NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: ESM 212

COURSE TITLE: TROPICAL CLIMATOLOG

ESM 212 TROPICAL CLIMATOLOG

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MODULE 1

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Unit 1: Meaning of Climatology

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 generalization of all the recorded weather observations in a given area. Branch of atmospheric science concerned with describing climate and analyzing 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 AIMS AND OBJECTIVES

The aim and objective of this unit is to introduce and expose student to the general knowledge of climatology. It is believed that at the end of this unit, you will be able to have better understanding of;

1. Definition climatology
2. The relevance of study the climatology
3. The difference approaches to the study of climatology

3.0 MAIN CONTENT

3.1 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:

(1) climate is non-stationary

(2) climate varies over a number of temporal and spatial scales

(3) major modes of atmospheric circulation exist which may produce climate teleconnections

(4) 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

(5) the climate system responds non-linearly to both internal and external forcing and regulates itself through positive and negative feedback

(6) the climate of a location is influenced by the balance between large and local scale factors

(7) climate can be a determinant of, a resource for and a hazard to human activities

(8) human activities have the potential to influence climate

3.2 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. Climate 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.

4.0 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 industrialization, **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

5.0 SUMMARY

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

6.0 TUTOR- MARKED ASSIGNMENT

1. What is climatology?

2. With relevance example, explain the different approaches to the study of climatology

7.0 REFERENCES/FURTHER READINGS

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UNIT 2: NATURE AND SCOPE OF CLIMATOLOGY

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5.0 SUMMARY

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7.0 REFERENCES/FURTHER READINGS

UNIT 2: SCOPE OF CLIMATOLOGY

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, millimeters 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 AIMS AND OBJECTIVES

1. Define climate and state the various aspect of climatology

2. To examine the study of climatology as it relates to other sciences such as ecology.

3. To understand climatology and changes resulting from human influence

3.0 MAIN CONTENT

3.1 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 analyzed 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.

3.2 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

Microclimatologic al 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 analyze 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 interference with nature by diverting and damming rivers, clearing its lands, stripping its soils, and scarring its landscape has produced changes in climate. These changes have been on the micro and meso scale and possibly even on the macro scale.

3.3 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 characterizes 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 industrialization, 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

4.0 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.

5.0 SUMMARY

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. 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.

6.0 TUTOR- MARKED 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?

7.0 REFERENCES/FURTHER READINGS

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UNIT 3: INTRODUCTION TO TROPICAL CLIMATOLOGY

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1.0 INTRODUCTION

A tropical climate is a kind of climate typical in the tropics. Köppen's widely-recognized 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 AIMS AND OBJECTIVES

1. State the various indices of climate in Tropic

2. To explain the climatic model

3.0 MAIN CONTENT

3.1 INDICES OF CLIMATE IN TROPIC

Scientists use climate indices based on several climate patterns (known as modes of variability) in their attempt to characterize 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 generalized, overall description of the atmosphere or ocean which can be used to characterize 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 characterized 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 normalized sea level pressure (SLP) between Ponta Delgada, Azores and Stykkisholmur/Reykjavik, Iceland. The SLP anomalies at each station were normalized by division of each seasonal mean pressure by the long-term mean (1865-1984) standard deviation. Normalization 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% 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.

3.2 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.

4.0 CONCLUSION

5.0 SUMMARY

6.0 TUTOR- MARKED ASSIGNMENT

1. List and explain the indices of climate in tropical part of the world

2. What do you understand by climate modelling?

7.0 REFERENCES/FURTHER READINGS

UNIT 4: TROPICAL CYCLONES

UNIT 4: TROPICAL CYCLONES

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 organized 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 AIMS AND OBJECTIVES

1. To examine the difference between “hurricane”, “cyclone” and “typhoon
2. State the different between tropical cyclones and wind speed
3. Requirements for Tropical Cyclone Formation

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 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.

3.1 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

3.2 Different 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 1 to 5:

- Category 1 hurricane is referring to the hurricane with maximum sustained wind speeds of 119-153 km/h.
- Category 2 hurricane is referring to the hurricane with maximum sustained wind speeds of 154-177 km/h.
- Category 3 hurricane is referring to the hurricane with maximum sustained wind speeds of 178-209 km/h.
- Category 4 hurricane is referring to the hurricane with maximum sustained wind speeds of 210-249 km/h.
- Category 5 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 Tropical Predict 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 organizations 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 Specialized Meteorological Centers with the activity specialization in tropical cyclones, and Tropical Cyclone Warning Centres, all designated by WMO, are functioning within the Organization'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 5 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 sixteen named tropical cyclones formed in the Atlantic including eight hurricanes, five of which were major hurricanes at Category 3 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, sixteen named tropical cyclones were recorded in 2008, of which seven evolved into hurricanes and two of them into major hurricanes at Category 3 or higher. In the Western North Pacific, twenty two named tropical cyclones were recorded in 2008, ten of which were classified as typhoons compared to the long-term average of twenty seven and fourteen, 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.

3.3 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 preexisting 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% 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 favorable temperature that can then support convection. A wetbulb 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

4.0 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 fourteen 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.

5.0 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

6.0 TUTOR- MARKED ASSIGNMENT

1. What is Different between Tropical Cyclones and Wind Speed?

2. What are the major require for cyclones formation

7.0 REFERENCES/FURTHER READINGS

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UNIT 5: IMPACT OF TROPICAL CLIMATOLOGY

Unit 5: The Implication of Tropical Climate Characteristics and Behaviour on Plant and Animals

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 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 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 reorganization 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% 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% and 74% of that region. At the continental scale, about 70% 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% and 77% 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 AIMS AND OBJECTIVES

1. to examine the characteristics of tropical montane ecosystem

2. to understand the relationship between agricultural and climate change within the tropic

3. to examine the layer of tropical rainforest, as well as plants and animals life in the tropic environment.

4. to have an understanding of climatology and climate change in Nigeria

3.0 MAIN CONTENT

3.1 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% of Peruvian endemic vertebrates are localized 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 is 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.

3.2 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 CO2. 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 savannahs

The savannahs are 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, claystones (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 If 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%; 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% 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% 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 leukemia has a 99% 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 the 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.

3.3 The layer of Tropical Rainforest as well as Plant Life within the Tropic

3.3.1 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 % 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.

3.3.2 Plant Life

Besides these four layers, a shrub/sapling layer receives about 3 % 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% 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.

3.3.3 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 vocalizations, and diets heavy on fruits.

Insects make up the largest single group of animals that live in tropical forests. They include brightly colored 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% 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 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.

3.4 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 minimize 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 emphasizes the defence of vulnerable areas, population centers, 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 emphasize 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, stabilizing 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 and

(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.

4.0 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.

5.0 SUMMARY

6.0 TUTOR- MARKED 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

7.0 REFERENCES/FURTHER READINGS

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MODULE 2

UNIT 1: NATURE AND COMPONENT OF ATMOSPHERE

1.0 INTRODUCTION

2.0 AIMS AND OBJECTIVES

3.0 MAIN CONTENT

3.1 STRUCTURE OF THE ATMOSPHERE

3.2 COMPOSITION OF THE ATMOSPHERE

3. 3 HOW DOES SOLAR ENERGY INFLUENCE THE ATMOSPHERE?

3.4 IMPORTANCE OF THE ATMOSPHERE

4.0 CONCLUSION

5.0 SUMMARY

6.0 TUTOR- MARKED ASSIGNMENT

7.0 REFERENCES/FURTHER READINGS

UNIT 1: NATURE AND COMPONENT OF ATMOSPHERE

INTRODUCTION

The atmosphere is a deep blanket of gaseous envelope that surrounds the solid and liquid surface of the earth. It extends upward for hundreds of kilometres, and eventually meets the rarefied inter-planetary medium of the solar system. The gas which constitutes the atmosphere is called air. It is a mixture of several gases. The most abundant of the elements in the air are nitrogen, oxygen and argon.

The atmosphere is essential for life, and without it, life would not exist and there would be no clouds, winds and storms, indeed, there would be no weather. Besides being an essential for life and a medium for weather processes, the atmosphere acts as a great canopy that protects the earth from the full force of the sun by day. It also prevents loss of too much heat at night.

If there were no atmosphere, the temperatures of the earth would rise to over 93oC in the daytime, and drop to around -344oC at night.

The atmosphere is also refers to a layer of gases which surrounds the entire Earth. It consists mainly of Nitrogen, Oxygen, as well as a few other gaseous elements. The purpose of this "layer" around the Earth is to prevent excessive amounts of radiation from reaching the Earth, thereby allowing us, as animals/planets, to survive. A planet such as Mars has very little, if any, atmosphere and hence has little or no life on it (at least as we see it now). Several million years ago Mars may have supported life. Has your class ever seen pictures of the huge "ancient rivers" or Canyons on Mars? Many scientists these formations could have been made by water, rivers, etc many millions of years ago.

The entire mass of air and other gases surrounding the earth is called atmosphere. With increasing height above earth's surface, the atmosphere becomes rarer and rarer.

The earth's atmosphere is a covering of various gasses that surrounds the plant to a depth of 1000km, or about 600 miles. Without these gases to create an atmosphere, no life would exist and there would be no weather. We would just be another lifeless planet in existence. Scientist has divided the atmosphere into five separate layers – the exosphere, the thermosphere, the mesosphere, the stratosphere and the troposphere. The troposphere is the nearest layer to the surface of the earth and is the only part of the atmosphere where weather happens.

If you look at a photo of the earth taken from a satellite in space you can see the weather systems clearly moving around the atmosphere. The height of the troposphere varies between different areas of the earth. At the equator for example, it stretches to about 20KM, or 12 miles above the surface. At the poles, the layer reaches a height of about 10KM or about six miles.

AIMS AND OBJECTIVES

The specific objectives of this study are to;

1. Explain the Structure of the atmosphere
2. State the composition of the atmosphere
3. Explain how solar energy influence the atmosphere
4. State the importance of the atmosphere

3.0 MAIN CONTENT

3.1 STRUCTURE OF THE ATMOSPHERE

The atmosphere has a distinct vertical structure comprising four broad layers, each with its own characteristics. Each layer is warmed by different portions of the Sun's radiation, so the temperature of the atmosphere varies between layers. The atmosphere is divided vertically into four layers based on temperature: the troposphere, stratosphere, mesosphere, and thermosphere. Throughout the Cycles unit, we'll focus primarily on the layer in which we live the troposphere.

The lowest layer, the troposphere, is the layer in which we live. It gets its warmth from the ground, which is heated by the Sun. Temperatures in the troposphere decrease steadily with distance from the ground. The rate of cooling, known as the environmental lapse rate, is remarkably even at around 6°C (42.8F) per 1,000 metres (3,280 feet). The troposphere contains 75 per cent of the atmosphere's gas. It also holds huge amounts of dust and water vapour, and is often dense with clouds and mist. Air pressure is greatest in the troposphere, because gravity pulls the atmosphere towards the Earth, squeezing most of its weight into this lowest layer.

The boundary that separates the troposphere from the stratosphere is called the tropopause. The height of this boundary varies between about 15 kilometres (9 miles) at the Equator and 8 kilometres (5 miles) at the North and South Poles. In the stratosphere, temperatures begin to rise. This is due to the presence of the ozone layer, which absorbs the Sun's ultraviolet (UV) light and, at the same time, protects the Earth from the dangerous effects of UV rays. The ozone actually soaks up so much UV light that the stratosphere gets quite warm towards the top. Since the air gets warmer beyond the tropopause, moisture evaporated from the sea can never rise into the stratosphere, because it is carried by colder, denser air in the troposphere. Because the air in the stratosphere contains little moisture, and is heated from above as ozone absorbs UV light, the stratosphere is still and calm, which is why jet airliners climb up to this level for long distance flights. The only clouds are faint noctilucent (nightshining) clouds and mother-of-pearl clouds. The stratosphere contains 19 per cent of the atmosphere's gas.

Higher still, the mesosphere is heated as oxygen and nitrogen are warmed by extreme ultraviolet light, but temperatures begin to drop with height as the gases get thinner and thinner. The air in the mesosphere is very thin, but thick enough to slow down meteorites, which burn up as they hurtle into it, leaving fiery trails in the night sky.

The mesopause is the boundary that separates the mesosphere from the fourth layer of the atmosphere, the thermosphere. Gases in the thermosphere are even thinner than those in the mesosphere, but because they are exposed to the full glare of the Sun, temperatures soar to 2,000°C (3,632C). However, because there is so little gas, there is very little real heat.

The upper part of the mesosphere and the lower part of the thermosphere are together referred to as the ionosphere, since this layer contains many electrically charged particles called ions. Ions are atoms or molecules that have lost or gained one or more negatively charged electron. Ions in the atmosphere are formed when gas molecules, such as nitrogen and oxygen, are energized by ultraviolet rays from the Sun to such an extent that they lose one or more of their electrons. Because ions are electrically charged, they are capable of reflecting radio signals. During the day, the Sun's ultraviolet rays turn more and more atoms into ions, and so the ionosphere is most highly charged just after sunset. By dawn, the ionosphere is much weaker because the electrons slowly recombine with ions during the night.

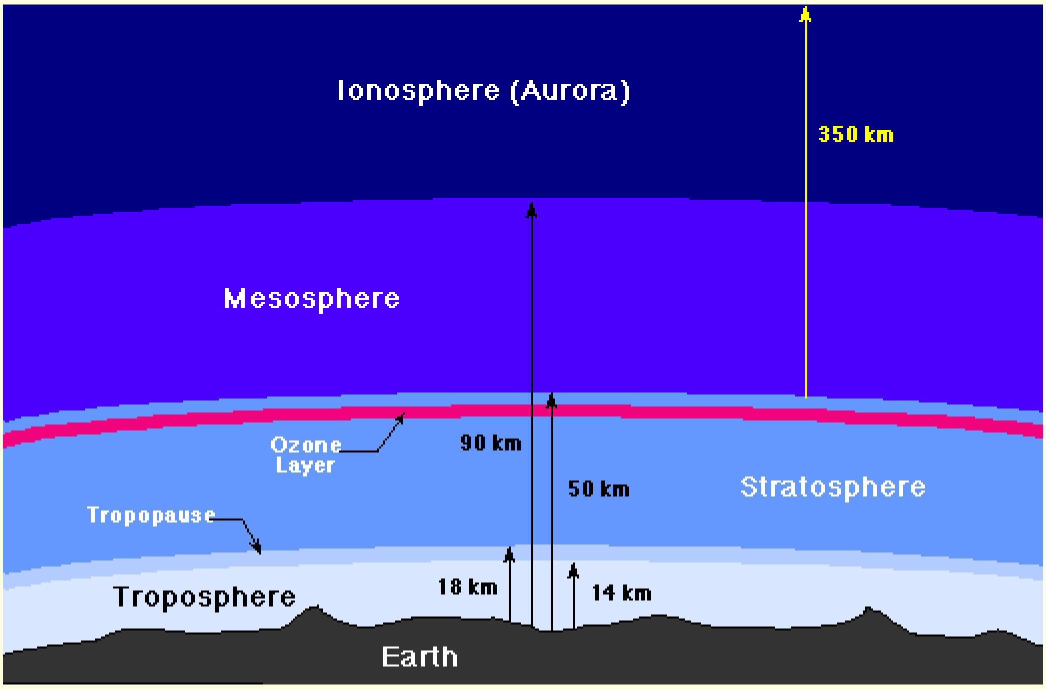
The electrical nature of the Earth's atmosphere is responsible for the coloured lights known as aurorae. Aurorae are permanent features of the Earth's upper atmosphere, although they vary in vividness. There are two aurorae—the aurora borealis at the North Pole, and the aurora australis at the South Pole. Aurorae are gigantic, stretching far up through the atmosphere. The lowest fringes hang about 64 kilometres (40 miles) above the ground, while the upper rays extend more than 965 kilometres (600 miles) into space—three times as high as the space shuttle's orbit. The coloured lights we see in the sky are the atoms and molecules of the atmosphere glowing as they are bombarded by charged particles streaming from the Sun. These atoms and molecules are then deflected towards Earth's magnetic poles.

The outer layer of the atmosphere, the exosphere, lies more than 483 kilometres (300 miles) above the ground. At this height, gases become so rarefied that they drift off into space. Even further out are indistinct regions called the heliosphere and protonosphere. In the heliosphere, the atmosphere has thinned out to a near vacuum, but slight frictional drag on spacecraft indicates that gas is present - mostly helium, which is why it is called the heliosphere. The protonosphere, which stretches out more than 60,000 kilometres (37,200 miles) above the

Earth, is even more rarefied, and probably consists of a sparse scattering of charged hydrogen particles, known as protons, hence the name.

Layers of the Atmosphere

The atmosphere of the Earth may be divided into several distinct layers, as the following figure indicates.



Layers of the Earth's atmosphere

3.2 COMPOSITION OF THE ATMOSPHERE

The Earth's atmosphere consists mainly of the harmless inert gas nitrogen (78 per cent), and the vital oxygen we need to breathe (21 per cent). It also contains tiny traces of argon, ozone, carbon dioxide, neon, krypton, xenon, helium, methane, and hydrogen. Water vapour and solid particles, such as dust, pollen, and salt spray from the oceans are also present in the lowest level of the atmosphere, the troposphere.

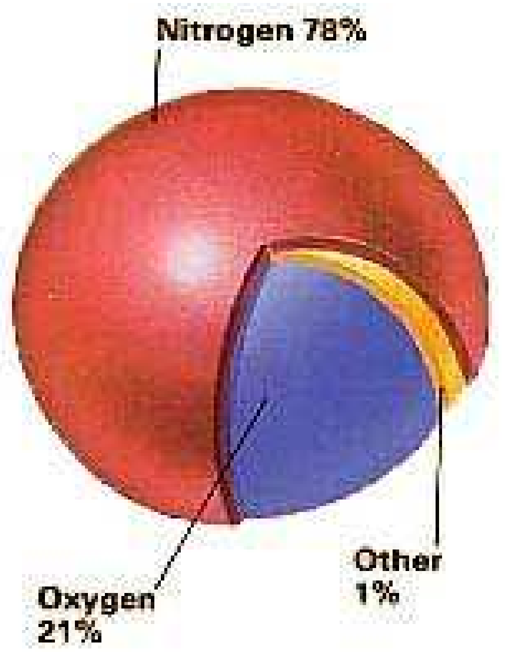
No other atmosphere in the solar system is remotely like that of the Earth. The atmosphere of Venus, for instance, is 96 per cent carbon dioxide, while that of Mars is 95 per cent carbon dioxide. Earth's atmosphere contains practically no carbon dioxide, because most of this gas was absorbed by the oceans early in the planet's history, where it combined with calcium to form the mineral calcium carbonate, or limestone. Mars and Venus have no oceans, so their carbon dioxide is still present in their atmospheres.

The air is almost always moist, even when it is not raining, because it contains water vapour. This water vapour is normally invisible, but if the air is cooled enough, it condenses into drops of liquid water or solid ice and forms clouds, fog, mist, dew, rain, or snow. Water is continually being recycled between the atmosphere and the oceans in a process known as the water cycle.

The air is filled with a wide range of minute airborn particles, known as aerosols. Most of these aerosols are natural, such as volcanic ash, ash from forest fires, pollen, and fungal spores. The biggest sources of aerosols are salt from the sea and dust from soil. More than a billion tons of sea salt joins the air from sea spray every year, and almost a quarter of a billion tons of soil dust is whipped up by the wind. Without these aerosols, there would be nothing for water in the atmosphere to condense on, and there would be no mists, clouds, or rain.

The oxygen so characteristic of our atmosphere was almost all produced by plants (cyanobacteria or, more colloquially, blue-green algae). Thus, the present composition of the atmosphere is 79% nitrogen, 20% oxygen, and 1% other gases.

Composition of the Atmosphere



3.3 HOW DOES SOLAR ENERGY INFLUENCE THE ATMOSPHERE?

The heat source for our planet is the sun. Energy from the sun is transferred through space and through the earth's atmosphere to the earth's surface. Since this energy warms the earth's surface and atmosphere, some of it is or becomes heat energy. There are three ways heat is transferred, into the atmosphere: radiation, conduction and convection

If you have stood in front of a fireplace or near a campfire, you have felt the heat transfer known as radiation. The side of your nearest the fire warms, while your other side remains unaffected by the heat. Although you are surrounded by air, the air has nothing to do with this transfer of heat. Heat lamps, that keep food warm, work in the same way. Radiation is the transfer of heat energy by electromagnetic radiation.

Most of the electromagnetic radiation that comes to the earth from the sun is in the form of visible light. Light is made of waves of different frequencies. The frequency is the number of instances that a repeated event occurs, over a set time. In electromagnetic radiation, the frequency is the number of times an electromagnetic wave moves past a point each second. Our brains interpret these different frequencies into colors, including red, orange, yellow, green, blue, indigo, and violet. When the eye views all these different colors at the same time, it is interpreted as white. Waves from the sun which we cannot see are infrared, which have lower frequencies than red, and ultraviolet, which have higher frequencies than violet light.

Most of the solar radiation is absorbed by the atmosphere and much of what reaches the earth's surface is radiated back into the atmosphere to become heat energy. Dark colored objects such as asphalt absorb more of the radiant energy and warm faster than light colored objects. Dark objects also radiate their energy faster than lighter colored objects.

Learning Lesson: Melts in your bag, not in your hand

Conduction

Conduction is the transfer of heat energy from one substance to another or within a substance. Have you ever left a metal spoon in a pot of soup being heated on a stove? After a short time the handle of the spoon will become hot. This is due to transfer of heat energy from molecule to molecule or from atom to atom. Also, when objects are welded together, the metal becomes hot (the orange-red glow) by the transfer of heat from an arc. This is called conduction and is a very effective method of heat transfer in metals. However, air conducts heat poorly.

Convection

Convection is the transfer of heat energy in a fluid. This type of heating is most commonly seen in the kitchen when you see liquid boiling. Air in the atmosphere acts as a fluid. The sun's radiation strikes the ground, thus warming the rocks. As the rock's temperature rises due to conduction, heat energy is released into the atmosphere, forming a bubble of air which is warmer than the surrounding air. This bubble of air rises into the atmosphere. As it rises, the bubble cools with the heat contained in the bubble moving into the atmosphere.

As the hot air mass rises, the air is replaced by the surrounding cooler, more dense air, what we feel as wind. These movements of air masses can be small in a certain region, such as local cumulus clouds, or large cycles in the troposphere, covering large sections of the earth. Convection currents are responsible for many weather patterns in the troposphere.

3.4 IMPORTANCE OF THE ATMOSPHERE

- The atmosphere is earth's protective armour. The atmosphere separates the earth from the space and thus, hot asteroids do not hit the ground all the time. Another very very important significance of the atmosphere is that it regulates temperature on earth. Although now the increasing greenhouse effect has become such a big crisis as it is causing global warming, the earth does need the greenhouse effect to some extent. This is because the atmosphere traps some of the heat that comes from sun during the day so that the nights are tolerable too. Do you know that Mercury, the planet closest to the sun and therefore the hottest has a night time temperature of -173oC while during daytime, it is almost 350oC? That is because it has no atmosphere. Imagine how impossible it would have been to inhabit earth if its temperatures fluctuated between such extremes every day!
- The atmosphere also offers protection against the harmful rays of the sun. That is the issue of concern about the ozone holes. As the layer of atmosphere disintegrates from an area, it is in direct contact with sunlight without the atmosphere between it to remove the harmful radiation. This increases the risk of sunburns and skin cancer to a great degree.
- The atmosphere is the source of every living thing in the world, it plays a very important role in serving the world's need and it supports the earth and it's consisting elements.....it provides ventilation to the earth because the atmosphere filters the ultraviolet rays coming from the sun which causes the living things in the world to

die....it also gives the air we breathe,the food we eat and the water we drink and above all it supports life

- It protects us from ultra violet rays of the sun. It also protects us from the meteors. Without the atmosphere, the earth's surface will look like the surface of the moon (full of craters). Summary of other Importance of Atmosphere
- Atmosphere serve as an umbrella which protects us from harmful UV rays that results to melanoma, a skin disease. Anonymous
- The layers of atmosphere is very important for living beings because it reflects some of the heat of the sun and some is also absorbed by it
- The Atmosphere is very important part of the biosphere.
- It controls the heat
- Protects us from the Ultra contains ray of the sun
- Separates the earth from the space
- Helps us to breath as atmosphere contains air
- Regulates the temperature on the Earth
- Traps some of the heat that comes from the sun during the day, so that the nights are tolerable too.

4.0 CONCLUSION

The atmosphere is the envelope of gases that surrounds the earth. Earth's atmosphere makes conditions on earth suitable for living things. The atmosphere contains oxygen and other gases that living things need to survive. It protects living things from radiation of sun. Atmosphere also prevents earth's surface from being hit by meteoroids or rocks from outer space. So imagine the world without the atmosphere, it will be better to live on any other planet rather to live on the earth! Living things would probably die from living on earth.

Scientists divide earth's atmosphere into four main layers classified according to changes in the temperature

5.0 SUMMARY

The atmosphere consists of the following layers.

1- Troposphere: it extends to about 7 miles.

2- Stratosphere: it extends to 20 miles.

3- Mesosphere: it extends to about 80 miles. Here ozone gas is generated by the action of the sun.4- Ionosphere: it is the region of upper atmosphere with layers of electric particles formed by loss or gain of electrons.

5- Exosphere: t extends beyond 400 miles, and is the last distinct feature of atmosphere.

The Troposphere

The troposphere is where all weather takes place; it is the region of rising and falling packets of air. The air pressure at the top of the troposphere is only 10% of that at sea level (0.1 atmospheres). There is a thin buffer zone between the troposphere and the next layer called the tropopause.

The Stratosphere and Ozone Layer

Above the troposphere is the stratosphere, where air flow is mostly horizontal. The thin ozone layer in the upper stratosphere has a high concentration of ozone, a particularly reactive form of oxygen. This layer is primarily responsible for absorbing the ultraviolet radiation from the Sun. The formation of this layer is a delicate matter, since only when oxygen is produced in the atmosphere can an ozone layer form and prevent an intense flux of ultraviolet radiation from reaching the surface, where it is quite hazardous to the evolution of life. There is considerable recent concern that manmade flourocarbon compounds may be depleting the ozone layer, with dire future consequences for life on the Earth.

The Mesosphere and Ionosphere

Above the stratosphere is the mesosphere and above that is the ionosphere (or thermosphere), where many atoms are ionized (have gained or lost electrons so they have a net electrical charge). The ionosphere is very thin, but it is where aurora take place, and is also responsible for absorbing the most energetic photons from the Sun, and for reflecting radio waves, thereby making long-distance radio communication possible.

The structure of the ionosphere is strongly influenced by the charged particle wind from the Sun (solar wind), which is in turn governed by the level of Solar activity. One measure of the structure of the ionosphere is the free electron density, which is an indicator of the degree of ionization. Here are electron density contour maps of the ionosphere for months in 1957 to the present. Compare these simulations of the variation by month of the ionosphere for the year 1990 (a period of high solar activity with many sunspots) and 1996 (a period of low solar activity with few sunspots)

6.0 TUTOR- MARKED ASSIGNMENT

1. with the aid of diagram where necessary, write short note on the following;

a. Layers of the atmosphere

b. Composition of the atmosphere

c. Conduction

d. Convention

2. What is the importance of the atmosphere?

7.0 REFERENCES/FURTHER READINGS

UNIT 2: WEATHER AND CLIMATE; AND THEIR VARIOUS ELEMENTS

UNIT 2: WEATHER AND CLIMATE; AND THEIR VARIOUS ELEMENTS

INTRODUCTION

Weather is the current atmospheric conditions, including temperature, rainfall, wind, and humidity at a given place. If you stand outside, you can see that it's raining or windy, or sunny or cloudy. You can tell how hot it is by taking a temperature reading. Weather is what's happening right now or is likely to happen tomorrow or in the very near future.

Climate, on the other hand, is the general weather conditions over a long period of time. For example, on any given day in January, we expect it to be rainy in Portland, Oregon and sunny and mild in Phoenix, Arizona. And in Buffalo, New York, we're not surprised to see January newscasts about sub-zero temperatures and huge snow drifts.

Some meteorologists say that "climate is what you expect and weather is what you get." According to one middle school student, "climate tells you what clothes to buy, but weather tells you what clothes to wear."

Climate is sometimes referred to as "average" weather for a given area. The National Weather Service uses data such as temperature highs and lows and precipitation rates for the past thirty years to compile an area's "average" weather.

The earth's climate is generally defined as the average weather over a long period of time. A place or region's climate is determined by both natural and anthropogenic (human-made) factors. The natural elements include the atmosphere, geosphere, hydrosphere, and biosphere, while the human factors can include land and resource uses. Changes in any of these factors can cause local, regional, or even global changes in the climate.

The weather is made up of different elements, which are measured either by special instruments or are observed by a meteorologist. These measurements are then recorded and used in the making of climate graphs and weather forecasts.

Although an area's climate is always changing, the changes do not usually occur on a time scale that's immediately obvious to us. While we know how the weather changes from day to day, subtle climate changes are not as readily detectable. Weather patterns and climate types take similar elements into account, the most important of which are:

3.0 MAIN CONTENT

3.1 ELEMENTS OF WEATHER AND CLIMATE AND IMPORTANCE OF MEASURING THEM

When studying weather or climate, the elements of each seem to be interchangeable. Though the difference between terms like "precipitation" and "average precipitation" may seem negligible, their differences are important factors in what separates climate from weather. Weather is the combination of daily factors that result in rain or sunshine, while climate is the long-term total of those daily factors over periods of decades. To truly distinguish the differences in how these elements concern weather and climate, you first have to understand what the elements are.

Precipitation

Precipitation is simply any water form that falls to the Earth from overhead cloud formations. As an element of weather, precipitation determines whether outdoor activities are suitable or if the water levels of creeks and rivers will rise. As an element of climate, precipitation is a long-term, predictable factor of a region's makeup. For instance, a desert may experience a storm (weather) though it remains a typically dry area (climate).

Humidity

Humidity is the measurable amount of moisture in the air of the lower atmosphere. The humidity element of weather makes the day feels hotter and can be used to predict coming storms. However, the humidity element of climate is the prolonged moisture level of an area that can affect entire ecosystems. For instance, tropical jungles can sustain different forms of life than dry, arid climates because of the overall humidity from rainfall and other factors. This is an aspect of climate rather than weather, in that the typically high humidity levels of these regions is predictable over periods of decades.

Temperature

Temperature is simply the measurement of how hot or cold a region is on a day-to-day basis. The weather aspect of temperature can change throughout the day, however, it generally falls within a certain range of predictable highs and lows (as climate). Cold snaps and heat waves are weather that affects the temperatures of particular climates. For example, a heat wave in northern Siberia is an aspect of weather affecting a climate that is typically considered to be cold. The weather in this case (the heat wave) is simply happening inside of a climate (the normal cold range of Siberian temperatures).

Atmospheric Pressure

Atmospheric pressure is basically the "weight" of the air. It is used primarily by meteorologists to monitor developing storms that can seem to come out of nowhere. While typically considered an aspect of weather, certain regions of the world exist in zones where changing atmospheric pressures form part of the predictable climate. Because of their proximity to large bodies of water (a major factor in atmospheric pressure changes), places like coastal regions and islands experience severe storms on a regular basis.

Meteorological Phenomena

Tornadoes, hail storms and fog are all examples of meteorological phenomena that are hard to predict. As an element of weather, these occurrences can seem random and are a result of a set of unique circumstances. However, some regions of the world can factor meteorological phenomena into their climate. For instance, the American Midwest's "Tornado Alley" (tornadoes), the Great Lakes region (lake effect snow), and places like London (fog) and Bangladesh (drastic and rapid climate changes) have these occurrences so often that they are an almost predictable part of the region's climate.

Importance of measuring and recording Weather and Climatic Element

- Helps in describing the climate of a place; weather it is equatorial climate or tropical climate among other climatic types.

- Helps farmers to plan when to plant their crops and when to harvest them.
- Important in the aviation industry, in that it helps pilots to know when to take off and when to land.
- Helps sailors at sea to timetable their journeys.
- Helps farmers to plan when to plant and when to harvest their crops.
- Helps people to plan what to put on or dress for the day for example they will know whether or not to put on a sweater or jacket and weather or no to carry an umbrella.
- Helps the government to prepare for disasters like floods, drought, and very strong winds among others.

3.2 FACTORS INFLUENCING WEATHER AND CLIMATE

Relief: - Highlands or mountains lead to the formation of relief rainfall on the windward side and dry conditions on the lee ward side.

Altitude: - Highlands experience lower temperatures than low lands. The higher one goes the cooler it becomes.

Latitude: - The tropical areas i.e. areas of low latitude experience higher temperatures and rainfall. Areas of higher latitude e.g. the temperate and Polar Regions experience lower temperatures.

Water Bodies: - Nearness to a large water body influences the climate of the area. Water bodies are sources of atmospheric moisture through evaporation and areas near them experience higher rainfall.

Natural Vegetation:- Forested and wetland areas contribute to the atmospheric vapour though transpiration leading to the formation of rainfall. Areas without vegetation or limited vegetation experience less rainfall.

Prevailing Winds: - Moist prevailing winds bring in rainfall unlike dry winds. Winds also help in the distribution of temperatures i.e. warm winds bring in warm conditions while cold winds bring in cool conditions.

Ocean Currents: - These are moving ocean waters. They may be cold or warm i.e. cold and warm ocean currents. Warm ocean currents lead to the formation of high rainfall on the adjacent coastal areas. Cold ocean currents lead to low rainfall and formation of marine deserts in the adjacent coastal areas e.g. the Namib Desert.

Man's Activities: - Activities like deforestation, swamp reclamation; industrialisation, etc. lead to semi arid and arid conditions through the process of desertification. In addition environmentally unfriendly human activities lead to global warming.

Also, weather and climate are different, they are very much interrelated. A change in one weather element often produces changes in the others element and in the region's climate. For example, if the average temperature over a region increases significantly, it can affect the amount of cloudiness as well as the type and amount of precipitation that occur. If these changes occur over long periods of time, the average climate values for these elements will also be affected.

3.3 EQUIPMENT OF STANDARD METROLOGICAL STATION

A Metrological station is a place where weather instruments are kept and used for measuring and recording the elements of weather. A similar facility which is bigger and more advanced is known referred to as a Meteorological station. A weather station is normally established in an open area free from any form of obstruction, to ensure accurate and reliable data collection. A major structure in a weather station is a Stevenson screen. The other instruments in a weather station include a rain gauge, wind vane, anemometer, evaporimeter, windsock, sunshine recorder etc. They are fenced off so that animals cannot get in and damage the equipment.

Rain gauges

Rain gauges are used to determine the precipitation at a certain point which is representative for a certain area. It is essential that the day-figures have an accuracy of 0.2 mm.

Important characteristics of rain gauges are:

An adequate measuring area.

A collecting bucket with a sharp edge, a smooth inside and such a shape that splashing out of precipitation is avoided.

Rain gauge, type Rain-O-Matic

Combined electronic rain- and temperature meter with 10 m cable and digital read-out unit with memory and an accuracy of 1.0 mm which is especially used at home. The digital LCD is placed indoors. The meter has a memory function for precipitation, and highest and lowest registered temperatures during the measuring period.

Rain Gauge with Large (External) Collecting Jar

Rain gauge consisting of a collecting funnel with collecting jar and measuring vessel placed in an open area. The rain gauge is connected to an external collecting jar (contents 20 liter) by a syphon tube. The rain gauge is specially designed for intensive precipitation (tropics). The collecting area measures 200 cm2.

Standard Rain Gauge

Rain gauge (in accordance with DIN 58666C) consisting of a collecting funnel with a 1 liter collecting jar and measuring vessel of 0-10 mm with a 0.1 mm division with collecting area 200 cm2.

Mechanical Precipitation Recorder

Mechanical self-recording rain gauge with sheet metal funnels with limit ring and siphon with automatic drain after 10 mm height of precipitation. The precipitation recorder has a

collecting area of 200 cm2. Registration over a 7 day period. Scale division 0.1 mm. Complete with recording sheets and accessories. The mechanical self-recording rain gauge is suitable for measuring the precipitation intensity (determination of precipitation peaks).

Thermometer

Temperature and humidity

Temperature and humidity are two important meteorological parameters. They have a great influence on numerous processes in nature, such as the evaporation rate of water, germination of seeds and the spread of (plant) diseases. Specially the daily temperature cycle is important here. Measuring the air temperature usually takes place at a standard height. The thermometer must be protected against direct sunlight. This can be done by using a temperature screen.

Digital thermometer

The K-thermocouple thermometer has a standard probe with a length of 12 cm packed in a case. There are also three specially designed compost temperature probes available with a length of 50, 100 and 150 cm.

The thermometer is waterproof (IP67), has a large display and membrane key-pad.

The thermometer can be used to measure temperature in degrees Celsius and Fahrenheit and has a measuring range of -50 tot +150°C. Accuracy is 0.5°C. The display can be read to 0.1°C. The thermometer has options to display the measurement and to reset the maximum- and minimum temperature and hold facility. Power supply four 1.5 V AAA batteries. The stainless steel compost temperature probes have a handle and a rod with a diameter of 10 mm. The point of the rod contains a temperature sensor, thermical insulated from the rod by an insulation collar. Influence of heat exchange between rod and material to be measured is minimal. The instrument can also be used to measure temperature in ensilage, hay, peat or other soft materials or liquids.

Assmann psychrometer

Model in chromed design. The model is equipped with two thermometers and a psychrometer with a measuring range of -10 to +60°C. The psychrometer is fitted with a mechanical ventilator. Accuracy of both thermometers +/- 0.2°C. Division 0.2°C. The psychrometer is supplied inclusive accessories and psychrometer

Portable relative humidity and temperature meter

The portable digital relative humidity and temperature meter displays directly relative humidity or temperature. The meter is equipped with a separate probe with 1.5 m cable and has a high contrast LCD display.

- Measuring range relative humidity 0 to 100%
- Resolution 0.1% Accuracy +/- 2%
- Measuring range temperature -20 to +60°C
- Resolution 0.1°C Accuracy +/- 0.2°C

Thermo-hygrograph

The hygro-thermograph independently measures and records the relative humidity and the

temperature of the surroundings. This self-recording thermohygrograph has a bimetal as temperature element and a hair-wire measuring element for humidity. The instrument is supplied with a quartz clockwork (switchable 1, 7 or 31 days). Measuring range 0-100% relative humidity. Accuracy +/- 2.5% of the measuring range. Temperature range -10 to +50°C. Accuracy +/- 1%. Inclusive registration charts with recording period of 7 days and

Piche Evaporation Meter

Simple and cheap instrument for measuring the evaporation. A humid filter paper disk is used here under a glass measuring tube closed at one end and filled with water. The paper surface is constantly wetted. Division 0 - 30 mm. Inclusive evaporation discs and disc holder. The instrument only indicates the evaporation rate. Suitable for educational purposes.

Stevenson Screen

This is a specially designed box – like structure on stands in which some instruments for recording weather is kept. A Stevenson screen has a number of characteristics or features.

- Important Features of a Stevenson Screen:
- It is made up of wood: i.e. to prevent absorption and conduction of heat.
- Panted white or silver grey;- In order to reflect sunshine.
- Stands are 1 metre high:- to avoid the influence of ground conditions.
- The sides and floor are made of louvers or slats to allow free circulation of air and to keep off direct sun rays.
- It has an insulated roof to create a bad conductor of heat. This is done by creating an air space between the layers of the roof.

- The roof is slanting to avoid the accumulation and stagnation of rain water.
- It stands on grass covered ground.
- It is fixed or placed far from buildings or obstacles to avoid any interference.

Campbell-Stokes Sunshine Recorders

Principles and Structure

A Campbell-Stokes sunshine recorder concentrates sunlight through a glass sphere onto a recording card placed at its focal point. The length of the burn trace left on the card represents the sunshine duration.

The focus shifts as the sun moves, and a burn trace is left on the recording card at the focal point. A burn trace at a particular point indicates the presence of sunshine at that time, and the recording card is scaled with hour marks so that the exact time of sunshine occurrence can be ascertained. Measuring the overall length of burn traces reveals the sunshine duration for that day. For exact measurement, the sunshine recorder must be accurately adjusted for planar levelling, meridional direction and latitude. Campbell-Stokes and Jordan sunshine recorders mark the occurrence of sunshine on recording paper at a position corresponding to the azimuth of the sun at the site, and the time of sunshine occurrence is expressed in local apparent time.

Reading of Recording Paper

To obtain uniform results for observation of sunshine duration with a Campbell-Stokes sunshine recorder, the following points should be noted when reading records:

(a) If the burn trace is distinct and rounded at the ends, subtract half of the curvature radius of the trace’s ends from the trace length at both ends. Usually, this is equivalent to subtracting 0.1 hours from the length of each burn trace.

(b) If the burn trace has a circular form, take the radius as its length. If there are multiple circular burns, count two or three as a sunshine duration of 0.1 hours, and four, five or six as 0.2 hours. Count sunshine duration this way in increments of 0.1 hours.

(c) If the burn trace is narrow, or if the recording card is only slightly discoloured, measure its entire length.

(d) If a distinct burn trace diminishes in width by a third or more, subtract 0.1 hours from the entire length for each place of diminishing width. However, the subtraction should not exceed half the total length of the burn trace.

Jordan Sunshine Recorders

A Jordan sunshine recorder lets in sunlight through a small hole in a cylinder or a semi-cylinder onto photosensitized paper set inside the cylinder on which traces are recorded. One common type has two hollow semicylinders arranged back to back with their flat surfaces facing east and west

(a). Each flat surface has a small hole in it. The Jordan sunshine recorder used by JMA is the same in principle, but consists of a hollow cylinder with two holes.

(b). The instrument has its cylinders inclined to the relevant latitude and their axes set in the meridional direction. Photosensitized paper with a time scale printed on it is set in the cylinders in close contact with the inner surface. When direct solar radiation enters through the hole, the paper records the movement of the sun as a line. Sunshine duration is ascertained by measuring the length of time the paper was exposed to sunlight

Radiometers (Solar Radiation Measuring Instruments)

A radiometer absorbs solar radiation at its sensor, transforms it into heat and measures the resulting amount of heat to ascertain the level of solar radiation. Methods of measuring heat include taking out heat flux as a temperature change (using a water flow pyrheliometer, a silver-disk pyrheliometer or a bimetallic pyranograph) or as a thermoelectromotive force (using a thermoelectric pyrheliometer or a thermoelectric pyranometer). In current operation, types using a thermopile are generally used.

The radiometers used for ordinary observation are pyrheliometers and pyranometers that measure direct solar radiation and global solar radiation, respectively, and these instruments are described in this section.

For details of other radiometers such as measuring instruments for diffuse sky radiation and net radiation, refer to ”Guide to Meteorological Instruments and Observation Methods” and “Compendium of Lecture Notes on Meteorological Instruments for Training Class III and Class IV Meteorological Personnel” published by WMO.

Evaporation pan

The class-A evaporation pan is used to determine the evaporation rate of open water. The pan has a 1206 mm diameter and an inside height of 254 mm, an evaporation area of 1.15 m and is made of high grade stainless steel. The evaporation pan is supplied complete with highly qualified evaporation micrometer and stilling well (wave dampening cylinder), water level and wooden support for evaporation pan. Measuring range of the evaporation micrometer

100 mm with accuracy 0.02 mm. For a more exact use of the evaporation pan it is recommended to use an additional wind path meter.

For automatic measurement of the evaporation use can be made of a level sensor. The level sensor consists of a sensitive pressure transducer built in stainless steel housing. The sensor has a pressure range of 0-20 mbar, accuracy 0,25%. With output signal 0-20 mA, power supply voltage 8-28 V. The sensor is supplied with 5 m cable. The sensor is read-out with a datalogger. To configure and read-out the datalogger and to process the measuring data, use is made of the evaporation pan software.

Wind or Weather vanes

Weather vanes are one of the oldest of all weather instruments, working by swinging around in the wind to show which direction it is blowing from. Traditionally, weather vanes had a religious importance and appeared in the form of weathercocks on church roofs as early as the 9th Century AD. The head of the cockerel would point into the wind, indicating the direction the wind was blowing from. Weather vanes now appear in a wide variety of forms and it is even possible to make your own. Keep an eye out for weather vanes and see how many different types you see

Wind Stocks

Another device used to measure the wind is a wind sock. This instrument is found mainly at airports, seaports and other open areas such as mountain roads where a very visual indication of the wind is needed. Wind socks actually show both the direction and speed of the wind. The direction is shown when the wind blows into the open end and the sock points the way the wind is blowing. An indication of wind strength is given by the shape and movement of the wind sock. If it is flapping about gently the wind is only light, whereas if it sticks out in a straight line the wind is much stronger. This information is very useful to people on both ships and planes, and sometimes to car drivers too. If you want to discover more about wind socks, why not make one for yourself

Anemometer

The cup anemometer is at present the standard instrument used for mean wind speed measurement in wind energy. It is being applied in high numbers around the world for wind energy assessments. It is also applied exclusively for accredited power performance measurements for certification and verification purposes, and for purposes of optimisation in research and development. The little cups on this device catch the wind and spin round at different speeds according to the strength of the wind. A recording device is used to count how many times they spin round in a given time. If you have ever seen an anemometer, you will have noticed that the cups spin round very fast in a strong breeze.

3.4 MEASUREMENT OF WIND SPEED AND DIRECTION

Wind speed is the average velocity at which the air travels over a one-minute period and is measured in nautical miles per hour (NM/H or knots). The display is in miles per hour (mph), with the knots in parentheses.

Wind speed has always meant the movement of air in an outside environment, but the speed of air movement inside is important in many areas, including weather forecasting, aircraft and maritime operations, building and civil engineering. High wind speeds can cause unpleasant side effects, and strong winds often have special names, including gales, hurricanes, and typhoons

Wind speed is typically judged as the velocity of wind. Most measurements of air movement are taken of outside air, and there are several factors that can affect it. Average wind speed is often determined by an anemometer and is usually categorized in a standardized measurement scale, called the Beaufort Scale.

Factors Affecting Wind Speed

Wind speed is affected by a number of factors and situations, operating on varying scales (from micro to macro scales). These include the pressure gradient, Rossby waves and jet streams, and local weather conditions. There are also links to be found between wind speed and wind direction, notably with the pressure gradient and surfaces over which the air is found.

Pressure gradient is a term to describe the difference in air pressure between two points in the atmosphere or on the surface of the Earth. It is vital to wind speed, because the greater the difference in pressure, the faster the wind flows (from the high to low pressure) to balance out the variation. The pressure gradient, when combined with the Coriolis Effect and friction, also influences wind direction.

Rossby waves are strong winds in the upper troposphere. These operate on a global scale and move from West to East (hence being known as Westerlies). The Rossby waves are themselves a different wind speed from what we experience in the lower troposphere.

Local weather conditions play a key role in influencing wind speed, as the formation of hurricanes, monsoons and cyclones as freak weather conditions can drastically affect the velocity of the wind.

The major factors that influence wind speed, the most important is called the pressure gradient, created by a graduated disparity in atmospheric pressure that occurs in different places. Some areas have low pressure, while others have higher pressure. For example, a valley may have a higher atmospheric pressure than the peak of a mountain that is only a few miles away. Usually, the pressure increases gradually between both points

An anemometer measures the force or speed of the wind. A common anemometer uses cups mounted on four horizontal arms at equal distance from each other on a vertical shaft. The air flow past the cups turns the cups in proportion to the speed of the wind.

Many anemometers convert the revolutions per minute into wind speed measured in several different ways:

MPH (miles per hour) – unit of speed measuring the number of miles covered in a period of one hour.

Knots – unit of speed measuring one nautical mile per hour.

M/S (meters per second) – unit of speed measuring the number of meters covered in one second.

F/S (feet per second) – unit of speed that tells the number of feet covered in one second.

KM/H (kilometres per hour) – unit of speed that tells the number of kilometres covered in one hour.

Information about wind speed, collected from anemometers world-wide, is used by weather forecasters, pilots, sailors, scientists and builders for planning and management purpose

A crane operator, for example, needs to know wind speed and direction when there are plans to operate a tall crane. A landfill must know the behaviour of the wind in order to maintain odour control. The speed at which the wind is moving the clouds is especially important in forecasting (predicting) the weather.

Wind Direction

Wind direction is reported by the direction from which it originates. For example, a northerly wind blows from the north to the south. Wind direction is usually reported in cardinal directions or in azimuth degrees. So, for example, a wind coming from the south is given as 180 degrees; one from the east is 90 degrees.

Winds are caused by many different climactic conditions. The ocean currents, temperature and air pressure have a large impact of wind direction. When two areas have different levels of air pressure, air tends to flow from the high-pressure area into the low-pressure area to balance the system, creating winds. Often, pressure differences are accompanied by rainstorms, or even tornadoes or hurricanes

Wind direction is the direction from which a wind originates. It is usually reported in cardinal directions or in azimuth degrees.

There are a variety of instruments used to measure wind direction, such as the wind stocks and wind vane. Both of these instruments work by moving to minimize air resistance. The way a weather vane is pointed by prevailing winds indicates the direction from which the wind is blowing. The larger opening of a windsock faces the direction that the wind is blowing from; its tail with the smaller opening points in the direction the wind is blowing.

True Wind Direction Indicators

1. Flags and Windsocks: Flags and windsocks are an excellent way to determine where the true wind is coming from. This does not include a flags or windsock on the boat or other boats that may be moving. It has to be a stationary object to give an accurate true direction, otherwise you'll get the apparent direction instead.

2. Smoke Stacks: Smoke coming from a smoke stack will help to give an indication of the true direction. Smoke will fly away from the true direction. Steam can also give an indication of the direction, but tends to dissipate quickly making it hard to follow.

3. Water Surface: The surface of the water can indicate the true direction of the wind. Water will create wavelets that are horizontal to the true direction.

4. Boats Anchored or Moored: When a boat is anchored or moored, it will sway away from the wind and its bow will eventually face into it. It's important to keep in mind that the current may affect how the boat is positioned in the water, so this method may only provide an approximation of the true direction.

5. Trees and Plants: If the wind is strong enough to move a tree then it can be used to determine the direction of the true wind. In the fall, leaves falling to the ground or pollen moving through the air can also be used to understand the changing patterns in the area.

Apparent Wind Direction Indicators

1. Masthead Wind Indicator: One of the best ways to determine the apparent wind direction on your boat is to use a masthead indicator. The masthead indicator is impacted by the direction of the boat as it moves through the water as well as the true wind. It will give you an accurate account of how the wind is acting on your boat at any point in time. You can also check out the masthead indicators of other boats to determine how the wind is affecting them and what may be coming your way.

2. Club Burgee: Another method to determine the apparent wind is to look at club burgees. Like the masthead indicator, it will provide an accurate assessment of the current apparent direction.

3. Face: The feeling of the wind on your face while you're on the boat will provide a rough estimate of the apparent direction. Trust your instincts and they will help you guide the boat.

4. Testing the Wind: If a masthead indicator isn't available, you can always test the wind by turning the boat into the wind until the sails begin to luff. This will give you a rough indication of the apparent direction based on the edge of the 'no go' zone.

5. String: Another method of determining the apparent direction is attaching a string to a shroud. The string will fly away from the apparent wind and can be used as a continual visual indicator while you are sailing. This method is a favourite among many sailors since you don't have to strain to look up at the masthead indicator. In addition, many strings can be tied to several places on the shrouds to see how the wind is impacting different parts of the boat.

Method of Determine Wind Speed and Direction

Wind-sock Method

- Suspend a wind-sock on a tall pole that is unobstructed from the wind by buildings, trees, etc. Note the direction of wind using a compass. Note that direction is measured in degrees so a wind from the east (easterly) is recorded as 90º, and from the south-east as 135º.Take readings in the morning and afternoon.

Wind vane Method

- A more accurate way is to use a wind vane, on a 6–10 ft (1.8–3.0 m) pole, connected to a meter or data logger. Recordings can be averaged daily and plotted as a radial diagram

Anemometer Method

- Measure wind speed in an unobstructed area. Hold the anemometer or pitot gauge tube at arm’s length and read off the wind speed in kilometres per hour.

- Some gauges will give a number against the pith ball path that is converted on a table to kilometres per hour.

- Daily statistics can be more easily obtained from an electronic anemometer wired to a meter/data logger.

- Repeat at the same time each day.

4.0 CONCLUSION

5.0 SUMMARY

6.0 TUTOR- MARKED ASSIGNMENT

1. What are the factors influencing weather and climate

2. Write short note on all element of weather and climate

3. Write short note on any five of a standard meteorological equipment

4. List and explain the true and apparent wind direction indicators

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UNIT 3: RADIATION AND MEASUREMENT

UNIT 3: RADIATION AND MEASUREMENT

1.0 INTRODUCTION

Radiation quantities may be classified into two groups according to their origin, namely solar and terrestrial radiation.

Solar energy is the electromagnetic energy emitted by the sun. The solar radiation incident on the top of the terrestrial atmosphere is called extraterrestrial solar radiation; 97 per cent of which is confined to the spectral range 290 to 3000 nm are called solar (or sometimes short-wave) radiation. Part of the extra-terrestrial solar radiation penetrates through the atmosphere to the Earth's surface, while part of it is scattered and/or absorbed by the gas molecules, aerosol particles, cloud droplets and cloud crystals in the atmosphere.

Terrestrial radiation is the long-wave electromagnetic energy emitted by the Earth's surface and by the gases, aerosols and clouds of the atmosphere; it is also partly absorbed within the atmosphere. For a temperature of 300 K, 99.99 per cent of the power of the terrestrial radiation has a wavelength longer than 3 000 nm and about 99 per cent longer than 5_000 nm. For lower temperatures, the spectrum is shifted to longer wavelengths.

The various fluxes of radiation to and from the Earth's surface are among the most important variables in the heat economy of the Earth as a whole and at any individual place at the Earth's surface or in the atmosphere. Radiation measurements are used for the following purposes:

(a) To study the transformation of energy within the Earth-atmosphere system and its variation in time and space;

(b) To analyse the properties and distribution of the atmosphere with regard to its constituents, such as aerosols, water vapour, ozone, and so on;

(c) To study the distribution and variations of incoming, outgoing and net radiation;

(d) To satisfy the needs of biological, medical, agricultural, architectural and industrial activities with respect to radiation;

(e) To verify satellite radiation measurements and algorithms.

Measurement methods

Meteorological radiation instruments are classified using various criteria, namely the type of variable to be measured, the field of view, the spectral response, the main use etc

Absolute radiometers are self-calibrating, meaning that the irradiance falling on the sensor is replaced by electrical power, which can be accurately measured. The substitution, however, cannot be perfect; the deviation from the ideal case determines the uncertainty of the radiation measurement.

Most radiation sensors, however, are not absolute and must be calibrated against an absolute instrument. The uncertainty of the measured value, therefore, depends on the following factors, all of which should be known for a well characterized instrument:

(a) Resolution, namely, the smallest change in the radiation quantity which can be detected by the instrument;

(b) Drifts of sensitivity (the ratio of electrical output signal to the irradiance applied) over time

(c) Changes in sensitivity owing to changes of environmental variables, such as temperature, humidity, pressure and wind;

(d) Non-linearity of response, namely, changes in sensitivity associated with variations in irradiance;

(e) Deviation of the spectral response from that postulated, namely the blackness of the receiving surface, the effect of the aperture window, and so on;

(f) Deviation of the directional response from that postulated, namely cosine response and azimuth response;

(g) Time-constant of the instrument or the measuring system;

(h) Uncertainties in the auxiliary equipment.

Instruments should be selected according to their end-use and the required uncertainty of the derived quantity. Certain instruments perform better for particular climates, irradiances and solar positions

2.0 AIMS AND OBJECTIVES

1. Identification of measurement and calibration of radiation

2. To examine the measurement and instrument of solar radiation

3 To examine the measurement and instrument of total and long-wave radiation

4. To examine the measurement and instrument UV Radiation

5. To examine the measurement and instrument of sunshine duration

3.0 MAIN CONTENT

3.1 Measurement of Solar Radiation

Everything in nature emits electromagnetic energy, and solar radiation is energy emitted by the sun. The energy of extraterrestrial solar radiation is distributed over a wide continuous spectrum ranging from ultraviolet to infrared rays. In this spectrum, solar radiation in short wavelengths (0.29 to 3.0 m) accounts for about 97 percent of the total energy

Solar radiation is partly absorbed, scattered and reflected by molecules, aerosols, water vapor and cloudsnas it passes through the atmosphere. The direct solar beam arriving directly at the earth's surface is calledmdirect solar radiation. The total amount of solar radiation falling on a horizontal surface (i.e. the direct solar beam plus diffuse solar radiation on a horizontal surface) is referred as global solar radiation.

Direct solar radiation is observed from sunrise to sunset, while global solar radiation is observed in the twilight before sunrise and after sunset, despite its diminished intensity at these times.

The solar irradiance is expressed in watts per square meter (W/m2) and the total amount in joules per square meter (J/m2). Conversion between the currently used unit (SI) and the former unit (calories) can be performed using the following formulae: Solar irradiance: 1 kW/m2 = 1.433 cal/cm2/min. Total amount of solar radiation: 1 MJ/m2 = 23.89 cal/cm2

Measurement methods

The principles used for measuring sunshine duration and the pertinent types of instruments are briefly listed in the following methods:

(a) Pyrheliometric method: Pyrheliometric detection of the transition of direct solar irradiance through the 120 W m–2 threshold (according to Recommendation 10 (CIMO-VIII)). Duration values are readable from time counters triggered by the appropriate upward and downward transitions.

Type of instrument: pyrheliometer combined with an electronic or computerized threshold discriminator and a time-counting device.

(b) Pyranometric method:

(i) Pyranometric measurement of global (G) and diffuse (D) solar irradiance to derive the direct solar irradiance as the WMO threshold discriminator value and further as in (a) above.

Type of instrument: Radiometer systems of two fitted pyranometers and one sunshade device combined with an electronic or computerized threshold discriminator and a time-counting device.

(ii) Pyranometric measurement of global (G) solar irradiance to roughly estimate sunshine duration.

Type of instrument: a pyranometer combined with an electronic or computerized device which is able to deliver 10 min means as well as minimum and maximum global (G) solar irradiance within those 10 min.

(b) Burn method: Threshold effect of burning paper caused by focused direct solar radiation

(Heat effect of absorbed solar energy). The duration is read from the total burn length.

Type of instrument: Campbell-Stokes sunshine recorders, especially the recommended version, namely the IRSR (see section 8.2).

(c) Contrast method: Discrimination of the insolation contrasts between some sensors in different positions to the sun with the aid of a specific difference of the sensor output signals which corresponds to an equivalent of the WMO recommended threshold (determined by comparisons with reference SD values) and further as in (b) above.

Type of instrument: Specially designed multisensory detectors (mostly equipped with photovoltaic cells) combined with an electronic discriminator and a time counter.

(d) Scanning method: Discrimination of the irradiance received from continuously scanned, small sky sectors with regard to an equivalent of the WMO recommended irradiance threshold (determined by comparisons with reference SD values).

3.1.1 Measurement of Direct Solar Radiation

Direct solar radiation is measured by means of pyrheliometers, the receiving surfaces of which are arranged to be normal to the solar direction. By means of apertures, only the radiation from the sun and a narrow annulus of sky is measured, the latter radiation component is sometimes referred to as circumsolar radiation or aureole radiation. In modern instruments, this extends out to a half-angle of about 2.5° on some models, and to about 5° from the sun’s centre (corresponding, respectively, to 6 · 10–3 and 2.4 · 10–2 sr). The pyrheliometer mount must allow for the rapid and smooth adjustment of the azimuth and elevation angles. A sighting device is usually included in which a small spot of light or solar image falls upon a mark in the centre of the target when the receiving surface is exactly normal to the direct solar beam. For continuous recording, it is advisable to use automatic sun following equipment (sun tracker).

Primary standard Pyrheliometers

An absolute pyrheliometer can define the scale of total irradiance without resorting to reference sources or radiators. The limits of uncertainty of the definition must be known; the quality of this knowledge determines the reliability of an absolute pyrheliometer. Only specialized laboratories should operate and maintain primary standards. Details of their construction and operation are given in WMO (1986a). However, for the sake of completeness, a brief account is given here.

All absolute pyrheliometers of modern design use cavities as receivers and electrically calibrated, differential heatflux meters as sensors. At present, this combination has proved to yield the lowest uncertainty possible for the radiation levels encountered in solar radiation measurements (namely, up to 1.5 kW m–2).

Normally, the electrical calibration is performed by replacing the radiative power by electrical power, which is dissipated in a heater winding as close as possible to where the absorption of solar radiation takes place.

The uncertainties of such an instrument's measurements are determined by a close examination of the physical properties of the instrument and by performing laboratory measurements and/or model calculations to determine the deviations from ideal behaviour, that is, how perfectly the electrical substitution can be achieved.

3.2 Measurement of total and Long-Wave Radiation

The measurement of total radiation includes both short wavelengths of solar origin (300 to 3_000 nm) and longer wavelengths of terrestrial and atmospheric origin (3_000 to 100_000 nm). The instruments used for this purpose are pyrradiometers. They may be used for measuring either upward or downward radiation flux components, and a pair of them may be used to measure the differences between the two, which is the net radiation. Single-sensor pyrradiometers, with an active surface on both sides, are also used for measuring net radiation. Pyrradiometer sensors must have a constant sensitivity across the whole wavelength range from 300 to 100_000 nm.

Instruments for the measurement of total radiation

One problem with instruments for measuring total radiation is that there are no absorbers which have a completely constant sensitivity over the extended range of wavelengths concerned. Similarly it is difficult to find suitable filters that have constant transmission between 300 and 100000 nm.

The use of thermally sensitive sensors requires a good knowledge of the heat budget of the sensor. Otherwise, it is necessary to reduce sensor convective heat losses to near zero by protecting the sensor from the direct influence of the wind. The technical difficulties linked with such heat losses are largely responsible for the fact that net radiative fluxes are determined less precisely than global radiation fluxes. In fact, different laboratories have developed their own pyrradiometers on technical bases which they consider to be the most effective for reducing the convective heat transfer in the sensor. During the last few decades, pyrradiometers have been built which, although not perfect, embody good measurement principles. Thus, there is a great variety of pyrradiometers employing different methods for eliminating, or allowing for, wind effects, as follows:

(a) No protection, in which case empirical formulae are used to correct for wind effects;

(b) Determination of wind effects by the use of electrical heating;

(c) Stabilization of wind effects through artificial ventilation;

(d) Elimination of wind effects by protecting the sensor from the wind.

3.3 Measurement of UV Radiation

Measurements of solar UV radiation are in demand because of its effects on the environment and human health, and because of the enhancement of radiation at the Earth’s surface as a result of ozone depletion (Kerr and McElroy, 1993). The UV spectrum is conventionally divided into three parts, as follows:

(a) UV-A is the band with wavelengths of 315 to 400 nm, namely, just outside the visible spectrum. It is less biologically active and its intensity at the Earth’s surface does not vary with atmospheric ozone content;

(b) UV-B is defined as radiation in the 280 to 315 nm band. It is biologically active and its intensity at the Earth’s surface depends on the atmospheric ozone column, to an extent depending on wavelength. A frequently used expression of its biological activity is its perythemal effect, which is the extent to which it causes the reddening of white human skin;

(c) UV-C, in wavelengths of 100 to 280 nm, is completely absorbed in the atmosphere and does not occur naturally at the Earth’s surface.

UV-B is the band on which most interest is centred for measurements of UV radiation. An alternative, but now nonstandard, definition of the boundary between UV-A and UV-B is 320 nm rather than 315 nm.

Measuring UV radiation is difficult because of the small amount of energy reaching the Earth’s surface, the variability due to changes in stratospheric ozone levels, and the rapid increase in the magnitude of the flux with increasing wavelength

Instruments

Three general types of instruments are available commercially for the measurement of UV radiation. The first class of instruments use broadband filters. These instruments integrate over either the UV-B or UV-A spectrum or the entire broadband UV region responsible for affecting human health. The second class of instruments use one or more interference filters to integrate over discrete portions of the UV-A and/or UV-B spectrum. The third class of instruments are spectroradiometers that measure across a pre-defined portion of the spectrum sequentially using a fixed passband.

3.4 Measurement of Sunshine Duration

Sunshine duration is the length of time that the ground surface is irradiated by direct solar radiation (i.e., sunlight reaching the earth's surface directly from the sun). In 2003, WMO defined sunshine duration as the period during which direct solar irradiance exceeds a threshold value of 120 watts per square meter (W/m2). This value is equivalent to the level of solar irradiance shortly after sunrise or shortly before sunset in cloud-free conditions. It was determined by comparing the sunshine duration recorded using a Campbell-Stokes sunshine recorder with the actual direct solar irradiance.

Sunshine Duration Measuring Instruments

Campbell-Stokes sunshine recorders and Jordan sunshine recorders have long been used as instruments to measure sunshine duration, and are advantageous in that they have no moving parts and require no electric power. Their disadvantages are that the characteristics of the recording paper or photosensitized paper used in them affect measurement accuracy, differences between observers may arise in determining the occurrence of sunshine, and the recording paper must be replaced after sunset. As sunshine is defined quantitatively at present, a variety of photoelectric sunshine recorders has been developed and is used in place of these instruments. As the threshold value for the occurrence of sunshine is defined in terms of direct solar irradiance, it is also possible to observe sunshine duration with a pyrheliometer.

4.0 CONCLUSION

Sunshine recorders and radiometers should be installed in a location where solar radiation is not shaded by trees or buildings in any season from sunrise to sunset and where there are no smoke emission sources. Pyranometers in particular should be installed at a site where the instrument is not influenced by intense reflected light from the wall surfaces of buildings. Usually, such instruments are installed on rooftops or towers, but the convenience of routine maintenance and checking tasks such as cleaning of the sensor part should be taken into consideration.

When installing a sunshine duration or solar radiation instrument, it must be set properly using a spirit level. It must also be oriented in the prescribed direction using the meridional plane as reference with its elevation angle set to the latitude of the site. It should be checked that the pyranometer's output does not fluctuate when the sensor rotates in clear weather.

5.0 SUMMARY

6.0 TUTOR- MARKED ASSIGNMENT

1. Write short note on the following;

a. Sunshine duration

b. UV radiation

c. Long-wave radiation

2. Give a detail description of measurement and instrument of solar radiation

3 Give a detail account of the measurement and instrument of total and long-wave radiation

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UNIT 4: TEMPERATURE AND MEASUREMENT

Unit 4: Temperature and Measurement

1.0 Introduction

Temperature is a measure the sensation of warmth or coldness of an object, felt from contact with it. This sensation of touch gives an approximate or relative measure of the temperature. Temperature is measured in different scales, including Fahrenheit (F) and Celsius (or centigrade, C). The units of the Fahrenheit and Celsius scales are called degrees and are denoted by. Swedish astronomer Anders Celsius devised the Celsius scale in 1742. He fixed the of the scale at the freezing of water, and the at the boiling of water

In simple terms, temperature is the ‘degree of hotness’ of an object or, more specifically in science and technology, the ‘potential for heat transfer’.

A proper understanding of what it is, and how it relates to heat, was only developed in the mid-to-late nineteenth century, when it was realised that it is a measure of the average energy of an ensemble of particles at equilibrium. The particles may be the atoms or molecules of a gas, a liquid or a solid, but they may also be the ‘photons’ of electromagnetic radiation inside a closed blackbody cavity.

If two objects are placed in contact, heat will flow from the hotter to the colder. Eventually, when no more heat flows, we can say that they are at equilibrium with each other and that their temperatures are the same. We use this property in measuring temperature when we place a thermometer in contact with an object: the reading of the thermometer after they have reached equilibrium tells us what the temperature of the object is.

It is easy to demonstrate that when two objects of the same material are placed together (physicists say when they are put in thermal contact), the object with the higher temperature cools while the cooler object becomes warmer until a point is reached after which no more change occurs, and to our senses, they feel the same. When the thermal changes have stopped, we say that the two objects (physicists define them more rigorously as systems) are in thermal equilibrium. We can then define the temperature of the system by saying that the temperature is that quantity which is the same for both systems when they are in thermal equilibrium.

If we experiment further with more than two systems, we find that many systems can be brought into thermal equilibrium with each other; thermal equilibrium does not depend on the kind of object used. Put more precisely, if two systems are separately in thermal equilibrium with a third, then they must also be in thermal equilibrium with each other, and they all have the same temperature regardless of the kind of systems they are.

Strictly this is the ideal case – to come to equilibrium they must be isolated from any other objects and their surrounding environment. We would also like the thermometer to be small enough that it does not upset the temperature of the object under measurement. Many of the difficulties of measuring temperature come from achieving these conditions.

Further ideas about temperature and its significance in physics and engineering came through the development of the second law of thermodynamics, which considers the fundamental limits to the conversion of heat into work. They are discussed in textbooks of thermodynamics.

The important point to note here is that the second law shows how a ‘thermodynamic’ (absolute) temperature can be derived as a fundamental parameter of physics and chemistry, independent of any particular material property (like the expansion of a liquid or the resistance of a wire). Thus experiments to measure thermodynamic temperature, for example using the fundamental laws governing the properties of gases or thermal radiation, should all give the same results. Such experiments are very difficult and time-consuming, but they nevertheless form the basis of the temperature scale used in science, technology and everyday life.

To put the measurement of temperature on a quantitative and objective basis, with sufficient accuracy, we need an agreed unit and temperature scale, and reliable thermometers to work with

The accurate measurement of temperature is vital across a broad spectrum of human activities, including industrial processes (e.g. making steel), manufacturing; monitoring (in food transport and storage), and in health and safety. In fact, in almost every sector, temperature is one of the key parameters to be measured.

The two temperature scales commonly in use today date from the eighteenth century and are named after Gabriel Daniel Fahrenheit and the Swedish astronomy professor Anders Celsius. Fahrenheit designed his scale to have two reference points that could be set up in his workshop. He originally chose the melting point of pure ice and the temperature of a normal human body, which he took as being 32° and 96° respectively. These conveniently gave positive values for all the temperatures he encountered. Later he changed to using the boiling point of water (212°) as the upper fixed point of the scale.

Celsius also used the ice and steam points, but took them to be 0°C and 100°C respectively. Although the Celsius scale has taken precedence over the Fahrenheit scale, the latter is still familiar in weather reports in the United Kingdom: a summer's day temperature of 75°F seems much more pleasant than one of 23°C!

A third, fundamental, temperature scale was proposed in 1854 by the Scottish physicist William Thomson, Lord Kelvin. It is based on the idea of the absolute zero, the point of no discernible energy, which is independent of any particular material substance. The Kelvin scale is widely used by physicists and engineers to determine and apply fundamental laws of thermodynamics.

2.0 AIMS AND OBJECTIVES

1. To examine the evolution and growth of the use of thermometer

2. Type and classification of thermometer

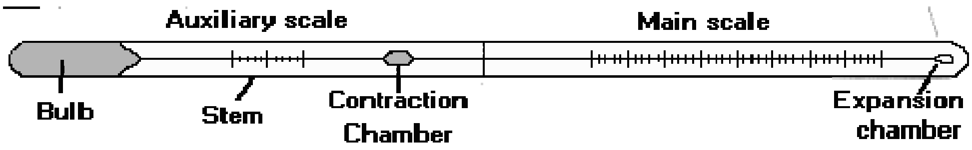
3. To examine the development of thermometers and temperature scales

4. Kinetic theory

3.0 MAIN CONTENT

3.1 History of Thermometry

A thermometer is used to measure the temperature of an object – it is used to find how cold or hot the object is. Galileo invented a rudimentary water thermometer in 1593. He called this device a "thermoscope". However, this form was ineffective as water freezes at low temperatures. In 1714, Gabriel Fahrenheit invented the mercury thermometer, the modern thermometer. The long narrow uniform glass tube is called the stem of a thermometer. The small tube called the bulb, which contains mercury. Mercury is toxic, and it is very difficult to dispose it when the thermometer breaks. So, nowadays digital thermometers are used to measure the temperature, as they do not contain mercury



The mercury-in-glass thermometer illustrated in the above figure contains a bulb filled with mercury that is allowed to expand into a capillary. Its rate of expansion is calibrated on the glass scale.

The most significant 17th century contribution to the study of heat was the appearance of the thermometer (ref. 5), a term apparently first used by Leurchon in 1626. The first thermometers, introduced early in the century, were air thermometers, of which there were two types: the open (Italian) and the differential (Dutch) . The discovery of the former has been popularly associated with Galileo, but the evidence is inconclusive, being based on assertions by his friends and pupils. Independent discovery has also been attributed to Santorio Santorii and Robert Fludd. The first known description of an open air thermometer

is that of Santorio Santorii in 1611, and the first diagram is that in the Telioux manuscript

(Rome, 1611) (ref. 6). The discovery of the differential air thermometer is usually attributed to Cornelius Drebbel. Air thermometers were quite common in the second quarter of the 17th century, but, with the awareness (from the 1640s) of the variability of atmospheric pressure, the main defect of the open variety (i.e. its response to pressure as well as temperature changes) became apparent.

For liquid—in—glass thermometers, the question of discovery is less ambiguous. The open variety was invented by Jean Rey, a French doctor living in the Dordogne, before 1632. Two

sealed varieties (Florentine thermometers) , the familiar liquid-in-glass model and another based on changes in liquid density with temperature, were invented by the Grand Duke Ferdinand II of Tuscany, a member of the Medici family, around the mid-l7th century. Such thermometers, particularly the usual liquid-in—glass type, were widely used. Various liquids, including mercury, were tried, but initially spirit of wine was preferred because of its greater coefficient of thermal expansion. In 1713 Daniel Gabriel Fahrenheit (1686-1736) experimented with the use of mercury, and four years later he began to make mercury—in-glass thermometers commercially. These and imitations thereof soon became the most widely used model.

In the second half of the 17th century, the need for a satisfactory temperature scale was recognised; in the 1660s, for example, the Royal Society of London, Huygens, and Boyle independently referred to the importance of making thermometers comparable. An early attempt to do so was that of Robert Hooke in his Micrographia (1665); this scale was based on a single fixed point (the freezing point of water) , and the degree corresponded to a particular fractional change (1/1000) in the volume of a liquid (spirit of wine). There followed a proliferation of temperature scales (refs 5, 7); the mid-l8th century saw thermometers with more than a dozen scales attached. Only three survived into the 19th century: the Raumur, Celsius and Fahrenheit scales. These were based on two fixed points, although the first started off as a one fixed point scale. Eventually, the melting and boiling points of water became the accepted fixed points, but doubts about the constancy of these lingered well into the 18th century. In the 1690s, Halley and Amontons independently reported the constancy of the boiling point of water, but some doubted this (ref. 7). It was fairly widely believed that the freezing point of water was lower in cold climates (ref. 7).

Early Thermometric Studies

Thermometric measurements from the mid—l7th to the mid-l8th century yielded many, now familiar results: thermal equilibrium, thermal expansion, the constancy of melting and boiling points at constant pressure, their variations with pressure, the temperature changes accompanying many chemical reactions, the depression of the freezing point when salts are added to water, and so on. It is sometimes difficult to appreciate that such results were often controversial.

The means of accurately measuring temperatures has long fascinated people. One of the differences between temperature and other physical concepts, such as mass or length, is that it is subjective: different people will have different perceptions of what is hot and what is cold. To make objective measurements, we must use a thermometer in which some physical property of a substance changes with temperature in a reliable and reproducible way.

Thermoscopes, the ancestors of modern thermometers, have been around since about 200 BC. The first recognisable, modern thermometers were made in the 16th century by both the Italian Galileo Galilei and Santorio Santorio, a physician to the King of Poland. The latter produced a thermometer incorporating a scale, and his writings show that he understood the importance of the temperature measurement in the diagnosis of disease. The first sealed thermometer was made by the Grand Duke Ferdinand of Tuscany in 1641. This thermometer was more accurate than its predecessors since it wasn't dependent on atmospheric pressure. Later, the scientists Fahrenheit and Celsius both made glass thermometers containing mercury, and used reference points (the melting point of pure ice and the boiling point of water) to improve the accuracy.

3.2 Types and Classification of Thermometer

3.2.1 Types and Classification of Thermometer

Liquid-in-Glass

Liquid-in-glass, in particular mercury, thermometers have been used for almost 300 years in science, medicine, metrology and in industry. They rely on the expansion of a fluid with temperature. The fluid is contained in a sealed glass bulb and the temperature is read using a scale etched along the stem of the thermometer.

Platinum Resistance

In the modern world, mercury and spirit-filled thermometers have largely given way to electrical devices, which can be digitised and automated. Platinum resistance thermometers are electrical thermometers which make use of the variation of resistance of high-purity platinum wire with temperature. This variation is predictable, enabling accurate measurements to be performed. They are sensitive and, with sophisticated equipment, measurements can routinely be made to better than a thousandth part of 1°C.

Thermocouples

Thermocouples are the most common sensors in industrial use. They have a long history, the original paper on thermoelectricity by Seebeck being published in 1822. They consist of two dissimilar metallic conductors joined at the point of measurement. When the conductors are heated a voltage is generated in the circuit, and this can be used to determine the temperature.

Radiation thermometer (or Pyrometers)

Radiation thermometers, or pyrometers, make use of the fact that all objects emit thermal radiation, as seen when looking at the bars of an electric fire or a light bulb. The amount of radiation emitted can be measured and related to temperature using the Planck law of radiation. Temperatures can be measured remotely using this technique, with the sensor situated some distance away from the object. Hence it is useful for objects that are very hot, moving or in hazardous environments.

3.2.2 Classification of Thermometers

There are different types of thermometers that measure the temperatures of different things like air, our bodies, food and many other things. There are clinical thermometers, laboratory thermometers, Galileo thermometers and digital remote thermometers. Among these, the commonly used thermometers are clinical thermometers and laboratory thermometers

Clinical Thermometer

These thermometers are used to measure the temperature of the human body, at home, clinics and hospitals. All clinical thermometers have a kink that prevents the mercury from falling down rapidly so that the temperature can be noted conveniently. There are temperature scales on either side of the mercury thread, one in Celsius scale and the other in Fahrenheit scale

A clinical thermometer indicates temperatures from 350C to 420C or 940F to 1080F, note a reading, place the thermometer in the person’s mouth. Since the Fahrenheit scale is more sensitive than the Celsius scale, body temperature is measured in degrees Fahrenheit only. A healthy person’s average body temperature is between 98.60F and 98.80F

Precautions:

Wash the thermometer before and after use with an antiseptic solution, and handle it with care.

See that the mercury levels are below the kink and don’t hold the thermometer near its bulb.

While noting down the reading in the thermometer, place the mercury level along the eye sight.

Do not place the thermometer in a hot flame or in the hot sun

Laboratory Thermometers

These thermometers are used to measure the temperature in school and other laboratories for scientific research. They are also used in the industry as they can measure temperatures higher than what clinical thermometers can record. The stem and the bulb are longer when compared to that of a clinical thermometer. A laboratory thermometer has only the Celsius scale ranging from -10o C to 110 o C.

Precautions:

A laboratory thermometer doesn’t have a kink.

Do not tilt the thermometer. Place it upright.

Note the reading only when the bulb has been surrounded by the substance from all sides

3.3 The Development of Thermometers and Temperature Scales

The historical highlights in the development of thermometers and their scales given here are based on "Temperature" by T. J. Quinn and "Heat" by James M. Cork.

One of the first attempts to make a standard temperature scale occurred about AD 170, when Galen, in his medical writings, proposed a standard "neutral" temperature made up of equal quantities of boiling water and ice; on either side of this temperature were four degrees of heat and four degrees of cold, respectively.

The earliest devices used to measure the temperature were called thermoscopes. They consisted of a glass bulb having a long tube extending downward into a container of colored water, although Galileo in 1610 is supposed to have used wine. Some of the air in the bulb was expelled before placing it in the liquid, causing the liquid to rise into the tube. As the remaining air in the bulb was heated or cooled, the level of the liquid in the tube would vary reflecting the change in the air temperature. An engraved scale on the tube allowed for a quantitative measure of the fluctuations.

The air in the bulb is referred to as the thermometric medium, i.e. the medium whose property changes with temperature.

In 1641, the first sealed thermometer that used liquid rather than air as the thermometric medium was developed for Ferdinand II, Grand Duke of Tuscany. His thermometer used a sealed alcohol-in-glass device, with 50 "degree" marks on its stem but no "fixed point" was used to zero the scale. These were referred to as "spirit" thermometers.

Robert Hook, Curator of the Royal Society, in 1664 used a red dye in the alcohol . His scale, for which every degree represented an equal increment of volume equivalent to about 1/500 part of the volume of the thermometer liquid, needed only one fixed point. He selected the freezing point of water. By scaling it in this way, Hook showed that a standard scale could be established for thermometers of a variety of sizes. Hook's original thermometer became known as the standard of Gresham College and was used by the Royal Society until 1709. (The first intelligible meteorological records used this scale).

In 1702, the astronomer Ole Roemer of Copenhagen based his scale upon two fixed points: snow (or crushed ice) and the boiling point of water, and he recorded the daily temperatures at Copenhagen in 1708- 1709 with this thermometer.

It was in 1724 that Gabriel Fahrenheit, an instrument maker of Däanzig and Amsterdam, used mercury as the thermometric liquid. Mercury's thermal expansion is large and fairly uniform, it does not adhere to the glass, and it remains a liquid over a wide range of temperatures. Its silvery appearance makes it easy to read.

Fahrenheit described how he calibrated the scale of his mercury thermometer: "placing the thermometer in a mixture of sal ammoniac or sea salt, ice, and water a point on the scale will be found which is denoted as zero. A second point is obtained if the same mixture is used without salt. Denote this position as 30. A third point, designated as 96, is obtained if the thermometer is placed in the mouth so as to acquire the heat of a healthy man." (D. G. Fahrenheit,Phil. Trans. (London) 33, 78, 1724)

On this scale, Fahrenheit measured the boiling point of water to be 212. Later he adjusted the freezing point of water to 32 so that the interval between the boiling and freezing points of water could be represented by the more rational number 180. Temperatures measured on this scale are designated as degrees Fahrenheit (° F).

In 1745, Carolus Linnaeus of Upsula, Sweden, described a scale in which the freezing point of water was zero, and the boiling point 100, making it a centigrade (one hundred steps) scale. Anders Celsius (1701-1744) used the reverse scale in which 100 represented the freezing point and zero the boiling point of water, still, of course, with 100 degrees between the two defining points.

In 1948 use of the Centigrade scale was dropped in favor of a new scale using degrees Celsius (° C). The Celsius scale is defined by the following two items that will be discussed later in this essay:

(i) The triple point of water is defined to be 0.01° C.

(ii) A degree Celsius equals the same temperature change as a degree on the ideal-gas scale.

On the Celsius scale the boiling point of water at standard atmospheric pressure is 99.975 C in contrast to the 100 degrees defined by the Centigrade scale.

To convert from Celsius to Fahrenheit: multiply by 1.8 and add 32.

$$°\ F = 1.8°\ C + 32$$

$$°\ K = °\ C + 273.$$

In 1780, J. A. C. Charles, a French physician, showed that for the same increase in temperature, all gases exhibited the same increase in volume. Because the expansion coefficient of gases is so very nearly the same, it is possible to establish a temperature scale based on a single fixed point rather than the two fixed- point scales, such as the Fahrenheit and Celsius scales. This brings us back to a thermometer that uses a gas as the thermometric medium.

In a constant volume gas thermometer a large bulb B of gas, hydrogen for example, under a set pressure connects with a mercury-filled "manometer" by means of a tube of very small volume. (The Bulb B is the temperature-sensing portion and should contain almost all of the hydrogen). The level of mercury at C may be adjusted by raising or lowering the mercury reservoir R. The pressure of the hydrogen gas, which is the "x" variable in the linear relation with temperature, is the difference between the levels D and C plus the pressure above D.

P. Chappuis in 1887 conducted extensive studies of gas thermometers with constant pressure or with constant volume using hydrogen, nitrogen, and carbon dioxide as the thermometric medium. Based on his results, the Comité International des Poids et Mesures adopted the constant-volume hydrogen scale based on fixed points at the ice point (0° C) and the steam point (100° C) as the practical scale for international meteorology.

Experiments with gas thermometers have shown that there is very little difference in the temperature scale for different gases. Thus, it is possible to set up a temperature scale that is independent of the thermometric medium if it is a gas at low pressure. In this case, all gases behave like an "Ideal Gas" and have a very simple relation between their pressure, volume, and temperature:

$$pV = (\text{constant})T.$$

This temperature is called the thermodynamic temperature and is now accepted as the fundamental measure of temperature. Note that there is a naturally-defined zero on this scale - it is the point at which the pressure of an ideal gas is zero, making the temperature also zero. We will continue a discussion of "absolute zero" in a later section. With this as one point on the scale, only one other fixed point need be defined. In 1933, the International Committee of Weights and Measures adopted this fixed point as the triple point of water , the temperature at which water, ice, and water vapor coexist in equilibrium); its value is set as 273.16. The unit of temperature on this scale is called the kelvin, after Lord Kelvin (William Thompson), 1824-1907, and its symbol is K (no degree symbol used).

To convert from Celsius to Kelvin, add 273.

$$K = {}^\circ C + 273.$$

Thermodynamic temperature is the fundamental temperature; its unit is the kelvin which is defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Sir William Siemens, in 1871, proposed a thermometer whose thermometric medium is a metallic conductor whose resistance changes with temperature. The element platinum does not oxidize at high temperatures and has a relatively uniform change in resistance with temperature over a large range.

The Platinum Resistance Thermometer is now widely used as a thermoelectric thermometer and covers the temperature range from about -260° C to 1235° C.

Several temperatures were adopted as Primary reference points so as to define the International Practical Temperature Scale of 1968. The International Temperature Scale of 1990 was adopted by the International Committee of Weights and Measures at its meeting in 1989. Between 0.65K and 5.0K, the temperature is defined in terms of the vapor pressure - temperature relations of the isotopes of helium. Between 3.0K and the triple point of neon (24.5561K) the temperature is defined by means of a helium gas thermometer. Between the triple point of hydrogen (13.8033K) and the freezing point of silver (961.78°K) the temperature is defined by means of platinum resistance thermometers. Above the freezing point of silver the temperature is defined in terms of the Planck radiation law.

T. J. Seebeck, in 1826, discovered that when wires of different metals are fused at one end and heated, a current flows from one to the other. The electromotive force generated can be quantitatively related to the temperature and hence, the system can be used as a thermometer - known as a thermocouple. The thermocouple is used in industry and many different metals are used - platinum and platinum/rhodium, nickel-chromium and nickel-aluminum, for example. The National Institute of Standards and Technology (NIST) maintain databases for standardizing thermometers.

For the measurement of very low temperatures, the magnetic susceptibility of a paramagnetic substance is used as the thermometric physical quantity. For some substances, the magnetic susceptibility varies inversely as the temperature. Crystals such as cerrous magnesium nitrate and chromic potassium alum have been used to measure temperatures down to 0.05 K; these crystals are calibrated in the liquid helium range. This diagram and the last illustration in this text were taken from the Low Temperature Laboratory, Helsinki University of Technology's picture archive. For these very low, and even lower, temperatures, the thermometer is also the mechanism for cooling. Several low-temperature laboratories conduct interesting applied and theoretical research on how to reach the lowest possible temperatures and how work at these temperatures may find application.

Heat and Thermodynamics

Prior to the 19th century, it was believed that the sense of how hot or cold an object felt was determined by how much "heat" it contained. Heat was envisioned as a liquid that flowed from a hotter to a colder object; this weightless fluid was called "caloric", and until the writings of Joseph Black (1728-1799), no distinction was made between heat and temperature. Black distinguished between the quantity (caloric) and the intensity (temperature) of heat.

Benjamin Thomson, Count Rumford, published a paper in 1798 entitled "an Inquiry Concerning the Source of Heat which is Excited by Friction". Rumford had noticed the large amount of heat generated when a cannon was drilled. He doubted that a material substance was flowing into the cannon and concluded "it appears to me to be extremely difficult if not impossible to form any distinct idea of anything capable of being excited and communicated in the manner the heat was excited and communicated in these experiments except motion."

But it was not until J. P. Joule published a definitive paper in 1847 that the the caloric idea was abandoned. Joule conclusively showed that heat was a form of energy. As a result of the experiments of Rumford, Joule, and others, it was demonstrated (explicitly stated by Helmholtz in 1847), that the various forms of energy can be transformed one into another.

When heat is transformed into any other form of energy, or when other forms of energy are transformed into heat, the total amount of energy (heat plus other forms) in the system is constant.

This is the first law of thermodynamics, the conservation of energy. To express it another way: it is in no way possible either by mechanical, thermal, chemical, or other means, to obtain a perpetual motion machine; i.e., one that creates its own energy (except in the fantasy world of Maurits Escher's "Waterfall"!)

A second statement may also be made about how machines operate. A steam engine uses a source of heat to produce work. Is it possible to completely convert the heat energy into work, making it a 100% efficient machine? The answer is to be found in the second law of thermodynamics:

No cyclic machine can convert heat energy wholly into other forms of energy. It is not possible to construct a cyclic machine that does nothing but withdraw heat energy and convert it into mechanical energy.

The second law of thermodynamics implies the irreversibility of certain processes - that of converting all heat into mechanical energy, although it is possible to have a cyclic machine that does nothing but convert mechanical energy into heat!

Sadi Carnot (1796-1832) conducted theoretical studies of the efficiencies of heat engines (a machine which converts some of its heat into useful work). He was trying to model the most efficient heat engine possible. His theoretical work provided the basis for practical improvements in the steam engine and also laid the foundations of thermodynamics. He described an ideal engine, called the Carnot engine that is the most efficient way an engine can be constructed. He showed that the efficiency of such an engine is given by

$$\text{efficiency} = 1 - T''/T',$$

where the temperatures, T' and T'' , are the hot and cold "reservoirs" , respectively, between which the machine operates. On this temperature scale, a heat engine whose coldest reservoir is zero degrees would operate with 100% efficiency. This is one definition of absolute zero, and it can be shown to be identical to the absolute zero we discussed previously. The temperature scale is called the absolute, the thermodynamic, or the kelvin scale.

The way that the gas temperature scale and the thermodynamic temperature scale are shown to be identical is based on the microscopic interpretation of temperature, which postulates that the macroscopic measurable quantity called temperature is a result of the random motions of the microscopic particles that make up a system.

The International Temperature Scale of 1990 (ITS-90)

Since 1954 the unit of (thermodynamic) temperature has been defined as the kelvin, and is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. This is the unique temperature and pressure at which the three phases of water (solid, liquid and vapour) co-exist in equilibrium. It is fractionally higher than the melting point, being 0.01°C or 273.16 K. From this single point it is possible to generate a thermodynamic temperature scale using gas thermometers and radiation thermometers which accurately obey known laws.

Such experiments are not easy and are rarely done, but good values have been established for a series of fixed points: freezing points of pure metals at high temperatures and triple points of gases at low temperatures. These are incorporated into the International Temperature Scale so that standard platinum resistance thermometers and radiation thermometers can be calibrated with excellent reproducibility. The National Physical Laboratory maintains the temperature scale (currently the International Temperature Scale of 1990, the ITS-90) in the UK, and compares this with the ITS-90 maintained in other national laboratories. In this way temperature standards around the world can be accurately equivalent, and all manner of thermometers can be reliably calibrated for everyday use.

Future of Thermometry

The international temperature community is working towards a redefinition of the kelvin. This would be based on a fundamental constant of nature known as the Boltzmann constant. The advantages of this is that the new definition would be freed from any physical artefact (i.e. the triple point of water) and allow the use of any appropriate thermodynamic method for temperature measurement

3.4 The Kinetic Theory

This brief summary is abridged from a more detailed discussion to be found in Quinn's "Temperature"

About the same time that thermodynamics was evolving, James Clerk Maxwell (1831-1879) and Ludwig Boltzmann (1844-1906) developed a theory describing the way molecules moved - molecular dynamics. The molecules that make up a perfect gas move about, colliding with each other like billiard balls and bouncing off the surface of the container holding the gas. The energy associated with motion is called Kinetic Energy and this kinetic approach to the behaviour of ideal gases led to an interpretation of the concept of temperature on a microscopic scale.

The amount of kinetic energy each molecule has is a function of its velocity; for the large number of molecules in a gas (even at low pressure), there should be a range of velocities at any instant of time. The magnitude of the velocities of the various particles should vary greatly - no two particles should be expected to have the exact same velocity. Some may be moving very fast; others, quite slowly. Maxwell found that he could represent the distribution of velocities statistically by a function known as the Maxwellian distribution. The collisions of the molecules with their container give rise to the pressure of the gas. By considering the average force exerted by the molecular collisions on the wall, Boltzmann was able to show that the average kinetic energy of the molecules was directly comparable to the measured pressure, and the greater the average kinetic energy, the greater the pressure. From Boyles' Law, we know that the pressure is directly proportional to the temperature; therefore, it was shown that the kinetic energy of the molecules related directly to the temperature of the gas. A simple relation holds for this: average kinetic energy of molecules=3kT/2, where k is the Boltzmann constant. Temperature is a measure of the energy of thermal motion and, at a temperature of zero, the energy reaches a minimum (quantum mechanically, the zero-point motion remains at 0 K).

In July, 1995, physicists in Boulder, Colo.achieved a temperature far lower than has ever been produced before and created an entirely new state of matter predicted decades ago by Albert Einstein and Satyendra Nath Bose. The press release describes the nature of this experiment and a full description of this phenomenon is described by the University of Colorado's BEC Homepage.

Dealing with a system which contained huge numbers of molecules requires a statistical approach to the problem. About 1902, J. W. Gibbs (1839-1903) introduced statistical mechanics with which he demonstrated how average values of the properties of a system could be predicted from an analysis of the most probable values of these properties found from a large number of identical systems (called an ensemble). Again, in the statistical mechanical interpretation of thermodynamics, the key parameter is identified with a temperature which can be directly linked to the thermodynamic temperature, with the temperature of Maxwell's distribution, and with the perfect gas law.

Temperature becomes a quantity definable either in terms of macroscopic thermodynamic quantities such as heat and work, or, with equal validity and identical results, in terms of a quantity which characterized the energy distribution among the particles in a system. (Quinn, "Temperature")

A second mechanism of heat transport is illustrated by a pot of water set to boil on a stove - hotter water closest to the flame will rise to mix with cooler water near the top of the pot. Convection involves the bodily movement of the more energetic molecules in a liquid or gas.

The third way that heat energy can be transferred from one body to another is by radiation; this is the way that the sun warms the earth. The radiation flows from the sun to the earth, where some of it is absorbed, heating the surface.

A major dilemma in physics since the time of Newton was how to explain the nature of this radiation

4.0 CONCLUSION

With this understanding of the concept of temperature, it is possible to explain how heat (thermal energy) flows from one body to another. Thermal energy is carried by the molecules in the form of their motions and some of it, through molecular collisions, is transferred to molecules of a second object when put in contact with it. This mechanism for transferring thermal energy by contact is called conduction.

5.0 SUMMARY

A thermometer is an instrument that measures the temperature of a system in a quantitative way. The easiest way to do this is to find a substance having a property that change in a regular way with its temperature. The most direct 'regular' way is a linear one:

$$t(x) = ax + b,$$

where t is the temperature of the substance and changes as the property x of the substance changes. The constants a and b depend on the substance used and may be evaluated by specifying two temperature points on the scale, such as 32° for the freezing point of water and 212° for its boiling point.

For example, the element mercury is liquid in the temperature range of -38.9° C to 356.7° C (we'll discuss the Celsius ° C scale later). As a liquid, mercury expands as it gets warmer, its expansion rate is linear and can be accurately calibrated.

6.0 TUTOR- MARKED ASSIGNMENT

1. With the aid of annotated diagram, describe a thermometer

2. . List and explain type and classification of thermometer

3. What did you understand by kinetic theory

7.0 REFERENCES/FURTHER READINGS

UNIT 5: PRECIPITATION AND MEASUREMENT

UNIT 5: PRECIPITATION AND MEASUREMENT

1.0 Introduction

Water evaporates into the air from every water surface on Earth and from living things. This water eventually returns to the surface as precipitation. Precipitation is any form of water that falls from clouds and reaches Earth’s surface.

Precipitation always comes from clouds. But not all clouds produce precipitation. For precipitation to occur, cloud droplets or ice crystals must grow heavy enough to fall through the air. One way that cloud droplets grow is by colliding and combining with other cloud droplets. As the droplets grow larger, they fall faster and collect more and more small droplets. Finally, the droplets become heavy enough to fall out of the cloud as raindrops.

Precipitation varies across a range of space–time scales. Larger space-scale variations generally occur at longer time scales, and are associated with correspondingly larger scale phenomena in the atmosphere or ocean–atmosphere system. For example, scales of variability within an individual convective storm may vary from metres and seconds to kilometres and hours, while the El Niño–Southern Oscillation (ENSO) related scales of variability are regional to hemispheric in extent and multi-year in length (Daly, 1991).

However, these different scales are not unrelated: precipitation within individual storms is likely to be more intense and of longer duration when ENSO is causing a general enhancement in precipitation across a region. At all these time and space scales, precipitation is inherently more variable than other commonly reported climate variables, such as temperature and pressure, with the result that precipitation measurement and analysis are more demanding. Overlying this variability of precipitation within the climate system is the potential for secular changes in the intensity and distribution characteristics of precipitation.

2.0 AIMS AND OBJECTIVES

1. Examine the various form of precipitation

2. Identification of measurement and calibration of precipitation

3. Factors that modify are precipitation amounts

3.1 Types of Precipitation

In warm parts of the world, precipitation is almost always rain or drizzle. In colder regions, precipitation may fall as snow or ice. Common types of precipitation include rain, sleet, freezing rain, hail, and snow.

Rain is the most common kind of precipitation is rain. Drops of water are called rain if they are at least 0.5 millimeter in diameter. Precipitation made up of smaller drops of water is called mist or drizzle. Mist and,drizzle usually fall from stratus clouds.

Sleet Sometimes raindrops fall through a layer of air below 0°C, the freezing point of water. As they fall, the raindrops freeze into solid particles of ice. Ice particles smaller than 5 millimetres in diameter are called sleet.

Freezing Rain at other times raindrops falling through cold air near the ground do not freeze in the air. Instead, the raindrops freeze when they touch a cold surface. This is called freezing rain. In an ice storm, a smooth, thick layer of ice builds up on every surface. The weight of the ice may break tree branches onto power lines, causing power failures. Freezing rain and sleet can make sidewalks and roads slippery and dangerous

Hail Round pellets of ice larger than 5 millimeters in diameter are called hailstones. Hail forms only inside cumulonimbus clouds during thunderstorms. A hailstone starts as an ice pellet inside a cold region of a cloud. Strong updrafts in the cloud carry the hailstone up and down through the cold region many times. Each time the hailstone goes through the cold region, a new layer of ice forms around the hailstone. Eventually the hailstone becomes heavy enough to fall to the ground. If you cut a hailstone in half, you can often see shells of ice, like the layers of an onion. Because hailstones can grow quite large before finally falling to the ground, hail can cause tremendous damage to crops, buildings, and vehicles.

Snow often form water vapour in a cloud is converted directly into ice crystals called snowflakes. Snowflakes have an endless number of different shapes and patterns, all with six sides or branches. Snowflakes often join together into larger clumps of snow in which the six-sided crystals are hard to see.

3.2 Identification of Measurement and Calibration of Precipitation

Gauges that measure precipitation at a point remain the most common approach to ground-based measurement. Although radar observations have tended to supplant gauges by providing a real estimate directly, the gauge remains the ultimate reference and is the only measurement method available in many regions of the world. Other forms of surface observation include standard present-weather classifications and more qualitative historic documentary records, such as wet day counts (Ohara and Metcalfe, 1995; Rodrigo et al., 1995, 1999; Kastellet et al., 1998; Pfister et al., 1999). The first rain gauge in Europe was developed by Richard Townley in Burnley, Lancashire, in 1677. Even earlier gauge measurements are believed to have occurred in Korea, where the Japanese used a type of gauge to determine the annual rice tax each region should pay. However, analyses of these data are considered unreliable as many Koreans probably understood the tax system and modified the amounts in the ‘gauges’ accordingly.

Gauge design (often called ombrometers in earlier times) varied considerably across Europe until some form of standardization came in the late nineteenth century (Middleton, 1953, 1965). Developments were largely dependent on climate regime, with Russian, Scandinavian and Canadian scientists emphasizing designs that maximized snow catch, particularly during strong winds. Other countries realized that catch was higher if the gauge was located at ground level rather than 1–2 m above the ground. The main result of these developments has been that nearly all long-term records of precipitation are not homogeneous, exhibiting trends and/or discontinuities attributable to design changes (see Section 2.2). It has been estimated that at least 250000 different precipitation gauges have been established globally by various meteorological and hydrological agencies over the last few decades (Groisman and Legates,

1995).

Precipitation is 'any liquid or solid aqueous deposit from the atmosphere'. This includes rain, drizzle, snow, ice, hail, diamond dust, snow grains, snow pellets, ice pellets, rime, glaze, frost and dew, and any deposit from fog. The term 'rain' instead of 'precipitation' will be used here for simplicity.

There are generally two types of rain gauge — the automatic, which makes a record of the time a known sized container is filled and emptied — and the storage, which collects and stores the rain for later measurement. The copper splayed-base and Snowdon are examples of storage gauges, though increasing use is also being made of stainless steel. The notes below concern mainly storage gauges.

Make sure the amount of rain collected is not increased by condensation, splash-in, or flooding, and is not decreased by evaporation, leaks or splash-out.

Occasionally test the funnel for leaks by placing thumb over the tube end and pouring water into the funnel. Or trap air in the funnel with your thumb while lowering it upside down into a bucket of water — air will escape through

Measurements from storage gauges Manually-read gauges All measurements should be made as close as possible to 10 a.m. during British Summer Time or 9 a.m. for the rest of the year, unless you have an alternative arrangement, or you are unable to make the measurement for some reason.

Always note the date and time of your reading. If your reading is not at your usual time, make a note of why not.

If you provide values weekly instead of daily, make sure you do them on the same day each week and on Daily read the 1st of each month. Monthly gauge readings should be done on the 1st of each month.

Make sure you use the measure that is appropriate for your size of rain gauge — commonly a tapered 10 mm measure for daily-read gauges, or flat-base 50 mm measure for Octapents or large Bradfords

Methodology of Measuring Liquid Precipitation

- Carefully lift the funnel out of the base of the rain gauge.
- Lift out the collection bottle.
- Carefully pour the water into the rain measure. If there is too much for the measure, pour in less than a full measure each time, write down each value, then add them all up to get the total.
- Then empty each amount into a spare container to repeat the process to check the total.
- Carefully replace the empty bottle and put the funnel back into it.
- For accuracy, read the measure with the water surface at your eye level and the measure vertical, held between thumb and first finger.
- You can check the measure is vertical by making sure that the scales on both sides of the measure are lined up as you look through the glass.

Measuring a trace

There is a continuous ring below the 0.1 mm mark on the rain measure. This shows the limit of a trace.

If the rain amount is exactly on or above that mark, your reading should be 0.1 mm.

Record a trace when the amount is below that mark (and you are sure this is from precipitation since your last measurement).

Also, record a trace if there have been a few spots of rain, drizzle, etc. since your last reading but the bottle is dry.

If you know the weather has been dry since your last reading, do not record droplets left over from your previous measurement as a trace.

Take care to consider if there has been dew or frost, and make a note if there was.

Method of Measuring Heavy rain

- To get more information about heavy rain in short periods, you can measure the rainfall as soon as it stops.
- Put the rain back into the bottle so that the next reading is not affected.
- Note the start/stop times of the rain. If it is raining heavily through the day, check that the gauge won’t overflow by taking a reading and discarding the water.
- Remember to add the amount to the next routine measurement.
- Measuring liquid equivalent of solid precipitation
- Always try to note the type of precipitation — whether it is snow, ice pellets, hail, etc.

Slight falls

- If precipitation is not falling, take the funnel and collecting bottle indoors to melt the snow.
- Keep the funnel covered while the snow is melting to prevent evaporation.

How to Measure Snow

If snow is falling, you can either:

• pour in a measured amount of warm water (but not hot, as it may crack the bottle) to melt the snow. Measure the total then subtract the amount of warm water you poured in;

• or wrap a cloth dipped in hot water around the bottle and funnel to melt the snow and then measure it in the usual way. Make sure water from the cloth does not get into the bottle or freeze the cloth to the funnel.

Moderate or heavy falls

Measurement can be complicated because wind eddies may carry snow over or blow it out of the gauge, or even lift lying snow and blow it into the gauge. Sometimes the gauge may be completely buried in snow. However, your readings are very important, particularly for assessing the risk of flooding if the snow thaws quickly.

If there was no snow lying when you made your previous reading, take a sample of the (level, undrifted) snow by pressing the inverted funnel of the gauge downwards through the snow.

Take this sample indoors to melt it and measure the water.

It is a good idea to make three readings like this, as it is often difficult to find a representative sample of snow. Take each sample about a metre apart and report the average of these three samples.

(b) If snow was lying when you made your previous reading, you need to be able to measure the fresh snow that has fallen since. You can do this by placing a board onto and flush with the old snow. Sweep the board clean after measuring the snow on it, by taking a funnel sample as in (a), and then replace the board, ready for later measurements. You may wish to mark the place of the board with a thin cane so you can find it under new snow.

If the gauge becomes covered with snow, make a measurement as soon as you can and clear the gauge to continue collecting. Add this measurement to your next routine reading.

Solid and liquid precipitation between readings

Extra care is needed if a mixture of rain and snow has fallen. If it is a slight fall of snow, follow the guidelines for slight falls.

If the fall is moderate or heavy, then follow the guidelines for moderate or heavy falls. Don’t forget any liquid precipitation in the bottle and make a note of the amount from melting, if possible.

Do not throw away snow or hail in the funnel when you make a measurement — melt it and add it to the bottle to be measured in the usual way.

If measurement is not possible, leave the snow in the funnel to melt in its own time, but please note this on the relevant form (Rainfall data or 3208b) along with the reason, such as the examples below.

- snow filling funnel — no more snow can enter
- snow being blown out of funnel, even if not full
- drifting or blowing snow being deposited in funnel
- gauge covered by snow due to heavy falls or drifting

Measuring the depth of frozen precipitation

This includes snow, hail and ice pellets.

If, at the time of your observation, the ground representative of the station is covered by snow or other solid precipitation, then the depth should be measured and reported.

Measure the depth in centimetres using a ruler held vertically in a location free from drifting or scouring by wind.

Choose a location as near as possible to the rain gauge. Ideally, take three measurements at different places and report the average of these.

You must ensure that the ruler is either adapted to read zero at ground level or you take account of the length of the short gap between the end of the ruler and the zero mark, when you make your measurement.

Make sure your ruler does not pierce the grass or other ground surface beneath the frozen precipitation, as this will give a false reading.

Average annual precipitation is a vital piece of climatic data - one that is recorded through a variety of methods. Precipitation (which is most commonly rainfall but also includes snow, hail, sleet, and other forms of water falling to the ground) is measured in units over a given time period. In the United States, precipitation is commonly represented in inches per 24-hour period. This means that if one inch of rain fell in a 24-hour period and water wasn't absorbed by the ground nor did it flow downhill, after the storm there would be a layer of one inch of water covering the ground.

The low-tech method of measuring rainfall is to use a container with a flat bottom and straight sides (such as a cylinder coffee can). While a coffee can will help you determine whether a storm dropped one or two inches of rain, it's difficult to measure small amounts of precipitation.

A tipping bucket electronically records precipitation on a rotating drum or electronically. It has a funnel, like a simple rain gauge, but the funnel leads to two tiny "buckets." The two buckets are balanced (somewhat like a see-saw) and each holds .01 inch of water. When one bucket fills, it tips down and is emptied while the other bucket fills with rain water. Each tip of the buckets causes the device to record an increase of .01 inch of rain.

Snowfall is measured in two ways. The first is a simple measurement of the snow on the ground with a stick marked with units of measurement (like a yardstick). The second measurement determines the equivalent amount of water in a unit of snow. To obtain this ratio, the snow must be collected and melted into water. Generally, 10 inches of snow produces one inch of water. However, it can take up to 30 inches of loose, fluffy snow though as little as 2-4 inches of wet, compact snow can produce an inch of water.

Wind, buildings, trees, topography, and other factors can modify the amount of precipitation that falls so rainfall and snowfall tend to be measured away from obstructions. A thirty-year average of annual precipitation is used to determine the average annual precipitation for a specific place.

Determining and recording the average annual precipitation is very important and for a meteorologist it is a vital piece of climatic data. There are several methods used by meteorologists to measure precipitation. Precipitation is generally rainfall, but is also includes snow, sleet, hail, and other types of water that falls to the ground. It is measured over a given period of time in units.

Precipitation measurement is typically represented per 24-hour period in inches. This means that if an inch of rain fell within a 24-hour period of time and the ground didn't absorb the water, or the water didn't flow down a hill, after a storm has occurred there would be a one-inch layer of water covering the ground.

Low-Tech Measuring Method

To measure precipitation using a low-tech method, one would use a flat-bottom container that has straight sides, such as a coffee cans that is cylindrical in shape. With this method small amounts of precipitation are difficult to measure, but it can help to determine if a storm lead to one to two inches of precipitation being dropped. This method to measure precipitation is typically only used to measure rainfall.

Rain Gauges

Rain gauges are an instrument used to measure precipitation that has wide openings at the top. The rain that falls will be funneled into a narrow tube that is one-tenth the diameter of the gauges top. Since the funnel is less narrow than the tube, the measurement units are further apart than on a ruler making it possible for exact measuring to the one-hundredth of an inch. It is known as a trace of rain, when less than .01 inch of rain drops to the ground.

Tipping Bucket

This instrument used to measure precipitation records precipitation electronically or on a rotating drum. Like a simple rain gauge, it has a funnel, but on a tipping bucket, two tiny buckets are what the funnel leads to. The two tiny buckets each hold .01 inch of water and they are balanced, similar to how a sea-saw balances when there is a person on each end. A tipping bucket tips down, when one bucket fills, and then it is emptied while the other bucket fills up with rain water. Every time the buckets tip, this precipitation measurement tool records a .01 inch increase in rain.

Measuring Snow

There are two different precipitation measurement methods used to measure snow. The first instrument is similar to a yardstick and it is marked with the measurement units. It is used to measure snow that has already fallen to the ground. The second tool to measure snow is used to measure how much water a unit of snow contains. The snow has to be collected and then melted into water in order to obtain this ratio. In most cases, one inch of water will be produced by ten inches of snow. However, if the snow is fluffy and lose it can take approximately thirty inches of snow to produce the same amount of water as two to four inches of snow that is compact and wet.

3.3 Factors that Modify Precipitation Amounts

Certain factors can modify precipitation amounts, such as buildings, topography, wind, and trees. Because of this, precipitation, such as snowfall and rainfall, are measured in areas that are free of obstructions. To determine the annual precipitation for a specific area, a thirty-year annual precipitation average is used.

Precipitation is all liquid and solid products of water that are deposited from the atmosphere on the ground, and is generally caught by precipitation gauges at a point. If a spatial scale looking for is expanded, it is effective that many precipitation gauges are installed in the area or precipitation of the area is estimated using radar. Further, in the case that precipitation is expanded to a grid scale, the estimation using satellites is effective. Since the amount of precipitation using radar and satellites is necessary to compare with that of precipitation gauges, the precipitation measured by the precipitation gauges is fundamental and important values.

However, it has been recognized widely so far that gauge-measured precipitation has systematic errors mainly caused by wind-induced undercatch, wetting and evaporationmm losses and that the error of snowfall observation in high wind speeds is very large. Since many types of precipitation gauges are used in the world at present [Sevruk and Klemm, 1989], the different types are measuring different precipitation amounts, respectively [e.g., Goodison et. al., 1981. From a viewpoint of accurate precipitation data set for better understanding of the water cycle and providing them to the modeling activities, we should not neglect this scientific issue. In order to test the performance of precipitation gauges and to adjust the precipitation measurements, the World Meteorological Organization (WMO) initiated international precipitation measurement intercomparisons

4.0 CONCLUSION

Precipitation is ‘any liquid or solid aqueous deposit from the atmosphere’. This includes rain, drizzle, snow, ice, hail, diamond dust, snow grains, snow pellets, ice pellets, rime, glaze, frost and dew, and any deposit from fog. The term ‘rain’ instead of ‘precipitation’ will be used here for simplicity

5.0 SUMMARY

Weather observers use more sophisticated instruments, known as rain gauges and tipping buckets to more precisely measure precipitation. Rain gauges have wide openings at the top for rainfall. The rain falls and is funneled into a narrow tube, one-tenth the diameter of the top of the gauge. Since the tube is thinner than the top of the funnel, the units of measurement are further apart than they would be on a ruler and precise measuring to the one-hundredth (1/100 or .01) of an inch is possible. When less than .01 inch of rain falls, that amount is known as a "trace" of rain.

6.0 TUTOR- MARKED ASSIGNMENT

1. Compare and contrast the basic method of measuring liquid and solid precipitation

2. List and explain the various types of precipitation

7.0 REFERENCES/FURTHER READINGS????

MODULE 3

UNIT 1 TROPICAL CLIMATE

CONTENTS

1.0 INTRODUCTION

Any of the approaches to climate classification (empirical, genetic, or applied) might be employed logically to identify patterns of climatic change, but far less is known about the nature and causes of climates in the distant past than those of the present. This system for organising climatic types is designed to facilitate the explanatory description of world climates. It follows the approach of Koppen, relying heavily on temperature and precipitation, their seasonal regimes, and (on land) the response of natural vegetation as criteria for subdivision.

2.0 OBJECTIVES

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

- Explain different approaches to climate classifications
- Define Tropical Humid climate, and other climate types
- Explain climatic characteristics of tropical climate and other climatic types

3.0 MAIN BODY

3.1 Approaches to Climate Classification: Climate classification has three interrelated objectives: (a) to bring order to large quantities of information, (b) to speed retrieval of information, and (c) to facilitate communication. It is concerned with organization of climatic data in such a way that both descriptive and analytical generalizations can be made, and it attempts to store information in an orderly manner for easy reference and communication, often in the form of maps.

Thus, in the design of a climatic classification we should begin by defining the purpose. There are three fundamental approaches to climatic classification. (1) empirical, (2) genetic, and (3) applied. Together they constitute a classification of classifications, but the features of all three may be incorporated into a single system.
Empirical classifications are based on the observable features of climate, which may be treated singly or in combination to establish criteria for climatic types. Temperature criteria, for example, might yield ''hot'', ''warm'', ''cool'', and ''cold climates, each of which can be defined in terms of strict mathematical limits. Heat and moisture factors, have dominated empirical classification, but all elements are inherently significant for one purpose or another.

Genetic classification attempts to organize climates according to their causes. Ideally, the criteria employed in the differentiation of climatic types should reflect their origins if climatology is to be explanatory as well as descriptive. In practice, however, explanations are often theoretical, incomplete, and difficult to quantify. Genetic classification also is subject to theoretical biases, a system based on causes tends to perpetuate faulty or over-generalized theories. A common genetic approach attempts to distinguish the relative continentality or maritimity (sometimes termed oceanity) of a climate. In practice, indices to express the influences of land of water surfaces have been determined from various empirical data, mainly temperature, precipitation, wind, and air mass frequency.

Applied (also known as technical or functional) classifications of climate assist in the solution of specialized problems that involve one or more climatic factors. They define class limits in terms of the effects of climate on other phenomena. Outstanding among modern attempts at climatic classification are those that seek a systematic relationship between climatic factors and the world pattern of vegetation. Natural vegetation integrates certain effects of climate better than any instrument that has so far been designed, and it is thus an index of climatic conditions.

There have been diverse opinions on what should be the basis for climate classification. The climate of any area is not created by a single climatic element, but by the distinctive combination and interrelation of several elements. The many variations of climate from place to place as determined by different combinations of climatic controls produce a correspondingly large number of climatic types. For each type of climatic, certain important common characteristics are recognized, and these enable the vast amount of climatic data available on the surface of the earth to be grouped together, so that some distributional patterns become apparent.

However, it is generally agreed that four main basic divisions can be recognized. These are (a) the tropical humid climates (b) the middle latitude humid climates (c) the arid climate and (d) the polar and arctic climates. In the discussions that follow, it is only the description of the characteristics of the tropical humid climates is given

3.2 What is Tropical humid (KOPPEN'S 'A') Climates

The definition of the term tropical humid climate is a problem for which there is no completely acceptable solution. The term, humid has for example been defined in many ways depending upon the context in which it is used. Two issues need to be resolved. The first one is that of the length of seasonality before a station is classified as humid. The second one relates to the basis for delimiting the boundaries. One of the most widely used system of classification in its original form or with modifications is that of Wladimir Koppen (1846 – 1940), a German biologist who devoted most of his life to climatic problems. Koppen aimed at a scheme which would relate climate to vegetation but would provide an objective, numerical basis for defining climate types in terms of climatic elements. Kuchler in 1961 employed vegetation as a criteria for delimiting the humid tropics and defines humid tropicality as optimum conditions for plant growth, organic productivity, agriculture and forestry. B. J. Garnier in the same year, used rainfall, temperature and vapour pressure as his criteria. Instead of temperature and precipitation which were employed by Koppen, the concepts of precipitation effectiveness and temperature efficiency were introduced by Thornthwaite in his 1931 classification. In determining his climatic types, Thornthwaite, therefore used empirical approach, noting vegetation, soil and drainage pattern in relation to climatic characteristics.

3.3 Characteristics of Tropical Climates

The tropical humid climates experience high temperatures with a mean of about 27^oC throughout the year. They lie in low latitudes near the equator, covering between the equator and 5^o or 6^o north or south of the equator. They are also generally in the belt of Intertropical Convergence and the trade winds which originate in the subtropical high pressure cells around latitude 30^{o}N or S, and flow towards the equator. The location in the low latitudes implies that the area is characterized by all year abundance of insolation.

3.1.1 Tropical Rainy Climate: Tropical rainy climates are located on lowlands on or near the equator. They are also found on tropical coasts exposed to trade winds and backed by highlands. The climate is dominated by the presence of plentiful rainfall, well distributed throughout the year, and by temperatures which are high with small diurnal ranges. The ranges are in the vicinity of 8^o to 10^{o}C around an average daily temperature of 25^o to 28^{o}C. Temperature conditions are remarkably steady and vary little from day to day or month to month. The intertropical convergence zone dominates the greater part of the tropical rainy climates.

3.3.2 Tropical Dry climates: These climates constitute a direct contrast to tropical rainy climates. We have called them ‘dry’ because characteristically have too little rainfall at any time of the year to sustain much vegetation. They are, indeed the great tropical deserts of the world. They coincide with the zone dominated with subtropical high pressure cells. The principal areas covered by this climatic type are in the northern part of Africa (the Sahara and Somalia), the west coast of southern Africa, part of south-eastern Asia, from Arabia to Pakistan, and in both North and South America. Although described ‘dry’, these climates do have precipitations at atimes.

3.4 Other Climate Types

Middle Latitude Humid climates. The most distinguishing characteristic of the middle latitude humid climates is the lack of constant heat of the tropics and the constant cold of the polar areas

Polar and Arctic climates. In the polar climate mean monthly temperatures are all below 0^{o}C and vegetation is entirely lacking. Snow, ice, or barren rock covers such areas. The polar climate and the associated icecaps predominate over most of Greenland, the permanent ice of the Arctic Ocean, and Antarctica. The lowest mean annual temperatures are those of the polar icecaps on Greenland and Antarctica. Monthly means in the polar summers are well below freezing in spite of the continuous daylight. Winters in the polar climates are colder still; monthly means range from -20°C to less than - 65°C. Diurnal variations of temperature are small throughout the year in polar climates. In summer they decrease generally toward the poles, where the change in altitude of the sun during the day is least.

Arid Climates. The classification of arid and semi-arid climates presents one of the most difficult climatological problems. The two most commonly employed parameters in the literature are temperature and precipitation. Examples of the definitions of the concept are those by Koppen and Thornthwaite in their respective climatic classifications. Of the many indices developed for defining aridity, none is completely satisfactory. They all express the idea of excess of potential evapotranspiration or water loss over precipitation. The semi-arid types are essentially a transition zone from the very dry regions to the bordering moister climates. In contrast to the semi-arid climates, the arid climates are located in the core areas of the regions of air subsidence, divergence and temperature inversion, which are opposed to the development of fronts or atmospheric disturbances which might give rainfall. The tropical arid and semi-arid climates are centred approximately on the latitudes 20° to 25° N and S, where the controlling air masses are those which subside in the subtropical highs. The arid and semi-arid climates of the middle latitudes primarily result from their location deep into the interior of the continents, and thus, far removed from the oceans, which are primary sources of atmospheric moisture (ie, the principal control of the middle latitude deserts is their location in the continents far removed from the windward coasts). The dry climates of the middle latitudes differ from the tropical arid and semi-arid climates in two important respects. (a) average temperatures are lower and (b) migrating winds and pressure systems are not the chief controlling factors. The tropical arid and semi-arid area, an important temperature characteristic is the large annual range, a reflection of continental location. In common with the tropical arid and semi-arid climates, the middle latitude arid and semi-arid climates are characterized by low precipitation, usually lower than 500 mm for the semi-arid climates and less than 250 mm for the completely arid climates.

Exercise 1.1

1. What are the objectives of climate classification?
2. Explain the different approaches to climate classification
3. Write a short note on Tropical humid climate

4.0 SUMMARY

This unit has within its limit defined and explained tropical humid climate and the different approaches to climatic classifications. Apart from explaining the characteristics of tropical humid climate, other climate types and their characteristics were also identified as middle latitude humid climate, polar and arctic climate, and arid climate.

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UNIT 2: WEATHER AND CLIMATIC HAZARDS IN THE TROPICS

CONTENTS

1.0 INTRODUCTION

Sometimes people make daily adjustments to the changing weather, they also face decisions involving climate when planning a vacation or when they contemplate a change of residence for any reason, be it improved economic or social status, retirement, health, or climate itself. Human perception of climate and its hazards embraces the criteria of cause, magnitude, time and duration, spatial arrangement, uncertainty, and resultant effects. Many weather and climatic hazards are linked to major natural disasters. The nature of the hazards may vary from country to country, but their implications to society remain a common factor. The characteristics of weather hazards in the tropics have been explained and recent examples given in the passage.

2.0 OBJECTIVES

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

- Explain characteristics of weather hazards in the tropics
- Explain characteristics of climate hazards in the tropics
- Mention some weather and climate hazards in the tropics
- Know the consequences of changes in our future climate

3.0 MAIN BODY

3.1 Weather and Climatic Hazards in the Tropics

Characteristics of Weather hazards in the tropics

Although tropical weather have other features similar to those of mid-latitudes storms, they generally do not exhibit sharp discontinuities of temperature. Many have weak pressure gradients and lack well defined-wind systems. Extensive, shallow lows occasionally bring long periods of overcast weather with continuous rain. In the intertropical convergence there may be convective activity and thunderstorms, the smallest and most frequent type of tropical disturbance. Convergence tends to increase when the equatorial trough of low pressure moves poleward in summer, producing bands of cumulonimbus clouds and high overcasts of cirrus. A common feature of tropical weather is the easterly wave, which normally forms in the convergent flow of trade winds and moves slowly from east to west. Squally weather and precipitation frequently accompany such a disturbance. Some easterly waves move poleward and curve toward the east to become extratropical cyclones. Others may develop vortices, become tropical cyclones, and even grow to hurricane intensity. The violent and destructive forms of tropical cyclones are much better known than the weaker variety although the former are, fortunately, much less common. They originate over the tropical oceans only. In the Caribbean and off the Pacific Coast of Mexico they are known as hurricanes; in the seas off China, the Philippines, Japan, and the other islands of western Pacific they are called typhoons; in the Indian Oceans they are simply called cyclones, a term which should not be confused with cyclones in general. In the Southern Hemisphere they occur east of the African coast and along the northwest and northeast coast of Australia.

Some Weather Hazards

Recent weather hazards of the last few decades have been rather conspicuous to such an extent that the whole world is expressing the view that a major global climate change is going on. It has become aware of the increasing degree of devastation and insecurity to lives and property by weather hazards and the resultant impacts on the socio-economic development of nations. Records show that weather hazards date back from history. The existence of such hazards as droughts, desertification, storms, floods, heat waves, global warming, hurricanes, acid rains, erosion etc are very rampant and have, over the last couple of years, become one of the world’s major topical subjects. In the United States and the Caribbean for example, several thousand lives and property have been lost in the past through the occurrence of hurricanes and tornadoes. On the other hand, the ravages of tropical storms in India, Bangladesh and Pakistan are still annual events each time sweeping away whole villages and destroying crop-lands. In recent years, severe drought has affected countries in sub-saharan Africa; Sudan, Madagascar, Mozambique, Comoros, Mauritius, Reunion, Seychelles, and China have been hit by worst flooding many times.

3.2 Characteristics of Climatic Hazards in the tropics

Climate and its variability also affect many aspects of socio economic development and can take on the form of a meteorological hazard. In Africa, and elsewhere, an appraisal of climate as a natural resource is important, especially as this resource may now be subject to significant change. Projected global climate change due to the so called ‘’greenhouse effect’’ would be an unprecedented event in the history of human civilization. Its magnitude is comparable only with changes on a geological time scale, and its rate is going to be much swifter than that of any past natural long term climatic fluctuations. It is this rate of change that makes us consider future climate change as a hazard, since ecological and socio-economic systems would find it difficult to adapt to it without serious implications.

Expected changes in Climatic Hazards

Future climate change is very often referred to in terms of climate warming. Indeed, changes in atmospheric concentration of ‘greenhouse gases’ or GHGS (Carbon dioxide and other trace gases) would lead to warming near the Earth’s surface and in the troposphere. It is generally agreed that the global mean surface temperature has increased by 0.6^o to 0.7^oC since 1860, when instrumental records began. Certainly many other meteorological and hydrological variables will change. There may be changes in regional climate patterns, global atmospheric circulation, and sea level. This can lead to changes in frequency, magnitude and location of such hazardous phenomena as floods, storms and droughts. Sea level rise associated with this warming, which is estimated to be between 20 to 140cm, will constitute a very serious hazard for many islands and low lying coastal areas, especially in the topics.

Exercise 1.1

1. What are the characteristics of weather hazards in the tropics?
2. What are the consequences of changes in regional future climate patterns?
3. (a) Enumerate some major weather hazards in the tropics
   (b) Explain, how some major weather events can lead to hazards in the tropics

4.0 Summary

This unit has within its limit explained the characteristics of weather and climatic hazards in the tropics. Some tropical weather hazards have also been mentioned in the passage. Also explained are the consequences of the regional future climate changes in the tropics.

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UNIT 3: PHYSIOLOGICAL COMFORT

CONTENTS

1.0 INTRODUCTION

Human health, energy, and comfort are affected more by climate than by any other element of the physical environment. Physiological functions of the human body respond to changes in the weather, and the incidence of certain diseases varies with climate and the seasons. Our selection of amounts and types of food and clothing also tends to reflect weather and climate. The state of the atmosphere even influences our mental and emotional outlook. Among the climatic elements that affect the human body, the more important are temperature, sunshine, and humidity. The human body maintains a balance between incoming and outgoing heat by means of the chemical process of metabolism and the physiological processes of thermoregulation in response to external factors of radiation, temperature, moisture, and air movement.

2.0 OBJECTIVES

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

- Explain what is physiological comfort
- Explain climate and human comfort
- Mention some aspects of human physiology
- Know the basic principles of physiological climatology

3.0 MAIN BODY

3.1 What is physiological comfort?

Physiology is the science of the normal functions of living things, especially animals. Therefore, physiological comfort simply refers to the normal functions of living things, (plants and animals). Human health and comfort suggest another possible approach to defining climatic types, with potential applications in clothing design, housing, physiology and medicine. In much the same way that heat and moisture data are used to determine critical boundaries for natural vegetation or crops, optimum and limiting values of climatic elements afford a basis for classification in terms of human response. Everyone is aware that the reaction of the body to a given air temperature is conditioned by wind, humidity, and sunshine. An individual's state of health, emotional outlook, type of clothing, degree of acclimation, and a host of other factors also influence personal reaction to climate. On the other hand, CO_2 is essential for life on earth. Plants, through photosynthetic processes, take up CO_2 and produce oxygen in the presence of sunlight, thereby synthesizing organic compounds from inorganic raw materials and becoming food for other organisms.

3.2 Climate and human comfort

In considering climate and human comfort we are dealing with an application of climatology which looks at climatic conditions from the viewpoint of their effects on or relationship with human beings. Such a study is often known as physiological climatology or human bioclimatology. Most of us are aware of feeling different on different days. Very often this is due to the weather. People find some days exhilarating and stimulating: others too hot or too humid or too cold for comfort.

Some aspects of human physiology**:** Human beings form part of a general group of living organisms known as homeotherms. This term is used for those organisms that have a mechanism for regulating their internal body temperature so as to keep it at the correct level for healthy operation in changing atmospheric or environmental conditions. Homeotherms contrast in this respect with organisms known as poikilotherms (a lizard is an example of a poikilotherm) have no internal regulating process and have to conform to the conditions of their surroundings. Human beings produce internal heat through the chemical breakdown of carbohydrates and the food they eat. The process is known as metabolism and the rate at which it generates heat is known as metabolic rate. Every homeotherm has an ideal internal body temperature at which the rate of chemical combustion is at such a level that the organism does not have to deal with too great extremes in its rate of chemical combustion.

3.3 Basic principles of physiological climatology

1. Metabolic heat production: One principle is to recognize the importance of action as a producer of heat in a human being. Different activities affect a person's metabolic rate. Some examples are sleeping, sitting, typing, standing etc.

2. Clothing insulation: There is insulation provided by the clothes. In the example of an ideal comfort, the person considered was wearing light clothes.

3. Heat exchange with environment: There is exchange of heat between a human being and the surrounding conditions. Heat loss has been shown to occur by three main physical processes: radiation, convection and evaporation. All three depend on a gradient, either of temperature or humidity, between a human being and the surroundings.

Exercise 1.1

1. What is physiological comfort?
2. Explain the concept of climate and human comfort
3. Discuss some aspects of human physiology
4. Critically examine the basic principles of physiological climatology

4.0 Summary

This unit has within its limit explained what a physiological comfort is. The passage also examined critically the effects of climatic elements and human comfort. In much the same way as animals, man reacts unconsciously in his first responses to favourable or unfavourable microclimatic conditions. Conscious direction of microclimatic conditions extends to the control of the plants and animals that provide nourishment for men, and to their own lives, homes, and work. An individual's state of health, emotional outlook, type of clothing, degree of acclimation, and a host of other factors also influence personal reaction to climate. Also explained are some aspects of human physiology, for example, those organisms that have a mechanism for regulating their internal body temperature so as to keep it at the correct level for healthy operation in changing atmospheric or environmental conditions. Finally, the basic principles of physiological climatology are also introduced.

5.0 References / Further Readings

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Module 4

Module 4

UNIT 1 CLIMATE AND URBAN PLANNING IN THE TROPICS

CONTENTS

1.0 INTRODUCTION

Climate is an active factor in the physical environment of all living things. Its influences on human welfare range from the immediate effects of weather events to complex responses associated with climatic change. City populations are expanding by natural increase and also because of urban migration. The increase of population in cities is accompanied by an expansion of buildings for accommodation and also to provide for industrial and commercial exploitation. The process of urbanization produces major and fundamental changes to the surface and atmospheric properties of the area which has been urbanized.

2.0 OBJECTIVES

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

- Understand man and microclimate
- Explain Climate and Urban Planning in the tropics
- Know the characteristics of City Climates

3.0 MAIN BODY

3.1 Man and Microclimate

Micro-climate is the climate of smaller regions near the ground where nearly all biological entities on earth are affected by the spatial and temporal variations of temperature, humidity, radiation and other climatic factors.

In much the same way as animals, man reacts unconsciously in his first responses to favourable or unfavourable microclimatic conditions. Men are also forever creating new kinds of microclimate. Every building constructed displaces the original climate of its site, creating a warm, sunny, and dry climate with a southern exposure on one hand, and a shady, cold, and damp northern climate on the other. Industrial works are shrouded with thick haze which alters the whole radiation economy. Replacement of the original order of creation by the all-encompassing economic order ordained by man makes changes in the general climate of a country as well, and the measures adopted to further the advancement of industry are, in a long-term view, by no means always such that they also favour the advancement of life.

History has taught us more than once that increasing urbanization has brought in its train great damage to the heat and water budgets of a land. The risk of bringing about a deterioration of climate by human intervention depends on the type of climate, and is greatest where plant life is fighting for its existence because of a shortage of water or heat.

3.2 Climate and urban planning in the tropics

As more and more people crowd into the world’s cities, it becomes increasingly important for city planners and developers to ensure that cities are comfortable places to live in. One step towards this is to recognize the contribution of climate to this objective. It is true that most cities have not been planned with climatic principles in mind. Urban expansion is taking place in many areas; also redevelopment and construction take place as city centres age and need renewal. Such activity provides an opportunity for ‘climatic engineering’ to enter into the urban development picture along with other considerations. Heat island and pollution effects rank high in the local climate produced by a city. ‘Climatic engineering’ should aim to reduce to a minimum their adverse consequences.

In tropical cities it is especially important to try to reduce the additional heat stress produced by urbanization. Planning in relation to natural climatic conditions can help towards this end. Many tropical cities are coastal. The sea breeze effect, therefore, can be used to help ventilate the city by day. Yet it is surprising how many high-rise buildings line the seashore of tropical cities, effectively blocking the sea-breeze from cooling the built-up area behind them. At night outgoing longwave radiation and the effects of nocturnal air drainage may be used in a cooling role. Few cities are designed to take full advantage of this. To do so involves radiation from vegetation, parks and water surfaces which, unlike buildings, will not have absorbed and stored large amounts of heat during the day. Moreover, the presence of vegetation and parks within the city fabric will contribute notably to a reduction in the city heating effect. The object of planning is to achieve the best possible outcome. It involves making appropriate land-use decisions backed up by appropriate environmental policies. Climatologists can contribute through the data they provide. They can also contribute by emphasizing the benefits that can be achieved by recognizing and putting into practice the principles of climatic science in the field of urban development and growth.

3.3 City Climates

The total transformation of natural landscape into houses, streets, squares, great public building buildings, skyscrapers, and industrial installations has brought about changes of climate in the region of large cities. The basic reason for the differences found in city climate is the alteration of the heat and the water budgets. This is caused by natural ground becoming largely replaced by stone, from which precipitated water is quickly lost, and because the roughness of the surface has been increased by the presence of buildings. In addition, heat is supplied by domestic and industrial fires, and finally, city air is rich in dust stirred up by traffic, and in exhaust fumes from vehicles, from fires, and from industrial works. Cities concentrate people and their activities in small areas, thereby providing excellent opportunities to examine cultural modifications of climate. Urban areas also differ from their rural counterparts in surface materials, surface shapes, and heat and moisture sources. In turn these affect radiation, visibility, temperature, wind, humidity, cloudiness, and precipitation. Concentrations of pollutants in the air above a city create an urban aerosol, which attenuates insolation, especially when the sun angle is low. Temperatures normally are highest near the city centre and decline gradually toward the suburbs, beyond which there is a steep downward temperature gradient at the rural margin. Owing to the blanketing effect of pollutants on the radiation budget, diurnal ranges of temperature are less in urban areas than over the countryside.

Exercise 1.1

1. How has man influenced the microclimatic factors in his environment?
2. What are the necessary climatic requirements for urban planning in the tropics?
3. (a) Examine the extent of modification of City climate by man.
   (b) How does the urban climate differ from its rural counterpart?
4. What are the climatic characteristics of an urban area?

4.0 Summary

This unit has within its limit explained the relationship between man and the microclimate. Replacement of the original order of creation by the all-encompassing economic order ordained by man makes changes in the general climate of a country as well, and the measures adopted to further the advancement of industry are, in a long-term view, by no means always such that they also favour the advancement of life. Heat island and pollution effects rank high in the local climate produced by a city. Planning in relation to natural climatic conditions can help towards this end.

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UNIT 2 TROPICAL DISTURBANCES

CONTENTS

2.0 INTRODUCTION

Daily synoptic streamline charts show many features which are absent from mean annual or monthly charts. This is due to the smoothing which occurs when average values are taken. The synoptic systems found on daily charts include various types of eddies or vortices, wave patterns and convergence zones. These may be associated with convergence and divergence. Ascent or descent of the air takes place, resulting in many different types of weather on a synoptic scale. These, in turn are modified by local effects in the various localities. The most vigorous tropical disturbances are the intense cyclonic storms that form over warm tropical waters.

2.0 OBJECTIVES

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

- Define a tropical disturbance
- Identify some of the synoptic systems associated with the tropical disturbances
- Know where and how the disturbances are located in a weather chart

3.0 MAIN BODY

3.1 What is Tropical Disturbance?

We shall use the term tropical disturbance to describe any feature of the circulation which disturbs the basic tropical air currents. Unlike the mid-latitude depressions, tropical disturbances are rarely frontal. They vary widely according to their location, and there are many different systems of classification. The most commonly recognized are: (a) Wave disturbances (b) Monsoon depressions (c) Linear depressions (including line squalls or other equatorial trough disturbances) and (d) Cyclones and Cyclonic vortices

Wave disturbances: These are troughs developed in the trade winds and in the equatorial easterlies. They are unlike depressions, being scarcely detectable in the surface pressure field, but form a closed low pressure area in the middle troposphere. They are sometimes referred to as tropical streamlines. The origin of the phenomenon is rather difficult to trace. Possible causes include weak trade-wind inversions which tend to disturb the pressure and wind systems, and the penetration of cold fronts into the low latitudes. A sequence of weather conditions usually occur with the passage of these waves. In the ridge a head of the trough, fine weather with scattered cumulus cloud and some haze occur. Close to the trough are cumulus clouds, occasional showers and poor visibility. Finally, behind the trough, the wind veers in the direction, heavy cumulus and cumulonimbus clouds form with moderate to heavy thundery showers, temperatures decrease and there is a general clearing of the air. This is very similar to the passage of mid-latitude depressions.

Monsoon Depression: These are weak cyclones which occur in many portions of oceanic and continental tropics. They are most prominent over southern Asia in the mid-summer, when the equatorial low pressure is extended to the Asiatic continent. They also happen in West Africa and Central America. They move westward in strong easterly air stream around 8,000 – 10,000m (25,000 to 30,000 feet) above the ground surface. There are various types depending on the intensity of the development.

Linear Depressions: These comprise line squalls, linear depressions, or equatorial rough disturbances and are another variant of the weak cyclonic weather common in the tropical regions. They are associated mainly with a trough of low pressure at the surface. They happen in the region where trade winds converge, causing a major building of tropical cumulus clouds. The weather pattern associated with linear systems is often traced to the break up of the trade wind system into small cyclones which move from east to west. These cyclones form disturbance lines which are very important causes of rainfall particularly in West Africa.

Tropical cyclones: These are the violent disturbances termed hurricanes in the Atlantic and eastern Pacific, typhoons in the western pacific and cyclones or hurricanes in other areas of occurrence. Unlike the middle latitude depressions, they are found only at certain seasons in certain regions of the tropics. The life cycle of a tropical cyclone averages 6 days from the time of their inception until they enter land and recurve into the middle latitudes. The regions of formation are normally characterized by high temperatures and high water vapour content. The first sign of the development of a tropical cyclone is a pressure drop accompanied by a wind circulation which is clockwise in the northern hemisphere and anti-clockwise in the south. After some days, the pressure in the centre drops more rapidly and the winds get stronger. The wind rises to gale force over a confused sea; the clouds get thicker and lower finally forming dense nimbostratus with continuous rain. At maturity, the surface pressure at the centre of the cyclone no longer falls and the wind speeds no longer increase. Many hurricanes sometimes break out of the tropics into the middle latitudes and thus recurving poleward and subsequently eastward into the belts of westerlies. Alternatively, others may move over the land and dissipate quickly within the tropics, particularly in areas where the convective rains generally cool the air in the low levels. The centre of the tropical cyclone known as the eye is usually a region with diameter varying from 16 and 32 km (10 and 20 miles) at the surface, and widening upwards to about 50 or even 80 km at a height of about 10 km.

3.2 Location of tropical disturbances on a weather map

Daily synoptic streamline charts for tropical regions sometimes indicate more complex patterns than those found on mean annual or monthly charts. Various types of eddies, indrafts, outdrafts, wave patterns, convergence zones, etc can be located. Particular attention needs to be given to areas of convergence and divergence, as ascent or descent of the air in those regions can lead to many different types of weather on the synoptic scale. In many localities local effects, such as topography or differential heating, may accentuate these developments. In the absence of tropical disturbances, the synoptic charts would consist of more or less smooth straight streamlines with no variations in wind speed.

Exercise 1.1
1. Mention some the tropical disturbances you know and describe any two.
2. Describe the characteristics of a tropical cyclone
3. Explain how some physical processes can lead to the formation of different types of weather on a synoptic scale.

4.0 Summary

This unit has within its limit explained what a tropical disturbance is all about. The various types of tropical disturbances have been mentioned and discussed in the passage. Some synoptic systems associated with the tropical disturbances have been mentioned. The synoptic systems found on daily charts include various types of eddies or vortices, wave patterns and convergence zones. The most vigorous tropical disturbances are the intense cyclonic storms that form over warm tropical waters.

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UNIT 3 TROPICAL AGRO-CLIMATOLOGY

CONTENTS

1.0 Introduction
2.0 Objectives

1.0 INTRODUCTION

There is perhaps no other human activity which is more affected by weather than agriculture. Weather and climate pervade every phase of agricultural activity. No doubt, crop growth depends on its genetic constitution, but it is the environmental condition of soil and climate, which affects crop in all its phenological stages and ultimately determines its yield. It will be obvious that meteorological expertise and advice can make a valuable contribution to decisions in agricultural management and practice, both on climatological-strategic matters and on actual weather applications for tactical decisions. Too often the agricultural community has to ask for raw weather data series, to be analysed by agrospecialists without much real meteorological insight, because the weather service is not providing the minimal locally necessary amount of agro-climatological information. The weather service should know and care about more operational application aspects of their data than is needed for synoptics.

2.0 OBJECTIVES

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

- Define Agro-climatology
- Identify some of the agro-climatic data used in the tropics
- Know the importance of agro-climatic classifications

3.0 MAIN BODY

3.1 What is Agro-Climatology?

Agro-climatology deals with the science for the study of climatic features such as distribution of wind speed, temperature, humidity etc, and factors such as energy and water balance characteristics of underlying surfaces that influence them. It deals with environmental conditions of open surfaces, inside and above crops, forests and other vegetation. The climatic water balance provides, apart from actual evapotranspiration, an assessment of water surplus, water deficit and run-off. Climate and agriculture are closely linked.

Benefits of Agro-climatological studies: Apart from many applications of climatology and weather forecast to current agricultural problems, Agro-climatological studies can be of considerable interest in three other fields.

1. Selection of the production sites for a given crop. This is because lack of detail knowledge on plant-climate relationships has hampered intelligent planning of land use on a wider scale.

2. Climatic analysis for proper interpretation of results of agronomic experiments. A comprehensive climatic analysis and documentation with a limited number of field trials would yield more practical information than a large number of trials without such analysis.

3. Irrigation, row spacing, timing of fertilizer application, variety selection and transplanting, etc, can best be planned and implemented when viewed in the light of appropriate climatic analysis.

3.2 Types of agro-climatic information that is required

(a) Air Temperatures

Temperature probabilities
Degree Days
Hours or days above or below selected temperatures
Interdiurnal variability
Maximum and Minimum temperature statistics
Growing season statistics (onset and cessation)

(b) Precipitation

Probability of specified amount during a period
Number of days with specified amounts of precipitation
Probabilities of thunderstorms, hail
Probability of extreme precipitation amounts

(c) Wind

Wind rose (frequency distribution per direction sector of 30^o or 45^o width)
Average wind speed (hourly, daily)
Maximum wind (average and gust)
Diurnal variation
Hours of wind less than selected speed

(d) Sky cover, sunshine, radiation

Percentage of possible sunshine
Number of clear, overcast, scattered, and Few
Amounts of global and downward IR radiation

(e) Humidity

Probability of specified relative humidity
Duration of specified threshold exceedance of humidity

(f) Free water evaporation

Total amount
Diurnal variation of evaporation
Relative dryness of air
Evapotranspiration

(g) Dew

Duration and amount of dew
Diurnal variation of dew
Association of dew with vegetative wetting
Probability of dew formation with season

(h) Soil temperature

Mean and standard deviation at standard depth

Depth of frost penetration
Probability of occurrence of specified temperatures at standard depths
Dates when thresholds values of temperature (germination, vegetation) are reached

(i) Soil moisture
Mean value at standard depth

Plants and crop microclimate: development and growth of plants depend on environmental conditions at every stage. An understanding of the interrelation between the structure of the environment (ground cover, surface slope, degree of shelter, etc) and the local microclimate, in the crop and around the crop, may result in actions aimed at the long-term improvement of the growth situation. Even before planting, the influence of the weather should be considered. The quality of the seed sown depends on meteorological conditions during the year in which it was produced. The productivity of long-rotation crops, e.g, vines, fruit and forest trees, can also be affected by weather experienced over many previous seasons. Post-harvesting operations, such as drying grass and other crops, and the capacity to maintain the quality of stored farm crops are affected by seasonal weather. Weather and climate are important in the occurrence of forest, bush and grass fires, and knowledge of them is important for the defence against such hazards.

3.3 Agro-climatic classification

The saying that farmers learn to live within the limitations of their local conditions through trials and errors over generations, is no longer completely true. It is now evident, that deriving maximum benefit from agriculture and silviculture calls for an in depth knowledge of agro-climatic conditions, without which the most effective cropping pattern and the development of additional irrigation schemes, which are needed in different zones, cannot be planned. Most of the earlier climatic classifications used vegetation as an index of climate. Starting at the middle of the 20th century, a group of climatologists tried to develop climatic / agro-climatic classifications, with a view to using them for maximizing crop production. The Moisture Availability Index (MAI) developed by Hargreaves is now well recognised in agroclimatic classification. The index is the ratio of probabilistic rainfall and potential evapotranspiration. Each country is expected to develop its own regional classification based on its climate types.

Exercise 1.1

1. What are the advantages of Agro-climatological studies?
2. Why do farmers need Agro-climatological data
3. Enumerate some of the Agro-climatological information required in farm planning

4.0 Summary

This unit has within its limit explained what agro-climatology is all about. The passage has been able to identify some of the agro-climatic data that are used in the tropics. The benefits of agro-climatological studies have also been explained. Climatic analysis assumes a great significance in nearly every phase of agricultural activity, from the selection of sites to agronomic experiments and from long term planning to daily operatins.

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