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CLIMATIC ZONES AND TYPES

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The basic goal of the geographic study of climate, as with the geographic study of anything else, is to understand its spatial characteristics – its distribution over Earth. Such understanding is exceedingly difficult to achieve for climate, however, because so many variables are involved. It is relatively easy to describe and even to map the distribution of such uncomplicated phenomena as giraffes, voting patterns, and a host of other concrete entities or simple relationships. Climate, however, is a result of a number of elements that are, for the most part, continuously and independently variable. Temperature for instance, is one of the simplest climatic elements, and yet it fluctuates in time and place frequently

Although temperature can be measured precisely, some form of abstraction is necessary for tabulation and analysis. Most widely used is the arithmetic mean (or average). For some purposes, however, the most probably temperature or some expression of variation (for example, standard deviation) is more useful, and for still other purposes extremes are more important than averages. The point at issue is that climate involves almost continuous variation, not only of temperature but also of a host of other factors. Thus, a satisfactory synthesis of all these data involves a great deal of generalization and subjectivity.

Climatic Classification

To cope with the great diversity of information encompassed by the concept of climate, the most meaningful climatic characteristics must be selected and some systematic way must be found to classify them. Classifiers generally have chosen temperature and precipitation as the most significant and understandable features of climate, as well as the most available.

The purpose of classifying climates

We need a classification scheme that is useful as a learning tool. Specifically, we need a device to simplify, organize, and generalize a vast array of data into a comprehensible system that helps us understand the distribution of climates over Earth.

Many classification schemes

The earliest known climatic classification scheme originated with the ancient Greeks in the first or second century B.C. Although the 'known world' was very small at that time, some Greek scholars were aware of the shape and approximate size of Earth. They knew that at the southern limit of their world, along the Nile River and the southern coast of the Mediterranean, the climate was much hotter and drier than on the islands and northern coast of that sea. At the other end of the world known to the Greeks, along the Danube River and the northern coast of Black Sea, things were much colder, especially in winter. So the Greeks spoke of three climatic zones: the Temperate Zone of the mid latitudes, in which they lived (Athens is at 38° N latitude), the Torrid Zone of the tropics to the south, and the Frigid Zone to the north. Because they knew that Earth is a sphere, they suggested that the Southern Hemisphere has similar Temperate and Frigid zones, making five in all.

For many centuries, this classification scheme was handed down from scholar to scholar. Gradually these five climatic zones were confused with, and eventually their climates ascribed to, the five astronomical zones of the Earth, bounded by the Tropics of Cancer and Capricorn and the Arctic and Antarctic circles. This revision put the equatorial rainy zone in with the hot arid region in the Torrid Zone, extended the Temperate Zone to include much of what the Greeks had called Frigid, and moved the Frigid Zone pole ward to the polar circles. This simplistic but unrealistic classification scheme persisted for more than a thousand years and was finally discarded only in the twentieth century.

We recognize five basic climate zones in the world: equatorial warm-wet, tropical hot dry, subtropical warm temperature, mid latitude cool temperate, and high-latitude cold. The equatorial and tropical zones are differentiated by rainfall amount and frequency. The two temperate zones differ primarily in whether summer or winter is the dominant season (in Atlanta, for instance, houses are designed to be cool in summer, whereas in Minneapolis keeping warm in winter is more important; thus summer is the dominant season in the former, and winter is the dominant season in the latter). The cold zone has hardly any summer – not enough to grow important crops. Many climatologists have refined this five-zone scheme by subdividing the zones into various types and subtypes, with most schemes relying primarily on natural vegetation as the principal climate indicator.

The Koppen System

Classification schemes having the greatest pedagogic value share three important attributes:

1. They are relatively simple to comprehend and to use.
2. They show some sort of orderly pattern over the world.

3. They give some indication of zone genesis.

The **Koppen system** meets these criteria reasonably well and is by far the most widely used climatic classification system. Wladimir Köppen (1846-1940) was a Russian-born German climatologist who was also an amateur botanist. The first version of his scheme appeared in 1918, and he continued to modify and refine it for the rest of his life, the last version being published in 1936. The Köppen system was a numerical basis of classification (either average temperatures or average amounts of precipitation), and zone boundaries are determined by vegetation patterns. Thus, the boundaries in the Köppen system represent climatic expressions of floristic limits.

The system uses as a database only the mean annual and monthly values of temperature and precipitation, combined and compared in a variety of ways. Consequently, the necessary statistics are commonly tabulated and easily acquired. Data for any location (called a 'station') on Earth can be used to determine the precise classification of that place, and the areal extent of any recognized climatic type can be determined and mapped. This means that the classification system is functional at both the specific and the general level.

Köppen defined four of his five major climatic zones by temperature characteristics, the fifth (the B zone) on the basis of moisture. He then subdivided each zone into types according to various temperature and precipitation relationships. The system's distinctive feature is a symbolic nomenclature to designate the various climatic types. This nomenclature consists of combination of letters, with each letter having a precisely defined meaning.

The Köppen system has been widely used, although often modified, and its terminology has been even more widely adopted. There are some deficiencies in the system, however, as in the any other climatic classification scheme. Köppen himself was unsatisfied with his last version and did not consider it a finished product. Thus, many geographers and climatologists have used the Koppen system as a springboard to devise systems of their own or to modify the 'final' Köppen classification.

The Modified Koppen System

The system of climatic classification used here is **modified Koppen** that encompasses the basic design of the Köppen system with a variety of minor modifications. Some of these modifications follow the lead of Glen Trewartha, late geographer/climatologist at the University of Wisconsin. No attempt is made to distinguish between pure Köppen and modified Köppen as our goal is to comprehend the general pattern of world climate, not to learn a specific system or to nitpick about boundaries.

In the modified system, we have Köppens five major climatic zones (A through E) plus a sixth zone (H) called highland climates. The first five of the six zones are broken down into various types and subtypes.

Climographs

Probably the most useful tool in a general study of world climatic classification is a simple graphic representation of monthly temperature and precipitation for specific weather stations. Such a graph is called a **climograph**. The customary climograph has 12 columns, one for each month, with a temperature scale on the left side and precipitation scale on the right. Average monthly temperatures are connected by a curved line in the upper portion of the diagram, and average monthly precipitation is represented by bars extending upward from the bottom.

The value of a climograph is twofold: (1) it displays precise details of important aspects of the climate of a specific place, and (2) it can be used to classify the climate of that place.

World distribution of major climatic types and subtypes

Tropical Humid Climates (Zone *A*)

The tropical humid climates occupy almost all the land area of Earth within some 15-20° of the equator, in both the Northern and Southern hemispheres. This globe-girdling belt of *A* climates is interrupted slightly here and there by mountains or small regions of aridity, but it dominates the equatorial regions and extends pole ward to beyond the 25° parallel in some windward coastal lowlands.

The *A* climates are noted not so much for warmth as for lack of coldness. These are the only truly winterless climates of the world. They are characterized by moderately high temperatures throughout the year, as is to be expected from their near-equatorial location. The sun is high in the sky every day of the year, and even the shortest days are not appreciably shorter than the longest ones. These are climates of perpetual warmth (although they do not experience the world's highest temperatures). The fundamental character of the *A* climates, then, is molded by their latitudinal location.

The second typifying characteristic of the tropical humid climates is of course the prevalence of moisture. Although not universally rainy, much of the A zone is among the wettest in the world. Warm, moist, unstable air masses frequent the oceans of these latitudes and the inter tropical convergence (ITC) zone is in the *A* zone for much of the year. Moreover, onshore winds and thermal convection are commonplace phenomena. Thus the *A* zone has not only abundant sources of moisture but also abundant mechanisms for uplift. High humidity and considerable rainfall are expectable results.

The tropical humid climates are classified into three types of the basis of annual rainfall. The tropical wet type (*Af* in the modified Koppen system) has abundant rainfall (above 2.5 inches) every month of the year. The tropical monsoonal type (*Am*) has a distinct dry season in which the monthly rainfall average is below 2.5 inches and a very rainy wet season in which the monthly average is much higher. The tropical savanna type (*Aw*) is characterized by a longer dry season (3-6 months) and a prominent but not extraordinary wet season.

Tropical Wet Climate (Af) – Climates of the *Af* type (*f* = ***feucht***, German for 'moist') characteristically occur in an east-west sprawl astride the equator, extending some 5-10° poleward on either side. In some eastern coast situations, they may extend as much as 25° away from the equator. The largest areas of *Af* climate occur in the upper Amazon basin of South America, the northern Zaire (Congo) basin of Africa, and the islands of the East Indies.

The single most descriptive word that can be applied to the tropical wet climate is **monotonous** because it is a season less climate, with endless repetition of the same weather day after day after day. Warmth prevails, with every month having an average temperature close to 27° C. the terms **summer** and **winter** do not apply because the annual temperature range (the difference between the average temperatures of the coolest and warmest months) is minuscule, typically only 1 or 1.5° C and only rarely over 4° C, by far the smallest annual temperature range of any climatic type. This season less condition in *Af* regions has given rise to the saying, 'Nigh is the winter of the tropics'.

The word **winter** and **summer** are used in discussing tropical climates, though, as in the 'winter monsoon' and the 'summer monsoon'. In this context, these adjectives mean that time of the year when places that are farther from the equator are indeed cold. Alternately, we refer to the 'high-Sun season' (summer) and the 'low-Sun season' (winter), where high and low are strictly relative terms.

Daily temperature variations are somewhat greater than annual ones, although still not impressive. This is one of the few climates in which the average daily temperature range exceeds the average annual temperature range. On a typical afternoon, the temperature rises to the high

30s° C, dropping to the middle or low 20s° C in the coolest period just before dawn. The temperature rarely extends much into the mid-30s° C, even on the hottest days, and equally unusual is much cooling at night.

Regardless of the thermometer reading, however, the weather feels warm in this climate because high humidity makes for high sensible temperatures, except perhaps where a sea breeze blows. Both absolute and relative humidity are notable, and rain can be expected just about every day – sometimes twice or three times a day. Rainfall is of the unstable, showery variety, usually coming from convective storms that yield heavy rain for a short time. A typical morning dawns bright and clear. Cumulus clouds build up in the forenoon and develop into cumulonimbus thunderheads, producing a furious convectional rainstorm in early afternoon. Then the clouds usually disperse, so that by late afternoon there is a partly cloudy sky and a glorious sunset. The clouds often recur at night to create a nocturnal thunderstorm, followed by dispersal once again. The next day dawns bright and clear, and the sequence repeats.

Each month receives several inches of rain, and the annual total normally is between 60 and 100 inches (150 and 250 centimeters), although in some locations it is considerably greater. Yearly rainfall in the *Af* climate is exceeded by that of only one other type of climate (tropical monsoonal).

Another characteristic of an *Af* climate is lack of wind. Except along coastlines, where sea breezes may be frequent or even persistent, the *Af* climate is poorly ventilated.

Why these climatic conditions occur where they do is relatively straightforward. The principal climatic control is latitude. A sun high in the sky throughout the year makes for relatively uniform insolation through the year, and so there is little opportunity for seasonal temperature variation. This extensive heating produces considerable thermal convection, which accounts for a portion of the raininess. More important, trade-wind convergence in the ITC zone leads to widespread uplift of warm, humid, unstable air. Also, persistent onshore winds along trade-wind (that is, east-facing) coasts provide a consistent source of moisture and add another mechanism for precipitation – orographic ascent. Indeed, the maximum poleward extent of *Af* climate is found along such trade-wind coasts, as in Central America and Madagascar.

Tropical Monsoonal Climate (Am) – The tropical monsoonal climate (*Am* type; *m* = monsoon) is most extensive on the windward (west-facing) coasts of southeastern Asia [primarily India, Myanmar (formerly Burma), and Thailand], but it also occurs in more restricted coastal regions of western Africa, northeastern South America, the Philippines, and some islands of the East Indies.

The distinctiveness of the *Am* climate is shown primarily in its rainfall pattern. During the high-Sun season, an enormous amount of rain falls in association with the summer monsoon. It is not unusual to have more than 75 cm of rain each of two or three months. The annual total for a typical *Am* station is between 250 and 500 cm. An extreme example is Cherrapunji (in the Khasi hills of Assam, in eastern India), which has an annual average of 1065 cm. Cherrapunji has been inundated with 210 cm in three days, with 930 cm in one month, and with a memorable 2647 cm in its record year.

During the low-Sun season, *Am* climates are dominated by offshore winds. The monsoon during this season produces little precipitation: from 1 to 4 months may record less than 6 cm per month, and 1 or 2 months may be rainless.

A lesser distinction of the *Am* climate is its annual temperature curve. Although the annual temperature range may be only slightly greater than in a tropical wet climate, the highest *Am* temperatures normally occur in late spring, prior to the onset of the summer monsoon. The heavy cloud cover of the wet monsoon period shields out some of the insolation, resulting in slightly lower temperatures in summer than in spring.

Apart from these monsoonal modifications, the climatic characteristics of *Af* and am locations are similar.

Tropical Savanna Climate (Aw) – The most extensive of the *A* climates, the tropical savanna (*Aw* type: *w* = winter dry) generally lies both to the north and to the south of the *Af* and *Am* areas. It is widespread in Africa to the east of the tropical wet region, extending poleward to about latitudes 30° S and 30° N. It occurs broadly in South America and southern Asia and to a lesser extent in northern Australia, Central America, and the Caribbean Islands.

The distinctive characteristic of the *Aw* climate is its clear-cut seasonal alternation of wet and dry periods. This characteristic is explained by the fact that *Aw* climates lie between unstable, converging air on their equatorial side and stable, anti-cyclonic air on their pole ward side. As the global wind and pressure systems shift latitudinally with the Sun over the course of a year, *Aw* regions experience extreme contrasts in weather. During the low-Sun season (winter), all wind and air-pressure systems shift toward the opposite hemisphere, so that savanna regions are dominated by subtropical high-pressure conditions of subsiding and diverging air, which produce clear skies.

In summer, the system shift in the opposite direction, bringing the ITC zone and its wet tropical weather patterns into the *Aw* region. The pole ward limits of Aw climate are approximately equivalent to the pole ward maximum migration of the ITC zone.

Annual rainfall totals in the tropical savanna climate are generally less than in the other two *A* climates; typical *Aw* annual averages are between 90 and 180 cm. The high-Sun season is conspicuously wet, with one to four months receiving at least 25 cm of rain. The low-Sun season, on the other hand, is distinctly a time of drought, sometimes with three or four rainless months. Although both tropical monsoonal and tropical savanna climates have dry winters, total annual rainfall is much greater in *Am* regions than in *Aw* regions.

Average annual temperatures in *Aw* regions are about the same as in *Af* regions but with a somewhat greater month-to-month variation in the former. Winter is a little cooler and summer a little hotter than in *Af* regions, giving an annual temperature range generally between 5 and 15° F. As in tropical monsoon climates, the hottest time of the year is likely to be in late 'spring', just before the onset of the summer rains

The tropical savanna climate can be thought of as having three seasons rather than two. The wet season is much like the wet season anywhere else in the tropics, with high sensible temperatures, muggy air, and frequent convective showers. The early part of the dry season is a period of clearing skies and slight cooling. The later part of the dry season is a time of fire: wildfires, fueled by the desiccated grass and shrubs, are common almost every year during this season.

Dry Climates (Zone *B*)

The dry climates cover about 30 percent of the land area of the world, more than any other climatic zone. Although at first glance their distribution pattern appears erratic and complex, it actually has a considerable degree of predictability.

The arid regions of the world (other than in the Arctic) generally are the result of lack of air uplift rather than lack of moisture in the air. Most desert areas do not lack precipitable moisture; rather, they lack mechanisms for the upward air motion necessary for cloud formation and precipitation. Vertical motion is suppressed by persistent stability, which is due mainly to the subsidence associated with subtropical high-pressure cells and secondarily to subsidence in the lee of mountain barriers. High-altitude temperature inversions often develop, further inhibiting the likelihood of updrafts and adiabatic cooling.

The largest expanses of dry areas are in subtropical latitudes, where thermodynamic subsidence is widespread, and in the western and central portions of continents because anticyclonic conditions are more prevalent there. (Desert conditions also occur over extensive ocean areas, and it is quite reasonable to refer to marine deserts). In the midlatitudes, particularly in central Asia, the *B* climates are found in areas that are separated from sources of surface moisture either by great distances or by topographic barriers.

The concept of dry climate is a complex one because it involves the balance between precipitation and evapotranspiration and depends not only on rainfall but also on temperature. The basic generalization is that higher temperature engenders greater potential evapotranspiration, and so hot regions can receive more precipitation than cool ones but still be drier.

The two main categories of *B* climates are desert and steppe. Desert are arid, generally receiving less than 25 cm of precipitation annually, and steppes are semiarid, typically receiving 25 to 63 cm of precipitation annually. Normally the deserts of the world are large core areas of aridity surrounded by a transitional fringe of steppe that is slightly less dry.

The two *B* climates are further classified into four types: subtropical desert (*BWh*), subtropical steppe (*BSh*), mid latitude desert (*BWk*), and mid latitude steppe (*BSk*). The focus will be on deserts because they represent the epitome of dry conditions – the arid extreme. Most of what is stated about deserts applies to steppes but in modified intensity.

Subtropical Desert Climate (BWh) – In both the Northern and Southern Hemispheres, subtropical deserts (*BWh* climate; *W* = ***Wuste***, German for 'desert', *h* = ***heiss***, German for 'hot') lie either in or very near the band of the subtropical high. Arid conditions reach to the western coasts of all continents in these latitudes. Subsidence is weaker on the western sides of the subtropical high, with the result that, except in North Africa, which is sheltered from oceanic influence by the Arabian peninsula, the aridity does not extend to the eastern coast of any continent in these latitudes.

The enormous expanse of *BWh* climate in North Africa (the Sahara) and southwestern Asia (the Arabian Desert) represents more desert area than is found in the rest of the world combined. Such an extensive development is explained by the year-round presence of anticyclonic conditions and the remoteness from any upwind source of moisture.

The adjacency of Asia makes Africa a continent without an eastern coast north of 10° N latitude, and so the *Bwh* climate extends from coast to coast in Africa. This climate is also very expansive in Australia (50 percent of the continental area) because the mountains that parallel the eastern coast of that continent are just high enough to prevent Pacific winds from penetrating; most of Australia is in the rain shadow of those eastern highlands.

Subtropical deserts have a much more restricted longitudinal extent in southern Africa, South America, and North America, but they are elongated latitudinally along the coast because of the presence of cold offshore waters, which chill the overlying air and inhibit precipitation. The greatest elongation occurs along the western side of South America, where the Atacama Desert is not only the 'longest' but also the desert of the dry lands. The Atacama is sandwiched in a double rain shadow position; moist winds from the east are kept out of this region by one of the world's great mountain ranges (the Andes), and Pacific air is thoroughly chilled and stabilized as it passes over the world's most prominent cold current (the Humboldt).

The distinctive climatic characteristic of deserts is lack of moisture, and three adjectives are particularly applicable to precipitation conditions in subtropical deserts: *scarce*, *unreliable*, *and intense*.

1. *Scarce* – Subtropical deserts are the most nearly rainless regions on Earth. According to unofficial records, some have experienced several consecutive years without a single drop of moisture falling from the sky. Most *BWh* regions, however, are not totally without precipitation. Annual totals of between 5 and 20 cm are characteristic, and some places receive as much as 38 cm.
2. *Unreliable* – An important climatic axiom is that the less the mean annual precipitation, the greater its variability. The very concept of an 'average' yearly rainfall in a *BWh* location is misleading because of year-to-year fluctuations. Yuma, Arizona, for example, has a long-term average rainfall of 6.5 cm, but within the last decade it has received as little as 1.3 cm and as much as 18 cm in a given year. In short, percentage deviation from the norm tends to be very high in ***BWh*** climates.
3. ***Intense*** – Most precipitation in these regions falls in vigorous convective showers that are localized and of short duration. Thus, the rare rains may bring brief floods to regions that have been bereft of surface moisture for months.

Temperature in *BWh* regions also have certain distinctive characteristics. The combination of low-latitude location and lack of cloudiness permits a great deal of insolation to reach the surface, and nocturnal terrestrial radiation is likewise appreciable. Summers are interminably long and blisteringly hot, with monthly averages in the middle to high 30s° C. Midwinter months have average temperatures in the 20s° C, which gives moderate annual temperature ranges of 15-25° F. Daily temperature ranges, on the other hand,, are sometimes astounding. Summer days are so hot that the nights do not have time to cool off significantly, but during the transition seasons of spring and fall, a 50° F fluctuation between the heat of the afternoon and the cool of the following dawn is not unusual.

Subtropical deserts experience considerable windiness during daylight, but the air is usually calm at night. The daytime winds are apparently related to rapid daytime heating and strong convective activity, which accelerates surface currents. The persistent winds are largely unimpeded by soil and vegetation, with the result that a great deal of dust and sand is frequently carried along.

Specialized and unusual temperature conditions prevail along western coasts in subtropical deserts. The cold waters offshore (the result of currents and upwellings) chill any air that moves across them. This cooling produces high relative humidity as well as frequent fog and low stratus clouds. Precipitation almost never results from this advective cooling, however, and the influence normally extends only a few miles inland. The immediate coastal region, however, is characterized by such abnormal desert conditions as relatively low summer temperatures (typical hot-month averages in the low 20s° C), continuously high relative humidity, and greatly reduced annual and daily temperature ranges.

Subtropical Steppe Climate (BSh) – The *BSh* climates (*S* = steppe; *h* = *heiss*, German for 'hot') characteristically surround the BWh climates (except on the western side), the former separating the latter from the more humid climates beyond. Temperature and precipitation conditions are not significantly unlike those just described for *BWh* regions except that the extremes are more muted in the steppes. Thus rainfall is somewhat greater and more reliable, and temperatures are slightly moderated. Moreover, the meager precipitation tends to have a seasonal concentration. On the equatorward side of the desert, rain occurs in the high-Sun season; on the poleward side, it is concentrated in the low-Sun season.

Midlatitude Desert Climate (BWk) – the *BWk* climates (*W* = *Wuste*, German for 'desert'; *k* = *kalt*, German for 'cold') occur primarily in the deep interiors of continents, where they are either far removed geographically or blocked from oceanic influence. The largest expanse of midlatitude dry climates, in central Asia, is (1) distant from any ocean and (2) protected by massive mountains on the south from any contact with the Indian summer monsoon. In North America, high mountains closely parallel the western coast and moist maritime air from the Gulf of Mexico affects the eastern half of the continent; as a result, the dry climates are displaced well to the west. The only other significant *BWk* region is in southern South America, where the desert reaches all the way to the eastern coast of Patagonia (southern Argentina). This anomalous situation has developed because the continent is so narrow in these latitudes that all of it lies in the rain shadow of the Andes to the west and the cool Falkland Current to the east.

Precipitation in midlatitude (*BWk*) deserts is much like of subtropical (*BWh*) deserts – meager and erratic. Differences lie in two aspects: seasonality and intensity. Most *BWk* regions receive the bulk of their precipitation in summer, when warming and instability are common. Winter is usually dominated by low temperatures and anticyclonic conditions. Although most *BWk* precipitation is of the unstable, showery variety, there are also some periods of general overcast and protracted drizzle.

The principal climatic differences between midlatitude and subtropical deserts are in temperature, especially winter temperature, with *BWk* regions having severely cold winters. The average cold-month temperature is normally below freezing, and some *BWk* stations have six months with below-freezing averages. This cold produces average annual temperatures that are much lower than in *BWh* regions and greatly increases the annual temperature range; variations exceeding 50° F between January and July average temperatures are not uncommon.

Midlatitude Steppe Climate (BSk) – As in the subtropics, midlatitude steppes (*BSk* climate: *S* = steppe; *k* = kalt, German for 'cold') generally occupy transitional positions between deserts and humid climates. Typically midlatitude steppes have more precipitation than midlatitude deserts and lesser temperature extremes.

In western North America, the steppe climate is much more extensive in area that is the desert, so that the desert-core-and-steppe-fringe model is not followed exactly. Semiarid conditions are broadly prevalent; only in the interior southwest of the United States is the climate sufficiently and to be classified as desert.

Mid Midlatitude Climates (Zone *C*)

The middle latitudes which extend approximately from 30° to 60° N and S, have the greatest weather variability over the short run of days or weeks. Seasonal contrasts are also marked in these latitudes, which lack both the constant heat of the tropics and the almost-continuous cold of the polar regions. The midlatitudes are a region of air mass contrast, with frequent alternating incursions of tropical and polar air producing more convergence than anywhere else except at the equator. This air-mass conflict creates a kaleidoscope of atmospheric disturbances and weather changes. The seasonal rhythm of temperature is usually more prominent than that of precipitation. Whereas in the tropics the seasons are characterized as wet and dry, in the midlatitudes they are clearly summer and winter.

The mild midlatitude climates occupy the equatorward margin of the middle latitudes, occasionally extending into the subtropics and being elongated poleward in some western coastal areas. They constitute a transition between warmer tropical climates and severe midlatitude climates.

Summers in the *C* climates are long and usually hot; winters are short and relatively mild. These zones, in contrast to the *A* climate zones, experience occasional winter frosts and therefore do not have a year-round growing season. Precipitation is highly variable in the *C* climates, with regard to both total amount and seasonal distribution. Year-round moisture deficiency is not characteristic, but there are sometimes pronounced seasonal moisture deficiencies.

The *C* climates are subdivided into three types, primarily on the basis of precipitation seasonality, and secondarily on the basis of summer temperatures: Mediterranean (*Csa*, *Csb*), humid subtropical (*Cfa*, *Cwa*), and marine west coast (*Cfb*, C*fc*).

Mediterranean Climate (Csa, Csb) – The two *Cs* climates (*s* = summer dry; *a* = summer hot; *b* = summer warm) are sometimes referred to as dry subtropical, but the more widely used designation is Mediterranean. The proper terminology is without capitalization because it is a generic term for a type of climate; Mediterranean with the capital M refers to a specific region around the Mediterranean Sea).

Cs climates are found on the western side of continents, centered at about latitudes 35° N and 35° S. With one exception, all Mediterranean regions are small, being restricted mostly to coastal areas either by interior mountains or by limited landmasses. These small regions are in central and southern California, central Chile, the southern tip of Africa, and the two southwestern 'corners' of Australia. The only extensive area of Mediterranean climate is around the borderlands of the Mediterranean Sea.

***Cs* climates have three distinctive characteristics:**

1. The modest annual precipitation falls in winter, summers being virtually rainless.
2. Winter temperatures are unusually mold for the midlatitudes, and summers vary from hot to warm.
3. Clear skies and abundant sunshine are typical, especially in summer.
4. Average annual precipitation is slight, ranging from about 38 cm on the equatorward margin to about 64 cm at the poleward margin. The midwinter rainfall is from 8 to 13 cm per month, and two or three midsummer months are totally dry. Only one other climatic type, marine west coast, has such a concentration of precipitation in winter.

Most Mediterranean climate is classified as *Csa*, which means that summers are hot, with midsummer monthly averages between 24 and 29° C and frequent maxima above 38° C. Average cold-month temperatures are about 10° C, with occasional minima below freezing.

Coastal Mediterranean areas have much milder summers than inland Mediterranean areas as a result of sea breezes; these coastal climates are classified as *Csb*. In the coastal areas, the average hot-month temperature is between 16 and 21° C. *Csb* winters are slightly milder than *Csa* winters, the former having cold-month averages of about 13° C. *Csb* regions also have higher humidity, frequent nocturnal fog, and occasional low stratus overcast.

The genesis of Mediterranean climates is clear cut. These regions are dominated in summer by dry, stable, subsiding air from the eastern portions of subtropical highs (STHs). In winter, the wind and pressure belts shift equatorward, and Mediterranean regions come under the influence of the westerlies, with their migratory extratropical cyclones and associated fronts. Almost all precipitation comes from these cyclonic storms, except for occasional tropical influences in California.

Humid Subtropical Climate (Cfa, Cwa) – Whereas Mediterranean climates are found on the western side of continents, the climate at the same latitude but on the eastern side is classified as humid subtropical (*Cfa* and *Cwa* types: *f* = *feucht*, German for 'moist'; *a* = summer hot; *w* = winter dry). This climate covers a more extensive area, both latitudinally and longitudinally. In some places, it reaches equatorward to almost 15° of latitude and extends poleward to about 40°. Its east-west extent is greatest in North America, Asia, and South America.

The humid subtropical climates differ from Mediterranean climates in several important respects. Summer temperatures in humid subtropical regions are generally warm to hot, with the highest monthly averages between 24 and 27° C. This is not dissimilar to the situation in *Cs* climates, but the humid subtropical regions are characterized by much higher humidity in summer and so sensible temperatures are higher. *Cfa* days tend to be hot and sultry, and often night brings little relief. Winter temperatures are mild on the average, but winter is punctured by cold waves that bring severe weather for a few days at a time. Minimum temperatures can be 10-20° F lower in the humid subtropics than in Mediterranean regions, which means that killing frosts occur much more frequently in the former, especially in North America and Asia. The importance of this fact can be shown by agricultural adjustments. For example, the northernmost limit of commercial citrus production in the eastern United States (Florida, a *Cfa* climate) is at about 29° N latitude, but in the western United States (California, a *Cs* climate) it is at 38° N latitude, 1000 km farther north.

The mild-summer characteristics of *Csb* coasts have no counterpart in the humid subtropical regions because the offshore waters in the east are warm rather than cool. Mediterranean climates are all adjacent to cool currents, whereas warm currents wash the humid subtropical coasts.

Annual precipitation is generally abundant and in some places copious, with a general decrease from east to west. Averages mostly are between 100 and 150 cm although some locations record as little as 75 cm and some receive up to 250 cm. Summer is usually the time of precipitation maxima, associated with onshore flow of maritime air and frequent convection. Winter is a time of diminished precipitation, but it is not really a dry season except in China, where monsoonal conditions dominate. The rain and occasional snow of winter are the result of extratropical cyclones passing through the region. In the North American and Asian coastal areas, a late summer-autumn bulge in the precipitation curve is due to rainfall from tropical cyclones.

Marine West Coast Climate (Cfb, Cfc) – As the name implies, marine west coast climates (Cfb and *Cfc* types: *f* = *feucht*, German for 'moist', *b* = summer warm; *c* = summer cool) are situated on the western side of continents, which is a windward location in the latitudes occupied by these climates, between, about 40° and 65°. Only in the Southern Hemisphere, where landmasses are small in these latitudes (New Zealand and southernmost South America, for example), does this oceanic climate extend across to eastern coasts.

The most expensive area of marine west coast climate is in western and central Europe, where the maritime influence can be carried some distance inland without hindrance from topographic barriers. The North American region is much more restricted interiorward by the presence of formidable mountain ranges that run perpendicular to the direction of onshore flow. These regions are influenced by the westerlies throughout the year, and the persistent onshore air movement ensures that the maritime influence permeates throughout. This air current creates an extraordinarily temperate climate considering the latitude: lack of extreme temperatures, consistently high humidity, much cloudiness, and a high proportion of days with some precipitation.

The oceanic influence ameliorates temperatures most of the time; this moderation is particularly noticeable when the daily and seasonal maxima and minima are considered. Isotherms tend to parallel the coastline rather than following their 'normal' east-west paths. Indeed, temperatures on a western coast in these latitudes decrease poleward less than half as fast as on an eastern coast. Average hot-month temperatures are generally between 16° and 21° C, with cold months averaging between 2° and 7° C There are occasionally very hot days (Seattle has recorded a temperature of 37° C, and Paris has reached 38° C), but prolonged heat waves are unknown. Similarly, very cold days occur upon occasion, but low temperatures rarely persist. Frosts are relatively infrequent, except in interior European locations; London, for example, at 52° N latitude, experiences freezing temperatures on fewer than half the nights in January. There is also an abnormally long growing season for the latitude; around Seattle, for instance, the growing season is a month longer than that around Atlanta, a city lying 14° of latitude further equator ward.

Marine west coast climates are among the wettest of the middle latitudes, although the total amount of *Cfb*/*Cfc* precipitation is not remarkable except in upland areas. Some localities receive as little as 50 cm, but a range of between 75 and 125 cm is more typical. Much higher totals are recorded one exposed slopes, reaching 250-375 cm in some places. Snow is uncommon in the lowlands, but higher, west-facing slopes receive some of the heaviest snowfalls in the world.

Perhaps more important than total precipitation to an understanding of the character of the marine west coast climate is precipitation frequency. Rainfall probability and reliability are high, but intensity is low. Drizzly frontal precipitation is characteristic. Humidity is high, with much cloudiness. Seattle, for example, receives only 43 percent of the total possible sunshine each year, in contrast to 70 percent in Los Angeles, and London has experienced as many as 72 consecutive days with rain. (Is it any wonder that the umbrella is that city's civic symbol?) Indeed, some places on the western coast of New Zealand's South Island have recorded 325 rainy days in a single year.

The Idealized Pattern of the Mild Climates

It should be clear by now that there is a predictable pattern in the location of climatic types, based primarily on latitude and on the general atmospheric and oceanic circulation.

Severe Midlatitude Climates (Zone *D*)

The severe midlatitude climates occur only in the Northern Hemisphere because the Southern Hemisphere has limited landmasses at the appropriate latitudes – between about 40° and 70°. This climatic zone extends broadly across North America (encompassing the northeastern United States and much of Canada and Alaska) and Eurasia (from eastern Europe through most of Russia to the Pacific Ocean).

'Continentality', by which is meant remoteness from oceans, is a keynote in the *D* climates. Landmasses are broader at these latitudes than anywhere else in the world. Even though these climates extend to the eastern coasts of the two continents, they experience little maritime influence because the general atmospheric circulation is westerly.

The most conspicuous result of continental dominance of *D* climates is broad annual temperature fluctuation. These climates have four clearly recognizable seasons: a long, cold winter, a relatively short summer that varies from warm to hot, and transition periods in spring and fall. Annual temperature ranges are very large, particularly at more northerly locations, where winters are most severe. Precipitation is moderate, although throughout the *D* climates, it exceeds the potential evapotranspiration. Summer is the time of precipitation maximum, but winter is by no means completely dry and snow cover lasts for many weeks or months.

The severe mid latitude climates are subdivided into two types on the basis of temperature. The humid continental type (which is further classified into subtypes *Dfa*, *Dfb*, *Dwa*, and *Dwb*) has long, warm summers. The subarctic type (having subtypes *Dfc*, *Dfd*, *Dwc*, and *Dwd*) is characterized by short summers and very cold winters.

Humid Continental Climate (Dfa, Dfb, Dwa, Dwb) – The latitudinal range of humid continental climate (*Dfa*, *Dfb*, *Dwa*, and *Dwb* types: *f* = feucht, German for 'moist', *a* = summer hot; *b* = summer warm; *w* = winter dry) in North America and Asia is between 35° and 55°. The

European region spreads from 35° to 60° in central Europe and tapers easterly through Russia and into Siberia.

This climatic type is dominated by the westerly wind belt throughout the year, which means that there are frequent weather changes associated with the passage of migratory pressure systems, especially in winter. Variability, then, both seasonal and daily, is a prominent characteristic.

Hot-month temperatures generally average in the mid-20s° C, and summers are as warm as those of the humid subtropical climate to the south, although summer is shorter. The average cold-month temperature is usually between 12 and 4° C, with from 1 to 5 months averaging below freezing. Winter temperatures decrease rapidly northward in the humid continental climates and the growing season diminishes from about 200 days on the southern margin to about 100 days on the northern edge.

Despite their name, precipitation is not copious in humid continental climates. Annual totals average between 50 and 100 cm, with the highest values on the coast and a general decrease interior ward. There is also a decrease from south to north. Both these trends reflect increasing distance from warm moist air masses. Summer is distinctly the wetter time of the year, but winter is not totally dry, and in coastal areas the seasonal variation is muted. Summer rain is mostly convective or monsoonal in origin. Winter precipitation is associated with extratropical cyclones, and much of it falls as snow. During a typical winter, snow covers the ground for only 2 or 3 weeks in the southern part of these regions, but for as long as 8 months in the northern portions.

Day-to-day variability and dramatic changes are prominent features of the weather pattern. These are regions of cold waves, heat waves, blizzards, thunderstorms, tornadoes, and other dynamic atmospheric phenomena.

Subarctic Climate (Dfc, Dfd, Dwc, Dwd) – The subarctic climate (*Dfc*, *Dfd*, *Dwc*, *Dwd* types: *f* = feucht, German for 'moist'; *c* = summer cool; *d* = winter very cold; *w* = winter dry) occupies the higher mid latitudes, generally between 50° and 70°. This climate occurs as two vast, uninterrupted expanses across the broad northern landmasses: from western Alaska across Canada to Newfoundland and across Eurasia from Scandinavia to easternmost Siberia. The name **boreal** (which means 'northern' and comes from Boreas, mythological Greek god of the north wind) is sometimes applied to this climatic type in Canada; in Eurasia it is often called **taiga**, after the Russian name for the forest in the region where this climate occurs.

The key word in the subarctic climate is winter, which is long, and bitterly cold. In most places, ice begins to form on the lakes in September or October and does not thaw until May or later. For six or seven months average temperature is below freezing, and the coldest months have averages below -38° C. The world's coldest temperatures, apart from the Antarctic and Greenland ice caps, are found in the subarctic climate; the records are -68° C in Siberia and -62° C in Alaska.

Summer warms up remarkably despite its short duration. Although the intensity of the sunlight is low (because of the small angle of incidence), summer days are very long and nights are too short to permit much radiational cooling. Average hot-month temperatures are typically in the high mid-teens or low 20s° C, but occasional frosts may occur in any month. Annual temperature ranges in this climate are the largest in the world. Variations from average hot-month to average cool-month temperatures frequently exceed 45° C and in some places are more than 50° C. The absolute annual temperature variation (fluctuation from the very coldest to the very hottest ever recorded) sometimes reaches unbelievable magnitude; the world record is 188° F (-90 to +98°) in Verkhotyansk, Siberia.

Spring and fall are brief transition seasons that slip by rapidly, usually in April/May and September/October. Summer is short, and winter is dominant.

Precipitation is usually meager in the subarctic climates. Annual totals range from only 13 cm to about 50 cm, with the higher values occurring in coastal areas. The low temperatures allow for little moisture in the air, and anticyclonic conditions predominate. Despite these sparse totals, the evaporation rate is low and the soil is frozen for much of the year, so that moisture is adequate to support a forest. Summer is the wet season, and most precipitation comes from scattered convective showers. Winter experiences only light snowfalls (except near the coasts), which may accumulate to depths of 60 to 90 cm. The snow that falls in October is likely to be still on the ground in May because little melts over the winter. Thus a continuous thin snow cover exists for many months despite the sparseness of actual snowfall.

Polar Climate (Zone *E*)

Being farthest from the equator, the polar climates are the most remote from the heat of the Sun and receive inadequate insolation for any significant warming. By definition, no month has an average temperature of more than 10° C in a polar climate. If the wet tropics represent conditions of monotonous heat, the polar climates are known for their enduring cold.

They have the coldest summers and the lowest annual and absolute temperatures in the world. They are also extraordinarily dry, but evaporation is so minuscule that the group as a whole is classified as humid.

The two types of polar climates are distinguished by summer temperature. The tundra climate (*ET*) has at least one month with an average temperature exceeding the freezing point. The ice cap climate (*EF*) does not.

Tundra Climate (ET) – The name **tundra** originally referred to the low, ground-hugging vegetation of high latitude and high-altitude regions, but the term has been adopted to refer to the climate of the high-latitude regions as well. The generally accepted equatorward edge of the tundra climate (*ET* climate: *T*, of course, for tundra) is the 10° C isotherm for the average temperature of the warmest month. This same isotherm corresponds approximately with the poleward limit of trees, so that the boundary between *D* and *E* climates (in other words, the equatorward boundary of the tundra climate) is the 'treeline'.

At the poleward margin, the *ET* climate is bounded by the isotherm of 0° C for the warmest month, which approximately coincides with the extreme limit for growth of any plant cover. More than for any other climatic type, the delimitation of the tundra climate demonstrates Koppen's contention that climate is best delimited in terms of plant communities.

Long, cold, dark winters and brief, cool summers characterize the tundra. Only one to four months experience average temperatures above freezing, and the average hot-month temperature is in between 4 and 10° C. Freezing temperatures can occur at any time, and frosts are likely every night except in mid-summer. Although an *ET* winter is bitterly cold, it is not as severe as in the subarctic climate farther south because the *ET* climate is less continental. Coastal stations in the tundra often have cold-month average temperatures of only about -18° C, whereas an inland *ET* location is more likely to average -32° or -35° C. Annual temperature ranges are fairly large, commonly between 40 and 60° F. Daily temperature ranges are small because the Sun is above the horizon for most of the time in summer and below the horizon for most of the time in winter; thus nocturnal cooling is limited in summer, and daytime warming is almost nonexistent in winter.

Moisture availability is very restricted in *ET* regions despite the proximity of an ocean. The air is simply too cold to hold much moisture, and so the absolute humidity is almost always very low. Moreover, anticyclonic conditions are common, with little air uplift to air condensation.

Annual total precipitation is generally less than 25 cm but is somewhat greater in eastern Arctic Canada. Generally, more precipitation falls in the warm season than in winter, although the total amount in any month is small, and the month-to-month variation is minor. Winter snow is often dry and granular; it appears to be more than it actually is because there is no melting and because winds swirl it horizontally even when no snow is falling. Radiation fogs are fairly common throughout *ET* regions, and sea fogs are sometimes prevalent for days along the coast.

Ice Cap Climate (EF) – The most severe of Earth's climates is restricted to Greenland (all but the coastal fringe) and most of Antarctica, the combined extent of these two regions amounting to more than 9 percent of the world's land area. The *EF* climate is one of perpetual frost (*F* = frost) where vegetation cannot grow, and the landscape consists of a permanent cover of ice and snow.

The extraordinary severity of *EF* temperatures is emphasized by the fact that both Antarctica and Greenland are ice plateaus, so that relatively high altitude is added to high latitude as a thermal factor. All months have average temperatures below freezing, and in the most extreme locations the average temperature of the warmest month is below 0° F (18° C). Cold-month temperatures average between -34 and -51° C, and extremes well below -73° C have been recorded at interior Antarctic weather stations.

The air is chilled so intensely from the underlying ice that strong surface temperature inversions prevail most of the time. Heavy, cold air often flows downslope as a vigorous katabatic wind. A characteristic feature of the ice cap climate, particularly in Antarctica, is strong winds and blowing snow.

Precipitation is very limited. These regions are polar deserts; most places receive less than 13 cm of moisture annually. The air is too dry and too stable, with too little likelihood of uplift, to permit much precipitation. Evaporation, of course, is minimal, and so moisture may be added to the ice.

Highland Climate (Zone *H*)

Climatic conditions in mountainous areas have almost infinite variations from place to place, and many of the differences extend over very limited horizontal distances. Köppen did not recognize highland climate as a separate zone, but most of the researchers who have modified his system have added such a category. Highland climates are delimited to identify relatively high uplands (mountains and plateaus) having complex local climate variation in small areas.

The climate of any highland location is usually, closely related to that of the adjacent lowland, particularly with regard to seasonality of precipitation. Some aspects of highland climate, however, differ significantly from that of the surrounding lowlands.

With highland climates, latitude becomes less important as a climatic control than altitude and exposure. The critical climatic controls on a mountain slope are usually relative elevation and angle of exposure to Sun and wind.

Altitude variations influence all four elements of weather and climate. A vertical temperature gradient of about 2.3° C per 300 m generally prevails. Atmospheric pressure also decreases rapidly with increased elevation. Air movement is less predictable in highland areas, but it tends to be brisk and abrupt, with many local wind systems. Precipitation is characteristically heavier in highlands than in surrounding lowlands, so that the mountains usually stand out as moist islands on a rainfall map.

Altitude is more significant than latitude in determining climate in highland areas, so that a pattern of vertical zonation is usually present. The steep vertical gradients of climatic change are expressed as horizontal bands along the slopes. An increase of a few hundred feet in elevation may be equivalent to a journey of several hundred miles poleward insofar as temperature and related environmental characteristics are concerned. Vertical zonation is particularly prominent in tropical highlands.

Exposure – whether a slope, peak, or valley faces windward or leeward – has a profound influence on climate. Ascending air on a windward face brings a strong likelihood of heavy precipitation, whereas a leeward location is sheltered from moisture or has predominantly downslope wind movement with limited opportunity for precipitation. The angle of exposure to sunlight is also a significant factor in determining climate, especially outside the tropics. Slopes that face equatorward receive direct sunlight, which makes them warm and dry (through more rapid evapotranspiration); adjacent slopes facing poleward may be much cooler and moister simply because of a smaller angle of solar incidence and more shading. Similarly, west-facing slopes receive direct sunlight in the hot afternoon, but east-facing slopes are sunlit during the cooler morning hours. ***Changeability*** is perhaps the single most conspicuous characteristic of highland climate. The thin, dry air permits rapid influx of insolation by day and rapid loss of radiant energy at night, and so daily temperature ranges are very large, with frequent and rapid oscillation between freeze and thaw.

Daytime upslope winds and convection cause rapid cloud development and abrupt storminess. Travelers in highland areas are well advised to be prepared for sudden changes from hot to cold, from wet to dry, from clear to cloudy, from quiet to windy, and vice versa.

The Thornthwaite Classification

In the paper published in 1931, C.W. Thornthwaite proposed a climatic classification that is a marked departure from the previous systems. Unlike most classifications, he based his system on the concepts of moisture and thermal efficiency. However, he always felt the problem of lack of evaporation data. The scholar thus produced a precipitation-evaporation index that could be determined empirically from available data. Using this index, Thorthwaite devised **humidity provinces**. These formed the first order division of his classification scheme. It differs from Kop pen's system in that boundaries between provinces are not related any practical vegetation or soil criteria. Instead they are based on regular arithmetic intervals of values. This has always been considered a major contribution to the process of climate classification.

Of more significance at present is, however, 1948 classification which is radical departure from 31 scheme because it makes use of the important concept of **evapotranspiration**. The earlier system had been concerned with loss of moisture through evaporation, whereas, the new approach considers loss through the combined processes of evaporation and transpiration. Plants are considered physical mechanism by which moisture is returned to the air. The combined loss is termed evapotranspiration. When the amount of moisture available is non limiting, the term potential evapotranspiration is used. The two major aspects of the system are the used of precipitation effectiveness and temperature efficiency. Precipitation effective was designed as an indicator of net moisture supply, taking into account both the actual amount of precipitation and the estimated consumption of moisture by evaporation. The precipitation effectiveness is determined by calculating the ratio of the precipitation to evaporation (P/E) ratio for each month of the year and summing them to form the precipitation effectiveness (P-E) index. Temperature efficiency (TE) in the classification is used as an indicator of the energy or heat supply relative to evaporation rates. The T-E index is calculated in the same manner as P-E index using temperature and evaporation data. On the basis of precipitation effectiveness under, nine moisture provinces were established at a doubling of P-E indeed.

Nine divisions based on Moisture Efficiency

Nine Divisions based on Temperature Efficiency

Symbol	Type	MI	Symbol	Type	TE (cm)
A	Per Humid	100	A'	Megatherm	114.0
B4	Humid	80-100	B'4	Mesotherm	114.0
B3	Humid	60-80	B'3	Mesotherm	99.7
B2	Humid	40-60	B'2	Mesotherm	85.5
B1	Humid	20-40	B'1	Mesotherm	71.2
C2	Moist sub Humid	0-20	C'2	Microtherm	57.0
C1	Dry Sub Humid	-20-0	C'1	Microtherm	42.7
D	Semi Arid	-40- -20	D'	Tundra	28.5
E	Arid	-60- -40	E'	Frosted	14.2

On a comparable scale of the temperature efficiency index, nine major temperature provinces are recognized. As in case of P-E index, each progressively warmer province is bounded by an index double that of the preceding province. Thornthwaite used many of the same alphabetic symbol that Kop pen used in his classification. To the two indices of moisture and temperature are added a letter designation for rainfall distribution through the year. The initial classification yields 32 different climatic types.

Subdivisions based on seasonality of Precipitation

Moist climates (ABC2)		Aridity Index*
r	little or no water deficiency	0-16.7
s	moderate summer deficiency	16-7 – 33.3
w	moderate winter deficiency	16.7 – 33.3
s2	large summer deficiency	33.3+
w2	large winter deficiency	33.3+
Dry climates (C1, D, E)		**Humidity Index***
d	little or no water surplus	0 - 10
s	moderate winter surplus	10 – 20
w	moderate summer surplus	10 – 20
s2	large winter surplus	20+
w2	large summer surplus	20+

Trewartha's classification scheme

Glenn T. Trewartha, eminent American climatologist presented several modifications to Koppen's classification scheme. In his book '**An introduction to climate',** he presented the scheme radically different from that on Koppen's. The classification scheme devised by him represents a compromise between purely empirical and genetic methods. He highlighted the objective of simplifying the classification scheme. He made use of the two most important and basic weather elements - temperature and precipitation. Also like Koppen, his scheme is more identified to be empirical type.

He classified world climates into 6 great climatic groups, out if which **Tropical** (A type), **subtropical**

(C type), **Temperate** (D type), **Boreal** (E type), and **Polar** (F type) are based on temperature whereas **Dry** (B type) was the only type based on precipitation.

'A' type of climate - Mostly tropical humid, this climate type extends in equatorial and tropical latitudes. There is no occurrence of frost in any part of the year. It incorporates sub categories of **Ar**-tropical wet climate or equatorial climate – this climate type marks absence off very less extensive dry season applicable to equatorial belt where strong convective movement marks the prevalence of wetter conditions through out the year. Along the eastern or wind ward margins of the continent, the latitudinal extent may increase to 25° N/S. where it relates to tropical rain forests. **Aw** – tropical wet dry climate, relates to the tropical monsoonal and savannah type of regions. During winter season, this climatic regions are dominated by dry offshore trades due to the prevailing subtropical high. On the contrary during summers, equatorial westerlies and ITCZ control the weather conditions. The duration of dry season is longer than that of wet season. Monsoonal deciduous vegetation with tree studded grassland forms the basis of the nomenclature.

'B' type of climate - The boundaries of this type of climate are fixed by precipitation values. The characteristics of this climate group are that evaporation is more than precipitation. Extreme seasonal temperatures cause large annual ranges of temperature. Annual average precipitations in these climates are always meagre and highly variable. On the basis of annual average precipitation, the sub categories outlined includes - **Bw** is the arid climate and **Bs** is the semi arid or steppe type. The arid-semi arid boundary is set at ½ the annual precipitation separating dry regions for humid; e.g. if the humid dry boundary happens to be 40 cms, then the steppe-desert boundary will be 20 cms.

It is temperature criteria that make the sub-divisions of the climate - Bwh/Bwk and Bsh/Bsk. The isotherm of 8 months with a temperature of 10° C or above is taken to be the boundary between hot and kalt. Bwh and Bwk climates are constantly dry and are under the influence of subtropical high pressure and dry trades. Bsh climate is characterized by short moist season. Both summers and winter in this climate is influenced by high pressure and dry trades. Bsk climate is colder at higher latitudinal climate.

'C' type of climate - The isotherm of 18°C for the coolest month forms the equator ward boundary of this climate. Occasional frosts occur in the continental parts, but the marine locations are frostless. **Cfw** is the subtropical humid climate mostly found in the eastern margins of the continents. This climate represents wet conditions throughout the year. During summers lying at the western end of sub-tropical anticyclone, it experiences wetter conditions than winters when temperate cyclone yields precipitation. **Cs** is the dry subtropical characterised by moderate to scanty amount of precipitation. Frontal rains are experienced during winters and, summers are nearly dry. Locationally, this climate type presents transition zone between tropical dry and marine wet climates.

'D' type of climate- is known as micro thermal climate type. Its pole ward and equator ward boundaries are formed by average temperatures of 10°C for 4 to 8 months respectively. **Do** is temperate marine type of climate, the winters are mild; it is wet marine climate, typical to temperate west margins. **Dc** is the temperate continental type of climate. During winters, ground is covered with snow. Precipitation occurs in all the months of year with maximum concentration during summers.

'E' type of climate- is boreal climate and is supercontinents in temperature features. The summers are short and cool. Annual temperature ranges are usually large. Even though the climate is referred to be humid, annual precipitation is meagre. This climate group is also called sub arctic type of climate.

'F' polar type of climate has two subdivides. **Ft** is the tundra type and the equator ward boundary is determined by 10°C summer isotherm. It is actually subpolar climate. **Fi** is the ice cap climate confined to Greenland and Antarctica. Since the air close to the icecaps is intensely chilled, surface inversions are the common features of this climate.