Indira Gandhi National Open University
School of Sciences

MGG 005

CLIMATOLOGY

BLOCK

4

CLIMATIC CLASSIFICATION

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BLOCK 4: CLIMATIC CLASSIFICATION

Understanding climatic classification systems is essential for comprehending the diverse climates across the globe. This block explores various approaches to classifying climates and the significance of these classifications in understanding regional climate patterns and their impacts on natural and human systems.

Unit 12 on Approaches to Climatic Classification delves into the different approaches used in climatic classification, including empirical, generic, and genetic methods. Learners will understand the principles underlying each approach and how they contribute to our understanding of climate variability and change.

Unit 13 on Climatic Classification of Koppen focuses on the Koppen’s climate classification system, examining its bases, classification criteria, and methods for evaluating climate types. Learners will gain insight into how Koppen's classification system helps categorise climates based on temperature and precipitation patterns.

Unit 14 on Climatic Classification of Thornthwaite explores Thornthwaite's climatic classification system, including its bases, methods for assessing thermal efficiency and precipitation effectiveness. Learners will understand how Thornthwaite's system provides insights into the water balance of different climates.

Unit 15 on Climatic Regions of the World examines the major climatic regions of the world, including tropical, temperate, and polar climates. Learners will explore the characteristics, distribution, and significance of each climatic region in shaping global climate patterns and influencing ecosystems and human societies.

After studying this Block, you should be able to:

- analyse the differences between empirical, generic, and genetic approaches to climatic classification;
- describe the bases and classification criteria of the Koppen climate classification system;
- evaluate the effectiveness of Koppen's classification system in representing global climate diversity;
- explain the bases and principles of Thornthwaite's climatic classification system;
- assess the applicability of Thornthwaite's classification system in understanding climate-water interactions; and
- differentiate between tropical, temperate, and polar climatic regions based on their characteristics and climate parameters.

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

UNIT 12

APPROACHES TO CLIMATIC CLASSIFICATION

Structure

12.1 INTRODUCTION

In the previous units (Block I, II and III) of this course, you have studied about the seasonal and spatial variations of the basic elements of climate, such as - insolation, temperature, atmospheric pressure and winds, air masses and cyclones, humidity, condensation and precipitation. During the study, you must have noted that latitude, altitude, nature of surface, uneven distribution of land and sea and atmospheric circulations and oceanic circulations play a significant role as factors controlling weather and climate. In this chapter, you will study how these complex elements and controlling factors of climate can be generalised, simplified, and represented in the form of broad climatic classes.

The basic goal of climatic classification is to bring a systematic order to large and diverse information by organising similar entities together into groups that are different from other groups by specific attributes. In this way, an order is generated out of complexity. Climatic classification helps in comprehending the multiplicity of atmospheric conditions in meaningfully organised simple and general terms. It also helps in establishing an association of climate with other aspects of physical environment and human activities.

In this chapter, you will understand the bases, approaches and their comparative advantages and disadvantages in developing climatic classification system.

In the next unit, that is unit 13, you will study in detail the Koppen's climatic classification and unit 14 will focus on a detailed description and analysis of Thornthwaite's climatic classification.

Jitender Saroha

Expected Learning Outcomes

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

- define climatic classification;
- describe significance of climatic classification;
- explain different bases of climatic classification;
- differentiate between different types of approaches of climatic; and classifications and their merits and demerits.

12.2 DEFINITION AND SIGNIFICANCE OF CLIMATIC CLASSIFICATION

12.2.1 Definition of Climatic Classification

The elements of climate such as temperature, pressure, winds, cloudiness and precipitation show variations and complexities in distribution patterns. The climate controls such as intensity of sunshine and its variations with latitude, uneven distribution of land and water, geographic position and prevailing winds, nature of surface and topographic barriers, atmospheric and oceanic circulations, air masses, fronts and cyclones determine these diversities and complexities. The interactions of these climatic controls give every location on the earth surface a distinctive and unique nature of climate. Even the places in proximity have distinct or different climatic conditions.

The distinct climatic character of numerous sites shows variations from place to place and time to time. Thus, the number of distinct climates is extremely large. To address this great diversity and complexity of vast array of global climatic data, scholars have devised climatic classifications. In these classifications, the climatic items are grouped, based on principle of internal homogeneity and external heterogeneity. The internal homogeneity is not in absolute sense rather it is in relative terms, as per the criterion or criteria. The similarities of climatic conditions within a specific area, provides the base for identification of broad climatic classes or climatic regions. Thus, climatic classification is a system or a process that categorises a great variety of climatic conditions in a limited number of classes.

Climatic classification is a mechanism through which diversity and complexity of atmospheric conditions over earth surface are transformed into manageable classes which are meaningfully organised in order for simplification and generalisation. The objectives of climatic classification are – (i) to identify distinct types of major climates over earth surface; (ii) to establish relationships among these major classes; (iii) to provide a framework or hierarchical order of classes and sub-classes to cover macro, meso and micro level variations and specialities of climates; and (iv) to devise a classification which establishes links of the climatic elements and their determinants. These classifications identify, interpret, and streamline climatic similarities and differences between areas in order to strengthen the scientific understanding of world climates.

Applied climatologists and geographers have devised many classification systems based on various approaches to group the climates of individual places or sites into distinctive climate types. These climatic classifications are not exact replicas of the real-world climates they represent, but they help in simplification and generalisation about the complex real world. They contribute as a useful mechanism to summarise, communicate, and exchange information about them.

12.2.2 Significance of Climatic Classification

The objective of climatic classification is to replace the multiplicity of atmospheric conditions over the globe in a meaningfully organised, manageable units or classes. As mentioned, it helps in comprehending the variety and complexities of distribution patterns of climatic elements and their relationships with climate controls. Bringing order to huge quantities of information and data base not only helps in comprehension and understanding of climatic complexities in a simplified and generalised manner but also facilitates description, analysis, and explanation.

There is a spatial resemblance between climate and biomes. Biome classifications are based on vegetation structure, which is determined predominantly by climate. Thus, climatic classifications aid in description, explanation and understanding of biomes. They help in understanding the diversity and distribution of the basic elements of climate over globe and reflect their relationships with other aspects such as soils, landforms, plants and animals. This way, climatic classifications have significance not only for geographers but also for scientists and planners having research interests in physical environment, soils, plants and animals. They also enable the scholars to predict the climatic conditions of an area by correlating vegetation, soil, landform and animal life of the area with climatic elements.

Climatic classifications deal not only in the descriptions of the natural environment but also in assessing land use patterns. This role is particularly crucial in guiding the progress of developing nations as they seek to augment inadequate food resources and to achieve the goal of sustainable development. For instance, in India, the Planning Commission introduced the concept of Agro-climatic zonation to achieve the goals of food security and sustainable development.

SAQ I

Define climatic classification and describe its significance.

12.3 BASES OF CLIMATIC CLASSIFICATION

The major problem in the process of climatic classification is that climate is composed of many elements such as insolation, temperature, atmospheric pressure, winds, air masses, precipitation, cyclones, fronts etc. and any classification based on a single climatic element would be macro-level generalisation only and it will have limited utility. Whereas climatic classification based on numerous elements would be so complex that it would lose simplicity, clarity, and practical utility.

The most common elements which have been used for climatic classification are temperature, precipitation, and vegetation. The ancient Greeks recognised three climate zones in each hemisphere, those are, *torrid*, *temperate* and *frigid* which were derived on the basis of angle of sun's rays or latitude and temperature.

Based on the temperature, world can be delineated into 'hot', 'warm', 'cool', 'cold' and 'frigid' or 'permafrost' climates. The availability of data of daily minimum and maximum temperatures and monthly and annual means for many decades at thousands of observing stations located all over the world has been an important factor in favouring the use of temperature as criterion for climatic classification. A comparison of annual temperature cycles for different parts of the globe helps in the identification of several distinctive types, which can be called as 'thermal regimes.' Thermal regimes can be used to classify the climates. For instance, in the equatorial regime, temperature remains around 27^0C throughout the year but in the tropical continental regime it ranges from very hot in summer season to mild in winter season. The thermal regimes easily distinguish 'continental climate' from 'marine climate.'

Like temperature, precipitation data are abundantly available for a long period for thousands of observing stations widely distributed over the globe. That is why the monthly and annual precipitation data make the basis of most of the widely used climatic classifications. Climates based on rainfall can be defined as 'wet', 'humid', 'sub-humid', 'semi-arid' and 'arid' climates. The annual precipitation is a useful variable in highlighting the characteristics of a climate type but it can be a misleading statistic because there are well established seasonal cycles of precipitation. The presence of dry and wet seasons instead of a uniform distribution of precipitation throughout the year has great impact on natural vegetation and crops. Further, it also matters whether the wet season coincides with a season of high temperature or with a season of lower temperature because vegetation needs both heat and moisture.

Thornthwaite in his climatic classification (1931) used the criteria of thermal efficiency and precipitation effectiveness. Keeping in view the significance of temperature in vegetation growth, Thornthwaite introduced an index of thermal efficiency. It is expressed by the positive departure of monthly mean temperature from the freezing point. Precipitation Effectiveness is the amount of precipitation which is available for the growth of natural vegetation. It is also known as precipitation efficiency. It is a function of precipitation and evaporation. In 1948, Thornthwaite proposed a new classification of climates with several modifications in criteria. In this classification he developed and introduced the concept of potential evapotranspiration. Potential evapotranspiration is an index of thermal efficiency and water loss. It represents the amount of moisture that would be transferred to the atmosphere by evaporation of liquid or solid water plus transpiration from plants. In unit 14, a detailed description of these criteria is provided for in-depth understanding.

Two main elements of climate viz. temperature and precipitation affect vegetation of a particular region. So vegetation is a true reflection of climate. Therefore, by determining and identifying a particular vegetation the type of climate can be inferred. In genetic climate classification winds and air masses have also been used as bases of classification. Global patterns of precipitation are related to air mass source regions and prevailing movements of air masses.

SAQ 2

Describe the most used bases of climatic classifications.

12.4 APPROACHES TO CLIMATIC CLASSIFICATION

Taking into consideration the objectives, different approaches have been adopted by geographers for climatic classification. There are, however, four broad approaches for the delineation of climatic regions of the world. These approaches are as follows:

(i) Empirical Approach of Climatic Classification
(ii) Generic Approach of Climatic Classification
(iii) Genetic Approach of Climatic Classification
(iv) Applied Approach of Climatic Classification

(i) Empirical Approach of Climatic Classification

An empirical classification is based on the observable elements of climate which may be considered singly or in combination to frame criteria for climatic types. As mentioned in the basis of climate classification, based on temperature criteria classes can be identified as – hot, warm, cool, cold, and permafrost climates. Likewise based on precipitation, climate classes can be recognised as – wet, humid, sub-humid, semi-arid and arid climates. As these types of classifications are based on statistics or data, they have well defined boundaries which bring more objectivity in the classification as compared to qualitative criteria. In general, temperature and precipitation have been taken into consideration in most of the empirical classifications of climate. The variants of temperature and precipitation such as precipitation effectiveness, thermal efficiency and evapotranspiration have also been frequently used. This approach helps in summarising enormous amount of information. Another advantage is this that quantitative criteria produce distinct boundaries for climatic classes. Koppen's climatic classification and Thornthwaite (1931) climatic classification are based on empirical approach.

This approach has limitation, with additional criteria the number of possible combinations swiftly increases and soon the classification system becomes impractical. It is, therefore, mandatory to prefer the criteria that are most important in view of the set goal. Scholars have preferred thermal and moisture criteria for empirical classifications of climates but over dependence on these two factors side-lines other essential elements of climate having significance for other purposes.

(ii) Generic Approach of Climatic Classification

Generic classifications of climate are generally based on temperature and precipitation criteria. The levels of temperature and the amount of precipitation determine the rate of evaporation and aridity. Thermal effectiveness and aridity, which is usually expressed as precipitation effectiveness are associated with vegetation boundaries. Koppen identified climate classes on the basis of temperature and precipitation characteristics of a region. Because of strong resemblance between vegetation type and climate, his climate categories were originally based on the type of natural vegetation found in an area. He concluded that the distribution of natural vegetation was the best representation of overall climate. Therefore, the boundaries he demarcated were predominantly based on the limits of specific plant associations. He identified five principal climate groups at global level. In generic classification, types are recognised based on the response of flora to climate. The Koppen system of climatic classification, original and its modifications, applied the generic approach. To overcome some of the Koppen system deficiencies, the American Climatologist C.W. Thornthwaite devised a new classification system (1931). Both these systems were based on temperature and precipitation measurements and both established correspondence of natural vegetation with climate. However, to emphasise the significance of precipitation and evaporation on plant growth, Thornthwaite applied precipitation-effectiveness ratio, which is basically monthly precipitation divided by monthly evaporation. On the basis of twelve months ratios, he developed precipitation effectiveness index and identified five major humidity provinces and their characteristic vegetations types namely rainforest, forest, grassland, steppe and desert. Thus, the approach of Koppen system of climatic classification and the approach of the first climatic classification of Thornthwaite (1931, 1933) were empirical as well as generic.

(iii) Genetic Approach of Climatic Classification

A classification based on genetic or causative factors of climate is known as a genetic classification. It attempts to organise climates according to their causes. The bases of this type of classification include- latitude or angle of sun's rays, winds, pressure belts, air masses, topography and distribution of land and sea. The explanations of genetic classification are, however, theoretical, incomplete, and difficult to quantify. Genetic classifications can be grouped into three types, based on their criteria – (i) pertaining to the geographic determinants of climate; (ii) pertaining to the surface energy budget, and (iii) pertaining to air mass and fronts analysis.

The ancient Greeks identified three climate zones in each hemisphere, namely *torrid*, *temperate* and *frigid* on the basis of earth-sun relationships i.e., simply on the basis of angle of sun's rays, latitude and temperature. In this simple scheme of climate classification four important parallels of latitude: Tropic of Cancer, the Tropic of Capricorn, the Arctic Circle and the Antarctic Circle were used for climate zones delimitation. Thus, the earth surface was divided into winterless climates and summerless climates and an intermediate or transitional type that had seasonal characteristics of both. This classification is still popular as a broad generalised classification of world climates. It is based on the basic determinant of climate that is amount of insolation, which depends of geographic position or latitude or angle of sun's rays.

In addition to categorisation of climates based on latitudinal control of temperature, nature of surface and distance from sea were also used by the scholars to differentiate between maritime and continental climates. **Donald, R. Currey** (1974) identified and mapped climatic classes of North America based on criteria of ***relative continentality***. He derived relative continentality by analysing the data of temperature ranges and latitude. According to him, continentality can be incorporated into traditional climatic classifications on a basis that is comprehensive, sensitive, consistent in its criteria, and orthogonal with respect to other classificatory criteria. In his classification, two oceanic (ultra-oceanic and oceanic) and three continental (sub-continental, continental, and ultra-continental) subdivisions provided effective, yet efficient, resolution of the continentality spectrum. However, this concept of continentality-oceanity is effective within the mid latitudes and tropics where annual temperature ranges are generally very light and in Polar Regions long polar nights and ice covers introduce complexities.

Another classification based on wind regimes was proposed in 1950 by ***H. Flohn.*** Wind regimes generally depend on geographical positions of pressure belts and atmospheric circulations. Topographical barriers were used to classify climates into – windward and leeward climates. All these classifications were qualitative in nature and they were identified in a subjective manner and did not involve application of quantitative techniques and differentiating formula or equations.

In 1970, American geographer ***W.H. Terjung*** used *net insolation*, energy available for evaporation and heat available for heating the air and subsurface as criteria. Based on analysis of data of more than 1,000 locations distributed worldwide, he generated the annual patterns based on the maximum energy input, the annual range in input, the shape of annual curve, and the durations with negative magnitudes or energy deficits. Finally, based on homogeneity of net radiation, climatic regions were delineated and mapped.

Another simple but extremely effective and the most extensively used genetic classification of world climates based on *air masses* has been proposed by ***Strahler***. In 1951 he presented a qualitative classification of world climates based on the combination of air masses and front zones existing at a particular location throughout the year. Air masses have internal homogeneity of characteristics especially, temperature, humidity and density. Therefore, nature of air masses and convergence zones of contrasting air masses at fronts determine the weather conditions. As the source regions of air masses, their paths and front zones maintain almost same positions year after year, they provide useful base for classification of climates.

According to Strahler the latitude determines the temperature of the air mass and type of surface (land or ocean) controls the moisture content of the air mass. As the air-mass characteristics control the two most important climate variables – temperature and precipitation, they provide potential base for climatic classification. Contrasting air masses come in contact at frontal zones. The position of frontal zones changes with seasons. Seasonal movements of frontal zones also influence annual cycles of temperature and precipitation. Thus, air masses and frontal zones can be used to identity the climatic classes. He first divided the world climates into three broad groups of climates: low-latitude climate (Group I), mid latitude (Group II) and high-latitude (Group III). Within these three climatic groups, he identified a total of 13 climate types at global level: four in Group I, six in Group II and three in Group III.

J.E. Oliver (1968 and 1970) used a quantitative outline to assign a particular *air mass and air mass combinations* as “dominant,” “subdominant,” or “seasonal”, in location specific manner. He used *“thermohyet diagram”* based on average monthly temperatures and precipitation for classification of climates. This avoided dependence on the less common upper-air data for the classification.

(iv) Applied Approach of Climatic Classification

In applied climatic classifications, the climatic regions are delineated in terms of impacts of climate on other phenomena. These classifications help in addressing technical problems that involve one or more climatic elements. They are, therefore, also known as technical or functional classifications of climate. Several scholars have tried to identify the climatic factors which have deep impact on vegetation and various parallels between vegetation and heat and moisture have been established. The vegetation terms like rainforest, forest, savanna, steppe, desert and tundra have climatic connotations. Natural vegetation is basically in an index of mosaic of atmospheric conditions and far more efficiently represents climatic differences in a cumulative manner than data recorded by different instruments individually.

Thornthwaite in his second climatic classification 1948 and in his slightly revised (1955) classification used applied approach based on the concept of potential evapotranspiration. He applied the criteria of the moisture budget and potential evapotranspiration (i.e., the maximum moisture that will be transferred from surface to the atmosphere, provided that enough water is present in). This new scheme focused on the concept of potential evapotranspiration, which is the amount of moisture that would be lost from the soil and vegetation if the moisture were available. Water balance or soil-moisture budget studies based on potential evapotranspiration help in assessing water availability and water demands. In agriculture science, soil-moisture analysis provide scientific base for assessing cropping patterns and to suggest changes in cropping patterns based of climatic conditions. Mapping of moisture availability, deficiency and surplus conditions provide clues for irrigation, urban and regional planning. In view of climate change and sustainability concern, the applied aspects of potential evapotranspiration and moisture budget have gained significance.

Climatic classification can be based on criteria of human health and comfort. This type of classification has potential applications in the fields of cloth designing, housing, physiology, and medicine. They establish relationship of climate to health, clothing, food and nutrition, and human perceptions of the physical setting. **Werner H. Terjung** (1966) applied the concept of “physiologic climates” based on human responses to temperature, relative humidity, wind chill and solar radiation. He identified and mapped annual physioclimatic extremes in the United States. Some other scholars have generated applied climatic classifications based on different socio-economic adjustments to climate or based on the impact of human activities on the physical environment. Such classifications have utility in studies concerned with climate change.

SAQ 3

a. Briefly describe the major approaches of climatic classification.

b. Describe the applied approach of climatic classification.

12.5 SUMMARY

In this unit you have studied:

- A climatic class or region represents a homogenous set of climatic conditions. Climatic classification is essential for identification, mapping and description of climatic classes or regions.
- Classification of climates helps in generalisation and simplification of diverse atmospheric conditions prevailing over different parts of the earth surface. It helps in understanding relations of climate with vegetation, climate and biomes, climate and soils etc.
- The fundamental criteria used for climatic classification are temperature, precipitation and vegetation. In addition to these thermal efficiency, precipitation and potential evapotranspiration are same, precipitation effectiveness, potential evapotranspiration, latitudinal position, nature of surface, uneven distribution of land and sea, air masses and front zones, and prevailing winds and pressure systems have also been used by climatologists.
- The approaches of climatic classification are – empirical, generic, genetic and applied.
- Empirical approach uses observed data of climatic elements generally of temperature and precipitation.
- Generic approach uses the relationship of climate with vegetation structure as criteria for classification. Koppen’s climatic classification is both empirical and generic classification.
- Genetic classification is based climatic controls such as – earth-sun relationship or latitude, uneven distribution of land and sea and nature of surface, winds and pressure systems, air masses and frontal zones as criteria. These causative factors determine the types of climates.
- Applied classifications are based on impact of climate on vegetation, impact on housing impact as clothing human health and comfort housing and clothing and impact of climate on other socio-economic conditions and impact of human activities on climate.

12.6 TERMINAL QUESTIONS

1. Discuss the bases of climatic classifications.
2. Describe the merits and demerits of empirical and generic approaches of climatic classification.
3. Explain genetic approach of climatic classification and highlight its merits and demerits.

12.7 ANSWERS

Self-Assessment Questions (SAQs)

1. Every place of earth surface is unique or distinct in terms of climatic conditions. Therefore, real world situation is varied and complex. To address this great variety and complexity of climatic conditions scholars have used relative homogeneity of some climatic elements and controls to identify broad climatic groups or classes. The similarities of climatic conditions, within a specific area provide the base for identification of broad climatic classes or climatic regions. Thus, climatic classification is a mean to replace the multiplicity and complexity of atmospheric conditions by some meaningfully organised manageable number of classes. It is basically a system or a process that categorises a great variety of climatic conditions in a limited number of classes.

   The goal of climatic classification is to bring order to large and diverse information. By organising similar entities together into groups that are different from other groups by specific attributes an order is generated out of complexity. Climatic classifications help in simplification and generalisation. They contribute as a useful mechanism to summarise, communicate, and exchange information about them. They facilitate description, analysis, and explanation. For instance, they help in description, explanation and understanding of biomes. They are significant not only for geographers but also for scientists and planners having research interests in physical environment, soils, plants and animals. They have applications in urban, land use and regional planning.

2. a) The most used bases for climatic classification are temperature, precipitation and vegetation. The ancient Greeks classified world climate into three zones – tropical or torrid, temperate and frigid or polar on the basis of angle of sun's rays or latitude and temperature. Based on temperature world can be delineated into 'hot', 'warm', 'cool', 'cold' and 'frigid' or 'permafrost' climates. The annual precipitation is a useful quantity in highlighting the characteristics of a climate type. Climates based on rainfall can be defined as 'wet', 'humid', 'sub-humid', 'semi-arid' and 'arid' climates.

   These two elements of climate viz. temperature and precipitation affect vegetation of a particular region. The vegetation is a true reflection of climate. Therefore, by determining and identifying particular vegetation the type of climate can be inferred. In genetic climate classification latitude, winds, air masses, front zones and nature of surface have also been used as bases of classification. Global patterns of precipitation are related to air mass source regions and prevailing movements of air masses and front zones.

3. The different approaches for climatic classification are – empirical, generic, genetic and applied. The empirical approach of climatic classification is based on observed data of climatic elements like temperature, precipitation, humidity and vegetation structure etc.

   Generic classifications of climate are generally based on temperature and precipitation criteria. The levels of temperature and amount of precipitation determine rate of evaporation and aridity. Thermal effectiveness and aridity, which is usually expressed as precipitation effectiveness, are associated with vegetation boundaries. In generic approach classification is predominantly based on the limits of specific plant associations.

   Genetic approach uses the climatic controls like – angle of sunrays, winds and pressure systems, nature of surface, air masses and frontal zones to classify world climates.

   Applied approach is also known as technical or functional approach. It is based on the functional impact of climate on other phenomena for instance; the correlation of vegetation has been established with temperature, precipitation and moisture. The criteria of potential evapotranspiration have multiple applications in the field of hydrology, soil science and agriculture science.

b) In applied or technical or functional climatic classifications, the climatic regions are delineated in terms of effects of climate on other phenomena. There is strong spatial resemblance between climate and vegetation. Natural vegetation is basically in an index of mosaic of atmospheric conditions and far more efficiently represents climatic differences in cumulative manner than data recorded by different instruments individually. The vegetation terms like rainforest, forest, savanna, steppe, desert and tundra have climatic connotations.

   Thornthwaite in his modified climatic classification used applied approach based on the concept of potential evapotranspiration. He applied the indices of the moisture budget. Water balance studies have applications in hydrology, soil and agricultural sciences and in regional planning. Applied climatic classification have also been developed based on associations of climate with human health and comfort, and climate and socio-economic adjustments and impact of climate on man and impact of human activities on physical environment.

Terminal Questions

1. In this answer you must highlight in detail application of the empirical, general, genetic climatic classification in various studies. You should also mention name of scholars who applied these bases in their classifications. To answer this question, refer Sec. 12.3.

2. In this answer you must highlight the advantages and disadvantages of empirical and generic approaches of climatic classification. To answer this question, refer Sec. 12.4 sub sections (i) and (ii).

3. In this answer your focus should be exclusively on genetic approach of climatic classification. Mention the climate controls and name of the scholars who used these controls for climatic classification. To answer this question, refer Sec. 12.4 sub section (iii).

12.8 REFERENCES AND FURTHER READINGS

1. Lal, D.S. (2011). *Climatology*, Sharda Pustak Bhawan, Allahabad.
2. Critchfield, H. (2015). *General Climatology*, Fourth Edition, Pearson India Education Services, Noida.
3. Singh, S. (2009). *Climatology*, Pravalika Publications, Allahabad.
4. Trewartha, G.T. and Horn, L.H. (1980). *An Introduction to Climate*, McGraw Hill, Tokyo.
5. Barry, R.G. and Chorley, R.J. (1995). *Atmosphere, Weather and Climate*, Routledge, London and New York.
6. Strahler, A. (2013). *Introducing Physical Geography,* Sixth Edition,John Wiley and Sons, New York.
7. Lutgens, F.K., Tarbuck, E.J. and Dennis Tasa (2015). *The Atmosphere: An Introduction to Meteorology*, Twelfth Edition, Pearson India Education Services, Noida.
8. Ahrens, C.D. and Henson, R. (2019). *Meteorology Today: An Introduction to Weather, Climate and the Environment*, Twelfth Edition, Cengage, Boston.
9. Saroha, J. and Singh, S. (2023). *Physical Geography*, Pearson India Education Services, Noida.

UNIT 13

CLIMATIC CLASSIFICATION OF KOPPEN

Structure

13.1 INTRODUCTION

In the previous unit you have studied definition, significance, bases and approaches to climatic classification. In this unit, you will study one of the most popular empirical and generic climatic classification devised by Koppen. You will understand how based on mean monthly and mean annual temperature and precipitation data Koppen represented complexities of world climates in a simple and generalised manner. He also applied the concept of precipitation effectiveness in determining dry climates and levels of aridity. He recognised spatial correspondence of climate and vegetation. In this hierarchical order of world climates, he described distinct features of temperate climates in detail based on some other specific atmospheric conditions. Finally, he presented his macro and meso-climatic classes by the most important tool of geographers that is map. Sec. 13.2 will acquaint you with the history and bases of Koppen's climatic classification. In Sec.13.3, you will get a detailed description of Koppen's climatic classification. Finally in Sec. 13.4, you will get familiar with the advantages and also limitations of Koppen's climatic classification.

In the next unit, you will study another significant climatic classification of Thornthwaite based on empirical, generic and applied approaches of climatic classification.

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Expected Learning Outcomes

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

- describe the bases of climatic classification of Koppen;
- discuss the marco-level climatic classes and their sub-classes;
- distinguish between different types of global climates; and
- evaluate Koppen's classification of climates.

13.2 HISTORY AND BASES OF KOPPEN'S CLIMATIC CLASSIFICATION

In 1900, German botanist and climatologist Wladimir Koppen (1846-1940) presented his first scheme of climatic classification which was based on the vegetation classification of a French plant physiologist A. de Candolle (1874). Koppen revised his scheme in 1918 by giving more weightage to the monthly and annual averages of temperature and precipitation and their seasonal distribution. In 1931 Koppen represented the world map of climatic classification. In 1936 Koppen and his student Geiger published updated maps of world climate at continental levels. However, a further modified version of the classification was published in 1953 known as Koppen-Geiger-Pohl classification of world climates.

Koppen believed that vegetation type of an area is the best expression of totality of climate. His climatic classification was based on annual and monthly means of temperature and precipitation and also seasonal distribution of precipitation. He gave weightage to the ratio of precipitation and temperature in a single formation i.e. application of the concept of precipitation effectiveness. It is quantitative as well as empirical classification of climates.

13.3 KOPPEN'S SYSTEM OF CLIMATIC CLASSIFICATION

The Koppen system recognised five major categories of climates and each category is designated by a capital letter as listed below in Table 13.1.

Table 13.1: Broad Climatic Types of Koppen

Letter Symbol	ClimateType	Associated Vegetation
A	Tropical Rainy Climates	Megatherms
B	Dry Climates	Xerophytes
C	Humid Mesothermal Climates or Warm Temperate Rainy Climates	Mesotherms
D	Humid Microthermal Climates or Cold Forest Climates	Microtherms
E	Polar Climates	Hekistotherms

It is worth mentioning that four (A, C, D and E) of the above mentioned five groups are based on mean monthly temperature of the warmest and the coldest months, whereas B is based on precipitation-evaporation ratio.

Koppen has further divided these 5 major climatic types into sub-types based on seasonal distribution of precipitation, level of aridity and seasonal characteristics of temperature. Now let us get acquainted with these types and subtypes.

13.3.1 Tropical Rainy Climates (A)

In tropical rainy climates the temperature of the coldest month is above 18° C which means that the temperature remains above 18°C throughout the year. This climate type is associated with tropical rainforest or megatherms. Megatherms are plants which depend on high temperature and humidity throughout the year.

The climate is humid because rainfall is always in excess of evaporation. Based on precipitation regime or seasonal distribution of precipitation this climate type has been further sub-divided into the following four types:

i) **Af-** This is the tropical wet or rainforest climate or tropical humid climate where precipitation in the driest month is 6 cm or more. The seasonal distribution of precipitation is almost uniform throughout the year. The annual and diurnal range of temperature is very low. There is no dry season.

ii) **Aw-** This is the tropical wet and dry climate also known as tropical savanna. It is characterised by wet summer and dry winter. Here the precipitation of at least one month is less than 6 cm. High temperature conditions prevail throughout the year.

iii) **Am**- This is the tropical monsoon climate and is supposed to be the intermediate between Af and Aw. It resembles Af in annual amount of precipitation and resembles Aw in seasonal distribution of precipitation. Like Aw the precipitation of at least one month is less than 6 cm. This climate has short dry season but the total amount of precipitation is sufficient to support dense forests. The boundary between Aw and Am climates is demarcated on the basis of annual precipitation and precipitation of the driest month on the basis of the following formula:

$a = 10 - R/25$

Where, a = precipitation of the driest month R = annual precipitation in cm

If the precipitation of the driest month is less than the value of a, it will be Aw climate, if it is equal or more than the value of a, it will be Am climate. For example, when the annual rainfall is 200 cm, then according to the above formula "a" is 2 cm. So if the precipitation of the driest month is less than 2 cm then it is Aw and equal or more than 2 cm it is Am climate. However, the precipitation of driest month should be less than 6 cm, otherwise it would be Af climate.

iv) **As-** This is the tropical dry summer climate, which is rarely found. However, in India it is present in coastal Tamil Nadu, where summers are dry and rainfall takes place mainly in winter.

Koppen has further identified finer details in A climates by using the following lower case (small) letters with their meanings:

w' - maximum precipitation in autumn.

w" - two seasons of maximum precipitation separated by two dry seasons.
s - dry summers.

i - range of temperature of coldest and warmest months less than 5°C.

g - Ganga type, where hottest month is preceding the summer rainy season.

13.3.2 Dry Climates (B)

Dry climates are characterised by excess of evaporation over precipitation. In these climates precipitation is not sufficient to maintain permanent stable groundwater table. The boundary between the dry and humid climates is delineated based on the following formulas:

a) $R < 2T + 28$, when 70 per cent or more of precipitation occurs in 6 warmer months.

b) $R < 2T$, when 70 per cent or more of precipitation occurs in 6 cooler months.

c) $R < 2T + 14$, when neither half year has 70 per cent or more of precipitation.

Where, R is average annual precipitation in cm and T is average annual temperature in °C.

This way, for dry climates Koppen applied the criterion of precipitation effectiveness. The effectiveness of precipitation in providing moisture to the ground for plants depends not only on amount of precipitation but also on the rate of evaporation, which in turn varies directly with temperature. For instance, if 30 cm rainfall takes place in three summer months at one place and same amount in three winter months at another place, as evaporation will be higher in summer season the effectiveness of precipitation (availability of moisture for plant growth) will be higher at second location. To determine this, Koppen used average annual precipitation, average annual temperature and seasonal distribution of precipitation as variables. For example, if a place X has average annual precipitation (R) 40 cm, average annual temperature (T) 15°C and 80 per cent of precipitation takes place in warmer six months, in this situation applying the formula $R < 2T + 28$, we get the value as $40 < 58$.

This means that precipitation is less than evaporation, so the place X has B or Dry Climate.

Based on levels of aridity, Koppen further sub-divided B climates into BW and BS. BW is arid climate and BS is semi-arid climate. When R (in the above equations) is less than half of upper limit for B, the climate is BW and when R is more than half of upper limit for B, the climate is BS. Let us understand this with the help of an example.

In the above example, the place X has B climate and it is B type till the precipitation is less than 58 cm. Therefore, in this example the upper limit for B is 58 and half of it is 29. As R (40) is more than half (29) of upper limit (58) for B, the climate of place X is BS i.e. semi-arid. If the R at this place would have been say 25 cm then it would have been BW or arid climate because R (25) in that case would be less than half (29) of upper limit for B which is 58.

For identifying further details in B climates Koppen used following letters:

h (hiess or hot) = average annual temperature over 18°C.

k (kalt or cold) = average annual temperature below 18°C.

k' = temperature of the warmest month below 18°C.

s = summer drought, that is, at least three times as much rain in wettest winter month as in driest summer month.

w = winter drought, at least ten times as much rain in the wettest summer months as in the driest winter month.

n (nebel) = frequent fog.

Koppen identified the following sub-divisions of B climates based on criteria suggested above as:

i) BWh - Tropical Desert Climate.
ii) BSh - Tropical Steppe Climate.
iii) BWk - Mid-latitude Cold Desert Climate.
iv) BSk - Mid-latitude Cold Steppe Climate.
v) BWn and (vi) BSn climates are usually found along coastal lands associated with cold ocean currents.

13.3.3 Humid Mesothermal or Warm Temperate Rainy Climates (C)

Here the average temperature of the coldest month is above - 3°C but below 18°C and average temperature of the warmest month is above 10°C. On the basis of seasonal distribution of rainfall, these climates are divided into three major climate types with the help of the following three letters:

- f = no dry season
- w = dry season in winter; and
- s = dry season in summer

Hence, the climate types for C are as follows:

i) Cf- This climate is characterised by precipitation throughout the year and driest month of summer season receives more than 3 cm rainfall. This climate represents the Western European type of climate. It is further divided into two second order sub-divisions as Cfa (Humid Subtropical) and Cfb (Marine West Coast type).

These minor details in C - climate were identified by Koppen by using the following small explanatory letters:

a = Warm summer; average temperature of the warmest month > 22°C; at least four months above 10°C.

b = Cool summer, average temperature of the warmest month is < 22°C; at least four months above 10°C.

c = Cool short summer; average temperature of the warmest month< 22°C; at least one to three months above 10°C.

x = rainfall maximum in late spring or early summer, drier in late summer. i, n, g = same meaning as in A and B climates.

ii) **Cw-** This climate is characterised by dry winter. The wettest month of summer season receives at least ten times as much rain as the driest month of winter season. Seventy per cent or more of the average annual precipitation is received in the six warmer months. This type of climate prevails in southern China.

iii) **Cs-** This is the warm temperate climate characterised by dry summer. It has three times more precipitation in the wettest month of winter season than the driest month of summer season. The driest month of summer season receives less than 3 cm rainfall. It represents Mediterranean type of climate.

13.3.4 Humid Microthermal or Cold Snow Forest or Humid Cold Climates (D)

Here the average temperature of coldest month is below - 3°C and the warmest month average temperature is above 10°C. The ground surface remains covered with snow for several months of a year. This climate is divided into following two categories:

i) **Df**- This is the humid cold climate where there is no dry season. It is further divided in (a) Dfa - long warm summers, continental, (b) Dfb - short cool summer, subarctic.

ii) **Dw-** This is the humid cold climate with dry winters. It is further divided into

(a) Dwa- continental climate with long cool summer, (b) Dwb- cool short summer (sub-arctic type), (c) Dwc- cold winters, and (d) Dwd- average temperature of the coldest month is below -38°C.

13.3.5 Polar Climates (E)

The average temperature of the warmest month is less than 10°C. It is further divided into ET and EF:

i) **ET** - This is the tundra climate, where average temperature of the warmest month is below 10°C but above 0°C. The length of growing season is very short and vegetative cover is limited and scattered,

ii) **EF** - Perpetual Frost or Permafrost: the average temperature of the warmest month is below 0°C. It is represented by permanent ice caps without vegetation.

Now let us have a quick recap of Koppen's classification of climates with the help of Table 13.2.

Table 13.2: Koppen's Classification of Climates

Letter Symbol			**Precipitation and Temperature**
1st Order	**2nd Order**	**3rd Order**	
A			Average temperature of the coldest month is 18°C or above.
	f		Moist; Every month has 6 cm of precipitation or more; no dry season
	m		Short dry season in monsoon type of precipitation; driest month < than 6 cm but equal to or more than 10-R/25 (R is annual precipitation in cm)
	w		Well-defined winter dry season; precipitation in driest month <than 10-R/25.
	s		Well-defined summer dry season(rare distribution)
B			Potential evaporation exceeds precipitation. It is identified on the basis of average annual precipitation **(R),** average annual temperature (T) and seasonal distribution of precipitation in following manner:(i) R<2T+28, when 70 % or more of precipitation occurs in 6 warmer months.(ii) R<2T, when 70 % or more of precipitation occurs in 6 cooler months. (iii) R<2T+14, when neither half year has 70 % or more of precipitation.
	s		When **R** is more than ½ of the upper limit for B.
	w		When **R** is less than ½ of the upper limit for B.
		h	Average annual temperature is 18°C or above.
		k	Average annual temperature is less than 18°C.
C			Average temperature of the coldest month is < than 18°C and above -3°C; average temperature of the warmest month is greater than 10°C.
	w		At least ten times as much rain in the wettest month as in the driest winter month; precipitation in driest summer month < than 4 cm.
	s		At least three times as much rain in wettest winter month as in the driest summer months; precipitation in driest summer month < than 3 cm.
	f		Precipitation throughout the year and no dry season. Difference between the rainiest and driest months is less than that for w and s and the driest month of summer receives > 3 cm rainfall.
		a	Hot summer; average temperature of the warmest month > 22°C; at least four months above 10°C.
		b	Cool summer; average temperature of the warmest month < 22°C; at least four months above 10°C.

		c	Cool short summer; average temperature of the warmest month < 22°c; at least one to three months above 10°C.
D			Average temperature of coldest month is - 3°C or below; average temperature of warmest month is greater than 10°C.
	s, w, f		Same as under C.
		a, b, c	Same as under C.
		d	Average temperature of the coldest month is - 38°C or below.
E			Average temperature of warmest month is below 10°C.
	T		Average temperature of warmest month is between 0°C and 10°C.
	F		Average temperature of warmest month is 0°C or below.

SAQ I

a) Discuss the bases of Koppen's climatic classification for dry climates.
b) Describe Koppen's classification of the warm temperate climates.

13.4 EVALUATION OF KOPPEN'S CLIMATIC CLASSIFICATION

Koppen's classification of climates is most widely and frequently used classification system. It is based on temperature and precipitation statistics which are measurable and most effective in determining climate. As it is based on statistical parameters the climatic regions have precise boundaries. In determining the B or dry climates Koppen applied the concept of precipitation effectiveness by establishing relationship between heat and moisture. It is more appealing to geographers because due consideration has been given to interrelationship that exists between vegetation and climate.

As Koppen's climatic classification is based on vegetation classification of A. de Candolle, the climatic boundaries match with vegetation boundaries. For instance, 18°C average temperature of the coldest month separates A- Climates from C - Climates. This value is selected because certain sensitive tropical plants do not survive when the monthly temperature is below 18°C. The megatherms realm of plants is associated with high temperature and high precipitation. Likewise, the 10°C isotherm for the warmest month not only shows the southern boundary of the Tundra region but it also represents the northward or poleward limit of the Taiga vegetation. As this classification shows well established association of vegetation with climate it becomes more appealing to geographers.

The Koppen's classification of climates is very useful for geographers because it is descriptive and generalised. As it is based on shorthand code of letters for the climate types, the repetition of descriptive terms can be easily avoided.

The use of symbols and representation of climatic types on map further increases its utility for geographers. This classification is so simple and detailed that it is most frequently used at all levels of education i.e., from school to research levels.

Despite many revisions and modifications, there are certain limitations of this classification. As it is based on mean monthly temperature and precipitation values it fails to highlight the variations over time in one locality or region and makes comparison of one locality with another difficult. Further, Koppen ignored the role of weather elements such as winds, atmospheric pressure, cloudiness, air masses and cyclones etc. This way it is empirical but not genetic classification as causative factors were ignored totally.

Koppen applied the same formula for highlands and lowlands. As a result, many errors surfaced in his classification of climates. Though he believed that vegetation is the true reflection of climate but in his scheme, it is difficult to analyse and explain the presence of different types of vegetation in the same climatic region and same type of vegetation in different climatic regions.

However, in-spite of drawbacks and limitations of classification of climates propounded by Koppen, this scheme is still held in high esteem and widely used.

SAQ 2

Highlight the merits of Koppen's climatic classification.

13.5 SUMMARY

In this unit you have studied:

A climatic class or region represents a homogenous set of climatic conditions. Climatic classification is essential for identification, mapping and description of climatic classes or regions. Climatic classification helps in generalisation and simplification of diverse atmospheric conditions prevailing over different parts of the earth surface. The major challenge in the process of climatic classification is that climate is a complex of elements such as insolation, temperature, precipitation, winds and pressure belts, cloud cover, fronts and cyclones etc. Therefore, any classification based on limited elements would fail to represent the reality. Also, the inclusion of a large number of dynamic elements would make it too complex. The most used criteria for climatic classification are temperature, precipitation and vegetation.

Koppen used mean monthly temperatures of the warmest and coldest months, mean annual temperature, mean annual precipitation, seasonal distribution of precipitation and precipitation-evaporation ratio for climatic classification. Koppen's climatic classification is quantitative and generalised. It is very popular in geography due to its simplicity, clarity and practical utility.

Koppen's climatic classification is preferred for macro level understanding and comparisons. His classification system tries to identify the major types of climates prevailing on the earth's surface. It establishes relationships among the various climate types present in the classification. It provides a hierarchical framework from marco to micro levels.

13.6 TERMINAL QUESTIONS

1. Discuss Koppen's climatic classification.
2. Critically evaluate the Koppen's classification of climates.
3. Discuss the diversity of climates in mid-latitudes as compared to tropical and polar areas in Koppen's climatic classification.

13.7 ANSWERS

Self-Assessment Questions

1. a) According to Koppen, dry climates are characterised by excess of evaporation over precipitation. The criteria he adopted for dry climates was of precipitation effectiveness which depends not only on precipitation but also on the rate of evaporation which is directly associated with temperature. He used the criteria of average annual precipitation, average annual temperature and seasonal distribution of precipitation to identify dry climates. Based on levels of aridity, Koppen further sub-divided B climates into BW and BS. BW is arid climate and BS is semi-arid climate. The B or dry climates were further subdivided based on average annual temperature into hot (h) and cold (k) climates.

   b) Koppen identified the warm temperate group of climates based on the average temperature of the coldest month (above - 3°C but below 18°C) and average temperature of the warmest month (above 10°C). Based on seasonal distribution of rainfall, this marco group was classified at meso level into three major climate types based on precipitation and used the following three letters: f = no dry season; w = dry season in winter; and; s = dry season in summer. Further micro level variations were recognised mainly on the basis of length and intensity of summer season in mid-latitudes. For instance, symbol 'a' was used for Warm summer (average temperature of the warmest month > 22°C; at least four months above 10°C); symbol 'b' represents Cool summer (average temperature of the warmest month is < 22°C; at least four months above 10°C); and symbol 'c' shows cool short summer (average temperature of the warmest month< 22°C; at least one to three months above 10°C). Hence, the climate types for C are as: Cf (further subdivided into Cfa – Humid Subtropical and Cfb – Marine West Coast Type); and Cw – characterised by dry winter and this climate prevails in southern China; and Cs represents dry summer situation of Mediterranean type of climate.

2. Koppen's classification of climates is based on temperature and precipitation data which are measurable and most effective in determining climate. As it is based on quantitative parameters the climatic regions have precise boundaries. In determining the B or dry climates Koppen applied the concept of precipitation effectiveness by establishing relationship between heat and moisture. Thus, his criterion is unambiguous, relatively

simple to apply and understand.

It is more appealing to geographers because due consideration has been given to interrelationship that exists between vegetation and climate. He was convinced that the distribution pattern of natural vegetation is the best representative of overall climate. Further, it is descriptive and generalised classification. As it is based on shorthand code of letters for the climate types, the repetition of descriptive terms is easily avoided. The use of symbols and representation of climatic types on map further increases its utility for geographers. This classification is so simple and detailed that it is most frequently used at all educational levels i.e., from school to research levels.

Terminal Questions

1. Discuss the five major categories of climates as given by Koppen. It is a long answer so you must also describe the sub-divisions of all the categories as in Sec. 13.3 of this unit.

2. Start your answer by giving brief summary of major and meso-level climatic regions (Ist Order and II Order as shown in Table 13.2). The focus of the answer should be on merits and demerits of criteria and classes. For this refer Sec. 13.4 of this unit.

3. In this answer you must focus on climates of mid-latitude that is mainly – Humid Mesothermal (C) and Humid Microthermal (D) in detail and for this refer Sec. 13.3.3 and 13.3.4. Briefly mention that in tropical and polar areas climate types are limited as they represent extremes and in transitional part variations are more pronounced.

13.8 REFERENCES AND FURTHER READINGS

1. Lal, D.S. (2011). *Climatology*, Sharda Pustak Bhawan, Allahabad.
2. Critchfield, H. (2015). *General Climatology*, Fourth Edition, Pearson India Education Services, Noida.
3. Singh, S. (2009). *Climatology*, Pravalika Publications, Allahabad.
4. Trewartha, G.T. and Horn, L.H. (1980). *An Introduction to Climate*, McGraw Hill, Tokyo.
5. Barry, R.G. and Chorley, R.J. (1995). *Atmosphere, Weather and Climate*, Routledge, London and New York.
6. Strahler, A. (2013). *Introducing Physical Geography,* Sixth Edition,John Wiley and Sons, New York.
7. Lutgens, F.K., Tarbuck, E.J. and Tasa, D. (2015). *The Atmosphere: An Introduction to Meteorology*, Twelfth Edition, Pearson India Education Services, Noida.
8. Ahrens, C. D. and Henson, R. (2019). *Meteorology Today: An Introduction to Weather, Climate and the Environment*, Twelfth Edition, Cengage, Boston.

9. Saroha, J. and Singh, S. (2023). *Physical Geography*, Pearson India Education Services, Noida.

UNIT 14

CLIMATIC CLASSIFICATION OF THORNTHWAITE

Structure

14.1 INTRODUCTION

In the previous unit, you have studied the climatic classification of Koppen which was based on empirical and generic approaches of climatic classification. In this unit, you will study another very popular climatic classification devised by renowned American climatologist C.W. Thornthwaite. It is based on empirical, generic and applied approaches of climatic classification. He applied the concepts of precipitation effectiveness, thermal efficiency, seasonal distribution of precipitation, potential evapotranspiration, humidity and aridity indices in his classifications. He also revised his classification schemes to make it more effective. After going through his schemes, original and revised, you will be able to understand the complexities of global climates and finally, you will be able to compare climatic classifications of Koppen and Thornthwaite.

Sec. 14.2 will acquaint you with the 1931 scheme of climatic classification of Thornwaite. In sec 14.3, you will study his revised schemes which he presented in 1948 and again in 1955. In Sec 14.4 you will learn about the merits and limitations of the Thornwaite's scheme. In sec 14.5 you will compare both Koppen and Thornthwaite's classifications.

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Expected Learning Outcomes

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

- explain the bases of climatic classification of Thornthwaite;
- differentiate between precipitation and precipitation effectiveness, temperature and thermal efficiency, and actual and potential evapotranspiration;
- recognise the great diversity and complexity of global climatic classes; and
- evaluate and compare Thornthwaite's classifications with Koppen's classification.

14.2 THORNTHWAITE'S 1931 SCHEME OF CLIMATIC CLASSIFICATION: BASES AND CLASSES

American climatologist Charles Warren Thornthwaite (1889-1963) put forward his first scheme of classification of climates in 1931. It was initially devised for North America but in 1933 he applied this scheme for global climatic classification. He propounded his second scheme of climatic classification in 1948 and further improved it in 1955. Thornthwaite's climatic classifications are empirical, quantitative and complex. Like Koppen's climatic classification, Thornthwaite identified the boundaries of climatic regions on quantitative basis but instead of temperature and precipitation criteria he used the concepts of precipitation effectiveness and thermal efficiency in his first climatic classification system.

14.2.1 Bases of 1931 Climatic Classification

Thornthwaite's 1931 climatic classification was based on three criteria – precipitation effectiveness, seasonal distribution of precipitation and thermal efficiency.

A. Precipitation Effectiveness

Like Koppen, Thornthwaite also recognised the close relationship between climate and natural vegetation and their distribution patterns. However, he highlighted that precipitation effectiveness or precipitation efficiency is more important and indicative factor for the growth and type of natural vegetation. It is not necessary that two places receiving same amount of precipitation would have similar precipitation effectiveness. In these two places, the one having higher rates of evaporation will have lesser amount of moisture availability for the growth of natural vegetation as compared to the second place. Thus, Thornthwaite pointed out that it is not only precipitation that matters rather its availability as moisture depends upon differential rates of precipitation and evaporation. To measure precipitation effectiveness, he calculated mean monthly precipitation effectiveness by dividing the mean monthly precipitation by mean monthly temperature. In the absence of efficient instrumental measurements of evaporation, he used temperature data to estimate evaporation as the rate of evaporation depends on temperature. He propounded the following formulae to calculate precipitation effectiveness:

Precipitation Effectiveness Ratio (*P*/*E* ratio) = 11.5 (*P*/*T* - 10)10/9

where *P* = Mean monthly precipitation (in inches)

T = Mean monthly temperature (in degree F)

P/E Index = sum of all twelve months P/E ratios.

First, he calculated the *P/E* Ratio for all the twelve months of a year and then he summed up all twelve months P/E ratios to get the P/E index. Based on P/E index values he identified five humidity provinces and associated them with specific major natural vegetation zones (Table 14.1).

Table 14.1: Main Climatic Classes based on Precipitation Effectiveness

Humidity Provinces	Vegetation Zones	P/E Index
A (Wet)	Rainforest	Above 127
B (Humid)	Forest	64-127
C (Sub-humid)	Grassland	32-63
D (Semi-arid)	Steppe	16-31
E (Arid)	Desert	Below 16

Seasonal Distribution of Precipitation

Based on seasonal distribution of precipitation, Thornthwaite further sub-divided these five humidity provinces into twenty sub-classes. The criteria and symbols used are as under:

r = rainfall adequate in all seasons

s = rainfall deficient in summer

w = rainfall deficient in winter

d = rainfall deficient in all seasons.

1. Ar	5. Br	9. Cr	13. Dr	17. Er
2. As	6. Bs	10. Cs	14. Ds	18. Es
3. Aw	7. Bw	11. Cw	15. Dw	19. Ew
4. Ad	8. Bd	12. Cd	16. Dd	20. Ed

B. Thermal Efficiency

Like precipitation effectiveness, Thornthwaite gave importance not to temperature rather to thermal effectiveness or thermal efficiency instead of only temperature. He considered thermal efficiency as an important determinant of growth and type of vegetation. He conceptualised thermal efficiency as positive departure of mean monthly temperatures from the freezing point. Higher departure outcomes represent higher thermal efficiency. To measure thermal effectiveness, he first calculated monthly thermal efficiency (T/E) ratios by applying the following formulae and by summing up the T/E ratios of all twelve months he calculated thermal efficiency index:

Thermal Effectiveness (*T*/*E*) ratio = (*T*–32)/4

where *T* is the mean monthly temperature (degree F).

Thermal Efficiency (*T*/*E*) index = Sum of 1 to 12 months *T*/*E* ratios

Finally, based on positive departures of T/E index values he identified *six* major thermal efficiency provinces (Refer to Table 14.2).

Table 14.2: Thermal Efficiency Index and Thermal Provinces

Thermal Provinces	T/E Index
A′ – Tropical	Above 127
B′ – Mesothermal	64-127
C′ – Microthermal	32-63
D′ – Taiga	16-31
E′ – Tundra	1-15
F′ – Frost	0

14.2.2 Climatic Classes (1931)

Thornthwaithe, based on criteria of precipitation effectiveness (5 Humidity Provinces), seasonal distribution of precipitation (4 Humidity subclasses) and thermal efficiency (6 Thermal Provinces), identified following 32 climatic classes at world level out of statistically probable combinations of 120 (5 × 4 × 6) classes.

1. A A’r – Tropical wet climate with adequate rainfall in all seasons.
2. A B’r - Mesothermal wet climate with adequate rainfall in all seasons.
3. AC’r – Microthermal wet climate with adequate rainfall in all seasons.
4. B A’r – Tropical humid climate with adequate rainfall in all seasons.
5. B A’w – Tropical humid climate with deficient rainfall in winter.
6. BB’r - Mesothermal humid climate with adequate rainfall in all seasons.
7. B B’w – Mesothermal humid climate with rainfall deficient in winter season.
8. B B’s – Mesothermal humid climate with rainfall deficient in summer season.
9. B C’r – Microthermal humid climate with adequate rainfall in all seasons.
10. B C’s – Microthermal humid climate with rainfall deficient in summer season.
11. C A’r – Tropical sub-humid climate with adequate rainfall in all seasons.
12. C A’w – Tropical sub-humid climate with deficient rainfall in winter season.
13. C A’d – Tropical sub-humid climate with deficient rainfall in all seasons.
14. C B’r – Mesothermal sub-humid climate with adequate rainfall in all seasons.

15. C B’w – Mesothermal sub-humid climate with deficient rainfall in winter season.
16. C B’s – Mesothermal sub-humid climate with deficient rainfall in summer season.
17. C B’d – Mesothermal sub-humid climate with deficient rainfall in all seasons.
18. C C’r – Microthermal sub-humid climate with adequate rainfall in all seasons.
19. C C’s – Microthermal sub-humid climate with rainfall deficient in summer season.
20. C C’d – Microthermal sub-humid climate with rainfall deficient in all seasons.
21. D A’w – Tropical semi-arid climate with deficient rainfall in winter season.
22. D A’d – Tropical semi-arid climate with deficient rainfall in all seasons.
23. D B’w- Mesothermal semi-arid climate with deficient rainfall in winter season.
24. D B’s – Mesothermal semi-arid climate with deficient rainfall in summer season.
25. D B’d – Mesothermal semi-arid climate with deficient rainfall in all seasons.
26. D C’d – Microthermal semi-arid climate with rainfall deficient in all seasons.
27. E A’d – Tropical arid climate with deficient rainfall in all seasons.
28. E B’d – Mesothermal arid climate with deficient rainfall in all seasons.
29. E C’d – Microthermal arid climate with deficient rainfall in all seasons.
30. D’ – Taiga type climate.
31. E’ – Tundra type climate.
32. F’ – Permanently snow-covered polar climate.

SAQ I

a) Describe precipitation effectiveness.

b) Briefly explain the concept of thermal efficiency

14.3 THORNTHWAITE’S SECOND SCHEME OF CLIMATIC CLASSIFICATION

Thornthwaite propounded his second scheme of climatic classification in 1948 and revised it in 1955. In this classification he devised and applied the concept of potential evapotranspiration. He applied potential evapotranspiration as an index of thermal efficiency. Potential evapotranspiration represents the potential loss of moisture through evaporation from the water bodies and soil surface and through transpiration from vegetation. Due to non-availability of instruments to measure evapotranspiration he indirectly estimated it by using temperature criterion. Temperature varies from place to place and time to time even at a particular place, depending upon the amount of insolation received. Thus, Thornthwaite considered mean monthly temperature, number of days in a month and duration of sunshine to calculate the potential evapotranspiration of different locations.

Potential Evapotranspiration

First, he calculated monthly Heat Index (i) using the following formula:

Monthly Heat Index (i) = (t/5)1.514

where t is the mean monthly temperature in degree Celsius.

After that, he calculated Annual Heat Index (I) which has been defined as the sum of the Monthly Heat Indices (i) as follows:

Annual Heat Index (I) = the sum of 12 months of (t/5)1.514

He calculated potential evapotranspiration for each month of a year based on the following formula and then he calculated the annual potential evapotranspiration (in cm) which has been defined as the sum of the potential evapotranspiration for all the months of the year.

Potential Evapotranspiration (PE) = 1.6 $(10t/I)^{\alpha}$

where t is mean monthly temperature in degree Celsius of a particular month and I is annual heat index of that particular year and it is calculated based on summation of twelve months heat indices (i) as mentioned above; and

α = 6.75-7 × 10 × I 3 + 7.771 × 10-5 × I 2 + 0.01792 × I + 0.49239

The above equation represents the non-corrected potential evapotranspiration because the values are estimated by assuming a month of 30 days and sunshine duration of 12 hours. To make corrections for potential evapotranspiration for different places, the following equation is used:

PE (Potential Evapotranspiration) = PE non-corrected ×N/12 × d/30

where N is the average number of hours in a day between sunrise and sunset in a month and d is the actual number of days in a particular month.

Humidity index is the percentage ratio of water surplus and water need (PE).

Thornthwaite's Thermal Regime Classification

The key parameter to evaluate 'Thermal regime' of a region is Potential Evapotranspiration (PE) which is the index of thermal potential for vegetation growth. Based on annual potential evapotranspiration or thermal efficiency index Thornthwaite identified major thermal provinces (Table 14.3).

The thermal provinces were namely - Megathermal, mesothermal, microthermal, tundra and frost. The annual thermal efficiency above 114 cm with condition of very high temperatures throughout the year was identified as megathermal climate.

Mesothermal climate experiences thermal efficiency in the range of 57 to 114 cm. Microthermal climate has thermal efficiency value in the range of 28.5 to 57 cm.

Tundra (14.2 to 28.5) and Frost (below 14.2 cm) are cold climates with very low mean annual temperatures.

Table 14.3: Scheme of Climatic Classification- Thermal regime (major categorisation)

Annual TE (cm)	Thermal Provinces	Symbol
Above 114.0	Megathermal	A’
114.0-99.7	Mesothermal	B'_4
99.7-85.5	Mesothermal	B'_3
85.5-71.2	Mesothermal	B'_2
71.2-57.0	Mesothermal	B'_1
57.0-42.7	Microthermal	C'_2
42.7-28.5	Microthermal	C'_1
28.5-14.2	Tundra	D’
14.2 below	Frost	E’

Thermal regime-Supplementary classification- Summer Concentration of Thermal Efficiency (SCTE)

As thermal efficiency is the element of temperature and day-length, it also indicates seasonal variations. To emphasise the seasonal variations in thermal energy Thornthwaite added a supplementary classification by analyzing percentage of Summer Concentration of Thermal Efficiency (SCTE) (Table 14.4). SCTE is the percentage ratio of the sum of the thermal efficiencies (PE) of the three successive moths of highest thermal efficiency to the total annual thermal efficiency, calculated as:

SCTE= Sum of the Thermal Efficiency (PE) of the three maximum consecutive months X 100/Total Annual Potential Evapotranspiration

Table 14.4: Scheme of Supplementary Classification of Thermal Efficiency based on SCTE Percentages

SCTE (%)	Supplementary Climate Type	Symbol
Below-48.0	Megathermal	a’
48.0-51.9	Mesothermal	b'_4
51.9-56.3		b'_3
56.3-61.6		b'_2.
61.6-68.0	Microthermal	b'_1
68.0-76.3		c'_2
76.3-88.0		c'_1
Above 88.0	Tundra	d’

Thermal regime of particular region is represented by two letters.

First letter represents major climate based on Annual TE and second letter represents sub class based on SCTE %. For example A'a' indicates Megathermal and mega thermal.

Thornthwaite's Moisture Regime classification

Thornthwaite in his climatic analyses, realised the fact that precipitation alone is not an index to assess the moisture conditions of the environment. In the water balance analysis, comparing Precipitation (P) with Potential Evapotranspiration (PE) various water balances elements can be derived which in turn useful to evaluate certain indices such as, Aridity index (Ia), Humidity index (Ih) and Index of moisture (Im).

Index of Aridity= Annual water deficit X 100/ Annual P.E.

Index of humidity = Annual water surplus X 100/ Annual P.E.

Moisture Index (Im) = Ih – Ia

(Im) = Ih – Ia

Where

Im = Index of moisture

Ih = Index of humidity and

Ia = Index of aridity

Table 14.5: Categorisation of Moist Climates (Major climates)

Humid climates (Im > 0)		
Climatic type	**Symbol**	**Moisture Index (Im %)**
Pre humid	A	100 and above
Humid	B_4	80 to 100
	B_3	60 to 80
	B_2	40 to 60
	B_1	20 to 40
Moist Sub humid	C_2	0 to 20
Dry climates (Im < 0)		
Dry Sub humid	C_1	-33.3 to 0
Semi arid	D	-33.3 to -66.7
Arid	E	-66.7 to -100

Moisture regime- Supplementary classification (Based on seasonal variations)

The moisture index of a region in general indicates whether a region is humid or arid. But it does not indicate whether a region is continuously under wet or dry condition.

In the moist climate, if the dry season occurs, it is important to know the intensity of dryness. Similarly, in the dry climates, if wet season occurs the knowledge of intensity of wetness is essential.

In moist climates, the intensity of water deficit may be large, moderate, little or non-existent. Similarly, in dry climates the intensity of water surplus may large, moderate, little or non-existent.

Thus, keeping the seasonal variations of moisture in view, Thornthwaite proposed supplementary classification in moisture regime classification considering seasonal variation of effective moisture (SVEM).

Table 14.6: Scheme of Moisture Regime- Supplementary Classification

Moist climates (A, B C_{2})		**Aridity index (%)**
r	Little or no water deficit	0-10
s	Moderate summer deficit	10-20
w	Moderate winter deficit	10-20
s_2	Large summer deficit	Above 20
w_2	Large winter deficit	Above 20
Dry climates (C1, D, E)		Humidity index (%)
d	Little or no water surplus	0-16.7
s	Moderate winter surplus	16.7-33.3
w	Moderate summer surplus	16.7-33.3
s_2	Large winter surplus	Above 33.3
w_2	Large summer surplus	Above 33.3

In the moisture regime climatic analysis moisture regime classes are represented by two letters:

First letter represents major moisture regime class based on index of moisture (Im) and second letter represent seasonal variation based on moisture adequacy.

Example: Dd of a station indicates Semi arid and Little or no water surplus 'd'.

Thus the climate of any region is represented by two thermal regimes and two moisture regime classes.

Example: A'a'Dd.

14.4 EVALUATION OF THORNTHWAITE'S CLIMATIC CLASSIFICATIONS

The first scheme of climatic classification (1931) of Thornthwaite was based on the criteria of precipitation effectiveness, seasonal distribution of rainfall and thermal efficiency. In this classification Thornthwaite established strong relationship between climate and vegetation elements and viewed 'plants as meteorological instruments.' He identified 32 types of climates at global level with clear boundaries based on quantitative criteria and plotted them on the map.

In his second scheme (1948) of climatic classification he used four criteria - moisture index, thermal efficiency index or potential evapotranspiration, summer concentration of thermal efficiency and seasonal moisture adequacy. In this classification he viewed 'plants as the machinery of evaporation' through which moisture is transported from soil to atmosphere. He applied the concept of potential evapotranspiration, but due to instrumental limitations, used complex mathematical formulae to estimate it based on mean monthly temperature. Scholars have pointed out this as a limitation, as the actual evapotranspiration varies from the potential one. Another limitation of this classification is the huge number of classes which cannot be represented at global level. However, his concept of potential evapotranspiration and moisture balance is very popular and applied frequently in the fields of soil and agricultural sciences and hydrology. Thornthwaite's climatic classification is not a genetic classification, though it has impressed geographers and hydrologists but could not satisfy meteorologists and climatologists, it failed to incorporate causative factors of weather and climate and their interactions.

14.5 COMPARISON OF KOPPEN'S AND THORNTHWAITE'S CLIMATIC CLASSIFICATIONS

There are a lot of similarities and dissimilarities in climatic classifications of Koppen and Thornthwaite. The similarities include - (i) both the scholars sincerely researched for decades to devise satisfactory schemes of climatic classification; (ii) both the classifications are empirical but not genetic as both are based on observable elements of climate like temperature and precipitation but not on genetic factors like air masses, atmospheric circulations etc.; (iii) both the classifications are based on quantitative criteria therefore boundaries of climate classes are well defined; (iv) both the classifications have given weightage to relationship of climate and vegetation and finally, (v) both the scholars used letter symbols to represent different climatic classes and sub-classes to make the schemes simple and convenient.

The dissimilarities of their classifications include – (i) Koppen used mean monthly and average annual temperature and precipitation criteria whereas Thornthwaite applied the criteria of thermal efficiency, precipitation effectiveness and potential evapotranspiration and seasonal variations in thermal and moisture concentration. Conceptually and practically, Thornthwaite's criteria are better. But practically, it is difficult to measure these indices; (ii) Koppen used simple statistical methods whereas Thornthwaite used complex mathematical formulae to determine climatic classes; (iii) the number of climatic classes is limited in case of Koppen's classification to about 14 major climate classes but in case of Thornthwaite, the number of climatic classes or regions is huge (32 in 1931 classification and huge number of probable classes in 1948); (iv) Koppen's climatic classification is easy to understand and has applicability at all educational levels but Thornthwaite's classification can be understood only at higher educational levels; (v) Koppen's climatic classification is most suitable for macro level generalisations but for micro-level detailed analysis of climatic variations Thornthwaite's climatic classification is preferred, especially the second scheme of classification and finally, (vi) Koppen's climatic classification is empirical and generic but Thornthwaite's classification is empirical, generic and applied and it's concept of potential evapotranspiration is frequently used in soil-moisture balance studies, agriculture science and regional planning and in hydrological studies.

SAQ 2

Describe the concept of potential evapotranspiration.

14.6 SUMMARY

In this unit you have studied:

Thornthwaite's two schemes of classification of climates. These schemes are empirical, quantitative and generic. Thornthwaite's first climatic classification (1931) was based on three criteria – precipitation effectiveness, seasonal distribution of precipitation and thermal efficiency. Based on precipitation effectiveness he identified five humidity provinces – Wet, Humid, Sub-humid, Semi-arid and Arid. Based on seasonal distribution of precipitation, he further sub-divided these five humidity provinces into twenty sub-classes.

He considered thermal efficiency as an important determinant of growth and type of vegetation. He conceptualised thermal efficiency as positive departure of mean monthly temperatures from the freezing point. Based on thermal efficiency index he identified six thermal provinces – Tropical, Mesothermal, Microthermal, Taiga, Tundra and Frost. Thus, Thornthwaite, based on criteria of precipitation effectiveness (5 Humidity Provinces), seasonal distribution of precipitation (4 Humidity subclasses) and thermal efficiency (6 Thermal Provinces), identified 32 climatic classes at world level.

Thornthwaite propounded his second scheme of climatic classification in 1948 and revised it in 1955. In this classification he devised and applied the concept of potential evapotranspiration. He applied potential evapotranspiration as an index of thermal efficiency. Thornthwaite used following four indices for the classification of climates: (i) Moisture Index (Im); (ii) Potential Evapotranspiration (PE) or thermal efficiency index; (iii) Index of summer concentration of thermal efficiency or potential evapotranspiration; and (iv) Seasonal Moisture Adequacy based on Aridity and Humidity indices. This classification was devised mainly to identify climate diversity at micro and meso levels. His concept of potential evapotranspiration and moisture balance is very popular and applied frequently in the fields of soil and agricultural sciences and hydrology. Thus, Thornthwaite's climatic classification is empirical, generic and applied.

14.7 TERMINAL QUESTIONS

1. Differentiate between the first and second schemes of Thornthwaite's climatic classification.
2. Describe the merits and demerits of Thornthwaite's climatic classification.
3. Discuss the similarities and dissimilarities in climatic classifications of Koppen and Thornthwaite.

14.8 ANSWERS

Self-Assessment Questions (SAQs)

1. a) Thornthwaite recognised precipitation effectiveness or precipitation efficiency as an important and indicative factor of the growth and type of natural vegetation. It is noteworthy that two places receiving same amount of precipitation may not have same level of precipitation effectiveness. The place having higher rates of evaporation will have availability of lesser amount of moisture for the growth of vegetation due to moisture loss in evaporation. Thus, Thornthwaite pointed out that it is not only precipitation that matters rather its availability as moisture depends upon differential rates of precipitation and evaporation. Precipitation effectiveness, therefore, represents efficiency of precipitation as available moisture for vegetation growth. To measure precipitation effectiveness, he calculated mean monthly precipitation effectiveness by dividing the mean monthly precipitation by mean monthly temperature. Based on decreasing amount of precipitation effectiveness, he identified five humidity provinces (Per humid, Humid, Sub-humid, Semi-arid and Arid) and associated them with specific major natural vegetation zones of the world.

   b) Like precipitation effectiveness, Thornthwaite gave importance not to temperature rather to thermal effectiveness or thermal efficiency. He considered thermal efficiency as an important determinant of growth and type of vegetation. He conceptualised thermal efficiency as positive departure of mean monthly temperatures from the freezing point. Higher departure outcomes represent higher thermal efficiency. To measure thermal effectiveness, he first calculated monthly thermal efficiency (T/E) ratios and by summing up the T/E ratios of all twelve months he calculated thermal efficiency index. Based on thermal effectiveness he identified six thermal provinces. These thermal provinces in decreasing order of thermal effectiveness are – Megathermal, Mesothermal, Microthermal, Taiga, Tundra and Frost. The direction of thermal gradient is generally equator to pole.

2. Thornthwaite used potential evapotranspiration as an index of thermal efficiency. Potential evapotranspiration represents the potential loss of moisture through evaporation from the water bodies, soil surface and through transpiration from vegetation. Due to non-availability of instruments to measure evapotranspiration he indirectly estimated it by using temperature criterion. Temperature varies from place to place and time to time even at a particular place, depending upon the amount of insolation received. Thus, Thornthwaite considered mean monthly temperature, number of days in a month and duration of sunshine to calculate the potential evapotranspiration of different locations. He used potential evapotranspiration not only to identify thermal provinces but also humidity provinces. According to him surplus or deficiency of moisture is basically function of the differential amounts of precipitation and potential evapotranspiration.

Actual evapotranspiration is the actual amount of water-vapour return to the atmosphere from the ground and vegetation cover and it basically represents 'water use' but potential evapotranspiration represents 'water demand of the atmosphere.' The term 'need' signifies the quantity of soil water needed if plant growth is to be maximised for the given conditions of solar radiation and air temperature.

Terminal Questions

1. Discuss the three criteria of first classification and four criteria of second classification. It is a long answer so you must describe the conceptual differences of both the classification schemes and differences in terms of outcomes. For this refer Sec. 14.2 and 14.3 of this unit.

2. Start your answer by giving brief summary of Thornthwaite's climatic classifications. The focus of the answer should be on merits and demerits of criteria and classes. For this refer Sec. 14.4 of this unit.

3. In this answer you must focus on similarities and dissimilarities of both the classifications and for better answer and understanding go through previous units – 12 and 13 as well. Also refer Sec. 14.5 for comparative assessment.

14.9 REFERENCES AND FURTHER READINGS

1. Lal, D.S. (2011). *Climatology*, Sharda Pustak Bhawan, Allahabad.
2. Critchfield, H. (2015). *General Climatology*, Fourth Edition, Pearson India Education Services, Noida.
3. Singh, S. (2009). *Climatology*, Pravalika Publications, Allahabad.
4. Trewartha, G.T. and Horn, L.H. (1980). *An Introduction to Climate*, McGraw Hill, Tokyo.
5. Barry, R.G. and Chorley, R.J. (1995). *Atmosphere, Weather and Climate*, Routledge, London and New York.
6. Strahler, A. (2013). *Introducing Physical Geography,* Sixth Edition, John Wiley and Sons, New York.
7. Lutgens, F.K., Tarbuck, E.J. and Tasa, D. (2015). *The Atmosphere: An Introduction to Meteorology*, Twelfth Edition, Pearson India Education Services, Noida.
8. Ahrens, C. D. and Henson, R. (2019). *Meteorology Today: An Introduction to Weather, Climate and the Environment*, Twelfth Edition, Cengage, Boston.
9. Saroha, J. and Singh, S. (2023). *Physical Geography*, Pearson India Education Services, Noida.

UNIT 15

CLIMATIC REGIONS OF THE WORLD

Structure

15.1 INTRODUCTION

In the Previous Units, you have learned about the Climatic Classification Scheme presented by Thornthwaite and Koppen. You are also aware of the bases of Climatic Classification including Thermal Efficiency, and Precipitation Effectiveness. The climatic classification schemes of Koppen and Thornthwaite both used alphabets and abbreviations of the Roman script to indicate the variations in climatic characteristics. You have already studied that Koppen used four variables via, rainfall, temperature, vegetation, and altitude whereas; Thornthwaite used Moisture Adequacy Index, Thermal Efficiency Index, Seasonal Distribution of Moisture Adequacy and Summer Concentration of Thermal Efficiency for his climatic classification scheme. In the present unit, you will learn about the three comprehensive climatic regions of the world. As you know a climatic region is any portion of the earth's surface over which broad climatic characteristics are similar. You will learn about the Tropical Climatic Region and its sub-divisions in sec 15.2, Temperate in 15.3, and Polar Climatic Region in sec 15.4, respectively.

Expected Learning Outcomes

After studying this unit, you would be able to:

- identify the spatial location, latitudinal extent, and distribution of Tropical, Temperate and Polar Climatic Regions;
- classify sub-divisions of the Climatic Regions;
- differentiate between the climatic regions based on climatic conditions; and

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- compare and contrast climatic regions of the world.

15.2 TROPICAL CLIMATIC REGIONS

Here in this section, you will learn about the tropical climatic region. You will know that the tropical climatic region comprises of four climatic regions, though being latitudinally situated in the tropics; they have the distinct climatic characteristic.

The tropical Climatic region extends between 23.5^{O}degrees north to 23.5^{O} south of the equator. The tropical zone is considered astride (on both sides of Equator up to the Tropic of Cancer in the Northern Hemisphere and Tropic of Capricorn in the Southern Hemisphere. Some views favour a few-degree poleward extension of the tropical limit. It would be appropriate to consider the tropical region up to 30^{O} astride the equator.

This climatic region encompasses four climatic zones also known as low latitude climates. These zones have distinct climatic characteristics and different combinations of climatic elements.

Following climatic zones are found in the Tropical climatic region.

1. Equatorial Type of Climate
2. Tropical Wet and Dry or Savanna Climate
3. Tropical Monsoonal Climate
4. Tropical/ Sub-Tropical Hot Desert type of climate.

The last two climatic zones, that is, tropical monsoonal climateandtropical/ sub-tropical hot desert type of climate overlap with the sub-tropical andare the transition zones. The monsoonal climate is found in the eastern part of the globe in tropical latitude whereas hot deserts are concentrated in the western boundaries of the subtropical high-pressure belt between 30-35ºin both the hemispheres.

15.2.1 Equatorial Type of Climate

Equatorial Regions of the World

The tropical region of the world is dominated by Equatorial or Wet tropical or Tropical Rainforest climatic conditions. Refer to Fig. 15.1 to get an acquainted with the equatorial regions of the world.

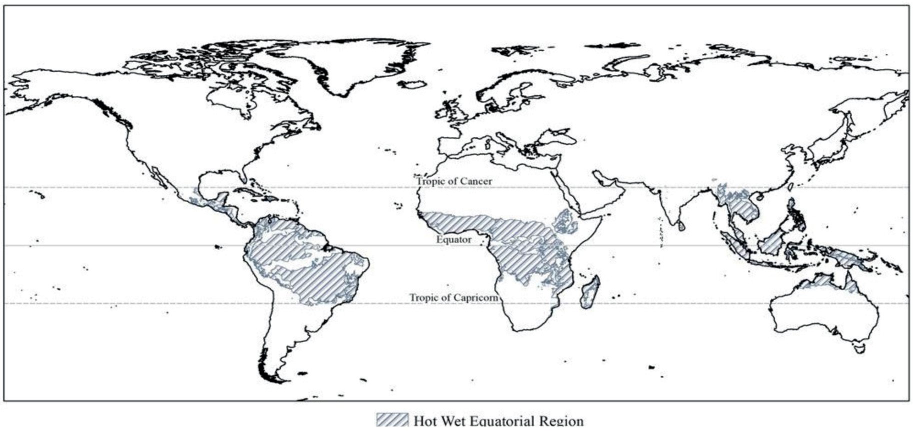

Fig. 15.1: Equatorial Regions.
(Source: Redrawn from 'Certificate Physical and Human Geography' by Goh Cheng Leong, OUP, 1992.)

Distribution

Equatorial regions are also known as tropical rainforests having tropical wet climate. The latitudinal extent of the equatorial regions is along the equator extending 5º to 10º on either side. This zone is also characterised by the ***Doldrums*** or the Inter-Tropical convergence zone (ITCZ). The Doldrums is a low pressure area extending from 5°N to 5°S of the Equator. Winds are eminently calm over here, with very little or no wind, making it extremely difficult to navigate through. It is called ITCZ as it is a place for trade winds to meet other the trade winds. Towards the north, equatorial zone merges into a savanna climate up to 30^{O} north and south. The western margins of the continents are characterised by the presence of hot deserts.The eastern margins of the continents are under the maritime influence and experienceTropical Monsoon Climate.

The tropical rainforest or equatorial type of climate is found in the Amazon River basin in South America, the Congo river basin and Guinea coast in Africa, a large part of Malaysia, Indonesia, and the Philippines island in South-Eastern Asia, eastern Central America (Parts of Panama, Costa Rica, Nicaragua, Honduras, British Honduras, and Guatemala, some of the islands ofWest Indies, Western Columbia, Coastal low lands of Eastern Brazil and Eastern Madagascar. Refer to Fig. 15.1 to understand better.East Africa and Andes mountainous region in South America are exceptions to equatorial climatic conditions owing to altitudinal impact. In India, similar conditions are found in the Western Ghat region, Tarai area of the Himalayas, Andaman and Nicobar group of islands, Northeastern India except the Loktak lake region.

Climatic Conditions

Day and night in the equatorial regions are always of the same length. This region receives maximum insolation. Uniformity of temperature throughout the year is an outstanding feature of this region. The mean temperature in this region lies between 24^{O}C-27^{O}C. This region has the lowest diurnal and yearly temperature range in the whole world. However, the diurnal temperature range may vary from 5^{O}C-14^{O}C.

This region experiences heavy precipitation between 152 cm to 254 cm and is well distributed throughout the year. This region has no distinct dry season.

Due to the updraft (upward movement) of warm air, strong convective activity is created leading to the formation of cumulonimbus clouds which causesheavy rains. The equatorial region is characterized by 60% (average) cloudiness and high humidity, making it sultry, oppressive, and enervating for human beings. Rainfall in tropical rainforest climatic regions is not only abundant but also highly dependable. Equatorial regions receive precipitation between 03:00 to 04:00 p.m. daily.

The equatorial region supports luxuriant growth of natural vegetation, having broad-leafed evergreen dense forest. Even though the laterite soil lacks the required nutrients, abundant heat, high humidity and competition of sunlight promote dense forest. The equatorial rain forest is also known as Selva. Lack of sunlight on the ground (sometimes even less than 1 % of sunlight reaches the forest ground, owing to thick multilayer tree foliage) hinders the growth of plants on the forest floor. However, in some favourable conditions (availability of sunlight) vines, ferns, Lianas, etc., create almost impenetrable undergrowth. The equatorial region has the maximum biodiversity in the globe. Theseforests are rich in valuable hardwood trees like Mahogani, Rosewood, Coconut, Palm, and commercial crops like Cinchona, Banana, Wild Rubber, and Bamboos are grown here.Known for being home to primitive people of hunters and gathers, this region still compriseshifting cultivation. This region is good for the plantation economy. Natural rubber, Cocoa, Coffee, Tea, Tobacco, Species, Cinchona, Banana, Pineapple, Sago, and in some cases sugarcane are important here. The important geographical regions famous for plantation economy are Java, Sumatra, Malaysia, West Africa (Ghana & Nigeria), Central America, Brazil, Amazon Basin, etc.

15.2.2 Tropical Wet and Dry or Savanna Climate

Spatial Distribution

Tropical wet and dry or Savanna Climate is typically located between $5^0$and 20^0 latitudes on either side of the equator. The region between 5^0 to 10^0 North and South is called woodland savanna, whereas 10^0 to 15^0 North and South is parkland, 15^0 to 20^0 north and south is grassland savanna. This nomenclature is made based on the tree density, which depends upon soil moisture, humidity, insolation, and rainfall. Savanna is flanked by a hot desert in the west and by the monsoonal climate in the east. It is a transitional zone between wet equatorial in the south and the semi-arid Steppe in the north. It is also known as the Sudan type of climate. Savanna climatic region vacillates between the rain-bearing ITCZ and rain suppressing subtropical high pressure (horse latitude) belt. Savanna Climatic region is extensively found in Latin America/ the Llanos of Orinoco Valley including Columbia and Venezuela, the Guiana Highlands and the Campos of Brazil. This region is spread over vast areas in Africa on either side of the tropical rain climatic region. It is known as veld in the southern part of Jerry, Angola, Zambia, Mozambique, Tanzania, Uganda, Central Zimbabwe, and Central & SouthwesternMadagascar. North of Congo Basin it is found in Sudan along with Cameroon, Central Nigeria, Ghana, Togo, the Ivory Coast, and eastern Guinea.

Climatic Characteristics

This type of climatic region is characterised by an alternate hot rainy season and cool dry season. The annual average temperature varies from $24^{O}C$ to 27 ^{O}C annual range of temperature is more than $3^{O}C$ but less than $8^{O}C$. Distance from the ocean / continentality is the main cause of the high annual range of temperature. The annual average rainfall varies from 100 to 150 cm.

Woodland Savanna (5^0 to 10^0 North and South) receives 75 to 150 cm annual average rainfall. Due to greater seasonal variation (inadequacy) in the availability of soil water/ moisture the woods are not densely found, they are scattered and dominated by the tree. The surface biome is dominated by savanna grasses. Parkland savanna (10^0 to 15^0 North and South) receives 50 to 75 cm annual average rainfall. This climatic region is dominated by savanna grasses with patches of trees.

Patches of trees emerge in either of four circumstances

- Moisture retaining soil is available.
- Physical depression/ low lying area.
- Caldera/ Crater Lake.
- Favourable groundwater table.

Savanna grassland ($15^0$to 20^0N & S) – average annual rainfall 30 to 50 cm. Decreasing rainfall is due to the impact of continentality and nearness to subtropical high pressure anti cyclonic belt. Rainfall is moderately favourable for the growth of grasses. The region of dominated by Savanna grasses which are tall, hard, and dense. This climatic condition emerged in the eastern African equatorial region due to altitudinal impact.

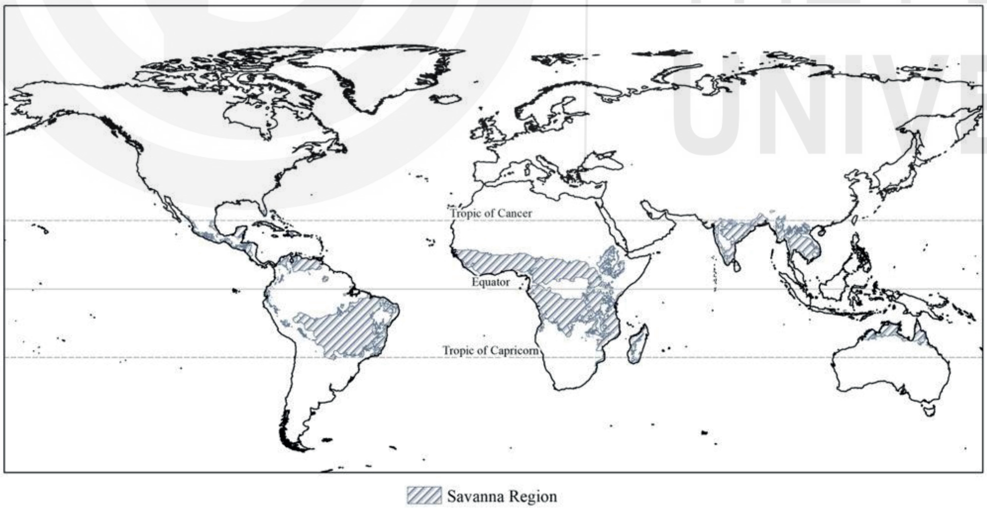

Fig. 15.2: Tropical Wet and Dry Savanna Climate.
(Source: Redrawn from Wikipedia.org)

Trees in this climatic region are deciduous and have long roots to prevent moisture loss through transpiration and avail water from deep within the ground during the dry season. Most of the trees savanna regions are fire-resistant. It is dominated by both herbivorous and carnivorous. It is a region of game animals due to the presence of a large number of herbivores and favourable conditions. This is also known as the natural zoo of the world and the land of big games. Savanna is a region of typical birds that run but don't fly like an ostrich in Africa Emu in Australia and is also home to Kangaroo, Giraffe, Zebra, etc.

Savanna is the land of many different tribes who are either cattle pastoralists like the Masai of the East African plateau or settled cultivators like the Hausa of northern Nigeria.

15.2.3 Tropical Monsoonal Climatic Region

Spatial Distribution

The tropical Monsoonal Climate region is found between $10^0$and 25^0 North and South latitudes. This climatic region is largely confined to the eastern margins of the continents. However, vast Indian subcontinent is an exception. Complete seasonal reversal of winds and more than 70% of the total rainfall confined into four months are the outstanding features of these climatic regions. Spatially the most defined monsoon regions are found in the coastal areas of eastern and southern Asia, like India, Myanmar, Bangladesh, Indonesia, Southern China and the Philippines. Hokkaido Island of Japan is a region of temperate monsoon. The cold condition is akin to a temperate climate but the pattern of precipitation in Hokkaido adheres to the monsoonal parameters. Areas outside Asia that experiences a seasonal reversal of wind are said to have the only monsoonal tendency or pseudo monsoon for example southwest coast of West Africa including the coasts of Guinea, Sierra Leone, Liberia and the Ivory Coast. Similarly, equatorial East Africa including the coastal area of Madagascar has the monsoonal climatic condition, due to onshore south westerly winds during summer, and northeast trade wind in winter. Pseudo monsoon is also noticeable along the northeast coast of Latin America from the mouth of river Orinoco in eastern Venezuela through Guyana, Surinam, and French Guyana to the northeast of Brazil. Puerto Rico and the Dominican Republic in the Caribbean Islands have also monsoonal effects.

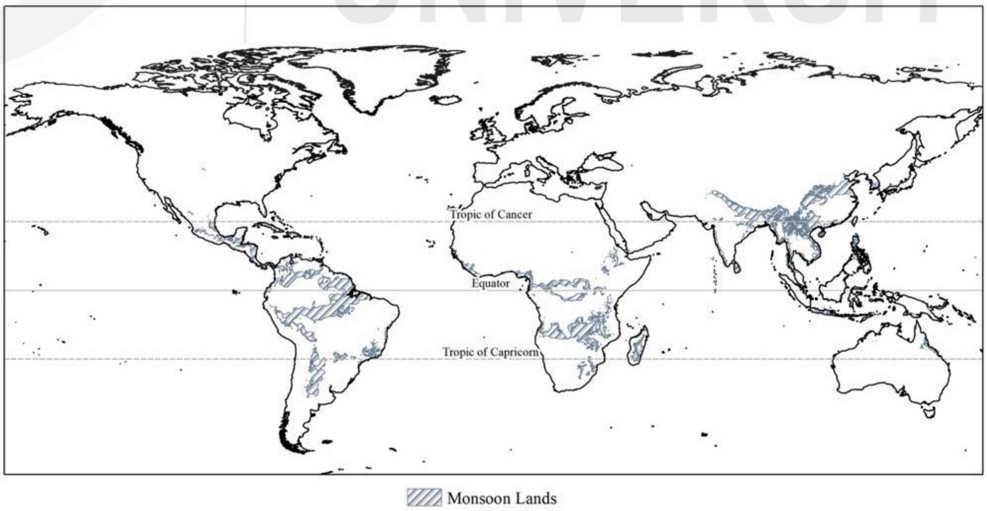

Fig. 15.3: Tropical Monsoon Climatic Region.

(Source: Redrawn from 'Certificate Physical and Human Geography' by Goh Cheng Leong, OUP, 1992.)

Climatic Characteristics

The monsoonal region experiences high to very high temperatures during summer. The average temperature for the summer months varies from 27^{O}C to 32^{O}C. During the winter months, mercury hovers between 10^{O}C to 26.7^{O}C for non–coastal stations. The temperature in western Rajasthan and some other inland stations may shoot up to 50 ^{O}C in summer and dropsto 0 ^{O}C in winter. The annual temperature range is very high and second only to the hot dessert climatic region. The annual temperature range varies from 2 ^{O}C to 11^{O}C. The high range of variation is due to continentality, latitude, altitude and cloud cover. The diurnal range of temperature is relatively low in the coastal regions.

The concentration of more than 70% of total annual rainfall within the four months of the summer is an outstanding feature. Indians monsoon rains are mainly orographic. The annual average rainfall is 200- 250cm, however, it varies from coastal location, Inland location, windward side, and leeward side. The onset of monsoon is in the form of south-western branch on Andaman and Nicobar group of Islands 15th May and at coastal Kerala on 1st June is in form of a burst of monsoon. It brings cyclonic torrential rains. The two distinct branches of the Indian monsoon viz., Arabian Sea and Bay of Bengal, together engulf the entire Indian subcontinent from June to September. The stifling heat during summer develops low pressure onthe Indian subcontinent. The complex interplay of the tropical easterly jet stream and high insolation developshigh-pressure over the Tibetan plateau during late April and early May, accentuated by a warm updraft of winds that augurs the already low pressure on the Indian landmass, begins a cyclic movement in the upper troposphere. This cyclic movement creates two limbs one at the top of the Tibetan plateau of high pressure and another of low pressure above the huge Indian landmass. The temperature over the sea continues to remain relatively low.The flow of air streams from above the surface of the sea/ ocean (high pressure) towards the Indian landmass (Low Pressure) is what we know as the southwest monsoon or summer monsoon. The reversal of the wind system from the Tibetan plateau towards the sea inthe winter is calledthe retreating monsoon. Since it blows over dry landmass, it is deprived of moisture except for a small stretch of the Bay of Bengal. TheTamil Nadu coast is the only region which receivesrainfall during the retreating/ winter monsoon.

Nature and types of vegetation in this climatic region are the testimony of the precipitation. Tropical rainforests are found in the areas having high rainfall. Teak, Sal, Shisham, Mahua, Mango, Neem etc. are the important tree species of the region.

The monsoon areas are regions of paddy culture. The Indian subcontinent, southern coastal areas of China including the river valleys of Yangtzekiang, Hwang ho, and others, Mekong and Menam delta regions of Thailand and Cambodia, Irrawaddy and Chindwin Riverdelta regions of Myanmar, low lying areas of Bangladesh,etc. are famous for paddy cultivation.Besides, paddy this climatic region is also knownfor its plantation crops like tea, sugarcane and coffee. The region has largely an agriculture-driven economy.

15.2.4 Hot Deserts or Sahara Type of Climate

Spatial Distribution

The distribution of hot deserts corresponds to the subtropical high-pressure belt and spatial location of land and water bodies. Latitudinally most of the hot deserts located from15^{0} to 35^{0} North and South. This climatic region is represented in the following deserts; coastal region of Peru and Chile in South America; Namib and Kalahari deserts of coastal Angola, South-West Africa; Interior of Botswana and South Africa; the great Australian desert; The Sahara and Arabian deserts; The Iranian deserts; the Thar desert of Pakistan and India; deserts of Northern Mexico.

The location situation of these deserts on the western margin of the continents is the complex interplay of a combination of various climatic conditions, such as location in the subtropical high-pressure belt, dryness of moisture-laden trade winds, and presence of cold oceanic currents off the western margins which causes an increase in the aridity.

Hot and Mid Latitude Deserts of the World

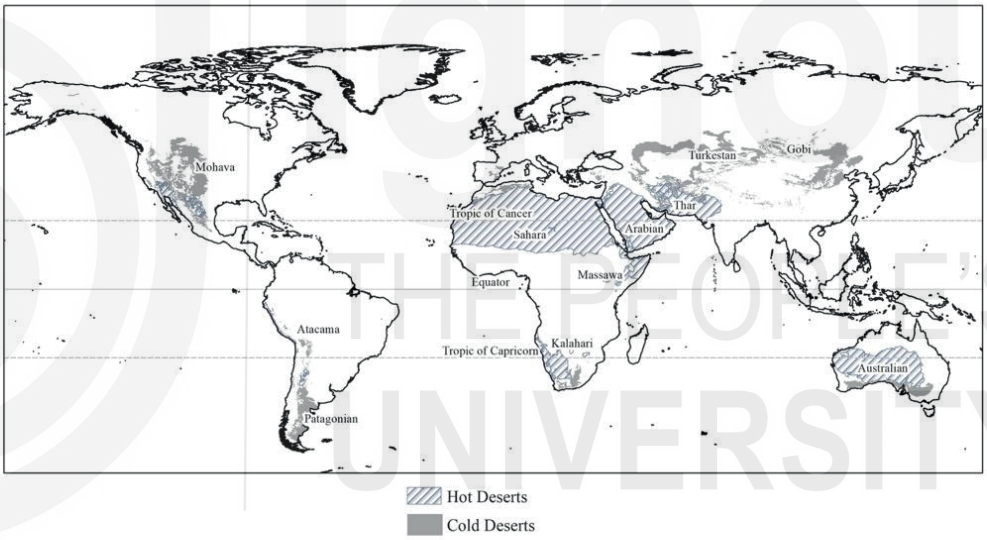

Fig. 15.4: Hot and Mid- Latitude Deserts of the World.
(Source: Redrawn from 'Certificate Physical and Human Geography' by Goh Cheng Leong, OUP, 1992.)

Climatic Characteristics

Hot deserts of the world experience not only high temperature and low humidity but also are the places havinga high annual and daily temperature range. The daily temperature range may vary from 22℃ to 28℃, while the annual range here varies from 17 ^{O}C to 22 ^{O}C. The average temperature is around 30 ^{O}C. Clear and cloudless sky with intense insolation, dry air and rapid evaporation are causes of high temperature. Though the coastal deserts have lower temperatures compared to their interior counterparts, aridity continues to be very high.

Annual precipitation varies from practically no rainfall (mid-Atacama) to 25 cm (William creek, Australia). Its location astride the Horse latitude/subtropical high-pressure belt experiences calm and clear atmosphere due to the descent of air. Descending air creates an anticyclonic situation bringing stability to the atmosphere, a condition least favourable for precipitation of any kind. This climatic region comes under the offshore trades winds while falls outside the influence of the rain-bearing onshore westerlies. Winds blowing from the cooler region to the warmer region of the deserts undergo a decrease in relative humidity which thwarts saturation and prevents subsequent condensation, hence practically little chance of rainfall.

Xerophytic or drought resistance scrub is the predominant vegetation of the deserts. Plants have long roots, few or no leaves, and the foliage is waxy, leathery, hairy, or needle-shaped to reduce the loss of water through transpiration.

Hot deserts of the world are inhabited by tribal communities who are primitive hunters and gatherers, important among them areBedouin of Arabia, Bushman of Kalahari, Bindibu of Australia, and Tuaregs of Sahara. These aborigines procure their livelihood from nomadic hunting and food gathering.

SAQ I

a. Monsoon Climatic Region is found on which margin of the continents?

b. What is the latitudinal extent of the Parkland Savanna Climatic Region?

15.3 TEMPERATE CLIMATE REGIONS

You learned about the tropical region and the different sub climatic regions found within the latitudinal extent of the tropics astride the equator. As we go towards the poles, we come across another natural and climatic region named Temperate or mid-latitude climate. Similar to the tropics the temperate region is further subdivided into distinct climatic zones/regions, based on their location on the eastern or western margins of the continents and the interiors of the continents.

Temperate climatic regionsare located between 35^0 and 65^0 North and South latitude. However, climatologists like Koppen, Thornwaite, Trewartha, etc. slightly differ in their latitudinal extent. Some include transition zones like Steppe as part of the temperate climatic region. A more generic classification of this climatic region is a warm temperate and cool temperate region. To have better clarity, temperate region is subdivided into the Mediterranean, Steppe region, China type of, British/ Western European, Central continental, and Laurentian climatic regions. The following table and diagram explain the latitudinal extent and spatial location of these regions.

Table 15.1: World Climatic Types

Climatic Region	Latitude (Approximate)	Climatic Type
1. Warm Temperate region	30 °C-45 °C North and South	a. Western margin (Mediterranean type) b. Central continental (Steppe Type) c. Eastern Margin: i) China type ii) Gulf type iii) Natal type
2. Cool Temperate Zone	45 °C -65°C North and South	a. Western Margin (British type) b. Central continental (Siberian type) c. Eastern Margin (Laurentian type)
3. Cold zone	65 °C - 90 °C North and South	a. Arctic or polar

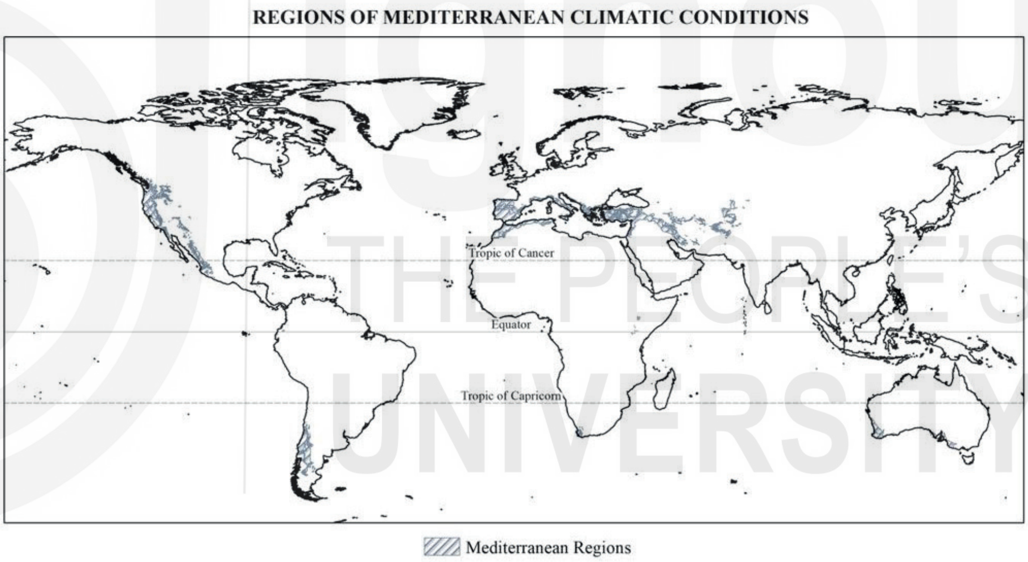

Fig. 15.5: Regions of the Mediterranean Climates.
(Source: Redrawn from 'Certificate Physical and Human Geography' by Goh Cheng Leong, OUP, 1992.)

Spatial Distribution

The warm temperate western margin (Mediterranean region) is also called asdry summer subtropical climate. It isentirely confined to the western portion of the continental masses between 30 °C-45 °C North and South. There are five regions of the world having the Mediterranean climate these are: the borderlands of the Mediterranean sea (north of the Mediterranean sea from Portugal to Turkey and Beyond of Iranian Highlands; the southern borderland includes Morocco, Northern Algeria, Tunisia and North of Bengasia in Libya); the central and southern California coast in the USA; Central Chile; The Cape town area of South Africa; South and south-western coast of Australia. This climatic region occupies only 1.7% of the total land area of the world.

The Mediterranean is the only climatic region of the world that receives rainfall only in winter. The existence of this climatic condition is due to the shifting of the pressure belts. During the southward movement/ shifting of the pressure belts of the world (please refer to the figure below), this climatic region comes under the influence of the warm, moist, and rain-bearing westerlies (corresponding to the 40^{O}C-45^{O}CNorth and Southlatitude). Westerlies bring winter rainfall to this region. The northward shiftof the pressure belts owing to the apparent movement of the Sun brings these regions under the influence of offshore trade winds and subtropical high-pressure conditions, thus depriving them from precipitation.

Climatic Characteristics

The Mediterranean climatic region is considered as one of the ideal climates for human habitation with maximum days of clear sky, plenty of sunshine, moderate temperature, and winter rainfall. This climatic region is famous for the production of citrus fruits and vines. The average temperature in the coldest month is usually between 4.4^{O}C to 10^{O}C and the hottest month is 21^{O}C to 27^{O}C. The mean annual temperature ranges between 11^{O}C and 17^{O}C. However, it may be higher in case of greater distance from the sea. The rainfall is confined to the winter, and varies from 35 cm to 90 cm.

The Mediterranean climatic region is famous for the origin of distinct local winds both hot and cold. Important among them are the **Mistral**, cold wind of South France blowing down the Rhone valley between the Alps and Massif Central, Bora of erstwhile Yugoslavia, a cold north-easterly wind along the Adriatic Sea, Sirocco is a hot dry and dusty wind of Sahara Desert causes rainfall on the Levante coastal areas known as ‘Blood rain’ due to presence of red particles of the sand that form the hygroscopic nuclei resulting in the red colour of the droplets, hence the name. Sirocco is known as **Chili** in Tunisia, **Ghibi** in Libia, **Leveche** in Spain, **Khamsin** in Egypt, and Gharbi in the Adriatic and Aegean Sea.

Mediterranean vegetation has the following characteristics:

- Trees have small broad leaves of moderate height and are widely spaced.
- Evergreen forests of Oaks are found in the region receiving more than 60 cm average annual rainfall, Eucalyptus Forests are common in Australian part of this climatic region.
- Scrubs and Bushes are the most predominant. The common species are Laurel, Myrtle, Lavender, Arbutus, and Rosemary of which a number of them are strong scented.
- The scrub vegetation (scattered, stunted trees and tall bushes) is known by different names.
- This type of vegetation is called **maquis** in southern France, and **Macchia** in Italy. In California, the term **Chaparral** is used, in Australia as **Mallee** scrub. In limestone uplands, where the soil is extremely thin and the scrub deteriorates into highly xerophytic ground creepers, a more exact term, **garrigue**, is used.

This climatic region is famous for Orchard farming as known as the world's Orchard lands. It is famous for citrus fruits like Oranges which have different names in their area of production due to distinct shape, size, taste, and quality. They are Sunkist oranges from California, Seville from Spain, Oranges of Israel are Jaffa. This region is also known for olive tree and wheat farming; Mediterranean region produces the best-quality wines which include **Sherryn** in southern Spain, **Port wine** in Portugal, **Chianti**, **Asti**, and **Marsala** from different parts of Italy. Among the famous wine-producing regions, champagnein the Paris basin, **Bordeaux** in the Garomme Basin, and **Burgandy** are located in the Rhone-Saone valley.

15.3.1 Steppe

Steppe is the grassland of Eurasia stretching eastwards from the source of the Black Sea across the Great Russian Plain to the foothills of Altai Mountain covering a distance of well over 3220 km. In North America, grassland is quite expensive, called prairies. They are situated between the foothills of the Rockies and Great Lakes Strides along the American Canadian border. This grassland in Hungary is known as Pustaz, Pampas in Argentina, Veld in South Africa, Downs in Australia, and New Zealand grassland in northern New Zealand Canterbury.

This climatic region is situated in the interior of the continent between 30º and 45º N&S. remoteness from maritime influence causes dryness even though being under the influence of westerlies.

Mid Latitude Grasslands (Steppes)

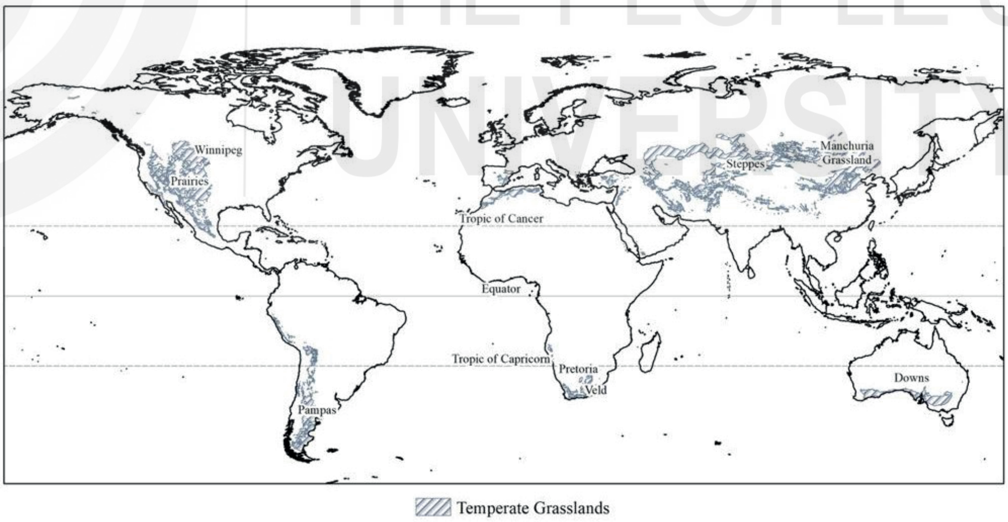

Fig. 15.6: Steppe or Mid-Latitudinal Grasslands.
(Source: Redrawn from 'Certificate Physical and Human Geography' by Goh Cheng Leong, OUP, 1992.)

Climatic Characteristics

Temperature ranges from 26^0 in summer and 10^0 in winter. The annual temperature range is less than 15^0 in the southern hemisphere and more than 30^0 in the northern hemisphere. Annual rainfall varies from 38 to 78 cm. Most of the rain occurs in summer.

Grasses are soft and nutritious in comparison to Savanna grasslands. Soil moisture is adequate to sustain grasses throughout the year. The distribution of grasses is interrupted by shrubs and low trees. This region is characterised by herbivores and extremely low bird density (27p/ 40 Hectare). The average life cycle of grasses is 1 to 10 years and because of this region remains green throughout the year.

This region is famous for wheat farming and livestock rearing dairy and meat production. Steppe temperate grasslands are also known as granaries of the world.

15.3.2 Warm Temperate Eastern Margin Region

Warm type of climatic region may be further divided into the western margin, central continental, and eastern margin. The Eastern margin temperate region has three distinct climatic conditions, namely China, Gulf, and Natal type.

Distribution

A. China Type of Climatic Region

On the eastern margins of the continents in warm temperature latitudes, China type of climate is found. Both Mediterranean and China type climate aresituated in the same latitudes. Chinatype of climate receives rainfall during summer, geographically it is found in **central and northern China, and southern Japan**. It receives heavy precipitation through the rain-bearing southeast monsoon, with decreasing trend towards the interiors. The annual range varies from 7.2℃ in central China to 12.8℃ in the northern part of China. The recurrent typhoon (intense tropical cyclones) is another characteristic feature in this climatic region. This climatic region also famous for mixed forest (presence of both evergreen and deciduous trees).

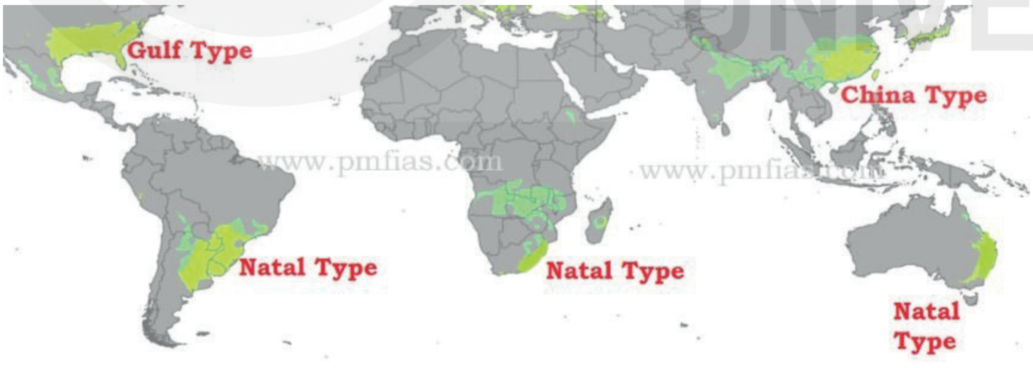

Fig. 15.7: Warm Temperate Eastern Margin Region.
(Source: www.pmfias.com)

B. Gulf Type of Climatic Region

It is found in the southeastern United States similar to that of Central China except that the monsoonal characteristics are less well established. Florida, New Orleans, and Alabama represent this climate. The average annual summer temperature is 27.8^0 C average annual winter temperature remains at 20^0.Onshore winds cause a moderate annual temperature range. Annual rainfall varies from 148 cm (maximum) in Miami and New Orleans to 105 cm (minimum) in Charleston. This region is famous for its extensive cultivation of cotton and maize. The famous cotton and corn belts of the USA are located in this climatic region.

C. The Natal type of Climatic Region is named after the Natal Province of South Africa and is located in New South Wales (Australia), Natal (South Africa), Parana-Paraguay-Uruguay basin (South America). This type of climate is found only in the Southern Hemisphere. The narrowness of the continents and the dominance of maritime influence result in a very small annual temperature range. This region receives 120 cm of rainfall on average with the maximum being 132 cm in Asuncion in Paraguay. The mean monthly temperature varies between 4° C and 25° C and is strongly modified by maritime influence. The warm temperate eastern margins are the home of several varieties of tree species which include Eucalyptus in Australia in the Australians Alps of Victoria and in Blue Mountain in New South Wales; Parana Pine and Quebracho (Axe Breaker, an extremely hardwood used for tanning), and Verba mate trees from the forest of southwestern Brazil, Eastern Paraguay, and North Eastern Argentina. Palm tree, Chest Nuts, Iron Wood, Black Woods, and wattle tree are some of other species found in the Natal climatic region. Oak, Camphor, Camelia, and Magnolia are some tree species that are found in the forest of China and southern Japan. Walnut, Oak, Hickory and Maple are important and common species in the Gulf States of USA.

15.3.2.1 Cool Temperate Zone

The latitudinal extent of this climate is 45^0 to 60^0 North and South. The major regions of occurrence are, the western coast of North America, Spanning Oregon, Washington, and British Columbia; Western Europe and the British Isles; Victoria and Tasmania; New Zealand; and Chile, South of 35^o. This is a moist climate where most of the precipitation fallsduring winter season and summer experiences minimum rainfall. The mean annual temperatures are between 4.4^oC to 15.5^o C. The climate is considered as ideal for comfort and mental alacrity. This region remains under the permanent influence of the Westerlies throughout the year. In this humid climate, precipitation is copious in all months but with a distinct winter maximum.Orographic barriers cause very large annual precipitation on the windward sides.

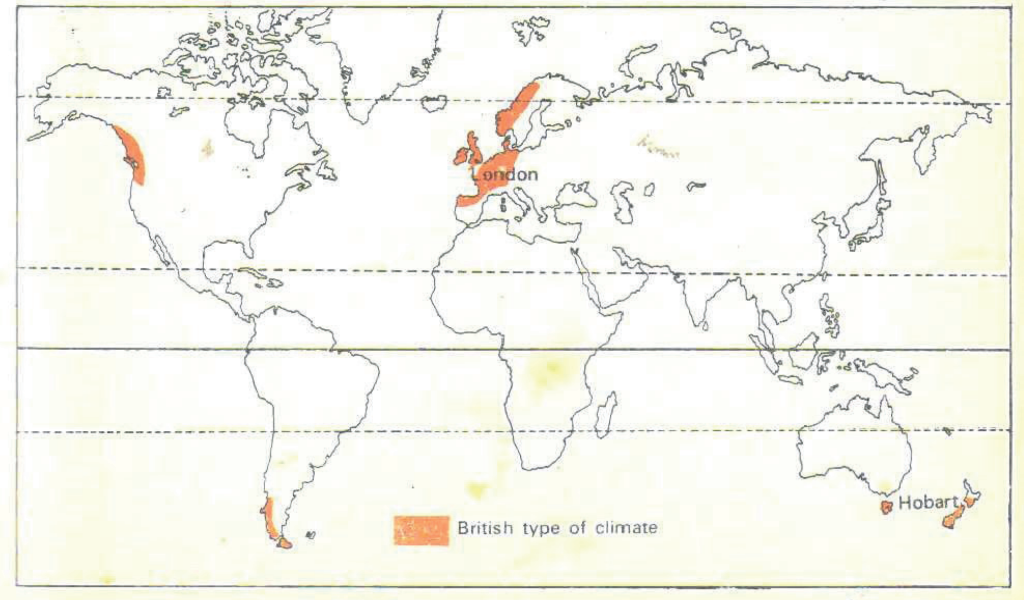

Fig. 15.8: Spatial Distribution of British Type or West European Climatic Region.

(Source: 'Certificate Physical and Human Geography' by Goh Cheng Leong, OUP, 1992.)

Among the valuable deciduous hardwood, temperate species include Oak, Elm, Ash, Berch, Beech, Poplar and Hornbeam. Willows, Alder, and Aspen grow in wetter areas and Chestnut, Sycamore, Maple and Lime are the other species. These species occurring in pure stands with sparse undergrowth and easy access and have immense lumbering value.

British type climate region comprises the most urbanised, industrialised and developed parts of the world.This climatic region is famous for Fishing activities (particularly in Britain, Norway, and British Columbia), Intensive Market Gardening (also known as Truck Farming in the USA), Horticulture, Mixed Farming, Dairy Farming, Sheep Rearing, and other advanced agricultural activities.The region is also a leading producer of Beat sugar.

15.3.2.1(a) The Cool Temperate Continental (Siberian) Climatic Region

This climatic region is found only in the Northern Hemisphere. On the poleward side, it merges into the Arctic tundra of Canada and Eurasia at around the Arctic Circle southwards it fades into the temperate Steppe climate.

This climatic region is characterised by several winters of long durations, and cool brief summer. The warmest month has a temperature of 10^0 while the winter months are always below the freezing point. It receives 62cm of annual average rainfall. Siberia is often referred to as the cold pole of the earth. Verkhoyansk of Siberia is the coolest place onthe earth. Taiga forest dominates this climatic region. Among themimportant species are pine, white pine, red pine, scots pine, jack pine, lodgepole pine, Douglas fir, and balsam fir. Spruce and larch are also found in pure stands. Fur-bearing animals like muskrat, ermine, mink, and silver fox produce the finest quality of fur in the world. The lumbering industry is the main sourceof economy in the region

15.3.2.1(b) The Cool Temperate Eastern Margins Laurentian Climatic Region

It occurs on the eastern side of North America between 35^0and55^0 N and on the eastern side of South America, South of 40^o S. It is found in Northeastern North America, including eastern Canada, North East USA (Maritime Provinces and New England state), and Newfoundland. In Asia, it is found in eastern costal lands including Eastern Siberia, Eastern China, Manchuria, Korea, and northern Japan.

This region is under the influence of continental polar air mass in winter causing temperatures as low as -9^oC to -7^oC, however, continental tropical and maritime tropical air masses during summer bring the temperature of the region to 15^oC to 34^oC. The annual temperature range is as high as 24^oC.

Precipitation in North America and North Japan occurs throughout the year, whereas in north East Asia (Except North Japan and North Korea) rainfall is confined to the summer months. Uniformity in precipitation (7.5 cm to 10 cm per month) in North American Region is an outstanding feature of this climate. The Asiatic and North Eastern Americans of this climate experience influence of both Westerlies and Easterlies. NE American region receives westerlydepressions during winters which sneak through the Rockies and blow over the Great Lakes to gather moisture and bring rainfall. However, onshore easterlies blow over warm Gulf Stream and Cold Labrador currents. The meeting of these to contrasting currents on the coastal waters off Newfoundland produces dense mist and fog, initiating heavy precipitation in the form of drizzles.

Fishing along with lumbering and agriculture is the most important economic undertaking here. This region is famous for having the world's famous fishing grounds including the Grand Banks of Newfoundland.

SAQ 2

a. Which climatic region receives rainfall only during winter months?

b. Why Newfoundland is famous for mist and fog?

15.4 THE ARCTIC OR POLAR ZONES

In the last two previous sections (15.2 and 15.3) you have learned about the climatic conditions found in the form of distinct climatic regions in the tropical and temperate world. Here in this section, you will study the climate found in the Polar regions of the world.

The polar climatic region is spread mainly, north of the Arctic Circle which include ice-caps found in Greenland and the highlands of these high latitude regions, where the ground is under permanent snow cover. Along with Greenland, the barren grounds of northern America and Alaska and the Arctic Seaboard of Eurasia above the 65^o latitude are taken as Polar or Tundra regions. The virtually uninhabited continent of Antarctica in the southern hemisphere is the greatest single stretch of ice cap where the layer of permanent ice is several kilometres thick.

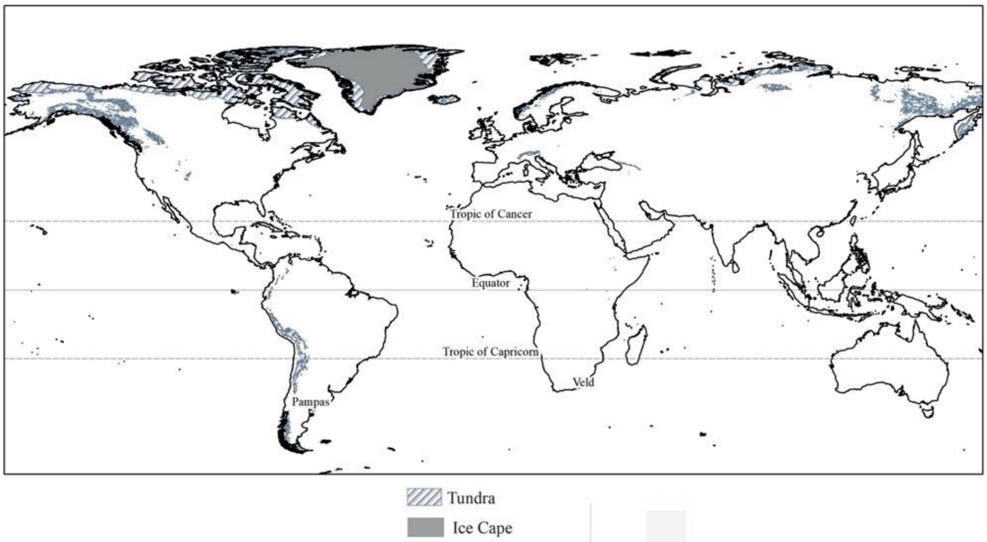

Fig. 15.9: Arctic or Polar Type.
(Source: Redrawn from 'Certificate Physical and Human Geography' byGohChengLeong, OUP, 1992.)

Climatic Condition

It is characterised by extremely low mean average temperature where the maximum temperature is seldom above 10°C. The lowest temperature drops to-37°C normally not more than 4 months have temperatures above freezing point. This is a region of permafrost where the ground remains solidly frozen for 8 months. Winter is long and very harsh and summers are cool and brief. Arctic and Antarctic Circles remains under darkness for 6 months. Despite 6 months of sun during summer, the temperature remains low, assun rays are feeble, slanting, and lack vigour.

Precipitation here is in the form of snow. Usually, it receives 12 inches or 30.48 cm of snowfall annually. It takes 10-12 inches of snow to make 1 inch of rain. Precipitation in form of rain and sleet is common during summer when evaporation is possible.

Arctic foxes, polar bears, grey wolves, caribou, snow geese and musk-oxen are found here. In mountainous areas, goats, sheep and marmots can be found.Penguins live in the Antarctic. Whales, seals and snowy owls are also found in Polar Regions. When the surface layer of the permafrost melts in the summer, shallow lakes and bogs appear which attract insects, birds and other wildlife.

Deficiency in heat is the greatest inhibiting factor for the growth of vegetation in this region. Tundra/Polar regions do not have trees because of unavailability of adequate temperature. Stunted birches, dwarf willows, and undersized alders along with mosses and grasses are the only vegetation in this region.

The polar / tundra region is largely devoid of human habitations except for quite a few who live semi-nomadic life and have to adapt themselves to the harsh environment **Eskimos** as a semi-nomadic tribe found in Greenland, Northern Canada and Alaska, live in igloos and hunt caribou (name of the reindeer in America) and other animals to secure a steady supply of their meat, milk, fat, skins, and bones. In the Eurasian tundra other nomadic tribes such as the Lapps of Northern Finland and Scandinavia, the **Samoyeds** of Siberia (from the Ural Mountains and the Yenisey Basin) the **Yakuts** from the Lena basin, and the **Kayaks** and **Chukchi** of North-Eastern Asia, Wander with their herds of Reindeer in search of pastures.

SAQ 3

a. Why do Eskimos live in a house made up of ice?

b. What is the area of habitation of Samoyeds and Yakut tribes?

15.5 SUMMARY

In this unit you have studied:

The whole unit can be divided broadly into three climatic regions which we discussed in detail in the above section. The classification is done based on latitudinal expanses from the equator towards the poles. However, it would be interesting to point out that the climatic conditions vary in the same latitude based on the coastal and continental location, altitude, influence of the prevailing winds, air masses and pressure belts. Precisely, that is why we have climatic regions having distinct characteristics in the same latitude having locations in the eastern and western margins of the continents. Geographical locations in the interior (impact of continentality) of the continents usually have relatively dry conditions. The Mediterranean, Steppe and the China type Climates with the similar latitudinal extent and broadly considered temperate climates, have distinct climatic characteristics.

15.6 TERMINAL QUESTIONS

1. Explain why hot deserts of the world are situated on the western margins of the continents? Explain.
2. Why the Mediterranean Climatic region receives rainfall only during the winter months?
3. Explain the differences in climatic conditions among the western European, Siberian and Laurentian types of the climatic region, situated in the same latitude.

15.7 ANSWERS

Self-Assessment Questions (SAQ)

1. a) Monsoon Regions are generally found on the eastern margins of the Continents.

b) Park Land Savanna is found between 10^0 and 15^0 N & S Latitudes.

2. a) Mediterranean Climatic Region receives rains only during the winter season.

   b) Meeting of two ocean currents of contrasting thermal characteristics, the warm Gulf Stream and cold Labrador currents off the coast of Newfoundland cause thick fog and mist. The onshore winds cause rainfalls in the form of drizzles in the region.

3. a) Eskimos live in the houses made of ice called igloos because the temperature inside an igloo remains constant at a higher temperature in comparison to the temperature outside.

   b) The Samoyeds tribe live in the Ural Mountains and Yenisey river basin in Siberia, whereas Yakuts are found in the Lena River basin area in North-East Asia.

Terminal Questions

1. Your answer must contain the following points

   A. The climatic significance of the subtropical high-pressure belt is characterised by anticyclonic atmospheric movement coupled with subsiding air.

   B. About the onshore trade winds that dry up completely by the time they reach the western margins.

   C. Presence of Cold Oceanic Currents off the western coast.

2. Start your answer by mentioning the shifting of the global pressure belts due to the northward and southward apparent movement of the Sun. Mention how during the winter months the shifting of global pressure belts brings the Mediterranean region under the influence of warm moist Westerlies.

3. Begin your answer by mentioning the latitudinal situation of these climatic regions on the globe.

   Although almost within the same latitudinal extent these regions are located on the eastern margin, western margin and the Continental location. Due to their locations, they come under the influence of different prevailing winds and air masses, causing a difference in climatic conditions.

15.8 REFERENCES AND FURTHER READINGS

1. Lal, D.S. (1985). Climatology, Chaitanya Publishing House, Allahabad.
2. Leong GohCheng, (1992). Certificate Physical and Human Geography, Oxford University Press, New York.
3. Strahler, A.N. and Strahler, A.H. (2001). Modern Physical Geography, Wiley and Sons, New York.

4. Trwartha, G.T. and Horn, L.H. (1980). An Introduction to Climate, McGraw Hill, Tokyo.

5. www.wikipedia.org.

6. www.pmfias.com.

GLOSSARY

Actual Evapotranspiration (AET) : This refers to the actual amount of water that is evaporated from the soil and transpired by plants under existing climatic conditions. It accounts for factors such as moisture availability, temperature, and vegetation cover.

Applied Climatic Classification : In this, the climatic regions are delineated in terms of impacts of climate on other phenomena.

Climatic Classification : It is a mechanism through which diversity and complexity of atmospheric conditions over earth surface are transformed into manageable classes which are meaningfully organised in order for simplification and generalisation.

Empirical Classification : It is based on the observable elements of climate which may be considered singly or in combination to frame criteria for climatic types.

Genetic Classification : A classification based on genetic or causative factors of climate is known as a genetic classification.

Mediterranean Climate : Characterised by mild, wet winters and hot, dry summers. Mediterranean climates are typically found around the Mediterranean Sea and in parts of California, Chile, and South Africa.

Moisture Index : Thornthwaite's moisture index, also known as the Thornthwaite Index, is a measure of the availability of moisture in a particular location based on the balance between precipitation and potential evapotranspiration. It categorises climates into groups such as hyper-arid, arid, semi-arid, etc., based on their moisture conditions.

Polar Climate : Found near the earth's poles, characterised by very cold temperatures and long winters with little daylight, experiences little precipitation and have permanent ice cover.

Potential Evapotranspiration (PET) : This is a measure of the evaporative demand of the atmosphere under specific climatic conditions, representing the maximum amount of water that could be evaporated from the soil and transpired by plants if water were unlimited.

Temperate Climate : Moderate climates found in the middle latitudes, with four distinct seasons: spring, summer, autumn, and winter. They have mild summers and cool winters.

Tropical Climate : Characterised by high temperatures throughout the year, typically found near the equator. Tropical climates often have distinct wet and dry seasons.

Water Balance : In Thornthwaite's climatic classification, water balance is the relationship between precipitation and evapotranspiration in a given area over a specific period. It indicates whether there is a surplus or deficit of water, which influences the moisture regime of the region.