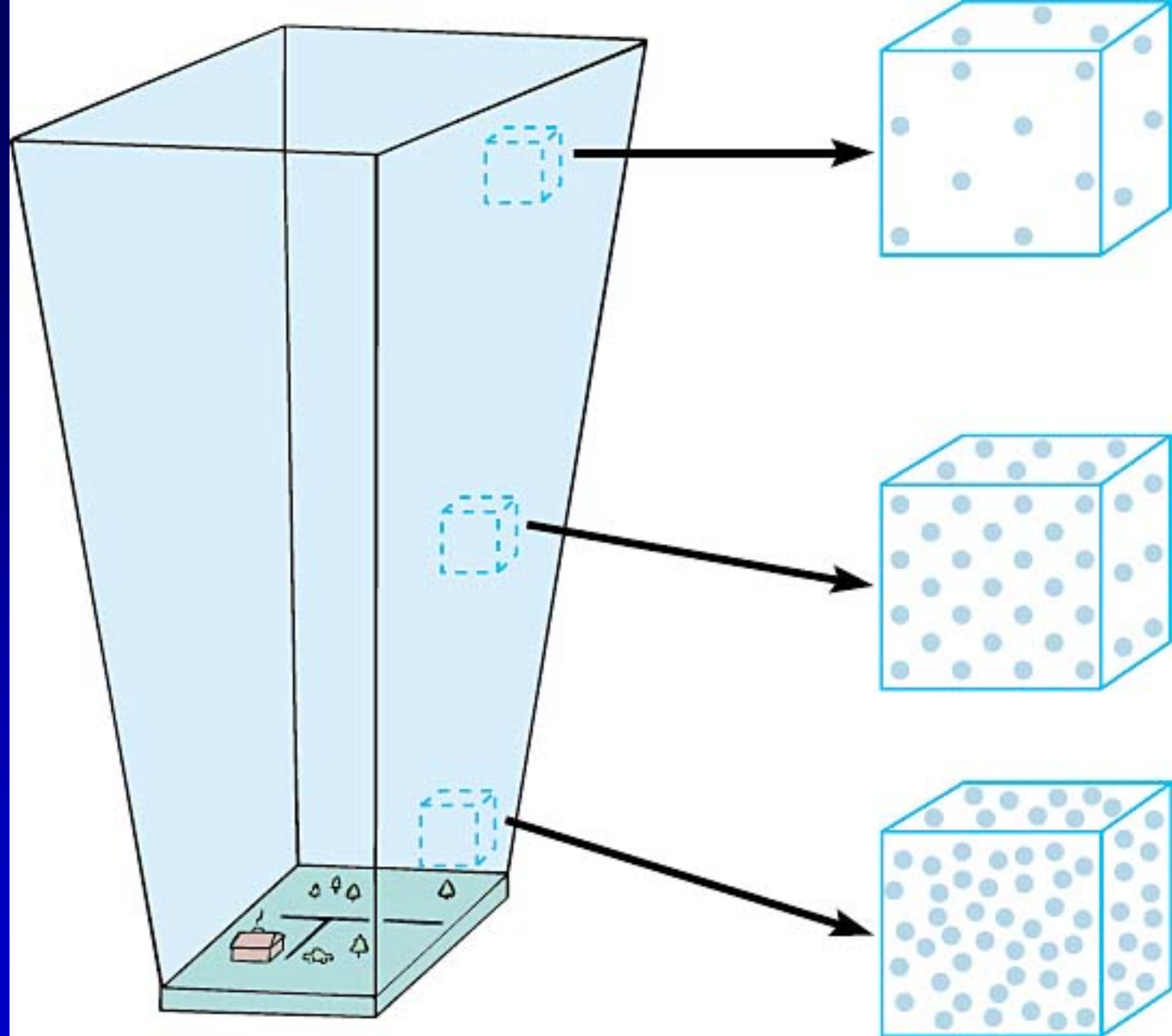


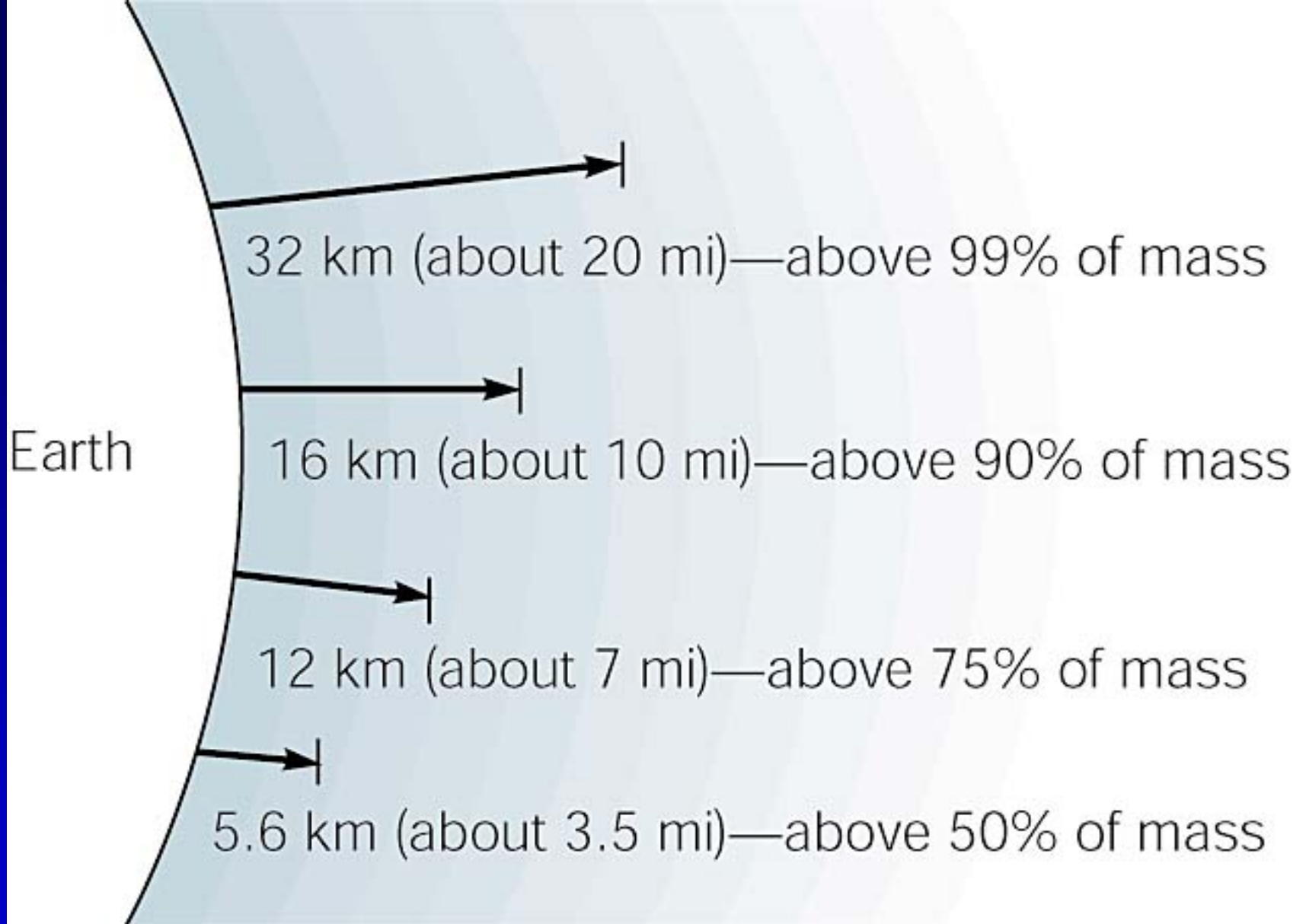
- Earth's atmosphere has a unique composition of gases when compared to that of the other planets in the solar system.

- **Atmospheric Pressure**

- The atmosphere exerts pressure on the Earth that decreases with increasing altitude
 - This is due to the fact that with increasing altitude, there is a decrease in the column of gases above the Earth's surface
- Hydrostatics considers the pressure that is exerted by a fluid that is at rest.
 - Using this as a frame of reference the atmospheric pressure is viewed as a result of the mass of the column of gases above the Earth.
- Using a molecular frame of reference, the atmospheric pressure is viewed as a result of the kinetic energy of molecules and the force with which they strike an object.
- Atmospheric pressure is actually a result of the interaction between these two factors.

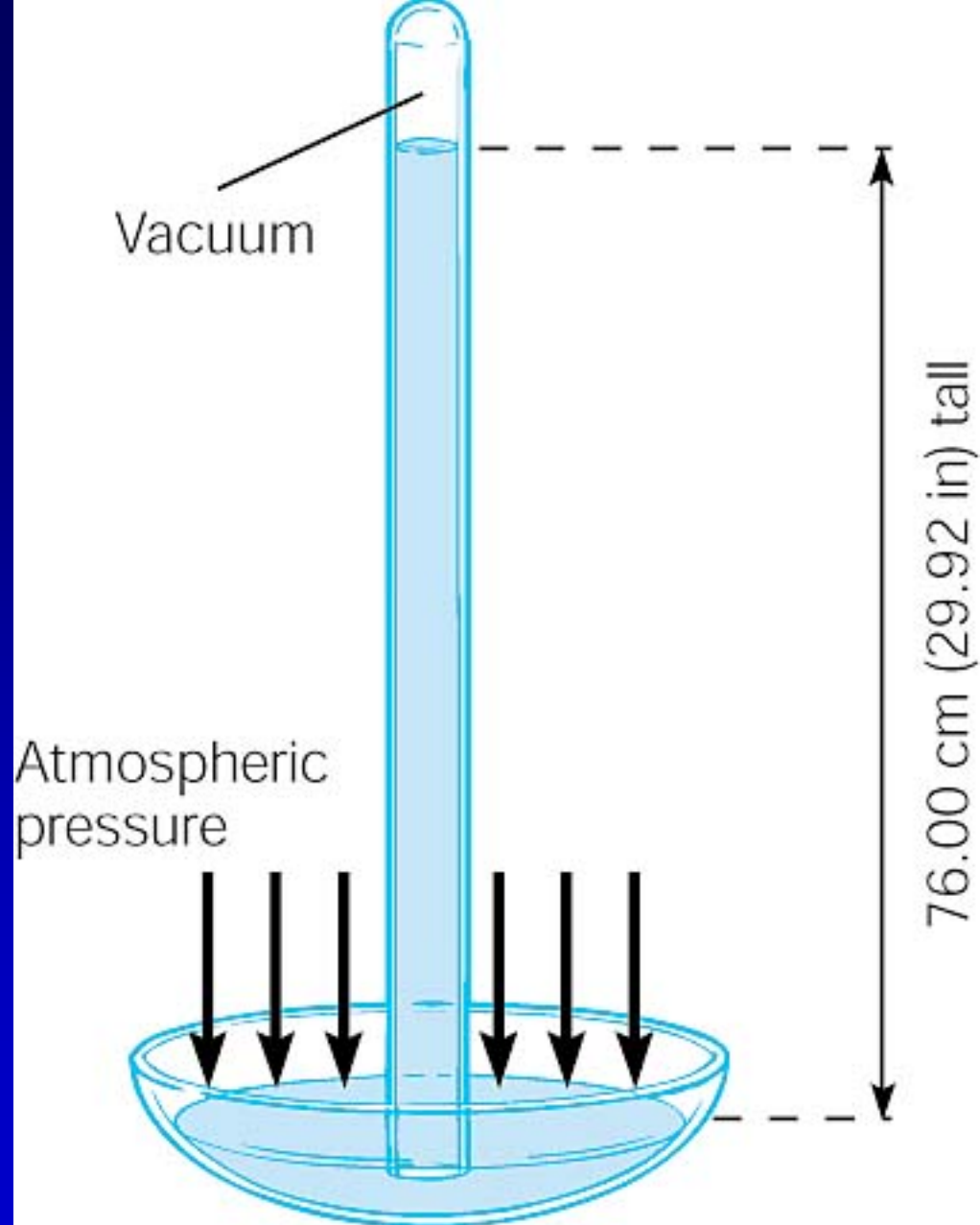
- At greater altitudes, the same volume contains fewer molecules of the gases that make up the air. This means that the density of air decreases with increasing altitude.





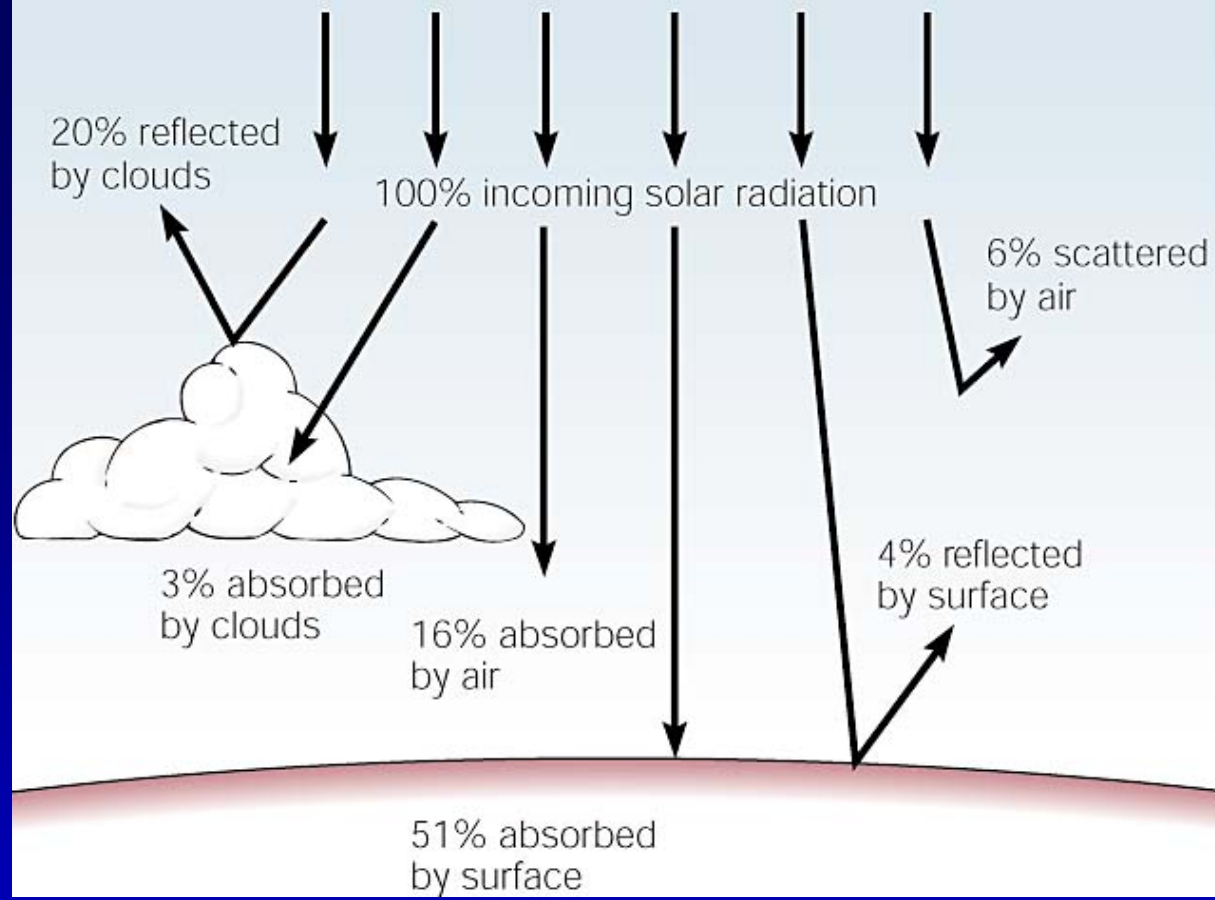
- The earth's atmosphere thins rapidly with increasing altitude and is much closer to the earth than most people realize.

- The mercury barometer measures the atmospheric pressure from the balance between the pressure exerted by the weight of the mercury in a tube and the pressure exerted by the atmosphere. As atmospheric pressure increases and decreases, the mercury rises and falls. This sketch shows the average height of the column at sea level.



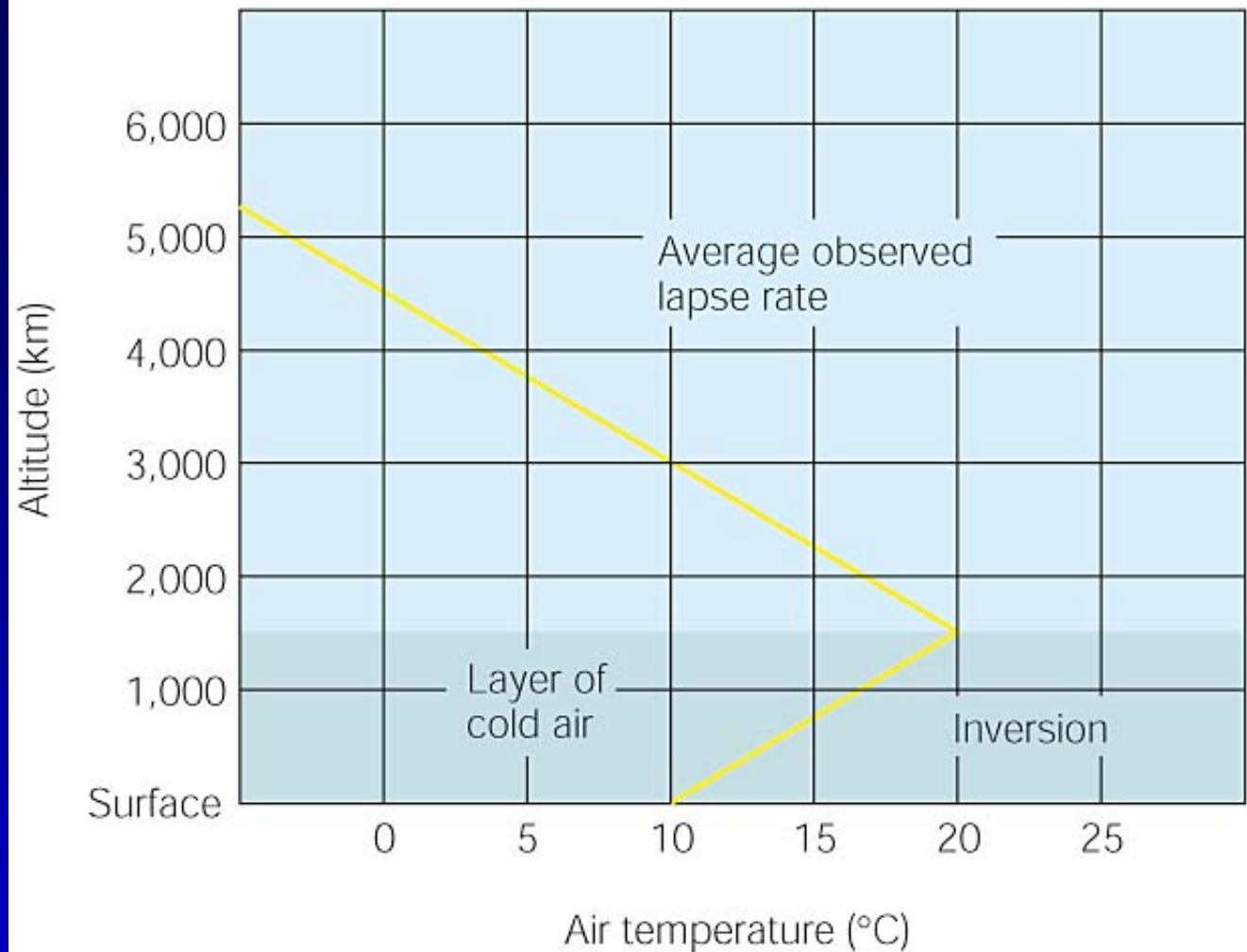
- **Warming the Atmosphere**

- The temperature of an object is actually a measure of the **kinetic energy** of the molecules that make up the object.
- Any object that contains any kinetic energy at all (i.e. has a temperature above absolute 0K gives off radiant energy.
- **Solar constant**
 - When the sunlight is perpendicular to the outer edge and the Earth is at an average distance from the Sun it produces about 1,370 watts per m².
 - This quantity is believed to remain constant.



- On the average, the earth's surface absorbs only 51 percent of the incoming solar radiation after it is filtered, absorbed, and reflected. This does not include the radiation emitted back to the surface from the greenhouse effect, which is equivalent to 93 units if the percentages in this figure are considered as units of energy.

- **Structure of the Atmosphere**
 - **Observed lapse rate.**
 - The temperature decreases approximately 6.5°C for each km of altitude ($3.5^{\circ}\text{F}/1,000\text{ ft}$)
 - **Inversion**
 - When a layer of the atmosphere increases with altitude.
 - **Troposphere**
 - The layer of the atmosphere from the surface of the Earth up to where it stops decreasing in temperature.
 - Up to a height of about 11 km (6.7 mi)
 - Air is constantly mixed due to denser air being above less dense air.



- On the average, the temperature decreases about $6.5^{\circ}\text{C}/1,000\text{ km}$, which is known as the observed lapse rate. An inversion is a layer of air in which the temperature increases with height.

– Tropopause

- The upper boundary of the Troposphere
- The temperature remains constant with increasing altitude

– Stratosphere

- Temperature begins to increase with height.
- Very stable as denser air is below less dense air.
- Up to about 48 km (30 mi)
- Temperature increases as a result of interactions between high energy UV radiation and ozone (O₃)

– **Stratopause**

- Where the temperature reaches a maximum of 10 °C (50 °F)

– **Ozone shield**

- A layer of ozone that absorbs much of the ultraviolet radiation that enter the atmosphere.
- Provides a significant shield to the Earth below from damaging UV radiation

– **Mesosphere**

- Temperature again begins to decrease due to a decrease in gas molecules to absorb radiation

– **Thermosphere**

- Temperature again begins to rise due to the presence of molecular fragments which absorb radiation from space.
- Temperature is extremely high here due to the average kinetic energy of the molecules.
- Very little energy transfers, however, due to the lack of molecules (very few molecules to collide with objects)

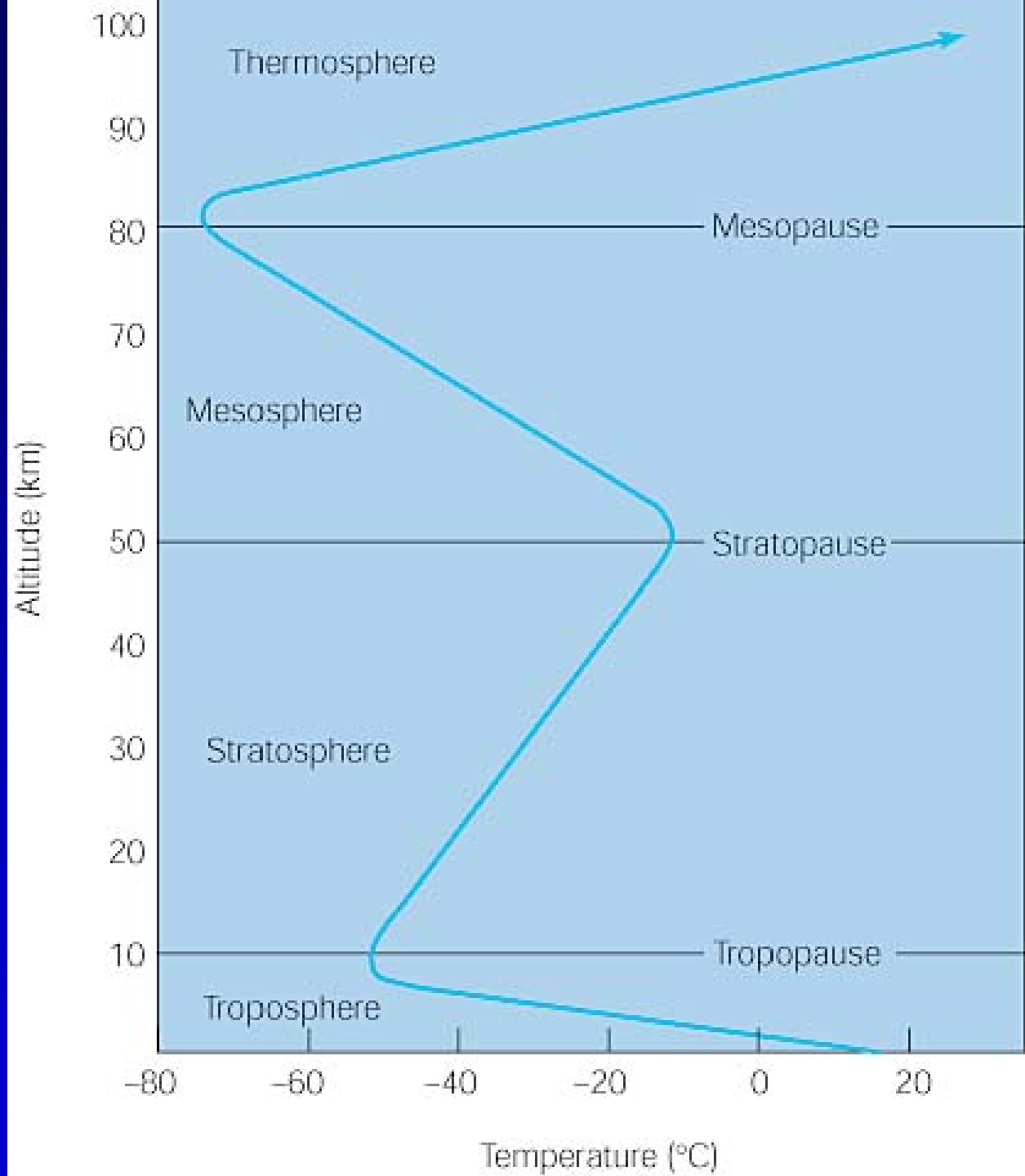
– Exosphere

- Outermost layer of the atmosphere where molecules merge with the vacuum of space.
- The high kinetic energy of the molecules at this height are significant enough to cause them to be able to escape into space.

– Ionosphere

- Alternative name for the thermosphere and upper mesosphere.
- Due to the occurrence of free electrons and ions.
- It is the electrons and ions in this layer that cause radio waves to be able to be reflected around the world.

- The structure of the atmosphere based on temperature differences. Note that the "pauses" are actually not lines, but are broad regions that merge.



- **The Winds**

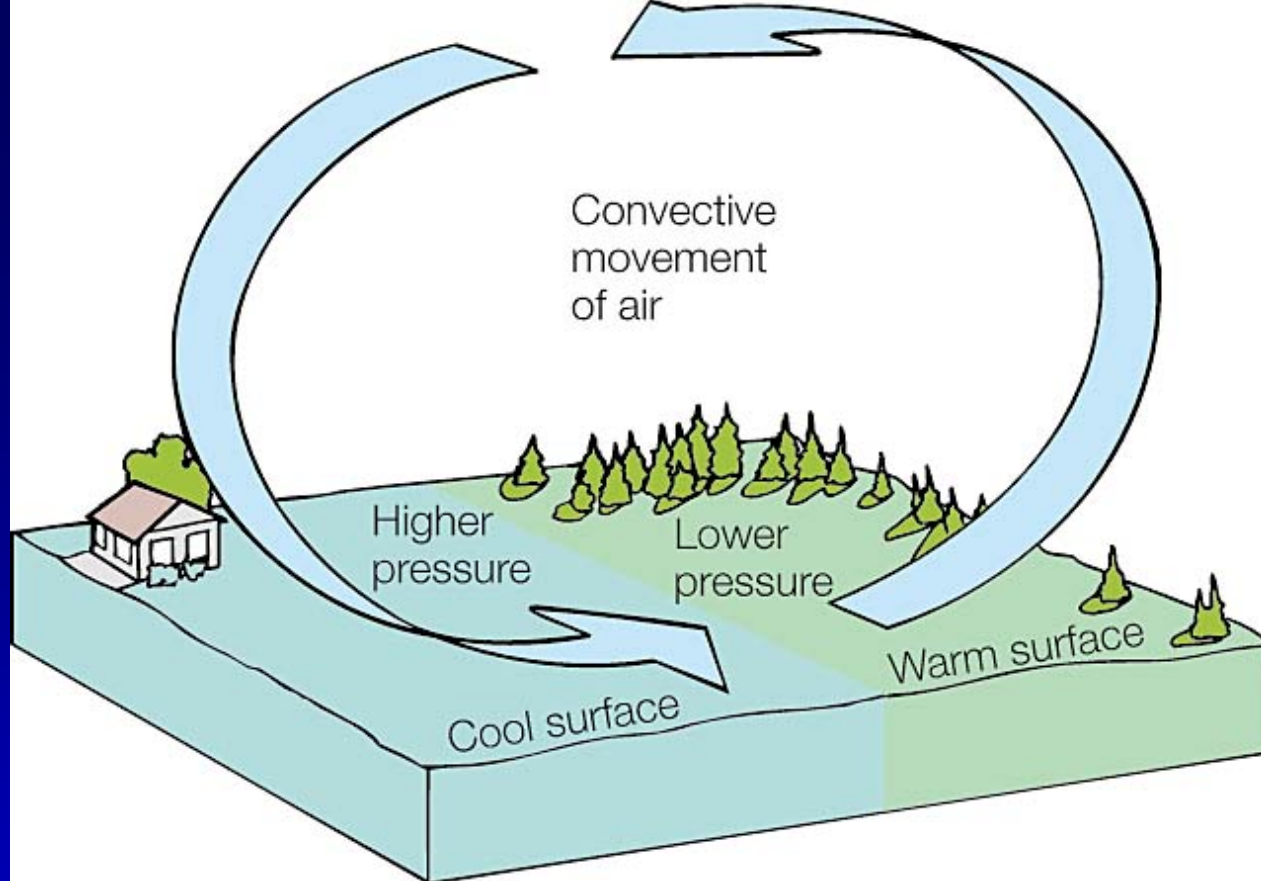
- **Local Wind Patterns**

- Due to:

- The relationship between air temperature and air density.
 - Relationship between air pressure and the movement of air.

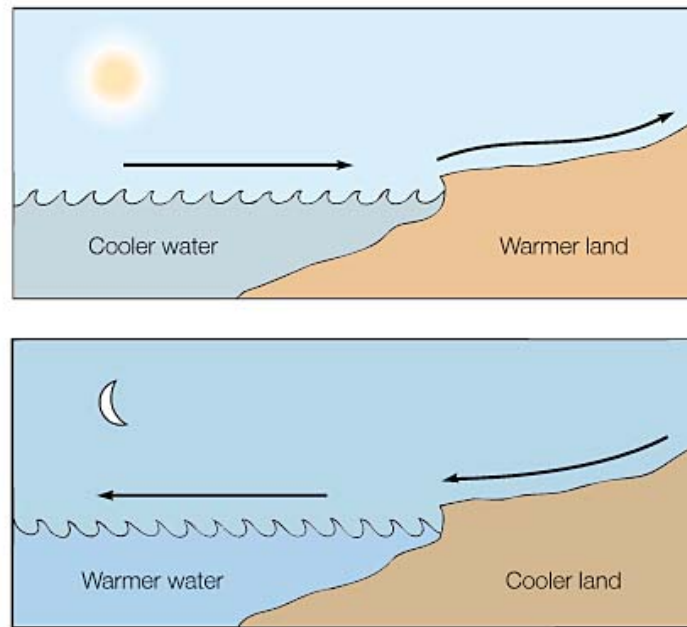
- Upward and downward movement of air leads to:

- The upward movement has a lifting effect on the surface that creates areas of low pressure
 - The downward movement of air has a piling up effect resulting in areas of high pressure.

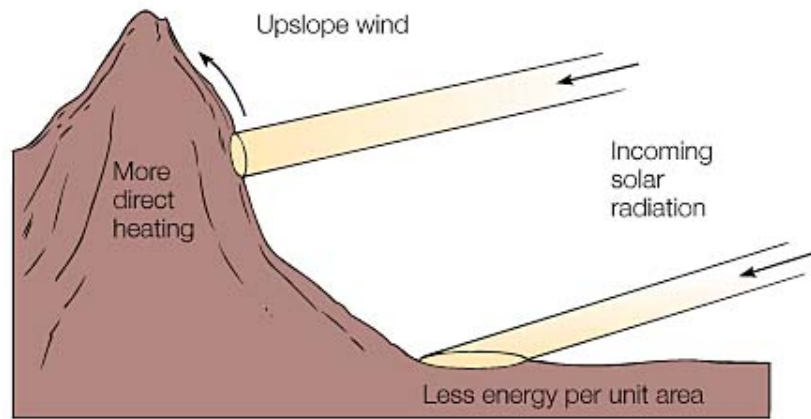


- A model of the relationships between differential heating, the movement of air, and pressure difference in a convective cell. Cool air pushes the less dense, warm air upward, reducing the surface pressure. As the uplifted air cools and becomes more dense, it sinks, increasing the surface pressure.

- Adjacent areas on the surface of the Earth can have very different temperatures due to differences in heating and cooling rates.
- This difference is usually greatest between bodies of water and adjacent land masses due to:
 - Water has a high specific heat.
 - Water is easily mixed, which keeps water cooler than adjacent land masses
 - Water cools by evaporation which also keeps a body of water at a lower temperature.
- This results in a sea breeze since the denser, cooler air from the body of water will move in under the less dense air over the land.



- The land warms and cools more rapidly than an adjacent large body of water. During the day, the land is warmer, and air over the land expands and is buoyed up by cooler, more dense air from over the water. During the night, the land cools more rapidly than the water, and the direction of the breeze is reversed.

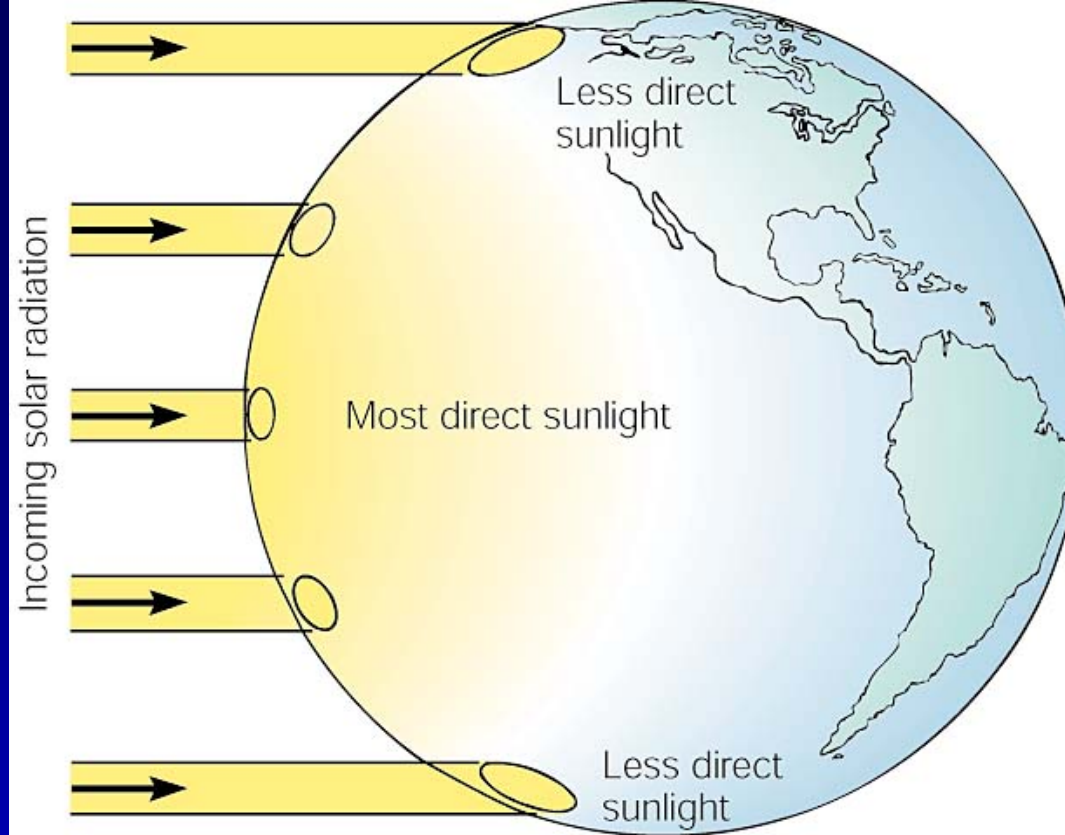


- Incoming solar radiation falls more directly on the side of a mountain, which results in differential heating. The same amount of sunlight falls on the areas shown in this illustration, with the valley floor receiving a more spread-out distribution of energy per unit area. The overall result is an upslope mountain breeze during the day. During the night, dense cool air flows downslope for a reverse wind pattern.

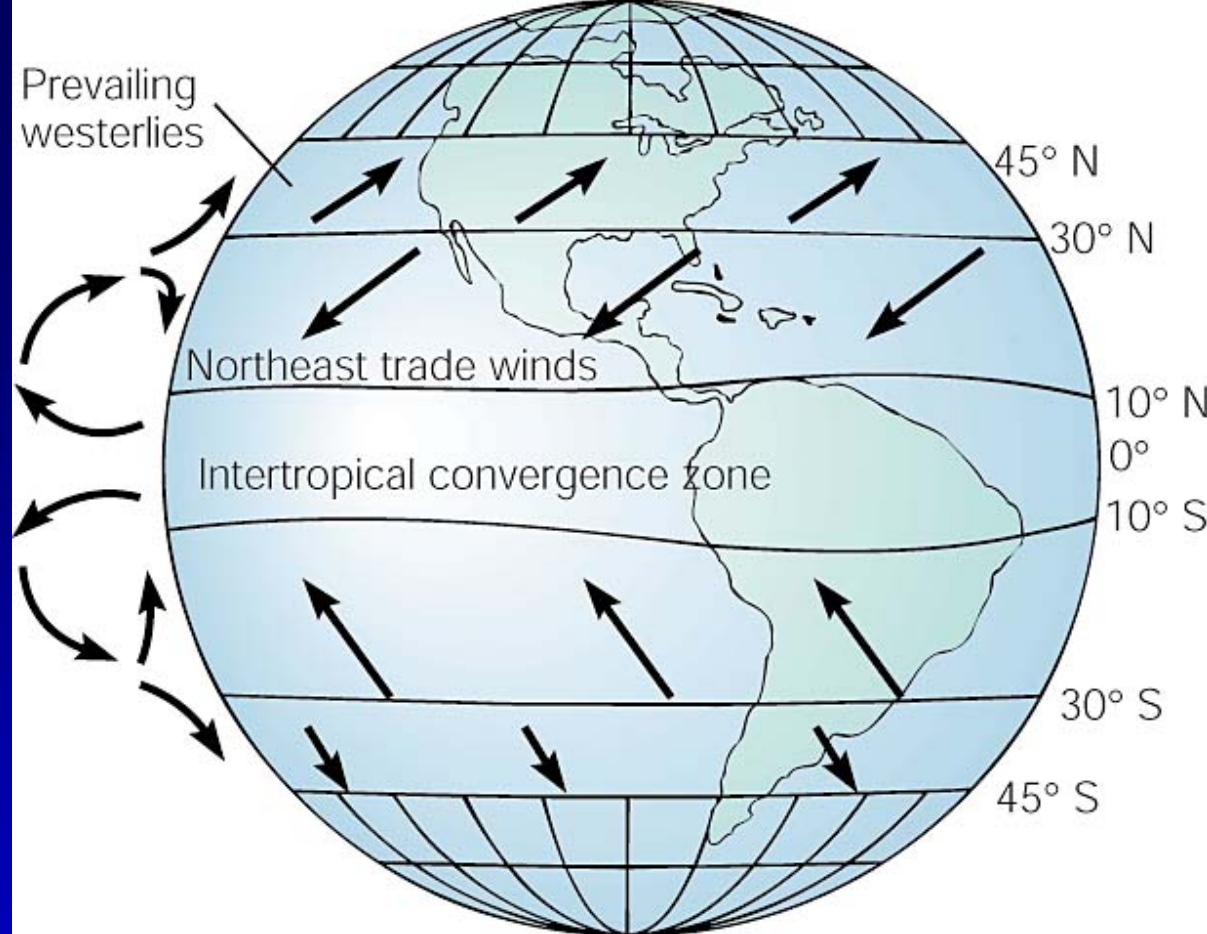
- **Global Wind Patterns**

- Hot air rises over the equator due to the fact that it is less dense.
 - This is called the **intertropical convergence zone**.
 - This rising air cools adiabatically as it rises resulting in high precipitation
- The cooled air descends to reach the surface at about 30°N and 30°S of the equator.
 - This forms a high pressure area
 - The great deserts of the world are located in this high pressure area

- Toward the poles from this high pressure area atmospheric circulation is controlled by a powerful belt of wind near the top of the troposphere called the **jet stream**.
 - The jet stream is a loop of winds that extend all the way around the globe.
 - Generally move from west in both hemispheres
 - Warm air masses move toward the poles ahead of this trough and cool air masses move toward the equator behind this trough.



- On a global, yearly basis, the equatorial region of the earth receives more direct incoming solar radiation than the higher latitudes. As a result, average temperatures are higher in the equatorial region and decrease with latitude toward both poles. This sets the stage for worldwide patterns of prevailing winds, high and low areas of atmospheric pressure, and climatic patterns.



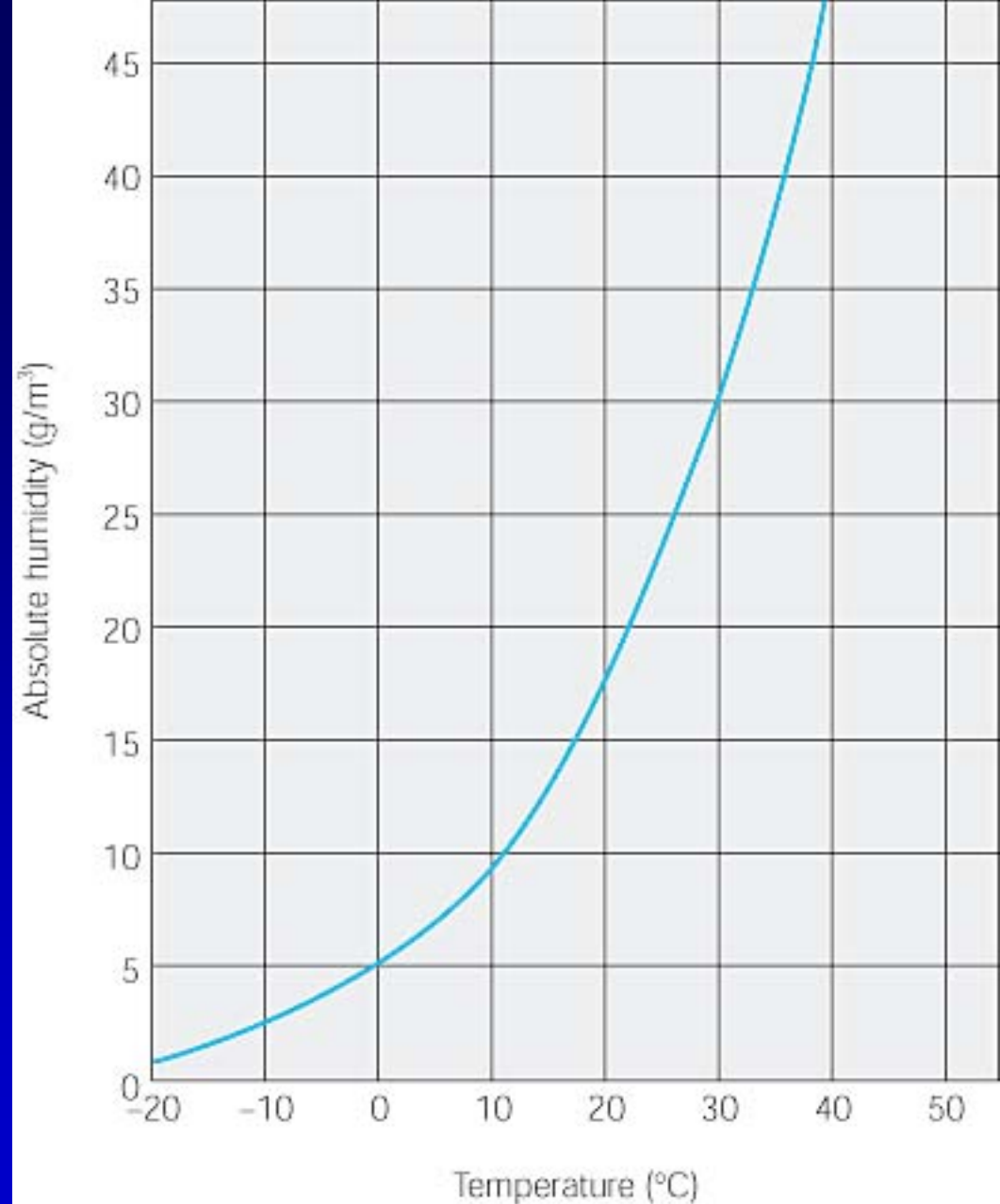
- Part of the generalized global circulation pattern of the earth's atmosphere. The scale of upward movement of air above the intertropical convergence zone is exaggerated for clarity. The troposphere over the equator is thicker than elsewhere, reaching a height of about 20 km (about 12 mi).

- **Water and the Atmosphere**

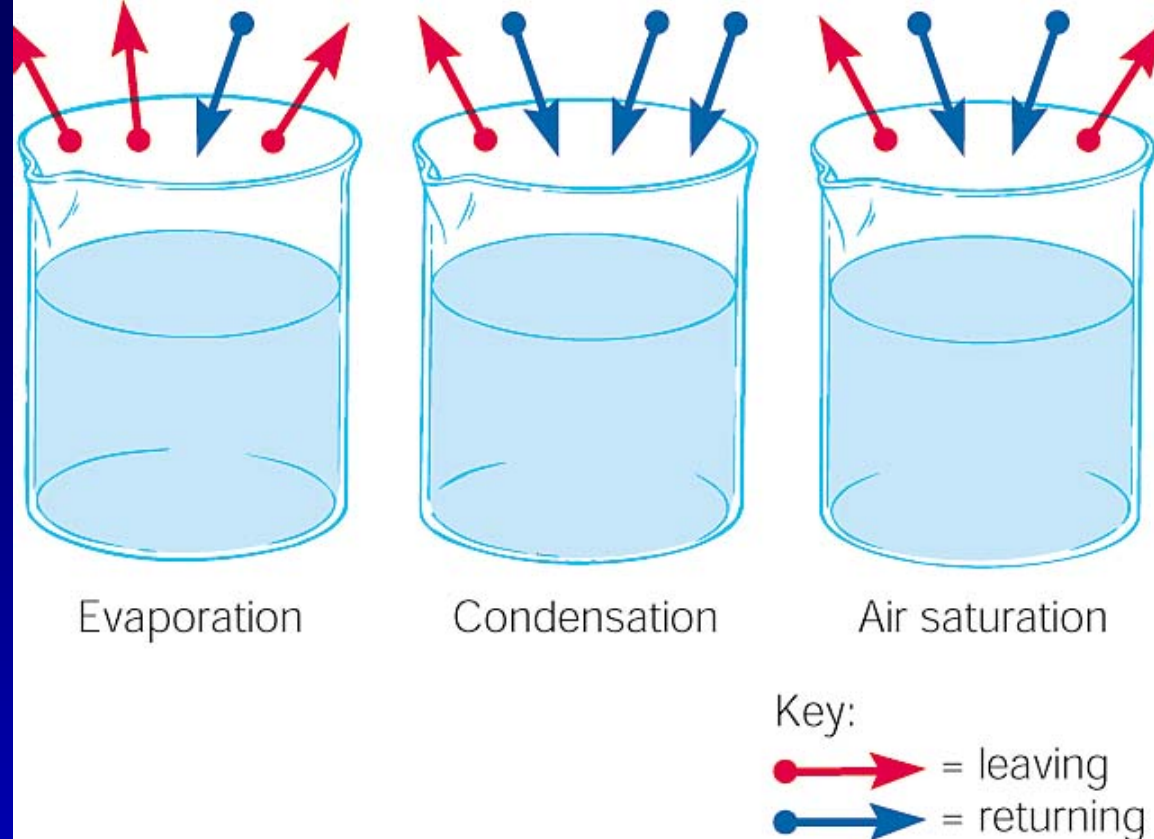
- Water exists in three states on the Earth.
 - **Liquid** when the temperature is above 0°C (32°F)
 - **Solid** when the temperature is below 0°C (32°F)
 - A **gas** when the temperature is above 100°C (212°F)

- Evaporation and Condensation
 - **Humidity**
 - The amount of water vapor in the air
 - **Absolute humidity** is a measure of the amount of water vapor present at a given time.
 - **Relative humidity** is a measure of the amount of water vapor present in the air relative to the amount that the air could hold at that temperature.

- The maximum amount of water vapor that can be in the air at different temperatures. The amount of water vapor in the air at a particular temperature is called the absolute humidity.



- The **Rate of Evaporation** depends on:
 - surface area of the exposed liquid.
 - Air and water temperature
 - Relative humidity
- The **Rate of Condensation** depends on:
 - relative humidity
 - Kinetic energy of the gas molecules in the air.



- Evaporation and condensation are occurring all the time. If the number of molecules leaving the liquid state exceeds the number returning, the water is evaporating. If the number of molecules returning to the liquid state exceeds the number leaving, the water vapor is condensing. If both rates are equal, the air is saturated; that is, the relative humidity is 100 percent.

– **Dew point** temperature

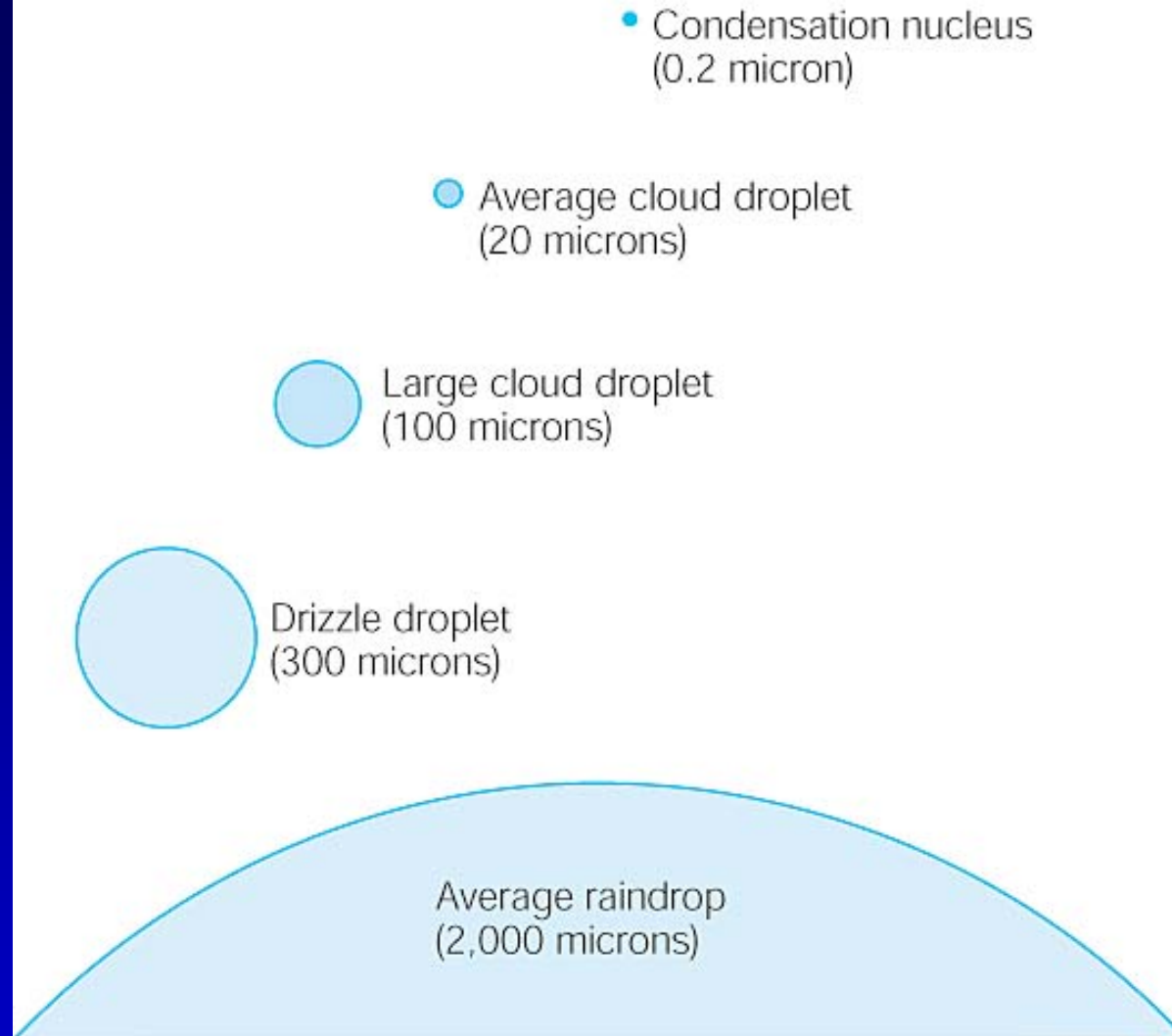
- Temperature at which the relative humidity and the absolute humidity are the same (saturated air)
- Dew begins to accumulate on surfaces.
- Form on C nights:
 - Clear
 - Calm
 - Cool



- Fans like this one are used to mix the warmer, upper layers of air with the cooling air in the orchard on nights when frost is likely to form.

– **Condensation nuclei**

- Gives condensing moisture in the atmosphere something to condense on.
- Necessary for the production of moisture in the atmosphere (rain, snow).
- As condensation continues, eventually there will be a point where enough water molecules have condensed on the nuclei that it can no longer remain air borne.
- It will then fall in the form of rain, snow, etc...



- This figure compares the size of the condensation nuclei to the size of typical condensation droplets. Note that 1 micron is 1/1,000 mm.

- **Fog and Clouds**

- Both of these are water droplets which have been condensed from the atmosphere.

- An upward movement of air keeps them from falling

- Clouds are identified according to whether they are:

- **Cirrus** – curly

- **Cumulus** – piled up

- **Stratus** – spread out



- (A) An early morning aerial view of fog between mountain at top and river below that developed close to the ground in cool, moist air on a clear, calm night. (B) Fog forms over the ocean where air moves from a warm current over a cool current, and the fog often moves inland.



- (A) Cumulus clouds. (B) Stratus and stratocumulus. Note the small stratocumulus clouds forming from increased convection over each of the three small islands. (C) An aerial view between the patchy cumulus clouds below and the cirrus and cirrostratus above (the patches on the ground are clear-cut forests). (D) Altocumulus. (E) A rain shower at the base of a cumulonimbus. (F) Stratocumulus.