MODULE 1

UNIT 1 INTRODUCTION TO THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

In order to study, describe and understand the events that occur within the atmosphere, meteorologists measure the physical characteristics of the air within which these events take place.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the factors that influence temperature distribution on earth's surface;
- give evidences used to reconstruct past climate; and
- give examples of proxy data.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Meteorology: the scientific study of the earth's atmosphere, especially its patterns of climate and weather

Proxy data: includes clay mineralogy, ice rafted debris, terrestrial dust

Gravity: the attraction due to gravitation that the earth or another astronomical object exerts on an object on or near its surface

Isotopes: each of two or more form of a chemical element with same atomic number but different number of neutron

5.0 MAIN CONTENT

5.1 PHYSICAL CHARACTERISTICS OF ATMOSPHERE

Meteorologists describe the air primarily in terms of its composition, temperature, pressure, wind speed, wind direction, precipitation, and humidity.

Air Temperature
Air molecules are in constant motion. The speed of air molecules corresponds to their kinetic energy, which in turn corresponds to the amount of heat energy in the air. Air temperature is a measure of the average speed at which air molecules are moving; high speeds correspond to higher temperatures. The temperature of a substance is measured by a thermometer.

Air Pressure
Air is held to the earth by gravity. This strong invisible force pulls the air downward, giving air molecules weight. The weight of the air molecules exerts a force upon the earth and everything on it. The amount of force exerted on a unit surface area (a surface that is one unit in length and one unit in width) is called atmospheric pressure or air pressure. The air pressure at any level in the atmosphere can be expressed as the total weight of air above a unit surface area at that level in the atmosphere. Higher in the atmosphere, there are fewer air molecules pressing down from above. Consequently, air pressure always decreases with increasing height above the ground. Because air can be compressed, the density of the air (the mass of the air molecules in a given volume) normally is greatest at the ground and decreases at higher altitudes.

Wind
Wind is air in motion. It is caused by horizontal variations in air pressure. The greater the difference in air pressure between any two places at the same altitude, the stronger the wind will be. The wind direction is the direction from which the wind is blowing. A north wind blows from the north and a south wind blows from the south. The prevailing wind is the wind direction most often observed during a given time period. Wind speed is the rate at which the air moves past a stationary object. A variety of instruments are used to measure wind. A wind vane measures wind

direction. Most wind vanes consist of a long arrow with a tail that moves freely on a vertical shaft. The arrow points into the wind and gives the wind direction. Anemometers measure wind speed. Most anemometers consist of three or more cups that spin horizontally on a vertical post. The rate at which the cups rotate is related to the speed of the wind.

Precipitation

Precipitation is any form of water (either liquid or solid) that falls from the atmosphere and reaches the ground, such as rain, snow, or hail. Rain gauges are instruments that measure rainfall. The standard rain gauge consists of a funnel-shaped collector that is attached to a long measuring tube.

Humidity

Humidity refers to the air's water vapor content. Hygrometers are instruments that measure humidity. The maximum amount of water vapor that the air can hold depends on the air temperature; warm air is capable of holding more water vapor than cold air. Relative humidity is the ratio of the amount of water vapor in the air compared to the maximum amount of water vapor that the air could hold at that particular temperature. When the air is holding all of the moisture possible at a particular temperature, the air is said to be saturated. Relative humidity and dew-point temperature (the temperature to which air would have to be cooled for saturation to occur) are often obtained with a device called a psychrometer. The most common type of psychrometer is a sling psychrometer. This instrument consists of two thermometers mounted side by side and attached to a handle that allows the thermometers to be whirled. A cloth wick covers one thermometer bulb. The wick-covered thermometer bulb (called the wet bulb) is dipped in water, while the other thermometer bulb (the dry bulb) is kept dry. Whirling both thermometers allows water to evaporate from the wick, which cools the wet bulb. By looking up the dry and wet bulb temperatures in a set of tables, known as humidity tables, it is possible to find the corresponding relative humidity and dew-point temperature.

If the earth was a homogeneous body without the present land/ocean distribution, its temperature distribution would be strictly latitudinal (Fig. 1). However, the earth is more complex than this being composed of a mosaic of land and water. This mosaic causes latitudinal zonation of temperature to be disrupted spatially.

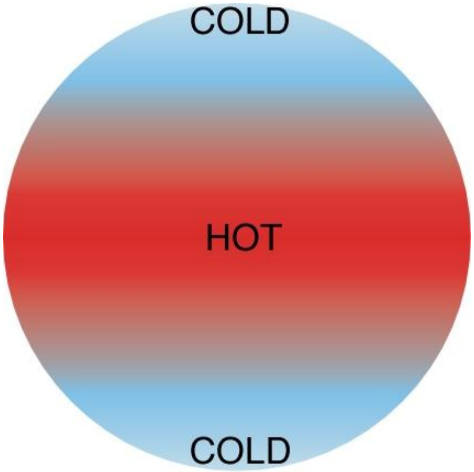

Fig. 1: Simple Latitudinal Zonation of Temperature

The following factors are important in influencing the distribution of temperature on the earth's surface:

- The latitude of the location determines how much solar radiation is received. Latitude influences the angle of incidence and duration of day length.
- Surface properties - surfaces with high albedo absorb less incident radiation. In general, land absorbs less insulation than water because of its lighter colour.

5.2 Earth's Climatic History

A wide range of evidence exists to allow climatologists reconstruct the earth's past climate. This evidence can be grouped into three general categories.

- **Meteorological Instrument Records:** Common climatic elements measured by instruments include temperature, precipitation, wind speed, wind direction, and atmospheric pressure. However, many of these records are temporally quite short as many of the instruments used were only created and put into operation during the last few centuries or decades. Another problem with instrumental records is that large areas of the Earth are not monitored. Another important advancement in developing a global record of climate has been the recent use of remote satellites.

- **Written Documentation and Descriptive Accounts of the Weather:** Weather phenomena commonly described in this type of data include the prevailing character of the seasons of individual years, reports of floods, droughts, great frosts, periods of bitter cold, and heavy snowfalls. Large problems exist in the interpretation of this data because of its subjective nature.

- **Physical and Biological Data:** This can provide fossil evidence of the effects of fluctuations in the past weather of our planet. Scientists refer to this information as "Proxy Data" of past weather and climate. Examples of this type of data include tree ring width and density measurements, fossilised plant remains, insect and pollen frequencies in sediments, moraines and other glacial deposits, marine organism fossils, and the isotope ratios of various elements. Scientists using this type of data assume uniformity in the data record. Thus, the response measured from a physical or biological character existing today is equivalent to the response of the same character in the past. However, past responses of these characters may also be influenced by some other factors not accounted for. Some common examples of proxy data include:

i. **Glacial Ice Deposits:** Fluctuations in climate can be determined by the analysis of gas bubbles trapped in the ice which reflect the state of the atmosphere at the time they were deposited, the chemistry of the ice (concentration or ratio of major ions and isotopes of oxygen and hydrogen), and the physical properties of the ice.

ii. **Biological Marine Sediments:** Climate change can be evaluated by the analysis of temporal changes in fossilised marine fauna and flora abundance, morphological changes in preserved organisms, coral deposits, and the oxygen isotopic concentration of marine organisms.

iii. **Inorganic Marine Sediments:** This type of proxy data includes clay mineralogy, aeolian terrestial dust, and ice rafted debris.

iv. **Terrestrial Geomorphology and Geology Proxy:** *Data*. There are a number of different types of proxy data types in this group including glacial deposits, glacial erosional features, shoreline features, aeolian deposits, lake sediments, relict soil deposits, and speleothems (depositional features like stalactites and stalagmites).

v. **Terrestrial Biology Proxy Data**: Variations in climate can be determined by the analysis of biological data like annual tree rings, fossilised pollen and other plant macrofossils, the abundance and distribution of insects and other organisms, and the biota in lake sediments.

6.0 ACTIVITY

i. What are proxy data and give five (5) examples that you know.

7.0 SUMMARY

In this unit, we have learnt that:

- temperature is unevenly distributed on the earth surface
- different substances have different specific heat
- evidences exist to allow climatologists reconstruct the earth's past climate.

8.0 ASSIGNMENT

i. State factors that influence temperature distribution on the earth's surface.
ii. History of past climate can be reconstructed. Discuss.
iii. Give two examples of proxy data

9.0 REFERENCES

Ernest, S. G. (1972). *Meteorology and Climatology for Sixth Forms*. London: Harrap.

Pidwirny, M. (2006). *Fundamentals of Physical Geography*. (2nd ed.).

UNIT 2 ATMOSPHERIC COMPOSITION

CONTENTS

1.0 INTRODUCTION

Air is a mixture of gases that composes which atmosphere that surrounding the Earth. These gases consist primarily of nitrogen, oxygen, argon, and smaller amounts of hydrogen, carbon dioxide, water vapor, helium, neon, krypton, xenon, and others. The most important attribute of air is its life-sustaining property. Human and animal life would not be possible without oxygen in the atmosphere. In addition to providing life-sustaining properties, the various atmospheric gases can be isolated from air and used in industrial and scientific applications, ranging from steel-making to the manufacture of semi-conductors.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list the basic composition of the atmosphere;
- state the importance of each gas to plant, man and the environment; and
- state the percentage composition of all the gases in the atmosphere.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Atmosphere: a mixture of gases that surrounds an astronomical object such as the earth

Grazing: grass and green plants for animals such as cows and sheep to eat

Methane: a colourless odourless flammable gas that is the main constituent on natural gas

Smog: a mixture of fog and smoke or other air borne pollutants such as exhaust fumes

Ozone: a gaseous form of oxygen with three oxygen atom per mole, formed by electrical discharge in oxygen

5.0 MAIN CONTENT

5.1 Atmospheric Composition

Table1 lists the eleven most abundant gases found in the Earth's lower atmosphere by volume. Of the gases listed, nitrogen, oxygen, water vapor, carbon dioxide, methane, nitrous oxide, and ozone are extremely important to the health of the Earth's biosphere.

Table 1: Average Composition of the Atmosphere (*Variable gases)

Gas Name	Volume (Per cent)	Chemical Formula
Nitrogen	**78.08**	N_2
Oxygen	**20.95**	O_2
***Water**	**0 to 4**	H_2O
Argon	**0.93**	Ar
***Carbon Dioxide**	**0.0360**	CO_2
Neon	**0.0018**	Ne
Helium	**0.0005**	He
***Methane**	**0.00017**	CH_4
Hydrogen	**0.00005**	H_2
***Nitrous Oxide**	**0.00003**	N_2O
***Ozone**	**0.000004**	O_3

The table indicates that nitrogen and oxygen are the main components of the atmosphere by volume. Together, these two gases make up approximately 99 per cent of the dry atmosphere. Both gases have very important association with life. Nitrogen is removed from the atmosphere and deposited at the Earth's surface mainly by specialised nitrogen-fixing bacteria, and by way of lightning through precipitation. The addition of this nitrogen to the Earth's surface soils and various water bodies supply the much needed nutrition for plant growth. Nitrogen returns to the atmosphere primarily through biomass combustion and denitrification.

Oxygen is exchanged between the atmosphere and life through the processes of photosynthesis and respiration. Photosynthesis produces oxygen when carbon dioxide and water are chemically converted into glucose with the help of sunlight. Respiration is the opposite process of photosynthesis.
In respiration, oxygen is combined with glucose to chemically release energy for metabolism. The products of this reaction are water and carbon dioxide.

The next most abundant gas on the table is water vapor. Water vapor varies in concentration in the atmosphere both spatially and temporally. The highest concentrations of water vapor are found near the equator over the oceans and tropical rain forests. Cold polar areas and subtropical continental deserts are locations where the volume of water vapour can approach zero per cent. Water vapor has several very important functional roles on our planet:

- it redistributes heat energy on the earth through latent heat energy exchange
- the condensation of water vapor creates precipitation that falls to the earth's surface providing needed fresh water for plants and animals
- it helps warm the earth's atmosphere through the greenhouse effect.

The fifth most abundant gas in the atmosphere is carbon dioxide. The volume of this gas has increased by over 35 per cent in the last 300 years. This increase is primarily due to human-induced burning from fossil fuels, deforestation, and other forms of land-use change. Carbon dioxide is an important greenhouse gas. The human-caused increase in its concentration in the atmosphere has strengthened the greenhouse effect and has definitely contributed to global warming over the last 100 years. Carbon dioxide is also naturally exchanged between the atmosphere and life through the processes of photosynthesis and respiration.

Methane is a very strong greenhouse gas. Since 1750, methane concentrations in the atmosphere have increased by more than 150 per cent. The primary sources for the additional methane added to the atmosphere (in order of importance) are: rice cultivation; domestic grazing animals; termites; landfills, coal-mining; and, oil and gas extraction. Anaerobic conditions associated with rice paddy flooding results in the formation of methane gas. However, an accurate estimate of how much methane is being produced from rice paddies has been difficult to ascertain. More than 60 per cent of all rice paddies are found in India and China where scientific data concerning emission rates are unavailable. Nevertheless, scientists believe that the contribution of rice paddies is large because this form of crop production has more than doubled since 1950. Grazing animals release methane to the environment as a result of herbaceous digestion. Some researchers believe the addition of methane from this source has more than quadrupled over the last century. Termites also release methane through similar processes. Land-use change in the tropics, due to deforestation, ranching, and farming, may be causing termite numbers to expand. If this assumption is correct, the contribution from these insects may be important. Methane is also released from landfills, coal mines, and gas and oil-drilling. Landfills produce methane as organic wastes decompose over time. Coal, oil, and natural gas deposits release methane to the atmosphere when these deposits are excavated or drilled.

The average concentration of the greenhouse gas nitrous oxide is now increasing at a rate of 0.2 to 0.3 per cent per year. Its part in the enhancement of the greenhouse effect is minor relative to the other greenhouse gases already mentioned. However, it does have an important role in the artificial fertilisation of ecosystems. In extreme cases, this fertilisation can lead to the death of forests, eutrophication of aquatic habitats, and species exclusion. Sources for the increase of nitrous oxide in the atmosphere include: land-use conversion; fossil fuel combustion; biomass burning; and soil fertilisation. Most of the nitrous oxide added to the atmosphere each year comes from deforestation and the conversion of forest, savanna and grassland ecosystems into agricultural fields and rangeland. Both of these processes reduce the amount of nitrogen stored in living vegetation and soil through the decomposition of organic matter. Nitrous oxide is also released into the atmosphere when fossil fuels and biomass are burned. However, the combined contribution to the increase of this gas in the atmosphere is thought to be minor. The use of nitrate and ammonium fertilisers to enhance plant growth is another source of nitrous oxide. How much is released from this process has been difficult to quantify. Estimates suggest that the contribution from this source represents from 50 to 0.2 per cent of nitrous oxide added to the atmosphere annually.

Ozone’s role in the enhancement of the greenhouse effect has been difficult to determine. Accurate measurements of past long-term (more than 25 years in the past) levels of this gas in the atmosphere are currently unavailable. Moreover, concentrations of ozone gas are found in two different regions of the Earth's atmosphere. The majority of the ozone (about 97 per cent) found in the atmosphere is concentrated in the stratosphere at an altitude of 15 to 55 kilometers above the Earth's surface. This stratospheric ozone provides an important service to life on the Earth as it absorbs harmful ultraviolet radiation. In recent years, levels of stratospheric ozone have been decreasing due to the buildup of human-created chlorofluorocarbons in the atmosphere. Since the late 1970s, scientists have noticed the development of severe holes in the ozone layer over Antarctica. Satellite measurements have indicated that the zone from 65° North to 65° South latitude has had a 3 per cent decrease in stratospheric ozone since 1978. Ozone is also highly concentrated at the Earth’s surface in and around cities. Most of this ozone is created as a byproduct of human-created photochemical smog. This build-up of ozone is toxic to organisms.

6.0 ACTIVITY

i. Give an account of the constituents of the atmosphere.

7.0 SUMMARY

In this unit, we have learnt that:

- the atmosphere comprises of various gases and water
- that nitrogen and oxygen are the main components of the atmosphere by volume and these two gases make up approximately 99 per cent of the dry atmosphere
- oxygen is used and reused by green plant and man
- water vapour varies in concentration in the atmosphere both spatially and temporally
- carbon dioxide has increased due to human-induced burning from fossil fuels, deforestation, and other forms of land-use change
- the average concentration of the greenhouse gas nitrous oxide is now increasing at a rate of 0.2 to 0.3 per cent per year.

8.0 ASSIGNMENT

i. The atmosphere is made up of different gases of various compositions. Discuss.
ii. List the base composition of atmosphere
iii. State the importance of each gas to plant, man and environment.

9.0 REFERENCES

Ayoade, J. O. (2004). *Introduction to Climatology for the Tropics*. Ibadan: Spectrum Books Limited.

Ernest, S. G. (1972). *Meteorology and Climatology for 6th Forms*. London: Harrap.

Pidwirny, M. (2006). *Fundamentals of Physical Geography*, (2nd ed.).

UNIT 3 THE LAYERED ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

The earth's atmosphere contains several different layers that can be defined according to air temperature. Figure 2 displays these layers in an average atmosphere. Variations in the way temperature changes with height indicate the atmosphere is composed of a number of different layers. These variations are due to changes in the chemical and physical characteristics of the atmosphere with altitude.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- draw and label the zones of the atmosphere;
- explain the term environmental lapse rate;
- briefly explain each layer of the atmosphere; and
- describe the consequences of ozone layer depletion.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Troposphere: the lowest and the most dense layer of the atmosphere
Isothermal: line showing relationship at same temprature
Aerosol: container with gas under pressure

5.0 MAIN CONTENT

5.1 Structure of the Atmosphere

By studying the atmosphere, meteorologists have discovered that it can be divided into a series of layers. Based on a vertical profile of temperature, the layers consist of the troposphere, stratosphere, mesosphere, and thermosphere. The atmosphere comprises of vertical layers (Figure 2) which vary with temperature.

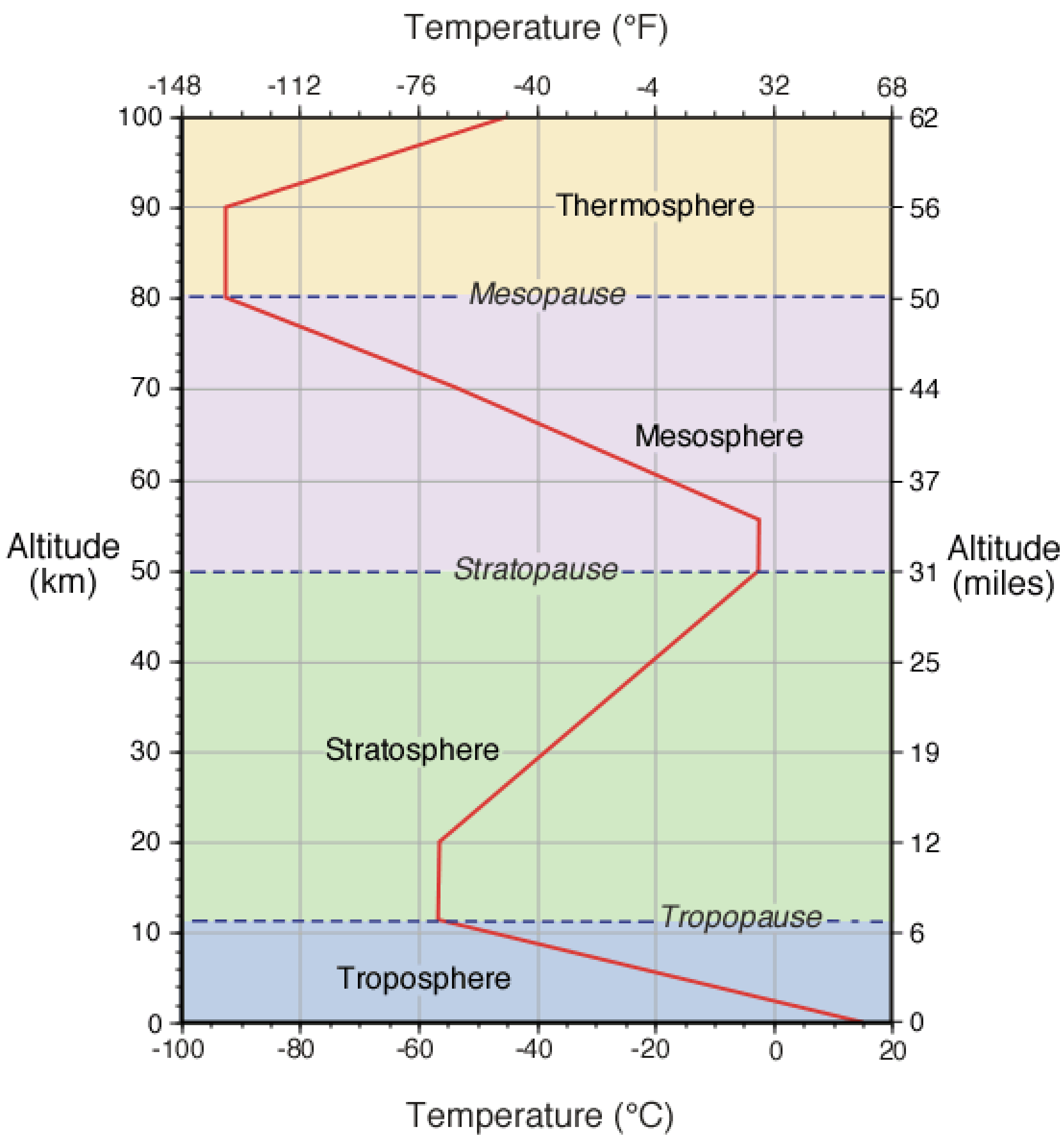

Fig. 2: Vertical Change in Average Global Atmospheric Temperature

A variation in the way temperature changes with height indicates that the atmosphere is composed of a number of different layers (labeled above). These variations are due to changes in the chemical and physical characteristics of the atmosphere with altitude.

According to temperature, the atmosphere contains four different layers:

- **Troposphere**

The first layer is called the troposphere. The depth of this layer varies from about 8 to 16 kilometers. Greatest depths occur at the tropics where warm temperatures cause vertical expansion of the lower atmosphere. From the tropics to the Earth's Polar Regions the troposphere becomes gradually thinner. The depth of this layer at the poles is roughly half as thick when compared to the tropics. Average depth of the troposphere is approximately 11 kilometers.

About 80 per cent of the total mass of the atmosphere is contained in troposphere. It is also the layer where the majority of our weather occurs. Maximum air temperature also occurs near the Earth's surface in this layer. With increasing height, air temperature drops uniformly with altitude at a rate of approximately 6.5° Celsius per 1000 meters. This phenomenon is commonly called the Environmental Lapse Rate. At an average temperature of -56.5° Celsius, the top of the troposphere is reached. At the upper edge of the troposphere is a narrow transition zone known as the tropopause.

- **Stratosphere**

Above the tropopause is the stratosphere. This layer extends from an average altitude of 11 to 50 kilometers above the Earth's surface. This stratosphere contains about 19.9 per cent of the total mass found in the atmosphere. Very little weather occurs in the stratosphere. Occasionally, the top portions of thunderstorms breach this layer. The lower portion of the stratosphere is also influenced by the polar jet stream and subtropical jet stream. In the first 9 kilometers of the stratosphere, temperature remains constant with height. A zone with constant temperature in the atmosphere is called an **isothermal layer**. From an altitude of 20 to 50 kilometers, temperature increases with an increase in altitude. The higher temperatures found in this region of the stratosphere occurs because of a localised concentration of ozone gas molecules. These molecules absorb ultraviolet sunlight creating heat energy that warms the stratosphere. Ozone is primarily found in the atmosphere at varying concentrations between the altitudes of 10 to 50 kilometers. This layer of ozone is also called the ozone layer. The ozone layer is important to organisms at the Earth's surface as it protects them from the harmful effects of the Sun's ultraviolet radiation. Without the ozone layer, life can not exist on the earth's surface.

- **Mesosphere**

Separating the mesosphere from the stratosphere is transition zone called the stratopause. In the mesosphere, the atmosphere reaches its coldest temperatures (about - 90° C) at a height of approximately 80 kilometers. At the top of the mesosphere is another transition zone known as the mesopause.

- **Thermosphere**

The last atmospheric layer has an altitude greater than 80 kilometers and is called the thermosphere. Temperatures in this layer can be greater than 1200°C. These high temperatures are generated from the absorption of intense solar radiation by oxygen molecules (O_2). While these temperatures seem extreme, the amount of heat energy involved is very small. The amount of heat stored in a substance is controlled in part by its mass. The air in the thermosphere is extremely thin with individual gas molecules being separated from each other by large distances. Consequently, measuring the temperature of thermosphere with a thermometer is a very difficult process. Thermometers measure the temperature of bodies via the movement of heat energy. Normally, this process takes a few minute for the conductive transfer of kinetic energy from countless molecules in the body of a substance to the expanding liquid inside the thermometer. In the thermosphere, our thermometer would lose more heat energy from radiative emission than what it would gain from making occasional contact with extremely hot gas molecules.

5.2 The Ozone Layer

The ozone layer is a region of concentration of the ozone molecule (O_3) in the earth's atmosphere. The layer sits at an altitude of about 10-50 kilometers, with a maximum concentration in the stratosphere at an altitude of approximately 25 kilometers. In recent years, scientists have measured a seasonal thinning of the ozone layer primarily at the South Pole. This phenomenon is called the ozone hole.

The ozone layer naturally shields Earth's life from the harmful effects of the Sun's ultraviolet (UV) radiation. Ozone is both a natural and human-made greenhouse gas. This ozone is formed by the action of ultraviolet light from the sun on molecules of ordinary oxygen. Some chemical compounds are known to destroy ozone molecules in the upper atmosphere. Ozone is destroyed naturally by the absorption of ultraviolet radiation, and by the collision of ozone with other atmospheric atoms and molecules. This can break down or deplete the ozone layer. A severe decrease in the concentration of ozone in the ozone layer could lead to the following harmful effects:

- an increase in the incidence of skin cancer
- a large increase in cataracts and sun-burning
- suppression of immune systems in organisms
- adverse impact on crops and animals
- reduction in the growth of phytoplankton found in the Earth's oceans
- cooling of the Earth’s stratosphere and possibly some surface climatic effect.

The ozone layer of the atmosphere protects life on earth by absorbing harmful ultraviolet radiation from the Sun. If all the ultraviolet radiation given off by the sun were allowed to reach the surface of earth, most of the life on earth’s surface would probably be destroyed. Short wavelengths of ultraviolet radiation, such as UV-A, B, and C, are damaging to the cell structure of living organisms. Fortunately, the ozone layer absorbs almost all of the short-wavelength ultraviolet radiation and much of the long-wavelength ultraviolet radiation given off by the sun.

In the 1970s scientists became concerned when they discovered that chemicals called chlorofluorocarbons or CFCs long used as refrigerants and as aerosol spray propellants—posed a possible threat to the ozone layer. Released into the atmosphere, these chlorine-containing chemicals rise into the upper stratosphere and are broken down by sunlight, whereupon the chlorine reacts with and destroys ozone molecules (up to 100,000 per CFC molecule). The use of CFCs in aerosols has been banned in the United States and elsewhere. Other chemicals, such as bromine halocarbons, as well as nitrous oxides from fertilisers, may also attack the ozone layer.

6.0 ACTIVITY

i. Ozone layer shield the earth surface from harmful radiation, explain.
ii. Discuss the consequence of ozone layer depletion.
iii. Briefly explain each layer of the atmosphere.
iv. Define the term: Environmental lapse rate

7.0 SUMMARY

In this unit, we have learnt that:

- the atmosphere comprises of four major layers
- the layers are classified according to temperature changes
- each layer consists of a transition zone
- the ozone layer naturally shields Earth's life from the harmful effects of the sun's ultraviolet (UV) radiation
- Ozone is created naturally in the stratosphere by the combining of atomic oxygen (O) with molecular oxygen (O_2).

8.0 ASSIGNMENT

i. Briefly explain the structure of the atmosphere.

9.0 REFERENCES

Ayoade, J. O. (2004). *Introduction to Climatology for the Tropics*. Ibadan: Spectrum Books Limited.

Pidwirny, M. (2006). *Fundamentals of Physical Geography*, (2nd ed.).

Strahler, A. N. & Strahler, A. H. (1973). *Environmental Geosciences*: *Interaction between Natural Systems and Man.*

UNIT 4 ATMOSPHERIC EFFECTS ON INCOMING SOLAR RADIATION

CONTENTS

1.0 INTRODUCTION

In the previous unit, we learnt that the atmosphere is structured into four different layers according to temperature changes with altitude. Within this structure, the atmosphere modifies the incoming solar radiation through scattering, absorption and reflection, thereby reducing the amount of solar radiation received on earth's surface. Warming of the atmosphere takes place at all levels, especially where there is an abundance of water vapour or aerosols to absorb energy. As air is warmed, it expands and being lighter than the surrounding air, it wants to rise. This is called convection.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list and explain all the processes that modify solar radiation;
- distinguish between direct and diffused solar radiation;
- explain the term albedo; and
- state the uses of solar energy.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Albedo: light reflected by planet
Photosynthesis: carbohydrate production using light and chlorophyll

5.0 MAIN CONTENT

5.1 Processes that Modify Solar Radiation

Three atmospheric processes modify the solar radiation passing through our atmosphere destined to the Earth's surface. These processes act on the radiation when it interacts with gases and suspended particles found in the atmosphere. They are:

- **Scattering**

The process of scattering occurs when small particles and gas molecules diffuse part of the incoming solar radiation in random directions without any alteration to the wavelength of the electromagnetic energy. Scattering does, however, reduce the amount of incoming radiation reaching the Earth's surface. A significant proportion of scattered shortwave solar radiation is redirected back to space. The amount of scattering that takes place is dependent on two factors (a) wavelength of the incoming radiation and (b) the size of the scattering particle or gas molecule. In the Earth's atmosphere, the presence of a large number of particles with a size of about 0.5 microns results in shorter wavelengths being preferentially scattered. This factor also causes our sky to look blue because this color corresponds to those wavelengths that are best diffused. If scattering did not occur in our atmosphere the daylight sky would be black.

- **Absorption**

Absorption is defined as a process by which solar radiation is retained by a substance and converted into heat energy. The creation of heat energy also causes the substance to emit its own radiation. In general, the absorption of solar radiation by substances in the Earth's atmosphere results in temperatures that gets no higher than 1800° Celsius. According to Wien's Law, bodies with temperatures at this level or lower would emit their radiation in the longwave band. Further, this emission of radiation is in all directions so a sizeable proportion of this energy is lost to space.

- **Reflection**

Reflection is a process where sunlight is redirected by 180° after it strikes an atmospheric particle. This redirection causes a 100 per cent loss of the insolation. Most of the reflection in our atmosphere occurs in clouds when light is intercepted by particles of liquid and frozen water. The reflectivity of a cloud can range from 40 to 90 per cent.

Sunlight reaching the earth’s surface unmodified by any of the above atmospheric processes is termed direct solar radiation. Solar radiation that reaches the earth’s surface after it was altered by the process of scattering is called diffused solar radiation. Not all of the direct and diffused radiation available at the earth’s surface is used to do work (photosynthesis, creation of sensible heat, evaporation, etc.). As in the atmosphere, some of the radiation received at the Earth's surface is redirected back to space by reflection.

5.2 Surface Albedo

Albedo is the ratio between the amount of light a body reflects or scatters and the amount of light that is absorbed. A body that has an albedo of 0.3, for example, reflects or scatters three-tenths, or 30 per cent of the light that falls on it while absorbing the rest. Various physical characteristics of a body determine its albedo. The earth’s moon has a rough surface that absorbs most of the sunlight that strikes it. The moon, therefore, has a low albedo of 0.12. The planet Venus has a highly reflective cloud layer, which gives the planet an albedo of about 0.65; the highest of any planet in the solar system. The earth’s albedo is about 0.37.

The reflectivity or albedo of the Earth’s surface varies with the type of material that covers it. For example, fresh snow can reflect up to 95 per cent of the insolation that reaches it surface. Some other surface type reflectivities are:

- dry sand 35 to 45 per cent
- broadleaf deciduous forest 5 to 10 per cent
- needle leaf coniferous forest 10 to 20 per cent
- grass type vegetation 15 to 25 per cent .

Reflectivity of the surface is often described by the term surface albedo. The earth’s average albedo, reflectance from both the atmosphere and the surface, is about 30 per cent.

Figure 3 describes the modification of solar radiation by atmospheric and surface processes for the whole Earth over a period of one year. Of all the sunlight that passes through the atmosphere annually, only 51 per cent is available at the Earth’s surface to do work. This energy is used to heat the Earth's surface and lower atmosphere, melt and evaporate water, and run photosynthesis in plants. Of the other 49 per cent, 4 per cent is reflected back to space by the Earth's surface, 26 per cent is scattered or reflected to space by clouds and atmospheric particles, and 19 per cent is absorbed by atmospheric gases, particles, and clouds.

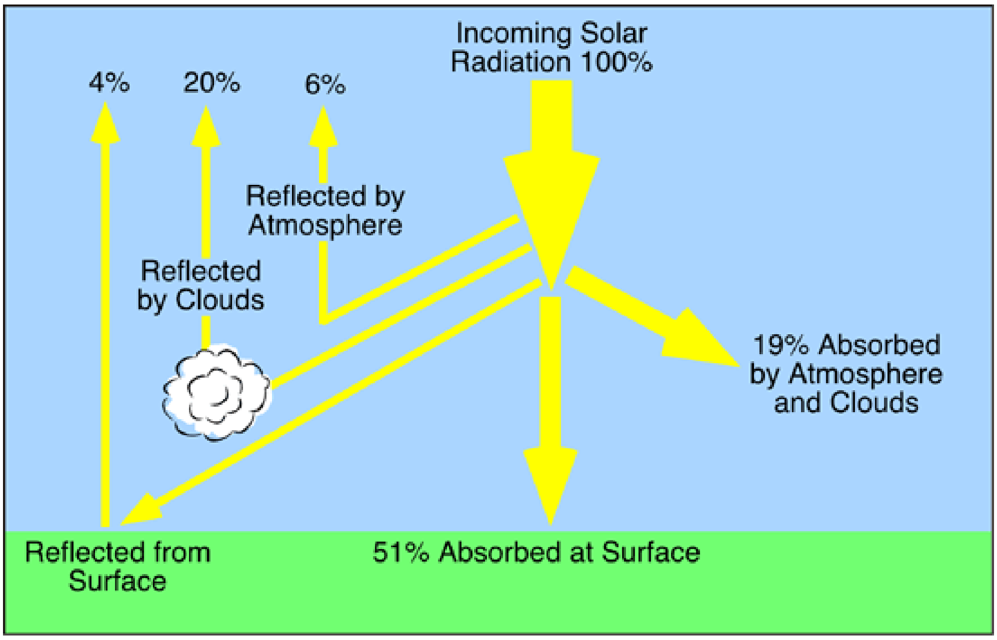

Fig. 3: Global Modification of Incoming Solar Radiation by Atmospheric and Surface Processes

Scientists measure two specific kinds of albedo:

- Bond albedo is the ratio between the amount of energy that a body reflects and the amount of energy that falls on the body. It is used to keep track of the energy balance of a body, or how much energy a body is gaining or losing.

- Normal albedo is the ratio between the amount of light that a surface reflects straight up and the amount of light that falls straight down on the surface. Depending on the composition of the surface, the normal albedo of a surface for different wavelengths of light can be different. By looking at the normal albedo of different wavelengths of light, astronomers can infer the chemical composition of the surface.

5.3 Uses of Solar Energy

The earliest reported use of solar energy has been attributed to Archimedes. According to legend, he used multiple reflectors to concentrate the energy of the sun on Roman ships attacking Syracuse, setting them on fire. Other early experimenters employed mirrors to concentrate radiation, so that metals were melted or other similar experiments performed.

The possible uses of solar energy fall into three categories:

- thermal processes
- photochemical processes
- photoelectric processes.

In thermal processes, the radiant energy is absorbed as heat by a receiver or receiving substance which then undergoes an increase in temperature, vaporisation, or other heat-absorbing process. Photochemical processes are those in which light energy causes a chemical process, and photoelectric processes involve a direct conversion of radiation to electrical energy like the solar inverters. The most commonly considered uses of solar energy are those which are classed as thermal processes. They include house-heating, distillation of sea water to produce potable water, refrigeration and air conditioning, power-production by solar-generated steam, cooking, water-heating, and the use of solar furnaces to produce high temperatures for experimental studies.

6.0 ACTIVITY

1. With the aid of diagram, explain the processes that modify the incoming solar radiation.
2. Distinguish between direct and diffused solar radiation

7.0 SUMMARY

In this unit, we have learnt that:

- not all solar energy released by the sun actually reaches the earth
- scattering does, however, reduce the amount of incoming radiation reaching the earth's surface
- atmospheric particles reflect solar radiation
- reflectivity or albedo of the earth's surface varies with the type of material that covers it
- solar energy can be put into various uses.

8.0 ASSIGNMENT

1. Explain the term surface albedo and state its effects on incoming solar radiation.
2. State the uses of solar energy

9.0 REFERENCES

Christiansen, E. H. & Hamblin, W. K. (1995). *Exploring the Plants* (2nd ed.).

Donald, A. C. (1994). *Meteorology Today*: *An Introduction to Weather, Climate and the Environment.*

Ernest S. G. (1972). *Meteorology and Climatology for Sixth Forms*. London: Harrap.

Pidwirny, M. (2006). *Fundamentals of Physical Geography* (2nd ed.).

UNIT 5 THE TEMPERATURE OF THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

The sun is the sole source of heat for the earth's atmosphere. From the sun, whose diameter is more than a hundred times that of the earth and whose surface is believed to have a temperature of about 6000^{o}C, there streams an immense quantity of radiant energy. Although only a small fraction of the energy emitted from the sun reaches the earth, all life on the planet owes its existence to this radiation. Temperature decreases with increasing elevation at an average rate of about 6.5°C per km (about 19°F per mi). As a result, temperatures in the mountains are generally much lower than at sea level. Temperature continues to decrease throughout the atmosphere's lowest layer, the troposphere, where almost all weather occurs. The troposphere extends to a height of 16 km above sea level over the equator and about 8 km above sea level over the poles. Above the troposphere is the stratosphere, where temperature levels off and then begins to increase with height. Almost no weather occurs in the stratosphere.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the processes by which earth surface is being heated; and
- explain the vertical and horizontal distribution of temperature.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Adiabatic:	without change in heat
Latitude:	imaginary line around earth
Isotherm:	line showing equal temperature
Radiation:	particles emitted by radio active substances

5.0 MAIN CONTENT

5.1 Methods by which Air is Heated

The atmosphere is heated by radiation from the earth's surface, which retransmits the sun's radiation in the form of long or heat waves. Consequently, the temperature of the atmosphere will vary with height above the earth's surface. Majorly, the atmosphere is heated by these three major processes.

- **Radiation**

This is simply the direct heating of a body by the transmission of heat-waves. The long waves from the earth's surface heat the air in close proximity to the ground. Earth is heated by short wave energy from the sun. The air is heated by long-wave energy from the earth.

- **Convection**

Our convection currents are upward movements of warm air which, because it is at a higher temperature than its surroundings, is less dense and lighter and therefore tends to rise. By convectional heating of the atmosphere, air is heated by the earth, expands, and raised cold air flows in and is itself warmed by the earth.

- **Conduction**

This is the process by which air is heated directly in the daytime by contact with the earth's surface. Since the air tends to be heated in these three ways the air near the surface on the whole attains the same temperature as the ground with which it is in contact. The ground temperature however, depends upon the amount of solar radiation reaching the earth's surface and upon the character of the surface which is receiving that radiation.

5.2 The Vertical and Horizontal Distribution of Air Temperature

5.2.1 The Vertical Distribution of Temperature

We have already examined the methods by which the atmosphere is heated, and have noticed that radiation from the earth's surface is the fundamental source of heat. Experimental observation of air temperature at different altitudes has verified the assumption that air temperature decreases as height increases.

Under normal conditions, while the rate of decrease is not uniform, the average is about 1.8^{o}C per 300 metres. This is called the 'lapse rate'; the steeper the lapse rate the more rapid the decrease in temperature. The rate of temperature decrease naturally varies from place to place and from one part of the year to the next.

Dry air, when forced to rise, will expand and cool at a rate of 30^{o}C per 300 metres. This is known as the 'dry adiabatic lapse rate' and is the rate at which rising dry air cools off; subsiding dry air warms when no heat is transferred from other surrounding sources. If the environmental lapse rate for a section of the atmosphere was 2.5^{0}C in 300 metres, and a portion of that air were made to rise, after 300 metres, the temperature of that dry air would be reduced by 30 ^{o}C. The portion of air would be 0.5^{0}C cooler than the surrounding air at the same level. The rate of decrease of temperature in ascending saturated air is known as the saturated adiabatic lapse rate and for lower levels of the troposphere in temperate latitudes is of the order of 1.5 ^{0}C per 300meters. The value is not constant and depends on the amount of moisture condensed. Cold air can contain less moisture than warm air and so the latent heat released in cold air will be less than that released in warm air.

5.2.2 The Horizontal Distribution of Temperature

The main features of surface air temperature over the earth are largely decided by latitude. Temperature decreases gradually from the equator to Polar Regions. These distributions, however, are largely modified by the position of land and sea surfaces and the seasonal changes in the sun's position relative to those surfaces. Surface air temperature can be shown on a map by a series of lines called Isotherms. An Isotherm is simply a line joining places having the same mean sea-level temperature.

6.0 ACTIVITY

1. Explain the following terms:
   (a) Lapse rate
   (b) Dry adiabatic lapse rate.
   (c) Isotherm.
2. Explain the vertical and horizontal distribution of temperature.

7.0 SUMMARY

In this unit, we have learnt that:

- the sun is the sole source of heat for the earth's atmosphere but only a small fraction of energy released by the sun reaches the earth
- the atmosphere is heated by three processes: radiation, convection and conduction
- air temperature decreases as height increases
- the rate at which air temperature drops varies from place to place

- temperature decreases gradually from the equator to the polar regions.

8.0 ASSIGNMENT

i. Discuss the methods by which air is heated.
ii. The higher you go the cooler it becomes. Explain this as it relates to atmosphere.

9.0 REFERENCES

Ayoade, J. O. (2004). *Introduction to Climatology for the Tropics*. Ibadan: Spectrum Books Limited.

Ernest, S. G. (1972). *Meteorology and Climatology for Sixth Forms*. London: Harrap.

Pidwirny, M. (2006). *Fundamentals of Physical Geography*, (2nd ed.).

Strahler, A. N. & Strahler, A. H. (1973). *Environmental Geosciences*: *Interaction between Natural Systems and Man.*