MODULE 1

UNIT 1 MEANING OF CLIMATOLOGY

CONTENT

1.0 INTRODUCTION

Climatology is the study of the long-term state of the atmosphere. Climatology is fundamentally concerned with the weather and climate of a given area. Climatology examines both the nature of micro (local) and macro (global) climates and the natural and anthropogenic influences on them. The term climate implies an average or long term record of weather conditions at a certain region for at least 30 years. It conveys a generalisation of all the recorded weather observations in a given area. Branch of atmospheric science concerned with describing climate and analysing the causes and practical consequences of climatic differences and changes. Climatology treats the same atmospheric processes as meteorology but it also seeks to identify slower-acting influences and longer-term changes, including the circulation of the oceans, the concentrations of atmospheric gases, and the small but measurable 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 day. The climate is often described in terms of the mean values of meteorological variables such as temperature, precipitation, wind, humidity and cloud cover. A complete 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 being very different from that for

July at most locations. Climate also exhibits significant year-to-year variability and longer-term changes on both a regional and global basis.

2.0 OBJECTIVES

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

- define climatology;
- explain the relevance of the study of climatology; and
- discuss the different approaches to the study of climatology.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit at least twice before attempting to answer the self-assessment questions or tutor- marked assignment.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all answers.
3. Share your difficulties with your course mates, facilitators and by consulting other related material, particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do more.

3.0 WORD STUDY

Decadal- a group of ten things
Millennial- occurring every 1000 years
Paradigm- an example serving as a pattern

4.0 MAIN CONTENT

4.1 The Relevance of the Study of Climatology

The goals of climatology are to provide a comprehensive description of the Earth's climate over the range of geographic scales, to understand its features in terms of fundamental physical principles, and to develop models of the Earth's climate for sensitivity studies and for the prediction of future changes that may result from natural and human causes.

Climatology is not only concerned with the analysis of climate patterns and statistics (e.g. temperature, precipitation, atmospheric moisture, atmospheric circulation and disturbances) but also with seasonal to inter-annual climate variability, decadal to millennial climate fluctuations, long-term changes in mean and variability characteristics, climate extremes and seasonality (Glantz, 2003). Climatology also addresses its subject matter on many spatial scales, from the micro through the meso and synoptic to the hemispheric and global. Further, climatology works within a general systems' paradigm. At the heart of this is climate system theory. This states that climate is the manifestation of the interaction among the major climate system components of the atmosphere of hydrosphere, cryosphere, biosphere and land surface and external forcing such as solar variability and long term earth–sun geometry relationships. It also recognises that humans are an integral component of the climate system through their ability to alter levels of atmospheric trace gases. A major goal of climatology is to understand the flow of energy and matter and the feedbacks and non-linear interactions between the main components of the climate system and their associated climate outcomes.

Science is said to be: 'concerned either with a connected body of demonstrated truths or with observed facts systematically classified and more or less colligated by being brought under general laws, and which includes trustworthy methods for the discovery of new truth within its own domain.

Clearly, climatology falls within this definition. Some of the demonstrated truths that underpin climatology as a science include:

- climate is non-stationary
- climate varies over a number of temporal and spatial scales
- major modes of atmospheric circulation exist which may produce climate teleconnections
- climate is the long-term manifestation of the interaction between the atmosphere and the earth's surface and of processes arising from other causes that are internal and external to the climate system
- the climate system responds non-linearly to both internal and external forcing and regulates itself through positive and negative feedback
- the climate of a location is influenced by the balance between large and local scale factors
- climate can be a determinant of, a resource for and a hazard to human activities
- human activities have the potential to influence climate

4.2 Approaches to Study of Climatology

Climatology is approached in a variety of ways.

The first approach is **paleoclimatology**: Paleoclimatology seeks to reconstruct past climates by examining records such as ice cores and tree rings (dendroclimatology).

Paleoclimatologists seek to explain climate variations for all parts of the Earth during any given geologic period, beginning with the time of the Earth's formation. The basic research data are drawn mainly from geology and paleobotany; speculative attempts at explanation have come largely from astronomy, atmospheric physics, meteorology, and geophysics. The study of ancient climates is the long-term expression of weather; in the modern world, climate is most noticeably expressed in vegetation and soil types and characteristics of the land surface. To study ancient climates, paleoclimatologists

must be familiar with various disciplines of geology, such as sedimentology and paleonotology,(Scientific study of life of the geologic past, involving analysis of plant and animal fossils preserved in rocks) and with climate dynamics, which includes aspects of geography and atmospheric and oceanic physics.
The second approach is the **paleotempestology:** Paleotempestology uses these same records to help 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 statistical or mathematical, which help by integrating different observations and testing how they fit together. Modelling is used for understanding past, present and potential future climates.

The third approach is **historical climatology**:
Historical climatology is the study of climate as related to human history and thus focuses only on the last few thousand years.

5.0 CONCLUSION

Global climate changes are threatening the balance of climatic conditions under which life evolved and is sustained. Temperatures are rising, ultraviolet radiation is increasing at the surface and pollutant levels are increasing. Many of these changes can be traced to industrialisation, deforestation and other activities of a human population that is itself increasing at a very rapid rate. Climatology today embraces the study of all these characteristics, components, interactions and feedbacks

6.0 ACTIVITY

1. State the 3 main approaches to the study of climatology.
2. What are the methods of acquiring climatology data by each approach?
3. List 2 challenges in the use of each of these approaches

7.0 SUMMARY

In this unit, you learnt about climatology and different approaches to the study of climatology. The three main approaches to the study of climatology are discussed. These are: paleoclimatology, paleotempestology and historical climatology.

8.0 ASSIGNMENT

1. What is climatology?
2. With relevance example, explain the different approaches to the study of climatology.
3. Explain the relevance of climatology

9.0 REFERENCES/FURTHER READING

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

Donald, A. C. (1994). *Meteorology Today*: *An Introduction to Weather, Climate and the Environment*. (5th ed.). U.S.A: West Publishing Company.

UNIT 2 NATURE AND SCOPE OF CLIMATOLOGY

CONTENT

1.0 INTRODUCTION

Climatology has made enormous contributions towards ensuring that we have a good understanding and control of these processes. The weather of a place refers to the atmospheric condition at a given point in time. Climate on the other hand is the synthesis of the weather of a place over a period of about 35 years. Climatology refers to the scientific study of climate. It is closely related to meteorology which is the science of the physical, chemical and dynamic state of the atmosphere. However, meteorology deals with the study of the weather while climatology is concerned with the climate.

Temperature is undoubtedly the most important climatic element. The temperature of an area is dependent upon latitude or the distribution of incoming and outgoing radiation; the nature of the surface (land or water); the altitude; and the prevailing winds. The air temperature normally used in climatology is that recorded at the surface. Moisture, or the lack of moisture, modifies temperature. The more moisture in a region, the smaller the temperature range, and the drier the region, the greater the temperature range. Moisture is also influenced by temperature. Warmer air can hold more moisture than can cooler air, resulting in increased evaporation and a higher probability of clouds and precipitation.

Moisture, when coupled with condensation and evaporation, is an extremely important climatic element. It ultimately determines the type of climate for a specific region.

Precipitation is the second most important climatic element. In most studies, precipitation is defined as water reaching Earth’s surface by falling either in a liquid or a solid state. The most significant forms are rain and snow. Precipitation has a wide range of variability over the Earth’s surface. Because of this variability, a longer series of observations is generally required to establish a mean or an average. Two stations may have the same amount of annual precipitation, but it could occur in different months or on different days during these months, or the intensity could vary.

Therefore, it often becomes necessary to include such factors as average number of days with precipitation and average amount per day. Precipitation is expressed in most studies in the United States in inches, but throughout the rest of the world, millimetres are normally used.
Since precipitation amounts are directly associated with amount and type of clouds, cloud cover must also be considered with precipitation. Cloud climatology also includes such phenomena as fog and thunderstorms.

Wind is the climatic element that transports heat and moisture into a region. The climate of an area is often determined by the properties of temperature and moisture that are found upstream of that region.

Climatologists are mostly interested in wind with regard to its direction, speed, and gustiness. Wind is therefore usually discussed in terms of prevailing direction, average speeds, and maximum gusts. Some climatological studies use resultant wind, which is the vectorial average of all wind directions and speeds for a given level, at a specific place, and for a given period.

2.0 OBJECTIVES

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

- define climate and state the various aspects of climatology;
- examine the study of climatology as it relates to other sciences such as ecology; and
- explain climatology and changes resulting from human influence.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit at least twice before attempting to answer the self-assessment questions or tutor- marked assignment.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all answers.
3. Share your difficulties with your course mates, facilitators and by consulting other related material, particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do more.

3.0 WORD STUDY

Synthesis - formation of chemical compounds

Catastrophy – any large and disastrous event of great importance
Iconic – famous and distinctive representative of its type
Albedo – radiation reflected by a surface or light
Protocol – an acceptable behaviour in a given situation or group

4.0 MAIN CONTENT

4.1 Types of Climatology

Climate is the average or collective state of Earth's atmosphere at any given location or area over a long period of time. While weather is the sum total of the atmosphere's variables for a relatively short period of time, the climate of an area is determined over periods of many years and represents the general weather characteristics of an area or locality. The term climate applies to specific regions and is therefore highly geographical.

Climatology is the scientific study of climate and is a major branch of meteorology. Climatology is the tool that is used to develop long-range forecasts. There are three principal areas to the study of climatology: physical, descriptive, and dynamic.

Physical Climatology
The physical climatology approach seeks to explain the differences in climate in light of the physical processes influencing climate and the processes producing the various kinds of physical climates, such as marine, desert, and mountain. Physical climatology deals with explanations of climate rather than with presentations.

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

Dynamic Climatology
Dynamic climatology attempts to relate characteristics of the general circulation of the entire atmosphere to the climate. Dynamic climatology is used by the theoretical meteorologist and addresses dynamic and thermodynamic effects.

4.2 Climatology as Related to Other Sciences

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

Microclimatology
Micro-climatological studies often measure small-scale contrasts, such as 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 the micro scale may be effectively modified by relatively simple human efforts.

Mesoclimatology
Mesoclimatology embraces a rather indistinct middle ground between macroclimatology and microclimatology. The areas are smaller than those of macroclimatology are and larger than those of microclimatology, and they may or may not be climatically representative of a general region.

Macroclimatology
Macroclimatology is the study of the large-scale climate of a large area or country. Climate of 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.

Climate has become increasingly important in other scientific fields. Geographers, hydrologists, and oceanographers use quantitative measures of climate to describe or analyse the influence of our atmospheric environment. Climate classification has developed primarily in the field of geography. The basic role of the atmosphere in the hydrologic cycle 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.

Ecology
Ecology is the study of the mutual relationship between organisms and their environment. Ecology is briefly mentioned here because the environment of living organisms is directly affected by weather and climate, including those changes in climate that are gradually being made by man.

During our growing years as a nation, our These changes have been on the micro and meso scale and possibly even on the macro scale.

4.3 Climatology and Changes Resulting from Human Influence

Climatology, once the study of ‘average weather’, now encompasses the atmosphere, hydrosphere, cryosphere, land surface and biosphere. Modern climatology includes not only these components but importantly their interactions involving detailed global observing systems and complex computer-based numerical models. People’s interest in climatology has been and is likely to continue to be concerned with social issues of habitability and sustainability.

Climatologists tend to evaluate climate in personal terms: Is it too hot or too cold? Is the air pleasant to breathe? Is there enough water for drinking and for growing crops? Does it feel comfortable? These characteristics are interdependent, together forming the climate system and posing a larger question: Can this planet continue to sustain life? Today, the atmosphere is undergoing global changes unprecedented in human history and, although changes as large as those that we are witnessing have occurred in the geological past, relatively few have happened with the speed which also characterises today's climate changes. Concentrations of greenhouse gases are increasing, stratospheric ozone is being depleted and the changing chemical composition of the atmosphere is reducing its ability to cleanse itself through oxidation. These global changes are threatening the balance of climatic conditions under which life evolved and is sustained. Temperatures are rising, ultraviolet radiation is increasing at the surface and pollutant levels are increasing. Many of these changes can be traced to industrialisation, deforestation and other activities of a human population that is itself increasing at a very rapid rate. Climatology today embraces the study of all these characteristics, components, interactions and feedbacks.

Global climate system changes resulting from human influence have been described as 'climatological catastrophes'. They are slow to develop and, therefore, may not become apparent until their effects have become dangerously advanced. The iconic example of a modern 'climatological catastrophe' is the 1985 British discovery of declining ozone abundance over the Antarctic station of Halley Bay.
Research showed that the so-called Antarctic ozone hole had been increasing in depth since the late 1970s and today stratospheric ozone concentrations at the South Pole in spring (October) are less than half of their values only 30 years ago.

Climatology is concerned with the study of chemical changes and with the radiative balance of the earth. Trace gases emanating from human activities today equal, and perhaps even exceed, emissions from natural sources.

Some, the greenhouse gases which absorb infrared radiation (water vapour, carbon dioxide, ozone, methane, nitrous oxide and the chlorofluorocarbons (CFCs)), play a major role in the earth's energy budget and climate through the greenhouse effect. The earth's radiative budget is controlled by the amount of incident solar radiation that is absorbed by the planet and by the thermal absorptivity of the gases in the atmosphere which controls the balancing emitted infrared radiation.

Radiation from the sun drives the climate of the earth and, indeed, of the other planets. Solar radiation is absorbed and, over the mean annual cycle, this absorption is balanced by radiation emitted from the earth. This global radiative balance, which is a function of the surface and atmospheric characteristics, of the earth's orbital geometry and of solar radiation itself, controls the habitability of the earth, mean temperatures, the existence of water in its three phase states. These characteristics, together with the effects of the rotation of the earth on its axis, determine the dynamics of the atmosphere and ocean, and the development and persistence of snow and ice masses.

Over very long time-scales, those commensurate with the lifetime of the earth, astronomical, geological and biological processes control persistence of ice caps and glaciers; the biota; rock structures and global geochemical cycling.

There are two different and complementary time frames of importance in climatology. The first is the evolutionary time-scale which controls the very long-term aspects of the climate components and those factors which force it such as the physics and chemistry of the planet itself and the luminosity of the sun. Viewed in this time frame, the earth's climate is prey to the forces of astro and geophysics. Within this very long time-scale it is possible to take a 'snapshot' view of the climate system and, in this 'quasi-instantaneous' view, the shortest timescale processes are most evident. Of these, the most important are the latitudinal distribution of absorbed solar radiation (large at low latitudes and much less near the poles) as compared to the emitted thermal infrared radiation which is roughly the same at all latitudes. This latitudinal imbalance of net radiation for the surface-plus-atmosphere system as a whole (positive in low latitudes and negative in higher latitudes) combined with the effect of the earth's rotation on its axis produces the dynamical circulation system of the atmosphere. The latitudinal radiative imbalance tends to warm air which rises in equatorial regions and would sink in Polar Regions were it not for the rotation of the earth. The westerly waves in the upper troposphere in mid-latitudes and the associated high and low pressure systems are the product of planetary rotation affecting the thermally-driven atmospheric circulation. The overall atmospheric circulation pattern comprises thermally direct cells in low latitudes, strong waves in the mid-latitudes and weak direct cells in Polar Regions. This circulation, combined with the vertical distribution of temperature, represent the major aspects of the atmospheric climate system. The state of the climate system at any time is determined by the forcings acting upon it and the complex and interlocking internal feedbacks that these forcings prompt. In the broadest sense, a feedback occurs when a portion of the output from an action is added to the input so that the output is further modified. The result of such a loop system can either be amplification (a positive feedback) of the process or a dampening (a negative feedback): positive feedbacks enhance a perturbation whereas negative feedbacks oppose the original disturbance. If some external perturbation, say an increase in solar luminosity, acts to increase the global surface temperature then snow and ice will melt and their overall areas reduce in extent. These cryospheric elements are right and white (i.e. their albedo, the ratio of reflected to incident radiation, is high), reflecting almost all the solar radiation incident upon them. The surface albedo, and probably the planetary albedo (the reflectivity of the whole atmosphere plus surface system as seen from 'outside' the planet), will decrease as the snow and ice areas reduce. As a consequence, a smaller amount of solar radiation will be reflected away from the planet and more absorbed so that temperatures will increase further. A further decrease in snow and ice results from this increased temperature and the process continues. This positive climate feedback mechanism is known as the ice–albedo feedback mechanism. Paleo-reconstructions of the earth's climate system, particularly from the most recent record over the past 100 000 years, indicate that climate does not respond to forcing in a smooth and gradual way.

Instead, responses can be rapid, and sometimes discontinuous, especially in the case of warm forcing.

If this is correct, a lesson we might learn from the past is that a possible response of the climate system to human-induced greenhouse gas build-up could come in ‘jumps’ whose timing and magnitude are very hard, perhaps impossible, to predict. Another message is that climate models, with which we hope to predict future climates, must be able to capture such paleoclimate records, particularly apparent discontinuities.

Although we cannot as yet predict future climatological states, we often behave as if we can. Policy development, business, financial and even personal decisions are made every day around the world as if we knew what climates people will face in the future. While local-scale climatic dependencies may seem rather weak, technology and engineering, international trade and aid, food and water resources are likely to become increasingly dependent on, and even an integral part of, the climate system. This is the reason for the development of international conventions and treaties designed to try to protect the climate, in particular, the Montreal protocol which aims to reduce the substances that deplete stratospheric ozone and the Kyoto protocol which is intended to reduce human contributions to the global greenhouse gas.

5.0 CONCLUSION

The study of climatology is fundamentally concerned with the weather and climate of any given area. Essentially, environmental scientists are interested in the processes which take place in the atmosphere because the processes affect the various components of the environment.

6.0 ACTIVITY

1. State 3 global changes that is threatening the climatic condition of the Earth.
2. Give 4 reasons precipitating these problems
3. Suggest at least 4 ways of overcoming the above challenges.

7.0 SUMMARY

The state of the climate system at any time is determined by the forces acting upon it and the complex and interlocking internal feedbacks that these forces prompt. In the broadest sense, a feedback occurs when a portion of the output from an action is added to the input so that the output is further modified. Although we cannot as yet predict future climatological states, we often behave as if we can. Policy development, business, financial and even personal decisions are made every day around the world as if we knew what climates people will face in the future. While local-scale climatic dependencies may seem rather weak, technology and engineering, international trade and aid, food and water resources are likely to become increasingly dependent on, and even an integral part of, the climate system.

8.0 ASSIGNMENT

1. What type of climatology is typically oriented to a geographic region?
2. What type of climatology applies to a small area such as a ploughed field?
3. Explain the 4 elements of weather and climate and when they are weather or climate elements.

9.0 REFERENCES/FURTHER READING

Henderson-Sellers, A. (Ed.). (1995). "Future Climates of the World: A Modelling Perspective." *World Survey of Climatology*. Vol. 16, Elsevier, Amsterdam.

Trenberth, K.E. (1992). *Coupled Climate System Modelling*. Cambridge: Cambridge University Press.

Wang, W.C., Dudek, M.P. & Liang, X. Z. (1995). "The Greenhouse Effect of Trace Gases, in Future Climates of the World: A Modelling Perspective." *World Survey of Climatology*, Vol. 16.

UNIT 3 INTRODUCTION TO TROPICAL CLIMATOLOGY

CONTENT

1.0 INTRODUCTION

A tropical climate is a kind of climate typical in the tropics. Köppen's widely-recognised scheme of climate classification defines it as a non-arid climate in which all twelve months have mean temperatures above 64.4 °F (18.0 °C). It is referred to that climate which is very hot and humid with heavy rains sometimes. Tropical Climatology aims to provide a geographical viewpoint on the physical processes in the tropical atmosphere: to offer explanations of how a location's climate is a product of these processes and to highlight the implications of tropical atmospheric behaviour and climate change for those living in the tropics. The scientific study of climate, is not only concerned with explaining why a location's or region's climate is like it is but also with describing the nature and availability of the climate resource for a wide range of human activities. This subject is of great relevance to the tropics as climate in many ways controls the lives and economic activities of the approximately 2400 million people living in tropical regions. Tropical climates also have effects that reach far beyond the limits of the regions where they actually prevail: the global general circulation is largely driven by the export of considerable amounts of heat energy from tropical to extratropical latitudes: a large part of all atmospheric water content originates from the tropics, and intermittent tropical phenomena, like El Nino Southern Oscillation (ENSO), not only influence the climates over extensive tropical areas but many parts of the extratropics. The climate sensitivity of populations and economic production in the tropics also makes these regions especially vulnerable to any negative impacts arising from human-induced climate change. Tropical Climatology aims to provide a geographical viewpoint on the physical processes in the tropical atmosphere: to offer explanations of how a location's climate is a product of these processes and to highlight the implications of tropical atmospheric behaviour and climate change for those living in the tropics.

2.0 OBJECTIVES

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

- state the various indices of climate in tropic; and
- explain the climatic model.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit at least twice before attempting to answer the self-assessment questions or tutor- marked assignment.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all answers.
3. Share your difficulties with your course mates, facilitators and by consulting other related material, particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do more.

3.0 WORD STUDY

Indices- a sign or an indication
Symmetric – having corresponding or parts or relation
Chronology – the science of determining the order in which things events occurred
Models – a simplify representative used to explain the workings of a real world system or events

4.0 MAIN CONTENT

4.1 Indices of Climate in the Tropic

Scientists use climate indices based on several climate patterns (known as modes of variability) in their attempt to characterise and understand the various climate mechanisms that culminate in our daily weather. Climate indices are used to represent the essential elements of climate. Climate indices are generally devised with the twin objectives of simplicity and completeness, and each index typically represents the status and timing of the climate factor it represents. By their very nature, indices are simple, and combine many details into a generalised, overall description of the atmosphere or ocean which can be used to characterise the factors which impact the global climate system.

The first index is:
El Niño - Southern Oscillation
El Niño-Southern Oscillation (ENSO) is a global coupled ocean-atmosphere phenomenon. The Pacific Ocean signatures, El Niño and La Niña are important temperature fluctuations in surface waters of the tropical Eastern Pacific Ocean. The

name El Niño, from the Spanish for "the little boy", refers to the Christ Child because the phenomenon is usually noticed around Christmas time in the Pacific Ocean off the west coast of South America. La Niña means "the little girl". Their effect on climate in the subtropics and the tropics are profound. The atmospheric signature, the Southern Oscillation (SO) reflects the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin. The most recent occurrence of El Niño started in September 2006 and lasted until early 2007.

ENSO is a set of interacting parts of a single global system of coupled ocean-atmosphere climate fluctuations that come about as a consequence of oceanic and atmospheric circulation. ENSO is the most prominent known source of inter-annual variability in weather and climate around the world. The cycle occurs every two to seven years, with El Niño lasting nine months to two years within the longer term cycle, though not all areas globally are affected. ENSO has signatures in the Pacific, Atlantic and Indian Oceans. El Niño causes weather patterns which cause it to rain in specific places but not in others, this is one of many causes for the drought.

In the Pacific, during major warm events, El Niño warming extends over much of the tropical Pacific and becomes clearly linked to the SO intensity. While ENSO events are basically in phase between the Pacific and Indian Oceans, ENSO events in the Atlantic Ocean lag behind those in the Pacific by 12 to 18 months. Many of the countries affected by ENSO events are developing countries within tropical sections of continents with economies that are largely dependent upon their agricultural and fishery sectors as a major source of food supply, employment, and foreign exchange. New capabilities to predict the onset of ENSO events in the three oceans can have global socio-economic impacts. While ENSO is a global and natural part of the Earth's climate, whether its intensity or frequency may change as a result of global warming is an important concern. Low-frequency variability has been evidenced: the quasi-decadal oscillation (QDO). Inter-decadal (ID) modulation of ENSO (from PDO or IPO) might exist. This could explain the so-called protracted ENSO of the early 1990s.

Madden-Julian Oscillation

The Madden-Julian Oscillation (MJO) is an equatorial travelling pattern of anomalous rainfall that is planetary in scale. It is characterised by an eastward progression of large regions of both enhanced and suppressed tropical rainfall, observed mainly over the Indian Ocean and Pacific Ocean. The anomalous rainfall is usually first evident over the western Indian Ocean, and remains evident as it propagates over the very warm ocean waters of the western and central tropical Pacific. This pattern of tropical rainfall then generally becomes very nondescript as it moves over the cooler ocean waters of the eastern Pacific but reappears over the tropical Atlantic and Indian Ocean. The wet phase of enhanced convection and precipitation is followed by a dry phase where convection is suppressed. Each cycle lasts approximately 30–60 days. The MJO is also known as the 30-60 day oscillation, 30-60 day wave, or intraseasonal oscillation.

North Atlantic Oscillation (NAO)
Indices of the NAO are based on the difference of normalised sea level pressure (SLP) between Ponta Delgada, Azores and Stykkisholmur/Reykjavik, Iceland. The SLP anomalies at each station were normalised by division of each seasonal mean pressure by the long-term mean (1865-1984) standard deviation. Normalisation is done to avoid the series of being dominated by the greater variability of the northern of the two stations. Positive values of the index indicate stronger-than-average westerlies over the middle latitudes.

Northern Annular Mode (NAM) or Arctic Oscillation (AO)
The NAM, or AO, is defined as the first EOF of northern hemisphere winter SLP data from the tropics and subtropics. It explains 23 per cent of the average winter (December-March) variance, and it is dominated by the NAO structure in the Atlantic. Although there are some subtle differences from the regional pattern over the Atlantic and Arctic, the main difference is larger amplitude anomalies over the North Pacific of the same sign as those over the Atlantic. This feature gives the NAM a more annular (or zonally symmetric) structure.

Northern Pacific (NP) Index
The NP Index is the area-weighted sea level pressure over the region 30N-65N, 160E-140W.

Pacific Decadal Oscillation (PDO)
The PDO is a pattern of Pacific Climate variabilitythat shifts phases on at least inter-decadal time scale, usually about 20 to 30 years. The PDO is detected as warm or cool surface waters in the Pacific Ocean, north of 20° N. During a "warm", or "positive", phase, the west Pacific becomes cool and part of the eastern ocean warms; during a "cool" or "negative" phase, the opposite pattern occurs. The mechanism by which the pattern lasts over several years has not been identified; one suggestion is that a thin layer of warm water during summer may shield deeper cold waters. A PDO signal has been reconstructed to 1661 through tree-ring chronologies in the Baja California area.

Interdecadal Pacific Oscillation (IPO)
The Interdecadal Pacific Oscillation (IPO or ID) display similar Sea Surface Temperature (SST) and sea level pressure patterns to the PDO, with a cycle of 15–30 years, but affects both the north and south Pacific. In the tropical Pacific, maximum SST anomalies are found away from the equator. This is quite different from the quasi-decadal oscillation (QDO) with a period of 8-to-12 years and maximum SST anomalies straddling the equator, thus resembling ENSO.

4.2 Climate Models

Climate models use quantitative methods to simulate the interactions of the atmosphere, oceans, land surface, and ice. They are used for a variety of purposes from study of the dynamics of the weather and climate system to projections of future climate. All climate models balance, or very nearly balance, incoming energy as short wave (including visible) electromagnetic radiation to the earth with outgoing energy as long wave (infrared) electromagnetic radiation from the earth. Any unbalance results in a change in the average temperature of the earth.

The most talked-about models of recent years have been those relating temperature to emissions of carbon dioxide (see greenhouse gas). These models predict an upward trend in the surface temperature record, as well as a more rapid increase in temperature at higher altitudes.

Models can range from relatively simple to quite complex:
A simple radiant heat transfer model that treats the earth as a single point and averages outgoing energy, this can be expanded vertically (radiative-convective models), or horizontally.

Finally, (coupled) atmosphere–ocean–sea ice global climate models discretise and solve the full equations for mass and energy transfer and radiant exchange.

5.0 CONCLUSION

We learnt that climate indices are generally devised with the twin objectives of simplicity and completeness, and each index typically represents the status and timing of the climate factor it represents.

6.0 ACTIVITY

1. What is El Nino-Southern Oscillation
2. Explain its atmospheric signatures and state where they are most felt.
3. Explain why developing countries and tropical sections of the continents are mostly affected

7.0 SUMMARY

Tropical Climatology aims to provide a geographical viewpoint on the physical processes in the tropical atmosphere: to offer explanations of how a location's climate is a product of these processes and to highlight the implications of tropical atmospheric behaviour and climate change for those living in the tropics.

8.0 ASSIGNMENT

1. List and explain the indices of climate in tropical part of the world.
2. What do you understand by climate modelling?
3. Explain 4 socio-economic impact of El Nino.

9.0 REFERENCES/FURTHER READING

"Arctic Climatology and Meteorology: Definition for Cyclogenesis". *National Snow and Ice Data Center*. http://nsidc.org/arcticmet/glossary/cyclogenesis.html. Retrieved 2006-10-20.

Chris, L. (2008). "How do tropical cyclones form?" Retrieved on 2008-06-08.

Goldenberg, S. (2004). "What is an Extra-Tropical Cyclone?". *Frequently Asked Questions*. *Atlantic Oceanographic and Meteorological Laboratory*, Hurricane Research Division. http://www.aoml.noaa.gov/hrd/tcfaq/A7.html. Retrieved 2008-08-30.

Landsea, C. (2010). "AOML Climate Variability of Tropical Cyclones paper". *Atlantic OceanographicandMeteorologicalLaboratory*. http://www.aoml.noaa.gov/hrd/Landsea/climvari/index.html. Retrieved 23 September 2010.

UNIT 4 TROPICAL CYCLONES

CONTENT

1.0 INTRODUCTION

A tropical cyclone is composed of a system of thunderstorms that shows a cyclonic rotation around a central core or eye. A *tropical cyclone* is a generic term for a storm with an organised system of thunderstorms that are not based on a frontal system.

Each individual tropical cyclone differs, but several characteristics are common to most all tropical cyclones including a central low-pressure zone and high wind speeds of at least 34 knots. At this point, the storms are given a pre-determined storm name. Most storms are accompanied by a lot of rain and storm surges near the shore. Often, once the storms make landfall, the tropical cyclone can cause tornadoes.

A tropical cyclone needs warm ocean temperatures in order to form. Temperatures in the ocean need to be at least 82 degrees Fahrenheit in order to form. Heat is drawn up from the oceans creating what is popularly called a 'heat engine'. Tall convective towers of clouds are formed within the storm as warm ocean water evaporates. As the air rises higher it cools and condenses releasing latent heat which causes even more clouds to form and feed the storm.

2.0 OBJECTIVES

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

- differentiate between “hurricane”, “cyclone” and “typhoon”;
- state the difference between tropical cyclones and wind speed; and
- list and explain the requirements for tropical cyclone formation.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit at least twice before attempting to answer the self-assessment questions or tutor- marked assignment.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all answers.
3. Share your difficulties with your course mates, facilitators and by consulting other related material, particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do more.

3.0 WORD STUDY

Coriolis force – any equivalent apparent force that deflects objects in a rotating reference frame
Baseline – a datum used as the basis for calculation or for comparison
Ambient - surrounding

4.0 MAIN CONTENT

4.1 Rotation and Forward Speed

The rotation of tropical cyclones in the Northern Hemisphere is counter-clockwise due to the Coriolis Effect. The opposite is true in the Southern Hemisphere.

The forward speed of a tropical cyclone can be a factor in determining the amount of damage the storm will cause. If a storm remains over one area for a long period of time, torrential rains, high winds, and flooding can severely impact an area. The average forward speed of a tropical cyclone is dependent on the latitude where the storm is currently. Generally, at less than 30 degrees of latitude, the storms will move at about 20 mph on average. The closer the storm is located to the equator, the slower the movement. Some storms will even stall out over an area for an extended period of time. After about 35 degrees North latitude, the storms start to pick up speed.

A good example of the fast formation of tropical cyclones comes when several storms stack up in the ocean back-to-back. Such an example occurred in 2009 with the formation of Ana, Bill, and Claudette as seen in this satellite image. The storms were very close to one another. Storms can also become entangle with one another in a process known as the Fujiwhara Effect where tropical cyclones can interact with each other.

Hurricanes, cyclones and typhoons are tropical cyclones with maximum sustained wind speed exceeding 119 km/h near their centres, and every year responsible of thousands of victims. Although loss of lives from tropical cyclones has significantly decreased over the last decades, economic losses have increased substantially. The decrease in fatalities is, at a large extent, attributed to the improvement in the tropical cyclones forecasting and early warning systems. The World Meteorological Organization (WMO) Tropical Cyclone Programme is aimed to establish national and regionally coordinated systems to ensure that the loss of lives and damage caused by tropical cyclones are reduced to a minimum.

4.2 The Difference between “Hurricane”, “Cyclone” and “Typhoon”?

"Hurricane", "cyclone" and "typhoon" are different terms for the same weather phenomenon which is accompanied by torrential rain and maximum sustained wind speeds (near centre) exceeding 119 kilometers per hour:

- In the western North Atlantic, central and eastern North Pacific, Caribbean Sea and Gulf of Mexico, such a weather phenomenon is called "hurricanes".
- In the western North Pacific, it is called "typhoons".
- In the Bay of Bengal and Arabian Sea, it is called "cyclones".
- In western South Pacific and southeast India Ocean, it is called “severe tropical cyclones.”
- In the southwest India Ocean, it is called “tropical cyclones.”

Times of formation

.Worldwide, tropical cyclone activity peaks in late summer when water temperatures are warmest. Each basin, however, has its own seasonal patterns. On a worldwide scale, May is the least active month, while September is the most active. This can be explained by the greater tropical cyclone activity across the Northern hemisphere than south of the equator.

In the North Atlantic, a distinct hurricane season occurs from June 1 through November 30, sharply peaking from late August through October. The statistical peak of the North Atlantic hurricane season is September 10. The Northeast Pacific has a broader period of activity, but in a similar time frame to the Atlantic. The Northwest Pacific sees tropical cyclones year-round, with a minimum in February and a peak in early September. In the North Indian basin, storms are most common from April to December, with peaks in May and November.

In the Southern Hemisphere, tropical cyclone activity begins in early November and depending on the country ends on either April 30 or May 15. Southern Hemisphere activity peaks in mid-February to early March virtually all the Southern Hemisphere activity is seen from the southern African coast eastward towards South America. Tropical cyclones are rare events across the South Atlantic Ocean and the south-eastern Pacific Ocean.

4.3 Difference between Tropical Cyclones and Wind Speed

Depending on the maximum sustained wind speed, tropical cyclones will be designated as follows:

- It is a tropical depression when the maximum sustained wind speed is less than 63 km/h.
- It is a tropical storm when the maximum sustained wind speed is more than 63 km/h. It is then also given a name.
- Depending on the ocean basins, it is designated a hurricane, typhoon, severe tropical cyclone, severe cyclonic storm or tropical cyclone when the maximum sustained wind speed is more than 119 km/h.

Tropical cyclones can be hundreds of kilometers wide and can bring destructive high winds, torrential rain, storm surge and occasionally tornadoes. According to the Saffir-Simpson Hurricane Wind Scale, the hurricane strength varies from Category one to five.

- Category one hurricane is referring to the hurricane with maximum sustained wind speeds of 119-153 km/h.
- Category two hurricane is referring to the hurricane with maximum sustained wind speeds of 154-177 km/h.
- Category three hurricane is referring to the hurricane with maximum sustained wind speeds of 178-209 km/h.
- Category four hurricane is referring to the hurricane with maximum sustained wind speeds of 210-249 km/h.
- Category five hurricane is referring to the hurricane with maximum sustained wind speeds exceeding 249 km/h.

The impact of a tropical cyclone and the expected damage depend not just on wind speed, but also on factors such as the moving speed, duration of strong wind and accumulated rainfall during and after landfall, sudden change of moving direction and intensity, the structure (e.g. size and intensity) of the tropical cyclone, as well as human response to tropical cyclone disasters.

How to Predict Tropical Cyclones

Since 1984, Colorado State University has been issuing seasonal tropical cyclone forecasts for the north Atlantic basin, with results that are better than climatology. The university has found several statistical relationships for this basin that appear to allow long range prediction of the number of tropical cyclones. Since then, numerous others have followed in the university's steps, with some organisations issuing seasonal forecasts for the northwest Pacific and the Australian region. The predictors are related to regional oscillations in the global climate system: the Walker circulation which is related to the El Niño-Southern Oscillation; the North Atlantic oscillation or NAO; the Arctic oscillation or AO; and the Pacific North American pattern or PNA.

Meteorologists around the world use modern technology such as satellites, weather radars and computers etc. to track tropical cyclones as they develop. Tropical cyclones are often difficult to predict, as they can suddenly weaken or change their course. However, meteorologists use state-of-art technologies and develop modern techniques such as numerical weather prediction models to predict how a tropical cyclone evolves, including its movement and change of intensity; when and where one will hit land and at what speed. Official warnings are then issued by the National Meteorological Services of the countries concerned.

The WMO framework allows the timely and widespread dissemination of information about tropical cyclones. As a result of international cooperation and coordination, tropical cyclones are increasingly being monitored from their early stages of formation. The activities are coordinated at the global and regional levels by WMO through its World Weather Watch and Tropical Cyclone Programmes. The Regional Specialised Meteorological Centers with the activity specialisation in tropical cyclones, and tropical cyclone warning centres, all designated by WMO, are functioning within the organisation's tropical cyclone programme. Their role is to detect, monitor, track and forecast all tropical cyclones in their respective regions. The centres provide, in real-time, advisory information and guidance to the National Meteorological Services.

Where did Tropical Cyclones Occur Recently?

Between 1886 and 1998, out of the 566 Atlantic hurricanes in the Atlantic, twenty two have grown as strong as to become category five hurricanes with maximum sustained wind speeds exceeding 249 km/h. The worst recent tropical cyclones include Hurricane Mitch (Honduras) in 1998, Hurricane Katrina (USA) in 2005 and most recently hurricane Gustav (Haiti) in 2008, and severe cyclone Nargis (Myanmar) in 2008.

In 2008, a total of 16 named tropical cyclones formed in the Atlantic including eight hurricanes, five of which were major hurricanes at Category three or higher on the Saffir-Simpson Hurricane Scale. These numbers are well above the long-term averages of 11, 6, and 2 respectively. The 2008 Atlantic hurricane season was devastating, with casualties and widespread destruction in the Caribbean, Central America and the United States of America. For the first time on record, six consecutive tropical cyclones (Dolly, Edouard, Fay, Gustav, Hanna and Ike) made landfall on the United States of America, and two major hurricanes (Gustav and Ike) hit Cuba.

In the East Pacific, 16 named tropical cyclones were recorded in 2008, of which seven evolved into hurricanes and two of them into major hurricanes at category three or higher. In the Western North Pacific, 22 named tropical cyclones were recorded in 2008, ten of which were classified as typhoons compared to the long-term average of 27 and 14, respectively.

As of early November 2009, the hurricane season in the Atlantic counts nine named tropical cyclones, of which three became hurricanes. These numbers are well below the long term average of tropical cyclones in the region.

The Western North Pacific has been hit several times in September - October 2009 by numerous typhoons such as Ketsana, Parma, Lupit and Mirinae, causing many casualties.

4.4 Requirements for Tropical Cyclone Formation

There are six main requirements for tropical cyclogenesis: sufficiently warm sea surface temperatures, atmospheric instability, high humidity in the lower to middle levels of the troposphere, enough Coriolis force to sustain a low pressure center, a pre-existing low level focus or disturbance, and low vertical wind shear. While these conditions are necessary for tropical cyclone formation, they do not guarantee that a tropical cyclone will form.

Warm Waters, Instability, and Mid-Level Moisture
Waves in the trade winds in the Atlantic Ocean—areas of converging winds that move slowly along the same track as the prevailing wind—create instabilities in the atmosphere that may lead to the formation of hurricanes. Normally, an ocean temperature of 26.5°C (79.7°F) spanning through at least a 50-metre depth is considered the minimum to maintain the special mesocyclone that is the tropical cyclone. These warm waters are needed to maintain the warm core that fuels tropical systems. This value is well above 16.1 °C (60.9 °F), the global average surface temperature of the oceans.[8] However, this requirement can be considered only a general baseline because it assumes that the ambient atmospheric environment surrounding an area of disturbed weather presents average conditions.

Tropical cyclones are known to form even when normal conditions are not met. For example, cooler air temperatures at a higher altitude (e.g., at the 500 hPa level, or 5.9 km) can lead to tropical cyclogenesis at lower water temperatures, as a certain lapse rate is required to force the atmosphere to be unstable enough for convection. In a moist atmosphere, this lapse rate is 6.5 °C/km, while in an atmosphere with less than 100 per cent relative humidity, the required lapse rate is 9.8 °C/km.

At the 500 hPa level, the air temperature averages -7 °C (18 °F) within the tropics, but air in the tropics is normally dry at this level, giving the air room to wet-bulb, or cool as it moistens, to a more favourable temperature that can then support convection. A wet bulb temperature at 500 hPa in a tropical atmosphere of -13.2 °C is required to initiate convection if the water temperature is 26.5 °C, and this temperature requirement increases or decreases proportionally by 1 °C in the sea surface temperature for each 1 °C change at 500 hpa. Under a cold cyclone, 500 hPa temperatures can fall as low as -30 °C, which can initiate convection even in the driest atmospheres. This also explains why moisture in the mid-levels of the troposphere, roughly at the 500 hPa level, is normally a requirement for development. However, when dry air is found at the same height, temperatures at 500 hPa need to be even colder as dry atmospheres require a greater lapse rate for instability than moist atmospheres. At heights near the tropopause, the 30-year average temperature (as measured in the period encompassing 1961 through 1990) was -77 °C (-132 °F). A recent example of a tropical cyclone that maintained itself over cooler waters was Epsilon of the 2005 Atlantic hurricane season.

5.0 CONCLUSION

Tropical cyclones can last for a week or more; therefore there can be more than one cyclone at a time. Weather forecasters give each tropical cyclone a name to avoid confusion. Each year, tropical cyclones receive names in alphabetical order. Women and men's names are alternated. The name list is proposed by the National Meteorological and Hydrological Services (NMHSs) of WMO Members of a specific region, and approved by the respective tropical cyclone regional bodies at their annual/bi-annual sessions. Nations in the western North Pacific began using a new system for naming tropical cyclones in 2000. Each of the 14 nations affected by typhoons submitted a list of names totalling 141. The names include animals, flowers, astrological signs; a few personal names are used in pre-set order. In 2010, the first hurricane in the Caribbean Sea, Gulf of Mexico and the North Atlantic region will be called Alex, and in Eastern North Pacific, it will be Agatha.

6.0 ACTIVITY

1. What is Tropical Cyclone?
2. State some of the major devastating social effects of tropical cyclone on a community.
3. Suggest how it can be avoided.

7.0 SUMMARY

The typhoon season in the western North Pacific region typically runs from May to November. The Americas/Caribbean hurricane season runs from June 1 to November 30, peaking in August and September. The cyclone season in South Pacific and Australia normally runs from November to April. In the Bay of Bengal and Arabian Sea, tropical cyclones usually occur from April to June, and September to November. The East Coast of Africa normally experiences tropical cyclones from November to April.

8.0 ASSIGNMENT

1. What is different between Tropical Cyclones and Wind Speed?
2. What are the major requirements for cyclones formation?
3. Explain the between Hurricane, Cyclone and Typhoon

9.0 REFERENCES/FURTHER READING

"Arctic Climatology and Meteorology: Definition for Cyclogenesis". *National Snow and Ice Data Center*. http://nsidc.org/arcticmet/glossary/cyclogenesis.html. Retrieved 2006-10-20.

Chris, L. (2008). "How do tropical cyclones form?" Retrieved on 2008-06-08.

Goldenberg, S. (2004). "What is an Extra-Tropical Cyclone?". *Frequently Asked Questions*. *Atlantic Oceanographic and Meteorological Laboratory*, Hurricane Research Division. http://www.aoml.noaa.gov/hrd/tcfaq/A7.html. Retrieved 2008-08-30.

Landsea, C. (2010). "AOML Climate Variability of Tropical Cyclones paper". *Atlantic Oceanographic and Meteorological Laboratory*. http://www.aoml.noaa.gov/hrd/Landsea/climvari/index.html. Retrieved 23 September 2010.

UNIT 5 THE IMPLICATION OF TROPICAL CLIMATE CHARACTERISTICS AND BEHAVIOUR ON PLANT AND ANIMALS

CONTENT

1.0 INTRODUCTION

Climatology, the scientific study of climate, is not only concerned with explaining why a location's or region's climate is like it is but also describes the nature and availability of the climate resource for a wide range of human activities. This subject is of great relevance to the tropics as climate in many ways controls the lives and economic activities of the approximately 2400 million people living in tropical regions. Tropical climates also have effects that reach far beyond the limits of the regions where they actually prevail: the global general circulation is largely driven by the export of considerable amounts of heat energy from tropical to extra-tropical latitudes: a large part of all atmospheric water content originates from the tropics, and intermittent tropical phenomena, like El Nino Southern Oscillation (ENSO), not only influence the climates over extensive tropical areas but many parts of the extra-tropics. The climate sensitivity of populations and economic production in the tropics also makes these regions especially vulnerable to any negative impacts arising from human-induced climate change.

This is the first global compilation of projected ecosystem impacts for humid tropical forests affected by these combined forces," remarked Asner. "For those areas of the globe projected to suffer most from climate change, land managers could focus their efforts on reducing the pressure from deforestation, thereby helping species adjust to climate change, or enhancing their ability to move in time to keep pace with it. On the flip side, regions of the world where deforestation is projected to have fewer effects from climate change could be targeted for restoration.

Tropical forests hold more than half of all the plants and animal species on Earth. But the combined effect of climate change, forest clear cutting, and logging may force them to adapt, move, or die. The scientists looked at land use and climate change by integrating global deforestation and logging maps from satellite imagery and high-resolution data with projected future vegetation changes from 16 different global climate models. They then ran scenarios on how different types of species could be geographically reshuffled by 2100.They used the reorganisation of plant classes, such as tropical broadleaf evergreen trees, tropical drought deciduous trees, plus different kinds of grasses as surrogates for biodiversity changes.

For Central and South America, climate change could alter about two-thirds of the humid tropical forests biodiversity -- the variety and abundance of plants and animals in an ecosystem. Combining that scenario with current patterns of land-use change, and the Amazon Basin alone could see changes in biodiversity over 80 per cent of the region.

Most of the changes in the Congo area likely to come from selective logging and climate change, which could negatively affect between 35 per cent and 74 per cent of that region. At the continental scale, about 70 per cent of Africa's tropical forest biodiversity would likely be affected if current practices are not curtailed.

In Asia and the central and southern Pacific islands, deforestation and logging are the primary drivers of ecosystem changes. Model projections suggest that climate change might play a lesser role there than in Latin America or Africa including Nigeria. That said, the research showed that between 60 per cent and 77 per cent of the area is susceptible to biodiversity losses via massive ongoing land-use changes in the region.

The student also suppose to know that the world's natural ecosystems will undergo profound changes -- including severe alterations in their species composition -- through the combined influence of climate change and land use," remarked Daniel Nepstad, senior scientist at the Woods Hole Research Centre. "Conservation of the world's biota, as we know it, will depend upon rapid, steep declines in greenhouse gas emissions.

2.0 OBJECTIVES

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

- examine the characteristics of tropical montane ecosystem;
- discuss the relationship between agricultural and climate change within the tropic;
- examine the layer of tropical rainforest, as well as plants and animals life in the tropical environment; and

- explain climatology and climate change in Nigeria.

2.1 HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit at least twice before attempting to answer the self-assessment questions or tutor- marked assignment.
2. Do not look at the solution given at the end of the unit until you are satisfied that you have done your best to get all answers.
3. Share your difficulties with your course mates, facilitators and by consulting other related material, particularly the internet.
4. Note that if you follow the instructions you will feel self fulfilled that you have achieved the aim of studying this unit. This should stimulate you to do more.

3.0 WORD STUDY

Latitude – the angular distance north or south of a planet's equator
Surrogate – a substitute
Orographic – of or pertaining to the physical features of mountains
Endemism- state of being prevalent or common in an area
Cumuliform- a large white puffy cloud that develops through convection, on a hot, humid day or a heap

4.0 MAIN CONTENT

4.1 Tropical Montane

Tropical montane cloud forests are unique among terrestrial ecosystems in that they are strongly linked to regular cycles of cloud formation. We have explored changes in atmospheric parameters from global climate model simulations of the Last Glacial Maximum and for doubled atmospheric carbon dioxide concentration conditions which are associated with the height of this cloud formation, and hence the occurrence of intact cloud forests. These parameters include vertical profiles of absolute and relative humidity surfaces, as well as the warmth index, an empirical proxy of forest type. For the glacial simulations, the warmth index and absolute humidity suggest a down slope shift of cloud forests that agrees with the available palaeodata.

Forests typically rely most on the moisture from cloud contact. At the same time, an increase in the warmth index implies increased evapo-transpiration. This combination of reduced cloud contact and increased evapo-transpiration could have serious conservation implications, given that these ecosystems typically harbour a high proportion of endemic species and are often situated on mountain tops or ridge lines.

Tropical montane cloud forests (TMCFs) occur where mountains are frequently enveloped by trade wind-derived orographic clouds and mist in combination with convective rainfall. Many features of these forests are directly or indirectly related to cloud formation, from vegetation morphology to nutrient budgets to solar insolation.

One of the most direct impacts of frequent cloud cover is the deposition of cloud droplets through contact with soil and vegetation surfaces (horizontal precipitation). Total horizontal precipitation is greater than that from vertical rainfall events in some systems during the dry season, when these forests can experience water stress. Because the combination of horizontal precipitation and lowered evapo-transpiration due to frequent cloud contact significantly increases precipitation minus evaporation in these forests, they function as important local and regional watersheds. Also, owing to the sponge-like effect of epiphytes (for example, mosses, bromeliads and ferns), these forests act as capacitors in regulating the seasonal release of precipitation, thereby providing flood and erosion control in the rainy season and water storage in the dry season.

In addition to their hydrological importance, these ecosystems typically harbour an impressive array of plants and animals.

Although the biodiversity of TMCFs is not as high as that of lowland moist tropical forests, the level of endemism found in resident animal species is exceptional. For example, 32 per cent of Peruvian endemic vertebrates are localised in cloud forests. The conservation status of these unique ecosystems is precarious as they are among the most endangered of all tropical forest types. A high annual deforestation rate in tropical mountain forests caused by harvesting fuel wood, resource logging and agricultural conversion are increasingly threatening cloud forests worldwide. Palaeoclimatic pollen evidence strongly suggests a down slope shift of the range of some current cloud forest species during the last glacial period. There is abundant evidence for down slope migrations of South and Central American montane taxa (Quercus, Alnus, Weinmannia and Podocarpus, for example) during glacial times. Weinmannia is now a characteristic genus of cloud forest trees in the high Andes, and Podocarpus is found in cloud forests throughout the tropics. Other evidence, ranging from noble gas concentrations in groundwater to Barbados corals, to snowline depression, indicates that certain regions of the tropics were cooler by some 2±5 8C, with considerable variation in both temperature and moisture conditions. Such changes surely affected both the altitudinal and latitudinal distributions of cloud forests in the glacial past. Cloud formation associated with trade winds often occurs as a result of orographic effects.

4.2 Tropical Agriculture

This final part of the series contains a brief overview of agriculture in the tropics, as well as its effects, noting the increasing human population in all tropical climate zones. In many places, humans have altered the distribution of plant and animal species, in almost all areas using plants and animals for food or labour. These changes, in turn, change the climate as the appearance and, therefore, the characteristics of the environment alter significantly. The sensitivity and effects of the tropics on global climate are important. Small changes in rainfall patterns, when experienced over a long period of years, have a great effect on the vegetation; this, in turn, affects populations dependent upon it. Small changes in temperature have changed rainfall patterns in the tropics within the past two million years, making some areas drier and others wetter (Burroughs, 2005). The global climate is regulated by conditions in the tropics: the source of energy for agriculture in the middle latitudes is partly supplied from the tropics, tropical forests absorb a large proportion of global carbon dioxide production, and protective ozone is created in the tropical stratosphere. It is thus increasingly important for us to study not only the weather and climate of the tropics, but also the interrelationship between tropical climates, agriculture and humankind.

Agriculture in the Humid Tropics and the Effects of Forest Clearance

Agriculture has resulted in the clearance of forest in many parts of the humid tropics, although it is the semi-deciduous forest that has been subject to most clearance historically.

In part, this is due to the relatively rich, but leached, red-brown (iron-rich) or grey (kaolin-rich) soils of the humid zone, but also due to patterns of settlement and the slightly favourable monsoon climate. Forests are ideally suited to the humid tropics with roots able to tap dissolved minerals below the surface soil layer (Ellis and Mellor, 1995). As the forest is cleared to open areas for agriculture and as a source of wood for construction and paper making, or to grow crops, there is a profound effect on the climate. Clearly, growing populations require more arable land, but the planting of cash crops remains a contentious issue. In the tropical rain forests of Southeast Asia, many areas have been either cleared, or the forest changed to a secondary form, often of palm and fruit trees initially, the clearance was to provide wood for housing, but latterly it has been to grow subsistence crops. In semi-deciduous ('monsoon') forest, crops such as tea, coffee, and chocolate, grown largely for export, have often replaced the woodland. Elsewhere, oil crops, tropical fruit or groundnuts are the principal crops where forest has been cleared. (It seems likely that oil crops will become increasingly important in future, at the expense of the natural forest.)

Forest clearance has an unfortunate and significant effect on climate and the effects of weather. As crops or grassland replace woodland, the daily temperature range rises, transpiration decreases and lower surface humidity reduces cloud formation – most of which is a result of convection in the tropics. Thus crops may require additional watering in the drier areas. The main feedback, however, is a reduced quantity of water carried through the hydrological cycle. Another feedback is an increase in cloud-base height of cumuliform clouds, which reduces the amount of rainfall that may reach the ground before evaporating.

As trees are cleared, there is a serious effect on the tropical latosols. Without trees, leaf-fall and fallen trees cannot contribute to the recycling of minerals, so the soils are more easily leached of essential nutrients. The lack of a leaf canopy increases the intensity of rainfall at ground level, so that the thin humus layer can be washed away more easily. Where crops are grown commercially, it is often necessary for large amounts of fertilizer to be added, even where relatively nutrient-rich river waters from mountains such as the Himalayas are used to water them. Although the potential

Latosols, as described briefly in part 9 (Galvin, 2009b), are the characteristic soil of the humid tropics. They are formed by leaching of nutrients from the upper layers in heavy rainfall, so are generally deficient in many nutrients. However, rapid decomposition in the warm moist conditions of this zone, as well as nitrogen from rainfall does provide a good source of minerals in the humus layer, especially where trees provide some shelter for productivity is very good, especially where there is a continuous growing season and the costs can be high.

Clearance and degradation of forests also emit carbon to the atmosphere, further affecting global climate. Net deforestation has contributed around a quarter of the historical rise of CO2, mainly from deforestation in the tropics (de Forster *et al.*, 2007).

Tropical forest cover declined by 250 million hectares between 1980 and 1990. The forestry sector is currently the third-largest contributor of global greenhouse gas emissions and is a larger emitter than transport.

Tropical forests are also vulnerable to climate change with some models predicting widespread loss of the Amazon rainforest due to climate change (Betts *et al.*, 2004; Cox *et al*., 2004), although any such impacts are highly uncertain. Severe impacts of climate change on tropical forests may be more likely if the forest is already affected by forestry activities (Betts *et al.*, 2007). Forest degradation may therefore increase the likelihood of climate–carbon cycle feedbacks, accelerating the rise of CO_2. Protecting tropical forests and the carbon they store is now being discussed as one possible measure to combat climate change through a mechanism called 'REDD' (Reducing Emissions from Deforestation and Degradation) (Gullison *et al.*, 2007).

Agriculture in the Savannah

The savannah is very important for humankind and many crops have replaced the climax vegetation of this climatic zone, in particular in India, the Americas and Africa. Perhaps most important of the crops grown in many savannah lands are the grains: rice, wheat, barley, oats, maize and millet. These plants, developed from grasses, feed a large proportion of the population of the tropics, although the cultivated area remains relatively small, compared with the natural grasslands used principally for pastoral farming. Many of these grains are ground to form flour for baking or bread-making. In general, tropical grains (apart from rice) contain little gluten, so bread does not rise well. Many grains are also used as animal-fodder supplements. In countries where alcohol may be produced, malted barley is used to make beer. The crop type depends partly on climate, but also on its familiarity to the population. Among the cereals, oats and barley are resistant to periodic cold, including frosts, whereas maize requires warmer, wetter conditions and millet is adapted to drier environments. Barley is salt-tolerant and oats can grow in very wet climates.

Weather and Locust Swarms

Locust infestation, which has a serious effect on agriculture in marginal desert areas, is related to the climate of these areas. Although different areas are affected in different years, locusts hopping and then flying in their millions destroy crops and thus livelihoods in the areas they land. Their pestilence is dependent on both weather and wind. Rain, usually associated with incursions of westerly winds, provides suitable conditions, promoting the growth of plants and the successful hatching of locusts (Dubey and Chandra, 1991). Plagues may develop following insect maturation once the wind returns into the east. This change of wind direction is typically seen in the transition from summer to winter. However, many factors determine the occurrence of locusts, on all meteorological scales. A text in the Bible (*Exodus* 10:13–15) readily suggests the serious effect of such plagues.

Over the Middle East and North Africa, locusts are carried from the northeast to reach the southern periphery of the Sahara – the Sahel. Eventually, provided sufficient surface vegetation is available, southwesterly monsoon winds may carry locusts northeast, into northwest African countries.

Southwest Asia, Pakistan and northwest India are also affected by locust plagues.

The Effects of Agriculture in the Tropics

Humans have altered this environment, mainly by agriculture (Turner and McCandless, 2004), the appearance of tropical lands, as modified by humankind. At first sight, the modification appears minimal, as the area under agricultural production is small (less than 10%). A closer look reveals that the areas of natural vegetation vary significantly in particular the area covered by tropical woodland. This is likely to have been a direct result of agriculture over the centuries. It is now generally accepted that areas formerly forested, but at the margins of arid areas, have become drier since the last ice age, some 10 000 years ago (Burroughs, 2005). This drying is probably caused, in part, by the spread of agriculture, although importantly the drying in itself reduces the tree cover. As discussed above, this, in turn, reduces rainfall, since evapotranspiration is reduced and so on. Clearly, humans must have the ability to grow sufficient food in the areas where it is needed: types that will grow well and that are familiar (IRRI, 2004). There is also a need to grow crops that will bring an income (e.g. tea, coffee, cocoa, copra, fruit) to provide cash and supplement the staple diet, thus generating sufficient wealth to allow education and health care. Although this has an effect on the environment (as seen very clearly in Europe or North America), this is generally small in the tropics (notwithstanding the changes discussed above). The lowland humid tropical zone has potential to produce vast crops from a small area, given its plentiful rainfall and sunshine, although a supplement in the form where there is sufficient water, agricultural productivity can be high, since the lack of rainfall restricts leaching of the soils. The soils may be thin and poorly formed, so that their mineral content has not been broken down to be readily used by plants but is still held within immature clays or bedrock. Nutrients may be rapidly consumed or leached when water is added, however, as soils are usually loose and friable. Irrigation water is readily transpired in the low humidity and daytime warmth of this zone.

Irrigation was traditionally seasonal, provided by great rivers, such as the Nile. Alluvial soils, largely of fine porous but impermeable clays, store water and help make agriculture productive (Ellis and Mellor, 1995). More recently, the building of dams and irrigation has allowed the greening of drier areas. The fertility of desert soils is also dependent on the geology of the surroundings. Where this is limestone, poorer soils are likely to form than from, say, clay stones (Open University, 1986). Other areas may be largely bare rock, unsuitable for anything other than hardy animals that can live on the scrubby vegetation growing in cracks in the rocks. Almost everywhere in the dry environment, soils are thin and poorly developed.

The effects of desert irrigation over a long period can have a serious effect in dry lands.

Soils naturally contain minerals, including salts. Addition of water gradually denudes the soil of essential phosphate and nitrate by leaching and as plants grow, whilst increasing many salts, in particular sodium chloride and calcium carbonate present in the water, due to evaporation. Sodium chloride is poisonous to many plants, so tolerant species may need to be grown.

In many parts of southern Asia, scrublands have long been irrigated. Groundnut is an important crop grown usually for its oil in central India, between the Eastern and Western Ghats, as well as in Indo-China. The Sahel of Africa has come to prominence, mainly due to the effects of a growing population and the ephemeral nature of fertilizers (natural or manufactured) will be needed to sustain this growth and the growing population.

Agriculture and Climate Change

The fact of increased greenhouse gas concentrations in the atmosphere and resultant warming is now well established (Le Treut *et al.*, 2007). The Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC, 2007) gives warming between about 2 and 4 degree C in the tropics by the end of the twenty-first century compared with 1980–1999, the greatest warming over land, mainly in areas of dry climate. Over the sea, the likelihood is that the greatest warming will be close to the Equator.

Any change of climate can take one of two forms as temperatures rise. Either the new climatic state has a similar variability as the current climate, or the variability changes. In the first case, the number of extreme weather events will change little, but in the latter case, it is likely that variability will increase.

More extreme events would be likely, posing a risk of greater danger: more torrential rain, more droughts, more (or more extreme) tropical revolving storms, more forest fires, even above the increase to be expected as temperatures rise (IPCC, 2007). Clearly, these scenarios could have very different outcomes and much research now goes into discovering which is more likely.

Increasing variability is likely and the climate is likely to be less stable with greenhouse gas concentrations increasing (Cox *et al.*, 2000). If the climate and the oceans, in particular, are warmer, more rainfall may result. Some parts of the tropics, however, are likely to become drier and others wetter. In general, the humid tropics are likely to become wetter, whilst drier parts of the tropics are likely to suffer more water shortages than occur at present (IPCC, 2007). In Asia, it seems likely that the southwest monsoon will become wetter and that monsoon rain will be heavier (Lowe *et al.*, 2005). On a regional scale, however, patterns of rainfall are likely to become more complicated. The Hadley Centre mesoscale climate model, running with a 25km grid length, suggests that there will be more rain on the highest ground, but areas in rain shadow in southern India, as well as the relatively cool ocean areas, are likely to become much drier (Met Office, 2004). Changes, although subtle, are likely to favour some crops over others.

Increasing rainfall is likely to increase river flow, although in many drier areas, any increase is likely to be minimal, the extra rainfall being used by plants, in particular in areas of marginal agriculture (Lowe *et al*., 2005). Although generally of benefit to the population of these zones, there is a risk that the additional rainfall will be mainly in the form of heavy rain and hail, posing a threat of damage to crops, either directly or from floods and landslides. Some other, unexpected, changes may also occur, as is already apparent in the western Pacific during the La Nina phase of the Southern oscillation. In Southeast Asia, when increased rainfall runs off high ground, rice terraces are often inundated, the rice seed washed away, or young rice plants drowned in deep water. Plants such as maize may not be able to germinate, or may suffer fungal infections when fields become waterlogged.

In areas of increased run-off and river flow, nutrients are likely to be more easily washed away, reducing natural fertility, as well as poisoning the sea, reducing oceanic productivity and fish stocks.

A warming world is also likely to bring changes to the El Nino-Southern oscillation the main control of climate variability in the tropics. Whilst some researchers suggest that El Nino will become more common, however, ice-core studies for 10 000–5000 years ago, when the global climate was warmer than at present, suggest that El Nino will be less common, decreasing tropical climate variability (Burroughs, 2005). Overall, the eastern equatorial of tropical climate variability is reduced, some of the hazards of tropical agriculture will either lessen, or can be allowed for Warmer oceans might reasonably be expected to produce a greater likelihood of tropical storms and there is some evidence of an increase in storm activity over warming waters (Saunders and Lea, 2008). However, many studies suggest an overall reduction in storm number, some areas seeing fewer storms, while others experience more.

Where they occur, they are likely to become more intense (Burroughs, 2005; Emanuel, 2005). Coastal and island populations are likely to bear the brunt of a warmed world as sea level rises, due to melting ice caps and ocean expansion (IPCC, 2007).

The tropical rain forest is a forest of tall trees in a region of year-round warmth. An average of 50 to 260 inches (125 to 660 cm.) of rain falls yearly.

Rain forests belong to the tropical wet climate group. The temperature in a rain forest rarely gets higher than 93 °F (34 °C) or drops below 68 °F (20 °C); average humidity is between 77 and 88 per cent; rainfall is often more than 100 inches a year. There is usually a brief season of less rain. In monsoonal areas, there is a real dry season. Almost all rain forests lie near the equator.

Rainforests now cover less than 6 per cent of Earth's land surface. Scientists estimate that more than half of all the world's plant and animal species live in tropical rain forests. Tropical rainforests produce 40 per cent of Earth's oxygen.

A tropical rain forest has more kinds of trees than any other area in the world. Scientists have counted about 100 to 300 species in one 2 1/2-acre (1-hectare) area in South America. Seventy percent of the plants in the rainforest are trees.

About 1/4 of all the medicines we use come from rainforest plants. Curare comes from a tropical vine, and is used as an anesthetic and to relax muscles during surgery. Quinine, from the cinchona tree, is used to treat malaria. A person with lymphocytic leukaemia has a 99 per cent chance that the disease will go into remission because of the rosy periwinkle. More than 1,400 varieties of tropical plants are thought to be potential cures for cancer.

All tropical rain forests resemble one another in some ways. Many of the trees have straight trunks that don't branch out for 100 feet or more. There is no sense in growing branches below the canopy where there is little light. The majority of the trees have smooth, thin bark because there is no need to protect them from water loss and freezing temperatures. It also makes it difficult for epiphytes and plant parasites to get a hold on the trunks. The bark of different species is so similar that it is difficult to identify a tree by its bark. Many trees can only be identified by their flowers.

Despite these differences, each of the three largest rainforests--the American, the African, and the Asian--has a different group of animal and plant species. Each rain forest has many species of monkeys, all of which differ from the species of the other two rain forests. In addition, different areas of the same rain forest may have different species. Many kinds of trees that grow in the mountains of the Amazon rain forest do not grow in the lowlands of that same forest.

4.3 The Layer of Tropical Rainforest as Well as Plant Life within the Tropic

4.4.1 Layers of the Rainforest

There are four very distinct layers of trees in a tropical rain forest. These layers have been identified as the emergent, upper canopy, understory, and forest floor.

- Emergent trees are spaced wide apart, and are 100 to 240 feet tall with umbrella-shaped canopies that grow above the forest. Because emergent trees are exposed to drying winds, they tend to have small, pointed leaves. Some species lose their leaves during the brief dry season in monsoon rainforests. These giant trees have straight, smooth trunks with few branches. Their root system is very shallow, and to support their size they grow buttresses that can spread out to a distance of 30 feet.

- The upper canopy of 60 to 130 foot trees allows light to be easily available at the top of this layer, but greatly reduced any light below it. Most of the rainforest's animals live in the upper canopy. There is so much food available at this level that some animals never go down to the forest floor. The leaves have "drip spouts" that allows rain to run off. This keeps them dry and prevents mold and mildew from forming in the humid environment.

- The understory, or lower canopy, consists of 60 foot trees. This layer is made up of the trunks of canopy trees, shrubs, plants and small trees. There is little air movement. As a result the humidity is constantly high. This level is in constant shade.

- The forest floor is usually completely shaded, except where a canopy tree has fallen and created an opening. Most areas of the forest floor receive so little light that few bushes or herbs can grow there. As a result, a person can easily walk through most parts of a tropical rain forest. Less than 1 per cent of the light that strikes the top of the forest penetrates to the forest floor. The top soil is very thin and of poor quality. A lot of litter falls to the ground where it is quickly broken down by decomposers like termites, earthworms and fungi. The heat and humidity further help to break down the litter. This organic matter is then just as quickly absorbed by the trees' shallow roots.

4.4.2 Plant Life

Besides these four layers, a shrub/sapling layer receives about 3 per cent of the light that filters in through the canopies. These stunted trees are capable of a sudden growth surge when a gap in the canopy opens above them.

The air beneath the lower canopy is almost always humid. The trees themselves give off water through the pores (stomata) of their leaves. This process, called transpiration, can account for as much as half of the precipitation in the rain forest.

Rainforest plants have made many adaptations to their environment. With over 80 inches of rain per year, plants have made adaptations that help them shed water off their leaves quickly so the branches don't get weighed down and break. Many plants have drip tips and grooved leaves, and some leaves have oily coatings to shed water. To absorb as much sunlight as possible on the dark understory, leaves are very large. Some trees have leaf stalks that turn with the movement of the sun so they always absorb the maximum amount of light. Leaves in the upper canopy are dark green, small and leathery to reduce water loss in the strong sunlight. Some trees will grow large leaves at the lower canopy level and small leaves in the upper canopy. Other plants grow in the upper canopy on larger trees to get sunlight. These are the epiphytes such as orchids and bromeliads. Many trees have buttress and stilt roots for extra support in the shallow, wet soil of the rainforests.

Over 2,500 species of vines grow in the rainforest. Lianas start off as small shrubs that grow on the forest floor. To reach the sunlight in the upper canopy it sends out tendrils to grab sapling trees. The liana and the tree grow towards the canopy together. The vines grow from one tree to another and make up 40 per cent of the canopy leaves. The rattan vine has spikes on the underside of its leaves that point backwards to grab onto sapling trees. Other "strangler" vines will use trees as support and grow thicker and thicker as they reach the canopy, strangling its host tree. They look like trees whose centers have been hollowed out.

Dominant species do not exist in tropical rainforests. Lowland dipterocarp forest can consist of many different species of Dipterocarpaceae, but not all of the same species. Trees of the same species are very seldom found growing close together. This bio diversity and separation of the species prevents mass contamination and die-off from disease or insect infestation. Bio diversity also insures that there will be enough pollinators to take care of each species' needs. Animals depend on the staggered blooming and fruiting of rainforest plants to supply them with a year-round source of food.

4.4.3 Animal Life

Many species of animal life can be found in the rain forest. Common characteristics found among mammals and birds (and reptiles and amphibians, too) include adaptations to a life in the trees, such as the prehensile tails of New World monkeys. Other characteristics are bright colours and sharp patterns, loud vocalisations, and diets heavy on fruits.

Insects make up the largest single group of animals that live in tropical forests. They include brightly coloured butterflies, mosquitoes, camouflaged stick insects, and huge colonies of ants.

The Amazon River basin rainforest contains a wider variety of plant and animal life than any other biome in the world. The second largest population of plant and animal life can be found in scattered locations and islands of Southeast Asia. The lowest variety can be found in Africa. There may be 40 to 100 different species in 2.5 acres (1 hectare) of a tropical rain forest.

When early explorers first discovered the rainforests of Africa, Southeast Asia and South America, they were amazed by the dense growth, trees with giant buttresses, vines and epiphytes. The tropical vegetation grew so dense that it was difficult to cut one's way through it. It was thought at the time that the soil of a rainforest must be very fertile, filled with nutrients, enabling it to support the immense trees and other vegetation they found.

Today we know that the soil of the tropical rainforests is shallow, very poor in nutrients and almost without soluble minerals. Thousands of years of heavy rains have washed away the nutrients in the soil obtained from weathered rocks. The rainforest has a very short nutrient cycle. Nutrients generally stay in an ecosystem by being recycled and in a rainforest is mainly found in the living plants and the layers of decomposing leaf litter. Various species of decomposers like insects, bacteria, and fungi make quick work of turning dead plant and animal matter into nutrients. Plants take up these nutrients the moment they are released.

A study in the Amazon rainforest found that 99 per cent of nutrients are held in root mats. When a rainforest is burned or cut down the nutrients are removed from the ecosystem. The soil can only be used for a very short time before it becomes completely depleted of all nutrients.

Where are the Rainforests are found
The tropical rain forest can be found in three major geographical areas around the world.

- Central America in the Amazon River basin.
- Africa - Zaire basin, with a small area in West Africa; also eastern Madagascar.
- Indo-Malaysia - west coast of India, Assam, Southeast Asia, New Guinea and Queensland, Australia.

4.4 Climate Change in Nigeria

According to the United Nations Framework Convention on Climate Change (UNFCCC), "climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the atmosphere, and that is in addition to natural climatic variability observed in the comparatively recent time periods. The IPCC (Intergovernmental Panel on Climate Change) has evolved its own usage of the term "climate change" as any change in climate over time, whether due to natural variability or as a result of human activity.

Following recent observations, it has been acknowledged that for the first time, humanity has the ability to alter the global environment within the life time of an individual. (Henderson Sellers, 1991). What is dramatic in the present evolution is the unprecedented potential rapidity of the changes in the earth's atmospheric environment.

Adaptation Strategies for Climate Change
In order to minimise the negative impacts of climate change, a number of adaptation measures are open to Nigeria. Such adaptation measures would vary from one region to another and from one socio-economic sector to another.

Coastal Areas Adaptation Strategies

Among the adaptation strategies that could be applied are technical, engineering and structural, biophysical and ecological and non-structural.

(a) **Technical, Engineering and Structural Adaptation Strategies**

Technical, Engineering and Structural Responses include the use of protection devices or responses and emphasises the defence of vulnerable areas, population centres, economic activities and natural resources. They include dikes, levees, flood walls, sea walls, revetments, and bulkheads, groins, detached breakwaters, floodgates and tidal barriers. Other technical, engineering and structural responses include salt-water intrusion barriers, soft options, beach nourishment (beach fill), dune restoration and creation, wetland restoration and creation and afforestation.

Biophysical and Ecological Adaptation Strategies

Biophysical and ecological options emphasise, conservation of ecosystem and some form of protection using biological and ecological strategies. The options also include responses, which involve modification of land use, changes in planting date, changes in cultivars, application of irrigation, and changes in crop. Replacing lost resources, developing of alternative habitat areas, (e.g. creating wetlands and sand dunes), protecting threatened ecosystems, afforestation, stabilising sand dunes (e.g. by planting vegetation) and adaptation to salt water intrusion (e.g. by preventing salinity increases) are also significant biophysical and ecological measures which can be used along the coast of Nigeria.

Non-Structural Options

These options involve no response measures. They include measures, which involve retreat, accommodation, and limiting development. Three ways used to foster a retreat in the Nigeria include (i) limiting development in areas likely to be flooded (ii) allowing for development subject to the requirement that it will eventually be removed (presumed mobility) and (iii) doing nothing about the problems and eventually requiring the developed areas to be abandoned.

Are there Evidences of Climate Change in Nigeria?

The prevalence and significance of climate change in Nigeria has been confirmed by a number of climatic characteristics. These include:

(a) The impacts of climatic variations and climate change on environmental dynamics and environment change and their implications on the socio-economic and socio-cultural activities in the country, as witnessed in recent years, especially during the past three or four decades. In particular, with floods and droughts, desertification, soil erosion, and such other consequences of climatic variations and climate change, the issues of climatic variability and climate change and their environmental and socio-economic impacts have been topical at discussions particularly since about the late 1960s.

(b) The general increase in surface temperatures in the country, with most stations having temperature increases of about 0.2-0.3oC per decade as discussed by Ojo (1998); Ojo (2002) are also enunciated in the section on temperature trends. In addition, sea level changes along the coast of Nigeria have shown that the characteristics of coastal area changes in the country have probably been exacerbated by sea level rise. These have been manifested as coastal erosion, flooding, saltwater intrusion, mangrove degradation and related socio economic problems as noted by Awosika et al., 1992, 1994, Ojo et al., 2002 and NEST, 2003.

All these experiences and results of research activities indicate the need to document information on the characteristics of climate, climate variability and climate change. In particular, the main questions that should be of concern in Nigeria, particularly as related to the climatic environment should be those related to:

(a) The characteristics of present weather, climatic variability and significant characteristics of the present climatic conditions especially as related to rainfall and temperature.

(b) The characteristics of the changes expected in the climate of Nigeria over the next 100 years. In considering these two areas of concern, emphasis should be placed mostly on rainfall and temperature, even though issues related to other climatic parameters should be mentioned as at when necessary.

5.0 CONCLUSION

The extremity of most tropical climates, the discomfort of humidity, large desert temperature ranges, the cold of high mountains, copious rainfall – are well represented by the climate data (Galvin, 2009b). The land area of the tropics is about 40% of the world total, although the habitable area is much less than half this. Clearly, there is a large and growing need for increased knowledge of the effects of the weather in all tropical countries. In recent years, there has been increasing research into the weather of the tropics, both to aid our understanding and improve forecast models. As this research proceeds, our understanding grows and numerical models improve – in particular as model resolution is increased (Galvin, 2005; Glenn Greed, personal communication) – yielding benefit to all. The Met Office provides many new services to assist tropical countries in dealing with the weather, adapting to the climate and assisting national development.

6.0 ACTIVITY

1. Define climate change
2. State some evidences of climate change in Nigeria
3. Suggest ways of overcoming its effects

7.0 SUMMARY

In summary, you learnt that climatology, the scientific study of climate, is not only concerned with explaining why a location's or region's climate is like it is but also describes the nature and availability of the climate resource for a wide range of human activities.

8.0 ASSIGNMENT

1. Write a comprehensive note on plants and animals life in tropics
2. What are the impacts of agricultural practice and climate change on plants and animal in the tropic?
3. Briefly explain the coastal areas adaptation strategies

9.0 REFERENCES/ FURTHER READINGS

ABC Radio National. (2008). “Rice Bowl Tales.” http://www.abc.net.au/rn/streetstories/ features/rice/ [Accessed 13 June 2008].

Andreae, M. O., Talaue-McManus, L.& Matson, P.A. (2004). “Anthropogenic Motification of Land, Coastal and Atmospheric Systems as Threats to the Functioning Earth System.” In: *Earth System Analysis for Sustainability.*

Galvin, J.F.P. (2008a). “The Weather and Climate of the Tropics: Part 3 – Synoptic-Scale Weather Systems.” *Weather* 63: 16–21.

Galvin, J.F.P. (2008b). “The Weather and Climate of the Tropics: Part 4 – Forecasting Significant Cloud and Associated Weather.” *Weather* 63: 31–36.

Galvin, J. F. P. (2008c). “The Weather and Climate of the Tropics: Part 6 – Monsoons.” *Weather* 63: 129–137

Galvin, J.F.P. (2008d). “The Weather and Climate of the Tropics: Part 7 – Tropical Revolving Storms.” *Weather* 63: 327–333.

Galvin, J.F.P. (2009a). “The Weather and Climate of the Tropics: Part 8.” *Mesoscale.*

Galvin, J. F. P. (2009b.) “The Weather and Climate of the Tropics: Part 9- Climate, Flora and Fauna.” *Weather* 64: 100–107.

Galvin, J. F. P. & Membery, D.A. (2008). “The Weather and Climate of the Tropics: Part 5 – Dry Environments.” *Weather* 63: 100–106.