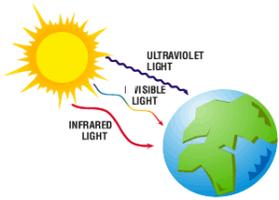


## Heat Transfer: Radiation, Conduction and Convection

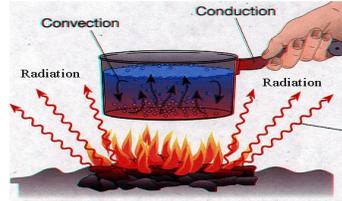


When radiation from the Sun (UV, IR, visible wavelengths) reaches the Earth, it is absorbed & reflected by the Earth's surface. The Sun provides most of the Earth's energy and along with the Earth's natural \_\_\_\_\_; our planet is able to maintain an average temperature of \_\_\_\_\_. It is the energy from the Sun that is the driving force behind all the \_\_\_\_\_ and \_\_\_\_\_ patterns on our planet.

### Transfer of Energy

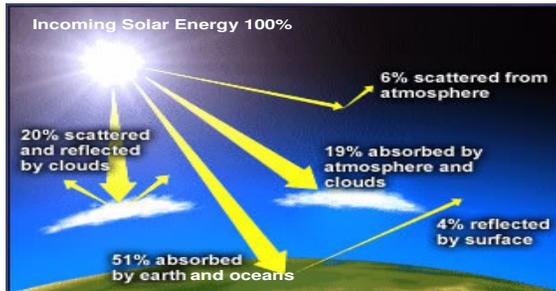
\_\_\_\_\_ energy is the energy of \_\_\_\_\_ of particles in a substance. \_\_\_\_\_ is thermal energy transferred from one substance to another. Energy can be transferred between two places by one of three methods:

- 1)
- 2)
- 3)



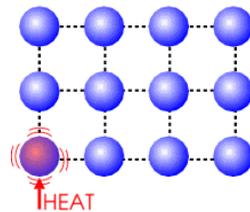
### Radiation

Radiation is the transfer of energy by means of \_\_\_\_\_. These waves do not require a \_\_\_\_\_. This is how the Sun's energy reaches the Earth. When solar radiation penetrates the Earth's atmosphere it can be either \_\_\_\_\_ or \_\_\_\_\_.



Examples of radiation include holding your hand above a grill to check if it's hot, spreading black coal on highways to melt surface ice and melt snow, using the shiny side of aluminum foil facing the food to reflect the radiant heat to cook the food faster.

### Conduction

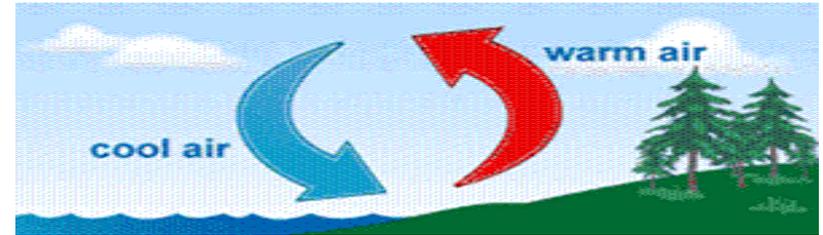


Conduction is the transfer of energy through the means of \_\_\_\_\_, mostly in \_\_\_\_\_. When highly energetic particles vibrate more quickly, they \_\_\_\_\_ with other particles and transfer some energy to them. Conduction occurs on Earth's surface, in \_\_\_\_\_, \_\_\_\_\_, & \_\_\_\_\_. Conduction is only a small part of the transfer of energy in weather.

Examples of conduction include insulating material around hot water bottles to keep the heat in; a potato cooks faster with an iron nail in the middle of it since the heat conducts along the nail to cook the potato from the inside out.

### Convection

Convection is the transfer of energy by the movement of molecules in a \_\_\_\_\_ (\_\_\_\_\_ or \_\_\_\_\_). Convection is the most important concept for weather systems, since they depend on the movement of \_\_\_\_\_ to create \_\_\_\_\_.



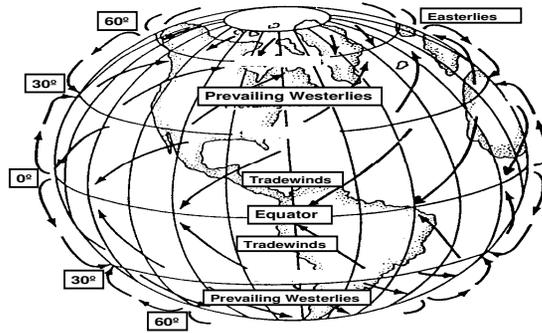
A convection current is set-up when particles of a fluid gain energy. As their movement increases, the particles \_\_\_\_\_ and that portion of the fluid becomes \_\_\_\_\_ compared to its surrounding; thus it \_\_\_\_\_. The warm fluid is replaced by cooler fluids as the flow of the convection current begins.

Examples of convection include holes on the top of a metal lamp shade, heating vents on the floor and not on the ceiling because hot air rises.



(ex. wind from BC to Ontario is moving East, but it is coming from the west therefore it is called "west winds" or "\_\_\_\_\_")

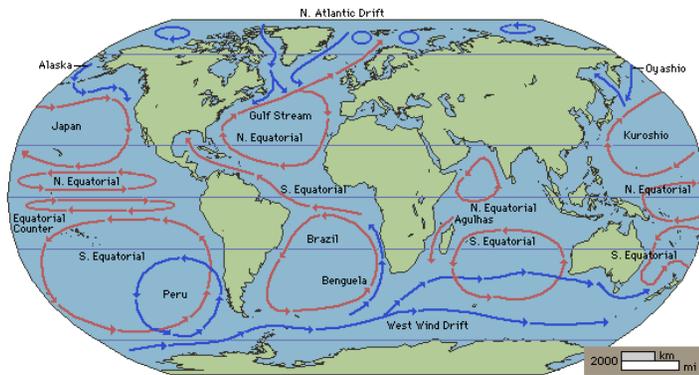
The \_\_\_\_\_ is a ribbon of extremely **fast moving air** near the top of the troposphere caused by the contact of **cold** and **warm** air masses. The polar jet stream forms at the boundary between the warmer prevailing westerlies and the cooler polar easterlies.



**Ocean Currents**

Ocean currents are \_\_\_\_\_ and are important for weather and climate since they occupy so much of the Earth's surface. Ocean currents patterns can be explained by:

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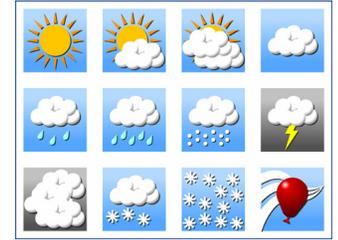


**Weather vs Climate**

**What is weather?**

Weather includes all of the atmospheric conditions that occur over a \_\_\_\_\_ of time (i.e., an hour, day, or week).

\_\_\_\_\_ are scientists who study the weather, and use the following information to describe the weather:



- >
- >
- >
- >
- >

In some areas the daily weather is the same, like the Sahara Desert where it is always hot and dry. In Canada, the weather changes, sometimes dramatically from day to day. Weather data has been collected since the 1800's, using weather stations, weather balloons, aircraft, and satellites.

Interactions between water, air and land on Earth and energy from the Sun all contribute to weather.

**What is climate?**



Climate is the usual, or average, pattern of weather in a region \_\_\_\_\_.

\_\_\_\_\_ are scientists who collect weather measurements made over \_\_\_\_ years or more and average the results to study the climate.

The climate of a region gives a range of temperatures that would be expected at a certain time of the year, and whether you can expect rain, snow, or high winds in certain seasons. The climate of a region determines the weather you can expect over many years.

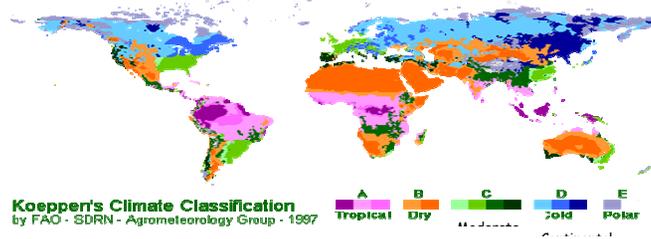
**"Climate is what you expect, but weather is what you get"**  
**-Robert Heinlein**

## Classifying Climate

\_\_\_\_\_ have been identified since the early 1900's using \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_. Wladimir Koeppen identified 5 climate zones, each is subdivided further into \_\_\_\_\_.

The 5 climate zones are:

- 
- 
- 
- 
- 



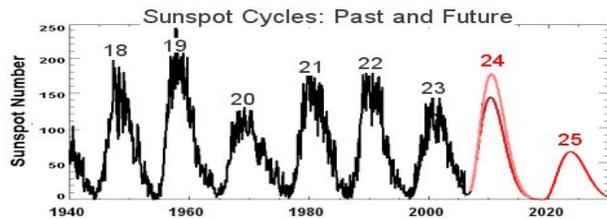
A graphic representation of an areas expected climate data is called a \_\_\_\_\_. Climatographs are useful because they allow scientists to view how temperature and precipitation change throughout the year and to compare weather patterns in different locations.

### Factors that Affect the Earth's Climate:

1)

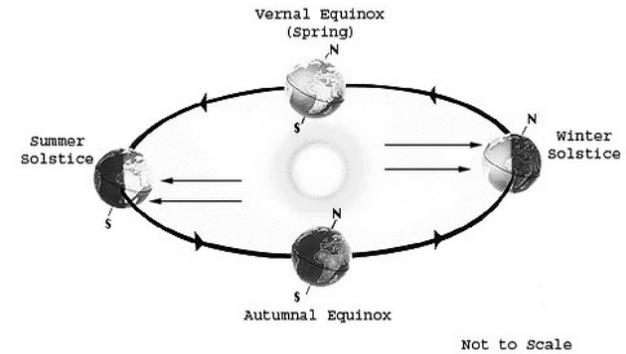
The amount of solar energy that reaches the Earth's surface depends on a number of factors:

\_\_\_\_\_ - the amount of energy produced by the Sun fluctuates by about 0.1% every \_\_\_ years ("sunspot cycle").



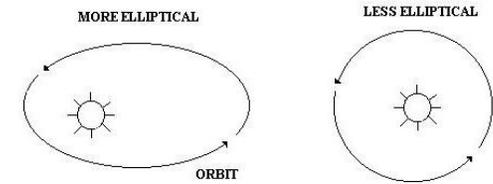
\_\_\_\_\_ - Earth's axis of rotation is tilted at an angle of about \_\_\_\_\_. This, combined with its annual orbit around the Sun, produces our seasons.

All Seasons are for Northern Hemisphere



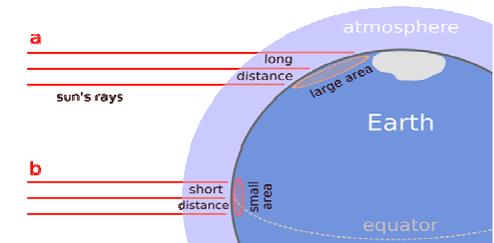
\_\_\_\_\_ - change in shape of the Earth's orbit due to the gravitational pull of the other planets (\_\_\_\_\_) is a \_\_\_\_\_ year cycle.

\_\_\_\_\_ - the angle of the Earth's tilt varies by about  $2.4^{\circ}$ ; a greater degree of tilt means greater temperature differences between summer and winter (\_\_\_\_\_ year cycle)



\_\_\_\_\_ - the Earth is not a perfect sphere, it wobbles slightly as it rotates (like a wobbly top). This determines whether the two hemispheres (N & S) will have similar contrasts between seasons, or if one will have greater differences than the other.

\_\_\_\_\_ - because of the spherical shape of the Earth, areas close to the equator receive more direct, intense sunlight than areas closer to the poles.



2)

Earth's atmosphere extends \_\_\_\_\_ up from its surface, and is composed mainly of  $N_2$ ,  $O_2$ , and  $CO_2$  gases.

The \_\_\_\_\_ is a natural part of Earth's climate system which helps keep temperature fluctuations within a certain range.

The movement of air from areas of \_\_\_\_\_ to \_\_\_\_\_ pressure (a.k.a. "\_\_\_\_\_") transfers energy around the world and affects the ocean currents and precipitation patterns. Wind is caused by the uneven heating of the Earth's surface and the rotation of the Earth (\_\_\_\_\_).

3)

Oceans and lakes act as "heat reservoirs" (they hold in heat) because water has a high \_\_\_\_\_

Ice and snow reflect heat because their light colour increases their \_\_\_\_\_ (ability to reflect light). \_\_\_\_\_ ice and snow would result in \_\_\_\_\_ of radiant energy.

4)

The Earth's out layer is composed of massive pieces of solid rock known as \_\_\_\_\_. Tectonic plates move a few \_\_\_\_\_ each year. This affects air and water circulation which transfer energy around the globe.

\_\_\_\_\_ release ash and other particles which \_\_\_\_\_ radiation and have a \_\_\_\_\_ effect on the climate. The 1815 eruption of Tambora in the Philippines caused the "Year Without Summer." Some types of volcanic eruptions may \_\_\_\_\_ global temperatures by releasing \_\_\_\_\_ gases.

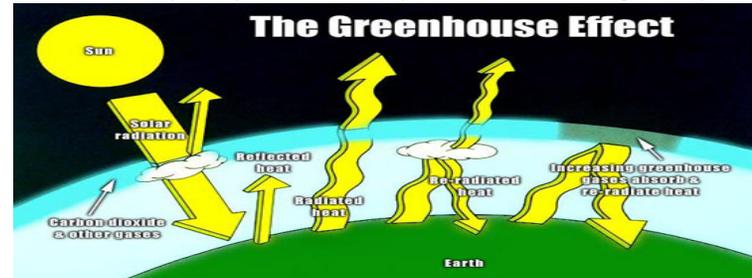
5)

The current change in climate is at least partly \_\_\_\_\_ (relating to or resulting from the influence of humans). The \_\_\_\_\_ started in the late 1700's/early 1800's. New machines were invented to do work for us by burning \_\_\_\_\_ (automobiles, trains, ships, aircraft, factories, farming/mining equipment, furnaces, etc...) When fossil fuels are burned to release \_\_\_\_\_, they release \_\_\_\_\_ and other \_\_\_\_\_ into the atmosphere as a waste product. Many of these gases affect the natural process that produces the greenhouse effect.

## The Greenhouse Effect

Earth's climate system maintains Earth's temperature by \_\_\_\_\_ energy from the Sun and distributing the energy around the world.

- A lot of the \_\_\_\_\_ radiation from the Sun that passes through the atmosphere is absorbed by the Earth's surface, and as a result, the Earth's surface \_\_\_\_\_.
- The Earth emits \_\_\_\_\_ radiation (IR), which is trapped by the \_\_\_\_\_ in the atmosphere.
- Atmospheric gases then radiate the energy in all directions, which means that about \_\_\_\_\_ of the radiation gets sent back toward Earth's surface warming the Earth even more.
- The **Greenhouse Effect** is a natural process in which gases and clouds \_\_\_\_\_ IR emitted from Earth's surface and radiates it, heating the atmosphere & Earth's surface. It is the phenomenon that keeps temperatures on our planet consistent during the day and night.

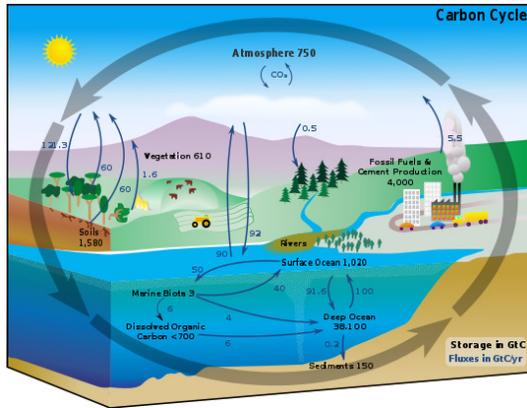


### Greenhouse Gases

- Most of the atmosphere is \_\_\_\_\_ (78%) and \_\_\_\_\_ (21%) neither of which absorbs radiation from the surface of the Earth.
- The greenhouse effect is caused by the gases that make up \_\_\_\_\_ of the atmosphere, called the \_\_\_\_\_.
- The contribution of a greenhouse gas to the greenhouse effect depends on its \_\_\_\_\_ in the atmosphere and by how much \_\_\_\_\_ each molecule of gas can absorb.

1) **Water vapour,  $H_2O(g)$**  - accounts for \_\_\_\_ of the natural greenhouse effect. The concentration of  $H_2O$  in the atmosphere is temperature dependent and ranges between \_\_\_\_\_ amounts and \_\_\_\_ of the atmosphere. As Earth's temperature increases, more liquid water becomes water \_\_\_\_\_ and the \_\_\_\_\_ air can hold more water vapour. Water vapour can \_\_\_\_\_, which further heats up the Earth. This is a \_\_\_\_\_ feedback loop.

2) **Carbon Dioxide,  $CO_2(g)$**  - accounts for \_\_\_\_\_ of the atmosphere, but is thought to account for  $\frac{1}{3}$  of the natural greenhouse effect on Earth. Since the \_\_\_\_\_, the concentration of  $CO_2$  has increased from \_\_\_\_\_. Natural sources of  $CO_2$  include \_\_\_\_\_ and \_\_\_\_\_.



The \_\_\_\_\_ is the movement of carbon between the lithosphere, hydrosphere, atmosphere and living things. \_\_\_\_\_ are important \_\_\_\_\_ in that they remove  $CO_2$  from the atmosphere and convert it to other forms of carbon.

3) **Methane,  $CH_4(g)$**  - even though there is much less methane in the atmosphere than  $H_2O$  or  $CO_2$ , the methane molecules \_\_\_\_\_ thermal energy than a molecule of  $CO_2$ . This makes methane \_\_\_\_\_ more powerful than  $CO_2$  as a greenhouse gas. Since the Industrial Age, the methane concentration has increased from \_\_\_\_\_. It is formed by natural sources such as \_\_\_\_\_ in swamps and \_\_\_\_\_.



4) **Ozone,  $O_3(g)$**  - Naturally, ozone is found in the \_\_\_\_\_ where it protects the Earth from \_\_\_\_\_ rays from the Sun. Ozone is found in the \_\_\_\_\_ in varying concentrations, and here it acts as a greenhouse gas.

5) **Nitrous Oxide,  $N_2O(g)$**  -  $N_2O$  molecules radiate much more energy than other greenhouse gases, it is almost \_\_\_\_\_ more effective than  $CO_2$ . This ability of  $N_2O$  to trap high levels of energy is balanced by its extremely \_\_\_\_\_ in the atmosphere. The concentration of  $N_2O$  has increased from \_\_\_\_\_ since the industrial revolution. It is produced by natural sources such as \_\_\_\_\_, and is also a \_\_\_\_\_.

## What is the Enhanced Greenhouse Effect?

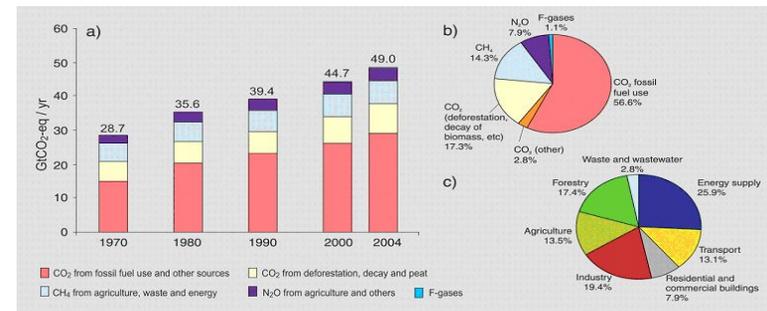
When there is a change in the amounts of the greenhouse gases there can be a disruption in the \_\_\_\_\_ of the climate system. This causes the Earth's temperature to \_\_\_\_\_.

**GLOBAL WARMING** is the \_\_\_\_\_ in the \_\_\_\_\_ temperature of Earth's near-surface air and oceans since the mid-20<sup>th</sup> century and its projected continuation.

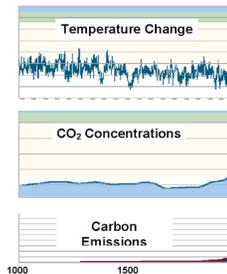
**CLIMATE CHANGE** is the \_\_\_\_\_ in the statistical distribution of \_\_\_\_\_ over periods of time that range from decades to millions of years. **Climate change is a result of global warming!**

What are the sources of the Greenhouse Gases?

"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to \_\_\_\_\_" (Intergovernmental Panel on Climate Change, January 2001)



Evidence points to an increase in the greenhouse gases,  $H_2O$ ,  $CO_2$ ,  $CH_4$ ,  $N_2O$ , which accounts for \_\_\_\_\_.



There is a strong correlation between the atmospheric \_\_\_\_\_ concentrations and global temperature \_\_\_\_\_.

Relatively small changes in average temperatures can have huge consequences. During the last Ice Age, about 20 000 years ago, average temperatures were \_\_\_\_\_ than they are today, but the \_\_\_\_\_ were only \_\_\_\_\_ colder.

## Evidence of Global Warming

- Earth's climate has always changed over time
- Recent changes have not been experienced for \_\_\_\_\_.
- This time, scientists believe changes are happening because of \_\_\_\_\_ (\_\_\_\_\_).

### Rising Temperatures

- Daily temperatures have been recorded since the 1800's
- Annual average temperature each year can be graphed
- By 2006, \_\_\_\_\_ of the previous \_\_\_\_\_ years, was the \_\_\_\_\_.
- \_\_\_\_\_ has warmed up by \_\_\_\_\_ in the past \_\_\_\_\_ years.

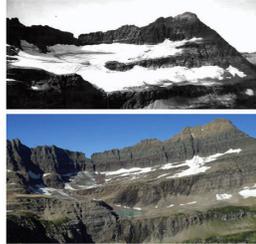


### Rising Sea Levels

- Sea levels have been rising almost \_\_\_\_\_ as fast as during previous warm periods, this can result in \_\_\_\_\_.
- Melting glaciers can cause sea levels to \_\_\_\_\_.
- As water temperatures increase, it \_\_\_\_\_.
- Water may be coming from North America, where levels of \_\_\_\_\_ have dropped \_\_\_\_\_.
- If the ice sheet covering Greenland were to melt, sea levels would rise \_\_\_\_\_.
- An increased amount of water in the oceans has changed the \_\_\_\_\_ from \_\_\_\_\_ to \_\_\_\_\_.

### Melting Glaciers and Ice

- Average size of glaciers is \_\_\_\_\_ as global temperatures \_\_\_\_\_
- Water from melting glaciers runs to the oceans, provides fresh drinking water for almost \_\_\_\_\_ of the world's population.
- If glaciers disappeared, there would be a \_\_\_\_\_.
- Ice and snow in the polar regions (Antarctica, Greenland) is melting.



### Severe Weather

- \_\_\_\_\_ are becoming more intense; a massive heat wave in Europe (2003) caused 1000's of deaths not to mention the destruction of Hurricane Katrina (2005)
- Warmer ocean temperatures lead to more \_\_\_\_\_ hurricanes, there are \_\_\_\_\_ the number of category 4-5 hurricanes in the last \_\_\_\_\_



### Precipitation

- Rising temperatures means more \_\_\_\_\_.
- The precipitation is heavier, with \_\_\_\_\_.
- There are increasing levels of precipitation in some areas such as \_\_\_\_\_, and less precipitation in drier areas such as \_\_\_\_\_.

### Changing Seasons

- Seasons are \_\_\_\_\_.
- Less cold days worldwide, and frosty nights \_\_\_\_\_ and ending \_\_\_\_\_.
- Many areas have \_\_\_\_\_, beneficial for farmers.



### Changing Ecosystems

- Many trees, shrubs and other plants are \_\_\_\_\_ earlier than usual.
- Animals are \_\_\_\_\_ earlier.
- Animals and plants are slowly \_\_\_\_\_ toward \_\_\_\_\_ and \_\_\_\_\_ as these areas warm up, changing ecosystems. This can lead to problems if the insects and plants are pests.

