AGR 309: AGRO CLIMATOLOGY AND BIOGEOGRAPHY

Course Writer: Dr. Dora Damar (UNIJOS)

Course Editor: Dr. S. Musa (Kogi State University Anyigba)

Course Co-ordinator: Dr. Awolumate Samuel (NOUN)

Programme Leader: Prof. N. E. Mundi (NOUN)

INTRODUCTION

Agro climatology and biogeography cannot be divorced from one another as they are inter-related. The climate of a place affects both biotic and abiotic life of an environment. The inter-play of climatic elements and land resources results in increased activities of both macro and microorganisms which in turn affect plant and animal life. The macro and micro climate could be harnessed for higher productivity.

Therefore, changes resulting from the climatic factors could be mitigated for higher animal and plant productivity that will better human life. The course agro climatology and biogeography is presented under eleven modules. The modules treated in this course are further elaborated as follows:

Module one is on principles, aims and scope of climatology and biogeography. The module discusses the meaning and principles of climatology, approaches to climatology, aims of climatology, scope of climatology, principles of biogeography, aims of biogeography, nature and scope of biogeography.

Module two discusses the elements and control of climate and weather and the dynamics of earth's atmosphere. Discussed in this module also are the meanings of climate and weather, differences between climate and weather, elements of climate and weather, factors controlling climate and weather, importance of climate and weather on agriculture, transportation and communication, mode of dressing and houses built, thermodynamics of the earth's atmosphere, forces in the atmosphere planetary waves, mid-latitude cyclone, planetary layer and general circulation of the atmosphere.

Module three is on radiation and heating of the atmospheric system. The module discusses meaning of radiation, principles of radiation, laws of radiation, the atmosphere, energy system, processes of heating, short wave energy, long wave energy, and heat balance.

Module four addresses atmospheric moisture. The emphasis of this module is on forms of water, process of heat transfer, hydrologival cycle, latitudes and earth rotation as causes of atmospheric circulation, tricellular models and atmospheric circulation, macro and meso scales.
Module five addresses the dynamics of pressure and wind systems. The module also discusses the concept of wind, patterns of movement of wind system, frictional surface wind systems, planetary winds and local winds. Also, discussed in this module are changes in wind pressure of wind systems and causes of atmospheric circulation.

Module six discusses condensation and precipitation. Addressed in this module is the mechanism of condensation, processes of precipitation, types of precipitation, measurement of rain, measurement of snow, measurement of hail, measurement of fog-drip and dewfall, short term variability, seasonal variability, causes of variations in precipitation and water balance.

Module seven addresses seasonal variations in temperature, day length, radiation, rainfall and evapotranspiration. The discussion in this module also centers on variation in temperature, variation in day length, radiation, rainfall and evapotranspiration.

Module eight is on equipment and maintenance of standard meteorological stations. Key discussions in this module are on the meteorological station, instruments in a meteorological station, positioning of instruments, advantages of good positioning and taking records of atmospheric conditions, maintenance of different instruments as well as maintenance of the inside and outside environments of a meteorological station.

Module nine discusses the tropical climates. These include equatorial trough, sub-tropical highs, trade winds, monsoons and tropical cyclones. Module ten discusses relationship between agriculture and climate with reference to crops, livestock, irrigation, pest and disease. Discussed in this module are the concepts related to agriculture, effects of rainfall on crop growth and distribution, temperature, wind, humidity and sunlight as factors in crop growth and distribution, effects of rainfall, temperature, wind, humidity and sunlight on agriculture, temperature, wind and disease spread.

Module eleven is on climate change issues in agriculture and various methods of amelioration. The concept and meaning of climate change, causes of climate change, evidences of climate change, impact of climate change on agriculture, impact of climate change on agricultural surfaces, impact of agriculture on climate, mitigation and adaptation to climate change and agricultural best practices are the issues discussed under this module.

COURSE AIM

The aim of this course-agro climatology and biogeography is to explain the relationship between climate and agriculture in order to appropriately make use of every given climatic conditions to maximize agricultural yield for maximum gains.

COURSE OBJECTIVES

After going through this course, you should be able to:

- Explain the principles of climatology and biogeography
- Determine the climatic conditions of places and relating them to the dynamics of the earth's atmosphere
- Explain the principle and laws of radiation
- Define atmospheric moisture with particular reference to humidity and the hydrological cycle
- Explain the dynamics of pressure and wind systems
- Describe the processes of condensation and precipitation
- Explain the causes of seasonal variations in temperature, radiation, rainfall and evapotranspiration
- Identify equipments in a meteorological station in relation to their positioning and uses
- State the characteristics of different climatic zones in the tropics
- Explain the relationship between agriculture and climate with reference to crops, livestock, irrigation, pest and disease
- Discuss climate change issues in agriculture and the various methods of amelioration

STUDY UNITS

Module 1 Principles, Aims and Scope Of Climatology And Biogeography.

Unit 1 Principles, aims and scope of climatology.
Unit 2 Principles, aims and scope of biogeography.

Module 2 The Elements And Control of Climate and Weather and the Dynamics of the Earth's Atmosphere.

Unit 1 Meaning and elements of climate and weather.
Unit 2 Factors controlling climate and weather.
Unit 3 Importance of climate and weather.
Unit 4 The dynamics of the earth's atmosphere.

Module 3 Radiation and Heating of the Atmospheric Systems

Unit 1 Meaning, principles and laws of radiation
Unit 2 Energy in the atmosphere
Unit 3 Heating of the atmosphere

Unit 1	Concepts and meaning of Climate change and agriculture
Unit 2	Climate change issues in agriculture
Unit 3	Methods of amelioration.

MODULE 1 PRINCIPLES, AIMS AND SCOPE OF CLIMATOLOGY AND BIOGEOGRAPHY

UNIT 1 PRINCIPLES, AIMS AND SCOPE OF CLIMATOLOGY

CONTENTS

1.0 INTRODUCTION

Climatology originated from two Greek words; Klima meaning zone or place and logia or climate science which means the study of climate, scientific definition of climate means an average weather condition of a place over a period of time. This modern field of study is regarded as a branch of the atmospheric sciences and a sub-field of physical geography which is one of the earth sciences. This unit will explain the principles, aims as well as the scope of climatology.

2.0 OBJECTIVES

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

- define climatology
- explain the principles of climatology
- examine various approaches to climatology
- state the aims of climatology

- identify the scope of climatology

3.0 MAIN CONTENT

3.1 Meaning and Principles of Climatology

3.1.1 Defining the Concept Climatology

Climatology is a science that deals with the study of the climates of different parts of the world. It is concerned with the description and explanation of climatic regions of the world, its spatial and temporal variations and influence on the environment and life on the earth's surface (Ayoade, 2011). Climatology studies the long-term state of the atmosphere. It is fundamentally concerned with the weather and climate of a given area. Climatology examines both the nature of micro, meso and macro (global) climates and the natural and anthropogenic influences on them. Climate implies an average or long – term record of weather conditions at a certain region for at least 30 years. It conveys a generalization of all the recorded weather observations in a given location. Climatology is a branch of atmospheric science concerned with describing and analyzing the causes and practical effects of climatic variations. Climatology treats other atmospheric processes as meteorology and also seek to identify slower-acting influences and long-term change including the circulation of the oceans, the atmospheric gases and the measureable variations in the intensity of solar radiation.

Climate is the expected mean and variability of the weather conditions for a particular location, season and time of the day. Climate is often described as the mean values of meteorological variables such as temperature, precipitation, wind, humidity and cloud cover. A complex description also includes the variability of these quantities and their extreme values. The climate of a region often has regular seasonal and diurnal variations, with the climate for January often being very different from that of July at most locations. Climate also exhibits significant year to year variability and longer-term changes on both a regional and global basis (Ayodele, 2011).

3.1.2 Principles of Climatology

The basic principles of the climatology include such sub-themes as; min-environment relationship, plants and animal life as product of the prevailing climatic conditions, the prevailing climatic condition in turn as a product of the amount of solar energy and its interaction with the earth's surfaces, and the climatic condition of a place as a great determinant of the atmosphere. Specific principles of climatology include thus;

1. Air temperature received from a place depends on the amount and duration of incoming solar radiation.
2. Air temperature is additionally moderated by the amount of water vapour in the atmosphere, the degree of cloud cover, the nature of the surface of the earth's surface, elevation above sea level and degree and direction of air movement
3. Much of the incoming solar radiation is sent back to space and the troposphere through re-radiation and reflection
4. Air is heated more by the process of re-radiation than by direct energy from the sun
5. Cold and hot temperature extremes are developed on land and not sea because the land is heated and gives out energy much more easily than the sea
6. Temperatures are moderated by large bodies of water near the land
7. Coastal areas have lower summer temperature and higher winter temperature than those places at the same distance from the equator excluding sea cost
8. Temperatures are warmest at the earth's surface and lower as elevation increases
9. Air is heavier and pressure is higher close to the earth's surface. Thus, cold air is denser than hot air.
10. Air pressure at a given location changes as surface heat or cold changes
11. Air moves from high pressure belt to low pressure belt. Thus, the greater the difference in air pressure between places, the greater the wind
12. Heavy air stay close to the earth's surface as it moves, thus, producing wind, forces an upward movement of worm air. The velocity, or speed of the wind is in direct proportion to pressure difference. If distance between high and low pressure zones are short, pressure gradients are steep and wind velocities are great
13. Wind movement is slowed by the fractional effect caused by the earth's surface. The effect is strongest at the surface and decreases with high until no effect is recorded
14. Wind systems of the world set ocean currents in motion
15. Difference in density of water cause water movement. High density water exist in areas of high pressure. Ocean water is low in density
16. Two air masses coming into contact creates the possibility of storm development
17. An intense tropical cyclone or hurricane begins in a low pressure zone over worm waters, usually in the northern hemisphere

3.1.3 Approaches to Climatology

Climatology is approached in different ways. These include:

i) Pale Climatology

This approach seeks to reconstruct past climates by examining records such as ice cores, and tree rings (dendroclimatology). Pale climatology seeks to explain climate variations for all parts of the earth during any given geological period, beginning with the time of the earth's formation. The basic research data are drawn mainly from geology and pale botany; speculative attempts at explanation have come largely from astronomy, atmospheric physics, meteorology and geophysics. Climate is the long-term expression of weather; in the modern world, climate is most noticeably expressed in vegetation and soil types and associated features of land surfaces. To study ancient climates, pale climatologists must be familiar with various disciplines of geology, such as sedimentology, and paleontology, (scientific study of life of the geologic past, involving analysis of plants and animals fossils, preserved in rocks) and with climate dynamics which includes aspects of geography, atmospheric and ocean physics.

ii) Paleotempestology

This is the second approach to climatology. This approach helps determine hurricane frequency over millennia. The study of contemporary climates incorporates meteorological data accumulated over many years, such as records of rainfall, temperature, and atmospheric composition. Knowledge of the atmosphere and its dynamics is also embodied in models, either mathematical or statistical, which help by integrating different observations and testing how they fit together. Modeling is used for presenting actual climatic phenomena and understanding of past, present and potential future climate.

iii) Historical climatology

This approach to climatology is the study of climate as it relates to human history which focuses only on the last few thousands of years.

3.2 Aims of Climatology

The aims of climatology are to provide a comprehensive description of the earth's climate over the range of geographic scales and to have a better understanding of its features in terms of physical principles, and to develop suitable models of the earth's climate for production of future changes that may result from natural and human influences. It also aims to develop sound understanding of how climatic elements affect human occupations of the earth: This subsumes an understanding of how climate influences the way people use the land, distribution of human population and activities, distribution of plants and animals as well as soil types and characteristics.

Climatology is concerned with seasonal to inter-annual variability characteristic, climate extremes and season ability not only analysis of climate pattern and statistics as it affects temperature, precipitation, atmospheric moisture; atmospheric circulation and disturbances. Climatology also addresses sits subject matter on many spatial scales, from micro through meso and synoptic to the hemispheric and global systems. Furthermore, climatology works within a general systems paradigm. The climate system theory states that, climate is the manifestation of the interaction among major climate system components of the atmosphere is influenced by the balance between large and logical factors, climate can be a determinant of a resource for and a hazard to human activities and human activities have a significant potential to influence climate, gives the opportunity for climatologist to constantly measure, record and analyze climatic data to provide information on the changing effects of climate on the environment, agriculture and other human activities. (Egeh, & Okoloye, 2008; Henderson-sellers, 1995; Donald, 1994).

3.3 Scope of Climatology

Climatological studies consist of the following:

1. Structure and composition of the atmosphere
2. Horizontal and vertical distribution of temperature
3. Vertical and horizontal distribution of pressure
4. Surface winds – corriolist effect, planetary and non-planetary winds, and local winds
5. Global air convergence and divergence
6. Upper atmospheric circulation – Hadley, Ferial and polar cells
7. Humidity
8. Condensation and precipitation
9. Air masses
10. Fronts
11. Cyclones and related phenomena
12. Climatic classification, location and characteristics
13. Hydrological cycle

Climatology is the tool used to develop long-range forecasts. There are three principal areas to the study of climatology; physical, descriptive and dynamic climatology. However, there are several other subdivisions in literature which are subsumed under one or more of the principal areas in climatology

i) Physical Climatology

This approach seeks to describe the variation in climate focusing on the physical processes influencing climate and the processes producing the various kinds of physical climates such as marine, desert and mountains. It also emphasizes the global energy and water balance regimes of the earth and the atmosphere Physical climatology deals with explanations of climate rather than with presentations.

ii) Descriptive or Regional Climatology

Descriptive climatology is presented by verbal and graphic description without going into causes and theory. This approach typically orients itself in terms of geographic regions; it is often referred to as regional climatology. A description of various types of climates is made on the basis of analyzed statistics from a particular location. A further attempt is made to describe the interaction of weather and climatic elements upon people and areas under consideration.

iii) Dynamic Climatology

Dynamic climatology attempts to relate the characteristics of the general circulation of the atmosphere to the climate. Dynamic climatology is often used by the theoretical meteorologists to address dynamics and effects of thermodynamics. Three other areas which Ayoade (2011) has described as new in the study of climatology are:

i. Synoptic climatology- the study of the weather and climate over an area in relation to the pattern of prevailing atmospheric circulation. It is essentially a new approach to regional climatology.
ii. Applied climatology- emphasizes atmospheric motions on various scales particularly the general circulation of the atmosphere.
iii. Historical climatology- the study of the development of climate through time.

Three prefixes can be added to climatology to denote scale or magnitude. They are micro, meso and macro, indicating small, medium and large scales respectively. These terms are also applied to meteorology.

i) Micro-climatology

Microclimatology often studies small-scale contracts, such as conditions between hilltop and valley or between city and surrounding country. They may be of an extremely small scale, such as one side of a hedge contrasted with the other, a ploughed furrow versus level soil or opposite leaf surfaces. Climate in micro scale may be modified by relatively simple human influences.

ii) Meso-climatology

This embraces a rather distinct middle ground between macro-climatology and microclimatology. The areas are smaller than those of macro and are larger than those of micro, and they may or may not be climatically representative of a general region.

iii) Macro-climatology

This is the study of large-scale climate of a large area or country. This type is not easily modified by human efforts. However, continued pollution of the earth, its streams, rivers and atmosphere, can eventually make these modifications easy. Geographers, hydrologists and oceanographers use quantitative measures of climate to describe or analyze the influence of atmospheric movement. Classification of climate has developed primarily in the field of geography. The basic role of the atmosphere is an essential part of the study of hydrology. Both air and water measurements are required to understand the energy exchange between air and ocean (heat budget) as examined in the study of oceanography.

iv) Ecology

This aspect of science studies the mutual relationship between organisms and their environment. This is briefly explained here due to the fact that environment and living organisms directly are affected by weather and climate, including those changes in climate that are gradually being made by action of man. The interference with nature by diverting and damming rivers, clearing its lands, stripping its soils and scarring its landscape has produced changes in climate. These changes have been on the micro and meso scales and possibly on the macro scale or magnitude.

SELF-ASSESSMENT EXERCISE

1. Identify the scope of Climatology
2. Explain the three principal areas to the study of Climatology.
3. Why do you think the study of Climatology is necessary?

4.0 CONCLUSION

Global climate changes are threatening the balance of climate under which life evolved and is sustained. Rise in temperature, ultraviolet radiation is increasing at the surface and pollutant levels are equally increasing. These changes can be traced to industrialization and other activities of man such as deforestation. Climatology today study all the characteristics, components, interactions and feedbacks. Focus has been on the processes which take place in the atmosphere as its affects the environment.

5.0 SUMMARY

The state of the climatic system at any time is determined by certain forces acting upon it and the complex internal feedbacks that these force prompt. Feedback often occurs when a portion of the output from an action is added to the input so that output is further modified. In this unit, the meaning of climatology, concepts and principles have been discussed; aims and scope of climatology with focus on types of climatology, relation to other field such as ecology, and approaches to climatology were discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define climatology
2. Explain any five principles of climatology
3. Briefly explain three approaches to climatology

7.0 REFERENCES/FURTHER READING

Ayodele, J. O. (2011). *Introduction to Climatology for the Tropics*. Ibadan: Spectrum Books Limited.

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UNIT 2 PRINCIPLES, AIMS AND SCOPE OF BIOGEOGRAPHY

CONTENTS

1.0 INTRODUCTION

Biogeography examines the characteristics of the environment and influence of atmospheric processes particularly climate on biotic and abiotic components of the terrestrial and aquatic ecosystems. Generally, climatic elements have significant influence on the ecological parameters studied in biography. For a better understanding of the effects of the dynamic characteristics of climatic components on the ecosystem, there is need to study biogeography with emphasis on the distribution of plants and animals using the scientific principles of environmental studies, interaction complex of soil, plants and animals, and the interaction of plants and animals with climate. This unit will explain the principles, aims and scope of biogeography.

2.0 OBJECTIVES

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

- explain the principles of biogeography
- discuss the aims of studying biogeography
- state the area of coverage of biogeography.

3.0 MAIN CONTENT

3.1 Principles of Biogeography

Biogeography is the study of the distribution of plants and animals in relation to the complex biological atmospheric and edaphic processes which control their activities and spread in space and time. Its subject matter covers many life form of plants and animals which inhabit the biosphere. Its field is the interface between many disciplines such as biology, geography, botany, zoology, genetics, geology, climatology, pedology, geomorphology, etc.

Biogeography deals with the geographical aspects of the distribution of plants and animal life. The geographical distribution of plants is referred to as phytogeography, while the distribution of animals is referred to as zoogeography. Biogeography also provides explanation of the factors responsible for the distribution of plants and animals using the scientific principles of environmental studies. From this note, biogeography is defined as the study of the distribution of plants and animals including microorganisms together with the geographical relationship with their environment.

Biogeography includes the study of all components of the physical environments that constitute the habitat of various species and organisms. Biogeography focuses on the biological and geographical components of the environment. Therefore, biogeography as a subject is both biological and geographical. This is because it studies the spatial distribution of plants and animals and the biological process taking place in nature. Furthermore, it tries to explain the biological factors of distribution and the implication of the pattern of distribution. Biogeography studies the biotic complex of the environment. Biotic complex is the interacting complex of soil, plants, animals and the interaction of plants and animals with climate (Bharatdwaj, 2006).

3.2 Aims of Biogeography

Biogeography is a science that uses methods of science to investigate and predict the relations between the observed patterns of species and the controlling abiotic and biotic processes. It is dependent therefore on objective empirical observations to generate research hypotheses that make prediction.

Biogeography aims to provide detailed examination of the origin, distribution, structure and functioning of the major terrestrial ecosystems and effects of humans on their ecological integrity. Particularly, biogeography examines how the patterns of energy, water and nutrients through the soil-vegetation – atmosphere continuum determine the biological functioning and diversity of the major terrestrial ecosystems.

Biogeography also aims to determine the impact of human activity on all scales with particular emphasis on the evolution and expansion of agro ecosystems as the world population has continued to increase. The other human impacts are directly related to human changes, global and local biogeochemical cycles, particularly via air pollution and acid deposition and via increases in atmospheric carbon dioxide and climate change. Both impact on the ecosystem.

3.3 Nature and Scope of Biogeography

Biogeography is the study of the biosphere which includes the consideration of the physical environment, soil, animals and plants. Biogeography indicates both biological and geographical science. Geographers study the distribution patterns of plants and animals of the biosphere in spatial and temporal contexts and attempts to analyze the processes and factors which are responsible for such spatial and temporal variations, the biologists limit themselves to the study of physiological, morphological, behavioural and functional aspects of an individual organism. Although the geographer studies distributional patterns of community of plants and animals also emphasizes two more aspects viz:

i) intimate inter-relationship between the abiotic and biotic components
ii) reciprocal relationship between man and biosphere

The scope of biogeography specifically includes the following:

1. phytogeography – the study of plants distribution
2. zoogeography – the study of animal's distribution
3. The study of all components of the physical environment that constitute habitat for various species of biological organisms.

   This consists of land, water, air and energy. Specifically, this include the following studies;

   a) study of the interactions of organisms and their physical environment
   b) atmospheric factors in the distribution of plants and animals –gaseous composition, supply of light, condensation and precipitation, temperature and general atmospheric conditions
   c) edaphic factors in the growth and distribution of plants and animals – this include those soil properties which affect plants growth and distribution and conversely that of animals. The physical and chemical properties of soil either promote or inhibit plants growth and distribution
4. biotic and anthropogenic factors in the growth and distribution of plants and animals
5. plants and animals evolution and distribution
6. effect of man on plants and animal evolution and distribution

7. ecosystem and the food chain
8. motor biomes of the world
9. environmental degradation and conservation and animals in relation to the complex biological, atmospheric and edaphic processes which control their activities and spread in space and time. Its subject matter covers many life forms of plants and animals which inhabit the biosphere. Its field is the interface or overlap between many disciplines such as biology, geography, geology, climatory, pedology, geomorphology, botany, zoology, genetics, to mention but a few.

SELF-ASSESSMENT EXERCISE

The field of biogeography is an interface between many disciplines. Explain this statement using the principles of biogeography to support your answer.

4.0 CONCLUSION

Biogeography is more concerned with the study of the distribution of plants and animals ecological concepts of interactions between abiotic components (plants and animals including man) and abiotic (physical) environment and among the biotic components themselves.

5.0 SUMMARY

In this unit, the meaning and principles of biography, aims of studying biogeography, the nature and scope of biogeography have been extensively discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the aims of studying biogeography
2. State the area of coverage of biogeography

7.0 REFERENCES/FURTHER READING

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MODULE 2 THE ELEMENTS AND CONTROL OF CLIMATE AND WEATHER AND THE DYNAMICS OF THE EARTH'S ATMOSPHERE

UNIT 1 MEANING OF CLIMATE AND WEATHER

CONTENTS

1.0 INTRODUCTION

Differences in weather conditions exist on daily basis due to certain climatic factors that play significant role on the planet earth. People often wonder why they experience hot and cold weather at time and location. This unit explains the meaning of climate and weather, the different elements of climate and weather and differentiates between the two concepts. The unit also discusses how to collect various climatic data and to prepare charts on them as well as how to observe and measure weather and climate over a period of time using weather instruments. Also discussed in this unit, are the characteristics of these elements.

2.0 OBJECTIVES

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

- define climate
- define weather
- differentiate between climate and weather
- list the elements of climate and weather and state what each is used for.
- identify the type of rainfall associated with your geographical area.

3.0 MAIN CONTENT

3.1 The Meaning of Climate And Weather

Climate can be defined as the average weather conditions of a place over a long period of time, usually about or above 30 years. The elements of weather which control the climate can be systematically observed, recorded and processed over a long period of time. The climatic conditions of a location may be affected by certain factors whose effects may differ based on the location and the factors present at the location. These factors include; Latitude or distance from the equator, altitude or elevation, distance from the sea, prevailing winds, direction of mountain, amount of rainfall, ocean currents, slope of the land and vegetation. The study of climate is called climatology while specialists in climatology are known as climatologists.

Weather is the condition of the atmosphere at a particular time over a certain or short period of time. This is determined by various meteorological conditions. The daily and seasonal changes or variation in weather influence human lives. The study of weather is known as meteorology while those who study meteorology are known as meteorologists. (Briggs & Smithson, 1985).

3.2 Difference between Climate and Weather

The following differences exist between weather and climate:

i. Weather is the condition of the atmosphere at any given time or a short period while climate is the average weather condition of a location over a long period of time.
ii. The study of climate is known as climatology and those who study climate are known as climatologists; while meteorology is the study of weather and those who study meteorology are called meteorologists.

3.3 Elements of Climate and Weather

The following are the elements of weather and climate: Temperature, rainfall, atmospheric pressure, humidity, wind, sunshine and clouds. The main elements considered as very significant for now are temperature and rainfall, the nature of winds and the degree of humidity.

3.3.1 Temperature

Temperature is a significant element of climate and weather, the sun is the ultimate source of energy on the Earth's surface. The energy exists in heat and light called solar radiation. Temperature is described as the hot and cold conditions experienced in a particular location at a given period of time. Temperature is highest at ground level compared to the atmosphere. This means that temperature decreases with increase in height. Usually of about $6.5^{o}C$ for every 1000 meters of ascend above the sea level.

Temperature is usually measured in degree centigrade (^{o}C) using an instrument called thermometer. It consists of a narrow glass tube containing some mercury of alcohol. There are two major types of thermometers which record temperature under different conditions: maximum and minimum thermometer. Maximum thermometer records the highest temperature attained during a day while minimum thermometer records the lowest temperature reached during the day. Thermometers are read at different time of the day and are kept alongside with other instruments in a place known as "Stevenson screen" designed to protect the thermometers from the effects of sun and rain so as to get accurate temperature readings of the day.

Temperature is usually represented on maps by lines drawn to join locations having the same amount of temperatures known as 'isotherm". $O^{o}{}_{C}$ and $32^{o}F$ are known to be the freezing point of temperature in centigrade and Fahrenheit respectively. The boiling point for centigrade is $100^{o}C$ while for Fahrenheit is $212^{o}F$. Temperature can be converted from centigrade to Fahrenheit and Fahrenheit to centigrade using the appropriate formula:

To obtain centigrade from Fahrenheit

$$C = \frac{^{o}F - 32}{1.8}$$

While to obtain Fahrenheit from centigrade

$$F = (1.8 \times {}^{o}C) + 32^{o}F$$

Calculating Temperature

There are formulae for calculating temperature applicable to the situation or condition of need.

1. Mean daily temperature = $\frac{\text{Max. Tempt + Min. Tempt}}{2}$

   That is, maximum temperature and minimum temperature for a day.
2. Duirnal range of temperature: diurnal means daily and is calculated as max. tempt – min. tempt for that day
3. Annual temperature = Total temperature from January to December for that year
4. Mean annual temperature is expressed by

   = $\frac{\text{Temperature from January to December}}{12}$
5. An annual range of temperature = difference between temperature of hottest month and coldest month
6. Monthly range of temperature = difference between temperature of hottest and coldest daily tempt for the month

3.3.2 Rainfall

Rainfall is an important element of climate which may result from the cooling of the air as it rises higher in the lower atmosphere. Rain is described as a liquid state of precipitation which is derived from large droplets of water – normally produced by the clouds. It is measured by an instrument called raingauge. Raingauge consists of a metal container, a metal jar or glass bottle and metal funnel. The instrument is kept in an open space far from buildings and shelter in order to obtain accurate measurement by collecting rain water directly without obstruction and addition from roof tops and trees after the rain has stopped.

Raingauge must be examined every day and records taken.

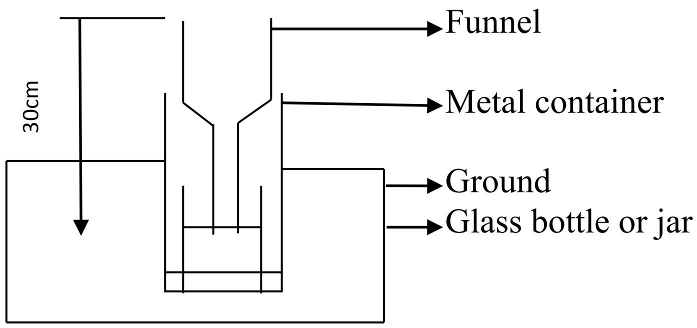

Fig. 1: Raingauge

When using the raingauge, the instrument should be sunk into the ground such that 30cm of it is above the ground level and firmly positioned. Rainfall is usually measured in (mm) or (cm),a line used to join two places on a map with same amount of rainfall is called "isohyets." Formulae for calculating rainfall is the same with that of temperature.

There are three types of rainfalls formed under different conditions with different features;

(i) **Convection rainfall**: is common in regions with high temperature i.e. the tropics, formed after intensive heating of the earth surface, air is forced to rise thus carrying water vapour into the upper atmosphere in a process called evaporation. The water vapour condenses into cumulonimbus clouds and later turn into droplets of water. Convectional rainfall has the following features:

- Normally accompanied with lightning and thunderstorm
- Torrential in nature
- It occurs in equatorial and tropical monsoon regions
- Usually occurs in the afternoon period of the day
- It falls within short distances

(ii) **Orographic Rainfall**: This is sometimes called relief rainfall. This occurs whenever moisture – laden air is forced to ascend an area with high-elevation. The air upon reaching the land surface is compelled to move to the upper atmosphere where the air becomes cool and saturated. Condensation at this point sets in thereby forming clouds and finally rain.

Orography rainfall has the following features:

- It only occurs where there is mountain barrier to deflect the prevailing wind upward
- Only the windward side (direction of the prevailing wind) receives or experiences a significant amount of rainfall, while the leeward side is occupied by the descending dry wind which brings no rainfall.

(iii) **Frontal (cyclonic) Rainfall**: This is associated with two different air masses of varying temperature. The meeting of the tropical warm air (tropical maritime airmass) and the polar cold air (tropical continental airmass) results in this type of rainfall.

The warmer moist air which is lighter in weight rises when it meets the heavier denser dry air along the inter-tropical convergence zone (ITCZ) otherwise known as the 'front'. The denser air will undercut the lighter air and forces it to rise and when this occurs, a low pressure condition is created so that the temperature of the warmer air decreases. The decrease in temperature of the warmer air will give rise to condensation and clouds formation, when the cooling is below the dew point, it results to rainfall.

Cyclonic rainfall is characterized by the following:

- It occurs between latitudes $50^oN – 70^oN$ and 50^oS and 70^oS of the equator
- It falls within a short distance and lass within a short period of time but may be continuous in nature within short intervals.

3.3.3 Atmospheric Pressure

Air is made up of a number of mixed gases and has weight. Atmospheric pressure is described as the weight of the volume of air which extends from the ground surface to the outermost layers of the atmosphere.

There is a decrease in atmospheric pressure with increase in height (altitude), temperature and the rotation of the earth. Atmospheric pressure over a place does not remain constant or fixed for a very long time due to both daily and seasonal variations. Pressure is measured with an instrument called barometer. Places with same amount of pressure on a map are joined together by lines called “isobars”.

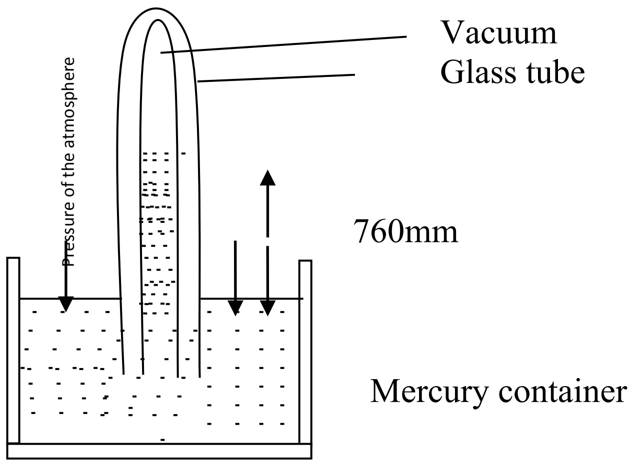

Fig. 2: A barometer

3.3.4 Humidity

This is expressed as the dampness of the atmosphere due to the pressure of water vapour. It is derived through evaporation and transpiration from water bodies and plants respectively.

There is a maximum amount of water vapour which the air can hold at a time and when reached, the air is saturated. The humidity of the air to a greater degree depends on the temperature because a rise in temperature leads to increase in the quantity of water vapour which it holds. The proportion of water vapour in the atmosphere compare with the quantity which could be in the same portion of the atmosphere, if such portion of the atmosphere were saturated is known as relative humidity (RH). It is measured using an instrument called hygrometer, which consists of wet and dry bulbs thermometer. The measurement of humidity is recorded in percentage.

3.3.5 Wind

Wind is air in motion and has direction and speed. Wind developed as the air moves from area of high pressure to area of relatively lower pressure. The air expands and rises when it get heated and becomes lighter. The surrounding air which is denser in nature then moves to take the place of the ascending air. It is the horizontal movement of air that creates wind. Wind has permanent characteristics of movement, from areas of higher pressure to areas of lower pressure. Wind vane is used to measure the direction of wind while anemometer is used for measuring wind speed.

3.3.6 Sunshine

The amount of sunshine in a given location to a greater extent depends on the season, and seasons in turn are determined by latitude and by the position of the earth in its revolution around the sun. The amount of sunshine may likely vary depending on the location of the place. Places located towards the equator receive considerable amount of sunshine because the sun is overhead twice on the equator and twice around the equator at 23^{o}North and South during revolution of the earth and the sun is inclined at an angle of $66½^{o}$North and South of the equator.Places located within this angle receive less and beyond the angle receives lesser compared to $66½^{o}$North and South. Sunshine is recorded using an instrument called sunshine recorder.

3.3.7 Clouds

When air cools, some of its water vapour may condense into tiny water droplets. The temperature at which this occur is called the dew point temperature. Some condensation takes place on tress and grasses directly on the earth surface. The water droplets forming on these surfaces are called dew, often formed in some parts of Nigeria at night in the dry season and it play a significant role in keeping plants alive. Clouds are formed by water droplets and ice particles. Mist and fog are also considered as cloud types because they are formed close to the earth surface. Meteorologists suggest that, weather can be determine according to the shape, height and movement of the clouds. Clouds are classified into three (3);

i) High clouds: whose height is between 6,000 to 12,000m above the earth surface. Examples include: Cirrus, cirrocumulus.
ii) Middle cloud: Middle cloud has two distinct parts namely: altocumulus and altostratus.
iii) Low cloud: Low clouds consist of three (3) layers namely: stratocumulus, nimbostratus and stratus clouds. These often bring dull weather to adjacent lands.

Cumulus and cumulonimbus are regarded as clouds with great vertical extent. Cumulus clouds are round topped and flat-based forming a whitish – grey globular mass, consisting of individual cloud units. On the other hand cumulonimbus cloud is a special type of cloud whose round tops are spread out in form of anvil. This type of cloud indicates convectional rainfall with a feature of thunder and lightning.

SELF ASSESSMENT EXERCISE

1. Define the word
   i.. Climate
   ii. Weather
2. List the elements of weather and climate and state what each is used for.
3. What type of rainfall is associated with your geographical area?

4.0 CONCLUSION

Weather describes the atmospheric condition of a place over a short period of time while climate explains the average weather condition of a place over a long period of time say 30 – 50 years. Both weather and climate are controlled by certain elements which include temperature, rainfall, humidity, cloud, atmospheric pressure, etc. These elements are measured using different instruments which are peculiar to the elements.

5.0 SUMMARY

In this unit, climate, weather and differences between climate and weather have been discussed. The study of climate is called climatology and climatologists are professionals who study the climate while the study of weather is called meteorology and those who study meteorology are called meteorologists.

In this unit, the elements of climate and weather alongside the instruments used for measuring each of the elements are considered; thermometer for measuring temperature, raingauge for rainfall, wind vane for measuring wind direction and anemometer for measuring wind speed. Barometer for measuring pressure and sunshine recorder for sunshine.

6.0 TUTOR-MARKED ASSIGNMENT

1. Differentiate between climate and weather
2. List the elements of climate and weather and state what each is used for.

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Oluwafemi, S. A. (1998). *Comprehensive Geography for Schools*: A Johnson Publishers Ltd, Nigeria.

UNIT 2 FACTORS CONTROLLING CLIMATE AND WEATHER

CONTENTS

1.0 INTRODUCTION

The climatic elements are controlled on a daily basis by the passage of the sun the nature of the weather systems and by local atmospheric factors such as local winds and air movements. In the longer term the climate is determined by the relationship of an area to the sun and by its position relative to major atmospheric features such as the permanent centres of high or low pressure, or the main components of the circulation. This unit will discuss the factors that control climate thereby creating variation in weather.

2.0 OBJECTIVES

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

- list the factors that control climate and weather
- discuss the role of these factors in controlling climate and weather.

3.0 MAIN CONTENT

3.1 Factors Controlling Climate and Weather

Climate varies based on location and as a result is influenced by the following factors:

3.1.1 Latitude

: The altitude of the sun is always high at the equator, resulting to hot condition within the latitudes of this region, those within the region where the sun's elevation is usually lower experience cold condition. Changes in latitudes cause changes in temperature and this brings about seasonal temperature changes.

3.1.2 Altitudes and Relief

This is described as the height of a place above the sea level and thus account for the reduction in temperature as one ascends higher. Areas of mountains and highlands always experiences cold climates. Altitudes reduces temperature at an average of about 6.5^{o}C for every 1000m of ascend while relief determines orographic rainfall.

3.1.3 The Nature of Ocean Currents

Ocean currents control the average weather which in the long term characterizes the climate. Ocean currents change the effects of winds blowing over them, thereby influencing the temperature of the coastal lands. A cold current causes the wind blowing over it to be cold and as such dry, whereas, a warm current causes the wind blowing over it to be warmed and moisture laden. The warm air from the seas often keep the immediate surrounding environment especially the lowlands warm, while the cold currents tend to have a reduction effect on summer temperature especially the onshore winds.

3.1.4 Prevailing Winds and the Location of the Main Pressure Centre

Wind blows from high pressure belts towards low pressure belts. When this happens, the climate of places or locations along their paths may be affected. The movement of winds brings about changes in temperature and relative humidity. This therefore, determines the type of precipitation that may occur in the location. The low pressure belt is usually situated along the equator while high pressure belts exist North and South of the equator.

3.1.5 Distribution of Land and Sea

This has a complex effect, for the land gains and losses heat rapidly than the sea. Thus, temperature range tends to be greater over the continents than over the oceans. The land surface warms up and cools down more quickly than the sea surface. Therefore, in temperate latitude, the sea warms coastal regions in winter, while in summer they are cooled by it. The temperature of such coastal areas is always affected by the influence of the cooled wind from the seas in summer and that of the warm wind from the sea in winter. (Briggs & Smithson, 1985).

SELF-ASSESSMENT EXERCISE

What are the factors that control weather and climate?

4.0 CONCLUSION

Climate and weather in any location are controlled by certain factors whose effects vary according to location. Latitudes, altitudes and relief, nature of ocean currents, prevailing winds and the location of the main pressure centres and the distribution of land and sea are the factors that control climate and weather.

5.0 SUMMARY

It is agreed that climate and weather are controlled by the altitude of the sun which always has high temperature at the equator, resulting to hot conditions within the latitudes of this region than places located far from the equator which usually have lower temperature resulting to cold conditions. Changes in latitudes cause changes in temperature and this brings about seasonal temperature changes. Altitudes and Relief describe the height of a place above the sea level and thus account for the reduction in temperature as one ascends higher. Areas of mountains and highlands always experience cold conditions. Altitudes reduce temperature at an average of about $6.5^{o}C$ for every 1000m of ascend while relief determines orographic rainfall. Ocean currents change the effects of winds blowing over them thereby influencing the temperature of the coastal lands. Prevailing wind blows from high pressure belts towards low pressure belts and when this happen, the climate of places along their paths may be affected determining the type of precipitation that may occur in the location. Distribution of land and sea has a complex effect on coastal areas by influencing the cooled wind from the seas in summer and that of the warm wind from the sea in winter.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the roles of the following factors in controlling climate and weather;
    a. Latitudes
    b. Altitudes and Relief
    c. Nature of Ocean currents
    d. Prevailing winds and the location of the main pressure centres
    e. Distribution of land and sea

7.0 REFERENCE/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

UNIT 3 IMPORTANCE OF CLIMATE AND WEATHER

CONTENTS

1.0 INTRODUCTION

Climate and weather control virtually all the activities of human beings. The importance of climate and weather as they affects agriculture and aviation among others will be discussed under this unit.

2.0 OBJECTIVES

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

- mention relevant areas where climate and weather significantly affect human activities and existence
- explain the importance of climate and weather on agriculture

3.0 MAIN CONTENT

3.1 Importance of Climate and Weather

3.1.1 Importance on Agriculture

Adequate knowledge of the atmospheric conditions of a place will assist farmers to plan for their various farming activities both seasonally and annually especially on rainfall regime. With good information to farmers, effective steps can be taken against hail, frost, heavy rainfall, drought and diseases.

3.1.2 Importance on Transportation and Communication

Transportation and communication can be enhanced where the atmospheric conditions is well understood. Air transport system requires an effective and reliable weather information before it can be successfully operated. Sailors at sea require adequate weather information at all times.

3.1.3 Importance on Mode of Dressing and Nature of Houses Built

A good knowledge of weather will assist in building the kind of houses that are suitable for our climate. The type of dresses used in any area is to a greater extent determined by the climatic and weather conditions obtainable in that particular area. For instance, in Polar regions where temperature is reduced, inhabitants wear thick and heavy clothing and a more higher clothing is used in the equatorial region where temperature is more or less high (Oluwafemi, 1998).

SELF-ASSESSMENT EXERCISE

1. Explain the importance of climate and weather to Agriculture.
2. Do you agree that weather conditions can negatively impact on human activities? Give your reasons.

4.0 CONCLUSION

In as much as climate and weather are controlled by certain factors, they equally play significant roles in human activities cutting across agriculture, transportation, communication, mode of dressing and houses built. Climate and weather control man's system of agriculture, transportation especially the aviation sector and communication. More so, climate plays a significant role on the mode of dressing and houses built to control the effects of temperature, sunshine and rainfall on human health and shelter.

5.0 SUMMARY

In this unit, the importance of climate and weather has been discussed as it affects agriculture, transportation and communication and mode of dressing as well as houses built. Farmers have the opportunity to plan for various farming activities both seasonally and annually, effective steps can be taken against drought and diseases. Transport systems are enhanced where atmospheric conditions are adequate; houses suitable for the type of climate are built and mode of dressing enhanced to suit the climate.

6.0 TUTOR-MARKED ASSIGNMENT

Mention five relevant areas where climate and weather can significantly affect human activities.

7.0 REFERENCE/FURTHER READING

Oluwafemi, S. A. (1998). *Comprehensive Geography for Schools*: A Johnson Publishers Ltd. Nigeria.

UNIT 4 THE DYNAMICS OF THE EARTH ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

Atmospheric dynamics encompasses all physical processes within atmospheres, including global and regional-scale circulation, convection, tropical cyclones, and inter-annual variability. Information about dynamics informs both short range weather forecasting and projections for medium to long term climate. This unit will explain fundamental set of physical principles and apply them in understanding large scale atmospheric motions, mathematical description of the atmospheric dynamics, thermodynamics of the atmosphere, forces of the atmosphere planetary waves, mid latitude cyclones, the planetary boundary layer, and aspects of the general circulation of the atmosphere.

2.0 OBJECTIVES

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

- explain applications of the thermodynamics of the earth atmosphere
- define the planetary boundary layer of the atmosphere
- describe the forces in the atmosphere planetary waves
- discuss the mid-latitude cyclones of the atmosphere
- describe the general circulation of the atmosphere

3.0 MAIN CONTENT

3.1 Thermodynamics of the Earth Atmosphere

Atmospheric thermodynamics is the study of heat to work transformations and the reverse in the atmospheric system in relation to weather or climate. Following the fundamental laws of classical thermodynamics, atmospheric thermodynamics studies phenomena such as properties of moist air, formation of clouds, atmospheric convection, boundary layer meteorology and vertical stabilities in the atmosphere. Atmospheric thermodynamics forms the basis for cloud microphysics and convection parameterizations in numerical weather models, and is in use in many climate considerations, including convection – equilibrium climate models. (Holton, 2004).

The atmosphere is a typical example of a non-equilibrium system. Atmospheric thermodynamics focuses on water and its transformations. The major role of atmospheric thermodynamics is expressed in terms of adiabatic and diabatic forces acting on air parcels included in primitive equations of air motion either as grid resolved or sub-grid parameterizations.

3.1.1 Applications of Thermodynamics

1) Hadley Circulation

In the application of thermodynamics, the Hadley circulation can be considered as a heat engine, identified with rising of warm and moist air in the equatorial region with the descent of cooler air in the subtropics corresponding to a thermally driven direct circulation with consequent net production of kinetic energy. The thermodynamic efficiency of the Hadley system, considered as a heat engine, has been relatively constant over the years, averaging 2.6%. The power generated by Hadley circulation between (1979-2010) according to Holton (2004) has risen at an average rate of about 0.54TW per year. This reflects an increase in energy input to the system consistent with the observed trend in the tropical sea surface temperatures.

2) Tropical Cyclone Cycle

The thermodynamics structure of the hurricane can be modeled as a heat engine running between sea temperature of about 300k and tropopause which has temperature of about 200k. Parcels of air travelling close to the surface take up moisture and warm, ascending air expands and cools releasing moisture (rain) during the condensation. The release of latent heat energy during the condensation provides mechanical energy for the hurricane. A decreasing temperature in the upper troposphere close to the surface will increase the maximum winds observed in hurricanes.

When applied to hurricane dynamics, it defines a carnot heat engine cycle and predicts maximum hurricane intensity.

3) Water Vapour and Global Climate Change

Clausius–Clapeyron relation shows how the water-holding capacity of the atmosphere increases by about 8% per Celsius increase in temperature. This water holding capacity can be approximated using August-Roche-Magnus formula.

$$\text{E.g. T} = 6.1094\exp\left(\frac{17.625T}{T+243.04}\right)$$

Where e.g. T is the equilibrium or saturation vapour pressure in pha, and T is temperature in degree Celsius. This shows that, when atmospheric temperature increases due to greenhouse gases, the absolute humidity should also increase exponentially, assuring a constant relative humidity. However, this pure thermodynamics argument is subject of consideration because convective processes might cause extensive drying due to increased areas of subsidence and efficiency of precipitation could be influenced by the intensity of convection and because cloud formation is related to relative humidity.

3.2 Forces in the Atmosphere Planetary Waves

Planetary waves are often called Rossby waves. They are natural phenomena in the atmosphere and oceans of planets that largely owe their properties to rotation. In other words, it is a periodic disturbance in the fields of atmospheric variables such as surface pressure or geo-potential height, temperature or wind velocity which may either propagate (travelling wave) or not (standing wave). Atmospheric waves range in spatial and temporal scale from large scale planetary waves (Rossby waves) to minute sound waves. Atmospheric waves with periods which are harmonics of one solar day are known as atmospheric tides.

The mechanism for the coring of the waves can vary significantly. Generally waves are either exerted by heating or dynamic effects. For instance the obstruction of the flow by mountain barrier like Rocky Mountains in the USA or the Alps in Europe. Heating effects can be on a small-scale like the generation of gravity waves by convection or large-scale (formation of Rossby) waves by the temperature contrast between continents and oceans in the Northern hemisphere winter. Atmospheric wave transport momentum which is fed back into the background flows as the wave dissipates. This wave forcing of the flow is particularly important in the stratosphere where this momentum deposition by planetary scale Rossby waves gives rise to sudden stratospheric warming and the deposition by gravity waves gives rise to the quasi-biennial oscillation. In the mathematical description of the atmospheric waves, spherical harmonics are used when considering a section of a wave along a latitude circle, this is equivalent to a sinusoidal shape.

3.3 Mid-Latitude Cyclone

These are large travelling atmospheric cyclonic storms up to 2000 kilometers in diameter with centres of low atmospheric pressure. An intense mid-latitude cyclone may have a surface pressure as low as 970 millibars, compared to an average sea-level pressure of 1013 millibars. Mid-latitude cyclones are the result of the dynamic interaction of warm tropical and cold polar air masses at the polar front. This interaction causes the warm air to be cyclonically lifted vertically into the atmosphere where it combines with colder upper atmosphere air. This process helps to transport excess energy from the lower latitudes to the higher latitudes. The mid-latitude cyclone is rarely motionless and commonly travels about 1200 kilometers in one day. Its direction of movement is generally eastward. Precise weather movement of weather system is controlled by the orientation of the polar jet stream in the upper troposphere. Mid-latitude cyclones can produce a wide variety of precipitation types such as rain, freezing rain, hail, sleet, snow pellets, and snow.

3.4 The Planetary Boundary Layer (PBL)

The lowest layer of the atmosphere is called the troposphere. The troposphere can be divided into two parts: a planetary boundary layer (PBL) extending upwards from the surface to a height that ranges anywhere from 100 to 2000m and above it, (the free atmosphere). The PBL is directly influenced by the presence of the earth surface, responding to such forcing as frictional drag, solar heating and evaporation. Each of these generates turbulence of various sized eddies, which can be as deep as the boundary layer itself lying on top of each other. PBL model is used for weather forecasting.

3.5 General Circulation of the Atmosphere

Climate and general circulation of the atmosphere are related to energy balance, transportation processes and the three cell model. Energy balance of the incoming solar radiation and the outgoing terrestrial radiation emitted by the earth is nearly balance over the year. When average over a latitude band, incoming radiation is a surplus in the tropics and deficit of radiation is found in the polar region due the outgoing terrestrial radiation being larger than the absorbed solar radiation. To compensate for the surplus and deficit of radiation in different regions of the globe, atmospheric and oceanic transport processes distribute the energy equally around the earth. This transport is accomplished by atmospheric winds and ocean currents.

SELF-ASSESSMENT EXERCISE

1. Explain the 3 applications of thermodynamics
2. Describe the general circulation of the atmosphere

4.0 CONCLUSION

The dynamics of the earth atmosphere has been discussed with reference to thermodynamic, forces of planetary waves, mid-latitude cyclones planetary boundary layers, and general circulation of the atmosphere.

5.0 SUMMARY

It is agreed that, corriolis force plays significant role in the activities of the atmospheric processes during rotation of the earth, the severity of effects depends on the magnitude of effects exerted at a given location. The earth atmosphere is not stationed but changes occur at different times and different region thereby bringing variation in weather and climatic conditions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the working of the forces in the atmosphere planetary waves
2. What do you understand by the planetary boundary layer?
3. What are mid-latitude cyclones of the atmosphere?

7.0 REFERENCES/FURTHER READING

Holton, J. R. (2004). *An Introduction to Dynamic Meteorology*. Elsevier Publishers.

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MODULE 3 RADIATION AND HEATING OF THE ATMOSPHERIC SYSTEMS

UNIT 1 MEANING, PRINCIPLES AND LAWS OF RADIATION

CONTENTS

1.0 INTRODUCTION

The sun provides 99.97% of the energy required for all the physical processes that take place on the earth and the atmosphere. As a result of absorbed insolation, different types of radiant heat or radiation flow throughout the earth-atmosphere system, and inputs and outputs of radiation are balanced at the planetary system. This unit focuses attention on the meaning of radiation, principles of radiation and the laws of radiation.

2.0 OBJECTIVES

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

- define and explain the concept of radiation
- discuss the principles of radiation
- state and explain the laws of radiation

3.0 MAIN CONTENT

3.1 Meaning of Radiation

Radiation may be regarded as a transmission of energy in the form of electromagnetic waves. The wave length of radiation is the distance between two successive wave crests. This wave length caries in different types of radiation and is inversely proportional to the temperature of the body that send it out. The higher the temperature at which the radiation is emitted, the shorter the wavelength of the radiation. The sun has a surface temperature of about 6900^{o}C, whereas the average surface temperature of the earth is approximately 15^{o}C. Thus, radiation coming from the sun is short-wave radiation and that emitted from the earth is long wave radiation. There is a wide spectrum ranges from very short waves, such as cosmic rays and gamma rays to very long waves, such as radio-and electric – power waves. (Briggs and Smithson, 1985; Blij, Muller, Williams, Conrad & Long, 2005).

3.2 Principles of Radiation

Radiant energy consist of electromagnetic waves of varying lengths. Any object whose temperature is above absolute zero (0K or -273.15^{o}C) emits radiant energy. The intensity and the character of this radiation depends on the temperature of the emitting object. As the temperature rises, the radiant energy increases in intensity but its wavelength decreases as the wavelength expands. The amount of radiation reaching any object is inversely proportional to the square of the distance from the sources. This distance decay factor account for the difference in solar inputs to the various planets in the solar system.

To a certain extent radiation is able to penetrate matter as exemplified in the x-rays which can pass through the human body. However, most radiant energy is either absorbed or reflected by objects in its path. An absorption occurs when the electromagnetic waves penetrate but do not pass through the object. The ability of an object to absorb or reflect radiant energy depends on a number of factors, including the detailed physical structure of the materials, its colour and surface roughness, the angle of the incident radiation and the wavelengths of the radiant energy.

An object which is able to absorb all the incoming radiation is referred to as a black body, although this has conceptual value. A perfect black body does not exist in reality. All objects absorb a proportion of the incoming energy and reflect the remainder. Variation also occurs according to the wave length of the energy.

When radiant energy is reflected by an object, very little change in the nature of the radiation occurs, although the effect may be to scatter the radiation. Scattering changes the direction of the incoming radiation without directly affecting its wavelength.

3.3 Laws of Radiation

The following are the radiation laws;

1. All substances emit radiation as long as their temperature is above absolute zero (0K or -237.15^{o}C)
2. Some substances emits and absorb radiation at certain wavelengths only. This is mainly true of gases
3. If the substance is an ideal emitter (black body) the amount of radiation given off is proportional to the fourth power of its absolute temperature. This is known as the Stefan-Boltzmann law and can be represented as E=GT4 where G is a constant (the Stefan-Boltzmann constant) which has a value 5.67 x $10^{-8}WM^{-2}K^{-4}$ and T is the absolute temperature.
4. As substances get hotter, the wavelengths at which radiation is emitted will become shorter. This is called Wien's displacement law which can be represented as Xm = a/T where Xm is the wavelength, T is the absolute temperature of the body and 'a' is a constant with a value of 2898 if Xm is expressed in micrometers.
5. The amount of radiation passing through a particular unit area is inversely proportional to the square of the distance of that area from the source ($1/d^2$).

SELF-ASSESSMENT EXERCISE

1. State the laws of Radiation
2. Explain the laws of Radiation relating each to your day to day experiences

4.0 CONCLUSION

Radiation is the transmission of energy in form of electro-magnetic wave. The energy released by the sun reaches the earth surface in form of short wave and absorbed into the long-infra red heat energy capable of heating the atmosphere through radiation, conduction and convection.

5.0 SUMMARY

In this unit, the meaning of radiation, principles and laws of radiation have been discussed. A body capable of absorbing all the energy released by the sun is called a perfect black body, but unfortunately nobody can absorb all. Instead, bodies absorb some and reflect some.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define and explain the concept of radiation
2. Discuss the principles of radiation

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Blij, H. J.. Muller, P. O., Williams, R. S., Conrad, C.T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

UNIT 2 ENERGY IN THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

The atmosphere is described as a dynamic, constantly churning component of a gigantic heat engine. The engine is being fuelled by incoming solar radiation (insolation). This unit will expose you to the concept of atmosphere and its energy systems.

2.0 OBJECTIVES

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

- explain the concept of atmosphere
- discuss the regions of atmosphere
- illustrate the vertical region of the atmosphere
- illustrate the variation of atmospheric temperature with height
- provide explanation on the energy system
- illustrate the schematic presentation of the solar energy cascade

3.0 MAIN CONTENT

3.1 The Atmosphere

The atmosphere may be broadly divided into two vertical regions. The lower region called the hemisphere, extends from the surface to 80 – 100km above the earth and has a more or less, chemical composition. Beyond this level, the chemical composition of the atmosphere changes in the upper region known as heterosphere. The hemisphere is the more important of the two atmospheric regions for human beings because we live in it. It contains three major groups of components; they are constant gases, variable gases and impurities (Briggs and Smithson, 1985; Blij, Muller, Williams, Conrad and Long, 2005).

Constant Gases: Two major constant gases make up 99% of the air by volume, and both are critical to sustaining human and other forms of terrestrial life. They are nitrogen (n) which constitutes 78% of the air and oxygen (O_2) which accounts for another 21%. Survival depends on oxygen and nitrogen. The oxygen and nitrogen is relatively inactive but bacteria convert it into other nitrogen (n) compounds essential for plant growth.

Variable Gases*:* They collectively constitute only a tiny proportion of the air. They contain certain atmospheric grades in varying quantities essential to human well-being. Examples include; carbon-dioxide (Co_2) 0.04% of dry air and is a significant constituent of the atmosphere in terms of its climatic influence and vital function in photosynthesis. Water vapour is an invisible gaseous form of water (H_2O), more sufficient in capturing radiant energy because of its storage capacity. Ozone (O_3) is a rare type of oxygen molecule, composed of three oxygen atoms instead of two, laying between 15km and 50km above the earth. It has the ability to absorb radiant energy, in particular the ultraviolet radiation associated with incoming solar energy. Other variable gases present in the atmosphere include; hydrogen, helium, sulphur dioxide, oxides of nitrogen, ammonia, methane and carbon monoxide. Some of these are air pollutants. They can produce harmful effects even when concentrations are one part per million (ppm) or less.
Impurities: The atmosphere contains great number of impurities in form of aerosols (tiny floating particles suspended in the atmosphere). Impurities play an active role in the atmosphere. Many of them help in the development of clouds and rain drops. Examples of aerosols include; dust, smoke, salt crystals, bacteria and plants spores.

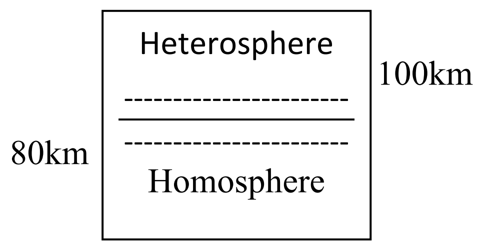

Fig. 1: Vertical Region of the Atmosphere

The atmosphere is an envelope of transparent, odourless gases held to the earth by gravitational attraction. The furthest limit of the atmosphere is said by international convention to be 10000km.Most of the atmosphere, and therefore our climate and weather is concentrated within 16km of the earth's surface at the equator and 8km at the poles. Fifty percent of atmospheric mass is within 5.6km of sea level and 99 percent is within 40km. Atmospheric pressure decreases rapidly with height and temperature. Changes in temperature means that the atmosphere can be conveniently sub-divided into four distinct layers: bottom layer (troposphere), upper boundary (tropopause), stratosphere and stratospause.

The bottom layer of the atmosphere, where temperature usually decreases with an increase in altitude, is called troposphere. The rate of a decline in temperature is known as Lapse rate, and in the troposphere, the average lapse rate is 6.5^{o}C/1000m. The upper boundary of the troposphere, which temperature stop decreasing with height, is called the tropopause.

Beyond this continuity, is a layer called stratosphere, temperatures either remain constant or start increasing with altitude. Layers in which the temperature increases with altitude exhibit positive lapse rates. These are called temperature inversions because they inverse or reverse what is believed to be the normal state of temperature change with elevation i.e. a decrease with height.

As the top of the stratosphere is approached, beyond 52km above the earth, temperatures remains constant with increasing altitude. This boundary zone is called the stratopause, and is topped by a layer known as the mesosphere. In the mesosphere, temperatures again fall with height, as they did in the troposphere. Eventually the decline in temperature stops at a boundary called menopause. This occurs at about 80km above the earth's surface. Not far beyond the mesopause, temperature once more increase with height in a layer called the thermosphere.

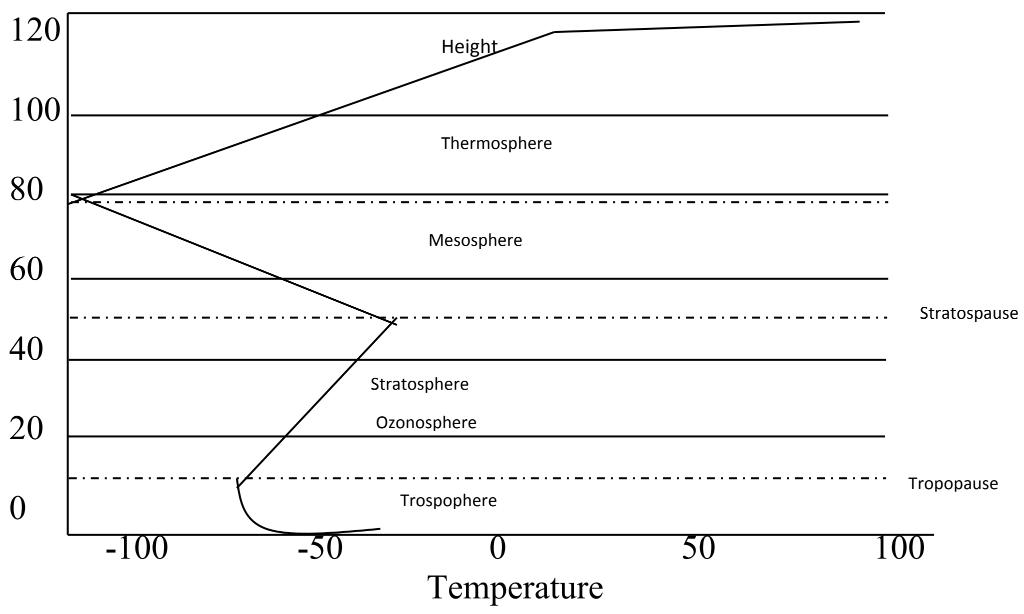

Fig. 2: Variation of Atmospheric Temperature with Height

3.2 The Energy System

The sun is the earth's prime source of energy. The earth receives energy as incoming short wave solar radiation (also referred to as insolation). It is this energy that controls the planet's climate and weather, which when converted by photosynthesis in green plants, supports all forms of life. The amount of incoming radiation received by the earth is determined by four astronomical factors;

i. The solar constant
ii. The distance from the sun
iii. The altitude of the sun in the sky
iv. The length of night and day

It is a theoretical assumption that there is no atmosphere around the earth. In reality, much insolation is absorbed, reflected and scattered as it passes through the atmosphere. Absorption of incoming radiation is mainly by ozone (O_3), water vapour, carbon dioxide and particles of dust, ice and clouds and, to a lesser extent, the earth's surface reflects a considerable amount of radiation back to space. The ratio between incoming radiation and the amount reflected expressed as a percentage is known as albedo. The albedo varies with cloud type from 30-40 percent in thin clouds, to 50-70 percent in thicker stratus and 90 percent in cumulo-nimbus (when only 10 percent reaches the atmosphere below cloud level). Albedos also vary over different land surfaces, from less than 10 percent over oceans and dark soil, to 15 percent over coniferous forest and urban areas, 25 percent over grasslands and deciduous forest, 40 percent over light coloured deserts and 85 percent over reflecting fresh snow. Where deforestation and overgrazing occur, the albedo increases. This reduces the possibility of cloud formation and precipitation and increases the risk of desertification. Scattering occurs when incoming radiation is diverted by particles of dust, as from volcanoes and deserts, or by molecules of gas. It takes place in all directions and some of the radiation will reach the earth's surface as diffuse radiation. As a result of absorption, reflection and scattering, only about 24% of incoming radiation reaches the earth's surface directly, with a further 21% arriving at ground level as diffused radiation. Incoming radiation is converted into heat energy when it reaches the earth's surface. As the ground warms, it radiates energy back into the atmosphere where 94% is absorbed (only 6% is lost to space), mainly by crater vapour and carbon dioxide, the green house (effect which traps so much of the outgoing radiation). This outgoing (terrestrial) radiation is known as long-wave or infra-red radiation.

Schematic presentation of the solar energy cascade

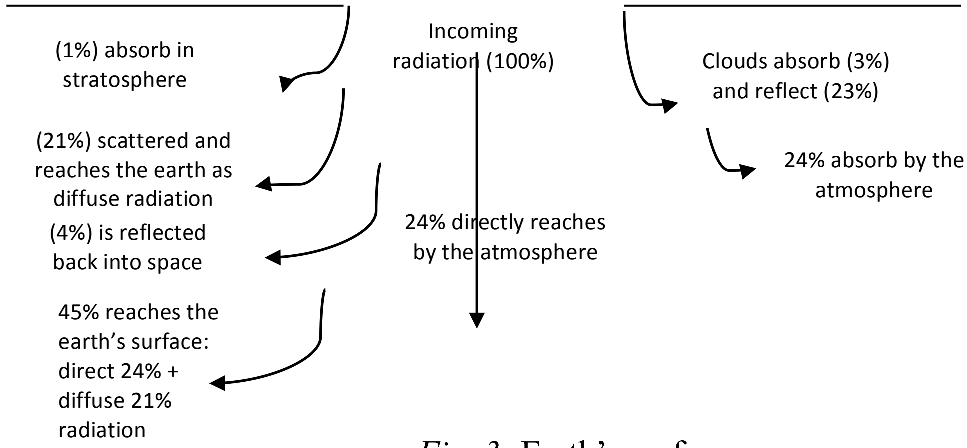

Fig. 3: Earth's surface

Radiant Energy: is the most relevant to our discussion, for it is in this form that the sun's energy is transmitted to the earth. The heat from the sun exerts or disturbs electric and magnetic fields, setting up a wave-like activity in space. The length of these waves – that is, their distance apart varies considerably, so that solar radiation comprises a wide range of electromagnetic wave length, only a very small proportion of these are visible to the human eye reaching the earth surface as light. However, it takes about 81/3 minutes to transit energy from the sun the earth (15-107km). On passing through the atmosphere which surrounds the earth, some of this radiant energy is reflected or absorbed. Because of this interception not all the radiant energy finds its way to the earth's surface. That which does, and that which is absorbed by the atmosphere is converted from radiant to other forms of energy. (Briggs and Smithson, 1985)

Thermal Energy: This is obtained from the conversion of radiant energy. It warms the earth's surface and the atmosphere by exerting the molecules of which they are composed. In simple terms, the radiant energy is transmitted into the molecules making up the earth and atmosphere.

Thermal energy which involves disturbance of magnetic and electric fields can therefore be considered as energy involved in the motion of extremely small components of matter, sometimes referred to as kinetic energy of molecules.

Kinetic Energy: This is the energy of motion. Any moving object possesses kinetic energy, and it is through the utilization of this energy that a stone thrown into a lake can disturbed the water to the extent of producing waves. It is also through the exploitation of kinetic energy that turbines and engines are able to produce heat, light and so on.

Potential Energy: This is related to gravity because of the apparent pull that the earth exerts upon objects within its gravitational field, material is drawn toward the earth's centre. Thus, objects lying at greater distances from the earth centre.

SELF-ASSESSMENT EXERCISE

Discuss with a diagrammatic illustration the vertical region of the atmosphere

4.0 CONCLUSION

Thermal, kinetic and potential energy are important to the earth's system but operate internally and so cannot be absorbed directly from space but impact is greatly felt.

5.0 SUMMARY

In this unit, the atmosphere and energy systems have been widely explained with focus on the components of the atmosphere and the energy system as they relate to forms and types such as thermal, kinetic, potential and radiant.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the concept and components of the atmosphere
2. Discuss the regions of the atmosphere
3. Illustrate the variation of atmospheric temperature with height
4. Provide explanation on the energy system of the atmosphere
5. Schematically present the solar energy cascade

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Blij, H. J., Muller, P. O., Williams, R. S., Conrad, C .T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

UNIT 3 HEATING OF THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

In unit one, you studied the meaning, principles and laws of radiation, whereby, you learn that radiation may be regarded as a transmission of energy in the form of electromagnetic waves. You also discovered that any object whose temperature is above absolute zero (OK-273.15E) emits radiant energy. And as the temperature rises, the radiant energy increase in intensity. The amount of radiation passing through a particular unit area is inversely proportional to the square of the distance of that area from the source – ($1/d^2$).

While in unit 2, you learned about the atmosphere, what happens within the regions of the earth's atmosphere and its energy system. You saw that, not all the radiant energy finds its way to the earth's surface because, on passing through the atmosphere, some of this energy is reflected or absorbed.

In this unit, you will learn how the atmosphere is being heated.

2.0 OBJECTIVES

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

- explain the term Short-wave energy
- define Long-wave energy and
- heat balance

3.0 MAIN CONTENT

3.1 Processes of Heating

The earth does more than absorb or reflect shortwave insulation; it constantly gives off long wave radiation on its own. When the earth's land masses and oceans absorb shortwave radiation. It triggered rise in temperature, and the heated surface now emits long wave radiation. One or two things can happen to this radiation leaving the planetary surface; either it is absorbed by the atmosphere or it escapes into space.

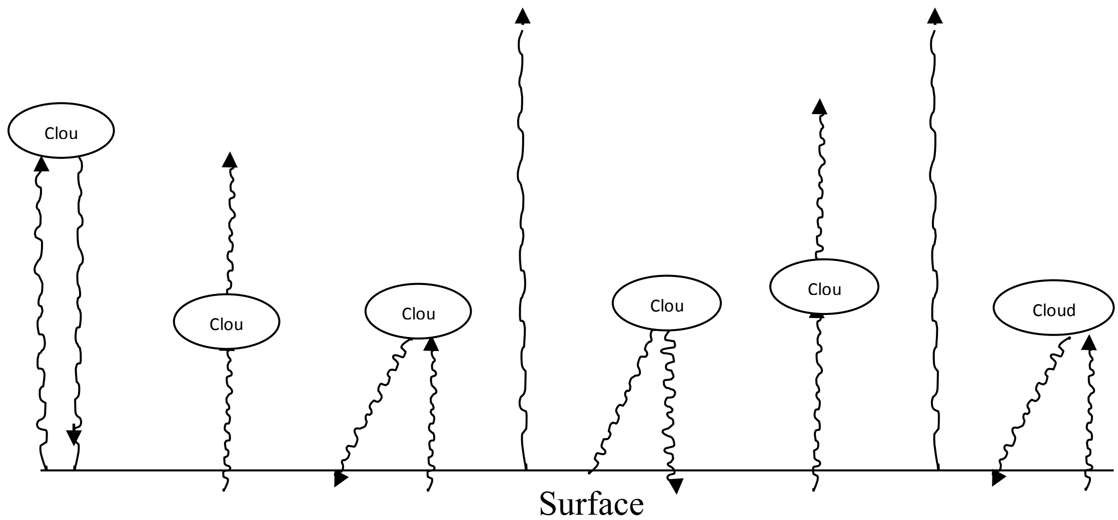

Fig. 4: Long Wave Radiation Emitted By the Earth

The major atmospheric constituent that absorbs the earth's long wave radiation are carbon dioxide, water vapour, and ozone. Each of these variable gases absorbs radiation at certain wavelengths but allows other wavelengths to escape through an atmospheric "window." Up to 9 percent of all terrestrial radiation is thereby lost to space, except when the window is shut by clouds. Clouds absorb or reflect back to earth almost all the outgoing long wave radiation. Therefore, a cloudy winter night is likely to be warmer than a clear one.

The atmosphere is heated by the long wave radiation it absorbs. Most of this radiation is absorbed at the lower, dense levels of the atmosphere, a fact that helps account for air's higher temperatures near the earth's surface. Thus, our atmosphere is actually heated from below, not directly by the sun above. The atmosphere itself, being warm, can also emit long wave radiation. Some goes off into space, but some known as counter-radiation, is reradiated back to the earth. Without this counter radiation from the atmosphere, the earth's mean surface temperature would be about -20^oC, 35^oC colder than its current average of approximately 15^oC. The atmosphere, therefore, acts as a blanket.

The blanket effect of the atmosphere is similar to the action of radiation and heat in a garden greenhouse. Shortwave radiation from the sun is absorbed and transmitted through the greenhouse glass windows, strikes the interior surface, and is converted to heat energy. The long wave radiation generated by the surface heats the inside of the greenhouse. But the same glass that let the short wave radiation now acts as a trap to prevent that heat from being transmitted to the outside environment, thereby raising the temperature of the air inside the greenhouse.

A similar process takes place on the earth, with the atmosphere replacing the glass. Not surprisingly, this is called the basic natural process of atmospheric heating greenhouse effect. Human being may be influencing the atmosphere's delicate natural processes through series of activities which may trigger sequence of events that could heighten a global warming trend with possibly dire consequences for near-future environmental change. (Blij, Muller, Williams, Conrad, Long, 2005).

3.2 Short-Wave Energy in the Atmosphere

Sunlight first enters the atmosphere and passes through the mesosphere with little change. In the stratosphere, the density of atmospheric gases increases. There is more oxygen available which reacts with the shortest or ultra-violet wavelengths and effectively removes them, warming the atmosphere in the process. It is in the troposphere that most effects take place. In the upper troposphere, the atmosphere is relatively dense with a pressure of about 20% of that at the surface. The size of the gas molecules of the air is such that they interact with the insolation, causing some of it to be scattered in many directions. This process depends on wavelength. The shorter waves are scattered more than the longer waves so we have these scattered waves as blue sky. If the reverse were true, the sky would be permanently red, and if there were no atmosphere, as on the moon, the sky would be black. Dust and haze in the atmosphere produce further scattering, but not all of this is lost.

Some of the scattered radiation is returned to space, but much is directed downwards the surface as down-scatter or diffuse radiation. This is also the type of radiation which is experience during cloudy conditions with no direct sunlight when the solar beam is 'diffused' by the water droplets or ice particles. Without diffuse radiation, everything we see would either be very bright, when in direct sunlight, or almost black when in shadow.

Another type of short wave energy loss is absorption. The gases in the atmosphere absorb some wavelengths as cloud equally do. In this manner, the atmosphere is warmed though the amounts involved are small. The most important loss of short-wave radiation in its path through the atmosphere is by reflection. The water droplets or ice crystals in clouds are very effective in reflecting insolation. The degree of reflection is usually called the albedo. Albedo is normally expressed as a ratio of the amount of reflected radiation divided by the incoming radiation, if multiply by 100, this can be expressed as a percentage.

The sunlight reaching the earth's surface which is not reflected, the radiation is returned to space in the short wave form and becomes part of the outflow of energy from the earth.

3.3 Long Wave Energy in the Atmosphere

All substances emit long wave radiation in proportion to their absolute temperatures. The earth's surface receives most short wave radiation and therefore normally has the highest temperatures. It follows from this form that, most long wave emission will be from the ground surface. The atmosphere is much more absorbent to long wave radiation than to shortwave radiation. Carbon dioxide and water vapour are much more effective absorbers of much of the longer part of the spectrum.

Clouds are also more effective at absorbing long wave radiation hence, their temperature will be higher than otherwise. This cloud effect is most noticeable at night. With clear skies, radiation is emitted by the surface but little is received from the atmosphere and therefore, the temperature falls rapidly. If the sky is cloudy, the clouds will absorbs much of the radiation from the surface and, because they are also emitters, more of the radiation will be returned to the grounds as counter radiation than if the sky had been clear (Briggs, Smithson, 1985).
Some of the radiation given off by the surface is lost to space but majority gets caught up in the two-way exchange between the surface and the atmosphere.

3.4 Heat Balance

Climate is often considered to be something derived from the atmosphere, and it is true that the climate of a place is essentially the result of the redistribution of heat energy across the face of the earth. However, the events of the atmosphere are greatly affected by the processes that operates on the earth's surface itself. Flows of heat energy to and from the surface are as much as part of the climate of an area as the winter snow or summer thunderstorm, in fact, because these heat energy flows operate continuously.

The heat energy balance of the earth's surface is composed in its simplest form of four different kinds of flows. One of these is the composite flows of radiant heat that makes up net radiation the second is latent heat which causes evaporating liquids to change to gases. All the air molecules contain heat energy, the heat that we feel on our skin, and this sensed heat is termed sensible heat flow. Usually during the day, the ground warms the air above it. Warm air rises, and parcels of air move upward in a vertical heat-transfer process known as convection, thereby causing a sensible heat flow.

Whereas, sensible heat flow depends on convection, the heat that flows into and out of the ground depends on conduction, the transport of heat energy from one molecule to the next. The heat that is conducted into and out of the earth's surface is collectively called ground heat flow or soil heat flow. This is the smallest of the four heat balance components.

Generally, the heat that passes into the ground during the day is approximately equal to that flowing out at night. Thus, over a 24 hour period, the balance of ground heat flow often is so small that it can be disregarded. Except for the usually small amount of energy used by plants in photosynthesis, the total heat balance of any part of the earth is made up of the flows of radiant heat, latent heat, sensible heat and ground heat.

SELF-ASSESSMENT EXERCISE

Clouds are more effective in absorbing long wave radiation. Explain

4.0 CONCLUSION

The sun releases energy in form of short wave and the earth inform of long-wave. The cloud play significant role in absorbing and reflecting greater proportion of these energy as seen in the effect of cloud that appears thin and thick respectively.

5.0 SUMMARY

In this unit, the heating of the atmosphere have been discussed with emphases on the long-wave, short wave and heat balance with the planet earth.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the following with relevant examples
   a. short-wave energy
   b. long-wave energy
   c. heat balance

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Blij, H. J., Muller, P. O., Williams, R. S., Conrad, C. T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

MODULE 4 ATMOSPHERIC MOISTURE

UNIT 1 FORMS OF WATER AND HEAT TRANSFERS

CONTENTS

1.0 INTRODUCTION

The physical world is characterized by energy flow which continually pass from one place to another on land, within the land and in the atmosphere. This unit looks at the ability of water to exist in three physical states and the process of transfer and energy required to transfer water from one state to another.

2.0 OBJECTIVES

At the end of the unit, you should be able to;

- discuss the various forms of water
- explain the different processes of heat transfer
- identify the energy required to transfer water from one state to another

3.0 MAIN CONTENT

3.1 Forms of Water

3.1.1 The Solid Form

The solid form of water, ice is made up of molecules that are linked together in a uniform manner. When there is enough heat energy, the bonds that link molecules together are broken making ice to change its state to become the liquid form which is known as water. Molecules in the liquid form are not evenly spaced though they exist together, moving around freely. (Goudie, 1986).

3.1.2 The Liquid Form

Water is a liquid compound which is converted by heat into vapour (gas) and by cold into solid (ice). The presence of water serves three essentials purposes:

a. It maintains life on earth: Flora, in the form of natural vegetation (biomes) and crops, and fauna, i.e. all living creatures, including humans.
b. Water in the atmosphere, mainly as a gas, absorb reflects and scatters insolation to keep our plant at a habitable temperature
c. Atmospheric moisture is of vital significance as a means of transferring surplus energy from tropical areas either horizontally to polar latitudes or vertically into the atmosphere to balance the heat budget.

Despite this need for water, its existence in a form readily available to plants, animals and humans is limited. It has been estimated that 97.2% of the world's water is in the oceans and seas. In this form, it is only useful to plants tolerant to saline conditions (halophytes) and to the populations of a few wealthy countries that can afford desalinization of plants.

Approximately 2.1% of water in the hydrosphere is held in storage as polar ice and snow. Only 0.7% fresh water found either in lakes and rivers (0.1%) as soil moisture and ground water (0.6%) or in the atmosphere. At any given time, the atmosphere only holds, on average, sufficient moisture to give every place on the earth 2.5cm (about 10 days supply) of rain. There must therefore be a constant recycling of water between oceans, atmosphere and cloud. This recycling is achieved through the hydrological cycle.

3.2 Measuring Water Vapour

Humidity is a measure of the water vapour content in the atmosphere. Absolute humidity is the mass of water vapour in a given volume of air measured in grams per cubic metre (g/m^3). Specific humidity is similar but expressed in grams of water per kilogram of air (g/kg). Humidity depends upon the temperature of the air. At any given temperature, there is a limit to the amount of moisture that the air can hold. When this limit is reached, the air is said to be saturated. Cold air can hold only relatively small quantities of vapour before becoming saturated but this amount increases rapidly as temperatures rise.

This means that the amount of precipitation obtained from warm air is generally greater than that from cold air. (Briggs, and Smithson, 1985).

Relative humidity (RH) is the amount of water vapour in the air at a given temperature expressed as a percentage of the maximum amount of vapour that the air could hold at that temperature. If the RH IS 100% the air is said to be 'moist' and the weather is humid or clammy. When the RH drops to 50%, the air is 'dry". Figures as low as 10% have been recorded over hot deserts. If unsaturated air is cooled and atmospheric pressure remains constant, a critical temperature will be reached when the air becomes saturated (i.e. RH – 100%). This is known as dew point. Any further cooling will result in the condensation of excess vapour, either into water droplets where condensation nuclei are present, or into ice crystal if the air temperature is below 0^oC.

This is shown in the following work examples.

1. The early morning air temperature was 10^oC. Although the air could have held 100 units of water at that temperature, at the time of reading it held only 90. This means that the RH was 90%.
2. During the day, the air temperature rose to 12^oC. A s the air warmed it became capable of holding more water vapour, up to 120 units. Owing to evaporation, the reading reached a maximum of 108 units which meant that the RH remained at 90% i.e. 108/120) x 100.
3. In early evening, the temperature fell to 10^oC at which point, as stated above, it could hold only 100 units. However, the air at that time contained 108 units, so, as the temperature fell, dew points was reached and the 8 excess units of water were lost through condensation.

3.3 Hydrological Cycle

The hydrological cycle model consists of a number of stages showing the relative amounts of water involved in each.

1. The largest amounts of water transferred in any component of the total cycle are those involved in the direct evaporation from the sea to the atmosphere and in precipitation back to the sea. Evaporation is the process by which water changes from liquid to gaseous (vapour) form. Precipitation includes any liquid water or ice that falls to the surface through the atmosphere.
2. The passage of water to the atmosphere through leaf pores is called transpiration and the term evapotranspiration encompasses the joint processes by which water evaporates from land surface and transpires from plants. Evapotranspiration combines the precipitation of water on land and plant surface to play a quantitatively smaller, but possibly more important part in the hydrological cycle.
3. If surplus precipitation at the land surface does not evaporate, it is removed via the surface network of streams and rivers, a phenomenon called Runoff. The run off value includes some water that infiltrates (penetrates) the soil and flows beneath the surface, eventually finding its way to rivers and the ocean.

SELF-ASSESSMENT EXERCISE

1. Differentiate between absolute humidity, specific humidity and relative humidity.
2. Relate how each type of humidity acts as an agent of heat transfer.

4.0 CONCLUSION

Despite the great need for water as a major source of human existence, its presence in a form readily available to plants, animals and humans is limited. The mass of water vapour in a given volume of air is the main source of heat transfer in the atmosphere. The forms in which water exist, stores and used is what translates into the hydrological cycle and as well form the basis for the atmospheric moisture.

5.0 SUMMARY

This unit has discussed in detail water in different forms, different types of humidity and how they act as agents of heat transfer. The three major stages of the hydrological cycle have also been discussed elaborately in unit.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the two different forms of water
2. Explain the three major stages of the hydrological cycle.

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Goudie, A. (1986). *The Human Impact on the Environment*. London: Basil Blackwell Ltd.

UNIT 2 CAUSES OF ATMOSPHERIC CIRCULATION

CONTENT

1.0 INTRODUCTION

This unit will explain the causes of atmospheric circulation. The basic factors that explain the circulation of air in the atmosphere; latitudes and the earth rotation and what makes the earth receives an unequal amount of heat energy at different latitudes and the earth rotation will be explained.

2.0 OBJECTIVES

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

- describe the concept of latitude as it affects atmospheric circulation
- explain the phenomenon of earth rotation as a cause of atmospheric circulation

3.0 MAIN CONTENT

3.1 Latitudes and Earth Rotation as Cause af Atmospheric Circulation

The sun strike the earth's surface at higher angles, and therefore at great intensity in the lower latitudes than in the higher latitudes. The equator receives about two and one-half times as much annual solar radiation as the poles do.

If this latitudinal imbalance of energy were not somehow balanced, the low-latitude regions would be continually heating up and the Polar Regions cooling down. Energy in the form of heat is transferred by atmospheric circulation (and to a much lesser extent oceanic circulation). Briggs, Smithson, 1985).

The simple rotation of the earth complicates the operation of the general atmospheric circulation. The most important effect is expressed as an apparent deflective force. This deflective force affecting movement on a rotating body is called the coriolis force. If the earth did not rotate and was composed of entirely land or water, there would be one large convection cell in each hemisphere. Surface winds would be parallel to pressure gradients and would blow directly from high to low pressure areas. In reality, the earth does rotate and the distribution of land and sea is uneven, consequently more than one cell is created as rising air warm at the equator loses heat to space and there is less cloud cover to retain it as it travels further from its source of heat.

Moving air tends to be deflected to the right in the northern hemisphere and to the left in the southern hemisphere by coriolis force.

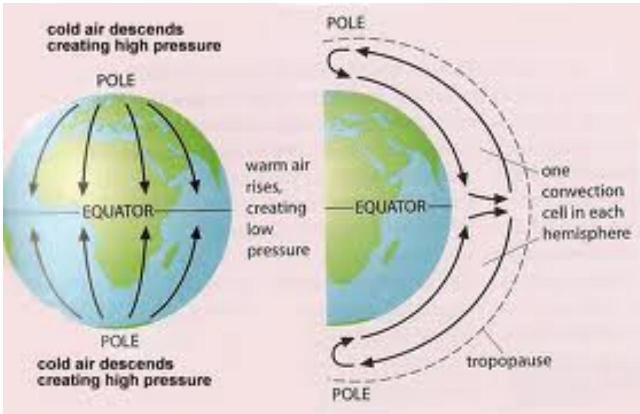

Fig. 1: Air Movement on a Rotation Free Earth

The earth's rotation through 360^o every 24 hours means that a wind blowing in a northerly direction in the northern hemisphere appears to have been diverted to the right on a curved trajectory by 15^o of longitude for every hour. This helps to explain why the prevailing winds blowing from the tropical high pressure zone approach Britain from the south-west rather than south. In theory, if the Coriolis force acts alone, the resultant wind would blow in a circle.

Winds in the upper troposphere, unaffected by friction with the earth's surface, shows that there is a balance between the forces exerted by the pressure gradient and the coriolis deflection. The result is the geostrophic wind which blows parallel to isobars. The existence of the geostrophic wind was recognized in 1857 by a Dutchman, Buys Ballot, whose law states that 'if you stand in the northern hemisphere with your back to the wind, low pressure is always to your left and high pressure to your right.'

Friction caused by the earth's surface upsets the balance between the pressure gradient and the coriolis force by reducing the effect of the latter. As the pressure gradient becomes relatively more important when friction is reduced with altitude, the wind blows across isobars towards the low pressure. Deviation from the geostrophic wind is less pronounced over water because its surface is smoother than that of land as indicated in the diagram

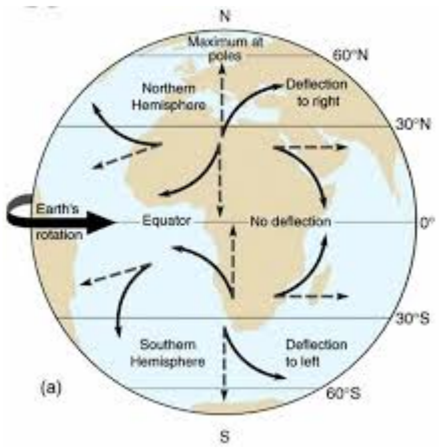

Fig 2: Latitudinal Variation in the Coriolis Force

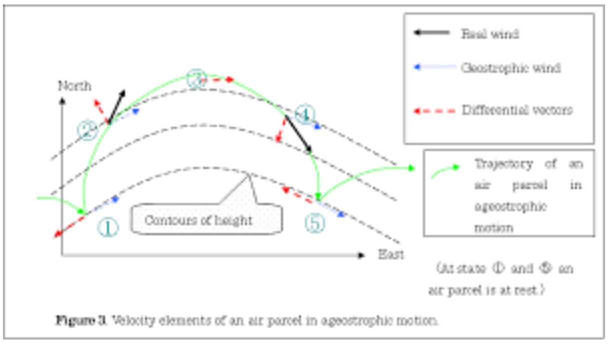

Figure 3. Velocity elements of an air parcel in ageostrophic motion.

Fig 3: Formation of Geostrophic Wind in the Northern Hemisphere

These are derived by combining these characteristics of latitude and humidity. When air masses move from their source region they are modified by the surface over which they pass and this alters their temperature, humidity and stability. For instance tropical air moving northwards is cooled and becomes more stable while polar air moving south becomes warmer and increasingly unstable. Each air mass therefore brings its own characteristic weather conditions to the location found. Each air mass is unique and dependent on climatic conditions in the source region at the time of its development; the path which it subsequently follows; the season in which it occurs; and since it has a three-dimensional form, the vertical characteristics of the atmosphere at the time.

The tropical maritime (TM) air and tropical continental (TC) air masses are dominant in Nigeria. They determine the occurrence of wet and dry seasons. TM dominates the wet season due to it sources of origin and direction of movement and is sometimes called the south-westerly trade winds while the TC dominates the dry season and is sometimes called the north-easterly trade winds.

SELF-ASSESSMENT EXERCISE

1. Atmospheric circulation depends on the function of latitude ad rotation. Discuss this statement
2. What is the resultant effect of the friction caused by the earth's surface?

4.0 CONCLUSION

Atmospheric circulation depends on the function of latitudes and earth rotation. The equatorial region which receives more energy than the polar region energy in form of heat is transferred by atmospheric circulation and to a much lesser extent oceanic circulation. A deflective force during earth rotation called coriolis force affects movement of a rotating body, thus affecting the movement of air and also influences circulation.

5.0 SUMMARY

In this unit, the effects of latitudes and earth rotation as causes of atmospheric circulation have been discussed. Surface winds move parallel to pressure gradient and blows directly from high to low pressure areas but blow in circular form when the coriolis force acts alone.

6.0 TUTOR-MARKED ASSIGNMENT

Explain in detail the following:
1. Effects of earth rotation on atmospheric circulation
2. Latitudinal variation

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Blij, H.J., Muller, P. O., Williams, R. S., Conrad, C. T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

UNIT 3 PLANETARY SCALE

CONTENTS

1.0 INTRODUCTION

Despite many modern advances using radiosonde readings, satellite imagery and computer modeling, the tricellular model still forms the basis of our understanding of the general circulation of the atmosphere. This unit explains the tricecullar model of understanding the general pattern of atmospheric circulation.

This unit also explains other scales used to provide understanding of the atmospheric circulation pattern. The concept of the synoptic systems is also the focus of this unit.

Local wind systems are often more significant in day-to-day weather because they respond to much more subtle variations in atmospheric pressure than are depicted. Moreover, because smaller distances are involved, the effect of the coriolis force can usually be disregarded. A number of common local winds serve to illustrate how topography and surface type can influence the pressure gradient and its resultant wind flow of the three meso-scale circulations described here, land and sea breezes and mountain and valley winds are caused by local temperature differences while fohn results from pressure differences on either side of a mountain range.

2.0 OBJECTIVES

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

- explain the tricellular model of atmospheric circulation
- schematically present the tricellular model of atmospheric circulation and describe the features of the model
- explain the concept of synoptic systems as a macro scale of atmospheric circulation
- mention the major air masses which affect a location at various times of the year
- differentiate between land and sea breeze systems
- explain the concept of mountain and valley

3.0 MAIN CONTENT

3.1 Tricellular Model and Atmospheric Circulation

The meetings of the trade winds in the equatorial region form the inter-tropical convergence zone (ITCZ). The trade winds which pick up latent heat as they cut across warm, tropical oceans, are forced to rise by violent convection currents.

The unstable, warm, moist air is rapidly cooled adiabatically to produce the towering cumulonimbus clouds, frequent afternoon thunderstorms and low pressure characteristics of the equatorial climate. It is these strong upward currents that form the ‘powerhouse’ of the general global circulation and which turns latent heat first into sensible heat and later into potential energy. At ground level, the ITCZ experiences only very gentle, variable wind known as the doldrums. Briggs & Smithson,1985).

As rising air cools to the temperature of the surrounding environmental air, uplift ceases and it begins to move away from the equator. Further cooling, increasing density and diversion by the coriolis force cause the air to slow down and to subside, forming the descending limb of the Hadley cell. In looking at the northern hemisphere, the southern is its mirror image; it can be seen that air subsides about 30^{o}N of the equator to create the sub-tropical high pressure belt with its clear dry sky and stable conditions on reaching the earth’s surface, the cell is completed as one of the air is returned to the equator as the north-east trade winds.

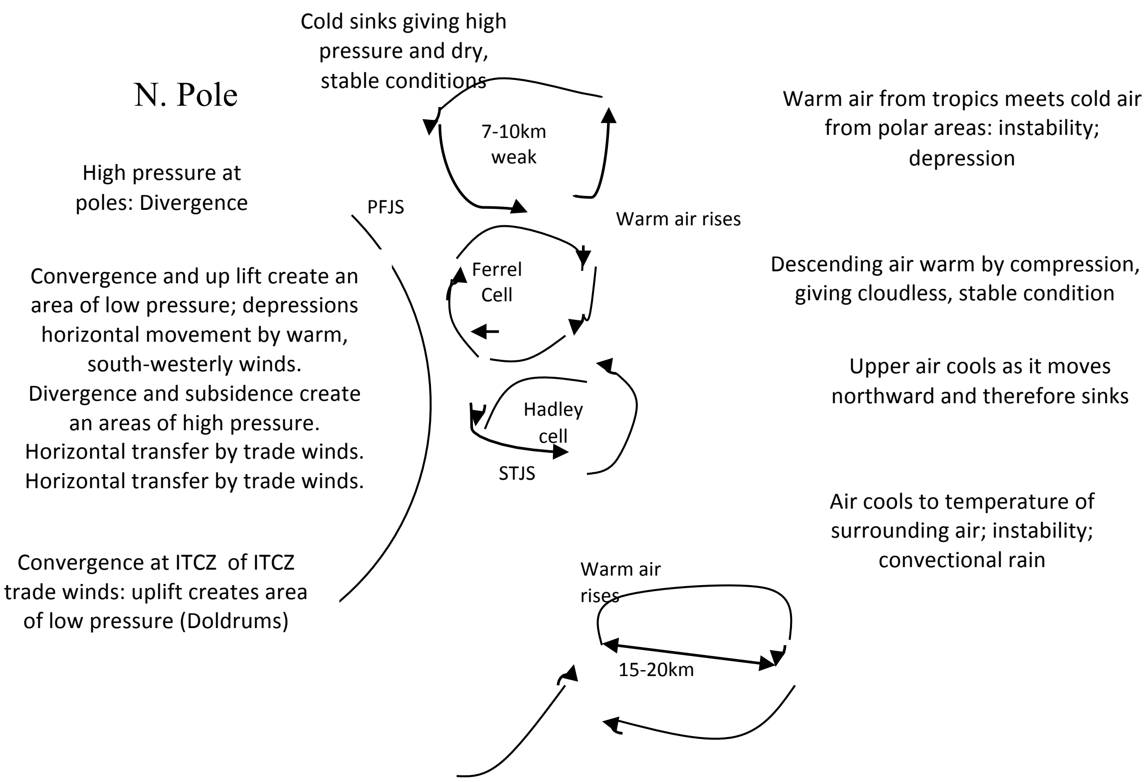

Fig. 4: Tricelullar Model Showing Atmospheric Circulation in the Northern Hemisphere

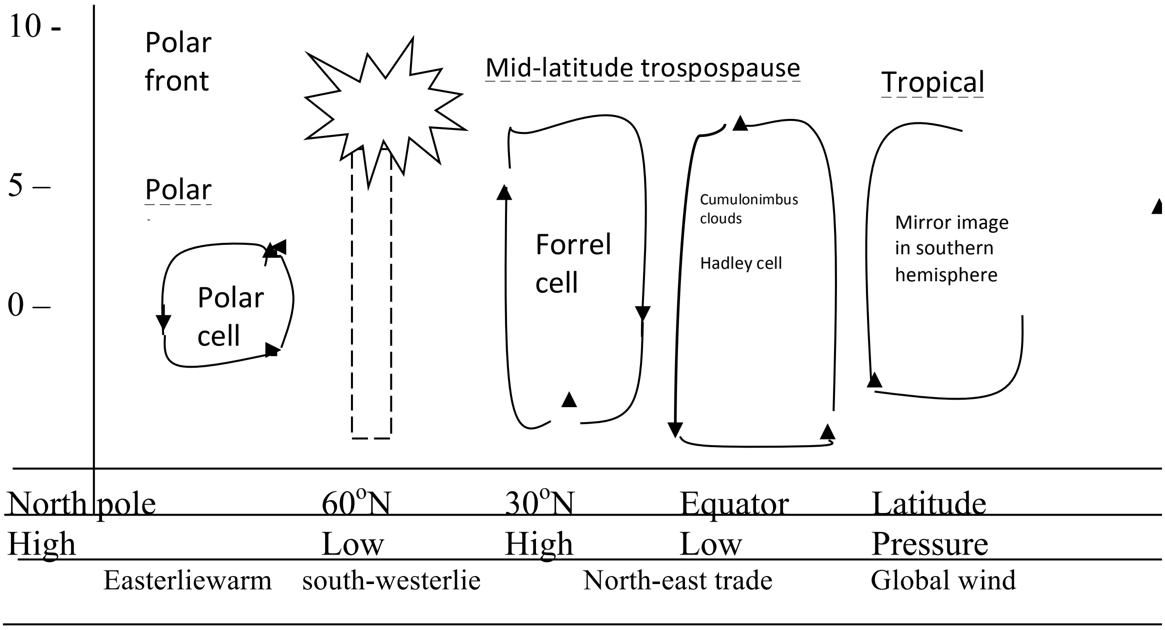

Fig. 5: Tricellular Model to Show Atmospheric Circulation in the Northern Hemisphere and with the Tropopause.

The remaining air is diverted pole wards, forming the warm south-westerlies which collect moisture when they cross sea areas. These warm winds meet cold artic air at the polar front (about 60oN) and are uplifted to form an area of low pressure and the rising limb of the Ferrel and polar cells. The resultant unstable conditions produce the heavy cyclonic rainfall associated with mid-latitude depressions. Depressions are another mechanism by which surplus heat is transferred while some of this rising air eventual returns to the topics, some travels toward the poles where, having lost its heat, it descends to form another stable area of high pressure. Air returning to the polar front does so as the cold easterlies.

3.2 Macro Scale

The concept of air masses is important because air masses help to categorized world climate types. In regions where one air mass is dominant all year, there is little seasonal variation in weather, for example at the tropics and at the poles. Areas such as the British Isles, where air masses constantly interchange, experience much greater seasonal and diurnal (daily) variation in their weather. (Blij and Muller, 2005).

If air remains stationary in an area for several days, it tends to assume the temperature and humidity properties of that area. Stationary air is mainly found in the high pressure belts of the subtropics and in high latitudes. The areas in which homogenous air masses develop are called source regions. Air masses can be classified according to the latitudes in

which they develop which determines their temperature – Artic (A), polar (P) or tropical (T) and the surface over which they develop, which affects their moisture contents – maritime (M) or continental (C).
The five major air masses which affect a location at various times of the year are as follows:

1. Artic Maritime Air Mass (AM)
2. Polar Maritime Air Mass (PM)
3. Polar Continental Air Mass (PC)
4. Tropical Maritime Air Mass (TM)
5. Tropical Continental Air Mass (TC)

3.3 Meso Scale

3.3.1 Land and sea breeze systems: Land surfaces and water bodies displays sharply contrasting thermal responses to energy input. Land surfaces heat and cool rapidly, whereas water bodies exhibit a more moderate temperature regime. During day, a land surface heats up quickly and the air layer in contact with it rises in response to the increased air temperature. This rising air produces a low pressure cell over the coastal land or island. Since the air over the adjacent water is cooler, it subsides to produce a surface high pressure cell. A pressure gradient is thereby produced, and air in contact with the surface now moves from high pressure to low pressure. Thus, during the day, shore-zone areas generally experience air moving from water to land. This is called sea breeze.

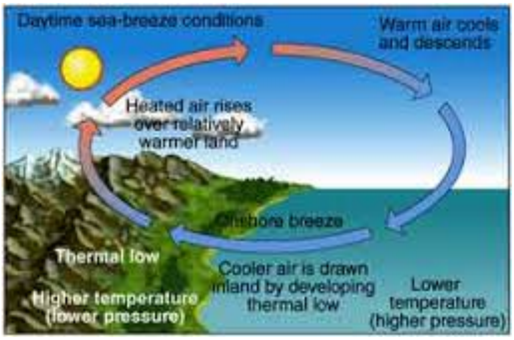

Fig 6: Sea Breeze

At night, when the temperature above the land surface has dropped significantly, the circulation reverses because the warmer air (and lower pressure) is now over the water. This result in air moving from land to water. This is called land breeze.

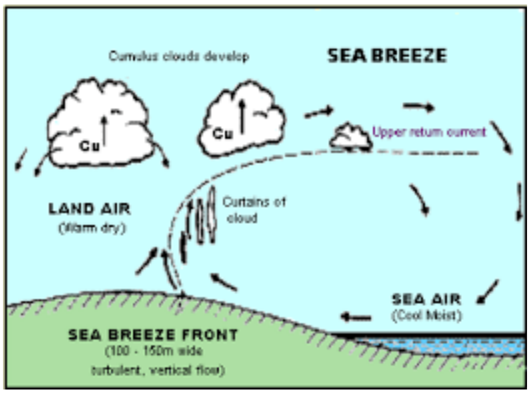

Fig 7: Land Breeze

When the system generates, sea and land breezes, it produces a circulation cell composed of the surface breeze, rising and subsiding air associated with the lower-and higher pressure areas respectively, air flow aloft in the direction opposite to that of the surface. Although it modifies the wind and temperature conditions at the coast, the effect of this circulation diminishes rapidly as one move inland. Note also that we use the word breeze. This accurately depicts a rather gentle circulation in response to a fairly weak pressure gradient. The sea/land breeze phenomena can easily be overpowered if stronger pressure systems are nearby. (Williams, Conrad & Long, 2005).

3.3.2 Mountain/Valley Breeze Systems

Mountain slopes are subject to the reversal of day and night local circulation systems. This wind circulation is also thermal, meaning that it is driven by temperature differences between adjacent topographic features. During the day, mountains terrain facing the sun tends to heat up more rapidly than the surrounding slopes. This causes low pressure to develop, spawning an up sloping valley breeze. At night, greater radiative loss from the mountain slopes cools them more sharply, high pressure develops, and a down sloping mountain breeze results. The wind that blows up the valley is also known as an anabatic wind while the down valley wind is called the Katabatic wind, which are usually gentle but much stronger if they blow over glaciers or permanently snow covered slopes.

3.3.3 Fohn

The fohn is a strong, warm and dry wind which blows periodically to the lee of a mountain range. It occurs in the Alps when a depression passes to the north of the mountains and draws in warm, moist air from the Mediterranean. As the air rises it cools at the DALR of $1^{o}C$ per 100m. If condensation occurs at 1000m, there will be a release of latent heat and

the rising air will cool more slowly at the saturated adiabatic lapse rate (SALR) of 0.5°C per 100m. This means that when the air reaches 3000m it will have a temperature of 0°C instead of the -10°C had latent heat not been released. Having crossed the Alps, the descending air is compressed and warmed at the dry adiabatic lapse rate (DALR) so that if the land drops sufficiently, the air will reach sea level at 30°C. This is 10°C warmer than when it left the Mediterranean. Temperatures may rise by 20°C within an hour and relative humidity can fall to 10 percent. (Williams, Conrad, Long, 2005).
This wind, also known as Chinook on the American prairies, has considerable effects on human activities. In spring, when it is most likely to blow, it melts snow and enable wheat to be grown. Conversely, it warmth can cause avalanches, forest fires and premature budding of trees.

4.0 CONCLUSION

The overall pattern as explained by the tricellular model is affected by the apparent movement of the overhead sun to the north and south of the equator (0°C). This movement causes the seasonal shift of the heat equator, the ITCZ, the equatorial low pressure zone and global wind systems and rainfall belts. Any variation in the characteristics of the ITCZ i.e. its location or width can have drastic effect on the surrounding climates, as seen in the sahel droughts of the early 1970s and most of the 1980s.

Categories of world climatic types are determined by air masses, seasonal variations and daily changes in weather are equally determined by air masses. Five major air masses affect the weather of a location. They include: artic maritime air mass (AM), polar maritime (PM), polar continental (PC), tropical maritime (TM) and tropical continental (TC). All these air masses have effects on the locations where they have dominance.

Local winds connote the winds that are peculiar to a relatively small area and are of local importance. They are seasonal and often confined to the lowest part of the atmosphere which result to differential heating and cooling of land and sea.

5.0 SUMMARY

In this unit, the tricellular model of atmospheric circulation has been discussed. There is a strong relationship between the equator and ITCZ and the atmospheric circulation as described by the tricellular model in understanding the atmospheric circulation pattern.

The synoptic system in understanding the circulation of atmospheric pressure or wind system with focus on the trade winds (air masses) and how they control or impact on seasons was also discussed.

SELF-ASSESSMENT EXERCISE

Schematically present the tricellular model of atmospheric circulation and describe the features of the model.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the tricellular model of atmosphere circulation.
2. Mention the major air masses which affect a location at various times of the year.
3. Differentiate between land and sea breeze systems.

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geograph*y. London: Unwin Hyman Ltd.

Blij, H. J., Muller, P.,O., Williams, R. S., Conrad, C. T., & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

MODULE 5 THE DYNAMICS OF PRESSURE AND WIND SYSTEMS

UNIT 1 CONCEPTS OF PRESSURE AND WIND SYSTEMS

CONTENTS

1.0 INTRODUCTION

The movement of air on the earth's surface is controlled by the imbalance or difference in air pressure of different places. Air pressure on the other hand is determined by the height of the column of air over a given place and its temperature. Thus, air pressure is a function of elevation and temperature. The general principle is that air moves from areas of high pressure to areas of low pressure. The movement of air in the atmosphere system may be vertical and horizontal. The two movements are called descending and ascending dynamic of air system

Near the surface of the earth, below an elevation of about 1000m, frictional forces come into play and disrupt the balance represented by the geostrophic wind. Friction both reduces the speed and alters the direction of a geostrophic wind. The frictional force acts in such that pressure gradient is forced over the coriolis force so that the wind at the surface blows across the isobars instead of parallel to them. This produces a flow of air out of high pressure areas and into low pressure areas, but at an angle of the isobars rather than straight across them. This unit will explain some wind systems caused by friction with particular focus on tropical cyclones and anticyclones.

2.0 OBJECTIVES

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

- describe the concepts of wind and pressure system
- explain the patterns of movement of wind
- explain the concept of hurricane as a form of tropical cyclone
- describea tropical anticyclone as a frictional surface wind system

3.0 MAIN CONTENT

3.1 Concept of Wind and Pressure Systems

Winds results from differences in air pressure which in turn may be caused by differences in temperature and the force exerted by gravity as pressure decreases rapidly with height. An increase in temperature causes air to be heated, expanded, becomes less dense and rises creating an area of low pressure below. Conversely, a drop in temperature produces an area of high pressure. Differences in pressure are shown on maps by isobars, which are lines joining places of equal pressure. Pressure is measured in millibars (mb) and it is usual for isobars to be drawn at 4mb intervals. Average pressure at sea level is usually 1013mb. However, the isobars pattern is usually more important in terms of explaining the weather than the actual figures. The closer together the isobars, the greater the differences in pressure, the pressure gradient and the stronger the wind. On the other hand, the further apart the isobars, the lower the difference in pressure gradient and the weaker the wind. Wind is nature's way of balancing out differences in pressure as well as temperature and humidity. (Blij, Muller, Williams, Conrad &Long, 2005).

3.2 Patterns of Movement of Wind System

3.2.1 Tropical Cyclones

Tropical cyclones are systems of intense low pressure known locally as hurricanes, typhoons and cyclones. They are characterized by winds of extreme velocity and are accompanied by torrential rainfall which may cause widespread damage and loss of life. Tropical cyclones are associated with rising air at their centres, other sources of development may include;

i) They tend to develop over warm tropical oceans where sea temperatures exceed 26^{o}C and where there is a considerable depth of warm water.
ii) In autumn, when sea temperatures are at their highest
iii) In trade winds belt; where the surface winds warm as they blow towards the equator
iv) Between latitude 50^{o}C and 20^{o}C north and south of the equator (nearer to the equator, the coriolis force is insufficient to enable the feature to 'spin'). Once formed, they move westwards, often on erratic, unpredictable courses, swinging poleward on reaching land, where their energy is rapidly dissipated. They are another mechanism by which surplus energy is transferred away from the tropics.

Hurricanes are tropical cyclones of the Atlantic. They form after the ITCZ has moved to its most northernly extent enabling air to converge at low levels, with a diameter of up to 650km. Hurricane rapidly declines once the source of heat is removed, i.e. when it moves over colder water or a land surface; this increases friction and so cannot supply sufficient moisture. The average life span of a tropical cyclone is 7 – 14 days. Tropical cyclones are a major natural hazard which often causes considerable loss of life and damage to property and crops. There are four main causes of damage. (i) High winds which often exceed 160km/hr and in extreme cases 300km/hr. (ii) ocean storm (tidal surges), resulting from the high winds and low pressure, may inundate coastal areas many of which are densely polluted. (iii) floodingwhich can be caused either by a storm of tidal surges or by the torrential rainfall (iv) landslides can result from heavy rainfall where buildings have been erected on steep unstable slopes.

This is an air circulation pattern associated with a tropical cyclic low pressure cell.

3.2.2 Anticyclones

An anticyclones is a large mass of subsiding air which produces an area of high pressure on the earth's surface. The source of the air is the upper atmosphere, where amounts of water vapour are limited. On its decent, the air warms at the dry adiabatic lapse rate (DALR). So dry conditions result pressure gradients that are gentle, resulting in weak winds or calms. The winds blow outwards in anticlockwise in the northern hemisphere. Anticlines may be 3000km in diameter, much larger than depressions and, once established, they can give several days or, under extreme conditions, several weeks of settled weather.

Blocking anticyclones often occur when cells of high pressure detach themselves from the major high pressure areas of the subtropics or poles. Once created, they last for several days and ‘block’ eastwards-moving depressions to create anomalous conditions such as extremes of temperature, rainfall and sunshine.

This is an air circulation pattern associated with an anticyclonic high-pressure cell.

3.3 Frictional Surface Wind Systems

Below an elevation of about 1000m, near the earth surface, frictional forces play significant role and disrupt the balance represented by the geostropic wind. Friction reduces the speed and alters the direction of a geostrophic wind, causing the pressure-gradient force to overpower the coriolis force so that the wind at the surface blows across the isobars instead of parallel to them. This produces a flow of air high pressure areas into low-pressure area at an angle of the isobars and not straight across them.

Surface pressure systems are often circular when viewed from above, the winds converge toward a cyclone (low-pressure cell), this converging air has to feed and move to somewhere else so it rises vertically in the centre of the low-pressure cell. The reverse is the case in the centre of an anticyclone (a high- pressure cell); the air diverges and moves outward. Thereby drawing air down in the centre of the high pressure cell. Cyclones are associated with rising air at their centres while anticyclones are associated with subsiding air at their centres. This movement of air produces varied weather conditions associated with each type of pressure system.

3.4 **Planetary Winds**

These are wind systems that result from planetary pressure distribution. These are the trade winds, the mid-latitude westerlies and the polar easterlies. Trade winds are winds that blow from sub-tropical belts of high pressure to the equatorial belt of low pressure. Their meeting point at the equatorial low pressure belt is called inter-tropical convergence zone (ITCZ), and the area occupied by the zone, doldrums. Mid-latitude westerlies are winds that blow from subtropical belt of high pressure to the sub-polar belt of low pressure in both hemispheres. Those blowing in the northern hemisphere are called south-westerlies and those blowing in the southern hemisphere are called the north-westerlies. They are generally inconsistent in direction and speed due to the influence of local pressure gradients which in turn are produced from the varied effects of land and sea. Polar easterlies are polar wind systems that tend to move towards the sub-polar low pressure belts of the northern and southern hemisphere. These result in the formation of a wind belt of complex condition and characteristics. The complexity is more defined in the northern hemisphere where the distribution of land and sea is widely varied. (Robert, Robert, Daniel and James, 1999)

3.5 Local Winds

These winds are peculiar to a relatively small area and are of local importance though seasonal in nature and usually confined to the lowest part of the atmosphere. They occur due to variation in temperature of land and sea and the effects includes land and sea breezes. They are local winds on daily basis. They are monsoon winds and the variations exist in areas adjacent to large water bodies, rivers or sea (Oluwafemi, 1998).

A sea breeze is a very cool moisture-laden wind that blows from the sea during the day towards the low pressure on the land due to the heating effect of the sun during the day. The land gets heated more rapidly than the sea during the day. The heated air on the land expands and becomes lighter and rises thereby creating a region of low pressure. The sea at that point remains comparatively cooler with a higher pressure making way carefully from the sea to replace the warm air rising on the land. At night the land cool more rapidly than the sea so that cold and heavy air is developed thus resulting to a high pressure condition over the land and a low pressure is created on the sea. As the land cools off at night, the sea retains much of its day time heat. An outward blowing land breeze is set up to replace the warm rising air on the sea.

SELF-ASSESSMENT EXERCISE

1. Explain the sources of tropical cyclones
2. What are the effects of tropical cyclones

4.0 CONCLUSION

Variation in temperature controls the wind systems. Winds result from differences in air pressure flowing from high pressure to low pressure areas. Differences in pressures are shown on maps by isobars which are lines joining places of equal pressures.

5.0 SUMMARY

In this unit, the concept of wind has been explained with focus on the factors that sprout the formation of winds. Wind is nature’s way of balancing out temperature and humidity. Atmospheric circulation is

influenced by friction thereby producing a frictional surface wind system which often brings about certain weather conditions that affect a particular region. Tropical cyclones are major natural hazard usually resulting in loss of life and damage of property and crops due to its extreme velocity accompanied by torrential rainfall. Anticyclones are large mass of subsiding air which produces an area of high pressure on the earth's surface. They produce several weeks of extreme conditions.
Tropical cyclones and anticyclones have been discussed with reference to hurricane as a type of tropical cyclone, their source of origin and their resultant effects when they occur, anticyclones, sources and effects are dominant in areas where they occur.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the following concepts;
   a) Wind
   b) Pressure
2. Describe the patterns of flow of wind and pressure
3. Discuss how an anticyclones is formed
4. Explain what you understand by hurricane as a form of tropical cyclone
5. Describe a typical anticyclone as a frictional surface wind system

7.0 REFERENCES/FURTHER READING

Blij, H. J., Muller, P. O., Williams, R. S., Conrad, C .T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

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UNIT 2 CAUSES OF ATMOSPHERIC CIRCULATION

CONTENT

1.0 INTRODUCTION

Atmospheric circulation is the large – scale movement of air, and the means by which thermal energy is distributed on the surface of the earth. The scale of circulation varies from year to year but the basic structure remains fairly constant. Individual weather systems, mid-latitude depressions or tropical convective cells occur randomly. Causes for these and other issues related to atmospheric circulation will be discussed and explained in this unit.

2.0 OBJECTIVES

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

- explain the following factors of atmospheric circulation;
  - heat energy and latitudinal location
  - rotation of the earth on its axis

3.0 MAIN CONTENT

3.1 Causes of Atmospheric Circulation

There are two factors that explain the circulation of air in the atmosphere. These include;

i) the amount of heat energy the earth receives at different latitudes
ii) the rotation of the earth on its axis

There is a marked surplus of net radiation between the equators, latitudes 35^{o}N. Pole wards where outgoing radiation exceeds incoming radiation. This is because the sun's rays strike the earth's surface at higher angles and therefore at greater intensity and magnitude in the lower latitudes than the other latitudes. As a result about two and one-half times ($2^{1/}{}_2$) as much as annual solar radiation received at the poles and the one received at the equator (Blij, Muller, Williams, Conrad & Long, 2005).

If this imbalance in energy continues without any balance, the low latitudes regions would experience great heating up and the Polar regions cooling down faster than expected. The weather at these latitudes is characterized by frequent north-south movement of air masses since considerable amount of energy in form of heat is transferred by atmospheric circulation polewards due to intense heat received at the equator which causes warm air to rise.

Heat transfer could occur by a simple cellular movement when the earth is stationary and there are no thermal variations between landmasses and ocean. Warm air at low latitudes however travels toward the poles at a high altitude and descends as it cools and then returns to the low latitudes as a surface wind.

When the earth rotates on its axis, a significant effect is expressed as an apparent deflective force. The deflective force affecting movement on a rotating body is called the coriolis force. Anything that moves over the surface of the spinning planet; from stream currents to missiles to air particles is subjected to the coriolis force. When other forces are absent, moving objects are deflected to their right in the northern hemisphere and to their left in the southern hemisphere. Therefore, if the wind is blowing from the North pole, it would be deflected to the right and becomes an easterly wind which blows towards the west. However, if it is blowing from the sub-tropical region, it would be deflected to the left and becomes westerly wind which blows towards the east (Wikipedia, 2015).

SELF-ASSESSMENT EXERCISE

1. What are the two factors that explain circulation of air in the atmosphere?
2. Explain in detail the two factors listed above

4.0 SUMMARY

The factors that explain circulation of air in the atmosphere were identified to form the basis of understanding the causes of atmospheric circulation. Differences exist greatly in the amount of heat energy on the basis of latitudinal location and this cause areas of greater insolation to develop the low pressure belt and areas of low insolation and high pressure. Air therefore, moves from areas of high pressure to areas of low pressure. This pattern of movement of air misses is modified by the effect of rotation known as corriolis effect.

5.0 CONCLUSION

The major factor responsible for the circulation of atmospheric pressure have been discussed with focus on heat energy and latitudinal locations as well as rotational effect known as coriolis effect.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the following factors responsible for atmospheric circulation
   a) Heat energy and latitudinal location
   b) Rotation of the earth on its axis

7.0 REFERENCES/FURTHER READING

Blij, Muller, Williams, Conrad and Long (2005). *Physical Geography*: The global Environment: Canada: Oxford University Press

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UNIT 3 CHANGES IN PRESSURE AND WIND SYSTEMS

CONTENTS

1.0 INTRODUCTION

The atmosphere is made up of gases and atmospheric pressure pushes against everything on the planet earth. The force is Omni-directional and is more like a gloved hand than a blanket. The bodies of all living things are balanced to the same pressure because of evolution. This unit will discuss the changes that occur in pressure of the wind systems.

2.0 OBJECTIVES

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

- describe the following changes in pressures and wind systems:
    - vertical changes in pressure
    - horizontal changes in pressure
- discuss changes in pressure with reference to the following seasons:
    - summer
    - winter

3.0 MAIN CONTENT

3.1 Vertical Changes in Pressure

The earth's gravity holds the atmosphere in place otherwise it would escape into space. Gravity is the invisible glue which keeps the universe together. The force of the earth's gravity is stronger on low altitude molecules than high altitude molecules. The effects of gravity on the lower altitudes is that the gas molecules are more concentrated due to gravitational force that is, the molecules in the lower atmosphere are denser therefore, more collisions occur and pressures tend to be higher. (Robert, Robert, Daniel & James, 1999).

3.2 Horizontal Changes in Pressure

Density and temperature can affect the pressure in the atmosphere and changes can occur. Horizontal changes in pressure can be classified into two categories: thermal – caused by temperature and dynamic-caused by motion.

3.2.1 Pressure and Thermal Changes

This describes how different surfaces heat and cool. One of the basic rules of gasses is that pressure and density of a given gas vary inversely with temperature. During the day, temperature increases thereby given room for the air to expand in volume while density decreases. The region around the equator is a region of low pressure. Air density increases towards the poles and decreases in volume. This condition makes the air subside and the pressure high. Though this might be contrary to the common principle where warm temperatures are related with low pressure and cool weather with high pressure. Pressures like temperatures are relative to each other.

3.2.2 Dynamic Changes

It is logical to assume that there would be a progressive increase in pressure from the equator to the poles, but in the real sense pressure is different and it changes apparently. There are areas of high pressure in the sub-tropics and areas of low pressure in the sub-polar regions. The zones of high or low pressure are more complicated than just thermal activity. The reason for this apparent inconsistency is the dynamic (motions) action of the earth.

The dynamic factors are the rotation of the planet and the great pattern of circulation of the ocean and atmosphere. Warm air rises from the equator and moves poleward direction but, the earth's rotation deflects the air to the east. When it reaches the subtropics, the air has changed direction and is now flowing west to east. The deflection causes the air to stack up over the subtropics which increases air pressure at those locations.

Secondly, there are high pressure areas over the poles and subtropical zones. Dynastically reduced zones of low pressure are formed between them in the sub-polar regions. One of the consequences is air flows or downhill from highs to lows where it will rise. This leads to another concept called pressure gradient.

3.3 Changes during the Seasons

Atmospheric pressure belts change positions because of the seasons. They meander northward in July and southward in January in the northern hemisphere. This migration is between latitude 23½^{o}N & S (Tropics of Cancer and Capricorn) because of changes in temperature. The pressure systems do not change very much in low latitudes because of the small temperature changes. However, in high latitudes where there is a variation between hours of sunlight and the angle of the sun, there will be more changes in pressure and temperature. The temperature extremes are more substantial in the northern hemisphere where the land takes up 40% of the total surface while the southern hemisphere takes only 20% land.

3.3.1 Changes during Winter

In the North Atlantic low-pressure cell called the Icelandic low another cell of low pressure develops in the north pacific called the Aleutian low. Since the air of the two low pressure cells have relatively lower pressures compared to the two subtropical or polar high systems, the air moves towards these cells from the north and south. These low pressure cells are associated with cloudy, unstable weather and forms the origin of winter storms. In winter in the mid latitude high-pressure cells are associated with clear blue skies, calm, starry nights, and cold stable weather. In the winder, cloudy conditions are tied to the oceanic lows, while clear weather is tied to the continental highs.

3.3.2 Changes during Summer

During summer, the anticyclone is very weak over the North pole due to the heating of the ocean and the continents as the length of day increases. The Aleutian and Icelandic lows almost disappear. Over the landmasses of Eurasia and North America, low pressure cells develop, in Asia a low-pressure system is formed but broken into two separate cells by the Himalayas. The low-pressure system above northwest India is strong enough to combine with the equatorial trough which has shifted from its winter location.

The subtropical highs in the northern hemisphere are more developed over oceans than continents. They also journey northward and are extremely important in the climate of the continents. In the pacific, the sub-tropic is designated the pacific high and has a very important part in moderating the temperatures of the west coast of northern America. In the Atlantic, a similar formation serving the same function is called the Bermuda high by Americans and Azores high to Europeans.

SELF-ASSESSMENT EXERCISE

It is a logical reasoning to assume that there would be a progressive increase in pressure from the equator to the poles. Discuss.

4.0 CONCLUSION

Pressure plays significant role in wind systems, the changing effects caused by relief; temperature and density determine the climatic condition of a location. Wind reacts to changes in air pressure and regulates the air pressure and temperature of the planet.

5.0 SUMMARY

Changes in atmospheric pressure have been discussed with focus on the types of changes that occur in pressure and the change factors as well as changes on the basis of seasons.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the following
   a) Vertical changes in pressure
   b) Horizontal changes in pressure
2. Discuss changes in pressure with reference to the following seasons
   a) Summer
   b) Winter

7.0 REFERENCE/FURTHER READING

Robert, E. G., Robert, J. S., Daniel, L. W. & James, P. (1999). *Atmospheric pressure and Wind*: Essentials of Physical Geography 6th Edition. Saunders College Publishing, Harcourt Brace College Publishers Rand McNally Goode's World Atlas.

MODULE 6 CONDENSATION AND PRECIPITATION PROCESSES

UNIT 1 PROCESSES OF CONDENSATION AND PRECIPITATION

CONTENTS

1.0 INTRODUCTION

Condensation is a process by which water vapour in the atmosphere is changed into liquid or, if the temperature is below 0^oC, a solid. It usually results from air being cooled until it is saturated. Cooling may be achieved by: Long wave radiation, advection, orographic and frontal uplift and convective or adiabatic cooling.

Condensation produces minute water droplets less than 0.05mm in diameter, or if the dew point temperature is below freezing, ice crystals. The droplets are so tiny and weight so little that they are kept buoyant by rising air currents which created them. Although condensation forms clouds, clouds do not necessarily produce precipitation. As rising air currents are often strong, there has to be a process within the clouds which enables the small water droplets and or ice crystals to become sufficiently large enough to overcome the uplifting mechanism and fall to the ground.

2.0 OBJECTIVES

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

- discuss the mechanism of condensation
- explain the two conditions for the formation of clouds
- discuss the two theories that explain the process by which droplets grow large enough to fall as precipitation
- state and explain the types of precipitation

3.0 MAIN CONTENT

3.1 Mechanisms of Condensation

Condensation takes place when the following mechanisms fully mature:

a) Radiation and contact cooling: This typically occurs on calm, clear evenings. The ground loses heat rapidly through terrestrial radiation and the air in contact with it is then cooled by conduction. If the air is moist, some vapour will condense to form radiation fog, dew or if the temperature is below freezing point, hoar frost will occur.

b) Advection closing: This results from warm, moist air moving over a cooler land and sea surface. This is formed when warm air from the land drifts over cold offshore ocean currents. Both radiation and advection involve horizontal rather than vertical movements of air. When this happens, the amount of condensation is reduced or limited.

c) Orographic and frontal uplift: Warm moist air is forced to rise either as it crosses a mountain barrier (orographic ascend) or when it meets a cooler, denser mass of air at a front and results in the formation of water droplets.

d) Convective or adiabatic cooling: This is when air is warmed during the day time and rises in pockets as thermals. As the air expands, it uses energy and so loses heat and the temperature drops. Because air is cooled by the reduction of pressure with height rather than by a loss of heat to the surrounding air, it is said to be adiabatically cooled.

Both orographic and adiabatic cooling involve vertical movements of air, they are more effective mechanisms of condensation. Condensation does not occur readily in clear air. Indeed, if air is absolutely pure, it can be cooled below its dew point to become super-saturated with an RH in excess of 100%. Laboratory tests have shown that, clean saturated air can be cooled to -40^{o}C before condensation or in this case, sublimation. Sublimation is when water vapour condenses directly into ice crystals without passing through the liquid state. However, air is rarely pure and usually contains large numbers of condensation nuclei. These microscopic particles referred to as hydroscopic nuclei because they attract water, include volcanic dust (heavy rain always accompanied with volcanic eruptions), dust from windblown soil, smoke and sulphuric acid originating from urban and industrial areas and salt from sea spray.

Hygroscopic nuclei are most numerous over cities, where these may be up to 1 million per cm^3 and least common over oceans (only 10 per cm^3). where large concentrations are found, condensation can occur with an RH as low as 75%. Clouds are visible masses of suspended, minute water droplets and/or ice crystals. Two conditions are necessary for the formation of clouds.

i) The air must be saturated, either by cooling below the dew point (causing water vapour to condense) or by evaporating enough water to fill the air to its maximum water-holding capacity.
ii) There must exist a substantial quantity of small airborne particles called condensation nuclei around which liquid droplets can form when water vapour condenses. Condensation nuclei are almost always present in the atmosphere in form of dust and salt particles.

3.2 Processes of Precipitation

There are two theories which explain the processes by which droplets grow large enough to fall out of a cloud as precipitation. (Blij, Muller, William, Conrad & Long, 2005).

The Ice-crystal Process
The ice-crystal process was first identified in the 1930s by meteorologists Tor Bergeron and Von Findeisen. This process requires both liquid droplets and ice particles in the cloud. Ice particles are normally present if the temperature is below 0^oC and if there are small particles called freezing nuclei. Freezing nuclei perform the same function for ice particles as condensation nuclei perform for water droplets.

When the cloud contains both ice particles and water droplets, the water droplets tend to evaporate and then the resultant water vapour sublimates (changes from a vapour to a solid) directly onto the ice crystals. The ice crystals attract more of the water vapour because the vapour pressure over the ice crystal grows at the expense of the liquid droplets. The ice crystals become larger and often joint together to form a snow flake. When the snow flake is heavy enough, it usually encounters higher temperatures and melts, eventually reaching the surface as a liquid rain drop. Most rainfall and snow fall in the mid-latitudes are formed by the ice-crystals process, but in the tropics the temperature of many clouds do not necessarily drop below freezing point. Therefore, a second process is initiated to make raindrops large enough to fall from cloud.

The Coalescence Process
The coalescence process (sometimes called the collisions – coalescence process) requires some liquid droplets to be larger than others, which happens when there are giant condensation nuclei. As they fall, the larger droplets collide and join with smaller ones. But narrowly mixed smaller droplets may still be caught up in the wake of the large ones and drawn to them. In this case, the larger droplets grow at the expense of the smaller ones and soon become heavy enough to fall to earth.

3.3 Types of Precipitation

Precipitation includes rain, snow, sleet, hail, dew, hoar frost, fog and rime.Among these onlyrain and snow provide significant totals in the hydrological cycle. Precipitation reaches the earth's surface in several forms.Large liquid water droplets form rain. If the ice crystals in the ice-crystal process do not have time to melt before reaching the earth's surface, the result is snow. Sleet refers to pellets of ice produced by the freezing rain before it hits the surface. If the rain freezes after reaching the ground, it is called freezing rain (or glaze). Soft hails pellets (sometimes called snow pellets) can form in a cloud that has more ice crystals than water droplets and eventually fall to the surface. True hailstones result when falling ice crystals are blown upward from the lower, warmer part of a cloud, where they gain a water surface to the higher, freezing part where the outer water turns to ice. This process, which often occurs in the vertical air circulation of the thunder forms, may be repeated over and over to form larger hailstones.

a) Rain: Main types of rainfall, distinguished by the mechanisms which cause the initial uplift of air. Rarely does each mechanism operate in isolation. The types are discussed as follows.

1. **Convergent and Cyclonic (frontal) Rainfall**
   This form of rainfall results from the meeting of two air streams in areas of low pressure. Within the tropics, the trade winds, blowing towards the equator meets at the inter-tropical convergence zone (ITCZ). The air is forced to rise and in conjunction with convection currents, produces the heavy afternoon thunderstorms associated with the equatorial climate. While in temperate latitudes,

depressions form at the boundary of two air masses. At the associated fronts, warm, moist, less dense air is forced to rise over colder, denser air, giving periods of prolonged and sometimes intense rainfall. This is often augmented by orographic precipitation.

2. **Orographic or Relief Rainfall**

This type of rainfall results when near-saturated, warm maritime air is forced to rise when confronted by a coastal mountain barrier. Mountains reduce the water holding capacity of rising air by enforced cooling and can increase the amounts of cyclonic rainfall by retarding the speed depression movement. Mountains also tend to cause air streams to converge and form through valleys. Rainfall total increases where mountains are parallel to the coast. As air descends on the leeward side of a mountain range, it becomes compressed and warmed and condensation ceases, creating a rain shadow effect where little rain falls.

3. **Convectional Rainfall**

This occurs when the ground surface is locally overheated and the adjacent air, heated by conduction, expands and rises. During its ascent, the air mass remains warmer than the surrounding environmental air and it is likely to become unstable with towering cumulonimbus cloud forming. These unstable conditions, possibly augmented by frontal or orographic uplift force the air to rise in a 'chimney'. The up draught is maintained by energy released as latent heat at both condensation and freezing levels. The cloud summit is characterized by ice crystals in an anvil shape and the top of the cloud being flattened by upper-air movements. When the crystals and frozen water droplets, i.e. hail, become large enough, they fall in a downdraught. The air through which they fall remains cool as heat is absorbed by evaporation. The downdraught reduces the warm air supply to the 'chimney' and therefore limits the lifespan of the storm. Such storms are usually accompanied by thunder and lightning. How storms develop immense amount of electric charge is not fully understood. One theory suggests that as raindrops are carried upwards into colder regions, they freeze on the outside. This ice-shell compress the water inside it until the shell bursts and the water freezes into positively charged ice-crystals while the heavier shell fragments which are negatively charged, towards the clouds and the cloud base including a positive change on the earth's surface.

Lightning is the visible discharge of electricity between the clouds or between clouds and the ground. Thunder is the sound of the pressure wave created by the heating of air along a lightning flash. Convection is one process by which surplus heat and energy from the earth's surface are transferred vertically to the atmosphere in order to maintain the heat balance.

b) Snow: Snow forms under similar conditions to rain except that at dew point temperatures are under $0^{o}C$, then the vapour condenses directly into a solid (sublimation). Ice crystals will form if hygroscopic or freezing nuclei are present and these may aggregate to fire snow flakes. As warm air holds more moisture than cold, snowfalls are heaviest when the air temperature is just below freezing. As temperature drops it becomes too cold for snow.

c) Hailstone: Hail is made up of frozen raindrops which exceed 5mm in diameter. It is usually formed in cumulo-nimbus clouds, resulting from the uplift of air by convection currents or at a cold front. It is more common in areas with warm summers where there is sufficient heat to trigger the uplift of air and less common in colder climates.

d) Dewfall, Hoar Frosts, Fog And Rime: Dew, hoar frost and radiation fog are all formed under calm, clear, anticline conditions when there is rapid terrestrial radiation at night. Dew point is reached as the air transpired from plants, condenses. If dew point is above freezingpoint dew will form. If it is below freezing, hoar frost develops. Frost may also be frozen dew. Dew and hoar frosts usually occur within 1m of ground level.

If the lower air is relatively warm, moist and contains hygroscopic nuclei, and if the ground cools rapidly, radiation fog may form.Wherevisibility is more than 1km it is mist, if less than 1km, it is called fog. In order for radiation fog to develop, a gentle wind is needed to stir the cold air adjacent to the ground so that cooling affects a greater thickness of air.

Advection fog is formed when warm air passes over or meets with cold air to give rapid cooling. Sufficient droplets fall to the ground as fog-drop to enable some vegetation grow.

Rime occurs when super cooled droplets of water, often in the form of fogcome into contact with and freeze upon solid objects such as masks, poles and trees.

e) **Sleet and Glazed Frost:** Sleet is a mixture of ice and snow formed when the upper air temperature is below freezing point allowing snowflakes to form and the lower air temperature is around 2^oC to 4^oC, which allow their partial melting. Glazed frost is the reverse of sleet and occurs when water droplets form in the upper air but turn to ice on contact with a freezing surface. When glazed frost forms on roads, it is known as 'black ice.'

f) **Acid Rain**: This is an umbrella term for the presence in rainfall of a series of pollutants which are produced mainly by the burning fossil fuels. Coal-fired power stations, heavy industry and vehicle exhausts emit sulphur dioxide and nitrogen oxides. These are carried by prevailing winds across seas and national frontiers to be deposited either directly onto the earth's surface as dry deposition or to be converted into acids (sulphuric and nitric acid).

Clean rainwater has a PH value of between 4 and 5; the lowest ever recorded was 2.4. The effects of acid rain include the following:

1. Increase in levels of water acidity, causing death of fish and plants life in rivers and lakes
2. Pollution of fresh water supply for human consumption and animal survival
3. Destruction of forests and important soil nutrient (calcium and potassium) are washed away to be replaced by manganese and aluminum which are harmful to root growth.
4. Acid rain has been linked with a decline in human health as seen by the increasing incidences of Alzheimer's diseases (which may result from higher concentrations of aluminium), bronchitis and lungs cancer
5. As soil becomes more acidic, crops yields are likely to fall
6. Chemical weathering may likely occur and this will erode buildings (Briggs and Smithson, 1985).

SELF-ASSESSMENT EXERCISE

Identify the different types of precipitation, stating the type most common to your geographical environment.

4.0 CONCLUSION

Precipitation is the product of condensation as condensation depends greatly on evapotranspiration and hygroscopic nuclei. Rainfall and snow are the two major forms of precipitation that contribute significant amounts of water in the hydrological cycle. Precipitations are formed through three different processes namely: Convection, orgraphic and frontal. All forms of precipitation depend on these processes mentioned.

5.0 SUMMARY

In this unit, condensation processes, types of precipitation and condition that necessitate the formulation of cloud have been discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the mechanism of condensation
2. Explain the two conditions for the formation of clouds
3. Discuss the two theories that explains the process by which droplets grow large enough to fall as precipitation
4. State and explain the types of precipitation

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography.* London: Unwin Hyman Ltd.

Blij, H. J., Muller, P. O., Williams, R. S., Conrad, C. T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

UNIT 2 MEASUREMENT OF PRECIPITATION

CONTENTS

1.0 INTRODUCTION

In Unit 1, you read about the mechanism of condensation, the two conditions for the formation of clouds and the types of precipitation. You also read about the two theories that explain the process by which droplets grow large enough to fall as precipitation.

In this unit, you will be exposed to the ways to which precipitation is measured using the rainguage as the instrument for measurement.

2.0 OBJECTIVES

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

- identify the instrument and explain how it is used in the measurement of rain
- explain the methods use in measuring snow
- discuss the process involved in the measurement of hail
- discuss how fog-drip and dew fall will be measured

3.0 MAIN CONTENT

3.1 Measurement of Rain

In normal operation, the amount of rainfall is collected in a gauge and measured once a day. An appropriately calibrated stick is used to measure the depth of water which has accumulated in the gauge to obtain the quantity of rainfall. The gauge is to be sited away from buildings and trees and the amount collected does not only depend on the gauge positioned away from obstacles but also on the diameter and height of the gauge above the ground.

In some instances, the rain water is collected and poured into a glass measuring cylinder, where the rainfall equivalent can be read directly. A standard rain gauge will only record the total rain which has fallen between readings. In many cases, it is important to know when the rain fell and at what intensity.

3.2 Measurement of Snow

Snow can be measured using different method. The water equivalent of snowfall can be obtained by melting the snow which has accumulated in the gauge. This method is not accurate especially during heavy snowfall when allowed gauge percent may be totally covered. A fall gauge maybe used to prevents this happenings but the gauge may tend to underestimate the amount of snow reaching the ground. Experiments have also been made to measure snow depth photogrammetrically, either with aerial or satellite photography. Where the snow fall is substantial, the depths can be obtained fairly accurately, but without ground observations the water-equivalent of the snow is unknown.

Whichever approach is used, measurements of the water-equivalent of snowfall always presents problems and probably inaccuracies.Apartfrom a few areas of intensive observations, precise inputs of water to the ground surface by snow cannot be known.

3.3 Measurement of Hail

Hail stones posses considerable kinetic energy and many will bounce out of a convention gauge, causing underestimation of the total fall. The size distribution of hail stones can be obtained from a hail pad which measures the degree of impaction made by the stones. If pads are left out for known times, the amount of ice and water-equivalent can be found. Fortunately, hail is normally insignificant as a precipitation input to the hydrological cycle. So it is normally recorded separately in terms of the number of days with hail.

3.4 Measurement of Fog-Drip and Dewfall

The water content of fog-drip and dew fall is small, therefore special measurement techniques have to be used. Fog drip falls to the surface after contact with the leaves or trees so trough-shaped rain gauges have been designed to increase the sampling area and make measurements more accurate. In principle, they work like an ordinary gauge. (Briggs and Smithson, 1985). The most commonly used instrument for dew fall is an accurate weighing device. The dew drops collect on hygroscopic plates which are attached to a balancing system to weight the amount of water collected. All methods suffer from the basic uncertainty of how accurately the gauges collect dew compared to natural surfaces. Fortunately, water quantities are minute so that even large errors are insignificant in relation to the total precipitation input. (Blij, Muller, Williams, Conrad & Long, 2005).

SELF-ASSESSMENT EXERCISE

Identify the different instruments used for measuring the following forms of precipitation:

1. Rain
2. Snow
3. Hail
4. Fog-drip

4.0 CONCLUSION

Precipitation has been classified into rainfall, hail, fog drip and dewfall. The processes for measuring each type of precipitation have also been outlined. For proper measurement and obtaining accurate information of precipitation,the procedures for setting the instruments used for measurement should always be followed.

5.0 SUMMARY

In this unit, measurements of different types of precipitation have been explained with focus on rainfall, snow, hail, fog drip and dew fall.

6.0 TUTOR-MARKED ASSIGNMENT

1. Identify the instrument and explain how it is used for measuring rain
2. Explain the methods used for measuring snow
3. Discuss the process involved in the measurement of hail
4. Discuss how fog-drip and dew fall are measured

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

Blij, H. J., Muller, P. O., Williams, R., S., Conrad, C.,T. & Long, P. (2005). *Physical Geography*: The Global Environment. Canada: Oxford University Press.

UNIT 3 VARIATIONS IN PRECIPITATION

CONTENT

1.0 INTRODUCTION

The circulation of the atmosphere is driven by the contrast in surface heating between the equator and the poles. That contrast results from the difference between incoming shortwave solar heating and outgoing loss from the surface through various modes of energy transport including traditional heat loss as well as heat loss through convection and latent heat release through evaporation. (Muller & Williams, 2005).

It therefore stands to reason that climate change which in principle involves changing the balance between incoming and outgoing eradicative loss via changes in the greenhouse effect is likely to alter the circulation of the atmosphere itself, and thus, large-scale precipitation patterns. The observed changes in precipitation patterns are far very variable and difficult to interpret than temperature changes however.

Regional effects related to topography (e.g. mountain ranges that force air upward leading to wet windward and dry leeward condition), ocean, atmosphere heating contrasts that drive regional circulation patterns such as monsoons, etc, lead to very heterogenous patterns of changes in rainfall, in comparison with the pattern of surface temperature changes. This unit discusses the variation in precipitation and the causes of the variation.

2.0 OBJECTIVES

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

- discuss, short term variability and seasonal variability
- discuss the causes of variations in precipitation
- explain the concept of water balance

3.0 MAIN CONTENT

3.1 Short Term Variability

The variations in rainfall overtime are of vital significance to hydrologists. Decisions about bridge size, storm sewage construction, culvert dimensions and even flood protection measures must be taken on the basis of the expected inputs of precipitation e.g. knowing what period of time or 25mm of rainfall in a day may not be significant, but if the amount of rainfall in an hour, or even less, then there should be drastic consequences. Surface run off may occur, soil erosion might be initiated, streams might start to swell and flooding might result. Clearly the precipitation intensity is extremely important.

The amount of rainfall per unit varies considerably. Heavy rainfall are normally seen to alternate with relatively quite periods. All types of rainfall show these variations; there is no such thing as steady rain. In convectional storms, the variation are often associated with the passage of the main convection zones across the land where the up draughts are strong, the raindrops are held in the cloud and prevented from falling, but as the up draughts weakens, the drops fall more easily to the ground, giving periods of higher intensity. Considerable variation too is seen in cyclonic rain often associated with temperature zone of instability in the cyclone.

Only when the source of precipitation is held stationary that is when we can get anything like the steady rainfall. The most common situation is when moist air is forced to rise over a mountain barrier. If the moist air is blowing over a sea at a constant speed, the air will be fairly uniform and the conversion of vapour to water droplets will proceed at a constant rate. In such cases rainfall is often prolonged and steady.

The short term variability of rainfall differs greatly from one area to another. It tends to be greatest in the tropics. For instance Djakarta recorded an annual rainfall of 1800mm in only 360 hours on average. By contrast, the average rainfall in London is only 600mm, yet this takes 500 hours to fall. Variability in precipitation is often most important in the more arid areas of the world, for quite small storms may be a rare event. Channels that have been dry for months or even years may fill with water, and the baked clay used to make houses may crumble and be washed away. Within a matter of hours the rainfall may have caused flood, the water almost vanished and within weeks the vegetation will have disappeared again.

3.2 Seasonal Variability

There is a predictable and consistent cycle of rainfall during the course of the year related to the latitudinal migration of the wind and pressure systems. Precipitation associated with areas of convergence and uplift tend to shift Polewards in summer and equator wards in winter, making areas within the same pressure system throughout the year and so seasonal variations are subdued. This is also true in the equatorial trough zone where rainfall can occur at any time throughout the year and in deserts, where rainfall is almost negligible. The brief rare storms which do occur can come at any time, so monthly rainfall, averaged over the long term shows little variation. Even within the same pressure system, some seasonal pattern may be evident.

In the mid latitudes where rainfall is associated with the activity of the rain bearing cyclones, the winter and autumn are relatively wet, for it is at these periods that the westerlies bring the most intense storms. In the tropics and sub-tropics, where convectional rainfall is more important, precipitation tends to be more abundant during summer months. The magnitude of these seasonal variations is even more marked in the monsoonal areas of the world where the year can be subdivided into wet and dry seasons.

Precipitation is more abundant during winter months in areas which experience the mid-latitude depressions during winter only. The Mediterranean Sea area is the best known example of this type of precipitation regime. In some areas where, the seasonal patterns may be more complex, there may be more than one peak in rainfall totals as found in many areas of supposedly Mediterranean climate and in tropics where seasonal migration of the equatorial trough produces two maxima.

3.3 Causes of Variations in Precipitation

Annual rainfall total varies from one part of the world to another, even when altitude allows for. Some atmospheric factors are responsible for spatial variation in precipitation e.g. convectional storms give high levels of spatial variation, while cyclonic rainfall is spatially much more uniform. In the tropics, where a greater proportion of rainfall comes from convectional storms, the spatial variation is particularly marked. It is clear that where the totals are very different, it is because, most rainfalls derived from individual cumulonimbus clouds produce intense precipitation over an area of about 2 to 60km^2. The storms often build up without any significant movement so that areas just beyond the limits of the cloud may receive no rainfall at all.

Sometimes the storms develop over a wider area; perhaps 500km^2, but even so, they do not give rain everywhere. If rainfall were high for a particular period in one area, it would be below 100km. Over the short term these differences might be considerable, but in the long term they are expected to balance out.

3.4 Water balance

As far as humans are concerned, the crucial segment of the hydrological cycle occurs at the planetary surface. Here at the interface between earth and atmosphere, evaporation and transpiration help plants grow and precipitation provides the water needed for that evapotranspiration and it is here at the surface that we may measure the water balance. The balance of water at the earth's surface can be describe in terms of surplus (gain) and deficit (loss) using methods devised by climatologist C. Warrant Thornthwaite.

Water can be gained at the surface by precipitation or more rarely by horizontal transport in rivers, soil or groundwater. Water maybe lost by evapotranspiration or through runoff along or beneath the ground. The water balance at a location is calculated by matching the gains from precipitation with the loss through runoff and evapotranspiration. When actual evapotranspiration is used for the computation, the balance is always zero because no more water can run off or evaporate than is gained from precipitation. However, when potential evapotranspiration is taken into account, the balance may range from a constant surplus of water at the earth's surface to a continual deficit. However, the range of water balance conditions may change when the potential evapotranspiration exceeds the water gained in precipitation, the soil contains less water than it could hold. Because plants depend on water, the vegetation in such location may appear sparse except where irrigation is possible.

The above situation is reversed where rainfalls sometimes as much as 45cm in a single month may exceed the amount of water than can be lost through evapotranspiration. The surplus water provides all that is needed for luxuriant vegetation and still leaves copious quantities to run off the land surface.

The amount of runoff in any location cannot exceed the amount of precipitation, and usually there is much less run off than precipitation. This is because some water almost always evaporates and/or infiltrates the soil.

SELF-ASSESSMENT EXERCISE

1. What are the possible causes of variations in precipitation?
2. The amount of run-off in any location cannot exceed the amount of precipitation. Explain

4.0 CONCLUSION

The evidence that the environment is not evenly distributed and in most cases they are caused by climatic factors. Variability exists in precipitation according to location and nature of climatic elements present.

5.0 SUMMARY

In this unit, variations in precipitation with focus on the short term and seasonal variability, causes and water balance have been discussed extensively.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the following nature of variability
   a) Short term variability
   b) Seasonal variability
2. Discuss the causes of variations in precipitation
3. Explain the concept of water balance

7.0 REFERENCES/FURTHER READING

Briggs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography.* London: Unwin Hyman Ltd.

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MODULE 7 SEASONAL VARIATIONS IN TEMPERATURE, DAY LENGTH, RADIATION, RAINFALL AND EVAPOTRANSPIRATION

UNIT 1 SEASONAL VARIATIONS IN CLIMATIC ELEMENTS OF TEMPERATURE, DAY LENGTH, RADIATION, RAINFALL AND EVAPOTRANSPIRATION

CONTENTS

1.0 INTRODUCTION

A season is a division of the year marked by changes in weather as a result of the yearly orbit of the earth around the sun and the tilt of the earth's rational axis. The seasonal variations usually pose some impact on:

i. Temperature
ii. Day length
iii. Radiation
iv. Rainfall and
v. Evapotranspiration

The main content of this unit discusses the listed elements in terms of the meaning of each element, seasonal variation and factors responsible for such variations.

2.0 OBJECTIVES

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

- briefly state the causes of seasonal variation in temperature and radiation
- explain the likely factors responsible for seasonal variations in temperature, rainfall and evapotranspiration in your area
- discuss the characteristics of seasonal variations in rainfall in different climatic zones.

3.0 MAIN CONTENT

3.1 Variation in Temperature

3.1.1 Meaning

Temperature is the degree of hotness or coldness of a place. Temperature varies with changes in seasons. The different locations on the globe experience temperature variations in length of hours, intensity and duration.

3.1.2 Causes

The earth's revolutions round the sun in every 365/6 days (1 year) are mark by changes in temperature. The tilting of the earth at an angle of 23½^{o} causes the earth's orientation to change, continually as the planet revolves about the sun.

3.1.3 Factors

Temperature can be affected by time of the year, cloud cover, latitude, nature of the surface cover and altitude. On latitude 23½^{o} N (tropic of Cancer), temperature is generally higher in the month of June as it is marked by summer solstice. The sun is overhead at the tropic as solar insolation is longer. However, temperature is higher during the day under a clear atmosphere than a cloudy atmosphere, on a bare ground than on snow covered land and when the ground is dry than on wet, ground.

On mountain tops temperature is lower than on flat surface. This is because solar radiation escapes to space faster on mountain tops and temperature decreases with altitude. (Houze, 2001)

On latitude 23½^{o}S (tropic of Capricorn) in the southern hemisphere on December 21st the sun is overhead marking summer solstices. The duration of day lengths are longer hence intense solar insolation is recorded. (Evans, 1999).

Temperature in the higher latitudes 66½^{o}N and S which is characterized by four distinct seasons, winter, summer, spring and autumn is marked by three months variations. Temperature varies within the four different seasons.

3.2 Variation in Day Length

3.2.1 Meaning

Day lengths are the duration of the hours of day light. This varies with seasonal changes.

3.2.2 Location

The tropics are marked by variation in day length as the season changes. The summers in the two tropics (Cancer in the northern hemisphere and Capricorn in the southern hemisphere) are characterised by longer days. The length of days increase continually to the higher altitude (Lat. 66½^{o}N and S). Summer solstice in the northern hemisphere is in June 21 when the sun is overhead at latitude 23½^{o}N. While the summer solstice in the southern hemisphere is in December 21 when the sun is overhead on Latitude 23½^{o}S.

Winters are characterized in both hemispheres by shorter length of days and longer nights. During winter, the length of nights become longer with increase in latitudes to 66½^{o}N and S. December 21 in the north and

June 21 winter solstice in the southern hemisphere. The equator which is the lower latitude (Lat. 0^o) is marked by equal length of days and night twice a year that is March 21 (spring equinox) and September 23 (autumn equinox). The length of days is calculated as a function of latitude and declination angle.

3.3 Variation in Radiation

3.3.1 Meaning

The intensity of solar insolation that the earth receives. The intensity of the solar radiation is inversely proportionate to the square of the earth-to-earth distance. Solar radiation receives on the earth's surface varies with seasons. More solar energy are accumulated during the longer days of summer than shorter days of winter.

3.3.2 Location

The solar radiation reaches its pole when the sun is overhead directly at noun between latitude 23½^{o}N & S. On June 21 northern hemisphere and December 21 in the southern hemisphere. The earth receives about 6.7% more radiation at perihelion. The total energy the earth receives from the sun luminosity is $3.827 x 10^{26}$ watts. Winters are marked by less solar radiation in both hemispheres.

3.3.3 Causes

Differences in solar radiation can be caused by annual variation in the angle of the sun's rays (cloudiness of the atmosphere) which affects the rays that pass through the thick cloud and the nature of the surface as higher insolation is received on the flat surface than on highlands (altitude). In the temperate and polar regions seasons are marked by changes in intensity of sunlight that reaches the earth surface. As a result, the regions have four calendar seasons – spring, summer, autumn and winter. Pyranometer is the instrument for measuring the intensity of solar radiation striking the horizontal surface.

3.4 Variation in Rainfall

3.4.1 Meaning

Rainfall is the condensed water vapours. It is the product of water vapours that enter the atmosphere through the surface evapotranspiration. Seasonal precipitation patterns are strongly influenced by seasonal variations in quassi-stationary pressure system, regional convergence zones and monsoonal circulations.

3.4.2 Location

Tropical precipitation is highest during the summer and lower during the winter. The annual rainfalls in the tropics vary from zero to 10000mm. The wettest regions of the tropics are the maritime content, inter tropical convergent zone (ITCZ). Precipitation over the equator has the largest annual range. Stations close to the equator have small seasonal variations.

3.4.3 Characteristics

The amount and distribution of rainfall is characterized by four climates:

i. Rainy climate
ii. Seasonal and monsoon climates
iii. Dry climates
iv. Tropical desert

3.4.4 Factors

The annual amount of rainfall is affected by;

a. relief of the area (topography)
b. amount of cloud condensation nuclei
c. trade winds
d. latitudes
e. nature of cloud
f. vegetation cover

3.5 Variation in evapotranspiration

3.5.1 Meaning

Evaporation is the release of water from the surfaces of water and land to form the atmospheric vapour. While transpiration is the release of water vapour through the stomata in leaves of plants from therefore, evapotranspiration means the release of water from water surfaces and water vapour from stomata in leaves of plants respectively into the atmosphere. Evapotranspiration is an important part of water cycle. Evaporation accounts for the amount of air from soil, canopy interception, and water bodies while transpiration accounts for the amount of water within the plants and the subsequent loss of water as vapour through the stomata of plants.

3.5.2 Location

Evaporation is less over land than ocean. Its distribution plays a vital role in the initiation and evaluation of convective weather system. Regions between the equator latitude 0^o to let 30^oN or S have much higher evaporation rates than the higher latitudes.

The tropical forested regions are significant sources of water vapour. The tropics drive the global energy and water cycle since the oceans receive most of the surplus radiative heating.

Evaporation is low along the equator as solar heating is at its maximum and deep convective cloud reduces the amount of solar radiation. The low wind speed in the equatorial ocean reduces the evaporation rates.

The highest evaporation rate occurs along the western side of the sub-tropical oceans during the winter when cold, dry continental air flows over warmer ocean currents. Evaporation is increased by wind speed, inflow areas of hurricane and storm.

3.5.3 Factors

Factors that affect evapo-transpiration are;

a. plant growth and type
b. soil cover
c. wind
d. solar radiation
e. humidity

Evapotranspiration rate is relatively low where the surface to atmosphere moisture gradient is weak and relatively high where the gradient is strong.

Instrument
Evaporation pans and lysineaters are two methods used to measure the potential evapotranspiration. (Houze, 2001, Yu, 2008).

SELF-ASSESSMENT EXERCISE

Discuss variation in radiation according to:
1. cause
2. location

4.0 CONCLUSION

The discussion on seasonal variations in the different elements of climate has given detail explanation on the meaning of each element, factors and characteristics of each of them. The seasonal variations are observed to have some impact on temperature, day length, radiation, rainfall and evapo-transpiration.

5.0 SUMMARY

This unit has discussed in detail the seasonal variations in temperature, day length, radiation, rainfall, and evapotranspiration with particular reference to their meanings, causes of the variations, factors responsible for such variations and the characteristics of each variation.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly discuss the causes of seasonal variations in temperature and radiation
2. Explain the factors responsible for seasonal variation in temperature, rainfall and evapotranspiration in your area.
3. Discuss the characteristics of seasonal variations in rainfall in different climatic zones.

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MODULE 8 EQUIPMENT AND MAINTENANCE OF STANDARD METEOROLOGICAL STATIONS

UNIT 1 EQUIPMENT IN A METEOROLOGICAL STATION

CONTENTS

1.0 INTRODUCTION

This unit will describe equipment found in a meteorological station and how they are used for measuring weather elements. These elements include; rainfall, temperature, wind, pressure, humidity and sunshine.

2.0 OBJECTIVES

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

- describe a standard meteorological station
- list the instruments found in a standard meteorological station and the elements they measure

- describe the equipment for measuring each of the elements of weather.

3.0 MAIN CONTENT

3.1 Meteorological Station

Meteorological station is a facility located either on land or sea, with instruments and equipment for measuring atmospheric conditions, where observations are undertaken on surface weather conditions. The measurements taken include temperature, pressure, humidity, wind speed, wind direction and precipitation amount. Wind measurements are taken with as much obstructions as possible, while temperature and humidity measurements are kept from direct solar radiation or insolation.

Observations are taken at least once daily (manually) whole automated measurements are taken at least once an hour. (Blij, Muller, Williams, Comrad and Long, 2005).

3.2 Instruments in a Meteorological Station

A typical meteorological station has the following instruments: thermometers, barometers, hygrometers, anemometers, wind vane, rain gauge and sunshine recorder.

3.2.1 Thermometer

This is a narrow glass tube containing mercury of alcohol. Thermometer is used for measuring temperature either at the air or sea surfaces. It is usually graduated in degree centigrade (^oC) or Fahrenheit (^oF). Thermometer measures or records temperature at its peak (highest attained during the day). This type of thermometer is called maximum thermometer while the minimum thermometer measures or records the lowest temperature attained during the day. Both maximum and minimum thermometers are jointed together in a u-shape and both are read at different times of the day. Thermometers are kept in a wooden cabinet called "Stevenson screen" to protect them thermometer from the effect of sun and rain in order to get accurate readings.

3.2.2 Barometer

This is used for measuring atmospheric pressure. Barometer is a glass tube containing mercury of alcohol connected to a container at its base. The mercury in the container supports a column of mercury about

760mm high or below depending on the condition at that particular time with a vacuum of air.

3.2.3 Hygrometer

This consists of wet and dry bulbs thermometers usually used for measuring humidity, either through transpiration, evaporation or evapotranspiration.

3.2.4 Anemometer

Is a cup-like instrument used for measuring wind speed.

3.2.5 Wind Vane

This is an instrument with a framework of four cardinal points connected with a pole and an indicator (arrow) used for measuring wind direction.

3.2.6 Rain Gauge

Is a metal container with a metal jar or glass bottle and metal funnel usually sunk into the ground at least 30cm above the ground level. Rain gauge is used for measuring liquid precipitation over a set period of time.

3.2.7 Sunshine Recorder

This is an instrument used for measuring sunshine.

In addition, at certain automated airport weather station, additional instruments may be employed, these include; present weather/precipitation identification sensor for identifying falling precipitation. For instance, Disdrometer is used for measuring drip size distribution; transmitter is used for measuring visibility; ceilometers for measuring cloud ceiling. More sophisticated stations may also measure the ultraviolet index, solar radiation, leaf wetness, soil moisture, soil temperature, water temperature in ponds, lakes, creeks or rivers and occasionally other data as described in Wikipedia, 2015. Except for those instruments requiring direct exposure to the elements (anemometer, rain guage, wind vane), the instruments should be sheltered in a vented box, usually a Stevenson screen, to keep direct sunlight off the thermometer and wind off the hygrometer. The instrumentation may be specialized to allow for periodic recoding otherwise significant manual labor is required for record keeping. Automatic transmission of data in a format like METAR, is also desirable as many weather station's data is required for weather forecasting (Waugh, 2000)

SELF-ASSESSMENT EXERCISE

1. Undertake a visit to a meteorological station in any location of your choice
2. Observe the positioning of the instruments, name them and describe the setting

4.0 CONCLUSION

Weather and climatic elements are measured using instruments to ascertain the changing conditions of the atmosphere and resultant effects on the earth surface. The instruments are kept in locations (positions) where they can be utilized. This portion marked for the instruments is called meteorological station. Instruments for recording temperature; thermometer, sunshine recorder for sunshine, rain gauge for rainfall are kept in the meteorological station. Others include wind vane, anemometer, hygrometer sand barometer.

5.0 SUMMARY

In this unit, instruments used for measuring weather and climate elements, a standard meteorological station have been listed and discussed.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe a standard meteorological station.
2. State the use of the following instruments found in a standard meteorological station
   a. Thermometer
   b. Rain gauge
   c. Barometer
   d. Hygrometer
   e. Wind vane

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UNIT 2 LAYOUT OF A METEOROLOGICAL STATION

CONTENTS

1.0 INTRODUCTION

This unit will examine the layout of a standard meteorological station and how equipments used for measuring weather elements are positioned for proper functioning without obstruction for adequate utilization.

2.0 OBJECTIVES

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

- draw out a layout of a typical meteorological station
- locate the positions of each instrument found in a meteorological station.

3.0 MAIN CONTENT

3.1 Positioning of Instruments

Generally, a meteorological station must be placed in a location where no shading can occur. It is important to remember that shade patterns vary with the season due to changes in earth-sun geometry. It is therefore best to place the station well away from large obstacles if possible. An open location is also necessary to measure wind speed and where the station is hidden from view behind an out-building or a solid wall will not accurately represent the wind speed over more open areas such as fairways or sports fields. Weather stations should be isolated from large obstacles such as fences, trees or buildings by a distance equal to 7-10cm times the height of the obstacle. Using this rule, one should place a station 70-100m away from a 10m high building to ensure proper wind flow at the site. The terrain surrounding the weather station should be relatively level if possible. The ideal situation would be to centrally locate the station in a large, well-watered turf area that is a considerable distance from objects that might disrupt wind flow or shade the station.

Except for those instruments requiring direct exposure to the elements (anemometer, rain gauge, wind vane and sunshine recorder), the instruments should be sheltered in a vented box, usually a Stevenson screen, to keep direct sunlight off the thermometer and wind off the hygrometer. The instrumentation may be specialized to allow for periodic recordings otherwise significant manual labour is required for record keeping. Space is generally required within the station to permit free movement. A normal station should have the Stevenson screen located at 1.5m away from the wire gauge used as fence or boundary of the station. Same measurement should equally be used for positioning wind vane and anemometer. Rain gauge should be placed at 1.2m away from the boundary. A 2m pillar should be used to install or mount the sunshine recorder at a of evaporation should be placed close to wind vane since d height has no significant impact in obstructing wind flow. See fig 1 for more detail.

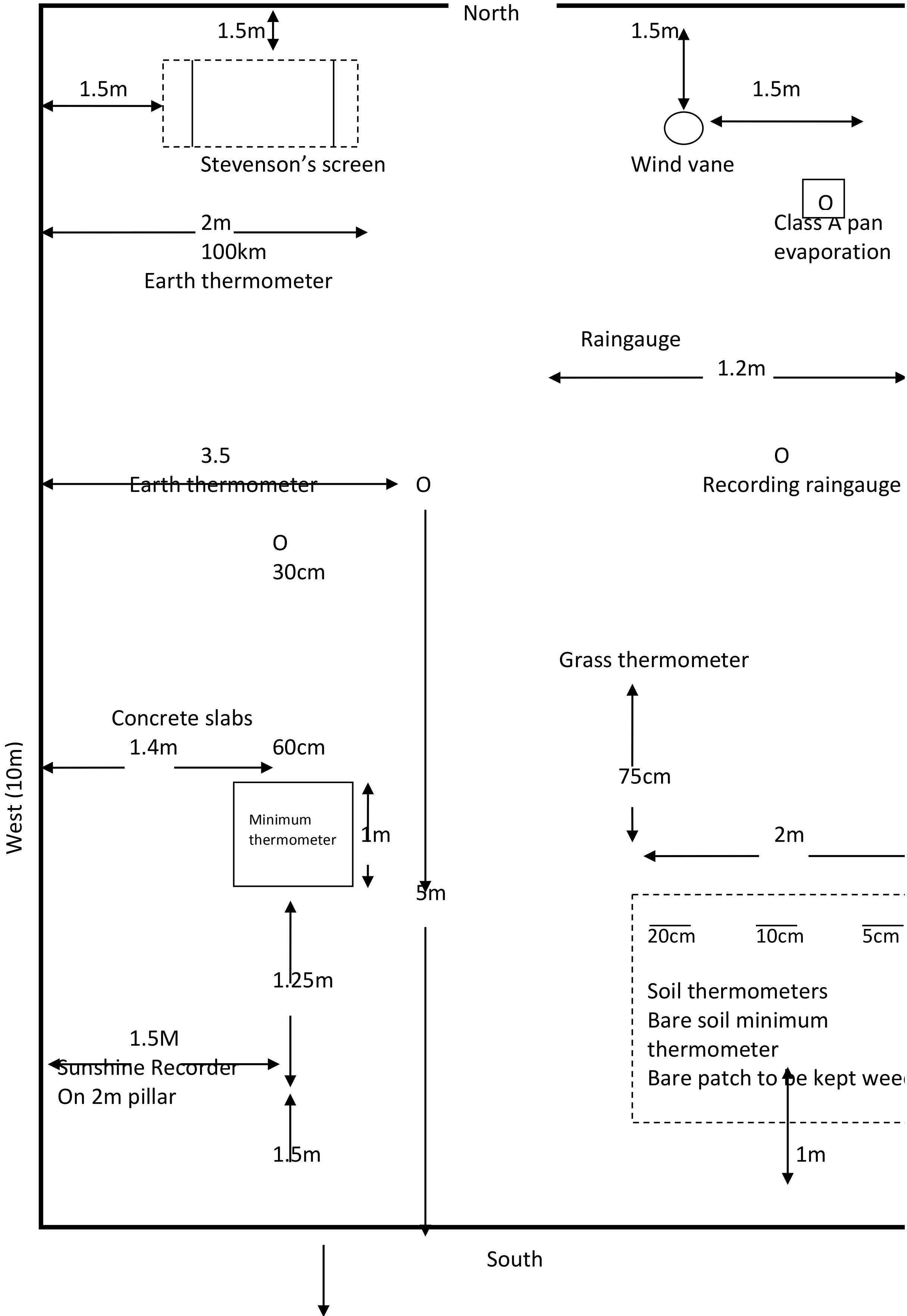

Fig.1: Layout of a Meteorological Station

3.2 Advantages of Good Positioning

To determine atmospheric conditions, weather elements are instrumentally observed and to achieve desired results it depends greatly on the positioning of the instruments in the meteorological station. Understanding the layout of a standard meteorological station is essential if the weather station is to provide the data necessary to estimate weather condition in a consistent and reliable manner. The following are advantages of good positioning of instrument in a meteorological station.

1. The positioning of thermometer in a Stevenson screen is to protect the thermometer against the effects of sunshine and rain so as to get accurate temperature of the day.
2. Keeping rain gauge in an open space free from trees, grasses and buildings enables the rain gauge to collect rain water directly and to ensure that no drops from roof or trees enter the funnel after the rain has stopped. When this is done, records are not overestimated but accurately done.
3. Accurate measurement of pressure and humidity are obtained when barometer and hygrometer are properly positioned thereby providing and obtaining accurate and reliable information concerning weather conditions.
4. Reliable data is obtained on wind direction and speed.
5. All activities conducted in the station yield results with complete absence or minimum errors.

3.3 Taking Records of Atmospheric Condition

1. Thermometer

This is used for measuring temperature. Records are taken on daily basis in degree centigrade or Fahrenheit. Thermometers are often read at different times of the day to find out the maximum and minimum temperatures of the day. Temperature is often designated on maps by a line drawn to join places having the same amount of temperature known as isotherm. The freezing or cooling point for centigrade scale is 0^0 and 32^0 for Fahrenheit scale. The boiling point for centigrade is 100^0 and 212^0 for Fahrenheit. There are two types of thermometer namely; maximum thermometer which records the highest temperature attained during the day and minimum thermometer which records the lowest temperature during the day.

2. Rain Gauge

This is used for measuring rainfall. When taking records of rainfall, the rain gauge must be examined every day and daily records taken. The instrument should be sunk into the ground such that 30cm of it is above the ground level and should be held firm in position. A line used on map to connect two places of equal average annual rainfall is known as isohyet.

3. Barometer

This is an instrument used for measuring the atmospheric pressure of an area. For the barometer to work well, Place the barometer and scale in a shaded location free from temperature changes (i.e. not near a window as sunlight will adversely affect the barometer's results). In your notebook or the table, record the current date, time, the weather conditions, and air pressure (i.e. the level where the end of the straw measures on the scale). Continue checking the barometer twice a day (if possible) each day over a period of several weeks.

4. Hygrometer

This is an instrument used for measuring the humidity of an area at a given time. Some hygrometers have internal data logging. In other cases they are read using a computer (by connection, or even wirelessly). Otherwise, records depend on the person reading and writing down results.

Always record the humidity value and units. For relative humidity measurements, temperature is usually essential. Pressure must be known for psychrometers, and sometimes for other cases such as measurements in compressed air lines especially if planning to convert to equivalent at atmospheric pressure. (Stephanie 2011)

As with all measurements, it is also good practice to record the date, time, place, method, operator, and anything else that allows the measurement to be understood later. Measuring humidity correctly takes some skill and judgment.

5. Anemometer

We use an instrument called an Anemometer to measure wind speed. The cup anemometer is the simplest type. It consists of four hemispherical cups mounted on the end of four horizontal arms. The speed at which the cups rotate is proportional to the speed of the wind.
Therefore, by counting the number of turns over a set time, we can work out the average wind speed.

Place the anemometer outside to see if the wind will spin it around. Using the watch, count the number of times the marked cup spins around in one minute. Repeat this every day for a month. Record the data on the notepad or work book.

Choose one month in winter and one in summer to show differences. After a month of recording, draw a graph to represent the data. Plot the days along the horizontal axis and the wind speeds (turns per minute) along the vertical axis and Join the dots. The experiment in different locations to record and compare the wind speed, will surely be different. Try to explain why there might be variations.

6. Wind Vane

Wind vane is used for measuring wind direction. It has the four cardinal points mounted on a pole. When recording the direction of wind, places the instrument outside and position the instrument far from obstacles such as buildings and trees. Observe the changing direction of the cardinal points at intervals of an hour or two then record the observation including the date and time the observations were made.

7. Sunshine Recorder

This is an instrument used for measuring sunshine. Sunshine recorder essentially consists of a glass sphere mounted in a spherical bowl and a metallic groove which holds a record card. Sun's rays are refracted and focused sharply on the record card beneath the glass sphere, leaving burnt marks on the card. As the sun traverses, continuous burnt marks will appear on the card. Observers can measure the sunshine duration based on the length of the burnt marks (according to LAM Hok-yin (2013)). To obtain uniform results for observation of sunshine duration with a sunshine recorder, the following points should be noted when reading records:

(a) If the burn trace is distinct and rounded at the ends, subtract half of the curvature radius of the trace’s ends from the trace length at both ends. Usually, this is equivalent to subtracting 0.1 hours from the length of each burn trace.
(b) If the burn trace has a circular form, take the radius as its length. If there are multiple circular burns, count two or three as a sunshine duration of 0.1 hours, and four, five or six as 0.2 hours. Count sunshine duration this way in increments of 0.1 hours.
(c) If the burn trace is narrow, or if the recording card is only slightly discolored, measure its entire length.
(d) If a distinct burn trace diminishes in width by a third or more, subtract 0.1 hours from the entire length for each place of diminishing width. However, the subtraction should not exceed half the total length of the burn trace.

4.0 CONCLUSION

When instruments are rightly positioned in the meteorological station adequate readings of information on weather element will be achieved.

When setting a weather station consideration should be placed on the size of the station and the position of the instruments as presented in the layout.

5.0 SUMMARY

In this unit, the layout of a standard meteorological station has been explained and presented schematically showing the positions of instruments and required distances between instruments.

6.0 TUTOR-MARKED ASSIGNMENT

Using a diagram, describe a standard meteorological station

7.0 FURTHER READINGS/REFERENCES

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UNIT 3 MAINTENANCE OF A METEOROLOGICAL STATION

CONTENTS

1.0 INTRODUCTION

For effective utilization and adequate results from the instruments positioned in a weather station, there is need for proper maintenance of the station. This unit will explain the maintenance of a standard meteorological station with focus on the maintenance of equipment, local chores and technical maintenance.

2.0 OBJECTIVES

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

- describe the process of maintaining a standard meteorological station
- identify local maintenance chores of a meteorological station
- explain the maintenance on the instruments in a meteorological station

3.0 MAIN CONTENT

3.1 Maintenance of Different Instrument

A meteorological station like any other piece of equipment, requires regular maintenance if it is to perform its assigned function correctly. These maintenance chores should be performed by local grounds maintenance personnel's since they access the station on a regular basis. Other maintenance work should be performed by trained meteorological technicians. Meteorological station is designed to monitor fire meteorological parameters; solar radiation, wind, temperature, humidity, and precipitation. (Wikipedia, 2016).

3.1.1 Maintenance of Thermometer and Hygrometer

These should be housed in a naturally ventilated radiation shield that will prevent direct sunlight from reaching them. This is because a platinum resistance thermometer sensor exhibit a change in electrical resistance in response to changes in temperature and humidity. (It is measured with sensors that generate a change in electrical resistance or capacitance with changes in humidity).

3.1.2 Maintenance of Windvane and Anemometer

The main problem that could arise from using windvane and anemometer is a guiding sound which may result in poor rotation at low speed. This is caused by poor bearings and should be replaced as soon as possible by a trained technician.

3.1.3 Maintenance of Raingauge

1. Keep the gauge on a ground level and the collection funnel constantly clean
2. Wipe out dirt and debris from the tipping bucket mechanism if required.

3.1.4 Maintenance of Power Supply

Power failure causes loss of data. A solar panel may provide power to weather stations located away from a reliable source of air condition A.C. power. Dust and debris should be removed weekly to maintain proper output from the panel. Bird droppings should be removed as soon as possible to ensure optimal panel performance and also charging circuit can be repaired by trained technicians in the case of battery usage.

3.1.5 Mechanical Maintenance of a Standard Meteorological Station

Technical maintenance should be carried out whenever routine maintenance reveals a problem. Therefore, it is suggested that there should be a technical representative to check the system once every year even when there is no problem observed during the routine local maintenance. Ensure that the following are regularly done.

1. Anemometer bearings should be replaced every 12 months to ensure proper measurement of wind speed.
2. Thermometer, hygrometer in an automated station and raingauge should be checked and examined regularly by the trained technical representative. Temperature and humidity sensors should be replaced every 24 months.

3.1.6 Technical Maintenance

This is best performed by a trained representative of the company that supplies the instruments. Technical maintenance is an essential aspect of operating a meteorological station, and turf facilities should be wary of suppliers that do not provide both telephone and on-site technical assistance. If the supplier does not provide on-site technical service, they should be able to train a third party who can. Doing this will improve the longevity and performance of instruments found in the meteorological station (National weather services, 2015).

SELF-ASSESSMENT EXERCISE

Identify the local maintenance chores of a meteorological station of your choice.

4.0 CONCLUSION

The maintenance of a standard meteorological station is of great importance to ensure accurate readings. Instruments should be kept and positioned rightly; equipment should be checked on daily basis to ensure that all equipment are functioning well. Parts such as bearings and sensors should be replaced to ensure accurate readings.

5.0 SUMMARY

The use of meteorological stations represents a significant advance in the field of turf grass irrigation management. Therefore, to obtain the best and most reliable results from a meteorological station, the station must be properly studied and maintained to avoid damage and unnecessary break down of the instruments.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain in detail the maintenance process of a standard meteorological station.

2. Explain the procedures for carrying out a technical maintenance on a standard meteorological station.

7.0 REFERENCES/FURTHER READING

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MODULE 9 THE TROPICAL CLIMATE

UNIT 1 THE TROPICAL CLIMATE

CONTENTS

1.0 INTRODUCTION

The tropics have been described as the Firefox of the atmospheric engine. Most of the solar radiation is absorbed in the tropics and energy transferred into the cooler, energy-poor latitudes. Thus, transfer is brought about by wind systems and ocean currents. Simple approach to climate in the tropics is distinguished in four main areas;

a) the equatorial trough zone (inter-tropical convergence zone)
b) the sub-tropical highs
c) the trade wind areas
d) the monsoons and tropical cyclones

2.0 OBJECTIVES

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

- identify the four main climatic zones (areas) in the tropics
- state the characteristics of the equatorial trough
- describe the features of the sub-tropical highs
- differentiate between trade wind and the monsoon.

3.0 MAIN CONTENT

3.1 Equatorial Trough

It is the equatorial trough area that most closely meets people's idea of a tropical climate. During the day, clouds build up massive cumulonimbus displays. Rainfall is frequent and abundant, temperature and humidity acting together, resulting to tropical rainforests. The tropical rainforest climate is located within 5^oN&S of the equator. This area lies within the Amazon basin in South America, Zaire (Central Africa) and the coast of West Africa. The climate is constantly warm with temperature of 26^oC and no winter, recording $>18^oC$ as the coldest month. The rainfall distribution is relatively high approximately 2,400mm and there is no month with rainfall less than 250mm. Double maximum rainfall pattern is experienced in the area with great intensity often accompanied by thunder storm and lightning.

The equatorial trough has many different forms of climatic conditions. It represents the area of low pressure somewhere near the equator towards which the trade winds blow. The precise form it takes will depend significantly upon the stability of the trades, their moisture content and the degree of convergence and uplift. For instance, the Brazilian Amazonia records a mean monthly temperature variation by 2.8^oC over the year and a mean monthly minimum by only 0.6^oC. Extremes are rare and insignificant by temperate latitude standards. Mean annual rainfall is high with 1811mm, though even in this zone there is a drier season when rain days are fewer. This is applicable to most of the equatorial through zone, though variation exists in terms of intensity and duration of the dry season. Only few areas have no dry season. For instance in Indonesia, Padang in Sumatra, an area located 7m above sea-level receives an average rainfall of 4427mm, only one month has less than 250mm. The driest season occur when the trough move pole wards in response to continental heating in the summer hemisphere. As one moves further away from the equatorial trough zone, the dry season lengthens reaching the monsoon or trade wind areas (Briggs and Smithson, 1985).

The multitude of names which have been used for the area gives some idea of its variety; the doldrums, intertropical front, intertropical convergence zone, intertropical trough, equatorial trough or intertropical confluence zone. For simplicity all are referred to as equatorial trough although it does extent towards the sub-tropics, and it is quite variable in features (Blij, Muller, Williams, Conrad and Long, 2005).

3.2 Sub-Tropical Highs

This pressure zone acts as the meteorological boundary between the tropical and temperate latitudes. The dominant air movement is usually away from the highs; the circulation is maintained by the subsiding air from the Hadley cell. Because the air is subsiding, it tends to be warm and dry. An inversion develops in the lower atmosphere and so these sub-tropical highs are generally cloud-free and deficient in rain. Where the highs remain fairly constant in position, the main desert areas of the world are found; Sahara, Kalahari, and the great Australian Desert.

Within this system, there is often low pressure area which result from intense heating of the ground during the cloudless days, taking temperatures above 40^{o}C in summer. The air becomes less dense and thermal lows form. They tend to be fairly shallow and are replaced by high pressure by the 850mb level.

Climate of this zone can be characteristerised by little rain and extremes of temperature. In mid-summer, the mean maximum temperatures are 42^{o}C but in winter the minimum temperatures are only 8^{o}C and frost can occur occasionally. The dry atmosphere helps by allowing long wave radiation from the ground to escape to space with little counter – radiation from water vapour or clouds. Precipitation is negligible, rainfalls is experienced for about 10 days per year giving a total of about 75mm. Most of it falls in winter and spring when temperate latitude depressions extend their effects far south and do give occasional rain (Evans, 1999).

In some of the sub-tropical high pressure belts, additional factors reduce the likelihood of rain. On the west coast of Sahara, Kalahari and Atacama deserts cold ocean currents flow offshore, prevailing wind and mountain barrier. They cool the air and make it even more stable. Mist and fog may be frequent but rain is rare. The result of these factors acting against the mechanisms of rainfall generation is produced on the driest parts of the earth, as seen in Africa and Atacama desert of Chile.

3.3 Trade Winds

Trade winds blow away from the sub-tropical anticyclones of each hemisphere; north easterlies in the northern hemisphere and south easterlies in the southern hemisphere. The trade winds of the world can be some of the most constant and reliable winds of the world.
Around the tropics, the trade winds are very stable, being affected by subsidence so the moist-layer near the surface is thin. The sudden rise of temperature and drying of the air at about 900mls pressure surface is called Trade wind inversion. In the north east of the Atlantic and pacific

oceans, it may be only a few hundred metres above the ground, effectively preventing rainfall over the oceans. When Canary Islands, rise through the inversion, the lower windward slopes may be moist due to cloud and some rain, but above the mean level of the inversion and on the leeward slopes, desert are formed.

Trade winds gradually pick up moisture as they blow away from their source areas, the anticyclone normally noticed in the shape of the trade winds cumulus clouds. They are visible signs that moisture is being evaporated from the seas and partly condensing as clouds. With more moisture being added and the influence of the anticyclones weakening, the intensity of the trade winds inversion weakens and its gets higher. Rainfall is likely to occur as seen on the western side of the Atlantic Ocean with much moist climate, although with a distinct wet and dry season.

3.4 Monsoons and Tropical Cyclones

In some parts of the world, the wind system appears to experience a seasonal reversal; they may be blowing from the south-west in one season; in the other season they are from the north-east. A large area of the tropics is affected by seasonal reversal in areas where trade winds are dominant.

Seasonal reversal is linked to the position of the continents in the northern hemisphere. During summer in the northern hemisphere, surface heating of the continental landmasses is intense. A shallow surface low pressure centre forms over the Sahara, India and Central Asia. The equatorial trough moves northwards allowing an inflowing of moist south-west to give the wet season in west Africa, India and some parts of Asia. In winter, the continents cool down, high pressure becomes established at the surface and winds between north-east and north predominate. This is the cool dry season for the monsoon areas of the northern hemisphere.

In the southern hemisphere, land masses are smaller and only Australia develops the semblance of a monsoon, though its influence does not extend very far inland. Over East Africa, set aside the equator, a seasonal reversal occurs, but the winds tend to be blowing parallel to the coast. As a result, the rainy season is between the main monsoon flows, rather than during one of them as in most of the other regions. The monsoon climates is characterized by 1,500mm annual rainfall distribution concentrated during the wet or rainy season, temperature is high about $27^{o}C$ with an average of $5^{o}C$. The climate is associated with alternating wet and dry seasons. Monsoons are usually found 10^{o} and 35^{o}N&S of the equator.

The major disturbance of tropical latitude is the cyclone. Its main features affect regional distribution of climates. It is apparent that cyclones only develop over warmer parts of the ocean, in each hemisphere; cyclones are most likely to strike in the summer and autumn. Along the Atlantic and Gulf coasts of the USA, the normal hurricane season is from June to November. Early in the season, storms develop in the Gulf of Mexico with progressive eastward movement from their starting points until September when they may reach as far east as the Cape Verde Islands of West Africa. There may be a shift back towards the Gulf of Mexico after September (Opeke, 2005).

The zone of recurvature may be affected by another seasonal change. Most storms initially move westwards but at some stage may begin a curving track towards north and then north-east. The average latitudes of recurvature is at its northernmost position in August and furthest South in November. Many storms could reach hurricane intensity and decay without being recorded by the global observing network. Pacific Ocean has the most hurricanes but the fixtures are difficult to compare.

The mean rainfall of areas affected by tropical cyclones in summer and autumn reflect the vast amounts of water which a hurricane can release. Not all tropical areas are affected by tropical storms or easterly waves. However, other less organized disturbances give appreciable precipitation. For instance in Mozambique and parts of Brazil. A few areas miss major disturbances altogether, anomalous dry zones occur in north-east Brazil where annual rainfall of less than 500mm is found. Less than 250mm as mean annual precipitation is experienced in Somalia and aridity prevails, though the area is only just north of the equator.

SELF-ASSESSMENT EXERCISE

1. Identify the four main climatic zones in the tropics
2. Differentiate between the trade winds and the monsoon

4.0 CONCLUSION

The location of the tropical areas at latitudes 5^{o}N & S of the equator give rise to experiences of high temperature and rainfall due to the high amount of sunshine received at different times of the year when the sun is overhead. The climatic conditions favour a variety of vegetation cover where some areas enjoy high temperature and rainfall and a forest based vegetation, while some others moderately experience, temperature and rainfall with grassland vegetation. Where the distribution of rainfall is extremely low and temperature is extremely high an arid condition is experienced and desserts are formed.

5.0 SUMMARY

In this unit, the features of the tropical climate as it affects temperature, rainfall humidity, and wind systems have been widely discussed. Only the tropical climate avail man a wide range of opportunities for economic agricultural and social activities without much disadvantage. Ocean current and the role played in modifying climate and bringing possible seasons have been discussed. Therefore, tropical climate has a lot of relationship between farming, animal rearing, pests and diseases as they could contribute in one way or the other in balancing either nitrogen or Co_2 in the atmosphere which in turn helps in balancing atmospheric conditions that may seem adverse to inhabitants and the crop systems.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the occurrence of seasons with reference to the effects of trade winds.
2. Explain in detail the characteristics of the following tropical conditions.
   i. equatorial trough
   ii. sub-tropical highs

7.0 REFERENCES/FURTHER READING

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MODULE 10 RELATIONSHIP BETWEEN AGRICULTURE AND CLIMATE WITH REFERENCE TO CROPS, LIVESTOCK, IRRIGATION, PEST AND DISEASE

UNIT 1 CONCEPTS RELATED TO AGRICULTURE

CONTENTS

1.0 INTRODUCTION

Climate is the most important of the factors which determine the type of agricultural practices of the world. The type of climate and fluctuations in climate from time to time and year to year may cause radical changes in species composition, disease spread and type of agriculture practiced.

No doubt, climate plays a significant role to agriculture. Most or virtually all agricultural processes depend to a greater degree on climatic factors especially rainfall, temperature, wind systems, humidity and sunlight.

This unit explains the identified relevant concepts in agriculture, stating their relationships to different climatic conditions with reference to crops, livestock, irrigation, pest and disease.

2.0 OBJECTIVES

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

- understand the following concepts;
    - agriculture
    - climate
    - crops
    - livestock
    - irrigation
    - pest
    - disease
- outline the conditions most favourable for crop and livestock production.
- outline pest and disease of plants and animals, stating some common ways of control.

3.0 MAIN CONTENT

3.1 Concepts Related to Agriculture

3.1.1 Agriculture and Climate in Focus

Agriculture is the science, art or occupation concerned with the cultivation of land for crop production and rearing of livestock of various types. In its broaden sense, it is the cultivation of crops, raising and breeding of livestock, processing, storage, distribution and marketing of agricultural products. On the other hand, weather is defined as the atmospheric condition of a place over a short period of time while climate is the average weather condition of a place measured over a long period of time, relatively 35 years. A branch of meteorology which studies weather condition as it affects agriculture is identified as agrometeorology. This discipline studies the meteorological, climatic and hydrological conditions as they relate to agricultural production. It is closely allied to biology, soil science, geography and the agricultural science. (Cayan, Maurer, *et al*, 2008)

Climate affects the distribution of crops as it determines the type of crop produced in a season and the location suitable for such production. For instance, tree crops thrive better under moist soil, rich in organic matter. This can be obtained in areas of high temperature and rainfall distribution. The leaves of plants around form the greater proportion of organic matter used by plants or crops. Tree crops and tuber crops are likely found in areas of sufficient rainfall and temperature. Such areas often have rich soil for crop production.

On the other hand, the vegetation of an area is determined by the climate of such area. Where the temperature is high and rainfall distribution is equally adequate, it is believed to have a luxuriant vegetation and gallery of forests with tall grasses and shrubs. But, when the climatic condition tends to be different with the stated condition above, grassland vegetation is likely to be formed. A typical example of grassland vegetation is seen in the northern part of Nigeria. Such vegetation only supports animal rearing in vast proportion and production of cereal crops (mostly grains). The grasses serve as feeds for cattle, sheep and goat. Changes in weather leads to the occurrence of seasons, leading to loss of available feeds for livestock due to shortage of water from the ultimate source (precipitation) through withering of plant leaves. This makes farmers from the north where such practices are dominant to the south in search of pasture. During the wet season, these herdsmen move their cattle northwards while southward in the dry season. This system of movement with changes in season is known as pastoral nomadism.

Also the movement can be up and down the plateau because valleys are then infested with tsetseflies during the wet season. In the dry season when the valley is free from tsetseflies and the plateau is dry, they move their flocks down the valley. This system of moving livestock up and down the highland by the herdsmen is known as transhumance.

3.2 Crops and Livestock

Crops refer to the yield or cultivated produce of the land while growing or gathered by the farmer while livestock are animals such as goats, cattle, sheep and other useful animals raised by farmers for either personal or commercial purpose. Crops produced by farmers can be annual (rice, maize, groundnut, soybean, etc) or biannual (ginger, etc) or perennial (mangoes, pineapple, pea, banana, etc).

Pests and diseases often attack and effect changes to both crops and livestock in areas where temperature is high and rainfall equally is equally high, frost are to emerge. Such areas are not conducive for livestock breeding as tsetseflies are predominantly habitat in such areas. The tsetse fly bite causes infection to animals especially cattle resulting in trypanosomiasis which is also injurious to man. This serve as indicator as to why domestic animals are not present in the south as much as in the northern part of Nigeria. The northern part is devoid of tsetseflies thereby making it safe for the animals to survive. (Cayan, Maurer, *et al*, 2008).

3.3 Irrigation

Irrigation is often regarded as dry season farming or farming that takes place in areas that experience deficit in rainfall distribution. It is the artificial application of water to land in order to improve the moisture content of soil and meet up with plants or crop water need. Climate plays a significant role in these operations. When the climatic condition is favourable i.e. temperature and rainfall are adequate throughout the year. Without deficit in rainfall, there will be no need for irrigation as farmers will cultivate under natural supply of rainfall and improved soil moisture condition. The changing nature of weather as experienced in the tropical region led to irrigation. During dry season, rainfall is absent, making it difficult to cultivate the land and plant seeds. During wet season, constant increase in the rate of evapotranspiration may force farmers to utilize streams, rivers, ponds, wells and other sources of water to produce crops in order to meet up with food demand.

3.4 Pest and Disease: Spread and Control

A pest is an insect or any other organism that harms or destroys garden plants. The presence of pests could result to pathogens that cause continuous irritation in plants. Disease on the other hand, means a malfunctioning process caused by continuous irritation. Plants develop diseases when they catch the pathogens. Plant diseases can be attributed to several factors in the environment which could be physical, chemical or biological. Diseases caused by biotic agents such as viruses, bacteria, fungi, nematodes and parasitic flowering plants are called infectious diseases while those caused by physical or chemical factors such as air pollutants, water, frost, nutrition, etc are called non-infectious diseases. Unlike the non-infectious diseases, the infectious diseases show a sigmoid curve. This means that they first increase as the biotic agent reproduces and later diminish on the non-availability of hosts.

It is estimated that between 10% and 16% of the world's crops are lost to disease outbreaks. The spread of pests and diseases could be traced to climate change. It is believed that global trade in crops is mainly responsible for the spread of pests and pathogens from country to country. Increase in temperature contributes to a pole ward movement or migration of many organisms and results in higher rate of growth and reproduction in insect herbivores. Cold winter temperature has helped to keep pest and disease life cycles at a minimum and that wise delay the growth and dispersal of pest organisms. Crop diseases are often spread through an insect vector. This can be achieved by wind dispersal either through spores carried by wind or an increase in severe weather event such as hurricanes.

A significant number of measures can be advanced to address the aforementioned challenge. This includes a combination of farming strategies, biological control agents and appropriate pesticide and herbicide using a variety of methods. (Blijand Smithson, 1985; Oluwafemi, 1998).

SELF-ASSESSMENT EXERCISE

Discuss the conditions that are most for making and make the growth of crops possible in your area.

4.0 CONCLUSION

Climate plays a significant role in the pattern of agriculture practice by a nation; for instance, the distribution of crops cuts across different geographical location with crops peculiar to them. Crops like oil palm are produced in the south-south, rubber in south-east and some parts of south-east, groundnut and cotton are predominantly produced in the north. All these are possible due to variation in climatic factors which in turn affects soils making it suitable for crop production and the spread of pests and diseases.

5.0 SUMMARY

In this unit, the concept of agriculture and climate have been discussed with emphasis on distribution of crops, livestock, irrigation, pests and diseases influenced by climatic factors such as temperature and rainfall. Climatic factors influence the movement of livestock up and down highland, south to north in search of pasture. Irrigation is a necessary solution to excess rate of evapotranspiration and deficit rainfall. The spread of pest and disease due to favourable climatic condition is detrimental to man's comfort and health.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly define the following concepts
    a. agriculture
    b. climate
    c. crops
    d. livestock
    e. irrigation
    f. pest
    g. disease
2. What are the common diseases of plants?

7.0 REFERENCES/FURTHER READING

Blij, B. & Smithson, P. (1985). *Fundamentals of Physical Geography*: London: Hutchinson Education Publishers.

Cayan, D. & Maurer, E. *et al* (2008). *Climate Change Scenarios for the California Region*. Climatic Change 87(0): 21-42.

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UNIT 2 RELATIONSHIP BETWEEN CLIMATE AND CROP DISTRIBUTION

CONTENTS

1.0 INTRODUCTION

Crops make up a greater proportion of food consumed by humans. It is evident that the production and distribution of crops depend on climatic factors which to a greater degree influence the distribution of crops on the basis of location suitable for them. This unit explains the relationship between climate and crop distribution with focus on the effects of rainfall, temperature, sunlight, wind and humidity on crop growth and distribution.

2.0 OBJECTIVES

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

- explain the role of rainfall on crop growth and distribution
- describe the effects of sunlight on crop growth and distribution
- describe the effects of temperature on crop growth and distribution
- identify the significance of wind as a factor in the growth and distribution of crops
- explain the role of humidity on the growth and distribution of crops

3.0 MAIN CONTENT

3.1 Effects of Rainfall on Crop Growth and Distribution

Rainfall distribution varies according to seasons and the lengths of seasons differ according to latitudinal location. This determines the growing seasons and nature of crop production.

The amount of rainfall determines the growth and distribution of crops. This is because some crops require high rainfall for greater productivity e.g. root and tuber crops, while others require little or moderate amount of rainfall supply across different regions e.g. cereal and legumes. Rainfall decomposes organic matter; increases soil fertility and dissolve minerals in soil for plant use. (Oluwafemi, 1998).

3.2 Temperature Wind, Humidity and Sunlight as Factors in Crop Growth and Distribution

3.2.1 Temperature as a Factor in Crop Growth and Distribution

Temperature variation has great influence on the growth and distribution of crops.Some crops require high temperature while others require cold temperature to grow favourably. Temperature contributes greatly in the decay of organic matter which in turn improves soil organic content.

3.2.2 Wind as a Factor in Crop Growth and Distribution

The variations in wind speed and direction play an important role in the growth and distribution of crops in different regions or areas. Wind prevents frost by disrupting a temperature invasion at different locations, movement of pollen grains to ensure fertilization and distribution of energy during photosynthesis by bringing carbon dioxide for plants utilization and oxygen for animal use.

3.2.3 Humidity as a Factor in Crop Growth and Distribution

Humidity plays a significant role in crop growth and production; it strongly determines the crop grown in a region. Internal water potentials, transpiration and water requirement for the growth of plants and crops depends on humidity though extremely high humidity is harmful as it enhances the growth of saprophytes and parasitic fungus, bacteria and pests while very low humidity reduces yield.

3.2.4 Sunlight as a Factor in Crop Growth and Distribution

Crops depend on sunlight. However, photoperiod varies greatly at different latitudes; therefore, many plants cannot be successfully moved from one latitude to another even though environmental and other cultural factors are compatible. Rainfall distribution varies according to seasons, and the length of seasons differs on latitudinal basis, thus determining the growing seasons and the nature of crops produced.
The hours or duration of sunlight also determines the growth and distribution of crops in different regions. This is due to variation in hours of sunlight in the various regions. This affects the growth and distribution of crops. Sunlight serves as the energy source for photosynthesis. (Blij and Smithson, 1985)

SELF-ASSESSMENT EXERCISE

1. Identify the types of crops grown in your area
2. Identify the climatic elements that have influenced the growth and distribution of the listed crops in your area

4.0 CONCLUSION

The climatic elements described in this unit have influence on crop growth and distribution. Elements such as rainfall, temperature, sunlight, wind and humidity significantly affect the distribution of crops across regions. Where the climatic conditions are favorable, the productivity level tends to be high but if otherwise low yield will be achieved.

5.0 SUMMARY

This unit explains the significant role climate plays on crop growth and distribution. Temperature facilitate the ripening of fruits, wind assists in the distribution of heat, absorption of carbon dioxide (Co_2) and distribution of oxygen to livestock from plants during photosynthesis. Rainfall improves moisture content of soil, dissolves minerals and contributes significantly in the decay of organic matter which in turn contributes to the fertility of the soil for improved growth. Humidity contributes to the amount of rainfall received in an area and the amount of rainfall significantly improves the growth of crops. Water vapour equally escapes from water surfaces and from plants through the process of evapotranspiration.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the significance of the following elements of climate on crop growth and distribution;

a) Sunlight
b) Temperature
c) Humidity
d) Wind
e) Rainfall

7.0 REFERENCES/FURTHER READING

Blij, B. & Smithson, P. (1985). *Fundamentals of Physical Geography*: London: Hutchinson Education Publishers.

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UNIT 3 RELATIONSHIP BETWEEN CLIMATE AND AGRICULTURE

CONTENTS

1.0 INTRODUCTION

This unit describes the relationship between agriculture and climate with focus on the effects of rainfall, temperature, wind, and humidity on livestock and crop growth and distribution; moisture on irrigation, temperature and humidity on pest and disease spread.

2.0 OBJECTIVES

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

- discuss the effects of rainfall and temperature on livestock distribution and crop growth
- explain the effects of moisture on irrigated agriculture
- explain the effects of temperature and humidity on pest distribution
- explain how temperature, wind and humidity aid in the disease spread of plants and animals.

3.0 MAIN CONTENT

3.1 Effects of Rainfall, Temperature, Wind, Humidity and Sunlight on Agriculture

3.1.1 Rainfall and Temperature on Livestock Growth and Distribution

Rainfall distribution and temperature are major climatic elements that have significant impact on human activities. They influence the growth and distribution of livestock because the presence of these elements when favourable provides viable grazing reservoir for livestock which provide the essential nutritional needs of livestock for proper growth and development. The amount of rainfall received provides a good source of drinking water which maintains the internal or optimum temperature of the animal body. Combined effects of these elements enhanced livestock growth (Jules, Robert, Frank and Vernon, 1981).

3.1.2 Moisture on Irrigated Agriculture

Irrigation becomes necessary when natural precipitation and moisture are absent either due to excess evapotranspiration or deficit in rainfall. Crops need water in the soil to help mix up minerals which they absorb through their root hair for metabolic system to be complete and where the water is absent, it signifies that moisture is poor and crops finds it difficult to thrive. Low water application levels and less irrigation frequencies reduces crop growth as well as low crop yield due to low or poor soil water.(Schneider, Hollier, et al, 2005).

3.1.3 Temperature and Humidity on Pest Distribution

Changes in climate resulting to increased temperature could impact crop pest-insect population in several complex manners. Increased temperature can potentially affect insect's survival, development, geographical range and population size. Temperature can impact insect physiological development directly or indirectly through the physiology or existence of the host depending on the development strategy of insect species.

The nature of humidity depends on the rate of evapotranspiration and the rate of humidity determines the extent and magnitude of rainfall. The rate of evapotranspiration renders most excess moisture-loving organisms to survive due to dryness of the environment. In this case, pest-insect, feeds population will reduce when the rate of evapotranspiration is high. High humidity increase the rate of rainfall and excess rainfall is detrimental to the survival of less moisture-loving organisms. (Parmesan, 2006).

3.4 Temperature, Wind and Humidity on Disease Spread

Weeds, diseases and insects pest benefit significantly from warming and will require more attention as climate changes; these changes are due to increase in temperature which is advantageous and facilitates the spread of pests and diseases.

Increase Co_2 concentration reduces land's ability to supply adequate livestock feeds as increased heat, disease and extreme weather condition reduces livestock production and increases the spread of pests and diseases. Global warming is a major cause of increase rainfall in some area which could lead to an increase in atmospheric humidity and the duration of wet season. These conditions favour the development of fungal disease. Similarly, because of higher temperature and humidity, there could be an increased spread of diseases.

3.5 Sunlight on pest and disease spread

Sunlight supplies not only energy to plants but all forms of animals including pests. Pest attack causes diseases to plants and spreads widely. Some pest thrives better under hot conditions while others under cold conditions. The hotness and coldness depends on the duration of light and magnitudes which also depends greatly on latitudinal location. The disease in most cases under cold conditions favour some disease causing agents and increase its spread while the reverse is the case when the condition changes. The magnitude of the effects of each disease depends on the location and the disease causing agent e.g. fungi that cause disease on sunflower.

Generally pests are considered as pathogens, predators and weeds, which can cause diseases and damage to both plants and animals. When sunlight and other environmental factors are in place, crop productivity level will be high and the effects of pests may be reduced. Crops suffer from disorders caused by climatic conditions. When sunlight is high and moderately distributed, the process of photosynthesis will be active and most pests will be comfortable and multiply fast produce fruits, e.g. fungi which depend on green plants for their food. Wind systems do not distribute only moisture and energy but also aid the spread of pathogens and diseases. The stronger the wind, the more likely the rate of spread of diseases. When the wind system is less, the magnitude of spread would be low. This is possible because most disease causing agents travel faster in air. (Prospero, Grunwald, Winton and Hansen 2009).

SELF-ASSESSMENT EXERCISE

1. Determine the extent to which rainfall and temperature have affected (positively or negatively) the distribution of livestock in Nigeria and particular in your area
2. What do you understand by pest?
3. In what ways can you say temperature and wind have aided the distribution of pests?

4.0 CONCLUSION

Climate play a significant role in agriculture, as all the components of agriculture depend on climatic elements. Pest and disease are widely effective and spread easily only when climatic conditions are favourable. Livestock growth and distribution is perfected only when grasses grow effectively and rainfall provide adequate amount of drinking water.

5.0 SUMMARY

In this unit, the relationship between agriculture and climate has been discussed with focus on the role of temperature, pest, disease spread, livestock production and rainfall.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the effects of moisture on irrigated agriculture
2. Outline 3 implications of lack of moisture on irrigated agriculture
3. How do temperature, wind, and humidity aid in disease spread in plants and animals?

7.0 REFERENCES/FURTHER READING

Brigs, D. & Smithson, P. (1985). *Fundamentals of Physical Geography*. London: Unwin Hyman Ltd.

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MODULE 11 CLIMATE CHANGE ISSUES IN AGRICULTURE AND VARIOUS METHODS OF AMELIORATION

UNIT 1 CONCEPTS AND MEANING OF CLIMATE CHANGE AND AGRICULTURE

CONTENT

1.0 INTRODUCTION

In the past, when climatology was still at an infant stage, it was a common belief that climate was a non-changing feature of the environment. By averaging climatic data over a sufficiently long period of time (30-50 years), it was assumed that true climate would be determined. However, it was rather established that climate fluctuates all the time giving rise to conditions affecting agriculture, environment, human health etc. This unit will describe the concept of climate change and resultant effects on agriculture.

2.0 OBJECTIVES

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

- define the concept of climate change
- state the causes of climate change
- enumerate evidences of climate change in your area

3.0 MAIN CONTENT

3.1 The Concept and Meaning of Climate Change

Climate change is a change in the statistical distribution of weather patterns which may last for an extended period of time (i.e. decades to millions of years). It is a change in average or longer weather conditions (i.e. more or fewer extreme weather events). Climate change is caused by factors such as biotic process, variations in solar radiation received by earth, plate tectonics and volcanic eruptions. Certain human activities have also been identified to play a significant role in recent causes of climate change which to a greater degree is called anthropogenic causes of climate change often referred to as global warming.

To understand past and future climate, observations and theoretical models has been actively used by climatologists. A record extending deep into the earth's past has been gathered and continues to be built up based on geological evidence from borehole temperature profiles, cores removed from deep accumulations of ice, flora and fauna records, glacial and periglacial processes, stable isotope and other analysis of sediment layers, and records of past sea levels. More recent data are provided by instrumental records. General circulation models, based on the physical sciences, are often used in theoretical approaches to match past climate data, make future projections and link causes and effects of climate change.

Fluctuations over periods shorter than a few decades do not represent climate change. The term sometimes is used to describe climate change caused by human activity, as opposed to changes in climate that may have resulted as part of earth's natural processes. In environmental policy context, the term climate change has become synonymous with anthropogenic global warming. Global warming scientifically refers to surface temperature increase while climate change includes global warming and everything else that increasing greenhouse gas levels will affect. (Wikipedia 2015).

3.2 Causes of Climate Change

The rate at which energy is received from the sun and the rate at which it is lost to space determine the equilibrium temperature and climate of the earth. Energy is distributed around the globe by wind system, ocean currents and other mechanisms to affect climatic condition of different locations.

Factors that can shape climate are called climate forcing or forcing mechanisms. These include processes such as variations in solar radiation, earth orbit, albedo or reflectivity of the continents and oceans, mountain-building and continental drift and changes in greenhouse gas concentrations. A variety of climate change feedbacks can either amplify or diminish the initial forcing; there are also key threshold factors which when exceeded can produce rapid change. Forcing mechanisms can either be internal or external.

3.2.1 Internal Forcing Mechanisms

Internal forcing mechanisms are natural processes within the climate system itself. Natural changes in the climate system result in internal climate variability. Examples include the type and distribution of species and changes in ocean currents.

Ocean Variability

The ocean is a fundamental part of the climate system; some changes in it occurring at longer time scales than in the atmosphere, gathering hundreds of times more and having very high thermal inertia. Short term fluctuations such as the ElNino-Southern oscillation, the pacific decadal oscillation, the north Atlantic oscillation and the arctic oscillation, represent climate variability rather than climate changes on a longer time scale. Alterations to ocean processes such as thermohaline circulation play a significant role in redistribution of heat by carrying out a very slow and extremely deep movement of water and the long term redistribution of heat in the oceans.

Species (Life)

Life affects climate through its significance in carbon and water cycles and through such mechanisms as albedo, evapotranspiration, cloud formation and weathering. Examples:

- Glaciation 2.3 billion years ago triggered by the evolution of oxygenic photosynthesis
- Glaciation 300 million years ago ushered in by long term burial of decomposition resistant detritus of vascular land-plants forming coal
- Termination of the Paleocene-Eocene-Thermal maximum 55 million years ago by flourishing marine phytoplankon.
- Reversal of global warming 49 million years driven by the expansion of grass-grazer ecosystems.

3.2.2 External Forcing Mechanisms

External forcing mechanism can either be natural (changes in solar output) or anthropogenic (increased re-emissions of greenhouse gases).

Orbital Variations

Slight differences in earth's orbit leads to changes in the seasonal distribution of sunlight reaching the earth's surface and how it is distributed across the globe. Little change occurs in the area, averaged annually, sunshine has a significant effect in the geographical and seasonal distribution. Three types of orbital variations exist; variations in earth's eccentricity, changes in the tilt angle of earth's axis of rotation, and precession of earth's axis. Combine together, these produce Milankovitch cycles which have a large impact on climate and are notable for their correlation to glacial and interglacial periods, advance and retreat of the Sahara and for their appearance in the stratigraphic record.

Milankovitch cycles drove the ice age cycles, CO_2 followed temperature change with a lag of some hundreds of years, and that as a feedback amplified temperature change. Ocean depths have a long time in changing temperature (thermal inertia on such scale). Temperature change upon sea water, the solubility of CO_2 in the oceans changed as well as other factors impacting air – sea CO_2 exchange.

Solar Output

On earth, the sun is the predominant source of energy, both long and short term variations in solar intensity affect global climate. Solar output also varies on shorter time scales, including the 11 years solar cycle and longer term modulations. Solar intensity variations possibly as a result of the wolf, sporer and maunder minimum are considered to have been influential in triggering the little ice age and some of the warming observed from 1900 – 1950. Therefore, variation in solar output increases from cyclical sunspot activity affecting global warming and climate may be influenced by the sum of all effects (solar variation, anthropogenic radiative forcing).

Volcanism

Volcanic eruptions capable of affecting the earth's climate on a scale of more than 1 year are the eruptions that inject over 100,000 tons of SO_2 into the stratosphere. This is due to the optical properties of SO_2 and sulfate aerosols, which strongly absorb or scatter solar radiation, creating a global layer of sulfuric acid haze. Such eruption on an average occur several times per century, and cause cooling by partially blocking the transmission of solar radiation to the earth's surface for a period of years though not much.

Small eruptions with injections of less than 0.1m+ of sulfur dioxide (SO_2) into the stratosphere, impact the atmosphere only partly, as temperature changes are comparable with natural variability. Smaller eruptions occur at a much higher frequency, they have a significant impact on earth's atmosphere.

Volcanoes are also part of the extended carbon cycle because the release carbon dioxide (CO_2) from the earth's crust and mantle, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. A study by the US geological survey estimates that, volcanic emissions are at a much lower level than the effects of current human activities which generate 100-300 times the amount of carbon dioxide emitted by volcanoes.

Plate Tectonics

The motion of tectonic plates reconfigures global land and ocean areas and generates topography. This can affect both the global and local patterns of climate and atmospheric ocean circulation. The position of the continents determines the geometry of the oceans and therefore influences patterns of ocean circulation. The locations of the seas are vital in controlling the transfer of heat and moisture across the globe and thereby determine the global climate systems. The size of the continents is also significant in stabilizing effects of the oceans temperature. Annual temperature variations are generally lower in coastal areas than they are inland. A larger super continent will therefore have more area in which climate is strongly seasonal than will several smaller continents or islands.

Human Influences

Anthropogenic factors are human activities which affect the climatic systems. The scientific consensus on climate change is that, the climate is changing and that these changes are in large proportion caused by human activities and it is irreversible to a greater extent.

The most concern in these anthropogenic factors is the increasing rate of CO_2 level due to emissions from fossil fuel combustion followed by aerosols (particulate matter in the atmosphere) and the CO_2 released by cement manufacture. Others include land use, ozone depletion, animal agriculture and deforestation which are of great concern for their significant impact on climate, micro climate and measures of climatic variables. (Wikipedia, 2015).

3.3 Evidences of Climate Change

Evidence for climate change is taken from a variety of sources that can be used to reconstruct past climates. Complete global records of surface temperature are available beginning from the mid-late 19th century. For early periods, most of the evidence is indirect, climate changes are referred from changes in proxies, indicators that reflect climate such as vegetation, ice cores, dendrochronology, sea level change and glacial geology.

3.3.1 Temperature Measurements and Proxies

Instrumental temperature record from surface stations was supplemented by radio sound balloons, extensive atmospheric monitoring by the mid-20th century and from the 1970s on, with global satellite data as well. The $^{18}O/^{16}O$ ratio in calcite and ice core samples used to deduce ocean temperature in the distant past is an indication of a temperature proxy method, likewise other climatic metrics observed in subsequent categories.

3.3.2 Historical and Archaeological Evidence

Climate change in recent past may be observed by changes in settlement and agricultural patterns. Archaeological evidence, oral history and historical documents can offer insights into past changes in the climate. Climate change effects have been linked to the collapse of various civilizations.

3.3.3 Glaciers

Are considered as the most sensitive indicators of climate change, their size is determined by a mass balance between snow input and melt output. As temperatures warms up, glaciers retreat unless snow precipitation increases to make up for the additional melt; the converse is also true.

3.3.4 Arctic Sea Ice Loss

The decline in sea ice both in extent and thickness over the last decades is a further evidence for rapid climate change. Sea ice is frozen sea water that floats on the sea surface covering over millions of square miles in the polar regions with differences on the basis of seasons with little ice remaining but southern ocean or Antarctic sea ice melts away and reforms annually.

3.3.5 Vegetation

A change in vegetation distribution may occur given a change in the climate. Some changes in climate may result to precipitation increase and warmth, resulting to improve plant growth and the subsequent sequestration of airborne Co_2. Warmth increase in a location will give rise to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Plants bio-cycles may be affected by cold faster; this may result in vegetation stress, plant loss and desertification in certain circumstances.

3.3.6 Pollen Analysis

The study of fossils palynomorphs, including pollen is called palynology. This is used to describe geographical distribution of plants species which vary under different climatic conditions. Different groups of plants have pollen with distinctive shapes and surface textures and since the outer surface of pollen is composed of a very resilient material, they resist decay. Changes in the type of pollen found in different layers of sediment in lakes, bogs or river deltas indicate changes in plant communities. These changes are often a sign of a changing climate. Palynological studies have been used to track changing vegetation patterns through the quaternary glaciating.

3.3.7 Cloud Cover and Precipitation

Precipitation can be estimated in the modern era with the global network of precipitation gauges. Surface coverage over oceans and remote areas is relatively sparse but reducing reliance on interpolation, satellite clouds and precipitation data has been available since 1970s. Quantification of climatological variation of precipitation in prior centuries and epochs is less complete but approximated using processes such as marine sediments, ice cores, cave stalagmite and tree rings.

Climatological temperatures substantially affect cloud cover and precipitation. Estimated global land precipitation increased by approximately 2% over the course of the 20^{th} century, though the calculated trend varies if different time end points are chosen, complicated by oscillations including greater global land cloud cover precipitation. Slight overall increase in global river runoff and in average soil moisture has been perceived.

3.3.8 Dendroclimatology

Is the analysis of tree ring growth patterns to determine past climate variations, wide and thick rings indicate a fertile, well-watered growing period, whilst thin, narrow rings indicate a time of lower rainfall and less than ideal growing conditions.

3.3.9 Animals

Remains of beetles are common in fresh water and land sediments. Different species of beetles tend to be found under different climatic conditions. Given the extensive lineage of beetles whose genetic makeup has not altered significantly over the millennia. Similarly the historical abundance of various fish species has been found to have a substantial relationship with observed climatic conditions. Changes in the primary productivity of autotrophs in the oceans can affect marine food webs.

3.3.10 Change in Sea Level

Global sea level change from much of the last century has generally been estimated using tide gauge measurements collated over long periods of time to give a long term average. More recent altimeter measurements in combination with accurately determined satellite orbits have provided an improved measurement of global sea level change.

To measure seal levels prior to instrumental measurements, scientist have dated coral reefs that grow near the surface of the ocean, coastal sediments, marine terraces, zooids in limestones and near shore archaeological remains. The predominant dating methods used are uranium series and radiocarbon, with cosmogenic radio-nuclides being sometimes used to date terraces that have experienced relative sea level fall.

SELF-ASSESSMENT EXERCISE

1. Enumerate with concrete evidences the presence of any form of climate change observed in your area
2. Discuss 2 human influences as a cause of climate change

4.0 CONCLUSION

Climate change is a change in the statistical distribution of weather patterns. It is otherwise described as a change or long term shift in weather patterns in a specific region. A times, the effect is global. Climate change evidence are seen in numerous ways among which include the following temperature measurements and proxies, historical and archeological evidence, vegetation, ice loss, pollen analysis, cloud cover precipitation, these posed great impact on the environment, agriculture, economic and social based human activities, plants and animal life.

5.0 SUMMARY

In this unit, the concept of climate change has been discussed with focus on the meaning, causes, evidence which describe the effects. Climate change impact directly to agriculture through the following ways; excess rainfall in some locations result in flooding which destroys farmland and crops and alter the ecosystem, desertification in area where total absence or little rainfall is received with high temperature.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the concept "climate change"
2. List and discuss any four causes of climate change
3. Explain any 5 of the following evidences of climate change
   a. Archeological evidence
   b. Glacier retreat
   c. Ice loss
   d. Volcanism
   e. Vegetation

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UNIT 2 CLIMATE CHANGE ISSUES IN AGRICULTURE

CONTENTS

1.0 INTRODUCTION

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate change affects agriculture a numerous ways, which include variation in average temperature, rainfall and climate extremes e.g. heat waves; changes in pest and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods and changes in sea level.

Climate change is already affecting agriculture with effects unevenly distributed across the world. Future climate change will likely negatively affect crop production in low latitude countries, while effects in northern latitudes may be positive or negative. Climate change will probably increase the risk of food insecurity for vulnerable group such as the poor. Agriculture contributes to climate changes by the following:

i. anthropogenic emissions of greenhouse gases (GHGS)
ii. conversion of non-agricultural land into agricultural land.

Agriculture, forestry and land-use change contributed around 20 to 25% to global annual emission as stated in 2010. There are range of policies that can reduce the risk of negative climate change impacts on agriculture, and to reduce GHG emissions from the agriculture sector.

2.0 OBJECTIVES

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

- explain the impact of climate change on agriculture
- discuss the potential effects of climate change on pests, diseases and weeds
- discuss the effects of glacier retreat and disappearance on agriculture
- explain the effects of temperature on growing period
- explain the effects of elevated carbon dioxide on crops.

3.0 MAIN CONTENT

3.1 Impact of Climate Change on Agriculture

Technological advancement has improved varieties, genetically modified organisms and irrigation system but weather and climate are still key factors in agricultural production, as well as soil properties and natural communities. The effect of climate change on agriculture is related to variabilities in local climates rather than in global climate pattern. Agricultural on the other hand, has grown in recent years, and provides significant amount of food, as well as comfortable income to exporting ones.

Climate change induced by increasing greenhouse gases is likely to affect crops differently from region to region. More favourable effects tend to depend to a larger extent on realization of the potentially beneficial effects of carbon dioxide on crop growth and increase of efficiency in water use. Decrease in potential yields is likely to be caused by shortening of the growing period, decrease in water availability and poor vernalisation.

In the long run, the climatic change could affect agriculture in the following ways.

i) Productivity, in terms of quantity and quality of crops
ii) Agricultural practices, through changes in water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers
iii) Environmental effects, particularly in the frequency and intensity of soil drainage leading to nitrogen leaching, soil erosion, reduction of crop diversity.

iv) Rural space, through the loss and gains of cultivated lands, land speculation, land renunciation and hydraulic amenities.

v) Adaption, organisms may become more or less competitive, as well as human may develop urgency to develop more competitive organisms such as flood resistant or salt resist and varieties of rice.

Agronomists believed that agricultural production will be mostly affected by the severity and the pace of climate change. If change is gradual, there may be enough time for biota adjustment. Rapid change in climate could harm agriculture in many countries, especially those that are already suffering from rather poor soil and climate conditions because there is less time for optimum natural selection and adaptation. (Briggs and Smithson, 1985).

3.1.1 Observed Impact of Climate Change on Agriculture

Change in crops phenology provides significant evidence of the response to climate change. Phenology is the study of natural phenomena that reoccur periodically and how these phenomena relate to climate and seasonal changes. Phenology has been observed significantly in agriculture and forestry in large parts of the northern hemisphere.

Secondly, droughts have been occurring more frequently because of global warming and they are expected to become more frequent and intense mostly in some parts of Africa, and other parts of the world continents. The impacts are aggravated because of increased water demand, population growth urban expansions, and environmental protection efforts in many areas. Drought results in crop failure and loss of pasture grazing land for livestock.

According to IPCC forth assessment report, on impacts of climate change on food security, there could be large decreases in hunger globally by 2080, compared to the previous one experience in 2006. Reduction in hunger was driven by projected socio-economic development. In Africa, 70% of the populations rely on rain-fed agriculture for their livelihoods; therefore the tendency of food insecurity may likely be in upward projection.

3.1.2 Potential Effects of Temperature on Growing Period

Duration of crop growth cycles are above all, related to temperature. An increase in temperature will speed up development. For instance, annual crops duration of sowing and harvesting will shorten, especially for maize between one and four weeks. The shortening of such cycle may have an adverse effect on productivity.

3.1.3 Effects of Elevated Carbon Dioxide (CO_2) on Crops

In the process of photosynthesis, carbon dioxide is essential to plant growth. Rising CO_2 concentration in the atmosphere can have both positive and negative consequences. Increased carbon dioxide CO_2 is expected to have positive physiological effects by increasing the rate of photosynthesis. This is known as carbon fertilization. Currently, the amount of CO_2 in the atmosphere is 380 parts per million. In comparison, the amount of oxygen is 210, 000 ppm, this means that, plants may be starved of carbon dioxide as the enzymes that fixes CO_2 also fixes oxygen in the process called photorespiration. The effects of an increase in CO_2 would be higher on C_3 crops (such as wheat) than C_4 crops (such as maize) because maize is more susceptible to carbon dioxide shortage.

3.1.4 Effects of Climate Change on Quality of Agricultural Products

The importance of climate change impacts on grain and forage quality emerges from new research. For grains such as rice, the amylose content of the grain which is the major determinant of cooking quality may increase under elevated CO_2. Cooked rice grain from plants grown in high CO_2 environments would be firmer than that from present plants. However, iron and zinc concentrations will be lower which are important for human nutrition.

The protein content of grains decreases under the combined increase of temperature and CO_2 because increase in CO_2 leads to decreased concentrations of micronutrients in crop plants. This may have effect on other parts of the ecosystems as herbivores will need to eat more food to gain the same amount of protein. Higher level of CO_2 leads to reduced plant uptake of nitrogen resulting in crops with lower nutritional value. This would impact primarily on populations in poorer countries less able to compensate by eating more food, more varied diets or possibly taking supplements.

Reduced nitrogen content in fields meant for grazing has also been shown to reduce animal productivity especially in sheep, which depends on microbes in their gut to digest plants which in turn depends on nitrogen intake.

3.2 Impact of Climate Change on Agricultural Surfaces

Increase in arable land in high-latitude region may be experience by reduction of the amount of frozen lands. However, an impact of global warming on agriculture indicates a conflicting effects on extension of arable and farmable lands with possible productivity losses and increased risk of drought. Low land meant for rice production may likely experience loss in productivity too, if a rise in sea level is experience. But any rise in sea level of no more than a meter will drown several km^2 of rice paddies, rendering the location incapable of producing its main staple and export of rice.

a) Climate Change on Erosion and Fertility

Erosion and soil degradation as environmental problem may likely occur when there is increase in atmospheric temperature leading to more vigorous hygrological cycle, with extreme rainfall. This will affect soil fertility. The ratio of carbon and nitrogen is suppose to be constant but in situation where carbon is higher a storage of nitrogen in soils as nitrate may equally be higher, thus providing fertilizing elements for plants and providing better yields. Extreme climate could result to increase in precipitation rate resulting to erosion and as well provide soil with better hydration, due to the intensity of rain. Temperature would increase the rate of production of essential minerals thereby reducing the content of soil organic matter and atmospheric CO_2 concentration would tend to increase.

b) Climate Change on Pests, Diseases and Weeds

Most weeds are C_3 plants that would undergo same acceleration of life cycle as cultivated crops with increase temperature resulting from climate change effect and also benefit from carbonaceous fertilization. They are likely to compete even more than C_4 crops such as maize.

Global warming causes increases in rainfall in some locations which would in turn increase atmospheric humidity and the duration of wet seasons. Combined with temperature, these could result to a favourable condition for the development of fungal diseases. Also, high temperature and humidity could increase pressure from insects and disease vectors.

c) Glacier Retreat and Disappearance

Retreat of glaciers have a number of different quantitative impacts on agriculture. Areas dependent on heavily water run-off from glaciers that melt during the warmer summer months, a retreat will eventually deplete the glacial ice and substantially reduce or eliminate run off. A reduction in runoff will affect the ability to irrigate crops and will reduce summer stream flows necessary to keep dams and reservoirs replenished.

d) Ozone and Ultraviolent Radiations B (UV-B)

According to some scientists, agriculture could be affected by any decrease in stratospheric ozone which could increase biologically dangerous ultraviolent radiation B. Excess UV-B can affect plant physiology directly and cause massive amounts of mutations and indirectly through changed pollinator behavior though such changes are not easy to quantify. Possible effect of increased temperature in significantly higher levels of ground level ozone, would substantially lower crop productivity.

e) ENSO Effects on Agriculture

ENSO is an acronym for EL Nino Southern oscillation. This climatic situation will affect monsoon patterns more intensely in the future as climate change warms up the ocean's water. Crops that lie on the equatorial belt or render the tropical worker circulation, such as rice, will be affected by varying monsoon patterns and more unpredictable weather. Planting scheduled and harvesting based on weather patterns will become less effective. As climate change affects ENSO and consequently delays planting, harvesting will be late and in drier conditions, resulting in less potential yields and productivity. (Wikipedia, 2015).

3.3 Impact of Agriculture on Climate

The agricultural sector is a driving force in the gas emissions and land use effects which is thought to cause substantial change in climate. Agriculture contributes directly to greenhouse gas emissions through practices such as rice and maize production and raising of livestock. Fossil fuels, land use and agriculture are considered the main causes of increased greenhouse gases observed over the years.

3.3.1 Land use Practices

Agriculture contributes to greenhouse gas increases through land use in four main ways:

i) carbon dioxide (Co_2) releases linked to deforestation
ii) methane releases from rice cultivation
iii) methane releases from enteric fermentation in cattle
iv) nitrous oxide releases from fertilizer application

These processes together comprises 54% of methane emissions, roughly 80% of nitrous oxide emissions and virtually all CO_2 emissions tied to land use. Deforestation has been identified as the earth's major changes to land cover. When forests woodlands are cleared to make room for fields and pastures, the albedo of the affected area increases which can result as either warming or cooling effects depending on local conditions.

Deforestation also affects carbon dioxide uptake, which can result in increased concentrations of CO_2, the dominant greenhouse gas. Land clearing methods such as slash and burn compounds directly releases greenhouse gases and particulate matter such as soot into the air.

3.3.2 Livestock

Livestock – related activities such as deforestation and increasingly fuel intensive farming practices and livestock rearing on grazing lands are responsible for over 18% of human-made greenhouse gas emission including:

i) 9% of global carbon dioxide emissions
ii) 35-40% of global methane emissions mainly due to enteric fermentation and manure
iii) 64% of global nitrous oxide emissions chiefly due to fertilizer use. Livestock activities also contribute disproportionately to land – use effects, since crops such as maize and alfalfa are cultivated in order to feed the animals. Livestock production occupies 70% of all land used for agriculture or 30% of the land surface of the earth.

SELF-ASSESSMENT EXERCISE

1. Deforestation has greatly altered the climate of place. Explain the extent to which this statement is true.
2. To what extent can climate change be said to have an effect on the quality of grains

4.0 CONCLUSION

Climate change has a significant effect on agriculture since temperature and rainfall play a significant role in the quality of agricultural products, food security, erosion and soil fertility among others. The increased use of fossil fuel, land use and livestock production contributes significantly to climate change. Other issues include, flooding from excess rainfall, desertification from rainfall deficit.

5.0 SUMMARY

In this unit, the impact of climate change on agriculture and the impact of agriculture on climate change have been extensively discussed with focus on temperature, rainfall, flood, drought, as resultant effects of climate change which affect agriculture. Food insecurity diseased are the issues of reduction in quantity and quality of food produced by farmers, pollution, especially thermal and global warming.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the impact of climate change on agriculture
2 Discuss the potential effects of climate change on:
   a) pest
   b) disease
   c) weeds
3. Discuss the effects of glacier retreat and disappearance on agriculture
4. Discuss the effects of temperature on growing period
5. Explain the effects of carbon dioxide on crops

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UNIT 3 METHODS OF AMELIORATION

CONTENTS

1.0 INTRODUCTION

Global warming will have profound effects on where and how food is produced, and also, to a reduction in the nutritional properties of some crops, all of which has policy implications for the fight against hunger and poverty and for the global food trade. The growing threat of climate change to global food supply and the challenges it poses for food security and nutrition, requires urgent concerted policy responses. This unit will examine some methods of amelioration of climate change towards sustaining agricultural productivity.

2.0 OBJECTIVES

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

- mention various methods of amelioration of climate change
- discuss mitigation and adaptation in developing countries
- explain crop development model as a method of reducing the effects of climate change.

3.0 MAIN CONTENT

3.1 Mitigation and Adaptation to Climate Change

The Inter-governmental Panel on Climate Change (IPCC) has reported that agriculture is responsible for over a quarter of total global greenhouse gas emissions. Given that agriculture's share in global gross domestic product (GDP) is about 4 percent: These figures suggest that agriculture is highly greenhouse gas intensive. Innovative agricultural practices and technologies can play a role in climate mitigation and adaptation. (IPCC AR5WG3, 2014).

The adaptation and mitigation potential is nowhere more pronounced "than in developing countries where agricultural productivity remains low; poverty, vulnerability and food insecurity remains high; and the direct effects of climate change are expected to be especially harsh. Creating the necessary agricultural technologies and harnessing them to enable developing countries to adapt their agricultural systems to changing climate will require innovations in policy and institutions which are considered important in multiple scales.

Six (6) policy principles of mitigation and adaptation to climate change were suggested by Travis Lybbert and Daniel Suminer; these include;

i) The best policy and institutional responses will enhance information flows, incentives and flexibility
ii) Policies and institutions that promote economic development and reduce poverty will often improve agricultural adaptation and may also pave the way for more effective climate change mitigation through agriculture
iii) Business as usual among world's poor is not adequate
iv) Existing technology options must be made more available and accessible without overlooking complementary capacity and investments
v) Adaptation and mitigation in agriculture will require local responses, but effective policy response must also reflect global impacts and inter-linkages.
vi) Trade will play a significant role in both mitigation and adaptation, but will itself be shaped importantly by climate change.

3.2 Agricultural Best Practices

Models are suggested for adaptation of the changing climate to suit agricultural production. Models for climate behavior are frequently inconclusive. In order to further study effects of global warming on agriculture, other types of model such as crop development models, yield prediction, quantities of water or fertilizer consumed, can be used. Such models condense the knowledge accumulated of the climate, soil, and effects observed from the results of various agricultural practices. They thus could make it possible to test strategies of adaptation to modifications of the environment.

These models are necessarily simplified natural conditions often based on the assumption that weeds, diseases and insect pests are controlled. It is not clear whether the results obtained have an in-field reality. However, some results are partly validated with an increasing number of experimental results. Other models such as insect and disease development models based on climate projections are also used; for instance simulation of aphid reproduction or septoria (cereal fungal disease development).

Scenarios are used in order to estimate climate change effects on crop development and yield. Each scenario is defined as a set meteorological variables based on generally accepted projections. For instance, many models are running simulations based on doubled carbon dioxide projections, temperature raise ranging from 1^oC-5^oC and with rainfall level an increase or decrease of 20%. Other parameters may include humidity, wind and solar activity. Scenarios of crop models are testing farm-level adaptation such as losing data shift, climate adapted species (vernalisation need, heat and cold resistance), irrigation and fertilizer adaptation, resistance to disease. Most developed models are about wheat, maize, rice and soybeans. (Lobell, 2008).

SELF-ASSESSMENT EXERCISE

From your understanding of the negative effects of climate change, what can you suggest as mitigation to curb such problems?

4.0 CONCLUSION

Following the increasing effects of climate change geared toward human activities and influences through agricultural and other practices, mitigation and adaptation are considered the most viable method of improving production under a changing climate.

5.0 SUMMARY

In this unit, a method of amelioration of climate change has been discussed with focus on agricultural practices, policies and institutions. Other agricultural practices that should be avoided to reduce emission of gases include bush burning, deforestation, use of inorganic compound on soil among others. Other equipments such as air conditioner, vehicles, generators should be minimally used to reduce the rate of emissions of greenhouse gases such as chlorofluorocarbons, carbon etc.

6.0 TUTOR-MARKED ASSIGNMENT

Discuss the following method of amelioration of climate change;

a) Mitigation and adaptation
b) Crop development model

7.0 REFERENCES/FURTHER READING

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