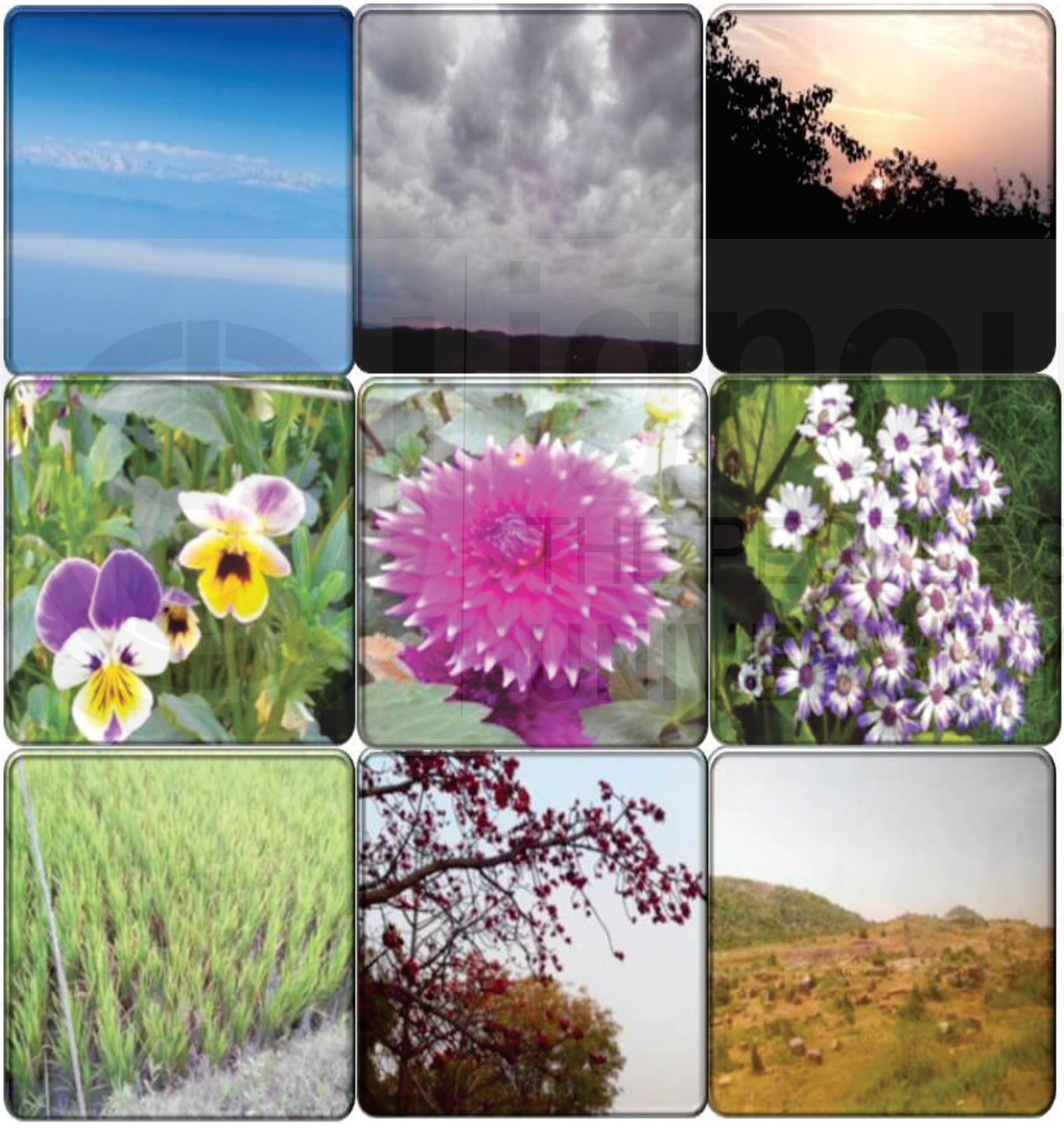
Indira Gandhi National Open University
School of Sciences

MGG-005
CLIMATOLOGY



CLIMATOLOGY

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MGG-005

CLIMATOLOGY

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FUNDAMENTALS OF CLIMATOLOGY

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ATMOSPHERIC PROCESSES

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MGG-003: CLIMATOLOGY (COURSE INTRODUCTION)

Climatology, as a subdivision of Physical Geography, focuses on analysing the long-term patterns and dynamics of climate and atmospheric conditions across different regions of the earth. It plays a crucial role in unravelling the complex interactions between natural atmospheric processes and human activities, shedding light on climatic changes at both local and global scales. The overarching objectives of climatology encompass equipping learners with fundamental knowledge regarding weather, climate, and the composition of the atmosphere, while also familiarising them with diverse atmospheric phenomena such as temperature variations, pressure systems, and general atmospheric circulations. Furthermore, it aims to deepen understanding about significant mechanisms like monsoons, air masses, and atmospheric disturbances. Additionally, climatology endeavours to elucidate broader concepts including global climates, climatic classification systems, and the multifaceted issue of climate change, alongside exploring its practical implications across various domains.

Block 1 introduces the learners to the foundational concepts of climatology, exploring its scope, development, and relationship with meteorology. It covers the distinction between weather and climate, the elements and controls of weather and climate, and provides an overview of the earth's atmosphere including its origin, composition, and structure.

Block 2 delves into the mechanisms driving climate systems, focusing on insolation, heat balance, temperature variations, pressure systems, and atmospheric circulations. Learners gain insights into the sources of energy, factors influencing temperature distribution, measurement of atmospheric pressure, and the patterns of global atmospheric circulation.

Block 3 explores the phenomena that disrupt regular patterns of weather and climate, such as humidity, precipitation, monsoons, air masses, and cyclones. It investigates the hydrological cycle, the dynamics of monsoon systems, the characteristics of air masses, and the formation and behaviour of cyclonic systems.

Block 4 examines various approaches to categorising climates, including empirical, generic, and genetic methods. It provides detailed analyses of renowned climatic classification systems like Koppen and Thorthwaite, elucidating their bases, classifications, and evaluations. Learners also explore the distinct climatic regions of the world, spanning tropical, temperate, and polar zones.

Block 5 deals with contemporary issues in climatology and addresses pressing concerns such as climate change and variability, emphasising historical chronologies, evidences, and theories of climate change. It investigates human-induced climate change, including the impacts of atmospheric pollution and global warming, and explores adaptation and mitigation measures. Additionally, learners delve into weather forecasting methodologies and the practical applications of climatology in diverse societal and environmental contexts, encompassing water resources, biodiversity, agriculture, tourism, housing, and public health.

We wish you good luck for studying this course. We suggest for any assistance regarding this course, you can contact at: satyaraj@ignou.ac.in

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CLIMATOLOGY

BLOCK

1

FUNDAMENTALS OF CLIMATOLOGY

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BLOCK 1: FUNDAMENTALS OF CLIMATOLOGY

This block introduces the learners to the foundational principles of climatology through three main units.

Unit 1 explores the meaning, scope, and historical development of climatology, emphasising its relationship with meteorology and the various scales and sub-fields within the discipline.

Unit 2 discusses the distinction between weather and climate, detailing the elements of each and the factors that control their patterns and variations.

Unit 3 provides an overview of the earth's atmosphere, covering its origin, evolution, composition, and structural layers, thus laying a solid groundwork for further study in Climatology.

After studying this block, you should be able to:

- explain the meaning and basics about climate;
- compare the scales and sub-fields of climatology;
- differentiate between weather and climate, meteorology and climatology;
- explain the action of various elements and controls of weather and climate;
- explain the origin and evolution of the atmosphere;
- discuss the composition of the atmosphere;
- describe different layers of atmosphere on the basis of temperature differences; and
- differentiate between homosphere and heterosphere.

Our best wishes are with you in this endeavour.

We suggest for any assistance regarding this course, you can contact satyaraj@ignou.ac.in.

MGG 005 CLIMATOLOGY

BLOCK 1 FUNDAMENTALS OF CLIMATOLOGY

BLOCK 2 ATMOSPHERIC PROCESSES

BLOCK 3 ATMOSPHERIC DISTURBANCES

BLOCK 4 CLIMATIC CLASSIFICATION

BLOCK 5 CONTEMPORARY ISSUES

UNIT 1

INTRODUCTION TO CLIMATOLOGY

Structure

1.1 INTRODUCTION

Climatology is closely related to geography because in geography, climate is studied as a part of the physical environment of man and like geography, the combined nature of various elements is kept in view in the description of events.

Climatology is described as the scientific study of the behavior of the thin gaseous layer surrounding the earth's surface i.e. the atmosphere. In fact, climatology is a holistic science which incorporates data, ideas and theories. Climatology is the science that describes the nature of climate at different places on the earth and explains the reasons for its variations. It also includes the study of the effects of climatic variations on other elements of the environment and human activities.

The primary goal of climatology is to study the unique characteristics of atmosphere in controlling the global climate, origin and types of climate, causes and processes influencing the climate variations, elements of weather and the impact of climate on human beings or vice-versa.

In fact, climatology is the study and description related to various types of climatic conditions of the earth's surface.

Climatology is closely interlinked between Physical Geography, Agronomy, Aerology and Meteorology.

The discoveries of meteorology have been given a more detailed form by climatology both in terms of space and time.

In this unit, you will learn about the climate and its study in the form of climatology. Sec. 1.2 you will familiarise you with the meaning and scope of climatology. In Sec. 1.3, you will learn how climatology as a subject has developed through different phases. Sec. 1.4 will acquaint you with the difference between climatology and meteorology. Sec. 1.5 and Sec. 1.6 will describe different scales and sub-fields of climatology respectively.

Expected Learning Outcomes

After completing the study of this unit, you should be able to:

- explain the basics about climate;
- describe the meaning of climatology;
- discuss the development of climatology;
- compare the scales of climatology;
- differentiate between climatology and meteorology; and
- describe the sub-fields of climatology.

1.2 MEANING AND SCOPE OF CLIMATOLOGY

Climatology is the science of studying the average atmospheric conditions of a region in a long-term perspective. Climatology studies the characteristics of gaseous atmosphere.

Climatology is mainly concerned with the study of atmospheric conditions on the earth surface and deals with the analysis of various climatic elements.

In fact, climatology is the science of climate which studies the physical state of the atmosphere, over a specific region, during a specific period and on the basis of climatic data.

In other words, one can say that the climatology is a science that seeks to describe and explain -

(a) The nature of climate.

(b) Why it differs from place to place?

(c) How it is related to other elements of the natural environment and human activities?

(d) The several types or varieties of climate found on the surface of the earth.

(e) The distribution of climatic types over the surface of the earth.

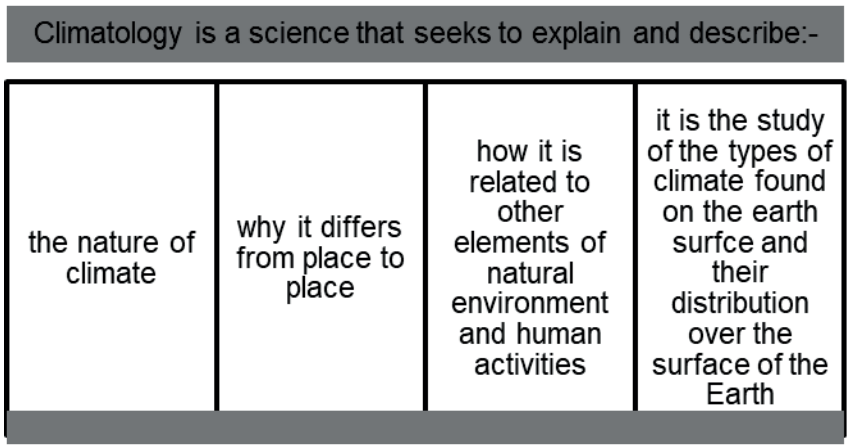

Fig. 1.1: Climatology. (Created by Author)

When we talk about definition of climatology, some important **definitions** of climatology are:-

(i) According to Critchfield:

"Climatology is the science that seeks to describe and explain the nature of climate, how it differs from place to place and how it is related to man's activities".

(ii) According to Austin Miller:

"Climatology is that branch of science which discusses the average conditions of weather".

(iii) According to Koppe and De Lang:

"Climatology is a summary and composition of weather conditions over a long period of time".

(iv) According to Thornthwaite:

"It is the study of the atmosphere as well as the earth's surface".

(v) According to Kendrew:

"In the study of climatology, the basic interest remains in the climatic elements of the earth, which are the essential parts of the natural environment where as the study of the weather factors of the climate remain secondary."

The term "climatology" is derived from the Greek term *"klima"*, means "inclination or latitude" or "slope" or "angle from the sun". It was used for the duration of day and night, and *"logos"*, means "study" or "discourse". Famous philosopher Aristotle used the term "klima" for latitudinal belts.

The meaning and purpose of climatology becomes clear from the above definitions. Climatology is more akin to geography than meteorology because it analyses the regional distribution of atmospheric conditions. In fact, climate is the average weather in a given area over longer period of time .The main objectives of a climatologist is to study the weather patterns and processes that cause them and to predict the weather changes.

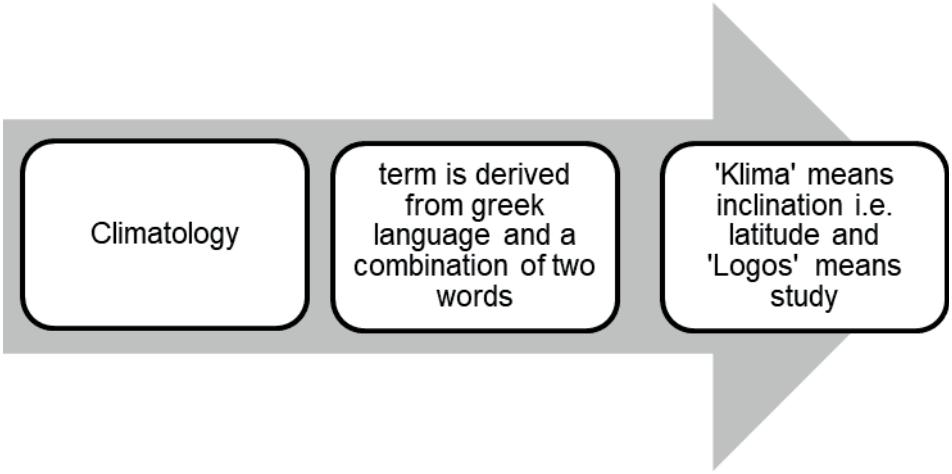

Fig. 1.2: Climatology. (Created by Author)

The main goal of climatology is to study the unique characteristics of atmosphere and its role in controlling the global climate, origin, types of climates, causes and processes influencing the climatic variations, elements of weather and the impact of climate on humans or vice-versa.

Climatology is a science that seeks to describe and explain the nature of climate, why it differs from place to place and how it is related to other elements of the natural environment and human activities. It is the study of the varieties of climates found on the earth and their distribution over the surface of the earth.

There are two aspects of the study of climatology. First, it studies the climatic factors of different types, their relative conditions, the effects of various types of actions on the life and plants and the processes that produce different physical types of climates. This first aspect is basically a scientific one. It is mainly based on causal relationships. It is more closely related to laws of physics and chemistry and the traditions of meteorology. It determines and describes different types of climate. Climate classification and their regional description are based on meteorological data. The second aspect is closely related to methods and principles of territorial divisions. In short, the first aspect can be called as physical climatology and the second aspect can be called as regional climatology.

In the study of climatology, the effects of weather and climate related elements on human life, their health and economy are also studied.

Climatologists seek to understand some main aspects of the climate. First, aspect is, how the weather patterns govern the normal conditions of the different regions of the world. Second is to study the relationship between different aspects of weather. Third is the way how the weather of a place changes over the time. Fourth is how human activities are the cause of climate change. Fifth, is how natural changes occur in the atmosphere and the oceans.

SAQ I

a) What do understand by the word climatology?
b) What are the main responsibilities of a climatologist?

1.3 DEVELOPMENT OF CLIMATOLOGY

With the passage of time, climatology has gone many changes. Since the 6th century B.C., the subject matter of climatology has widened gradually.

Climatology is known as ancient as well as a newer branch of study. Climatology is as old as human curiosity and new as the invention of aircraft, radio, radar and artificial satellites. First, study of the climate can be traced back to the ancient times of Greeks but it did emerge in the present form in the 19th century, only after advent of industrialisation.

From the ancient times, man has the curiosity about atmospheric phenomena.

In ancient saying, many examples related to weather can be seen. For example:

(i) Sayings are there in Old Testament about the description related to weather, which seems to be true after more than 3000 years.

(ii) There are examples related to the names given to the God/ deity for the elements of weather, such as- the Greeks gave the name 'Boreas' to the northern winds, 'Ra' was the deity of the sun for the Egyptian, 'Jupiter Pluvius' is the deity of rain for the Romans, *Indra* is the deity of rain for the Indians. In fact in India, since ancient times most of the forces of nature have been personified as Gods like *Pawandev* as wind, *Varuna* as water *Suryadev* as the Sun.

(iii) The Greeks used to measure wind direction on public buildings before 5th century B.C. The tower of winds in Athens was also built at the same time and for the same purpose.

The history of the development of climatology can be divided into following five periods of times:

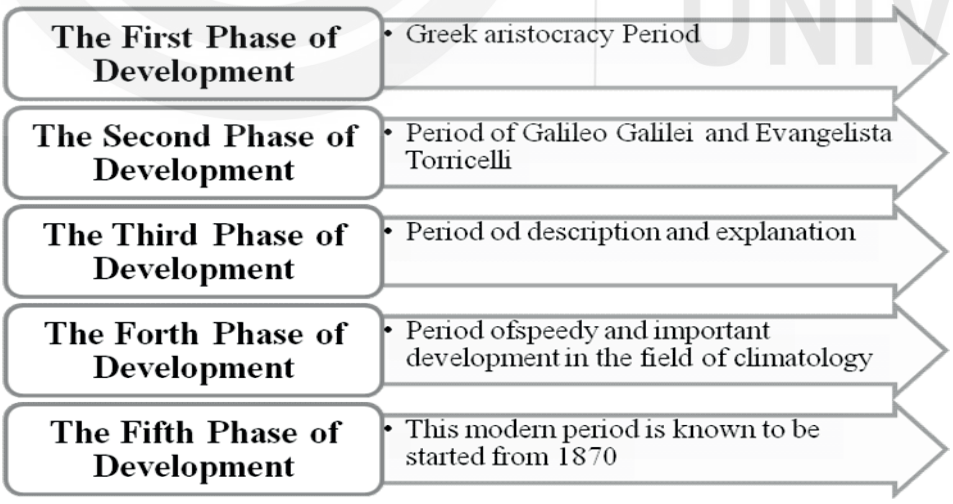

Fig. 1.3: Development of Climatology. (Created by Author)

(i) The First Phase of the Development:

The first phase of the development of climatology, which is known as the Greek aristocracy Period, can be traced between ancient times to 16th century.

The first definition of air is also found in the philosophical works of the Greeks. In the works of Homer and Hesiod, many ideas related to weather were presented in a poetic style.

During this period the evidences were neither authentic nor scientifically proved due to non-availability of the instruments. The experiments that were carried out during this period were not accurate.

Greek philosophers took keen interest in meteorology and climatology. They considered meteorology to literally mean the study of meteors, comets and space scenes. Though they had no clear ideas about the atmosphere, beside this their work formed the basis for the future.

Table 1.1: Significant Events in the History of Climatology

1.	400 B.C.	Influence of climate on health was discussed by Hippocrates the 'Father of Medicine' in his book "Airs, Water and Places.
2.	350 B.C.	Aristotle's masterpiece "Meteorologica" on climatology.
3.	300 B.C.	Description of winds by Theophrastus in his text "De Ventis",
4.	1593 A.D.	Thermometer was invented by Galileo Galilee
5.	1622 A.D.	Francis Bacon published "Historia Ventorum" and provided a systematic natural history of the winds.
6.	1643 A.D.	Barometer was invented by Evangelista Torricelli.
7.	1661 A.D.	Boyle's law was proposed.
8.	1664 A.D.	Weather observations began at Paris.
9.	1668 A.D.	Map on trade winds was constructed by Edmund Hally.
10.	1714 A.D.	Fahrenheit scale was introduced by Anders Celsius.
11.	1735 A.D.	Work on George Hadley described Trade winds and effects of the earth's rotation on the direction of the winds by Anders Celsius.
12.	1736 A.D.	Centigrade scale was introduced.
13.	1779 A.D.	Weather observations began.
14.	1783 A.D.	Hair hygrometer was invented. First time Daily Weather charts wer prepared by Brandes.
15.	1802 A.D.	First cloud classification was suggested by Lamark and Howard.
16.	1817 A.D.	First map showing mean monthly annual temperature was constructed by Alexander Von Humboldt.
17.	1825 A.D.	Psychrometer was invented by August.
18.	1837 A.D.	Pyrheliometer was invented.
19.	1844 A.D.	Coriolis force generated by earth's rotation was formulated by G.D. Coriolis.
20.	1845 A.D.	Berghans prepared the first world map of precipitation.
21.	1849 A.D.	Regular daily weather report started.
22.	1875 A.D.	Meteorological Department of India came into existence.
23.	1892 A.D.	Beginning of use of balloons to monitor air.
24.	1902 A.D.	Existence of stratosphere was identified.
25.	1913 A.D.	Ozone layer was identified.
26.	1925 A.D.	Aircraft was first time used to collect data.
27.	1928 A.D.	Radiosondes were first used.
28.	1940 A.D.	Phenomenon of jet streams was investigated.
29.	1960 A.D.	First meteorological satellite was launched.

(Compiled by Author)

Greek scholar Parmenides had divided the earth into three climatic zones: tropics, temperate and cold zones.

Hippocrates, who is also known as “the Father of Medicine”, had done his work on Medical climatology and wrote a book, titled “Airs, Waters and Places”. Climatological progress almost came to a halt during the time of Socrates.

Aristotle, had written a book on wind system, titled “Meteorologica”. This book is the oldest evidence on Meteorological works. In fact, the basis of all the climatological ideas of Europe is the work of Aristotle. He divided the atmosphere into three regions or parts.

This first period of development of climatology is actually full of superstitions and strange lectures. In the absence of instruments, whatever tests the ancient Greeks, Romans and Arab scientist conducted were not accurate. Quotations from ancient Palestine rain ideas have been found in the Bible and Jewish religious books. During this period only rainfall related tests can be considered quantitative.

The trade and the monsoon winds were the important subjects of the study for the Greek and the Arab merchants. After his expedition to India, Alexander the Great took the monsoon related information to Greece which was first used by Aristotle and later on by the Arab geographers.

In the third century B.C., Philo of Byzantium and Herro of Alexandria had described about the Thermoscope. In fact, from the time of Aristotle to the beginning of 17th century, there was little progress in the field of climatology.

(ii) The Second Phase of the Development:

This Phase was spread over 16th, 17th and 18th century and was with the beginning of the invention of new instruments.

In the 16th century the book *Pneumatics* written by Herro was translated into the Latin and this book was studied by Galileo, Porta and Drebbel.

17th and 18th century is considered as the golden period of climatology. This is the period of Galileo Galilei and Evangelista Torricelli. Galileo Galilei was the professor of mathematics and philosophy, who invented thermometer and telescope. Evangelista Torricelli was the student of Galileo Galilei, who invented Barometer in 1643 AD. Torricelli said that atmosphere has pressure and it can be measured. The invention of the barometer and thermometer proved to be the driving force of a new era in the history of climatology.

The first European rain gauge was invented by Vernedetto Castelli of Italy in 1639 A.D. At the same time a scientific council was established in Italy, in which nine of Galileo’s disciples were its members. This council made a very important contribution to the development of climatology. The credit for the international weather testing goes to Ferdinand, who established meteorological testing centers in northern Italy in 1653 A.D.

In 1735 A.D., George Hadley first mentioned that the effect of earth’s rotation on the trade winds. In 1749 A.D., Wilson of Glasgow succeeded in sending a thermometer to the atmosphere with the help of the kite. This was the first attempt to test the space connection above the earth surface.

In fact, the second phase of the development of climatology begins with Galileo and Torricelli and ends with Halley and Hadley. During this period a large number of instruments were used and new observations were initiated. The use of new instruments increased the accuracy of the knowledge of the atmospheric conditions and started quantitative tests.

Thus 17th and 18th century was the golden age of climatology.

(iii) The Third Phase of the Development:

The first half of the 19th century is considered as the third phase of development of climatology. Description and explanation took place about the experiments observation that was done up to the end of 18th century. In 1800 A.D., John Dalton described the presence of water vapor in the air. First time, between 1800 to 1815 A.D. Chevalier De Lamarch compiled the international weather observations, which were collected through the postcards. In the early 19th century, German climatologist Dove tried to explain the atmospheric air. In America, Redfield had studied the occurrence of land and ocean thunderstorms.

In 1820 and 1826 A.D., Germany's Brandes published two books titled as "Contribution to Meteorology" and "Physical Dissertation on the rapid variations on the pressure of the air" respectively.

In the first half of the 19th century, two Americans J. P. Espy and E. Loomis greatly contributed towards meteorology. Espy established first American weather observatory at Pennsylvania. From 1836 to 1859 A.D., Loomis exhibited several weather maps that shed the light on climate problems.

(iv) The Forth Phase of the Development:

This phase was spread in a very short period of fifteen years i.e. between 1850 to 1865-70 AD. This very short span, witnessed the speedy and important development in the field of climatology. The important scholars of this period were Fitz Roy, Le Verrier, Buys Ballot and Ferrel. Fitz Roy divides Great Britain and Ireland into three weather zones. They developed the system to collect the weather related information collectively. Their weather related observation was published in 1861.

In 1863 A.D. Francis Galton published a book titled as "Meteorographica", in which information related to high and low pressure areas was given.

In Europe, Le Verrier first time developed *the path method* for the study of the path of cyclones. Buys Ballot had organised the weather related services in Holland. In 1860, he gave the famous "Buys Ballot Law". According to this law, if anyone stands with his back to the wind, the atmospheric pressure is low to the left and high to the right in the Northern Hemisphere. In America, two important laws were published in 1856 and 1860. These are called as Ferrel's laws. According to these laws, by the rotation of the earth when air start moving from low to high pressure, in northern hemisphere, it would deflect right side and in the southern hemisphere it would deflect left side.

(v) The Fifth Phase of Development:

This modern period is known to have started from 1870. During this modern phase of development in USA, "National Weather Service" was started. In 1872, "First International Weather Conference" was held at Leipzig. In 1875, "Indian Meteorological Department" was established at Shimla which was transferred to Pune in 1928.

In 1878, "International Meteorological Organisation" was established in Utrecht in Holland. After this, almost each and every country had established his weather information station. During this period the development of climatology were divided into two groups by George R. steward in his book entitled "Storms".

SAQ 2

a) In how many phases we can divide the study of climatology?
b) What is the purpose of tower of winds? When the tower of winds was established in Athens?
c) Name the deity for the rain in India.
d) When and where was the International Meteorological Organisation established?

1.4 CLIMATOLOGY AND METEOROLOGY

The climate of any place is not decided by the weather of only a few days or few years but sometimes it is the average of many years. That is why in general term; climatology is also called an average or general meteorology. For a common person, the weather of one day or one hour is not as important as the average weather of that place or region. That is why climatology has become more popular than meteorology.

Climatology and meteorology are closely related to each other. In climatology general description and explanation is being done whereas the study related to daily changes in atmosphere is the part of meteorology.

Climatology is the study of the atmospheric processes and their impact. Climatology collects and interprets the data observed by meteorology to investigate the spatial patterns of climate and its interaction.

In climatology, the relationship between regional variations of climate and human action is determined, whereas in meteorology, the daily changing conditions of the atmosphere and their physical processes are being studied.

In simple words we can say that meteorology presents observations and evidences like physics and climatology interprets the data obtained from it by various statistical methods.

In general, climatology and meteorology are considered to be the same, although the methods and approaches of both are different.

More attention is being paid to the climate and climatic changes on the location of industries, places of entertainment, agriculture and mining sites.

The word “meteorology” is derived from Aristotle’s famous book “Meteorologica”, which means the study of space.

In meteorology the base of conclusion are observation and facts on which the description can be done in climatology by the use of various statistical methods. Meteorology deals with the day to day atmospheric conditions and their causes.

In India, “Meteorological Department” prepares the daily weather report

Meteorology is defined as the Physics of the atmosphere. Meteorology uses the methods of Physical science to interpret and explain the atmospheric processes. It deals with the meteorological techniques and geographically it deals with the spatial aspects of climatic phenomena.

Meteorology can be further divided into four sub parts-

(i) Dynamic and theoretical Meteorology:

Under this sub part of meteorology, those physical principles are explained which are related to the forces and energy of atmospheric flow. Theoretical aspects can be studied under this sub-part of meteorology. Description about the atmospheric movement is also studied under this sub part.

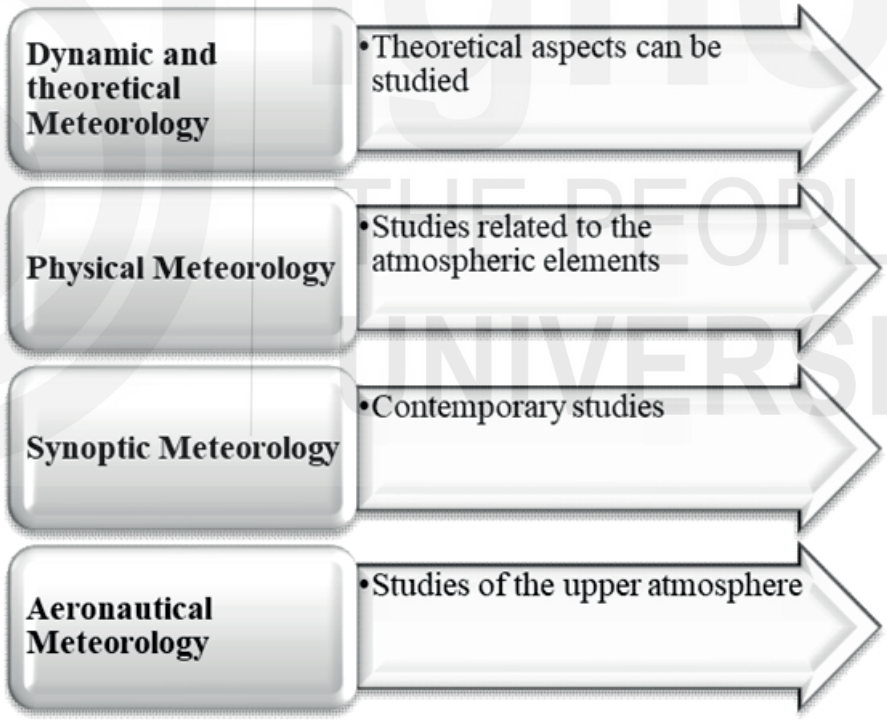

Fig. 1.4: Sub- division of Meteorology. (Created by Author)

(ii) Physical Meteorology:

Study related to the atmospheric elements through the various concepts of physics like- thermodynamic, electrical, optical phenomena etc. is being carried out under this sub-part of meteorology.

(iii) Synoptic Meteorology:

Under this sub-part of meteorology, there is a contemporary study of the subtlest conditions by regional, comparative and analytical methods. In this

sub-field, the complete conditions of the weather are studied in a particular period of a specific region. Making of weather related maps, forecasting the weather, the thorough study of the air masses, fronts and other elements of weather are being done under this sub-branch of meteorology.

(iv) Aeronautical Meteorology:

Under this sub-part of meteorology, the study of the upper atmosphere is carried out. Under this, there is a systematic study of the conditions of high atmospheric temperature, air pressure and humidity. Main aims of this sub-part are as follows-

a) Immediate forecast for the pilot.
b) Determination of height and bases of clouds.
c) Study of atmospheric transparency and visibility.
d) Study of storms, surges and accidental events.

Basic difference between the climatology and meteorology is that *climatology deals with the long term atmospheric behavior over a significant period of time whereas meteorology deals with atmospheric phenomena at any time and over a short period of time that lasts not more than a few days*.

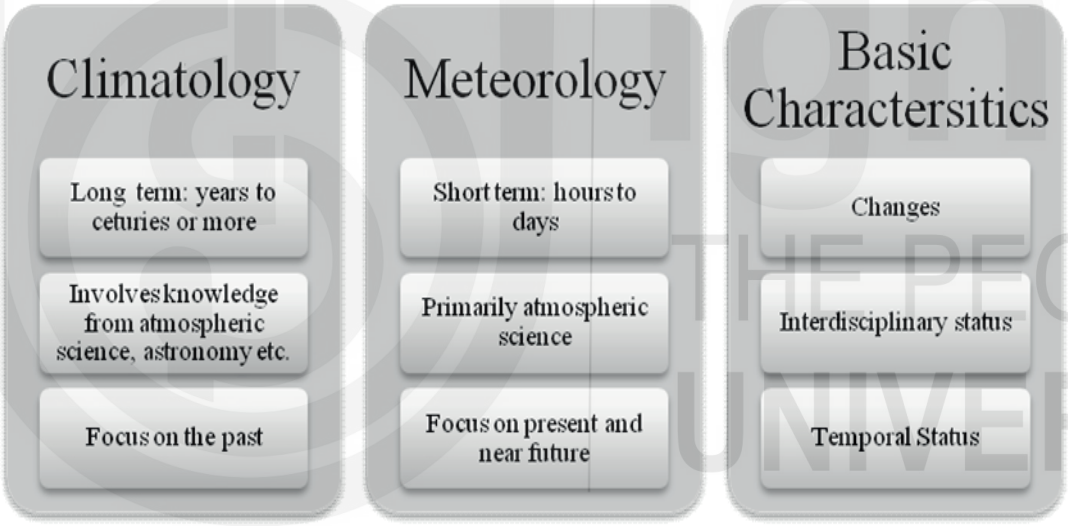

Fig. 1.5: Difference between Climatology and Meteorology. (Created by Author)

SAQ 3

a) Define meteorology.
b) In how many sub-parts meteorology can be divided?

1.5 SCALES OF CLIMATOLOGY

Climatology has following scales:

(i) Micro Scale: Micro Scale is the smallest of all the atmospheric scales. It involves the systems that operate over a smaller area that is less than 0.5 km. Under this scale, the study of the climate is confined very close to the ground. For example- Climate surrounding a house.

(ii) Local Scale: Local Scale is the larger scale than the Micro Scale. It involves the systems that operate over an area between 0.5 and 5 km. For example- Climate of a river valley.

(iii) Meso Scale: It involves the systems that operate over an area between 5-100 km. For example- Climate of a basin or any indentified region.

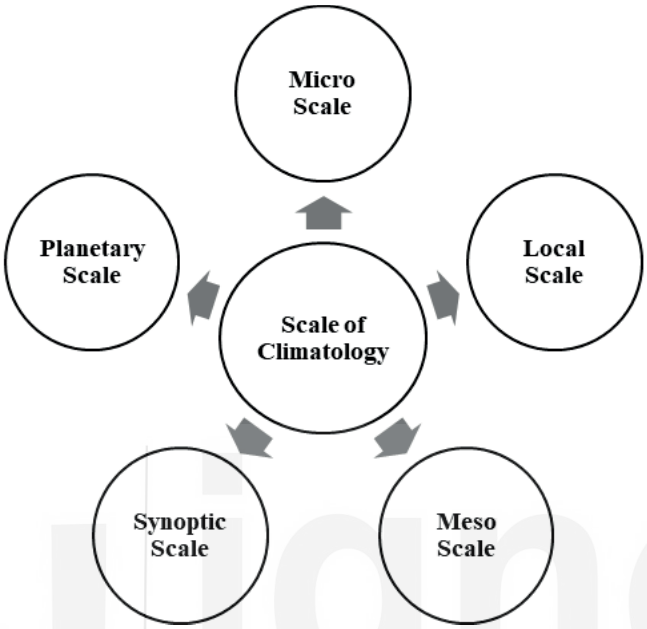

Fig. 1.6: Scale of Climatology. (Created by Author)

(iv) Synoptic Scale: It involves the systems that operate over an area between 100-10,000 km. For example- Climate of a region.

(v) Planetary Scale: Planetary Scale is the largest scale of all atmospheric scales. It involves the systems that operate over an area between 10,000-40000 km. For example- Climate of a hemisphere or the whole earth.

SAQ 4

How Many Scales the climatology have?

1.6 SUB-FIELDS OF CLIMATOLOGY

It is observed that in the past few years, there has not only been an increase in cooperation between branches of traditional science in the investigation of climate related problems, but some new combinations have also developed. Bio-Climatology, Agro-Climatology, Pharma-Climatology, Construction-Climatology and Urban-Climatology are the prime example of this.

According to Critchfield, there are three basic sub-fields of climatology (first three). But at the broad level, Climatology can be divided into following sub-fields –

(i) Physical Climatology

Physical climatology is closely related to meteorology. Physical climatology is mainly concerned with atmospheric phenomena. Physical climatology tries to

explain the factors that are responsible for temporal and spatial changes in atmosphere.

This sub-field of climatology deals with the study of elements of weather, namely- insolation, temperature, air pressure, wind, evaporation, humidity, precipitation, fog etc. Combination of all these or some of these elements formed different climates.

In other words, this sub-field studies the systematic description and analysis of:

(a) Energy balance of atmosphere and earth.
(b) Atmospheric temperature.
(c) Humidity and precipitation.
(d) Atmospheric motion's and air circulation.
(e) Air masses.
(f) Extreme atmospheric events like- atmospheric disturbances, droughts, floods etc.

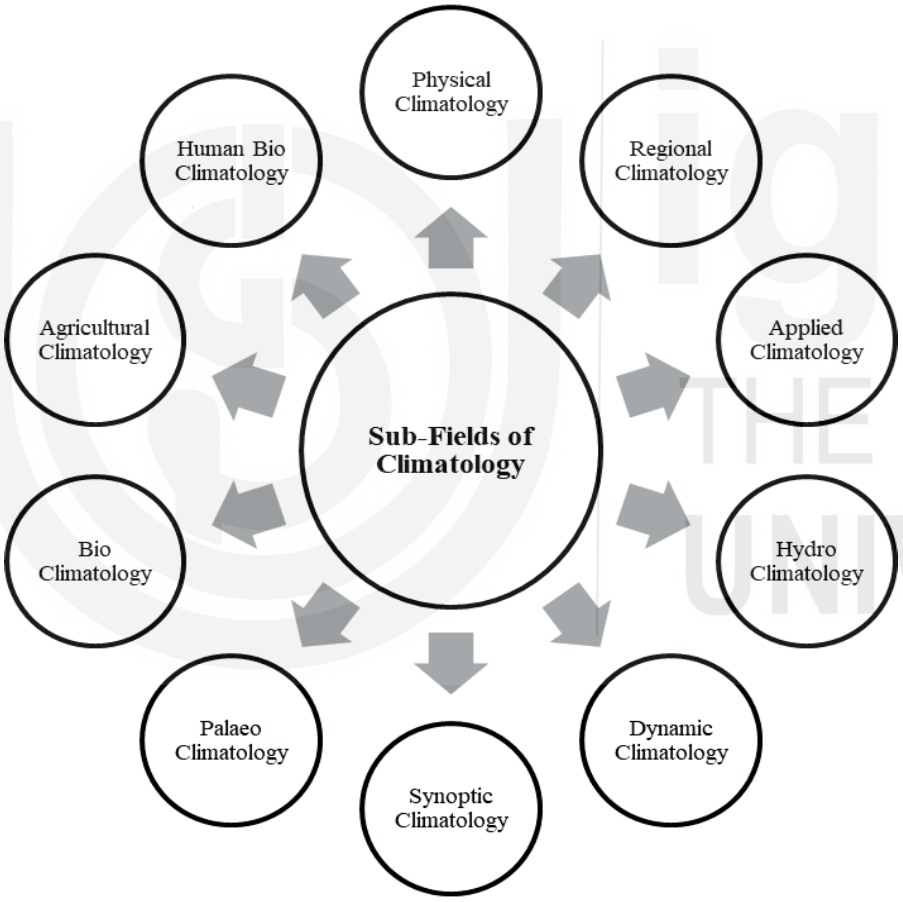

Fig. 1.7: Sub- Fields of Climatology. (Created by Author)

(ii) Regional Climatology

Spatial variations in the combinations of weather related elements can cause different types of climate in different parts of the earth. The size of the area or the region, over which similar types of climatic conditions are observed, can vary from each other. Regional Climatology deals with the description of the climate of a region. It seeks to determine and describe various types of climates. In this sub-branch, all the climatic elements of a certain region are studied by dividing the earth's surface into different climatic divisions. It is also known as specific climatology.

(iii) Descriptive Climatology

This sub-branch of climatology is concerned with the identification of important climatic characteristics and the interaction of weather and climatic elements upon life and the condition of a particular area or a region. In this sub-branch, climate elements are studied on the basis of different elements. Its method is like general geography. It is very difficult to differentiate between physical and descriptive climatology because practically both of them are very same.

(iv) Applied Climatology

The main purpose of the study of climatology is to find out the ways and means to make use of our knowledge of climatic elements for the betterment of human life on the earth.

So, applied climatology is concerned with the study of the effects of climate and with the application of the climatological knowledge to practical problems i.e. application of climatic principles and knowledge to solve various problems faced by human society. It also studies, how humans modify climate by introducing various changes in the physical environment. For example- weather modification by humans through cloud seeding and induced precipitation. It analyses the relationship between climatology and other sciences.

In general, it is in this aspect of climatology that the interdependence and unity of human knowledge emerges among all branches of science.

(v) Hydro Climatology

Hydro Climatology is mainly concerned with the processes of interaction between atmosphere and water in all its forms.

(vi) Dynamic Climatology

Dynamic Climatology is concerned with the general atmospheric processes. This sub-branch of climatology investigates the impact of changes in various physical parameters on climate.

(vii) Synoptic Climatology

Synoptic Climatology is the study of relationship between atmospheric circulation and environment of a particular region. It deals with local or hemispheric climate from the view point of atmospheric circulation because different circulation patterns lead to variations in climates.

It mainly studies the relationship between circulation patterns and severe weather conditions.

(viii) Palaeo-Climatology

Palaeo-Climatology mainly deals with the study of the past climatic data.

(ix) Bio-Climatology

Bio-Climatology is the study of the interaction of living things with their environment.

(x) Human Bio-Climatology

Human Bio-Climatology deals with the impact of atmospheric properties and processes on human beings. It is closely related with life science.

(xi) Agricultural Climatology

Agricultural Climatology deals with the impact of atmospheric properties and processes on agriculture.

SAQ 5

In how many sub-fields climatology can be divided?

1.7 SUMMARY

In this unit you have studied so far:

a) Meaning and scope of climatology.

b) Development of climatology through the ages.

c) Difference between climatology and meteorology.

d) Various scales of climatology.

e) Various sub-fields of climatology.

1.8 TERMINAL QUESTIONS

1. What is climatology? Write about the scope of climatology.
2. Write in detail about the development of climatology.
3. What are the various scales of climatology?
4. Write about the sub-fields of climatology.

1.9 ANSWERS

Self-Assessment Questions (SAQ)

1. a) The term “climatology” is derived from the Greek term “klima”, means inclination or latitude or slope or angle from the sun. It was used for the duration of day and night, and “logos”, means study or discourse. Famous philosopher Aristotle used the term “klima” for latitudinal belts.

   b) The main responsibilities of a climatologist are to study the climate, climate changes, climatic variability and patterns. A climatologist studies the effect of climatic factors on the biosphere. A climatologist must be equipped with the latest technologies for a better climate and weather prediction. This will help in various activities such as agriculture, economic development, resources management etc.

2. a) We can recognise the study of climatology in five phases.

   b) The purpose of tower of winds is to measure the direction of winds.

   c) Indra is the deity of rain for the Indians.

d) In 1878, “International Meteorological Organisation was established in Utrecht in Holland.

3. a) Meteorology is defined as the physics of the atmosphere. Meteorology uses the methods of physical principles to interpret and explain the atmospheric processes. It deals with atmospheric phenomenon over a short period of time.

   b) Meteorology can be divided into four sub-parts: dynamic, physical, synoptic and aeronautical.

4. Climatology has five scales: micro, local, meso, synoptic and planetary scales.

5. Climatology can be divided in ten sub-fields: Physical Climatology, Regional Climatology, Descriptive Climatology, Applied Climatology, Hydro Climatology, Dynamic Climatology, Synoptic Climatology, Palaeo-Climatology, Bio-Climatology and Agricultural Climatology.

Terminal Questions

i) You can start your answer giving the definition of climatology and then write its scope. Refer to Sec. 1.2.

ii) You can start your answer by stating that it is a newer branch of geography and then write in detail about its various phases of development. Refer to Sec. 1.3.

iii) You can start your answer by stating that there are five scales of climatology and after that you can describe it in detail. Refer to Sec. 1.5.

iv) You can start your answer by stating that there are ten sub-fields of climatology. After that you can write about these in detail. Refer to Sec. 1.6.

1.10 REFERENCES AND FURTHER SUGGESTED READING

1. Ayoade, J.O. (2004). *Introduction to Climatology for the Tropics.* Spectrum Books Ltd., Ibedan.

2. Barry, R.G. and Chorley, R.J. (1971). *Atmosphere, Weather and Climate.* Methuen publication, London.

3. Critchfield, H.J. (1993). *General* Climatology. Prentice Hall, India, New Delhi.

4. Lal, D.S. (1986). *Climatology*. Chaitanya Publications, Allahabad.

5. Koeppe, C.E. and Delong, G.C. (1958). *Weather and Climate.* McGraw Hill Publication, New York.

6. Miller, A. (1959). *Climatology.* Methuen publication, London.

7. Singh, S. (2011). *Climatology.* Prayag Pustak Bhawan, Allahabad.

8. Trewartha, G.T. (1954). *Introduction to Climate.* McGraw Hill Publication, New York.

UNIT 2

WEATHER AND CLIMATE

Structure

2.1 INTRODUCTION

In the previous unit, you got a general introduction to climatology. Climatology is concerned not only with the atmospheric conditions but also concerned with the climate and weather of the earth surface. The climate and weather vary from place to place and time.

"Climate is what you expect whereas weather is what you get."

Weather and climate are closely related to each other but they are not synonymous to each other.

"It is climate that attracts people to a location but it is the weather that makes them to think about the comfortability."

Major difference between weather and climate is a measure of time. Weather is the condition of the atmosphere of a place over a short period of time whereas climate is the atmospheric behaviour over a long period of time.

This unit explains the concept of weather and climate in detail. Sec. 2.1 deals with the general introduction to the terms 'weather' and 'climate', while Sec. 2.2 elaborates the differences between these two terms. Sec. 2.3 describes the different elements of weather and climate while Sec. 2.4 discusses in detail different controls of weather and climate in detail.

Expected Learning Outcomes

After completing the study of this unit, you should be able to:

- describe the basics of weather and climate;
- differentiate between weather and climate;

- explain the action of various elements of weather and climate; and
- compare the controls of weather and climate.

a. Basics of Weather

Weather is the sum of atmospheric condition of a place over a very short period of time, like few hours, one day or a week.

In fact, weather is the sum of various atmospheric variables like- temperature, humidity, cloudiness, precipitation, atmospheric pressure, winds, storms etc.

Renowned climatologists gave various definitions of the weather. Some important definitions of weather given by various scholars are-

According to G. T. Trewartha – *"Weather is the sum total of atmospheric condition like – temperature, pressure, winds, moisture and precipitation etc. for a short period of time".*

When these conditions change, then the weather of a place changes accordingly. For example – If today's morning is cold; cloudiness may form in the afternoon and evening may become quite pleasant.

H. J. Critichfield describe the weather in a more scientific manner – *"Weather, the day to day state of atmosphere, consists of short term variations of energy and mass exchanges within the atmosphere and between earth and atmosphere".*

Austin Millar described the weather as- *"Weather at a given place is the sum of total of all the meteorological variables, such as- temperature, wind, humidity, precipitation and the state of the sky at a given time".*

According to the Koppe and De Long- *"Condition of atmosphere at a given place and time is known as the weather of that place".*

On the basis of elements, there may be some common weather conditions, like – Cloudy, Humid, Sultry, Windy, Sunny, Rainy, Snowy etc.

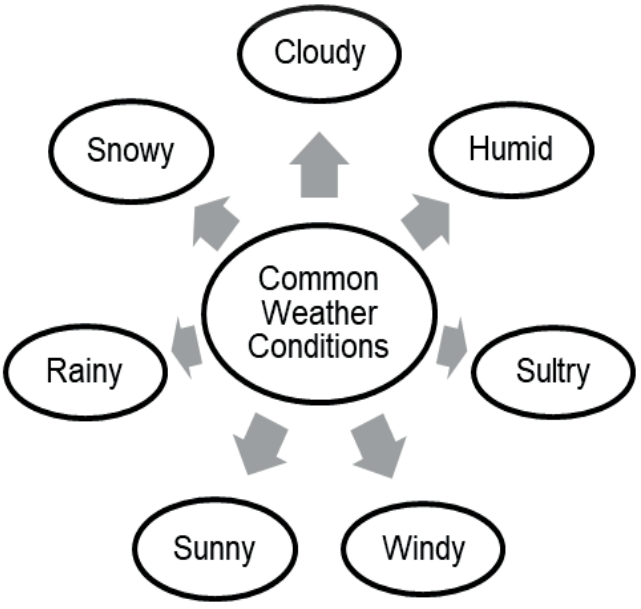

Fig. 2.1: Some Common Weather Conditions. *(Created by Author)*

a) Cloudy - Cloudy weather condition occurs when there are lots of clouds in the sky of a place that obstructs the sunlight. Sometimes – obstructions from the clouds may completely cover the sky. This situation is known as overcast. Usually, the cloudy days in summer season are warm while cloudy days in winter season cold.

b) Humid - This type of weather conditions found when there is a lot of moisture in the air of a place.

c) Sultry - Very hot and humid sweltering type of weather condition is characterised as sultry type of weather.

d) Windy - This type of weather occurs when the sustained wind speed at a place is from 20-30 mph (miles per hour).

e) Sunny - Weather condition is called sunny when the sky is clear without clouds to block the sunlight. Sunny days are quite common in the summer season.

f) Rainy - Rainy weather results when there is a large amount of the clouds in the sky of a place that produces rain too.

g) Snowy - Snowy type of weather conditions usually occur in winter, when precipitation falls as snow instead of rain. This type of condition results in the areas of high altitudes, where low temperatures cause the water in the clouds to freeze. Snowy days are often very cold.

In fact, weather changes from time to time and place to place. At a given time, the weather may differ between two adjacent areas.

B. Basics of Climate

When we talk about climate, we found that Climate refers to the state of the atmosphere for a given place over a long time. In other words, we can say that climate of a place is the average of weather conditions over a long period of time. Climate plays very significant role in the formation of soils, vegetation and influence animal life.

Several climatologists have tried to give the definition of the climate. Some important definitions of climate given by various scholars are-

According to J. O. Oyode – *"Climate refers to the characteristic conditions of the atmosphere deduced from repeated observations over a long period".*

According to F. J. Monkhouse – *"Climate really comprises a description of the conditions of the weather over a considerable area for a long time".*

According to G. T. Trewartha –*"Climate is a composite or generalisation of the variety of day to day weather conditions".*

According to H. J. Critichfield – *"More than the statistical average, climate is an aggregate of environmental conditions involving heat, moisture and motion".*

W. G. Kendrew described the climate as- *"Climate is a composite idea, a generalisation of the manifold weather conditions from day to day throughout".*

He further added that- "certainly no picture of it is real unless it is painted in all colors of the varieties of the weather".

G. F. Taylor describe the climate as- *"The main difference between the weather and the climate is time. If climate is an integral of weather, then weather is a differentiation of climate"*

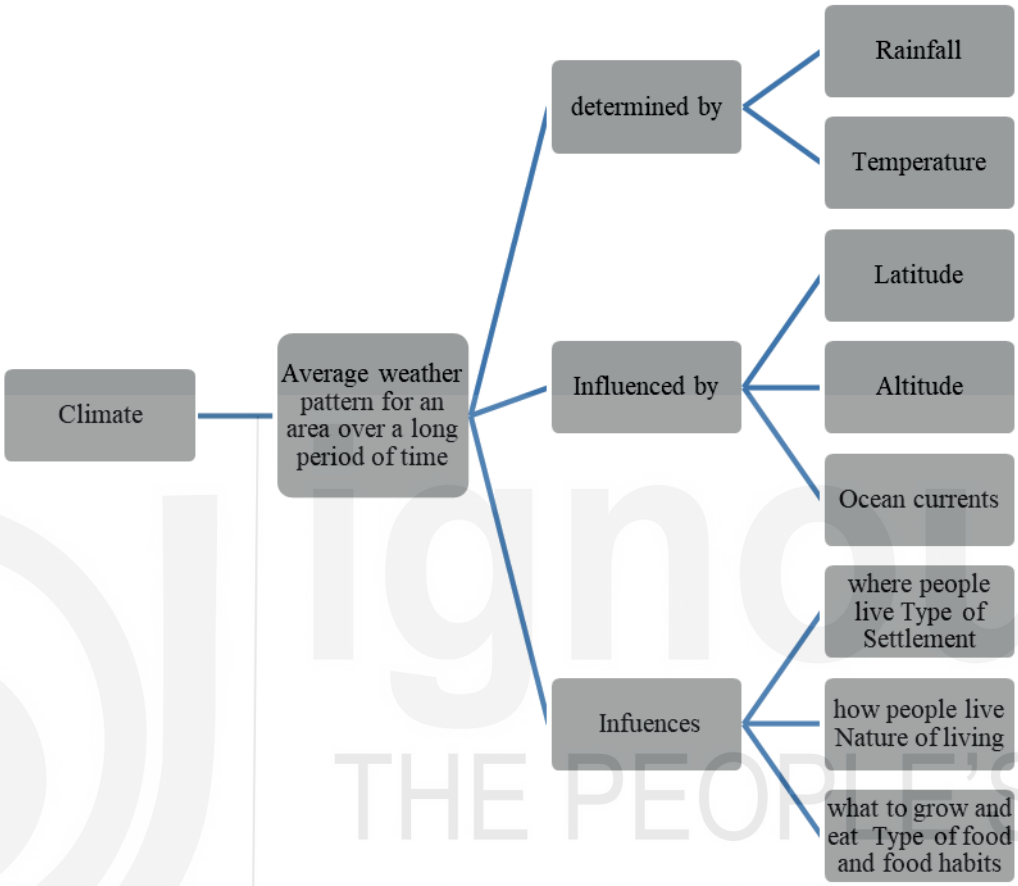

Fig. 2.2: Climate. *(Created by Author)*

As per **World Meteorological Organisation (WMO)**, the period of taking the average is of 31 years of weather demands.

Austin Miller takes this average period of 35 years.

2.2 DIFFERENCE BETWEEN WEATHER AND CLIMATE

Earth's atmosphere is a very complex medium. Its mechanisms and processes are often very complicated.

The main difference between Weather and Climate can be summarised by a popular phrase – *"Climate is what you expect, weather is what you get."*

Weather defines the condition of the atmosphere over a short period of time for example, a day or week whereas Climate defines the condition of the atmosphere over a longer period of time like an entire year or decade. Both Weather and Climate are meteorological terms that are related to each other but not interchangeable. Main differences between Weather and Climate are:-

(i) Weather is the sum of atmospheric condition of a place over a very short period of time, like few hours, one day or a week whereas the Climate refers to the state of the atmosphere for a given place over a long period of time.

(ii) Weather is the physical condition of atmosphere of a given time. It includes sunshine, cloud cover, winds, hail, snow, sleet, rain, storms, heat, heat waves, cold, cold waves etc. whereas Climate is the average of the weather conditions of a given place over a very long time. It includes precipitation, temperature, humidity, wind velocity etc.

(iii) Weather observations were made for small areas, where as Climate observation will be made on regional level.

(iv) Weather is an unstable condition and frequently changes where as Climate of a region decided based on the stable weather condition.

(v) Meteorology is the study of weather and climate based on physical principles, while climatology studies the long term weather patterns to understand past and how climate change will affect the future.

SAQ I

a) What is Weather?
b) What is Climate?
c) Differentiate between weather and climate.

2.3 ELEMENTS OF WEATHER AND CLIMATE

The nature of the atmosphere is generally expressed through the various measurable variables. The recorded data of these variables provide the materials in the raw form for understanding the temporary as well as long-term atmospheric conditions.

Elements responsible for the various atmospheric conditions of a place, is known as the elements of weather and climate.

Following are the important elements of weather and climate:

(i) Temperature

Sun is the main source of the temperature on the earth. Energy emitted by the sun reaches the earth's atmosphere and surface in the form of waves. The amount of the insolation varies from place to place on earth's surface because of the various causes, such as- the length of the days, angle of the sun rays, latitude of a place, transparency of the atmosphere etc. Due to this variation, the temperature also varies with space, time and altitude.

The temperature is shown on a map by a line connecting the places of equal temperature. This line is known as Isotherm line.

Temperature is the most important element of weather and climate because it influences or controls other elements of the weather, such as precipitation, humidity, clouds, atmospheric pressure etc. The particles in the air move or

vibrate at a certain speed, which creates kinetic energy. When the particles start to move or rotate around faster, temperature increases. When the particles begin to slow down, the temperature also starts to decrease.

The maximum temperature of the day occurs generally in the afternoon while the minimum temperature occurs generally in the early morning.

So, we can say that temperature is a driving force of the atmosphere. Due to the temperature various process results whether they are physical or chemical or biological.

Various kinds of atmospheric phenomena on the earth's surface namely - pressure, winds, humidity, turbulence in the atmosphere etc. are directly controlled by the temperature.

(ii) Air Pressure / Atmospheric Pressure

Atmospheric Pressure is another essential and important element of weather and climate. It has the weight of overlying layer of the air on a given place. In other words, we can say that the air pressure is the result of the pressure created by the weight of the air in the earth's atmosphere. The weight of the particles in the air creates pressure due to the gravitational force of the earth. Since more air is present above the air close to the ground, air pressure is the highest on the planet's surface and decreases with the increase in altitude.

Atmospheric pressure is a variable responsible for temperature, subsidence of air, gravitational force and coriolis force. Atmospheric pressure is measured by an instrument called Barometer. The average atmospheric pressure at the sea level is 1013.25 millibars (mb). Air pressure or Atmospheric Pressure is usually, inversely related with the temperature.

Seven belts of atmospheric pressure exist on the earth's surface. There are diurnal as well as seasonal variations in the distribution of atmospheric pressure. Atmospheric pressure varies because of the presence of the local winds, coastal areas, mountain and valley areas and desert areas shows the change of atmospheric pressure in the day and night. Seasonal winds like the monsoon, greatly affects the atmospheric pressure. Patterns and trends of atmospheric pressure of a particular place is the main key of weather forecast of a place.

Atmospheric Pressure is indicated by an imaginary line, known as isobar that connects the places of the equal atmospheric pressure reduced to the sea level.

Pressure is an important indicator of weather. For example- lowering of pressure in an area is indicating the arrival of storms in that particular area Increase in pressure indicates fair weather and low possibility of precipitation whereas decrease in pressure indicates unstable weather conditions and possibility of precipitation.

(iii) Winds

The horizontal movement of the air in a definite direction is called wind. Wind is a very important weather and climatic element that cannot be seen but can

be felt. Movement and direction of the winds are determined by the distribution of pressure on the earth's surface. The speed and strength of wind is also determined by the variation in air pressure. The movement of air (wind) is one of the main driving forces of weather. The majority of extreme weather events like cold & warm fronts, clouds, thunderstorms and hurricanes are the resultant events of wind. Winds are the main source of evaporation and precipitation throughout the world.

Direction of the wind is measured by an instrument known as wind vane where as velocity of wind is measured by an instrument known as anemometer.

There are various kinds of winds, such as- planetary, periodic and local winds. Temperature and moisture are transported by the winds.

Monsoon is an important seasonal wind which changes its direction according to the rhythm of seasons.

(iv) Humidity

Humidity is the most important element of the atmosphere which modifies the air temperature. Humidity is the amount of water vapour that is present in the atmosphere at any specific time. In other words, humidity is the presence of water vapour in the given volume of the air. There are various ways to represent the humidity in the air, such as - specific humidity (g/kg), absolute humidity (g/m^3) and relative humidity (%). It is measured by hygrometer. In general, the air over laying water bodies, forest areas and the humid areas of the earth's surface have high amount of humidity, while the desert and the dry areas of the earth's surface have low humidity. During rainy season there will be more humidity than the dry and hot season. Besides this, temperature and velocity of winds over the earth's surface are two other important determinants of humidity.

Humidity is the prolonged moisture level of an area that can affect entire ecosystems. For example - tropical forests can sustain different forms of life than dry, arid climates because of the overall humidity from rainfall and other factors.

When the relative humidity of a particular place reaches to 100% than the condensation of water vapour takes place and this situation is known as "saturation of the air". The temperature of the saturated air is known as the "dew point".

Humidity is very important element of weather and climate because the formation of clouds, fogs, mist and precipitation are determined by the presence of humidity at a given temperature in the air. Besides this, by releasing the latent heat after the condensation of water, humidity provides energy to the different types of storms, such as - cyclones, thunderstorm and tornados.

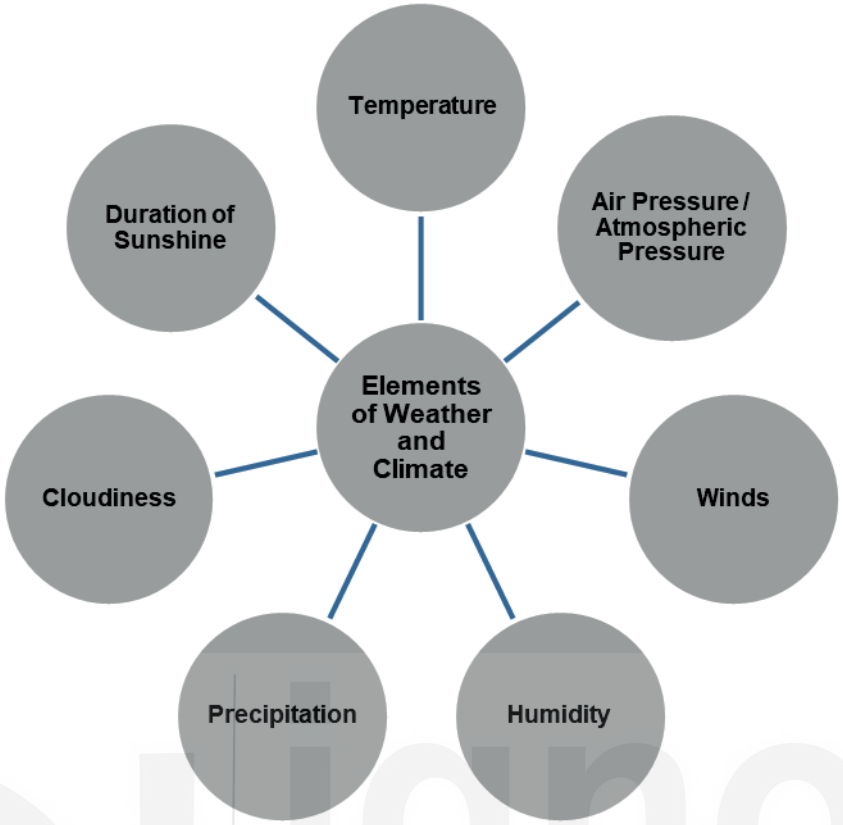

Fig. 2.3: Elements of Weather and Climate. *(Created by Author)*

(v) Precipitation

Precipitation is the term given to moisture that falls from the air to the ground in various forms like snow, hail, sleet, drizzle, fog, mist and rain.

In fact, precipitation is water in all its different forms, which formed after condensation turned water vapour into its solid form, which falls to the ground after it, becomes too heavy to stay suspended in the air.

Precipitation is primarily the result of evaporation and condensation.

(vi) Cloudiness

Clouds are water droplets or water in different forms (like ice and snow crystals), which formed after water vapour reached condensation level and could no longer remain in gaseous form. In simple words, we can say that cloud is a form of condensation of water vapour of an ascending moist air to the higher elevation from the earth's surface. Clouds are the combination of water droplets and ice crystals that hang in the upper part of troposphere.

Clouds give us a clue about what is going on in our atmosphere and how the weather might change in the hours or even days to come. Each type of cloud forms in a different way and each brings its own kind of weather. Knowing how to identify a certain type of cloud and the weather associated with it, can prove valuable when assessing weather conditions.

Clouds play multiple and critical roles to determining the weather and climate of a place. During summer season the cloudy days provide protection from the rays of the sun while during winter season; cloudy nights records radiation

from the earth and control the fall of the temperature. They efficiently reflect light to space and contribute to the cooling of the surface of the earth.

Clouds also control the amount of insolation reaching to the earth's surface. Clouds play an important role to determine the temperature of a place. For example- temperatures are high on a cloudy night because the terrestrial radiation is blocked by the clouds to reach the atmosphere from the earth's surface. Besides this, clouds play an important role in the formation of fog. Dew formation is also restricted by the clouds. In the tropical desert areas, the diurnal range of temperature is very high due to the clear skies while in the equatorial areas, the diurnal range of temperatures are relatively low due to the overcast conditions of the sky.

Due to the curvature of the earth, the amount of solar energy received is different at different latitudes and thus it affects the climate.

(vii) Duration of Sunshine

Solar radiation is the most important element of climate. It is also referred to as sunlight hours and measures the amount of exposure over a set period of time, generally in hours per day. Duration of the sunshine influence other weather elements, which can change the whole weather conditions of a particular place. Duration of sunshine is the length of the time, the earth's surface directly exposed to solar radiation.

SAQ 2

Which are the elements of weather and climate?

2.4 CONTROLS OF WEATHER AND CLIMATE

Variations in the elements of weather and climate are frequent and continuous. These variations are caused and influenced by certain attributes. These attributes are known as the controls of weather and climate. These factors are latitude, elevation, distance from the sea, ocean currents, topography and prevailing winds.

(i) Latitude: The amount of energy received by a particular latitude depends on how far it is to the equator. As the Earth is a sphere the amount of energy received varies according the latitude. Sun shines directly on equator for more hours during the year. As a result, solar radiation reception decreases from the equator towards poles. Latitude is the most important control of weather and climate. Locations near the equator are warm throughout the year. Locations near the poles get very little sunlight and as a result, these areas are cool throughout the year. For example – Indonesia located near the equator has a warm climate and Norway located far away from equator is having a cold climate.

(ii) Height from the Sea level or Altitude: Height from the sea level or altitude is a control that greatly influences weather and climate of a place. Three major elements- temperature, atmospheric pressure and moisture of the winds are generally decreased upwards.

The temperature decreases with the elevation under normal conditions. The average rate at which temperature changes per unit altitudinal change is known as lapse rate. Normal lapse rate of the temperature is 6.5^{o}C per km. Because of this tendency of decrease in temperature, the elevated regions are colder than plains. For example - Jalandhar in Punjab and Shimla in Himachal Pradesh are situated at same latitude of 31^{o}N, but due to height above sea level, Shimla is colder than Jalandhar.

(iii) Distance from the Sea: The distribution of water and land has an influential role in controlling the weather and climate. Land heats up quickly and cools rapidly. While water heats up slowly cools slowly. Due to this phenomena places situated near to the water bodies have less range of temperature and more amount of humidity while places situated away from the water bodies, in the continental areas, have more range of temperature and less amount of humidity. Due to this feature, the coastal areas experience moderate climate throughout the year, whereas the land areas that are situated away from the sea experiences extreme conditions of climate i.e., more hot in summer and colder in winter.

Oceans or water bodies are the abundant source of atmospheric moisture than the land areas. So, areas near the ocean are normally more humid than the areas far away from ocean.

Land and water bodies located at the same latitude do not have the same weather and climate because the characteristics of the two elements are different. There is a difference in the climate of two places located on the same latitude even on the land area. Places situated near the coast have less temperature differences during the days and nights and have more humidity whereas the places located the interior of the continents away from the coast have more temperature differences during the days and nights and have less humidity. For example – In India, though Mumbai and Nagpur in Maharashtra, which are situated on the same latitude of 21^{o}N, Mumbai experience less range of temperature and more rainfall due to its location near of sea as compared to Nagpur which is situated deep in the interior part away from water bodies. So, Nagpur experiences comparatively high temperature range and less rainfall as it situated in the interior parts and away from sea. This type of example can be traced throughout the world. In United States of America, Seattle and Fargo in North Dakota both are situated on the same latitude of 47^{o}N but due to the nearness of water bodies, Seattle has a lesser range of temperature as compared to Fargo which is situated in the interior part away from water bodies.

(iv) Direction of the Prevailing Winds: Winds blowing from water bodies are moisture laden and can cause precipitation while winds coming from land areas are dry and hot in nature, and possibility of precipitation is less. For example – In India, in the summer season, monsoon winds blow from the sea are moisture laden and can cause precipitation while in the winter, the monsoon winds blowing from land areas are dry and do not yield precipitation.

(v) Ocean Currents: Like the atmosphere, the oceans also have many minor movements. These oceanic circulations have a broad general pattern of currents. These current help in heat transfer by moving warm water towards

the polar areas and cold water towards the equatorial areas. Ocean currents greatly affect the temperature of a particular place. Warm oceanic currents move from warm areas to cold areas and increase the temperature on their path and can cause precipitation while cold oceanic currents move from cold areas to warm areas and decrease the temperature and can cause fog on their path. For example – due to the effect of warm oceanic current of north Atlantic drift, Bergen in Norway never freezes inspite of being located in very high latitude. On the other hand, due to the effect of Labrador cold oceanic current Quebec in Canada freezes in winter in spite of being located in comparatively lower latitude. Wind that comes from ocean also influences oceanic currents, change their nature accordingly.

(vi) Condition of the Cloudiness: Areas of clear sky, receives more solar energy in day time and reflect it quickly to the sky in night. While areas under cloudiness receive less solar energy in day time and reflect it to the sky at a slow pace. For example – Jaisalmer in Rajasthan having clear sky, experiences more temperature in day time (hot days) and low temperatures in night time (cold nights) while Thiruvananthapuram in Kerala having cloudy sky most of the time experiences more or less same temperatures in day time as well in nights.

(vii) Location of the Mountain Ranges: The position or the location of the mountain ranges have a special effect on weather and climate of a particular place. Due to the orographic uplift of the air, windward slopes of the mountain range receive more precipitation while leeward slopes of mountain ranges receive less precipitation. For example – windward slopes of Himalayas get more rainfall compared to the leeward slopes which receive less rainfall and are known as rain shadow areas.

Similarly, the slopes which are facing the sun will be warmer than the slopes away from the sun. Mountains also act as barriers by diverting winds which affect the moisture content of the surrounding areas. The windward slope of the mountains have a different climate than the other side of the mountain. For example – Himalayas play such type of role of a barrier between Tibet and India.

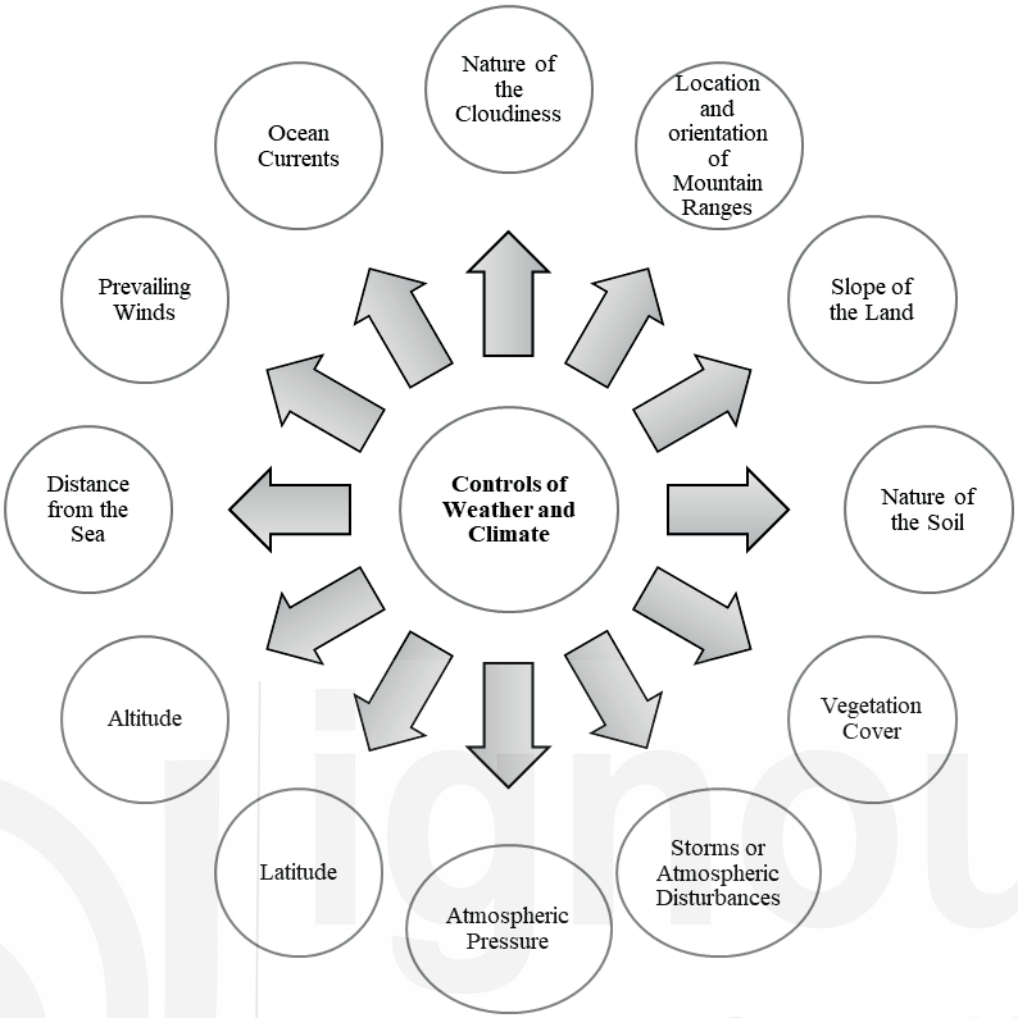

Fig. 2.4: Controls of Weather and Climate. *(Created by Author)*

(viii) Slope of the Land: Slope of the land is an important control of weather and climate. Slope facing the sun always receives more energy than the slope away from sun and have a different climate.

(ix) Nature of Soil: Colour and type of soil is an important control of weather and climate. For example the black colour soil absorbs the heat very quickly where as the sandy type of soil have a tendency of quick absorption and quick release of heat. This is the fact why desert areas are very hot during the day and very cold during nights.

(x) Vegetation cover: Vegetation cover is an important control of weather and climate. Areas with abundant vegetation cover are cooler than the areas with sparse vegetation cover. Thus, Vegetation cover plays an important role in determining the weather and climate of a place. For example – Surface having less amount of vegetation, have quick radiation and more range of temperature while those areas with abundant vegetation, have less range of temperature.

(xi) Storms or Atmospheric Disturbances: The storms that occur throughout the world may be widespread extensively or localised. These atmosphere disturbances create some specific weather conditions impacting men and environment. So, storms are often considered as a weather and climate control.

(xii) Atmospheric Pressure: Atmospheric pressure can be responsible for significant changes in the atmosphere. Pressure has an intimate relationship with wind and hence spatial variations in pressure are responsible for air movements. Atmospheric Pressure has a general tendency to decrease at higher altitudes in the atmosphere. Seven atmospheric pressure belts are found on the earth's surface in which the conditions of low and high pressure are found. These belts greatly affect the weather and climate of a place. The deflection of these pressure belts contributes to determine the weather and climate. Atmospheric pressure and patterns of wind are key aspects of the hydrologic cycle - the systematic movement of water around the planet.

SAQ 3

What are the controls of weather and climate?

2.5 SUMMARY

In this unit you have studied so far:

- About the weather and climate.
- Difference between weather and climate.
- About the elements of weather and climate.
- About the control of weather and climate.

2.6 TERMINAL QUESTIONS

1. What do you know about weather and climate?
2. Differentiate between weather and climate.
3. Write in detail about the various elements of weather and climate.
4. Write in detail about the controls of weather and climate.

2.7 ANSWERS

Self-Assessment Questions (SAQ)

1. a) Weather is the sum of atmospheric conditions of a place over a very short period of time, like few hours, a day or a week.

   b) Climate defines the conditions of the atmosphere over longer period of time like an entire year or decade.

   c) Weather defines the conditions of the atmosphere over a short period of time for example, a day or week whereas climate defines the conditions of the atmosphere over longer period of time like an entire year or decade.

2. Elements that are responsible for the variations in the atmospheric conditions of a place are known as the elements of weather and climate. These are precipitation, humidity, cloudiness, temperature, winds etc.

3. Weather and climate of a place is controlled by the various factors such as latitude, elevation, distance from the sea, wind direction, ocean currents etc. which are known as the controls of weather and climate.

Terminal Questions

1. You can write your answer by defining the weather and climate and elaborating it. Refer Sec. 2.1.
2. You can start your answer by writing about the definition of weather and climate and further write the main differences. Refer Sec. 2.2.
3. You can start your answer by writing about the definition of elements of weather and climate. Further you can write about each in detail. Refer Sec. 2.3.
4. You can start your answer by writing about the definition of controls of weather and climate. Further you can write about each in detail. Refer Sec. 2.4.

2.8 REFERENCES AND FURTHER SUGGESTED READING

1. Ayoade, J.O. (2004). *Introduction to Climatology for the Tropics.* Spectrum Books Ltd., Ibedan.
2. Barry, R.G. & Chorley, R.J. (1971). *Atmosphere, Weather and Climate.* Methuen publication, London.
3. Critchfield, H.J. (1993). *General* Climatology, Prentice Hall, India, New Delhi.
4. Lal, D.S. (1986). *Climatology*, Chaitanya Publications, Allahabad.
5. Koeppe, C.E. & Delong, G.C. (1958). *Weather and Climate,* McGraw Hill Publication, New York.
6. Miller, A. (1959). *Climatology,* Methuen Publication, London.
7. Singh, S. (2011). *Climatology,* Prayag Pustak Bhawan, Allahabad.
8. Trewartha, G.T. (1954). *Introduction to Climate,* McGraw Hill Publication, New York.

UNIT 3

INTRODUCTION TO ATMOSPHERE

Structure

3.1 INTRODUCTION

In this course so far, you have learnt about meaning and scope of climatology and development of discipline of climatology. You have also been introduced to various sub-fields of climatology. So now, you can differentiate between climatology and meteorology, weather and climate, etc. You are also aware of different scales of climatology. You may recall different elements and controls of weather and climate. In this unit, you will be introduced to atmosphere.

First of all, in Sec. 3.2, you will learn about the origin and evolution of the atmosphere. Sec. 3.3 will give an overview of composition of the atmosphere. This will give you an understanding of the uniqueness of our planet earth which supports different life forms. In Sec. 3.4, you will study about the vertical layers of the atmosphere. You will understand how vertical layers are arranged not only on the basis of temperature differences but also on the basis of chemical composition. This is the last unit of Block 1 of this course.

In the next Block you will study about atmospheric processes.

Expected Learning Outcomes

After completing the study of this unit, you should be able to:

- explain the origin and evolution of the atmosphere;
- discuss the composition of the atmosphere;

- describe different layers of the atmosphere on the basis of temperature differences; and
- differentiate between homosphere and heterosphere.

3.2 ORIGIN AND EVOLUTION OF ATMOSPHERE

You must have studied about the earth's atmosphere at earlier levels. You may recall that the earth's atmosphere is a dynamic mixture of gases that envelops the planet. It plays a great role in making the planet livable for different life forms. It provides us air to breathe, protects us from harmful ultraviolet (UV) radiation coming from the sun, traps the heat and creates a warming effect on the planet making it conducive to live by preventing extremes of temperatures. Without the atmosphere, temperatures would be well below freezing everywhere on earth's surface. Due to this warming effect, earth's average surface temperature is about 15°C (59°F), which is comfortable and pleasant.

Do you know that earth's atmosphere has evolved over billions of years through complex processes? Understanding its origin and evolution involves exploring various scientific disciplines such as astrophysics, geology, geography and atmospheric sciences. In this section, we will study the key stages in the formation and development of earth's atmosphere.

The story of the earth's atmosphere begins with the formation of the solar system. About 4.6 billion years ago, a rotating cloud of gas and dust collapsed to form the sun and a protoplanetary disk. In this disk, small particles began to collide with each other and merge, forming into planetesimals that eventually coalesced to form earth.

Around 4-4.5 billion years ago, during the early stages of formation of earth and its atmosphere, the primordial gases making up the earth's newly born atmosphere were very hot. They escaped from the earth due to low gravity and through their high molecular energies. Slowly, when the earth started cooling, a solid crust was formed over the molten core. At that time, the earth's atmosphere was likely composed of gases released during volcanic activity and the outgassing or degassing of volatile compounds from the planet's interior which was molten. This early atmosphere is believed to have been dominated by substances like water vapour, carbon dioxide, nitrogen, methane, and ammonia.

The planet started cooling around 4 - 3 billion years ago and in this process water vapour in the atmosphere began to condense. In the beginning, rain drops quickly evaporated owing to the hot surface of the earth. After subsequent evaporation and precipitation processes, the earth finally cooled. It is estimated that these rains lasted for some 40,000 years, leading to the formation of oceans. The emergence of primitive life forms, such as cyanobacteria, marked a critical transition. Cyanobacteria were capable of photosynthesis, releasing oxygen as a byproduct, gradually contributing to the development of the first oxygen-containing atmosphere.

The accumulation of oxygen in the atmosphere led to the Great Oxygenation Event (GOE) some 2.4 billion years ago. Cyanobacteria, through photosynthesis, significantly increased atmospheric oxygen levels. This event had profound consequences, causing the extinction of anaerobic life forms and paving the way for the evolution of oxygen-dependent organisms.

The Phanerozoic eon (around 542 million years ago - present) witnessed the proliferation of complex multicellular life forms and significant changes in the earth's atmosphere. During the Paleozoic era, plants colonised the land, contributing to increased oxygen levels. The Mesozoic era saw the rise of dinosaurs, and the Cenozoic era saw the evolution of mammals and the development of the modern climate system.

In recent centuries, human activities have significantly altered the composition of the atmosphere. This is also called anthropogenic influence. The Industrial Revolution introduced widespread burning of fossil fuels, releasing large amounts of carbon dioxide. Deforestation and industrial processes further contributed to greenhouse gas emissions, leading to anthropogenic climate change and alterations in atmospheric composition.

The ongoing study of earth's atmosphere involves monitoring contemporary changes and predicting future trends. Understanding the complex interplay of natural processes and human activities is crucial for addressing challenges such as climate change and air pollution.

SAQ I

What is the great oxygenation event?

3.3 COMPOSITION OF THE ATMOSPHERE

Earth's atmosphere is a multilayered gaseous envelope surrounding the earth from all sides and is attached to the earth’s surface by its gravitational force. It comprises of various gases and minute suspended solid and liquid particles. These elements are retained by the earth's gravitational force, creating conditions suitable for life. Now, a pertinent question arises: Is atmospheric density uniform or it varies with altitude? Let us probe into this.

Research indicates that 97% of the total atmospheric mass is concentrated within the first 25 km of altitude. So, atmospheric density diminishes as the altitude increases. Atmosphere is composed of three major constituents, that is, gases, water vapour and aerosols. Regarding gases, the composition can be studied under two heads e.g. (a) Constant gases and (b) Variable gases.

A. Constant Gases

Nitrogen and oxygen are the predominant constant gases, constituting approximately 99% of the earth’s atmosphere. Notably, the concentrations of nitrogen and oxygen remain constant up to an altitude of 80 km. Oxygen which is vital for living organisms is produced by vegetation and removed through diverse organic and inorganic processes. Nitrogen is comparatively an inert gas. So it acts as a diluent and enters the air through the processes like

decay or combustion of organic substances, volcanic activity etc. It is removed by specific biological processes. Other gases, including carbon dioxide, argon, traces of inert gases, water vapour, and ozone, make up the remaining 1% which are called minor gases and their concentration varies.

B. Variable Gases

The concentration of gases like carbon dioxide, water vapour, ozone etc. exhibits spatio-temporal variations. Carbon dioxide is crucial for photosynthesis and contributes to the greenhouse effect by trapping heat in the lower atmosphere. Human activities, particularly fossil fuels usage, have elevated its concentration to approximately 0.04% by volume of dry air.

Ozone, found around 30 km above earth, shields against harmful ultraviolet radiation of the sun. However, human interventions, such as CFCs and HFCs usage, have led to the formation of ozone hole, notably above Antarctica, posing a threat to life.

Water vapour is another variable gas, the concentration of which ranges from 0.02 to 4 percent by volume in dry and humid climates, respectively. It is a very important constituent of atmosphere and plays a role in the cloud formation, which yields rain and contributes to the greenhouse effect.

Apart from gases and water vapour, atmosphere also has suspended particulate matter (SPM) or aerosols which comprises of solid particles of varying sizes and liquid droplets collectively suspended in the atmosphere. Their size varies in size between 2.5 μ to 10 μ and originates from sources like dry soil, sea-salts, pollen, volcanic ash, industrial effluents and even meteoric particles. The concentration of particulate matter is higher in arid regions compared to humid ones, impacting the air quality and causing respiratory issues.

Let us summarise the composition of the atmosphere from the following Table 3.1.

Table 3.1: General Composition of the Dry Atmosphere below 80 km

Gases	Percentage of Gases (Approx.) by Volume of Dry Air
Nitrogen (N_2)	78.08
Oxygen (O_2)	20.95
Argon (Ar)	0.93
Carbon dioxide (CO_2)	0.04 (varies due to human activities and natural processes)
Neon (Ne)	0.0018
Helium (He)	0.0005
Methane (CH_4)	0.0002
Krypton (Kr)	0.0001
Hydrogen (H_2)	0.00005
Nitrous oxide (N2O)	0.00003
Xenon (Xe)	0.00001
Ozone (O_3)	Trace to 0.00080

There are also trace amounts of water vapour, varying from almost 0% to around 4% depending on the location and weather conditions. Now try answering a self-assessment question to check your understanding

SAQ 2

a) Mention any two gases of earth's atmosphere whose concentration varies?
b) Why the concentration of particulate matter is higher in arid regions compared to dry regions?

3.4 VERTICAL STRUCTURE OF THE ATMOSPHERE

The vertical structure of the earth's atmosphere has been the subject of significant interest for meteorologists and scientists throughout history. Critical aspects such as air navigation and the transmission of information through radio and TV signals rely on an understanding of the distinct regions within the atmosphere. To categorise these regions, meteorologists employ different criteria, with temperature being one of the most crucial factors. The atmosphere is characterised by a layered structure based on temperature differences.

Imagine the atmosphere as a series of concentric shells or layers encircling the earth, each defined by specific temperature characteristics. This stratification is vital for comprehending the dynamic and complex nature of our atmosphere. The layered structure is not only a conceptual framework but also a practical tool for meteorologists to study and analyse atmospheric phenomena.

The temperature-based classification of atmosphere results in distinct layers, each with unique thermal properties. Let us study the major layers of the atmosphere, from the earth's surface outward.

3.4.1 Vertical Layers of the Atmosphere Based on Thermal Properties

Earth's atmosphere is said to have the five layers based on the thermal characteristics. These are: Troposphere, Stratosphere, Mesosphere, Thermosphere and Exosphere. Most of the climatologists study ozonosphere as a part of stratosphere. Also ionosphere is taken under the layer thermosphere.

Let us learn about these layers in detail.

Troposphere

The troposphere is positioned as the lowermost layer of the earth's atmosphere and constitutes three-fourths of the total gaseous mass enveloping our planet. This layer is dynamic and crucial for various atmospheric processes, hosting almost all water vapour and dust particles. This nomenclature 'troposphere' was first suggested by Tiesserence de Bort.

It is derived from two Greek words, i.e., ‘tropos’ which means mixing and ‘sphere’ which means zone. So the term troposphere means the zone where mixing of gases occurs most readily. The troposphere serves as the arena for most convective air currents, giving rise to weather phenomena such as clouds, lightning, thunderstorms, and snowfall.

A distinctive characteristic of the troposphere is the uniform decrease in temperature with altitude. This decrease occurs at a rate of 6.5°C per 1000 meters of ascent and is known as the normal lapse rate. This information helps explain why higher-altitude locations like Manali, Gangtok, Kodaikanal etc. exhibit cooler temperatures compared to plains.

Interestingly, the height or extent of the troposphere is not constant either in time or space. At the poles, the troposphere's height is approximately 8 km, while at the equator; it extends to about 16 km. This non-uniformity is attributed to the higher surface temperatures at the equator, resulting in more vigorous convective air currents which push the extent of troposphere at equator than at the poles. Additionally, the height of the troposphere varies with the seasons, increasing during summer and decreasing during winter. The lower part of the troposphere, extending to about 3 km from the earth's surface, is often referred to as the friction layer due to it experiencing maximum friction between the earth's surface and the atmosphere. This layer also exhibits the phenomenon of temperature inversions. A temperature inversion exists when the temperature increases instead of decreasing with altitude. You will study about this in a forthcoming unit on temperature in this course.

At the upper boundary of the troposphere, a transitional zone known as the ‘tropopause’ separates it from the next layer, the stratosphere. The word ***‘tropopause’*** was coined by **Sir Napier Shaw** from two Greek words, i.e., ***‘tropos’*** and ***‘pause’*** which means the zone where mixing stops. Similar to the troposphere, the height of the tropopause is greater near the equator when compared to the poles. This variation contributes to the fact that the lowest temperature in the tropopause occurs over the equator rather than over the poles. The tropopause marks the end of the decrease in temperature due to the normal lapse rate, reaching a minimum of -50°C to -60°C. This temperature trend becomes reverse and is a crucial point of discussion in the subsequent section, highlighting the distinctive characteristics of the stratosphere.

Stratosphere

The stratosphere is situated approximately between 12 km and 50 km above the earth's surface, making it the second major layer of the earth's atmosphere. Unlike the troposphere beneath it, the stratosphere is characterised by unique features that distinguishes it from the layers above and below.

One prominent characteristic of the stratosphere is its relative stability and lack of turbulence. Unlike the dynamic troposphere, the stratosphere experiences minimal vertical movement of air. It happens in the lower part of the stratosphere up to a maximum of about 25 km from the earth's surface where this isothermal behavior is seen. This stability contributes to its

suitability for aviation, as airplanes preferentially fly in the stratosphere to minimise fuel consumption and to avoid turbulence and air resistance.

Cirrus clouds, a type of high-altitude cloud, are observed in the lower stratosphere. These clouds are composed of ice crystals and form under specific conditions in this stable layer.

Above 25 km in altitude, a distinct temperature trend emerges in the stratosphere. There is a steep increase in temperature with height, reaching approximately 0°C at an altitude of 50 km. This temperature rise is primarily attributed to the presence of ozone in this part of the stratosphere. As it absorbs the ultraviolet radiation of the sun, it leads to the warming of the stratosphere in this upper region. Ozone concentration is a characteristic feature of the stratosphere. It is found in the lower portion of the stratosphere, approximately between 15 km and 35 km above the earth. The average concentration is about 0.3 parts per million. Its thickness varies seasonally and geographically. This layer absorbs most of the sun’s ultraviolet radiation which is harmful to the earth living beings. It causes increase in the incidents of skin cancer, cataract, damage to the immune system, change in the genetic structure of life forms, retarded plant growth and reduction in phytoplankton growth in the oceans.

The upper boundary of the stratosphere is defined as the stratopause, marking the transition to the next layer of the atmosphere, the mesosphere. The stratopause extends to an average altitude of 50 km. The stability, dryness, and unique temperature characteristics of the stratosphere make it a critical component of earth's atmosphere, influencing both atmospheric dynamics and human activities such as air travel.

Mesosphere

Up to this point, you've gained knowledge about the troposphere and stratosphere. Now, let's delve into the mesosphere, the layer beyond the stratopause. Positioned between 50 km and 80 km from the earth's surface, the mesosphere exhibits distinct characteristics.

The mesosphere is marked by a temperature decrease with height, primarily due to the absence of the ozone layer in this region. The ozone layer, which absorbs harmful ultraviolet rays from the sun, contributes to the warming of the stratosphere. As you ascend through the mesosphere, temperatures drop, reaching a minimum of -100°C at an altitude of 80 km. The upper segment of the mesosphere is referred to as the mesopause.

Notably, the mesosphere hosts the thin noctilucent clouds, particularly visible over high latitudes during summer. These clouds exhibit luminescence during twilight or shine brightly during the night. Composed of extremely small ice crystals, measuring up to 200 nm in diameter, these mesospheric clouds exist at an altitude ranging from 75 to 85 km. They are considered the highest altitude clouds.

Additionally, the mesosphere is a zone where meteorites disintegrate due to substantial friction. A ***meteor*** is the flash of light that we see in the sky during night, when a small chunk of interplanetary debris burns due to friction while

passing through our atmosphere. The debris of the interplanetary matter is called ***meteoroid*** and a few which make their passage to the earth's surface are called ***meteorites***. This disintegration occurs here because the layers of the atmosphere above the mesosphere, namely the thermosphere and exosphere, have an extremely low density of air. Consequently, the mesosphere becomes the key location for the friction which meteorites encounter upon entering the earth's atmosphere.

Ionosphere or Thermosphere

Revisiting the region beyond the mesopause, you'll observe the presence of a high-temperature zone known as the thermosphere. The lower part of the thermosphere is referred to as the **ionosphere,** spanning altitudes between 100 and 400 km. The discovery of the ionosphere is credited to Kennelly and Heaviside. This layer earns its name because the gaseous atoms or molecules within it become ionised due to solar radiations. Ionisation is the process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons often in conjunction with other chemical changes. The ionosphere plays a crucial role in reflecting electromagnetic waves back to the earth, facilitating radio and TV communication.

An intriguing aspect of the ionosphere is the occurrence of Auroras, which typically manifest between 80 and 160 km in altitude. These natural displays of lights, especially near the magnetic poles, are caused by the excitation of the ionosphere by streams of high-energy particles from the sun. In the northern hemisphere, they are known as *Aurora Borealis* or northern lights, while in the southern hemisphere, they are termed as *Aurora Australis* or southern lights.

The ionosphere is further categorised into several ionised layers, namely the D, E, F1, F2, and G layers. Let us explore the characteristics of each of these layers.

D-Layer: It is present between 60-99 km from the earth's surface during the daytime. It absorbs medium and high-frequency waves and reflects low-frequency waves. It disappears after sunset.

E-Layer: Positioned at a height of 90-130 km from the earth's surface, the E-Layer reflects medium and high-frequency radio waves, also known as the *Kennelly-Heaviside layer*. This layer also vanishes after sunset.

Sporadic E-Layer: Occurring under special circumstances, just like meteors or auroras, the sporadic E-layer is associated with high-velocity winds. It reflects very high-frequency radio waves and is found at an altitude of about 110 km.

E2 Layer: Above the sporadic E-layer, the E2 layer is formed by the action of ultraviolet photons on oxygen molecules during the day, disappearing at sunset and appearing at a height of about 150 km from earth's surface.

F1 Layer and F2 Layer: Together known as the Appleton Layer, these layers are found at a height of about 150-380 km from earth's surface. They play a crucial role in reflecting medium and high-frequency radio waves, contributing to the long-distance radio communication.

G Layer: Positioned above the F2 layer, the G layer is a reflecting layer that cannot be detected as it reflects all the waves reflected by the F1 layer. Found at a height of about 400 km above the earth's surface, it is characterised by the presence of free electrons resulting from the reaction of ultraviolet photons with nitrogen atoms.

The thermosphere extends to several hundred km, with temperatures rising to about 2000°C at around 500 km in altitude. These high temperatures represent internal or kinetic energy of the molecules, but due to the sparse air density in this region, they cannot be recorded by a thermometer nor be felt, as is the case in the denser troposphere.

SAQ 3

a) What are the key characteristics and layers of the ionosphere?
b) How does the thermosphere's high temperature differ from that in the troposphere?

Exosphere

The outermost layer of earth's atmosphere begins roughly at 500 km from the surface and stretches up to an altitude of approximately 1000 km. Known as the exosphere; it serves as a transitional region between earth's atmosphere and interplanetary space. At such heights, air density is exceedingly low, explaining why despite temperatures soaring to above 5000°C, it remains unfelt. Hydrogen and helium are the primary components within this region.

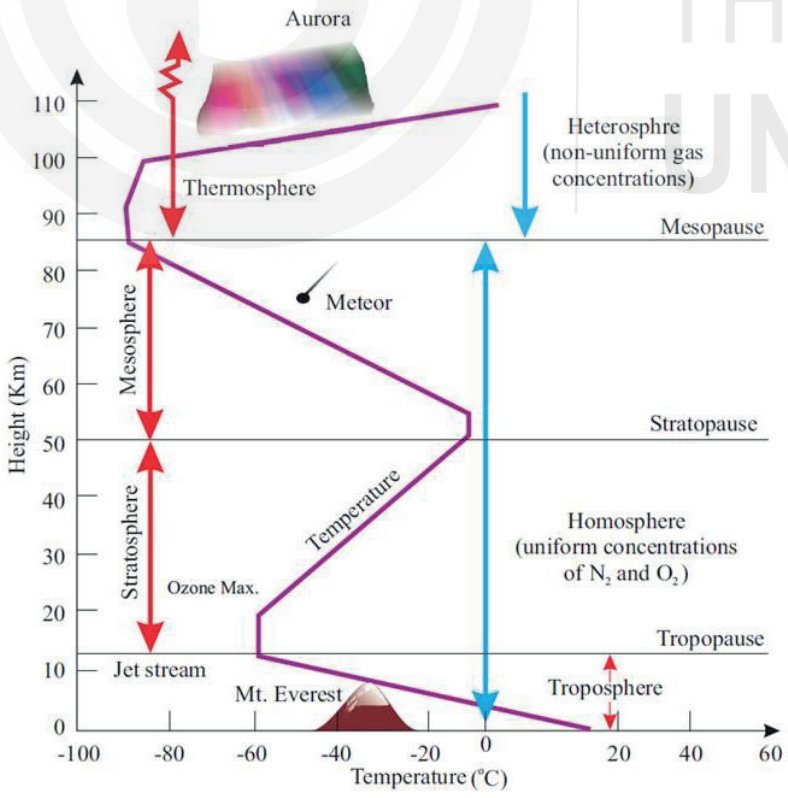

Fig. 3.1: Vertical Layers of the Atmosphere based on Temperature Properties.

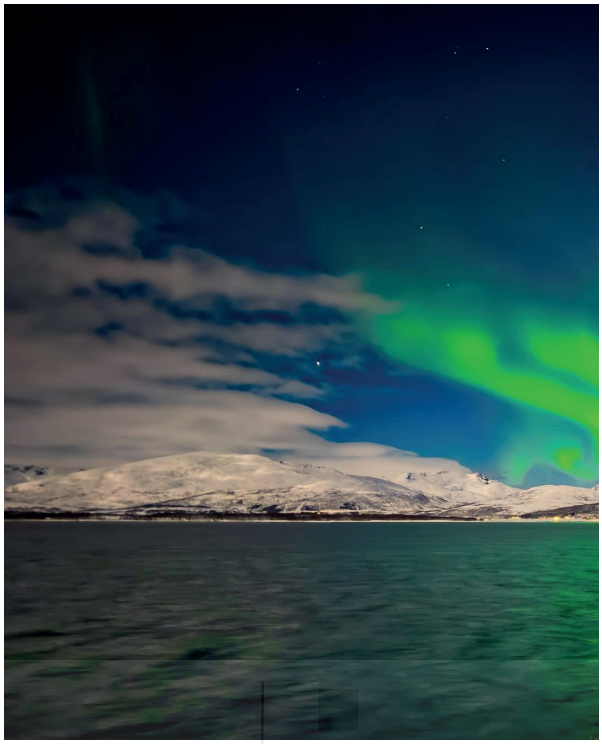

Fig. 3.2: Aurora. (Picture Courtesy: Dr. Rukman)

In addition to temperature-based classifications of atmospheric layers, another criterion for categorisation revolves around chemical composition. This leads to a broad division of atmosphere into two main spheres: the homosphere and the heterosphere. The subsequent section discusses these spheres.

3.4.2 Vertical Layers of Atmosphere Based on Chemical Composition

The layer of the atmosphere that spans from the earth's surface up to an altitude of 80-90 km is termed as homosphere. This designation stems from the fact that, despite some variations due to human activities, the proportion of component gases and their chemical compositions (as discussed in Sec. 3.3) remains uniform within this layer. The homosphere encompasses the troposphere, stratosphere, and mesosphere, including their transitional zones.

Above the homosphere lies the heterosphere, wherein the chemical composition undergoes changes with increasing altitude. The heterosphere is comprised of concentric layers of molecular nitrogen, atomic oxygen, helium, and hydrogen. This arrangement in the heterosphere is delineated into four regions:

a) A layer of molecular nitrogen encircling the earth from 80 km to 200 km.
b) A layer of atomic oxygen extending from 200 km to 1125 km in altitude.
c) A layer of atomic helium ranging from 1125 km to 3540 km in altitude.
d) A layer of atomic hydrogen extending from 3540 km to the outermost boundary of the atmosphere.

The rationale behind the organisation of these concentric layers lies in the atomic weights of the constituent gases. The heavier nitrogen occupies the lower part, while the lighter hydrogen dominates the topmost region of the atmosphere, reaching almost up to its outer limit or boundary. For a clearer

visualisation of the vertical layers of the atmosphere based on chemical composition, please refer to Fig. 3.3.

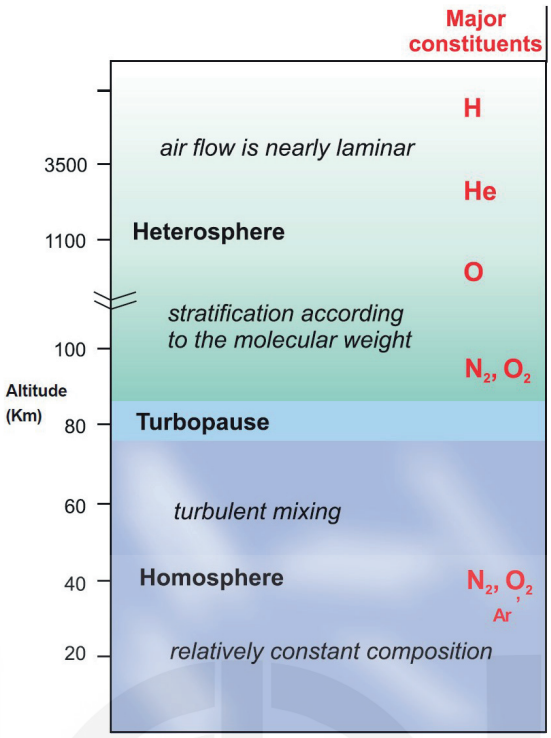

Fig. 3.3: Vertical Layers of the Atmosphere Based on Chemical Composition.

This stratification according to atomic weights contributes to the unique structure of the atmosphere, reflecting the distribution of gases based on their respective weights. The arrangement serves as a key factor in understanding the composition and behavior of different layers within the earth's atmosphere.

3.5 SUMMARY

In this unit you have studied so far:

- Atmosphere is a mixture of gases enveloping the earth.
- Nitrogen and Oxygen account for 99% of our atmosphere.
- Troposphere, stratosphere, mesosphere, thermosphere and exosphere are the major vertical layers of atmosphere based on temperature differences between them.
- Troposphere is known for turbulence and formation of weather phenomena such as clouds, thunder, lightning, rainfall and snow and has 75% of total mass of the atmosphere.
- Upper stratosphere is composed of ozone layer which protects earth from the harmful ultraviolet radiation.
- Ionosphere which forms the part of lower thermosphere is mainly responsible for the reflection of radio signals from the earth.
- Based on the chemical composition, the atmosphere is divided into homosphere and heterosphere.

3.6 TERMINAL QUESTIONS

1. Discuss the origin and evolution of atmosphere.
2. Describe the in detail the composition of atmosphere explaining the constant and variable gases.
3. Describe the vertical layers of atmosphere on the basis of thermal properties.
4. Differentiate between homosphere and heterosphere.

3.7 ANSWERS

Self-Assessment Questions (SAQ)

1. This is related to the evolution of earth's atmosphere. Some primitive life forms liken Cyanobacteria, released oxygen through the process of photosynthesis. This accumulation of oxygen in the atmosphere led to the Great Oxygenation Event (GOE). This event had profound consequences, causing the extinction of anaerobic life forms and paving the way for the evolution of oxygen-dependent organisms.
2. a) The two gases whose composition varies are Carbon dioxide and water vapour.

   b) In humid regions rainfall settles the particulate matter on the ground contrary to dry regions. Besides dry regions have lesser vegetation cover to bind the soil. Arid regions also experience dust storms which further increase the concentration of SPM in atmosphere.

3 a) The ionosphere, discovered by Kennelly and Heaviside, consists of layers such as D, E, F1, F2, and G. It reflects electromagnetic waves, enabling radio and TV communication. The occurrence of Auroras at 80-160 km altitude is a notable feature. The D-Layer absorbs medium/high frequency waves, the E-Layer reflects medium/high frequency radio waves, and the Sporadic E-Layer occurs under special circumstances, reflects very high-frequency radio waves. The E2 Layer forms above the Sporadic E-Layer during the day. The F1 and F2 Layers, collectively called the Appleton Layer, reflect medium/high frequency radio waves and are vital for long-distance radio communication. The G Layer, above the F2 Layer, is a reflecting layer with free electrons.

   b) The thermosphere, extending to several hundred km, experiences a temperature rise to 2000°C at 500 km altitude. This high temperature refers to the internal or kinetic energy of molecules which cannot be felt or recorded by thermometers due to sparse air density in thermosphere compared to the troposphere.

Terminal Questions

1. Describe primordial atmosphere and the way it has evolved at present. Refer to Sec.3.2.
2. Define atmosphere and then discuss the major gases present in atmosphere and their percentage. Discuss about gases whose

concentration remains constant at the same time gases whose concentration varies. Refer to Sec.3.3.

3. First of all define atmosphere and describe all the vertical layers of atmosphere based on thermal properties. Draw a figure of vertical layers of atmosphere to explain better. Refer to Sec.3.4.1.
4. Define homosphere and heterosphere and explain the difference. Refer to Sec.3.4.2

3.8 REFERENCES AND SUGGESTED FURTHER READINGS

1. Critchfield, H. (1981). *General Climatology*, Prentice Hall, New York.
2. Lal, D.S. (2009). *Climatology and Oceanography*, Sharda Pustak Bhavan, Allahabad.
3. Rohli, R.V. and Vega, A. J. (2012). *Climatology*, Johns and Bartlett Learning, Sudbury, MA.

Web Links

- Composition and Structure of Atmosphere: https://www.youtube.com/watch?v=uhQ6brtoyE8&list=PLDCsGRRaAZqf0UAvuVbte3ZssrUXVHBcb&index=1&t=49s
- Hayes, J.M. "evolution of the atmosphere". *Encyclopedia Britannica*, 16 Nov. 2020, https://www.britannica.com/topic/evolution-of-the-atmosphere-1703862. Accessed 13 May 2024.

GLOSSARY

Aerology : Aerology is the branch of meteorology that deals especially with the description and discussion of the phenomena of the free air as revealed by kites, balloons, airplanes and clouds.

Aeronomy : Aeronomy is the scientific study of the upper atmosphere of the earth.

Aerosols : Aerosols include particulates, tiny liquid or ice crystals. Particulates are solids suspended in the atmosphere.

Altitude : Altitude is defined as the height above a fixed reference point, which is usually taken as sea level. It is also referred to as elevation.

Angle of Incidence : The angle at which the sun's rays strikes the earth's surface.

Atmospheric Pressure : The force that is exerted by the atmosphere on a surface.

Average Lapse Rate : The average rate of temperature decrease with height in the troposphere—about 6.5° C per 1000 meters.

Barometer : Air pressure or Atmospheric Pressure is measured by an instrument called as Barometer. Its units of measurement are millibars or inches or centimetre.

Chlorofluorocarbons : Ozone layer of the stratosphere is depleting and is under tremendous threat due to continuous use of chlorofluorocarbons (used in refrigerators, air-conditioners etc), nitrous oxides (emitted from jet planes), halon etc. In the absence of ozone layer, the harmful ultra-violet radiation would reach the earth surface and cause various disorders inhuman beings as well as other life forms. It could even destroy many microscopic species from the earth.

Climatologists : Scientists who specialise in the field of Climatology are called Climatologist.

Cloud : Visible accumulation of tiny liquid water droplets or ice crystals suspended in the atmosphere.

Energy : Anything that has the ability to change the state or condition of matter.

Hydrologic Cycle : The continuous circulation of water in the earth-atmosphere system.

Hygrometer : It is an instrument that is used to measure humidity.

Insolation : Incoming solar radiation is known as insolation.

Ionisation : Ionisation is the process by which atom or a molecule acquires a negative or positive charge by gaining or losing electrons often in conjunction with other chemical changes.

Latent heat : Energy stored or released when a substance changes its state.

Latitude : Location described as an angle measured north and south of the equator.

Longitude : Location described as an angle measured (in degrees, minutes, and seconds) east and west from the prime meridian on the earth's surface.

Meteor : A meteor is the flash of light that we see in the sky during night, when a small chunk of interplanetary debris burns due to friction while passing through our atmosphere. The debris of the interplanetary matter is called meteoroid and a few which make their passage to the earth's surface are called meteorites.

Millibar : A measure of pressure, consisting of one-thousandth parts of a bar, or 1000 dynes per square centimeter.

Monsoon : A seasonal reversal of winds; a general onshore movement of wind in summer and a general offshore flow in winter, with a very distinctive seasonal precipitation regime.

Monsoon Winds : A monsoon is a major wind system that seasonally reverses its direction.

Psychrometer : Psychrometer is a device for measuring humidity.

Pyrheliometer : Pyrheliometer is an instrument for measurement of direct beam solar irradiance.

Radiosonde : Radiosonde is a small instrument carried aloft to measure, pressure, temperature and relative humidity and that is suspended below balloon.

Temperature Inversion : A temperature inversion exists when the temperature increases instead of decreasing with altitude.

Thermometer : It is an instrument that is used to measure temperature. Units of measurement of temperature are in degree Celsius (^{o}C) or Fahrenheit (^{o}F).

Trade Winds : The trade winds are those winds which blow from the sub-tropical high pressure areas towards the equatorial low-pressure areas. Therefore, these winds are confined to a region between 300N and 300S latitudes of the earth's surface. These winds were named by the crews of sailing ships who depended on these winds during their westward ocean crossings.

Tropopause : The word 'tropopause' was coined by Sir Napier Shaw from two Greek words, i.e., 'tropos' and 'pause' which means the zone where mixing stops.

Troposphere : This nomenclature 'troposphere' was first suggested by Tiesserence de Bort. It is derived from two Greek words, i.e., 'tropos' which means mixing and 'sphere' which means zone. So the term troposphere means the zone where mixing of gases occurs most readily.