Thermal Energy Transfer by Conduction, Convection, and Radiation

- After the land and water absorb solar energy, molecules from the land and water collide more frequently with molecules in the air that are close to the surface. These collisions transfer energy from the surface to the air by conduction.
- As a result, the temperature of this lowest level of air eventually comes close to the temperature of the land and water beneath it.
- Then convection occurs as air circulates and distributes the heat.
- As the lower layer of the air warms, it expands, becoming less dense.
- As the cooler air falls, it takes the place of the rising warmer air.

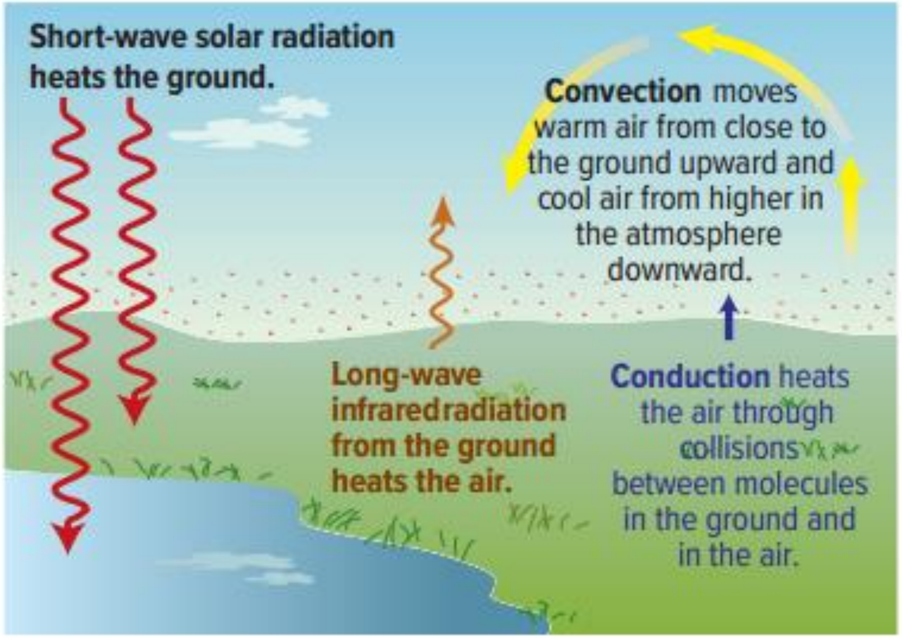


Figure 1.7 Conduction, convection, and radiation transfer thermal energy in Earth's atmosphere.
Explain *Solar energy passes through the atmosphere, but it does not have much of an effect on heating it. Instead, radiation of thermal energy from Earth's surface is the major source for heating air close to the surface. Why?*

THERMAL ENERGY TRANSFER BY CONDUCTION, CONVECTION, AND RADIATION

- Radiation also plays a part in transferring thermal energy to air (the atmosphere).
- Greenhouse gases are good at absorbing longer-wavelength infrared energy emitted by Earth's surface.
- This absorption of longer-wave energy is the major source of thermal energy for the air close to the surface.

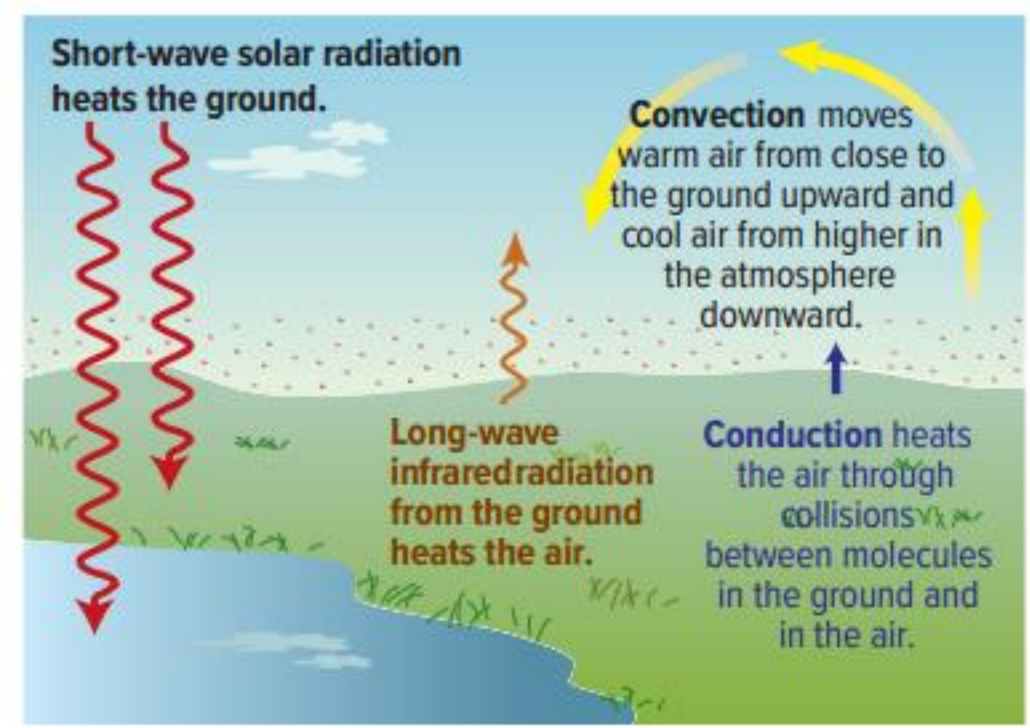


Figure 1.7 Conduction, convection, and radiation transfer thermal energy in Earth's atmosphere.
Explain *Solar energy passes through the atmosphere, but it does not have much of an effect on heating it. Instead, radiation of thermal energy from Earth's surface is the major source for heating air close to the surface. Why?*

1-1C Effects of Atmospheric Pressure

- Lab manual Find out activity

Atmospheric Pressure

- Atmospheric pressure the pressure exerted by air on its surroundings due to the weight of the air
- The SI unit for atmospheric pressure is the pascal (Pa).
- Pascals are used to measure the force per unit area.
- One pascal has a force of one newton per square metre. This is a very small amount, so most measurements are given in kilopascals (kPa). There are 1000 Pa per kPa.

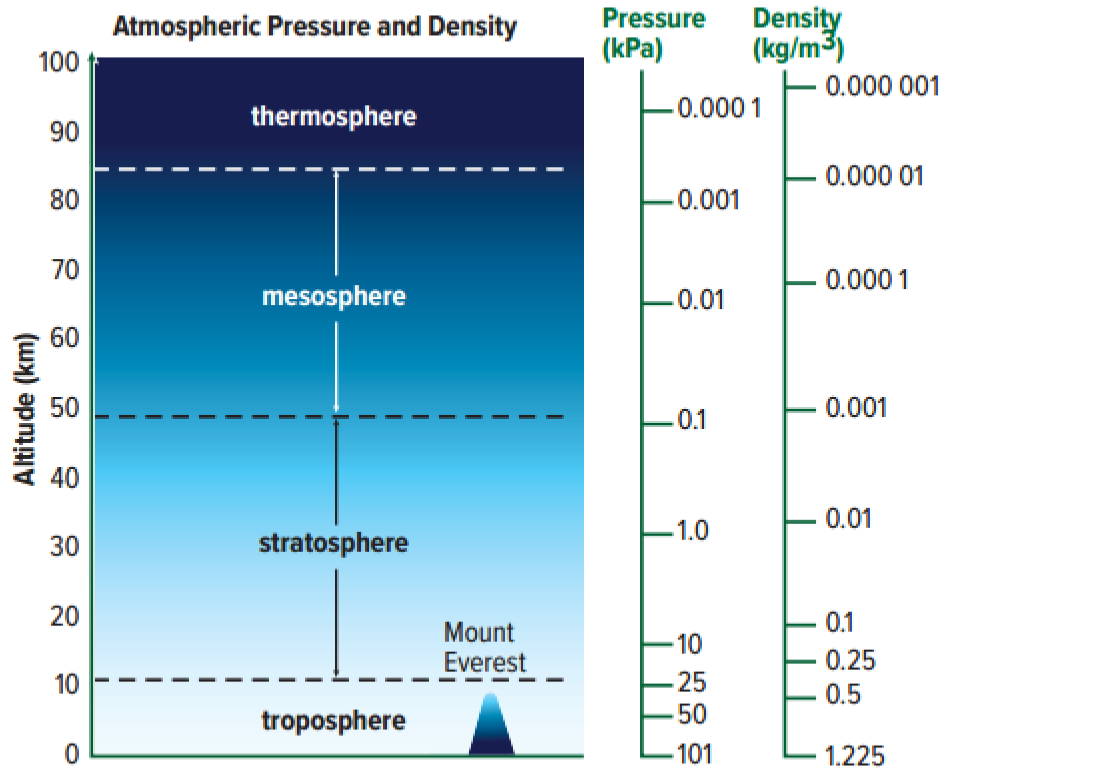
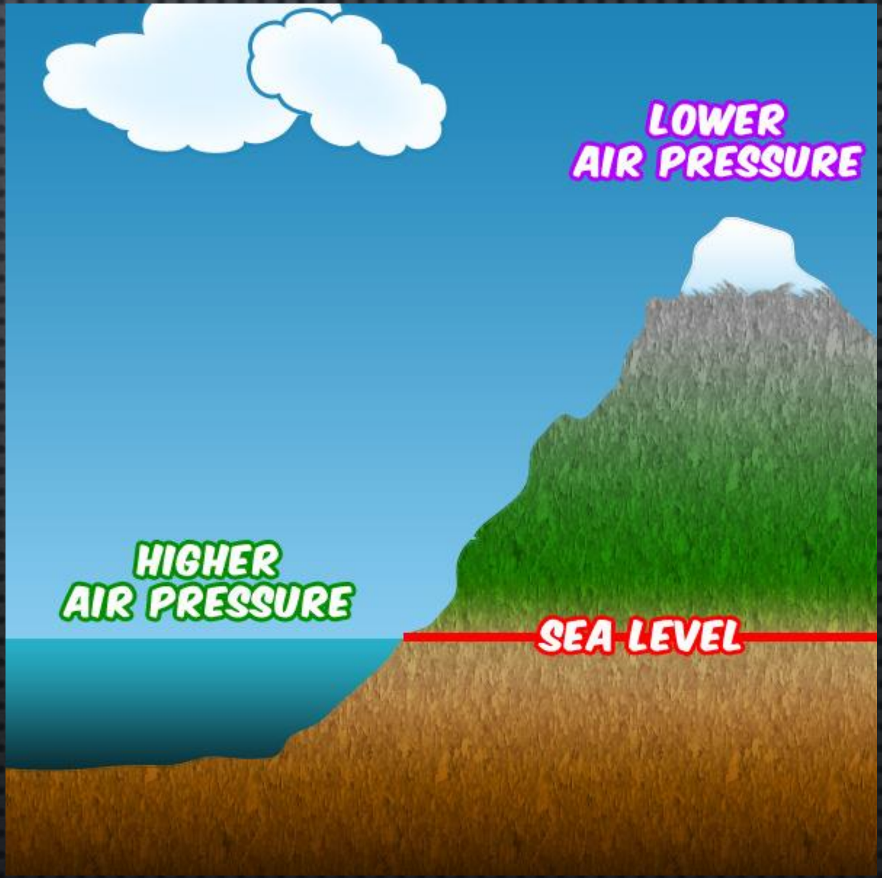


Figure 1.8 Atmospheric pressure and density at increasing altitudes. On average, the atmospheric pressure at the top of the troposphere is only about 10 percent of that at sea level. However, pressure differences vary throughout the troposphere due to the movement of air.

Interpret *What happens to the pressure and density of the atmosphere as altitude increases?*

ATMOSPHERIC PRESSURE AND ALTITUDE

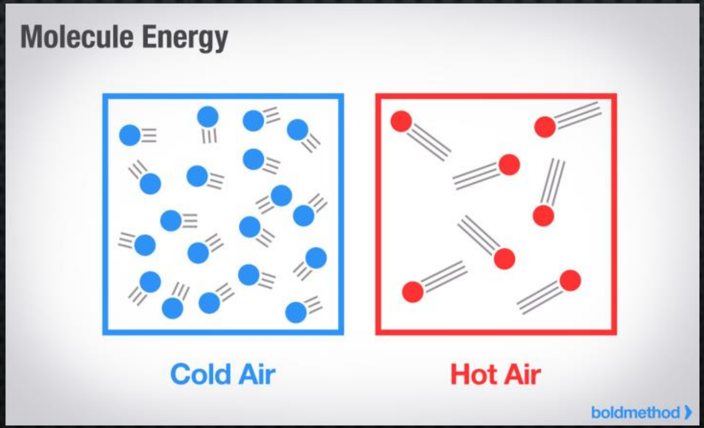
- AT SEA LEVEL, THE ATMOSPHERIC PRESSURE IS ABOUT 101.3 KPA, WHICH IS EQUAL TO 1 KG/CM^2.
- THIS MEANS THAT THERE IS ABOUT 1 KG OF AIR PUSHING ON EACH SQUARE CENTIMETRE OF YOUR BODY.
- IF YOU HAVE EVER BEEN ON A DRIVE UP A MOUNTAIN ROAD, FLOWN IN AN AIRPLANE, OR EVEN GONE UP IN AN ELEVATOR, YOU MAY HAVE EXPERIENCED "POPPING" IN YOUR EARS.
- AS YOUR ALTITUDE INCREASES, THE DENSITY OF THE AIR DECREASES. THE GAS MOLECULES IN THE AIR ARE SPREAD FARTHER APART AND COLLIDE WITH NEARBY SURFACES LESS OFTEN. THEREFORE, THE ATMOSPHERIC PRESSURE DECREASES.
- YOUR EARS "POP" TO BALANCE THE HIGHER ATMOSPHERIC PRESSURE WITHIN YOUR MIDDLE EAR WITH THE LOWER EXTERNAL ATMOSPHERIC PRESSURE OUTSIDE YOUR BODY.

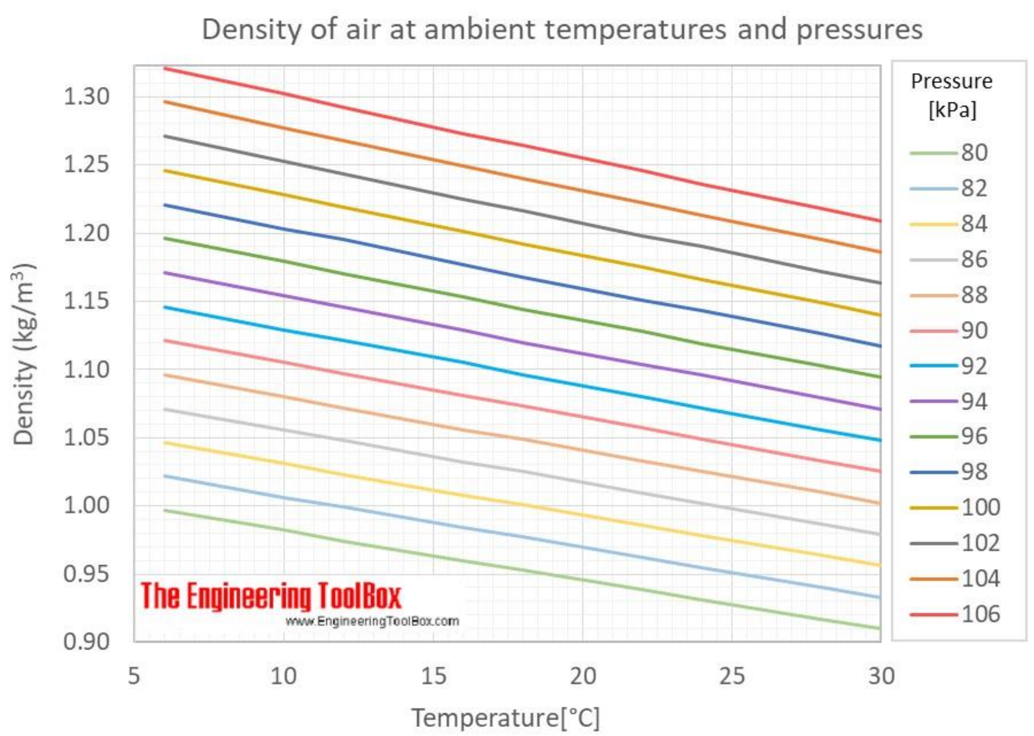


TEMPERATURE AND ATMOSPHERIC PRESSURE

- When warm air pushes into and replaces an area of cold air near the ground, the atmospheric pressure in that location decreases.

- When cold air pushes into and replaces a region of warm air, the atmospheric pressure in that location increases.





HUMIDITY AND ATMOSPHERIC PRESSURE

- HUMIDITY THE AMOUNT OF WATER VAPOUR IN THE AIR
- SOMETIMES HUMIDITY IS EXPRESSED AS GRAMS OF WATER VAPOUR IN 1 M^3 OF AIR.
- THE MORE WATER VAPOUR IN THE ATMOSPHERE, THE LIGHTER THE AIR IS. AS WATER VAPOUR IS ADDED TO A REGION OF THE ATMOSPHERE, IT DISPLACES (PUSHES OUT) AN EQUAL VOLUME OF DRY AIR. OXYGEN GAS AND NITROGEN GAS MAKE UP ABOUT 99 PERCENT OF DRY AIR. THEY ARE HEAVIER THAN WATER VAPOUR, SO IF WATER VAPOUR DISPLACES SOME OF THESE GASES FROM A CERTAIN VOLUME OF AIR, THE AIR WILL BECOME LESS DENSE. THEREFORE, HUMID, OR "WET," AIR EXERTS LESS ATMOSPHERIC PRESSURE THAN DRY AIR

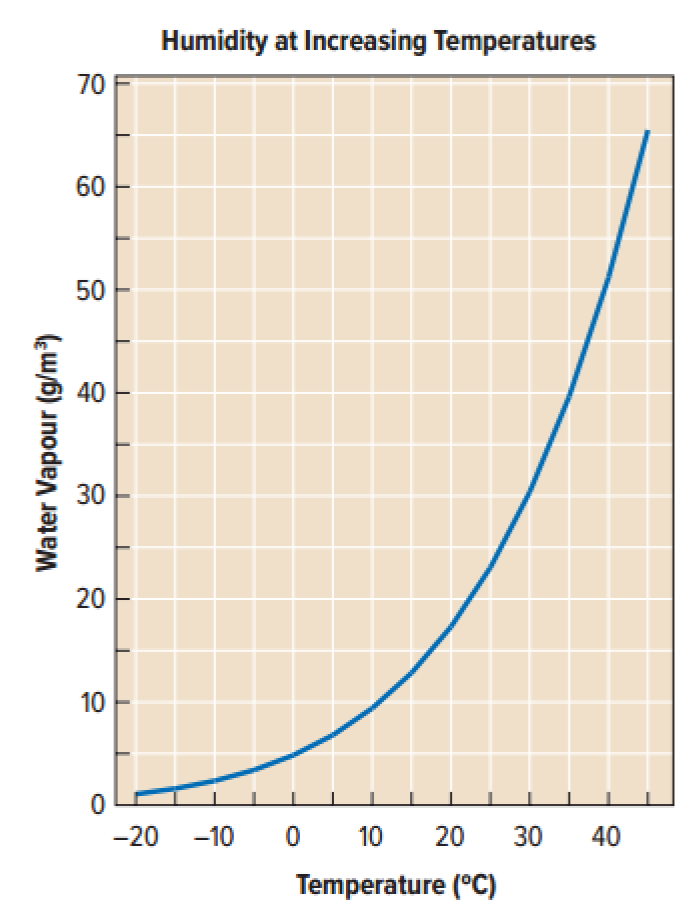
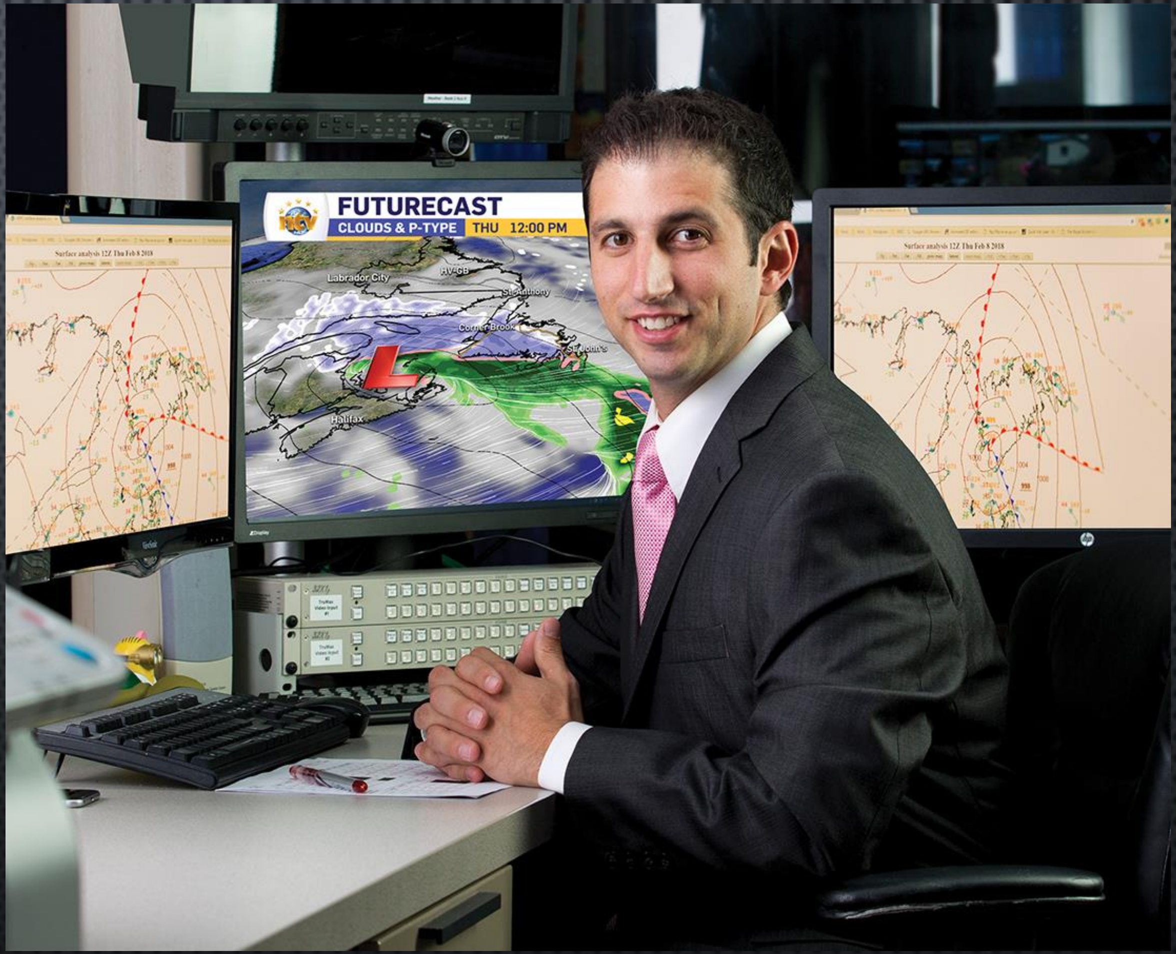
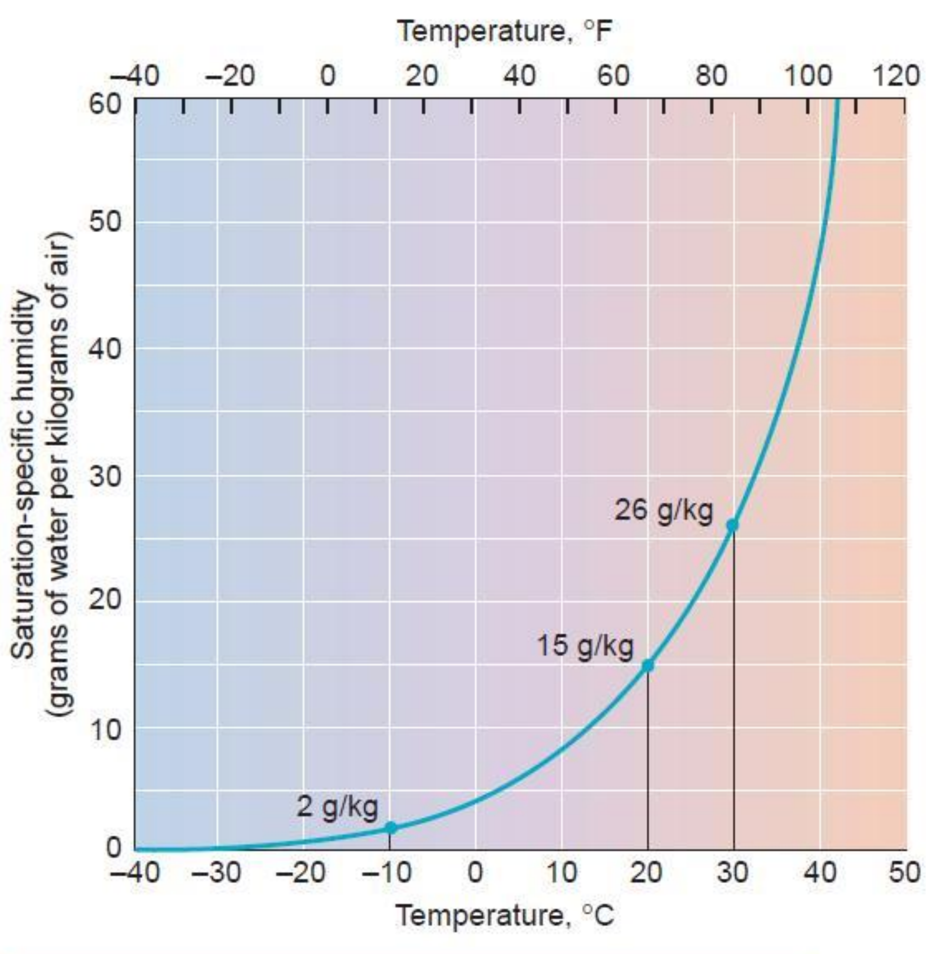


Figure 1.9 The capacity of air to hold water vapour is directly related to the temperature of the air. For every 11°C increase in temperature, air doubles its capacity to hold water vapour. For example, a kilogram of air has a capacity to hold 11 g of water at 15.5°C. At 26.5°C, the same air could hold 22 g of water vapour.

- Meteorologists scientists who study weather
- Use atmospheric pressure readings to predict changes in the weather.
- A decrease in atmospheric pressure suggests that warm, humid air is approaching and that the temperature will increase.
- An increase in atmospheric pressure suggests that cool, dry weather is on its way.



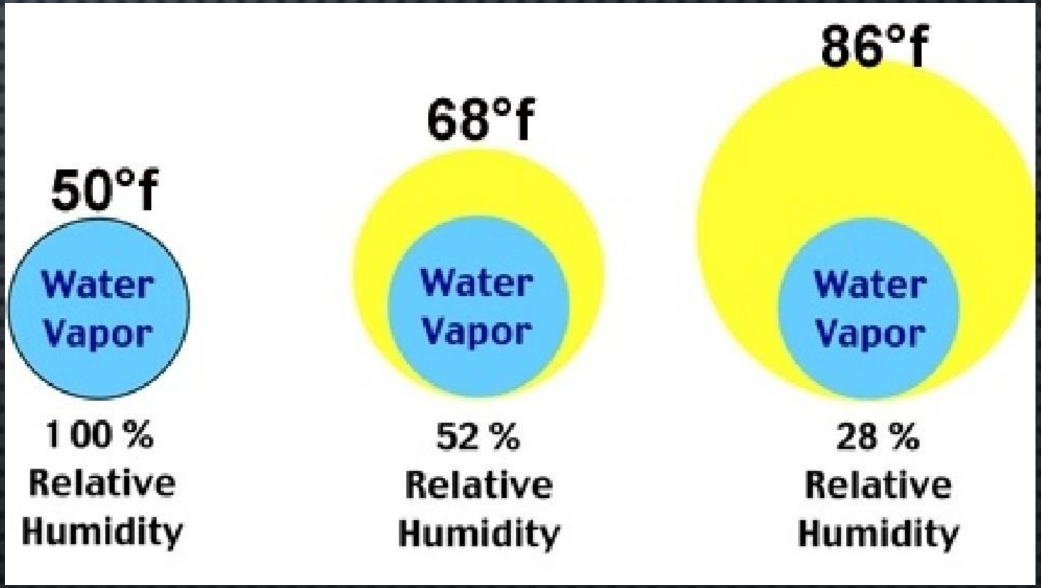
- SPECIFIC HUMIDITY IS EXPRESSED AS THE NUMBER OF GRAMS OF WATER VAPOUR IN 1 KG OF AIR.
- AS THE TEMPERATURE OF THE AIR INCREASES, ITS CAPACITY TO HOLD WATER VAPOUR ALSO INCREASES
- DEW POINT TEMPERATURE AT WHICH AIR IS SATURATED WITH WATER VAPOUR SO THAT IT CONDENSES AND FALLS AS PRECIPITATION



4.6 Saturation-specific humidity and temperature

The maximum specific humidity a mass of air can have—the saturation-specific humidity—increases sharply with rising temperature.

- Usually, the amount of water vapour in the air is less than the amount required to saturate the air at a given temperature.
- Meteorologists refer instead to relative humidity, which compares the amount of water vapour in the air with the amount if it were totally saturated.
- A relative humidity of 50 percent means the air is about 50 percent saturated.
- A relative humidity of 100 percent means that the air is completely saturated.



The Role of Water in Transferring Energy in the Atmosphere

- In nature, water freezes to form ice, snow, and hail. These processes release thermal energy into the environment. As well, when snow and ice melt or when liquid water evaporates, thermal energy is absorbed.
- The latent heat of fusion is the amount of heat needed to cause a phase change between solid and liquid.
- The latent heat of vaporization is the amount of heat needed to cause a phase change between liquid and gas.

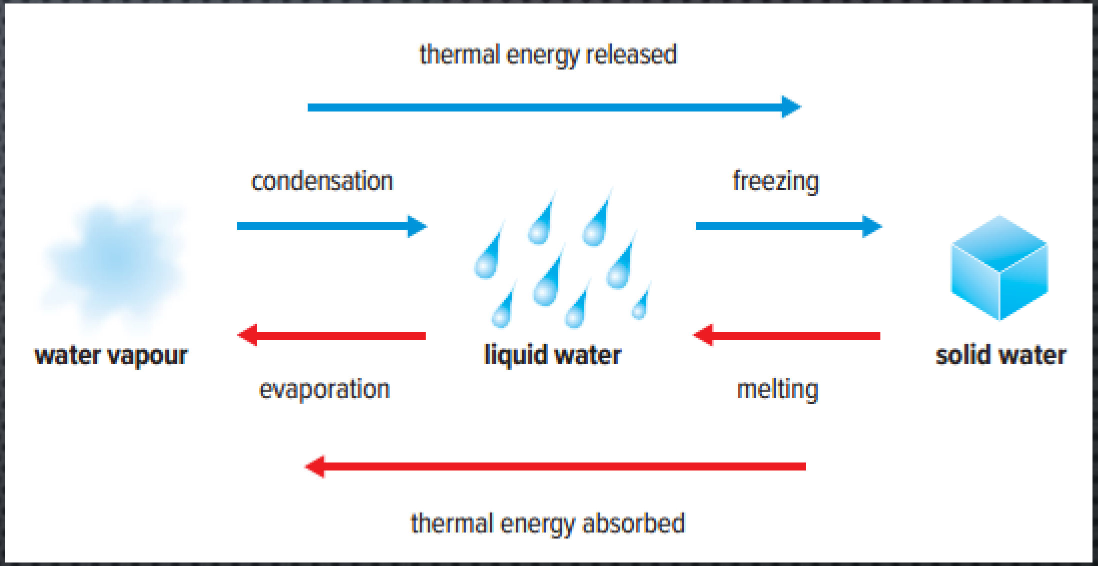
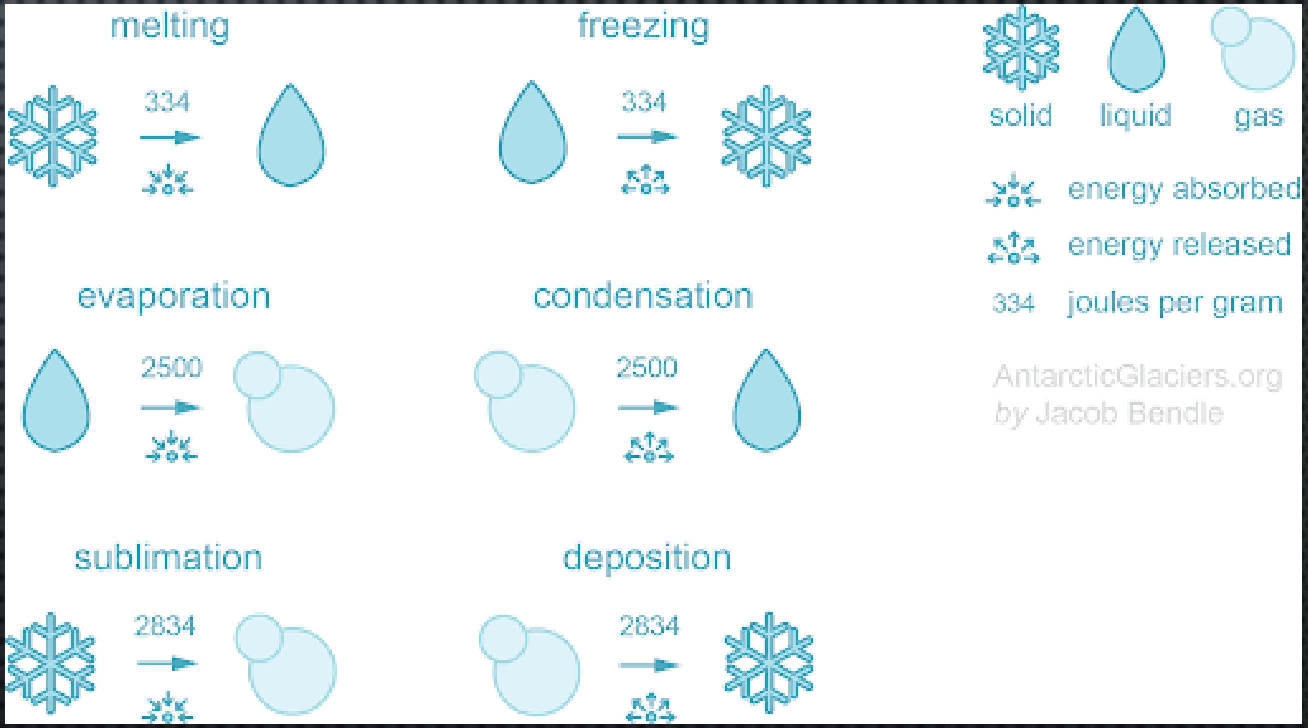


Figure 1.10 The changes of state of water in the water cycle involve the gain (absorption) and release of thermal energy.

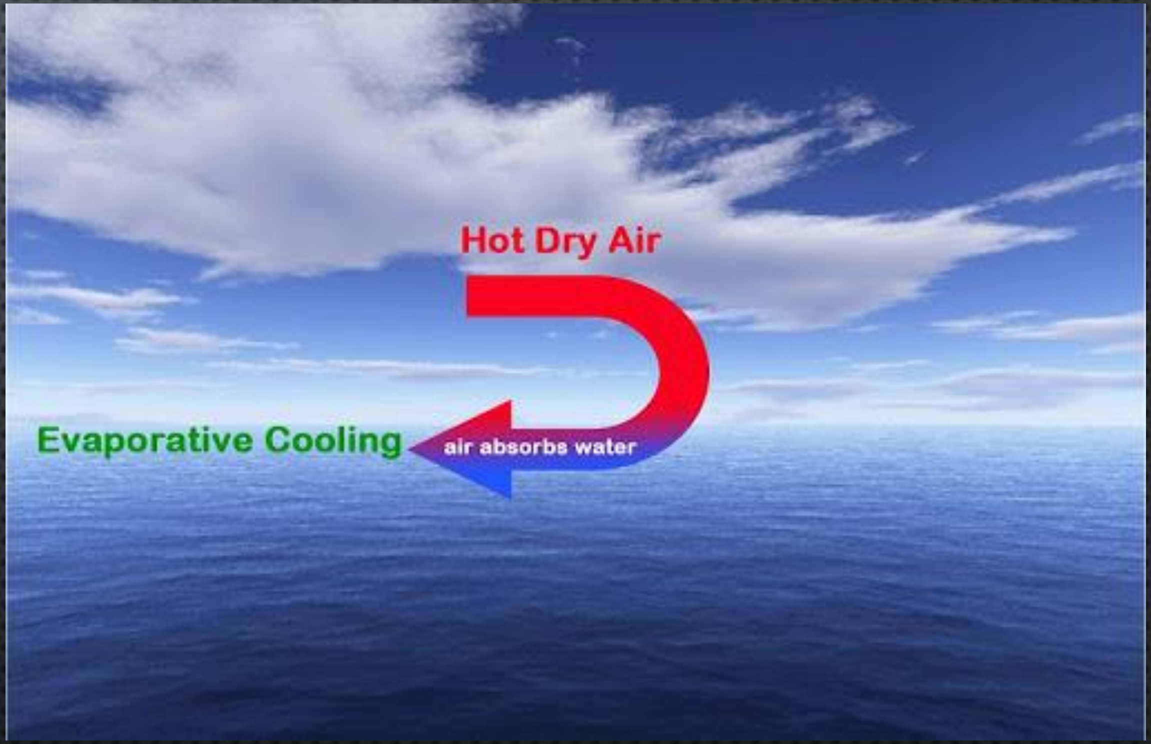
THE ROLE OF WATER IN TRANSFERRING ENERGY IN THE ATMOSPHERE

- EVAPORATION
- A LARGE AMOUNT OF ENERGY IS NEEDED TO BREAK THE FORCE ATTRACTING WATER MOLECULES TOGETHER. LIQUID WATER BECOMES A GAS.
- CONDENSATION
- WATER MUST LOSE A LOT OF ENERGY FOR MOLECULES TO COME TOGETHER TO FORM ATTRACTIVE FORCES. GASEOUS WATER VAPOUR BECOMES A LIQUID
- MELTING – SOLID TO LIQUID
- SOLIDIFICATION – LIQUID TO GAS
- SUBLIMATION – SOLID TO GAS
- DEPOSITION – GAS TO SOLID



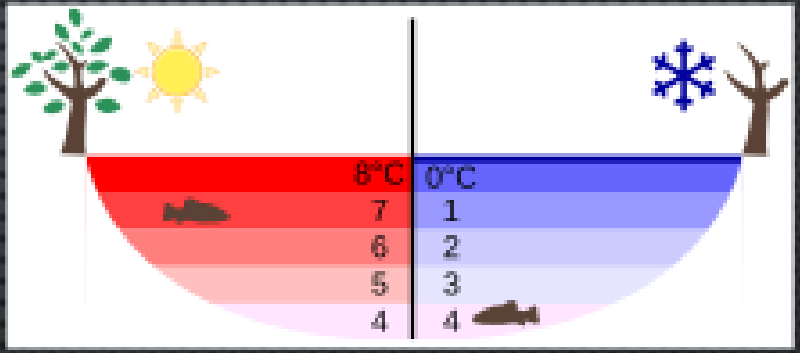
THE ROLE OF WATER IN TRANSFERRING ENERGY IN THE ATMOSPHERE

- WATER EVAPORATES WHEN ITS MOLECULES ABSORB ENOUGH ENERGY TO BREAK AWAY FROM NEIGHBOURING MOLECULES. THIS ENERGY CAN BE ABSORBED FROM SUNLIGHT, FROM AIR AT THE WATER'S SURFACE, OR FROM OTHER WATER MOLECULES. WHEN ENERGY IS ABSORBED FROM OTHER WATER MOLECULES, THEY LOSE ENERGY AND COOL. THIS PROCESS, CALLED EVAPORATIVE COOLING, CAUSES BODIES OF WATER TO REMAIN AT A FAIRLY STABLE TEMPERATURE.



The Role of Water in Transferring Energy in the Atmosphere

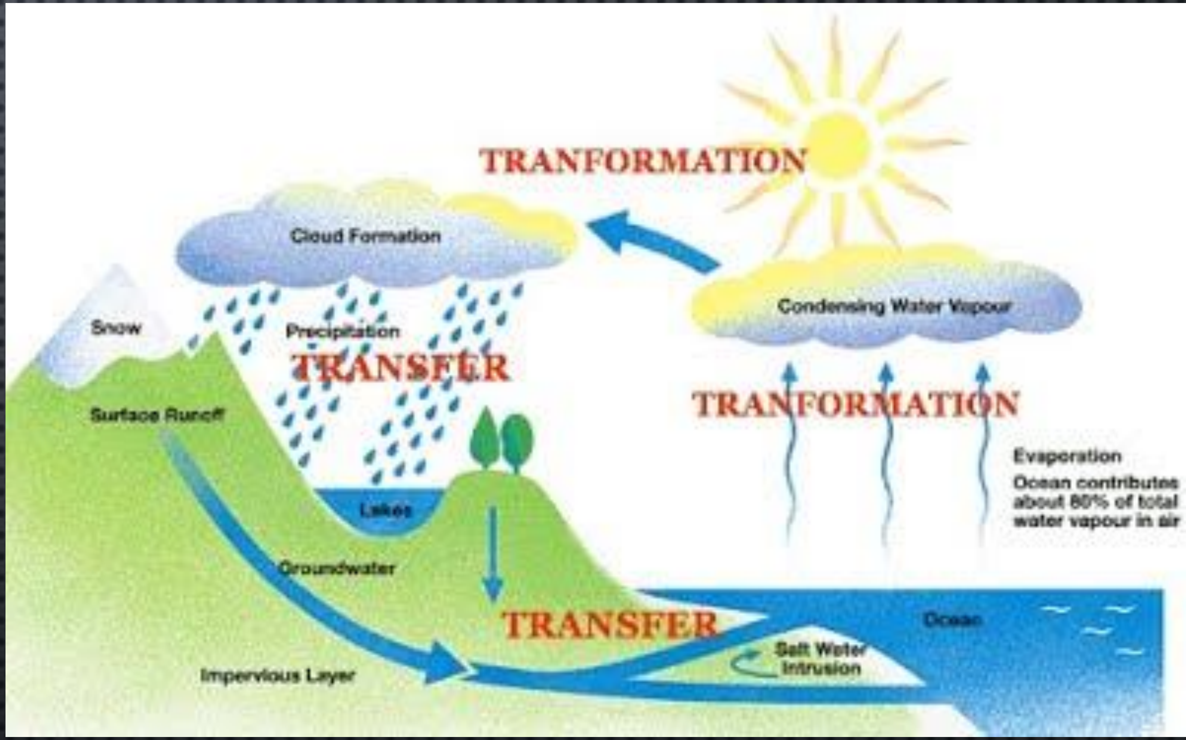
- Oceans, ponds, and rivers have a low albedo and absorb about 95 percent of the incoming solar energy.



- Due to its high specific heat capacity, a lot of energy is needed to change the temperature of water.
- Thus, oceans and large ponds have an effect on the air temperature of nearby land communities.
- water absorbs a large amount of thermal energy during the day and during the summer.
- Water releases this energy slowly at night and during the winter.

The role of water in transferring energy in the atmosphere

- When water evaporates, energy is absorbed.
- The water vapour sometimes travels great distances before condensing.
- When it does, thermal energy is released into the surroundings.



1-1D

- Lab manual: The role and transfer of energy in the water cycle

THE CAUSE OF WEATHER

- AIR MASS VERY LARGE MASS OF AIR WITH NEARLY UNIFORM PROPERTIES OF TEMPERATURE, HUMIDITY, AND PRESSURE

- THE AIR OVER A WARM SURFACE CAN BE HEATED BY CONDUCTION AND RISE BECAUSE IT IS LESS DENSE THAN THE SURROUNDING AIR.
- THIS PROCESS CAN TAKE PLACE OVER THOUSANDS OF SQUARE KILOMETRES FOR DAYS OR WEEKS.
- MOST AIR MASSES FORM OVER TROPICAL REGIONS OR POLAR REGIONS.

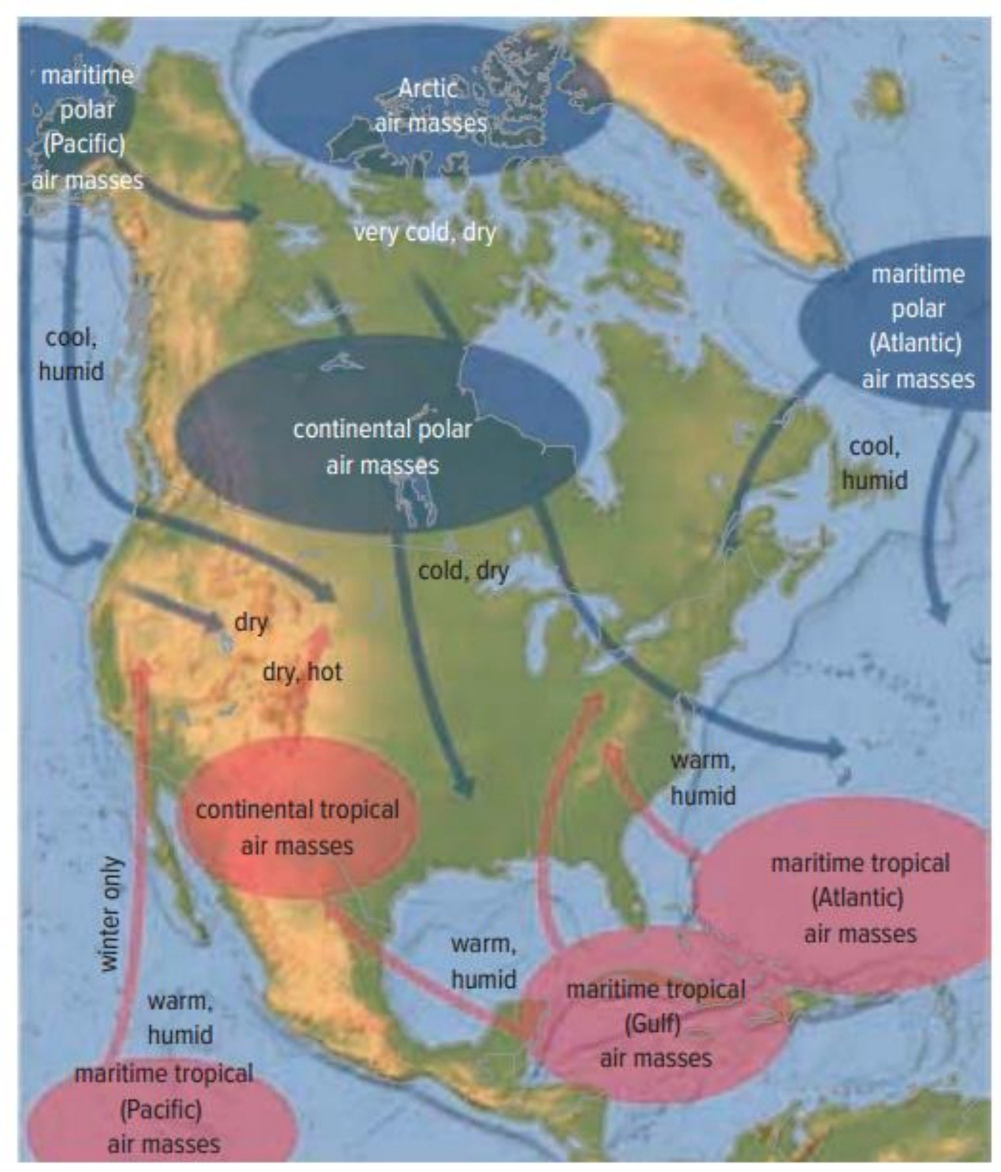
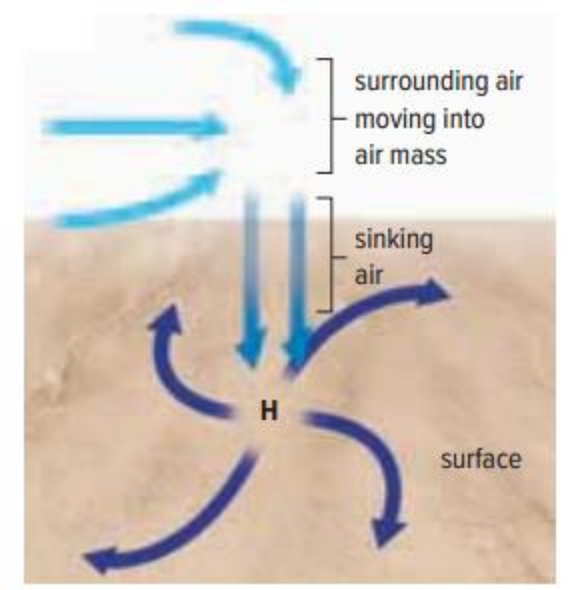


Table 1.2 Types and Characteristics of Air Masses		
Air Mass	**Winter Characteristics**	**Summer Characteristics**
Arctic	bitter cold, dry	cold, dry
Continental Polar	very cold, dry	cool, dry
Continental Tropical	warm, dry	hot, dry
Maritime Polar	cold, humid	cool, humid
Maritime Tropical	warm, humid	hot, humid

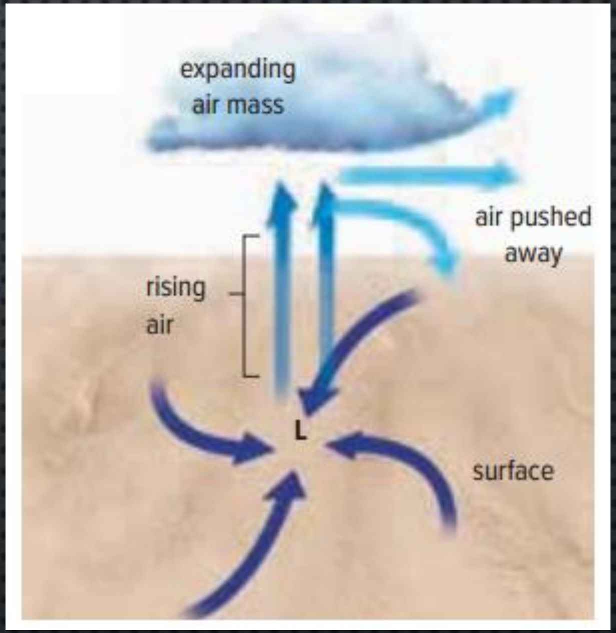
HIGH PRESSURE SYSTEMS

- HIGH PRESSURE SYSTEM WHEN AN AIR MASS COOLS OVER AN OCEAN OR A COLD REGION ON LAND.
- AS THE AIR MASS COOLS, PARTICLES IN THE AIR LOSE KINETIC ENERGY, AND THE AIR BECOMES MORE DENSE. THE AIR MASS CONTRACTS, AND THIS CONTRACTION DRAWS IN SURROUNDING AIR FROM THE UPPER TROPOSPHERE.
- THE ADDED WEIGHT OF THE EXTRA AIR INCREASES ATMOSPHERIC PRESSURE. THE DENSE, HIGH PRESSURE AIR MOVES OUTWARD TOWARD AREAS OF LOWER PRESSURE.
- THIS MOVEMENT OF AIR FROM AN AREA OF HIGHER PRESSURE TO AN AREA OF LOWER PRESSURE IS WHAT PEOPLE COMMONLY REFER TO AS WIND.
- IN THE NORTHERN HEMISPHERE, EARTH'S ROTATION CAUSES THE WIND TO MOVE IN A CLOCKWISE DIRECTION AROUND THE HIGH PRESSURE CENTRE IN THE NORTH AND COUNTER CLOCKWISE IN THE SOUTH.
- AS THE HIGH PRESSURE AIR SINKS, IT BECOMES WARMER AND DRIER. AS A RESULT, HIGH PRESSURE SYSTEMS OFTEN BRING CLEAR SKIES.



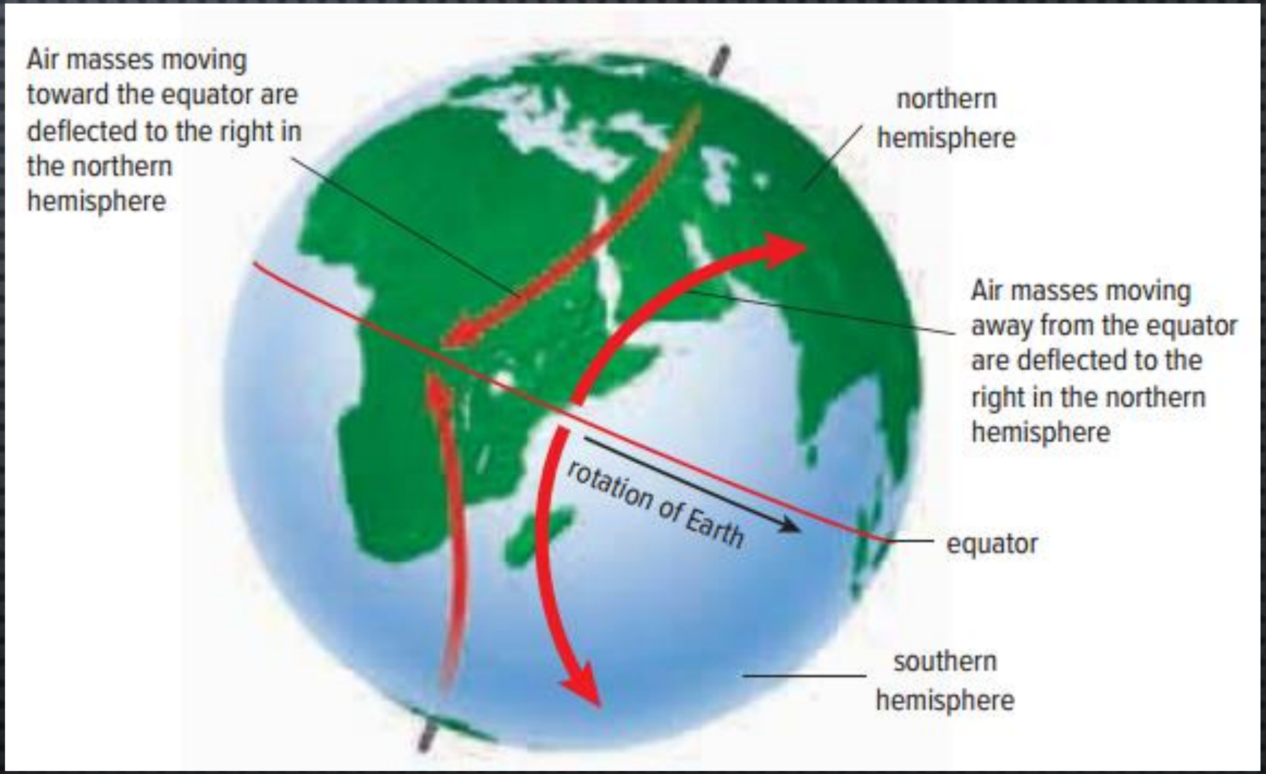
LOW PRESSURE SYSTEMS

- Air masses that travel over warm land or oceans may develop into low pressure systems.
- When an air mass warms, it expands and rises, making the layer of air thicker.
- However, as the air rises, it cools. Water vapour in the air may condense, producing clouds or precipitation.
- This is why low pressure systems often bring wet weather.
- The expanding air mass pushes away air in the upper troposphere.
- At Earth's surface, the atmospheric pressure decreases. The lower-pressure area at the surface draws in air from higher-pressure areas.
- As higher-pressure air in the atmosphere flows toward a low pressure area, Earth's rotation causes the air flow to curve.
- As a result, the wind flows counter clockwise around the low pressure centre in the northern hemisphere and clockwise in the southern hemisphere



The Coriolis Effect and Wind

- Air sinks at different latitudes: 30° (N and S), 60° (N and S), and the poles.
- Over long distances, wind is also affected by Earth's rotation.
- The Coriolis effect is a change in the direction of moving air, water, or any objects on Earth's surface due to its rotation.
- As Earth rotates, any location at the equator travels much faster than a location near either of the poles.
- Air moving northward from the equator travels east quickly in the same direction that Earth rotates. As a result, the Coriolis effect deflects winds to the right in the northern hemisphere and to the left in the southern hemisphere.



1-2A

- Lab manual : Modelling the Coriolis Effect

GLOBAL WIND SYSTEMS

- Wind systems are wide zones of prevailing winds.
- Wind is described by the direction from which it blows
- Earth has three major wind systems, which occur in both hemispheres.
- Sailors created the term "trade winds" to name the dependable winds that helped them transport and trade goods.
- The prevailing westerlies in the northern hemisphere are responsible for much of the weather in North America.
- The polar easterlies are cold, polar winds.

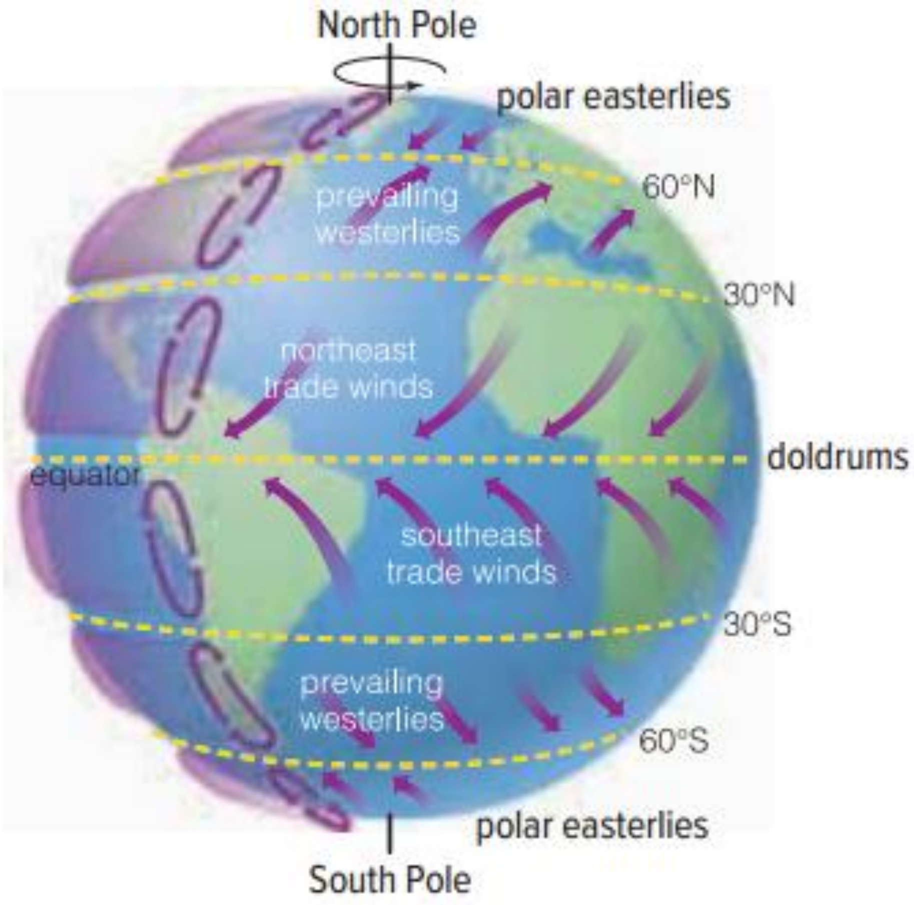
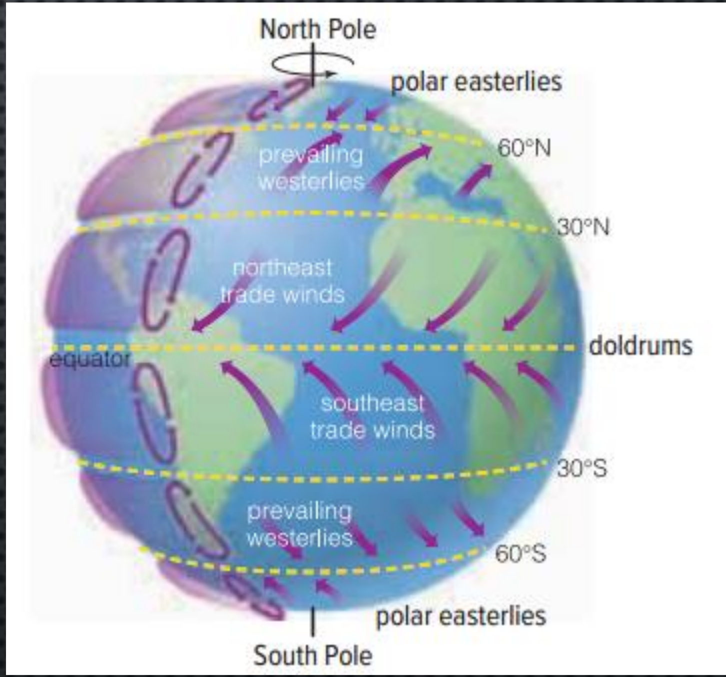


Figure 1.16 Earth's global wind systems.
Interpret *What evidence can you see that the global wind systems are the result of both convection currents and the Coriolis effect?*

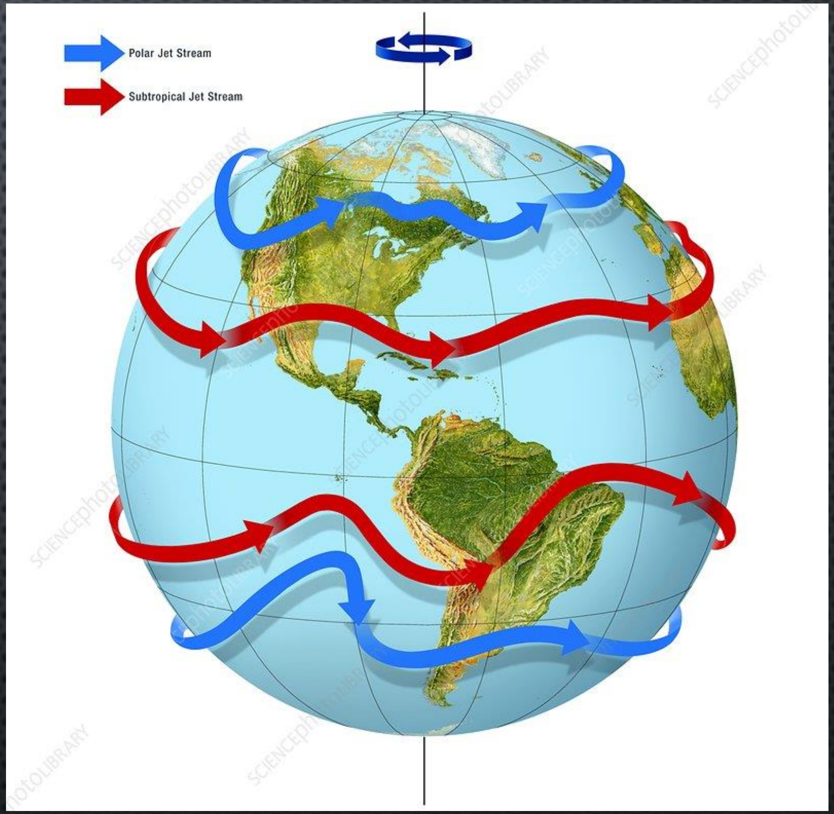
Table 1.3 Global Wind Systems

Wind System	Location	Path
Trade winds	• Between the equator and 30° north latitude • Between the equator and 30° south latitude	• Air at the equator warms, rises, and travels to 30° north or south latitude. • At 30° north or south, the air cools, sinks, and moves west toward the equator and is deflected west.
Prevailing westerlies	• Between 30° and 60° north latitude • Between 30° and 60° south latitude	• Air circulation pattern is opposite to that of the trade winds. • Surface winds blow from west to east and toward the Poles.
Polar easterlies	• Between 60° north latitude and the North Pole • Between 60° south latitude and the South Pole	• Air circulation pattern is similar to that of the trade winds. • Surface winds blow from east to west and away from the Poles.

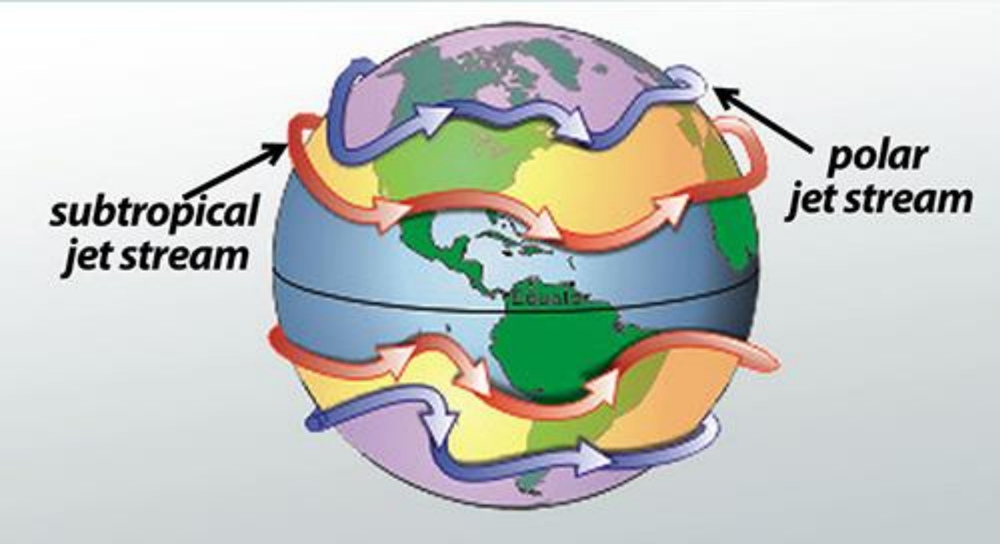


Jet Streams

- A large temperature gradient in upper-level air combined with the Coriolis effect results in strong westerly winds called jet streams. A jet stream is
- a narrow band of fast-moving wind. Its speed varies with the temperature differences between the air masses at the wind zone boundaries.
- A jet stream can have a speed up to 300 km/h or greater, at altitudes of 10 km to 12 km.

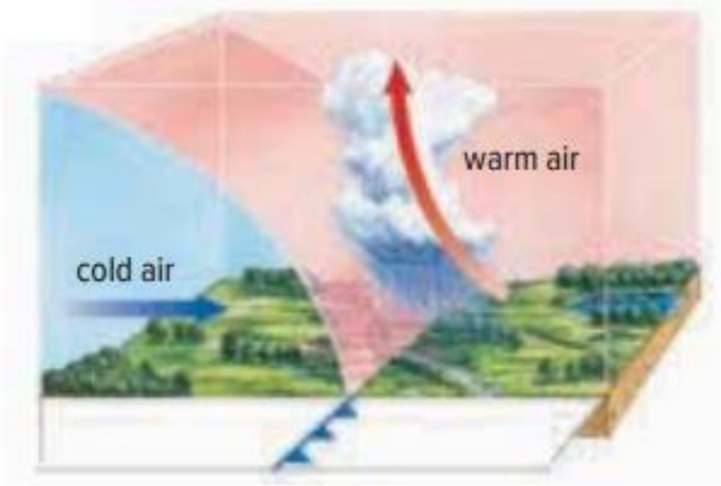


- The position of a jet stream varies with the seasons.
- It generally is located in the region of strongest temperature differences on a line from the equator to a pole.
- The jet stream can move almost due south or north, instead of following its normal west-to-east flow.
- It also can split into branches and re-form later. Whatever form or position it takes, the jet stream represents the strongest type of wind system on Earth.

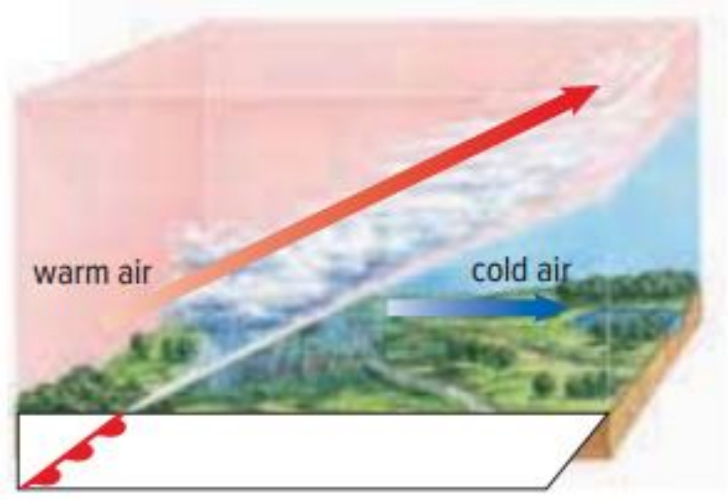


Fronts

- Front a zone that develops as a result of the meeting of two air masses with different characteristics
- Each air mass has its own temperature and pressure.
- These conditions change at the front.
- An approaching front means a change in the weather, and the extent of the change depends on the difference between conditions in the air masses.
- Fronts usually bring precipitation.
- Warm air at the front is displaced by denser cold air. The warm, moist air rises. As it cools, water vapour in the air condenses, forming clouds.
- Under the right conditions, the condensed water vapour will fall to Earth's surface as precipitation.

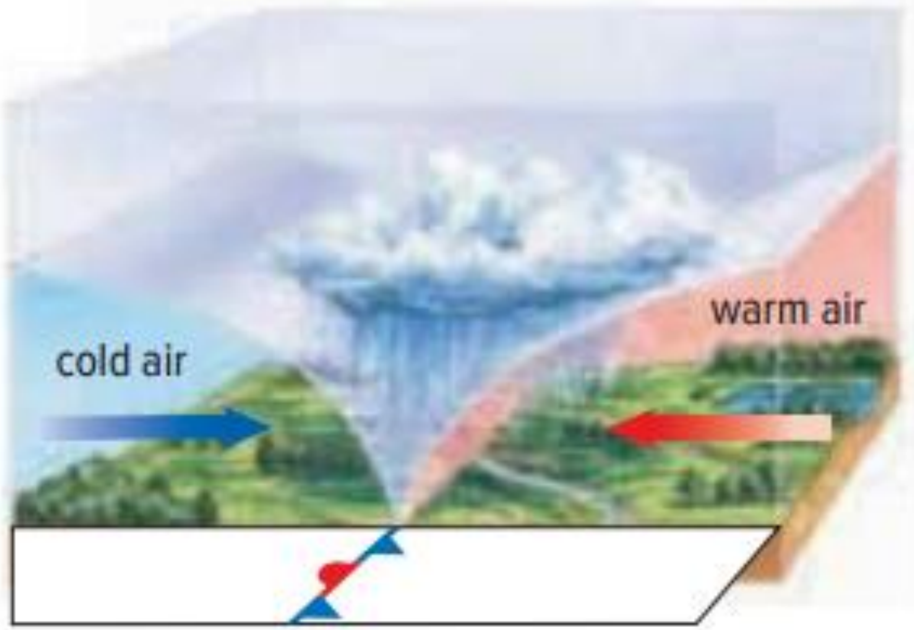


Cold Front: When cold, dense air displaces warm air, it forces the warm air, which is less dense, up along a steep slope.

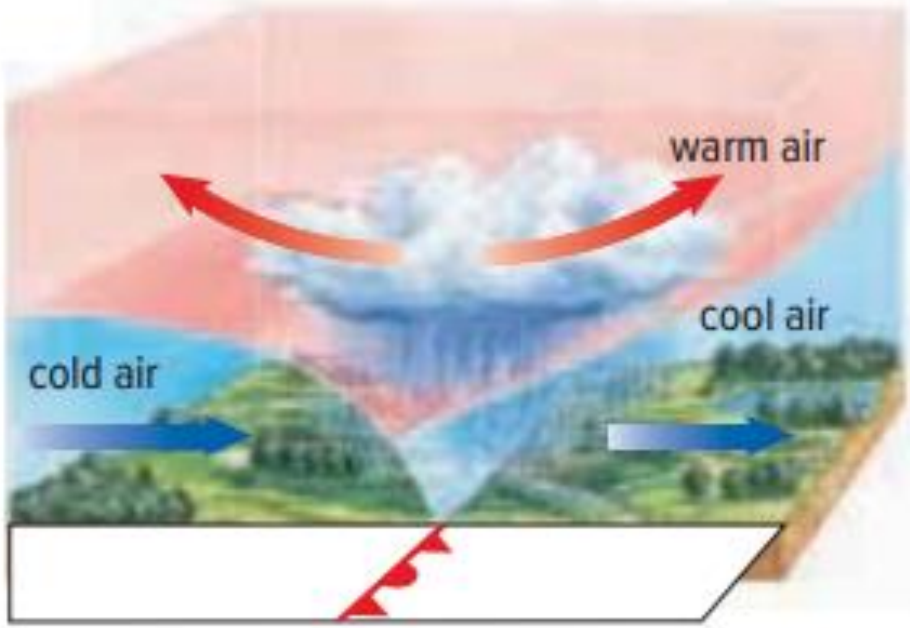


Warm Front: Advancing warm air displaces cold air along a warm front, which develops a gradual boundary slope.

FRONTS



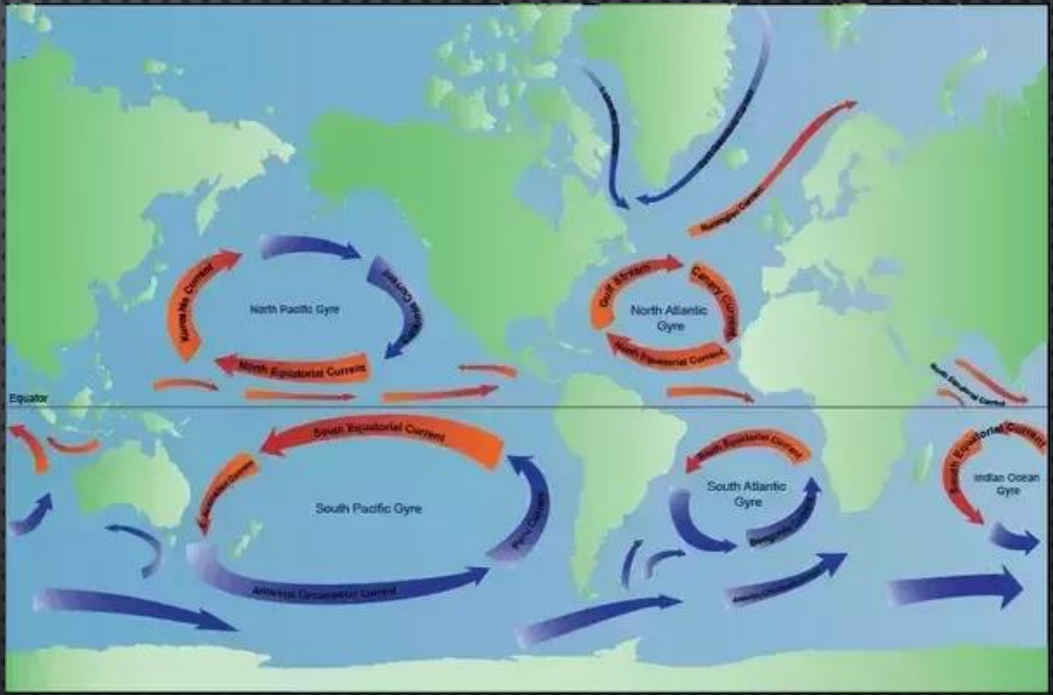
Stationary Front: When two air masses meet but neither advances, the boundary between them stalls. The resulting stationary front often occurs between two modified air masses with small temperature and pressure differences. The air masses can continue moving parallel to the front.



Occluded Front: Sometimes a cold air mass moves so fast that it overtakes a warm front, forcing the warm air up. As the warm air is lifted, the advancing cold air mass collides with the cold air mass in front of the warm front. (Occluded means obstructed.)

SURFACE CURRENTS IN THE OCEAN

- Like wind, ocean currents also move thermal energy around Earth.
- Surface currents are created by wind.
- There are five major sets of surface currents, one in each main ocean basin
- the North Pacific basin
- the South Pacific basin
- the North Atlantic basin
- the South Atlantic basin
- the Indian Ocean basin.
- Due to the Coriolis effect, the major currents in the northern hemisphere move in a clockwise direction, and those in the southern hemisphere move in a counterclockwise direction.
- Another result of the Coriolis effect is that currents on the western side of ocean basins tend to be narrow and fast-moving. Currents on the eastern side of ocean basins are wider and slow-moving.



- IN ALL OF THE OCEAN BASINS, THE WARM WATER CURRENTS NEAR THE EQUATOR FLOW IN A WESTERLY DIRECTION. WHEN THESE CURRENTS REACH A LANDMASS, SUCH AS A CONTINENT, THEY ARE DEFLECTED TOWARD THE POLES. THESE POLEWARD-FLOWING WATERS CARRY WARM, TROPICAL WATER TO HIGHER, COLDER LATITUDES.

Figure 1.19 Surface currents circulate in predictable patterns in each ocean basin. The red arrows represent warm water currents, and the blue arrows represent cold water currents.