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Contents

Introduction

Meteorology is a science that studies the gaseous atmosphere, the elements of climate and weather, and its impact on humans, animals, and plants. Climate, with its elements of solar radiation, heat, atmospheric pressure, wind, evaporation and condensation, and atmospheric disturbances, and the impact of these climatic elements on various aspects of human, plant and animal life are topics studied by meteorology.

The origin of the word meteorology is from the Greek language (*Meteor* means high and *logy* means science). Meteorology was the science of concern for mankind on earth since the beginning of animal domestication and the beginning of agriculture. The concern of mankind on rainy seasons, snow, wind, floods and drought times, which affected the attempt of mankind to overcome weather and climate problems to ensure his food safety. In ancient civilizations, for example the Pharaohs in ancient Egypt worshiped Sirius because they believed that its appearance is connected with the Nile floods, which the source of their welfare and prosperity. The Babylonians wrote their observations on thunder and rain on stone tablets. In ancient Greek, Aristotle in 340 BC, wrote the Meteorology book, he was considered as the father of meteorology (Alter, 1994). In India, Vedas, which are ancient Sanskrit texts, mentioned texts about clouds and seasons (Hellmann, 1908).

In the nineteenth century, there was a qualitative leap in meteorology, with advances in physics and chemistry and its applications to meteorology. In the twentieth century, with the invention of balloons and aircraft, advances in space and satellite science in the second half of the last century, the invention of the computer and the great leap in computer science, and remote sensing; great progress has been noticed in meteorology and has become of interest to all mankind.

Meteorology, with the help of modern technology in remote sensing and the ease of communications, is a very important science for human life, both for civil and military applications. Without the science of meteorology and the applications of weather forecasts, which are of the individual concern as well as governments and social organizations. With pre- warnings from meteorological services on floods, snow, heat waves, the tsunami waves, tornados, hurricanes, wind storms, and rainstorms, thousands of lives and billions of dollars are saved each year. Meteorological services are very important for aviation travels all over the world to save lives and properties. In agriculture, crops are saved from frost and heatwaves, and planning for planting seasons for each crop is very important all over the world, for the sake of war against famine and poverty. Also, environmental meteorology is important for the preservation of the environment against deforestation and desertification and for the preservation of water resources.

The topic of meteorology and climate is one of the important sciences for all scholars and researchers all over the world. Libraries and databases have hundreds of books, reports, brochures and scientific papers, concerning meteorology and related topics. One of the good books on meteorology for students and researchers, is “Essentials of Meteorology, an invitation for the atmosphere” for C. Donald Ahrens. The book came in 15 chapters, which cover most of the topics on meteorological subjects such as earth atmosphere, temperature, air pressure, wind, clouds, humidity, evaporation, condensation, water cycle, climate change, weather forecasting, air pollution, and global climate. At the end of each chapter, Ahrens introduces questions for review in which their answers are found in the text. He also introduces ate the end of each chapter, questions for thought and exploration, which require critical thinking and good understanding.

The following assignment is about the first five chapters form Ahrens's book "Essential of Meteorology, 6th edition. 2011". The assignment introduces answers for five questions from the review questions list and three questions from questions for thought and exploration list.

I- The Earth's Atmosphere

I.1- Questions for Review

1- What is the primary source of energy for Earth's atmosphere?

Answer:

The primary sustainable source of energy on planet Earth is the sun, which provide energy for the inhabitants of earth, fauna, and flora. It is necessary for the photosynthesis process in plants, which provides food for other living organisms.

2- Of the four most abundant gases in our atmosphere, which one shows the greatest variation from place to place at the earth's surface?

Answer:

The most abundant gases are Nitrogen (N_2), oxygen (O_2), water vapor (H_2O) and carbon dioxide (CO_2).

The percentage of Nitrogen and Oxygen remains constant up to a distance of 80km. Nitrogen is consumed through nutrients production by oceans planktons, and replenished through the decay of animals and plants. Oxygen is consumed through breathing, fermentation of organic material, and oxides formation, it is replenished by photosynthesis in plants that consumes carbon dioxide and produce sugar and oxygen at day time when the sun is shining.

Water vapor percentage varies from place to another and from time to time in the atmosphere, it may reach 4% of the total atmospheric gases, in the tropical steamy areas, and it may form only 1% of the atmospheric gases in arctic areas where weather is very cold.

3- List seven common weather elements.

Answer:

The seven common weather elements are:

- Air temperature, which is the measure of coldness or hotness of air surrounding us.
- Air pressure, which represents the force exerted by a column of air on a unit area. Air pressure is important in weather forecasts.
- Humidity, which indicates the amount of water vapor in the atmosphere.
- Clouds, which represent the condensation of water vapor in the form of a liquid or small ice particles that eventually lead to precipitation.
- Wind, which is the movement of air on the earth's surface, the direction and speed of the wind is important for weather forecasts.
- Precipitation, which is any form of falling liquid water, hail or snow on the earth's surface
- Visibility, which is the greatest that one can see through the atmosphere.

4- How does weather differ from climate?

Answer:

Weather is the daily description of the weather elements, which are temperature, pressure, humidity, wind, clouds, visibility and precipitation.

Climate is the accumulation of data concerning the changes in weather elements for a certain area over some time. Climate is an identity for some areas, for example, we say polar climate, desert climate, tropic climate.

5- Define meteorology and discuss the origin of this word

Answer:

Meteorology is the branch of natural science that concentrates on atmospheric weather processes and forecasting, with the application of atmospheric chemistry and atmospheric physics. The events of weather are very connected with changes in the earth's atmosphere; these events are temperature, pressure, wind, humidity and the interactions between these variables.

The origin of meteorology was referred to as the Greek philosopher Aristotle, who wrote a book in natural philosophy about 340 B.C., named "meteorologia", which describes the weather events at that time. The word meteorology came from the Greek word "*Meteoro*" which means high in the air, and the word "*Logia*", which means the study of things high in the air, (Ahrens, 2011), (Means, 2019).

I.2- Questions for Thought and Exploration

1- Why does a radiosonde observation rarely extend above 30 km (100,000 ft.) in altitude?

Answer:

Radiosondes are devices used to monitor weather parameters from high altitudes. Hundreds of radiosondes are spread in the atmosphere at variable altitudes. The devices are provided with sensors for temperature, humidity, and air pressure, and wind speed, GPS systems to detect elevation, latitude, and longitude. They are capable of sending data to earth stations.

The data collected from these radiosondes are used for weather forecasts, which are useful for civil and military purposes. They are used for safe aviation and for warning from sudden changes in weather.

The radiosondes are carried by balloons, which are filled with hydrogen or helium. And usually the balloons are not filled with the gas, to avoid explosions.

When the balloon reaches high elevations up to about 100,000fts or 30km, the atmosphere becomes thin and cold, so the air pressure becomes very low, which causes the gas in the balloon to expand

to compensate for the lowering of the pressure. The expansion of gas causes taut to the balloons and loss of costly equipment.

So it is preferable not to use radiosondes at high elevations, and to depend on Seattleites and remote sensors for monitoring weather parameters.

2- Explain how you considered both weather and climate in your choice of the clothing you chose to wear today.

Answer:

Before planning for any journey or an outside event, we look in the newspaper or through the internet to see the weather forecast for that day or the coming days. According to the weather forecast, we plan our clothes and our luggage.

Although weather parameters may change rapidly without warning in many cases, we still depend on weather forecasts to decide what to wear on a beautiful the sunny day.

The climate information for a certain place or country, are also useful in our decision for trips and travels. Usually, climate information is the average value of weather parameters, which means that the change is not rapid and can be predicted before starting the trip.

3- Which of the following statements relate more to weather and which relate more to climate?

(a) The summers here are warm and humid.

Answer: Climate; an accumulated knowledge on the weather elements

(b) Cumulus clouds presently cover the entire sky.

Answer: Weather; is a description of an instant observation of clouds in the sky.

(c) Our lowest temperature last winter was –29°C (–18°F).

Answer: Weather as this gives information on temperature, which is a weather event that happened at a definite time.

(d) The air temperature outside is 22°C (72°F).

Answer: Weather; a description of an instant reading of temperate.

(e) December is our foggiest month.

Answer: Climate, this a description of a continuous phenomenon based on previous knowledge

(f) The highest temperature ever recorded in Phoenixville, Pennsylvania, was 44°C (111°F) on July 10, 1936.

Answer: Weather, as it is a description of a weather event that happened at a certain time.

(g) Snow is falling at a rate of 5 cm (2 in.) per hour.

Answer: Weather, it is a description of a current weather event.

(h) The average temperature for January in Chicago, Illinois, is –3°C (26°F).

Answer: Climate, this an interpretation of a continuous phenomenon based on previous and accumulated data on recorded temperature in Chicago, Illinois.

II- Warming the Earth and the Atmosphere

II.1- Questions for review

1. Distinguish between temperature and heat.

Answer:

Heat is a form of energy stored in materials and can be transferred into kinetic energy or stored as potential energy. Heat can be in a certain body that can be measured by using a calorimeter, and is given the units of calorie or joule (1 Joule = 4.18 calories) and it is labeled as Q in scientific equations. The amount of heat that a material can hold depends on the type of the material and its phase, solid, liquid or gas. Het can flow from hotter bodies into cooler bodies.

Temperature is the measure of the intensity of heat. It increases with heating and decreases with cooling. Temperature is measured by a thermometer, and is given the symbol T in scientific equations. The scales of temperature measurement are Celsius, Kelvin and Fahrenheit scales.

2. Explain how heat is transferred in our atmosphere by:

(a) Conduction (b) Convection (c) Radiation

Answer:

a- Conduction is the transfer of heat inside material from one molecule to another which is in contact with each other. The valence shell electrons in metals are responsible for heat transfer. An example on the transfer of heat by convection is when heating a rod or a sheet of metal on a Bunsen burner, the whole metal gets heated after a short time.

b- Convection is the transfer of heat through the movement of the heated molecules. As an example, on heating a beaker full of water over a hot plate or a Bunsen burner, the molecules of water

adjacent to the bottom of the beaker and close to the heat source, are heated first and travel upwards holding heat to other parts and layers of water. The same thing happens when a wood or electric stoves heat the air molecules which then transfer heat to other parts around it.

c- Transfer of heat by radiation in which direct heat from the sources is transferred to the object without a media to carry it. Even if the body is in a vacuum place, the radiated heat works on heating the body. As an example heat from the sun can warm us in winter days when we sit behind the double- walled glass windows.

The heat of the sun is affected by the vacuum place between the layers of the glass.

3. How does the Kelvin temperature scale differ from the Celsius scale?

Answer:

Temperature is measured by a thermometer, which is made from a thin bulb of glass attached to a glass capillary less than 0.05mm in diameter. The bulb is filled with mercury or alcohol, depending on the degree of the system to be measured. The capillary is contained in an outer glass jacket, which is scaled into three different scales:

- The Kelvin scale, which is named after the British physicist Lord Kelvin. The Kelvin is the scientific notation for temperature in thermodynamics according to the International Unit Standards (SI) and is given the symbol K. The Kelvin scale starts with the value 273.15°K as the absolute zero, which is the point where molecules of the substance has the lowest energy. The freezing point of water at the Kelvin scale is 273.15°K and the boiling point is 373.15°K.
- The Celsius scale, which is named after the Scottish astronomer Anders Celsius in 1742, and is given the symbol °C. This scales assume the freezing point of water at 0°C and the boiling point of water at 100°C. Thermometer scale is divided into 100 degrees and for that, it is sometimes called centigrade scale in scientific notations.

To convert from Kelvin to Celsius we use the form:

K= °C + 273.15

- The Fahrenheit scale, which assume the freezing point of water at 32°F and the boiling point of water at 212°F, and thermometer scale is divided into 180 degrees. To convert from Fahrenheit to Celsius we use the formula:

  °C = 59 (°F -32)

4- How do the wavelengths of most of the radiation emitted by the sun differ from those emitted by the surface of the earth?

Answer:

The sun is the main source of energy for the earth. It radiates electromagnetic spectrum towards earth and other planets, in the speed of light which equals $3x10^8$ m/s. This spectrum has many components which differ in wavelength and in frequency and hence in their energies. The light that reaches earth is two parts, visible and invisible light. The invisible light has many components such as cosmic rays, gamma rays, X- rays and ultraviolet light. These invisible rays have high frequency and low wavelength and according to the energy equation $E= h\nu$, where E is energy in Joules, and h, is blank's constant and ν is the frequency and $\nu= C*\lambda$, C= speed of light and λ is wavelength.

The earth's surface is protected by the atmosphere, which absorbs most of the high energy component of the electromagnetic spectrum, but some of the ultraviolet light and visible light, reach earth and causes elevation of heat to earth components and provides a basic component in the food cycle of plants.

The radiation from earth is only for Infrared light (IR) which has a low frequency and longer wavelength. Figure 1, illustrates the components of the electromagnetic spectrum.

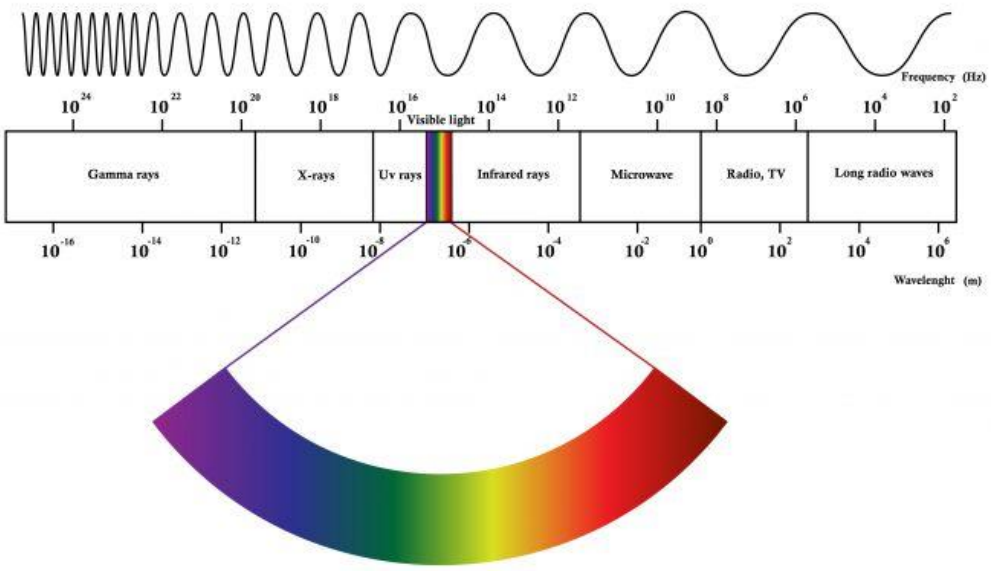

Figure 1: Electromagnetic spectrum (Lucas, 2015)

5- Why carbon dioxide, and water vapor are called selective absorbers?

Answer:

As the sun radiates the electromagnetic spectrum to earth's surface at day time. The presence of gases such as water vapor and carbon dioxide in the atmosphere causes selective absorbance of infrared radiation other than the rest of the spectrum components. This illustrates the feeling of cold during day time when clouds, which are made from water vapor that present in the atmosphere. Water vapor and carbon dioxide are good absorbers of infrared and not good absorbers for other components of the sun radiation such as UV and visible light. Also, water vapor and carbon dioxide absorb infrared radiation emitted from the earth's surface. They work at night to radiate the infrared energy back to earth's surface ate night, which raises the earth's temperature. This is the greenhouse effect that causes global warming, which is a daily concern for all scientists and scholars. Although the greenhouse effect harms the stability of polar ice and ocean levels, it is important for the

proceeding of the life of many creatures and plants on earth. Without the greenhouse effect, the earth's surface would be cold all the time, which threats the life of fauna and flora.

II.2- Questions for Thought and Exploration.

1- Which do you feel would have the greatest effect on the earth's greenhouse effect: removing? All of the CO2 from the atmosphere or removing all of the water vapor? Explain your answer.

Answer:

The global warming and the increase in earth's temperature, which are symptoms of climate change, are caused by what is called the greenhouse effect, or the atmospheric greenhouse effect, which is simply the prevention of earth's radiation from escaping into the outer space. The detention of earth's infrared, causes the raise in earth's temperature and increases the rates of the ocean's water evaporation and the melting of polar ice. The more evaporation means more water vapor in the atmosphere and hence more absorption radiated infrared and the more heating of earth's surface. Water vapor is responsible for about 60% of the greenhouse effect, while carbon dioxide CO2 is responsible for about 26% and the other gases are responsible for about 14% of the greenhouse effect (Ahrens, 2011).

Although water is the seed for clouds formation and then precipitation to earth, which gives life to all flora and fauna, the complete removal of water vapor would have the greatest effect on the greenhouse effect. The removal of carbon dioxide would only affect a small portion from the greenhouse effect.

2- How would the seasons be affected where you live if the tilt of the earth's axis *increased?* From 23½° to 40°?

Answer:

Earth rotates around the sun in an elliptical orbit in about 365 days, at an average distance of 150 M km, which produces the four seasons. Earth revolves around itself in 24hours, which makes day and night. The axis of rotation of earth, which is an imaginary line between the two poles, is tilted about 2312°, this tilt is always directed at the same direction, which means that the North pole is directed away from the sun in January and towards the sun in July (figure 2).

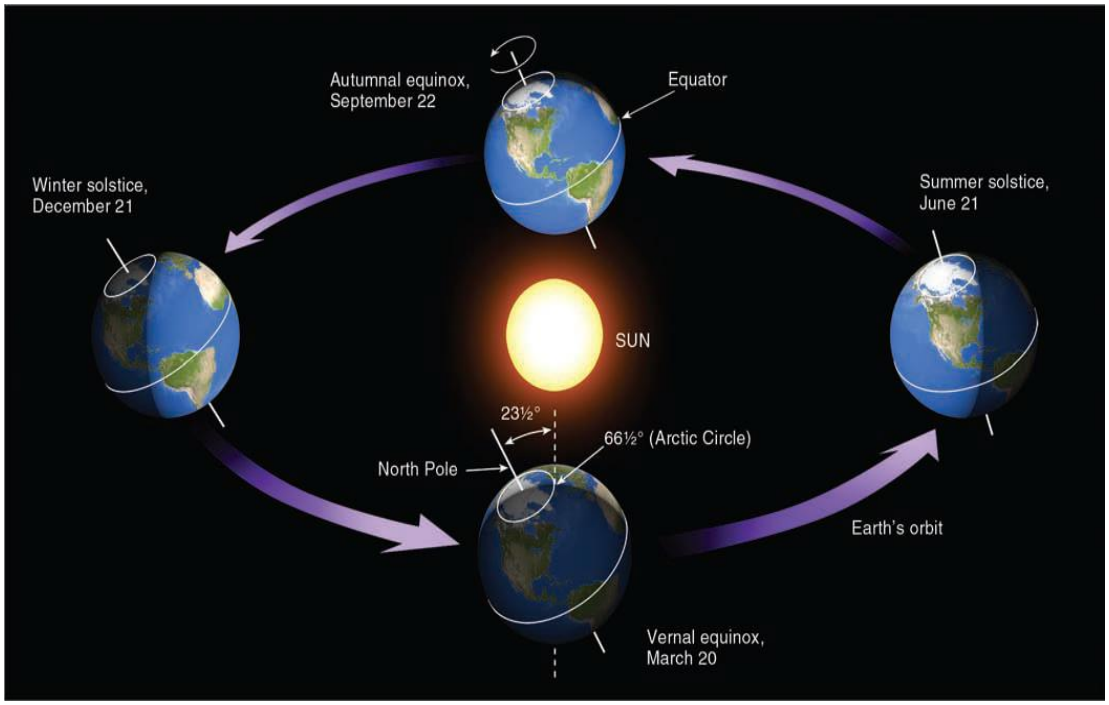

Figure 2: Movement of earth around the sun (Ahrens, 2011)

As we notice from figure 2, if the tilt of earth increases to 40°, the North pole in January will decline back and the intensity of the sunlight will be less on that area, and more area in the southern hemisphere will have more the sunlight, which means melting of ice and increase in sea level. In summer, the North pole will decline more towards the sun, and day time will be longer, which means more ice melting and floods from the sea in the northern hemisphere.

The tilt will also affect the tropical zones, where the rainforests will not be in their ordinary position and the sun position will tilt from the areas between the tropic of cancer and the tropic of Capricorn. So the tilt will change the seasons in every part on earth and will cause a change in climate and

weather. In the Middle East, the sun will be perpendicular to the area in winter, which will cause more evaporation which will affect the water budget. In summer the exposure to more light intensity will cause more drought and depletion of water resources.

3- Explain why an increase in cloud cover surrounding the earth would increase the earth's Albedo, yet not necessarily lead to a lower earth's surface temperature.

Answer:

If there was no atmosphere protecting and scattering parts of the sunlight, the earth would be like Mars or the Moon, without life. Some of the solar radiation reacts with some gases in the upper atmosphere like the reaction between ozone and the UV light, other components of the solar radiation are scattered in all directions by the tiny dust particles and air molecules atmosphere, some of these particles are smaller than the wavelength of the visible light. The sunlight can be reflected from the surface of the earth or gases in the atmosphere. The percentage of light reflected is called Albedo. The Albedo differs from one object to another, for example, snow has more albedo than other objects, green trees have lower albedo the desert, and clouds contribute in albedo percentage with about 30%. Thick and gray clouds have a greater contribution to albedo than light and white clouds. We might think that the more albedo means cooler the earth is, but the fact is albedo does not affect the temperature of earth when more clouds are in the sky.

The clouds are full of water vapor which can radiate back earth radiation from infrared energy, which keeps the temperature of earth's surface not affected by the albedo caused by clouds.

III Air Temperature

III. 1- Questions for review

1- Explain why the warmest time of the day is usually in the afternoon, even though the sun's rays are most direct at noon.

Answer:

As the sun starts radiating its energy towards earth in the early hours, the air close to earth's surface starts to heat up by the convection process. On the movement of the sun higher in the sky, more radiation heat more air and convection process occur, so thermal cells from hot air start to rise up and heat and transfer heat to other air molecules. When the sun reaches its highest position in the sky at the noontime, the maximum radiation it gives to earth, and at this time the sunburns may be severe and hurting. At this time of the day, the earth's surface is receiving more the sun radiation than giving back, depending on the cloud cover and wind speed. When the sun starts to decline towards the sunset in the afternoon, the sun radiation intensity decreases, and at the same time earth radiates back infrared energy to the air and the temperatures of air rise. So the hottest time is in the afternoon rather at noon.

2- Explain how radiation cooling at night produces a radiation temperature inversion.

Answer:

When the sun goes to the sunset, and the solar radiation decrease, the earth radiates long-wavelength infrared energy. This makes the surface of earth cooler than the air above it. This is called radiation cooling. When the air is dry and no wind and no clouds in the atmosphere, the radiation process cools the layer of air adjacent to the ground surface. Fog, dew, and frost may occur if the humidity is high. As the radiation of infrared energy goes on at night and the cooling

of earth's surface goes on, the warmer air above the ground may give some heat to the earth's surface, this process is very slow because of the low thermal conductivity of earth. The temperature of air increases when we go higher, this called radiation inversion or nocturnal inversion. Radiation cooling is more observed and effective in winter nights because the night is long and the radiation of infrared from the earth is longer and warmer air rises which make the surface cooler. It may also exist for a short time after the sunrise because the solar energy at this time is less than the radiated energy from the earth.

3- List four measures farmers use to protect their crops against the cold. Explain the physical principle behind each method.

Answer:

Radiation cooling causes the earth to cool below the freezing point of water, which causes freezing of plants and crops leaving farmers with great loss. Farmers do their best to protect their crops and plants from freezing at winter calm and dry nights:

- The use of orchard heaters or smokers, which will heat the air near the surface, and freezing is prevented.
- The use of fans or helicopters, which causes the mixing of cold air at the surface with the warmer air in the upper layers. This method can be thermally controlled by using thermostats to operate the fans. The helicopters are expensive and may cause breaking of branches.
- Flooding the orchard with a layer of water, which will protect plants and crops from freezing, because water has a high heat capacity and releases heat slower than dry soil. This method is also expensive and applied if enough water is available.

- Sprinkling plants with a thin film of water, this thin film of water freezes on leaves and fruits, which protects them from deep freezing at the freezing point. This method works well if the air is humid and it is not effective in dry conditions.
- For small orchards, farmers may cover fruits and branches with clothes, plastics or nets, as a procedure to protect crops and plants against frost.

4- Why are the lower branches of trees most susceptible to damage from low temperatures?

Answer:

At night when the solar radiation is depleted and the earth starts to radiate infrared energy and heats up the air, the lower layer adjacent to the earth's surface becomes very cold and the temperature may be below the freezing point of water. In this case, plants are more susceptible to the change in temperature, the lower branches are more affected by the low temperature because it is closer to the cold surface and the water inside the leaves and fruits freezes, which causes damage to these branches and fruits. To protect these branches, it is advisable to use one or more of the methods that farmers use to protect their crops, these methods are rapping trees with protecting cloth or plastic, use of orchard heaters, sprinkling with water, mixing cold air with hotter air by helicopters or big fans, and flooding the ground with water.

5- Describe each of the controls of temperature.

Answer:

Although the source of energy for earth is the solar energy, daily temperature may differ from one place to another, even if they are in the same country, and it may differ from time to time for the same place. Many factors have their effect on the temperature variation, these are called controls of temperature.

- Latitude: Latitudes are 180 imaginary circular lines that cur the surface of earth starting from the equator at 0° and at the North Pole at 90°, the same applies on the Southern hemisphere. The latitude circles are separated by 1° for each circle. Longitudes are 360 imaginary vertical circles So 180 longitudinal circles are to the right of the meridian and 180 longitudinal circles to the left of the meridian. Each longitudinal must pass through the two poles. The first circle is called the meridian circle, which passes through the Royal Observatory on Greenwich/ England. They are perpendicular with the latitudes. Latitudes and longitudes are important geographical coordinates which are used in the exact determination of any point on earth.

  The temperature isotherms in figure 3, show that the amount of solar energy, which is the main source of energy on earth, are the same for each latitude line, and they tend to decrease in winter as we go from the equator to the North Pole or to the South Pole. It is clear that temperature readings at sea level in any city on earth is controlled by latitude location of that city.

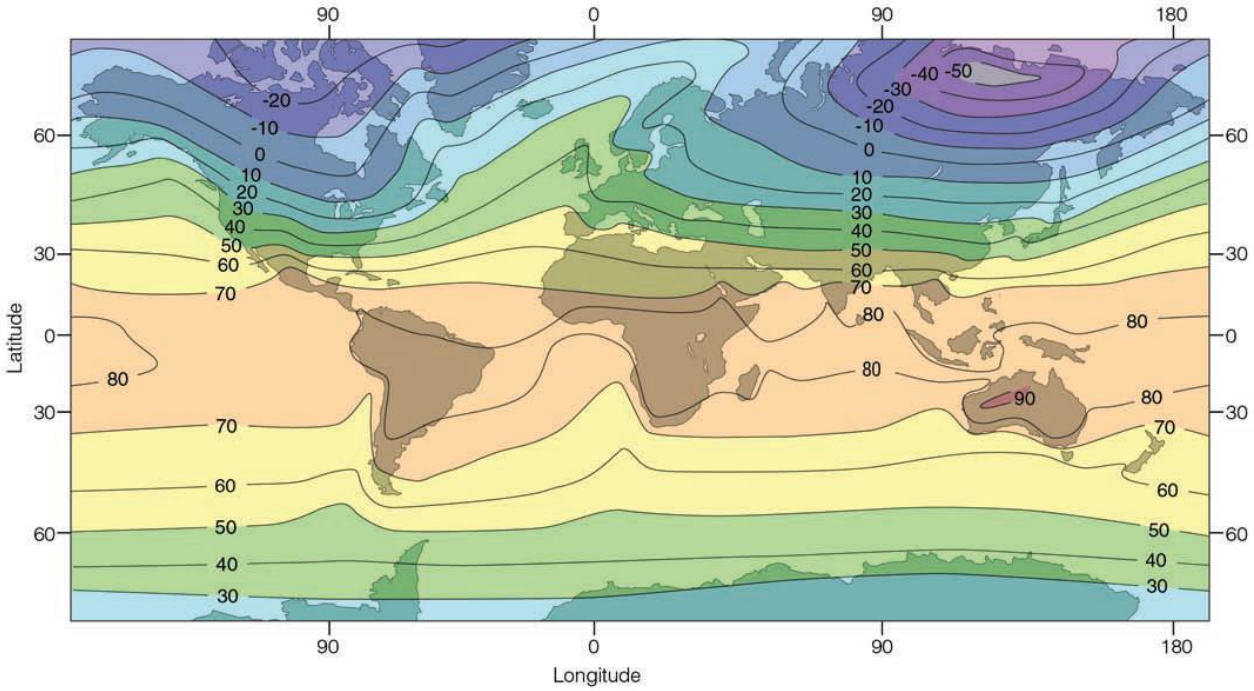

Figure 3: Isotherms of temperature variations according to latitude lines (Ahrens, 2011)

- The land and water location: The difference in the physical properties between water and soil properties, makes the heating of soil less than water. Solar energy heats a small layer of soil but in water, the solar energy penetrates longer distances and heats more water, also the movement of water mixes the temperature. For these reasons, in winter time the place in land are colder than places near the coasts, even if they are located at the same latitude. In summer times the reverse is true, the areas near the see is colder than those in the land, and this is because the solar energy evaporates water and this make the area cooler.
- Ocean currents: Oceans are reservoirs for heat on earth, most of the solar energy is absorbed by oceans and released back into atmosphere after the sunset. Oceans play an important role in the distribution of heat all over the globe. As water molecules absorb heat, they evaporate into atmosphere which increases heat and humidity in the

atmosphere, condensation of water vapor causes rain and storms on earth. Weather condition create ocean's currents , which are increase by earth rotation, salinity differences from place to another, tide and temperature differences in from the tropic areas and the poles. The ocean currents work as conveyors of warm water from the equator area to the poles and cold water from the poles to the equator region. So ocean currents are regulators of globe climate, without it, extremes of high temperatures at the equator and the cool temperatures in the polar areas would have an adverse on global climate and human life (US Department of Commerce, & National Oceanic and Atmospheric Administration, 2013).

- Elevation: Most of the solar energy are reflected by the atmosphere, which extends to about 16km at the equator and about 8 km at the poles (Deziel, 2018).

  The solar energy that reaches the ground, works on heating the earth's surface and the most temperature is measured on earth's surface. The temperature decrease with increase of elevation from sea level at a rate of about 6.5 °C for each 1000m. For that reason, the mountains show lower temperature and have higher rates of snow and rain.

  The exchange between warm and cold air, creates convection currents that slide up the mountains, which causes condensation of saturated air with water vapor and hence rain and snow and may cause storms on the upper parts of the mountains, the lower sides of the mountains become dry because the clouds are less saturated with water vapor (Deziel, 2018). The effect of elevation on control of temperatures is obvious in many places, which differ in elevations and the presence of high mountains. For example, Jericho city in Palestine is considered as the lowest city in the globe, it is about 480 m below sea level. The average temperature at Jericho in July is about 28°C and in January is about 14°C. The nearest city to Jericho is Jerusalem which has an average temperature in July

is 23°C and in January about 8°C (Holiday - Weather.com, n.d). The variation in temperature is reflected on the average of rainfall in the two cities and is reflected also on the types of agricultural crops and on the lifestyle of people in two cities.

III.2- Questions for Thought and Exploration

1. How do you feel a thick layer of low clouds would affect the lag in daily temperature?

Answer:

The sun is the main source of energy on earth. In clear days, where no clouds are present, most of the solar radiation reaches the earth's surface and raises its temperature, in this case, the maximum temperature of the earth's surface and atmosphere is achieved, at night, also with no clouds, and no solar energy, earth radiates infrared energy, which cools the earth's surface and the air above it. So at night, the minimum temperature of the earth's surface and the air is achieved. The difference between the maximum temperature and the minimum temperature is called the daily temperature range or diurnal range. The diurnal range is large in dry, clear, calm weather. If clouds are present in the sky, they reflect some of the solar radiation, which will not raise the temperature of the earth's surface and the air as in the case of a clear sky. At night the clouds work as absorbers of earth radiation, they reflect to earth's surface. So the diurnal range is lower in the case when clouds are present. Therefore, clouds, especially the thick ones, lower the day temperature and keep the earth's surface warmer at night.

2- Suppose peas are planted in Indiana on May 1. If the peas need 1200 growing degree days before they can be picked, and if the average maximum temperature for May and June is 80°F and the average minimum is 60°F, on about what date will the peas be ready to pick? (Assume a base temperature of 55°F.)

Answer:

Growing Degree Day (GDD), is an application used by farmers to predict the harvesting day for their crops. GDD depends mainly on the average or mean annual temperature and the specifications for each crop.

In the case of peas in the question above, the estimated date for harvesting is calculated as follows: July 19th

- We calculate the average temperature by adding the minimum and maximum temperature and divide the sum by 2 ; $T_{average} = \frac{Tmax+T\ min.}{2} = \frac{80+60}{2}$ =70°F
- Subtract base temperature from the average temperature,

  $T_{average} - T_{base}$ = 70°F - 55°F = 15 GDD
- Since peas require 1200 GDD for complete harvesting, then the complete days for harvesting will be

  $\frac{1200GDD}{15GDD}$ = 80 days

  If planting of peas was on May 1st, then harvesting will be suitable after 80 days of planting, or on July 19th.

3- In Pennsylvania and New York, wine grapes are planted on the sides of hills rather than in valleys. Explain why this practice is so common in these areas.

Answer:

At nights, when the sun stops radiating solar energy to earth's surface and the earth starts to radiate infrared to the atmosphere, the process of radiation cooling starts. A thin film of earth's surface becomes very cold and may lead to freeze and frost especially at nights when no clouds and wind are observed. The upper layer of the air is warmer than the air adjacent to the surface and this usually on the sides of hills. Farmers make use of this phenomenon and plant their

vineyards on the sides of the hills rather than in the valley. Also, the cold air in the valley may trap smoke and vapors of pesticides and other pollutants, which have an adverse effect on the quality of the fruits.

IV- Humidity, Condensation and Clouds

IV.1- Question for Review

1- Briefly explain the movement of water in the hydrologic cycle.

Answer:

The hydrologic cycle is the description of the route of water in nature, starting from oceans and surface water bodies, where evaporation of water by solar energy.

Water vapor in the air is carried by winds over land areas.

Water vapor also released from plants in a process called transpiration.

By the effect of low temperature in the upper layers of the troposphere, water vapor condensates into larger water droplets and falls as rainfall to the earth's surface or back to the ocean.

In some cases, precipitation may be as snow or hail.

Rainfall on the ground surface may infiltrate into groundwater aquifers and then pumped as freshwater for domestic uses, or it is stored as fossil water.

Rainfall water may form small streams from surface runoff, depending on the land use and the type of topsoil. Runoff may go to rivers and to the sea or ocean, or it may be stored in surface water bodies like lakes and ponds or manmade cisterns.

Water, either in sea, rivers, lakes, groundwater of in plant leaves or fruits, will eventually evaporate and condensate again and complete the hydrologic cycle. It may be stored for thousands or millions of years as fossil water or in glaciers in the poles.

2- Why do hot and humid summer days usually feel hotter than hot and dry summer days?

Answer:

Humidity is the presence of water vapor in the air, so humid air means that the air is saturated with water vapor. Water vapor is a good absorber and reflector of earth infrared energy, it is one of the greenhouse gases, which work on warming earth and contribute much to global warming. In a hot, humid summer day, water vapor reflects and keeps the earth temperature very high, while in a dry and hot summer day, there is less reflectance of infrared radiation back to earth during daylight.

3- What does saturation vapor pressure primarily depend upon?

Answer:

Air is composed of nitrogen, oxygen, water vapor and other gases in small amounts. Water vapor shares in only about 1% of the total air pressure. And this is called the actual vapor pressure. The more water vapor molecules increase in the air volume means the more actual vapor pressure is recorded.

Saturated vapor pressure is the amount of water vapor introduced into air to make it saturated with water vapor. If the air temperature increased, then the air molecules will move away from each other and more vacancies are created to hold more water vapor molecules, and the air is becoming more saturated with water vapor. So the main factor that affects saturated vapor pressure is the temperature of the air.

4- (a) What does the relative humidity represent?

(b) When the relative humidity is given, why is it also important to know the air temperature?

(c) Explain two ways the relative humidity may be changed.

(d) During what part of the day is the relative humidity normally lowest? Normally highest?

Answer:

a- Relative humidity (RH) represents the amount of vapor pressure in the air relative to the air capacity of water vapor, it is the ratio of the actual amount of water vapor in the air to the maximum capacity of air at a defined temperature and pressure.

It is expressed as RH = $\frac{actual\ vapor\ pressure}{saturation\ vapor\ pressure}$ x 100%

The more water vapor in the air means the closer to saturation of air and hence condensation occurs.

b- The main factor that affects the relative humidity (RH), is temperature. In any calculation or weather forecasting temperature must be associated with temperature. The rise in temperature means lowering in humidity as the saturation of vapor pressure is lowered, and a lowering in temperature means condensation of water vapor and then rising relative humidity. Always humidity is given at a certain temperature or RH for that temperature.

c- The relative humidity is changed by two factors

- A Change of water vapor content in the air, without a change in air temperature; an increase in water vapor molecules may increase the chance of collision between vapor molecules and then condensation chance increases, therefore RH increases. If the water molecules are removed quickly by raising the temperature or dry conditions then the relative humidity decreases.
- A change in air temperature changes the RH. As the temperature increases, the capacity of air to accept more water vapor increases and the kinetic energy of vapor molecules increases which makes it difficult for vapor molecules to condensate and therefore RH decreases. If the air temperature decreases, the chance of condensation increases and then the RH increases. The

more water vapor is absorbed and RH is decreased. If the temperature decreases, saturation is quickly achieved.

d- The lowest percentage for relative humidity in the day is during midday when the sun gives its maximum solar energy, the temperature of the air is very high and the saturation is less.

The highest percentage of relative humidity is observed in the morning when the earth's surface is cold and the sun still not giving energy. Water vapor molecules condensate rapidly and the air is saturated with water vapor and so the relative humidity is high.

5- Why is the wet-bulb temperature a good measure of how cool human skin can become?

Answer:

The elevated temperatures harm human life. In hot and dry weather, the relative humidity is very high and we feel very hot and discomfort. In this case of high relative humidity and high air temperature, evaporation of water from our bodies is low and we don't feel cool, the droplets of perspiration stuck to our skin and clothes become wet. Evaporation of our perspiration makes our bodies cool. A measure of how cool our bodies are, is done by measuring the wet-bulb temperature, which is the lowest temperature that can be reached when water evaporates from a surface or skin. It can be measured by rapping the bulb of mercury or alcoholic thermometer with a piece of cotton or soft cloth, wet with some water. Upon evaporation of water from the cotton or the cloth on thermometer bulb, the temperature of the thermometer is lowered, because water vapor extracts heat from the liquid in the thermometer bulb and then causes lowering of temperature. The same case is applied to our bodies. When water from perspiration evaporates, it extracts heat from our bodies and we feel cool. If no evaporation occurs then the temperature of our bodies remains hot and becomes a discomfort.

IV.2- Questions of Thought and Exploration

1- Use the concepts of condensation and saturation to explain why eyeglasses often fog up after coming indoors on a cold day.

Answer:

In cold weather, the earth's surface and solid surfaces become very cold, so in places, where water vapor is saturated, it condensates on cold surfaces. In the case when we're in the outside in the cold weather, our clothes and glasses are cool enough to condensate water vapor when we get indoor, where the air is saturated with water vapor from cooking, perspiration or breath or other house activities, when it meets the lenses cold surface it condensates soon, they will be clear after a short time when their temperature become in equilibrium with the room.

2- Suppose while measuring the relative humidity using a sling psychrometer, you accidentally moisten both the dry-bulb and the wet-bulb thermometers. Will the relative humidity you determine be higher or lower than the air's true relative humidity?

Answer:

The relative humidity (RH), is an indication of the amount of vapor pressure in the air. It is measured by a device called Psychrometer, which is composed of two thermometers that are fixed on a piece of wood adjacent to each other. The bulb of one of the thermometers is covered with a piece of cloth or cotton, the other thermometer is left without cover. For measuring the RH, we wet the cloth with some of the clean water and leave it for a short time, the water on the cloth begins to evaporate until it reaches the lowest temperature, at which the reading of thermometer stops. This temperature is called the wet-bulb temperature. The other thermometer, the dry bulb thermometer, will read the actual air temperature. If the air is dry and its temperature is high, the water on the cloth will evaporate more and then the RH is very low. If by mistake, we have wetted both the bulbs, then water will evaporate from both bulbs and the difference between the wet-bulb temperature and the

dry bulb temperature, which is called the wet-bulb depression, will be shorter, which means that RH is very high, and the reading is false representative for real RH.

3- With all other factors being equal, would you expect a lower minimum temperature on a night with cirrus clouds or on a night with stratocumulus clouds? Explain your answer.

Answer:

Clouds are formed from the condensation of water vapor, and they are distinguished by their appearance, shape, height and color.

- Cirrus clouds are those clouds that are found at high elevations, from 6 km t0 18 km. They are light, thin clouds that can be blown easily with wind and they look like horses tails. Because they are at high elevations, they contain tiny crystals of ice, and they almost white.

- Stratocumulus clouds, are categorized as low clouds, they are distinguished by their thick shape and light to dark grey color, they contain condensed water vapor, and they may give precipitation. Stratocumulus clouds are closer to earth's surface, from 0 km to 2km.

At cold nights, when the sky is covered with cirrus clouds, their ability to reflect infrared radiation is low compared with stratocumulus clouds, which are thicker and closer to earth's surface. The water vapor in the stratocumulus clouds works as a greenhouse gas, which works to warm the earth's surface by absorbing and radiating back the infrared energy to earth. So, the nights with cirrus clouds is much cloder than nights with stratocumulus clouds.

V- Cloud Development and Precipitation

V.1- Question for Review

1- What is an adiabatic process?

Answer:

This is a term used in thermodynamics. It means that within a system there is a transfer of heat or mass between the system and surroundings, the transfer is done as work only. As an example, when air close to the earth's surface it is heated by the solar energy absorbed by the earth's surface. This is a non- adiabatic process, but when an air parcel is heated, it rises and the pressure on it decreases be elevation. The heat inside the air parcel is not transferred to other parcels, the air parcel expands in volume which needed work to be done by the heat inside the air parcel. This is an adiabatic process in which no heat transfer occurred but rather work is done in the form of expansion or compression.

2- How can the atmosphere be made more stable? More unstable?

Answer:

Stability of systems means the lower energy they use, the same principle applies for atmospheric systems.

In a stable atmosphere, cold and saturated air parcels are forced to move upwards in an environment hotter than they are. The lapse rate, which is the rate at which air temperature decreases with elevation is small, is very small. These conditions that make the lapse rate small and the air parcels resist upward movement are obtained when:

- During radiation cooling of the earth, which happens at night and the sun solar energy is depleted.
- If a cold breeze of air is brought by the wind

- If air runs over a cold surface, such as snow.

Unstable atmosphere conditions, mean that air parcels are moving upwards and they move against stability. The lapse rate at unstable conditions deepens rapidly with elevation and the temperature of the aloft air is lowered with elevation. The conditions at which unstable condition are obtained are:

- At day light when solar energy heats the ground surface and the air adjacent to it.
- When air moves over a hot surface like desert sand or metal surfaces.
- When warm air over hot surfaces is moved by the wind.

The unstable atmospheric conditions occur when air is warmed and combined with cold air at elevated altitudes with a steep lapse rate. Usually, when forests go on fire, the air is warmed and rises up, then it cools by expansion and elevation, unstable conditions occur and cumulus clouds are formed.

3- What type of clouds would you most likely expect to see in a stable atmosphere? In an unstable atmosphere?

Answer:

-On stable atmospheric conditions, the lapse rate is the dry adiabatic rate in which air will resist the rising process, and it prefers to sink back to the earth's surface. Chance of layered clouds are formed like cirrostratus, altostratus and stratus clouds are formed. Also fog and haze are formed and spread horizontally over the earth's surface (Ahrens, 2011)

- On unstable conditions, warm air rises, it expands and cools until its cooling temperature reaches the dew point, then cumulus and cumulonimbus clouds are formed, unstable weather conditions are observed, and thunderstorms may occur at this point. Unstable atmospheric conditions happened over my country Palestine today afternoon, where thunderstorm established

in the afternoon after a very hot day, figure 4 is an example on cumulus clouds seen in the sky of Birzeit Palestine on 5/10/2019.

Figure 4: An example on cumulus clouds in Palestine 5/10/2019

4- List four primary ways in which clouds form.

Answer:

Clouds are formed primarily by four ways

- Surface heating and convection; as the solar energy heats ground's surface, air parcels are heated, they expand in volume and rise in the atmosphere. They reach a point where the pressure is reduced and they cool and when the condensation reaches the dew point temperature, the air rich with vapor condensate and form clouds.
- Lifting of air up to the topographical barriers. This done when warm air moves from the heated surface, and then meets a very high topographical barrier such as mountains, it

rises and mixes with cold air on the top of the mountain, condensation takes place and clouds are formed.

- Surface air convergence; when the surface is heated by solar energy, the air rises and a cold air leaving a lower pressure area, cold air comes to fill the center of low-pressure vacancy, which causes convergence of the air streams, the air rises, cools and condensates forming clouds.
- Cold fronts lifting; since cold air is denser than hot air, it sinks downs causing hot air to rise. This is seen when more than cold weather fronts meet, they cause rapid rising of hot air, which cools in the upper parts of the atmosphere and condensates forming clouds.

5- Why do typical cloud droplets seldom reach the ground as rain?

Answer:

The cloud droplets are very small, about 0.02mm in diameter, compared to rainfall droplets, about 2mm diameter. The cloud droplet is light enough to rise with air streams, and they are mostly charged as a cause of thunder storms. When charged cloud droplets collide, they form larger droplets which then come to the size of rain droplets. Rain droplets are heavy enough and sink down with the force of gravity (North Carolina Climate Office, n.d).

V.2- Questions of Thought and Exploration

1- Suppose a mountain climber is scaling the outside of a tall skyscraper. Two thermometers (shielded from the sun) hang from the climber's belt. One thermometer hangs freely, while the other is enclosed in a partially inflated balloon. As the climber scales the building, describe the change in temperature measured by each thermometer.

Answer:

The source of energy on earth's surface is the solar radiation, and the source of energy in the atmosphere at daylight, when the sun sets and no more solar energy is available, is the radiation of infrared from earth's surface.

The temperature of the atmosphere decreases with elevation in the troposphere, which extends to about 16km over the equator. The air pressure also decreases upon elevation.

The rate of decrease in temperature upon elevation is about 6.5°C / 100m. At night, the earth's surface is much cooler than the air above the surface, because of radiation cooling.

If the climber holds a thermometer in the daylight, when the sun is heating the earth's surface, the reading of thermometer will change with elevation at the rate of about 6.5 C / 1000m. This is true if no cold currents are affecting the thermometer reading.

If the thermometer is enclosed inside an inflated balloon, its bulb is insulated inside the balloon from the changes of temperature upon elevation, so it will read the surface temperature until it reaches a point where the air pressure decreases. At this point the air inside the balloon will expand to compensate the decrease in air pressure and it will cool with expansion, the thermometer will read a lower value from compared with its reading on the surface.

The balloon mimics thermal air parcel, which is heated by solar energy and when it meets a cold air in the upper parts of the atmosphere, it will cool and the vapor inside the air parcel will condensate, and its temperature is lowered.

2- A major snowstorm occurred in northern New Jersey. Three volunteer weather observers measured the snowfall. Observer #1 measured the depth of newly fallen snow every hour. At the end of the storm, Observer #1 added up the measurements and came up with a total of 12 inches of new snow. Observer

#2 measured the depth of new snow twice: once in the middle of the storm and once at the end, and came up with a total snowfall of 10 inches. Observer

#3 measured the new snowfall only once, after the storm had stopped, and reported 8.4 inches. Which of the three observers do you feel has the correct snowfall total? List *at least five* possible reasons why the snowfall totals were different.

Answer.

Snow is a form of precipitation. It comes in different forms, such as freezing drizzle, which is small raindrops that reach the freezing point, sleet, snow pellets, snowflakes, rime, graupel, hail, soft hail, and hailstone.

Measuring snow is sensitive and must be carried by well trained and professional persons. Many volunteers try to give values of snow during snowstorms, and some of their reading is not correct because of many factors that don't take into account.

-In the case of observer # 1, the measurements are considered accurate, as they give the true value each hour and the values can be used to calculate the rate of snowing.

Readings from Observers # 2 and # 3, are misleading because of many reasons:

- Snow may melt as it reaches the ground surface and does not accumulate, so part of the snowstorm was not recorded by the observers.
- In the presence of wind, some of the snow might be transferred to other places.
- During the snowstorm, gathering snow layers will compress them, so the actual height is not recorded accurately if measured in large intervals.
-The latent heat of freezing during snowing works on melting some of the snow on the ground surface, so the reading of snow depth is inaccurate.

-The difference between snow types, such as snowflakes, hail, rime, and hailstones affects the depth of the snow, as the heavy snow type compress or damage the snow depth, and may scatter the snow piles.

-The difference in readings might come from not adequate location or surfaces. Correct reading must be taken from open places that are far from obstacles such as trees and walls. The recorded readings are also affected by the type of surfaces on which the snow falls and accumulates. For example, snow will melt faster on roads and grass than on metal surfaces or stones. The correct reading must be taken over a white board.

3- Suppose a thick nimbostratus cloud contains ice crystals and super cooled cloud droplets all about the same size. Which precipitation process will be most important in producing rain from this cloud? Why?

Answer:

Nimbostratus clouds are one of the ten major clouds, they are considered as medium height clouds, 1500- 10000 ft. They are usually dark grey and they cover the sky. They are accompanied by heavy rain and snow and in some cases ice flakes.

When nimbostratus clouds full of ice crystals, approach a cloud with super cooled water droplets, the most likely precipitation will be aggregates of snowflakes. The reason behind this precipitation is that, when super cooled water droplets approache the ice crystals, the water molecules in the droplet move towards the ice crystals, like condensation of water vapor molecules on cold surfaces, which causes an increase in the size of ice crystal on the expense of the water droplets. The ice crystals will have branches like a flower, and the branched ice crystals stick to each other forming (Gabriela, 2016) aggregates of snowflakes, which fall on earth’s surface ad tree branches making beautiful shapes.

Conclusion

The chapters covered in this assignment, are of great importance for environmental students. They can be considered as the basis for understanding basic principles in meteorology.

I learned from the first chapter about the Earth's atmosphere and weather elements such as temperature, atmospheric pressure, humidity, and wind. I have also learned about atmospheric gases that form the atmosphere such as water vapor, carbon dioxide, oxygen, nitrogen, which forms the largest percentage of atmospheric gases. The first chapter also deals with atmospheric layers such as the troposphere, where most weather changes occur, and the stratosphere, which contains the ozone layer, which has a key role in protecting the Earth from harmful UV rays, mesosphere, thermosphere, exosphere, and the ionosphere.

In chapter two, I have learned about heat, temperature, and latent heat, and I learned about heat transfer in different ways such as radiation, convection, and advection. Chapter two also provided knowledge on solar radiation and earth radiation and the greenhouse effect, in which water vapor and carbon dioxide work as absorbers and radiators of infrared from the earth's surface. I also learned about the effect of the earth's axial tilt on the formation of seasons and the intensity of solar energy reaching the earth's surface.

In chapter three, I have learned about air temperature and its variation on the surface and in the upper air layers. The effect of heating earth in the daylight and the radiation cooling of the earth's surface and their effects on our daily life and agriculture. I have learned the methods that are used by farmers to protect crops from frost. In this chapter, I have learned about temperature data and different kinds of thermometers that are used to measure temperatures near the surface and the air temperature.

In chapter four, I have learned about the hydrologic cycle and the concepts of humidity and relative humidity and dew point, and the methods of measuring them. Also, I learned about the effect of dew pointy and humidity on the formation of morning frost, white freeze frost, and haze. I learned about condensation and the formation of clouds, their nomenclature and classification of clouds according to their height and physical characteristics.

From chapter five, I learned about atmospheric stability and its effect on clouds formation. Also, I learned about the conditions when precipitations occur. I learned about different types of precipitation and the ways of differentiating between them besides the traditional and modern methods of measuring different types of precipitation.

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