# CLIMATIC CLASSIFICATION OF KOPPEN

**Advanced Climatology**
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**Introduction: -**

Climate is an average weather condition at a specific place over a long period of time (30-35 years and more), including absolute extremes of temperature, precipitation etc. Factors such as latitude, altitude, prevailing winds, ocean currents, maritime and continental situations exercise direct influence in determining the climate. The classification of climates of the world is done in order to understand how the different climatic elements form combination in different parts of the world. Although, there are several ways in which the climates of the world can be classified, the lesson is devoted to discuss the Koppen's classification of world climates which is most widely used. In this lesson we will study the measurements, design and combinations of major, main and sub groups of the world climates as developed by Koppen.

**Historical Developments in Koppen's Climate Classification**

Wladimir Koppen (1846-1940), a Russian born German climatologist and botanist attempted he classification of world climates. Climate classification was first published as 'thermal zones of the earth' in 1884 in Russian language. Scholars E. Volken and S. Bronnimann translated the work in German. With several modifications, Koppen improved his classification later on, in 1918 and 1936. The details of climatic classification were published in 'Handbuch der

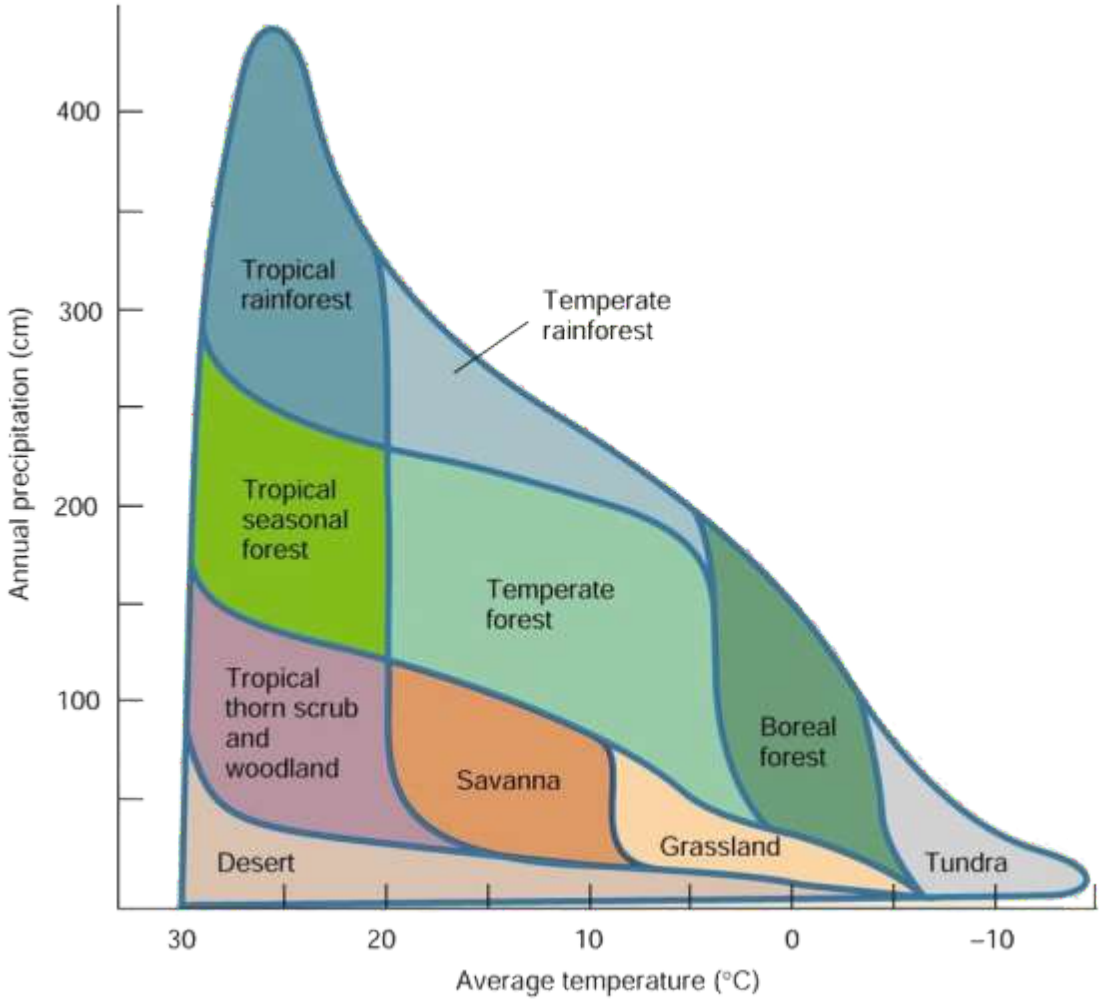
Kilmatologoie'. Later on, German climatologist Rudolf Geiger (1954, 1961) collaborated with Koppen on changes to the scheme of classification. Thus, the classification of world climates is also known as the Koppen- Geiger's climate classification, as the two scholar's co-authored the work, and was widely adopted. Classification is based on the empirical study of the distribution of vegetation across the world.

**Vegetation as an Index of Temperature and Precipitation**

Koppen assumed that the vegetation is the most representative feature of precipitation and temperature. For example, tropical evergreen vegetation represents high precipitation and high temperature. Similarly, alpine vegetation represents high precipitation and low to very low temperature. It is commonly found both in higher latitudes as well as in higher altitudes close to snowline. Deciduous vegetation represents high temperature and moderate precipitation in one season followed by a dry season with moderate to low temperature. Arid climates are marked with moisture deficiencies. While hot deserts have high temperatures and low precipitation, cold deserts have low temperature and low precipitation. The arid climates have xerophyte vegetation.

Vegetation as an index of temperature and precipitation is also used to represent major ecosystems and biomes on the earth. The fact is plotted on a graph (Figure 1) to represent temperature along X axis. It is to be noted that annual average temperature temperature is to be plotted in a manner that it begins with high values of temperature above $30^0$C and ending with very low temperatures up to less than $10^0$C. Whereas annual average precipitation is plotted along Y axis and it keeps on increasing in a manner that it begins with zero and ends up to more than 400 cm.

**Figure 1: Temperature and Precipitation vs Vegetation**




Vegetation response to precipitation and temperature anomalies, particularly during droughts, is of great importance in semi-arid regions, because ecosystem and hydrologic processes depend on vegetation conditions. One of the important indicators of vegetation presence, abundance and vigor is the NDVI (Normalized Difference Vegetation Index). Since NDVI makes use of bio physical interactions where green plant canopies absorb much of the radiation, it seems to be well suited for studies concerned with photosynthetic capacity of vegetation cover. Studies conducted by Prasad, et al. (2008) and Canon Julio et. al. (2011) have indicated that vegetation response to precipitation and temperature anomalies are of great importance.

**Delineation of climatic regions**

For the delineation of climatic regions, Koppen considered the following:

- mean monthly temperature,
- mean annual temperature,
- mean monthly precipitation, and
- mean annual precipitation.

Therefore, Koppen's classification is based on the measurement of temperature and precipitation. Viewing its utility and applicability, FAO published a Global climate map using Koppen classification in 1999.

**Design of climatic classification**

Koppen's scheme of climatic classification begins with English capital alphabet denoting prevalent vegetation type. It is followed by small English alphabets in second and third place with exception to B and E group of climates. In B and E groups, both letters first and second letters are in capital alphabets. A brief discussion on capital and small letters used in the design of classification is made below.

**Capital letters:** In all, Koppen has used ten capital alphabets in his scheme of climate classification. An expression of first five capital letters that denote vegetation zones is given below.

A - Mega -thermal,
B - Xerophytes,
C - Meso - thermal
D - Micro -thermal,
E - Heckisto - thermal

Next five capital alphabets denote distinct *regional characteristics.* They are as follows:

F - Permanently Frozen;
M - Marine;
S - Semi Arid/steppe;
T - Tundra;

W - Waste (desert)

**Small letters:** Similar to capital alphabets, Koppen has also used ten small alphabets (letters) to denote area specific characteristics that supplement the major climate group. The first six small letters signify *seasonal characteristics of precipitation.* They are as follows:

**Characteristics of seasonal precipitation**

| | | | |
|---|---|---|---|
| (i) | Feucht (precipitation round the year) | = | f |
| (ii) | Hot | = | h |
| (iii) | Cold | = | k |
| (iv) | Monsoon | = | m |
| (v) | Summer dry | = | s |
| (vi) | Winter dry | = | w |

**The level of heat:** The next four small letters denote the level of heat:

| | | | |
|---|---|---|---|
| (i) | Warmest month summer temperature > $22^0$ C | = | a |
| (ii) | Warmest month summer temperature < $22^0$ C | = | b |
| (iii) | Temperature constantly > $10^0$ C | = | c |
| (iv) | Average temperature of coldest month < $-38^0$ C | = | d |

Besides arrangements of alphabets, Koppen has also used following terms to denote:

POTET =Potential evapotranspiration and PRECIP =Precipitation

Thus, the climatic classification of Koppen is a self- explanatory. It is convenient to place values as per the order of alphabets.

**Table-1: Symbols used in the classification of world climates by Koppen-Geiger**

| Major Classification & symbols | Main Classification & symbols | Sub Classification and symbols |
|---|---|---|
| Group A: Tropical/mega- thermal climates. Vegetation is tropical rain forests. | Af.= Tropical Rainforest<br>Am= Tropical Monson<br>Aw=Tropical Savanna | |
| Group B**:** Dry (arid and semi-arid) climates Xerophytes type of vegetation | BW:<br>B =Arid, W= waste<br>h = hot**,** k= cold<br>BS**:**<br>B= Arid,<br>S=Semiarid/Steppe | BWh=Hot desert<br>BWk= Cold desert<br><br>BSh= Semiarid hot<br>BSk=Semiarid cold |
| Group C**:** temperate / Meso - thermal climates Plants adapted to moderate heat and moisture | Cf= Year round precipitation,<br>a= warmest month temperature >$22^0$ C<br>b= warmest month temperature <$22^0$ C<br>c= 1 to 3 month's temperature >$10^0$ C | Cfa<br><br>Cfb<br><br>Cfc |

| | | |
|---|---|---|
| | Cw= winter dry<br><br>Cs= summer dry | Cwa<br>Cwb<br>Cwc<br>Csa<br>Csb |
| Group D: Continental / micro- thermal climates Evergreen deciduous forests and steppes are the natural vegetation. | Df=Humid continental precipitation throughout the year.<br><br>Dw= Humid continental-winter dry.<br>Dwd= Coldest month temperature<-38$^0$ C | Dfa<br>Dfb<br>Dfc<br>Dwa<br>Dwb<br>Dwc<br>Dwd |
| Group E**:** Polar Climates/ Hekisto-thermal type of vegetation Mosses, lichens etc. are the natural vegetation. | This type of climate has an average temperature <10$^0$C | ET= Mild tundra climate with average temperatures between 0$^0$ C and 10$^0$ C.<br>ETf= Cold Tundra climate; at least one month with an average temperature > 0$^0$ C.<br>EF= Ice caps climate: average temperature in all the months <0$^0$ C. |

**Measurements in Koppen's climatic classification:**Koppen's classification of world climates is based on two types of measurements viz. primary and secondary. A brief account of these measurements is given below.

**a) Primary measurements:** The primary measurements are concerned with broad parameters that distinguish one major climate group with another. These measurements are related to the critical values of temperature and precipitation conditions. The details of critical values have been given against major climate groups in Table-2.

**Table-2: Primary Measurements**

| | |
|---|---|
| A- Tropical | $T_{cold} \geq 18^0$ C |
| B- Dry | $MAP < 10 \times P_{threshold}$ |
| C- Meso thermal | $T_{hot} \geq 10^0$ C &$0^0$ C >$T_{cold} < 18^0$ C |
| D- Micro- Thermal | $T_{hot} \geq 10^0$ C & $T_{cold} \geq 0^0$ C |
| E- Polar | $T_{hot} < 10^0$ C |
| H- High Land | Elevation≥2300 meters |

Where: $T_{cold}$ stands for temperature in coldest month, $T_{hot}$ temperature in hottest month, MAP mean annual precipitation and $P_{Threshold}$ for precipitation threshold. $P_{threshold}$ = precipitation threshold, which varies according to the following rules: if 70% of MAP occurs in winter, then $P_{threshold} = 2 \times MAT$, if 70% of MAP occurs in summer, then $P_{threshold} = 2 \times MAT + 28$, otherwise $P_{threshold}$ $2 \times MAT + 14$

**b) Secondary measurements**: Similar to primary measurements, Koppen's classification of world climates has also used measurements for secondary or sub group of climates. They have been so designed to distinguish one sub group with another. It also involves some elementary calculations to arrive at the critical values. The details have been given in table -3.

**Table-3: Secondary measurements**

| | | | |
|---|---|---|---|
| Af | $P_{dry} \geq 60mm$ | w | $P_{wdry} < P_{swet} \div 10$ |
| Am | Not (Af) $P_{dry} \geq 100mm - MAP \div 25$ | F | Not ( Cs Or Cw) |
| Aw | Not (Af) $P_{wdry} < 100mm - MAP \div 25$ | A | $T_{hot} \geq 18^0$ C |
| As | Not (Af) $P_{sdry} < 100mm - MAP \div 25$ | b | Not (a) $T_{mon} 10 \geq 4$ |
| W | $MAP < 5 \times P_{threshold}$ | C | Not (a or b or d) |
| S | $MAP \geq 5 \times P_{threshold}$ | d | Not (a or b) & $T_{cold} < -38^0$ C |
| h | $MAT \geq 18^0$ C | T | $T_{hot} > 0^0$ C |
| K | $MAT < 10^0$ C | F | $T_{hot} \leq 0^0$ C |
| s | $P_{sdry} < 40mm$ & $P_{sdry} < P_{wwet} \div 3$ | T | $T_{hot} > 0^0$ C (Highland Case) |

Where $P_{dry}$ (precipitation in driest month), $P_{wdry}$ (precipitation in winter driest month), $P_{sdry}$ (precipitation in driest summer month) $P_{swet}$ (precipitation in summer wettest month), $P_{wwet}$ (precipitation in wettest month winter) MAT (mean annual temperature), MAP (mean annual Precipitation), $T_{hot}$ (Temperature in hottest month), Tmon (monthly temperature), Tcold (temperature in coldest month).

**Combinations of alphabets as expressions of climates:** Based on the arrangements of capital as well as small alphabets, Koppen has developed combinations to explain the world climates. Combinations explaining climate types have been developed in three sets viz. two, three and four alphabet combinations. A brief account of each combination group is presented below.

**a) The two alphabet combination:** The combination has been used in two distinct ways. The first way is represented when both the alphabets, in the combination, are capital letters. For example, 'ET' and 'EF' which denote "Polar Tundra' and 'Polar Frost' climates respectively. The second way of two alphabet combination is that first, in sequence, is a capital letter while second one is a small letter. As usual, the first capital alphabet denotes the major vegetation group and the second small alphabet denotes seasonal characteristics of precipitation. For example: Af (tropical rainforest), As (tropical with summer dry season e.g. in eastern part of Tamil Nadu India) and Aw (tropical climate with winter dry season e.g large part of peninsular India south of Tropic of Cancer) represent a two alphabet combination.

**b) The three alphabet combination:** This combination is being used to denote vegetation, precipitation, thermal and locational characteristics of a climate type. It is mostly used to denote 'A' 'C' and 'D' type of climates. For example: 'Amw' (tropical monsoon with short dry winter) 'Cwg' (Meso thermal with dry winter in Gangetic plains of India), and 'Dfc' (micro thermal humid with short summer found in eastern Himalayan region of India).

**c) The four alphabet combination:** These combinations commonly used to denote 'B' group (arid and semiarid) of climates only. The first two alphabets are capital letters while remaining two are small letters. The first capital alphabet denotes 'B' which is common to all sub climates, while the second capital alphabet could be either 'W' (waste/ desert) or 'S' (semiarid/steppe). The third alphabet in this combination is a small letter and denotes the setting in which arid or semi-arid region lies. It could be either in a hot setting ('h') or in a cold setting ('k'). The fourth alphabet in the combination is again a small letter and denotes seasonal situation of moisture deficiency. The climatic sub group may experience moisture deficiency either a summer season (s) or a winter season (w). For example, in case of arid/ desert climates, the subgroup may be either BWhw (hot desert winter dry e.g. Thar desert in India) or BWks (cold desert summer dry) whereas in case of semiarid climates, the subgroup may be either BShw (semi- arid in hot setting- winter dry) or BSks (semi-arid in cold setting- summer dry).

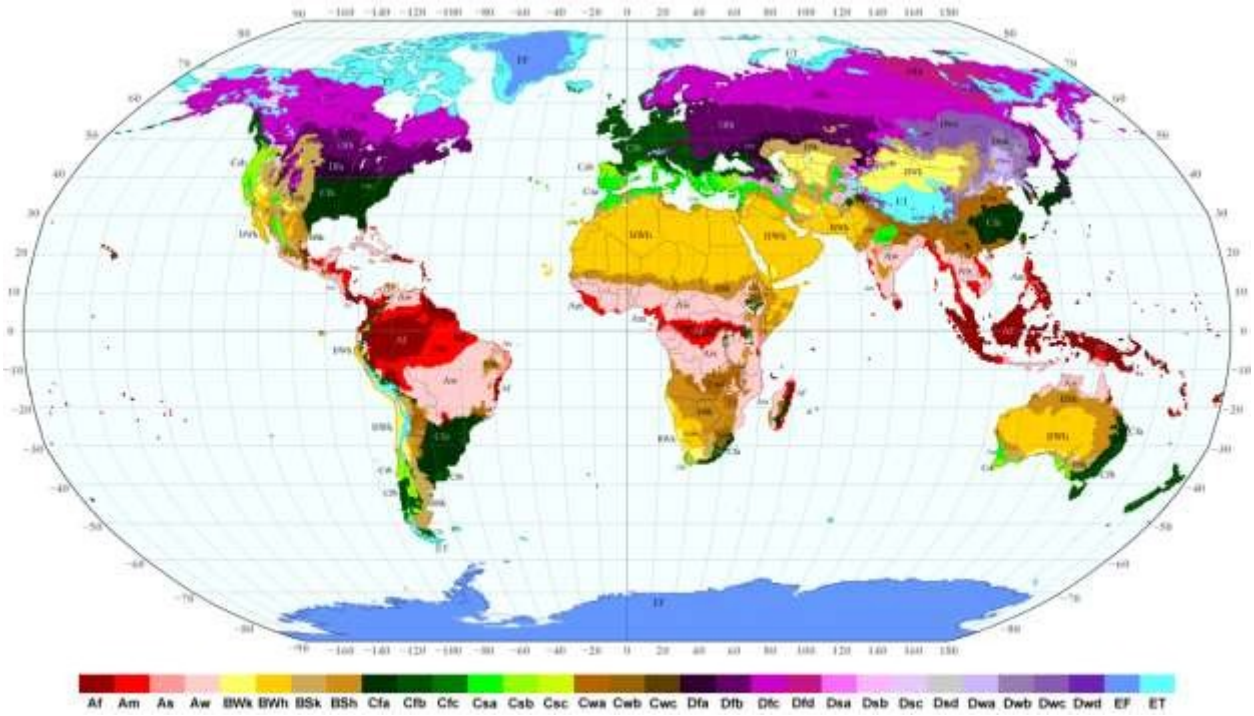
Based on combinational arrangements, Koppen, has divided the world in 5 major, 14 main and 29 sub classes of climates in the world. A detailed scheme of climates of the world as per Koppen - Geiger is given in the table-4. There could be some additional minor climate groups also.

**Table-4: Classification of world climates based on Koppen-Geiger**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Af | BWh | Csa | Cwa | Cfa | Dsa | Dwa | Dfa | ET |
| Am | BWk | Csb | Cwb | Cfb | Dsb | Dwb | Dfb | ETf |
| Aw | BSh | - | Cwc | Cfc | Dsc | Dwc | Dfc | Ef |
| As | BSk | - | - | - | Dsd | Dwd | Dfd | - |

**Spatial pattern of climatic classification:** The spatial pattern of climates can be studied based on the sun's angle of incidence on the earth. On both sides of equator up to tropics A group of climates prevail. From equator up to $10^0$ in both the hemispheres sub group of climate Af climate is found. It is closely followed by Am sub group along coastal margins. The two subgroups Aw and as extend upto tropics. While Aw sub group is quite common, as sub group is rare. Arid or B group of hot climates are found along the western margins of the continents. However, along eastern sides of the continents in low latitudes up to $30^0$, meso thermal or C group of climates are found. These climates are also found along western sides of the continents around coastal margins. D group of climates are found in temperate zones, interior parts of the continents and eastern margins of the continents. E group of climates are usually found in higher latitudes or in higher altitudes. Along arctic and sub- arctic regions, such climates are common. Maritime influences play a decisive and a balancing role in determining a climate and biological situations. Similarly, prevailing winds easterly adds to humidity proportions along eastern margins while westerly winds add to humidity in western margins of the continents. Figure 2: presents world map of climatic classification as attempted by Koppen – Geiger.

**Figure 2: World Koppen's Climate Classification**



**Characteristics of major climates**

A brief account of the characteristics of major climates is given below for the appreciation of Koppen's classification of world climates.

**A - Tropical climates:** These climates are commonly found in the tropical belt of both the hemispheres. It is characterized by consistently warm with all months averaging above $18^0$ C temperature. There is no winter season in this climate. Annual precipitation is high and exceeds POTET (potential evapotranspiration). There are three subdivisions of tropical climate.

**Af= Tropical rainforest climate:** The climate is characterized by rainfall throughout the year with average precipitation of at least 60 mm in every month. Because of hot and wet conditions throughout the year, tropical rain forests occur in this part of the earth. Towns such as Kishangani in (Congo), Singapore and Hawai (USA) are the typical examples of the climate.

**Am= Tropical monsoon climate:** This type of climate is characterized by short dry season registering less than 60 mm precipitation in driest month. Rainfall occurs excessively during summer rainy season making land surface moist throughout the year. Consequently, it supports the growth of dense forests which shed their leaves in dry season. It is typical of monsoon climate. Abidjan (Ivory Coast), Jakarta (Indonesia), Yangon (Myanmar) and Chittagong (Bangladesh) are typical examples of the climate.

**Aw or as = Tropical wet and dry or savanna climate:** This type of climate is known as tropical Savana or Grassland. Winter season in (Aw) climate is usually dry while summer season is dry in (As) climate. The amount of precipitation in driest month is less than 6 cm. The water balance remains in deficit during dry season and surplus during wet season. In terms of vegetation, tall grasses with scattered trees around are the common sight in this type of climate. Mumbai (India), Dhaka (Bangladesh), Dar es Salam (Tanzania), Darwin (Australia) and Ho Chi Minh City (Vietnam) are typical examples of winter dry (Aw) climate and Chennai (India) is a typical example of summer dry (As) climate.

**B – Dry (arid and semiarid) climates**: This type of climate is characterized by scarcity of moisture. The potential evapotranspiration (POTET) exceeds precipitation (PRECIP). The threshold values can be calculated in the following manner. Here MAT refers to mean annual temperature.

(a) MAT× $20^0$ C + 280 if 70% or more of the total precipitation is in summer months, or

(b) MAT× $20^0$ C + 140 if 30% -70% of total precipitation is received during spring and summer months, or

**(A)** MAT× $20^0$ C + 0 if less than 30% of the precipitation is so received.

If the annual precipitation is less than 50% of this threshold, the classification is BW (arid: desert climate); if it is in the range of 50% - 100% of the threshold, the classification is BS (semi-arid: steppe).

**Arid climates:** Precipitation is less than ½ of POTET.

BWh: These are low latitude hot deserts. Atmospheric conditions are hot and dry with an average annual temperature above $18^0$ C. Khartoum (Sudan), Doha (Qatar), and Death Valley (USA) are examples of the climate.

BWk: These are mid latitude cold deserts. Atmospheric conditions are cold and dry with average annual temperature less than $18^0$ C. Turpan (China), and Nukush (Uzbekistan) are typical examples of the climate.

**Semiarid climates:** These climates are characterized by the precipitation more than ½ of POTET but not equal to it. As such, semiarid conditions are the characteristic features of these climates. There are two sub divisions of semiarid climates.

BSh: These are semiarid tropical steppe climates where average annual temperature is more than $18^0$ C. These climates are usually found in the neighborhood of hot desert. Lahore (Pakistan), Odessa (USA) and Niamey (Niger) are the examples of the climate.

BSk: These are temperate steppe climates where average annual temperature is less than $18^0$ C. These climates are usually found in the proximity of cold deserts. Baku (Azerbaizan), Denver (USA), Lhasa (China) and Ulanbaatar (Mongolia) are examples of the climate.

There could be a fourth small letter to denote summer dry (s) or winter dry (w) with B group of climates.

**C – Type of climates:** This type of climate is characterized by meso - thermal conditions in which average temperature of the coldest month averaging between $0^0$ C and $18^0$ C and at least one month averaging above $10^0$C. The subdivisions of the climate are as under:

**Cfa:** These are subtropical wet climates. Precipitation occurs throughout the year. It is characterized by long and hot summer season. The average temperature of the hottest month is $22^0$ C and above and at least four months averaging above $10^0$ C. As compared to it, winter season is shorter and temperatures do not reach the extreme. Buenos Aires (Argentina), Srinagar (India), Shanghai (China) and Osaka (Japan) are examples of the climate.

**Cfb:** It is a temperate marine climate with adequate precipitation in all the seasons. Summer season is usually warmer. However, temperature of the hottest month is less than $22^0$C. Coldest month averaging above $0^0$ C. Winter season is marked with normal temperature conditions. Paris (France), Amsterdam (Netherlands), Port Elizabeth (South Africa) and Melbourne (Australia) are examples of the climate.

**Cfc:** This is a sub polar marine climate which is relatively cold in winter season. Summer season is short. The average temperature for a minimum of four months is around $10^0$C. No significant precipitation difference between seasons. Unalaska (USA), Punta Arenas (Chile), and Reykjavik (Iceland) are examples of the climate.

**Csa:** This type of climate is found in the interior areas of Mediterranean Sea. Summer season is hot and dry but winter season is normal and wet. Madrid (Spain), Dushanbe (Tajikistan), Perth (Australia) and Beirut (Lebanon) are the representative stations of the climate.

**Csb:** This type of climate is found in the coastal areas of Mediterranean Sea. It has a short summer season which is dry and hot. The winter season is usually favorable as it receives rainfall. The average temperature of the hottest month is less than $22^0$C. Santiago (Chile), Cape Town (South Africa) and San Francisco (USA) are representative stations of the climate.

**Cwa:** This is subtropical monsoonal climate. Summer season is hot and wet. Temperature rises to more than $22^0$C for at least one month. Winter season is normal and dry. Islamabad (Pakistan), New Delhi (India), Kathmandu (Nepal) and Hong Kong are the representative stations of the climate.

**Cwb:** It is a highland type of climate where temperature remains less than $22^0$ C in hottest month. Winter season is cold and dry while summer season is warm and wet.

**D – Type of climates:** These are cold temperate climates. They are also called as micro thermal in which normal minimum temperature of coldest month is less than $-3^0$ C while normal

temperature of warmest month is above $10^0$ C. There are 8 sub classes of this group of climates. Together these climates account for about 21 percent of the earth's land surface. It equals to about 7 percent of the total surface area of the earth.

**Dfa:** This climate is located in the continental areas close to the polar front zone. The annual range of temperature is high and weather is highly variable. Summers are warm and winters are cold. Precipitation occurs in all the months. It is found in central and eastern parts of Eurasia between forty to fifty-five-degree north. New York City (USA), Almaty (Kazakhstan), Beijing (China) and Seoul (South Korea) represent the climate.

**Dfb:** This type of climate is found in eastern Asia, China, Korea, and Japan. More rainfall occurs in summer season and there is a drier winter. The climate is generally found between $45^0$ to $60^0$ North latitudes. Sapporo (Japan) is a typical example of the climate.

**Dwa:** This is a monsoon influenced hot- summer humid continental climate. It is commonly found in north eastern U.S.A. and south Eastern Canada. Both coniferous and deciduous forests are found in this belt. The climate is characterized by moist continental with short period of summer dryness. Pyongyang (North Korea) and Tianjin (China) are the typical examples of the climate.

**Dwb:** This type of climate is found along oceanic margins of the continents in higher latitudes. It is wet climate with long dry and severe cold winter season, short and cold summer season. Vladivostok (Russia), and Pembina (USA) are representative stations of the climate.

**Dwc:** It is a sub- arctic climate characterized by long cold and dry winter season. Summer season is short and mild. Moron (Mongolia) and Yushu City (China) are examples of the climate.

**Dwd:** This type of climate is found in the proximity of Sub-Arctic region. It is characterized by long dry and extreme cold winter season. Summer season is short and mild warm. Yakutsk (Russia) and Oymyakon (Russia) are examples of the climate.

**Dsa:** This type of climate exists only at higher elevations adjacent to areas with hot summer Mediterranean (Csa) climates. Sanandaj (Kurdistan-Iran), Hakkari (Turkey) are examples of the climate.

**Dsb:** It is warm, dry- summer continental climate. Temperature recorded in coldest month averaging $< 0^0$ C, all months with average temperature $<22^0$ C and at least four months averaging

>$10^0$ C. There is at least three times as much precipitation in wettest month of winter as in driest month of summer. Sivas (Turkey), Roghun (Tajikistan), Dras (India) and Bridgeport (California-USA) are examples of the climate.

**Dsc:** It is warm dry summer subarctic climate. Temperature recorded in coldest month averaging < $0^0$ C and 1-3 months averaging >$10^0$ C. There is at least three times as much precipitation in wettest month of winter as in driest month of summer. Homer (Alaska, USA), Mount Olympus (Greece) and Handud, (Badkhshan Province, Afghanistan) are examples of this type of climate.

**Dsd:** Places with this type of climate have severe winters, with temperatures in their coldest month lower than -38$^0$C. Seymachan, (Magadan Oblast, Russia) is a typical example of the climate.

**E – Types of climate (Polar and alpine (montane) Climates):** This type of climate has every month of the year with an average temperature below $10^0$ C.

**ET:** It is a Tundra type of climate. It is characterized by short a summer season. The normal temperature of warmest month ranges between 0$^0$C to 10$^0$C. Stanley (Falkland Islands), Mount Wellington (Australia) and La Rinkonada (Peru) are examples of the climate.

**ETf:** This is a polar climate. It experiences glaciations throughout the year and temperature remains below freezing point. Mount Fuji (Japan), Nuuk (Greenland) and Esperanza Base (Antarctica) are examples of the climate.

**EF:** This type of climate occurs in Antarctica and inner Greenland. It is also experienced in extremely high altitudes on mountains. Temperatures never exceed $0^0$ C ($32^0$ F). Mount Everest (Nepal), Mount Ararat (Turkey), Vostok station (Antarctica) and Summit Camp (Greenland) are examples of the climate.

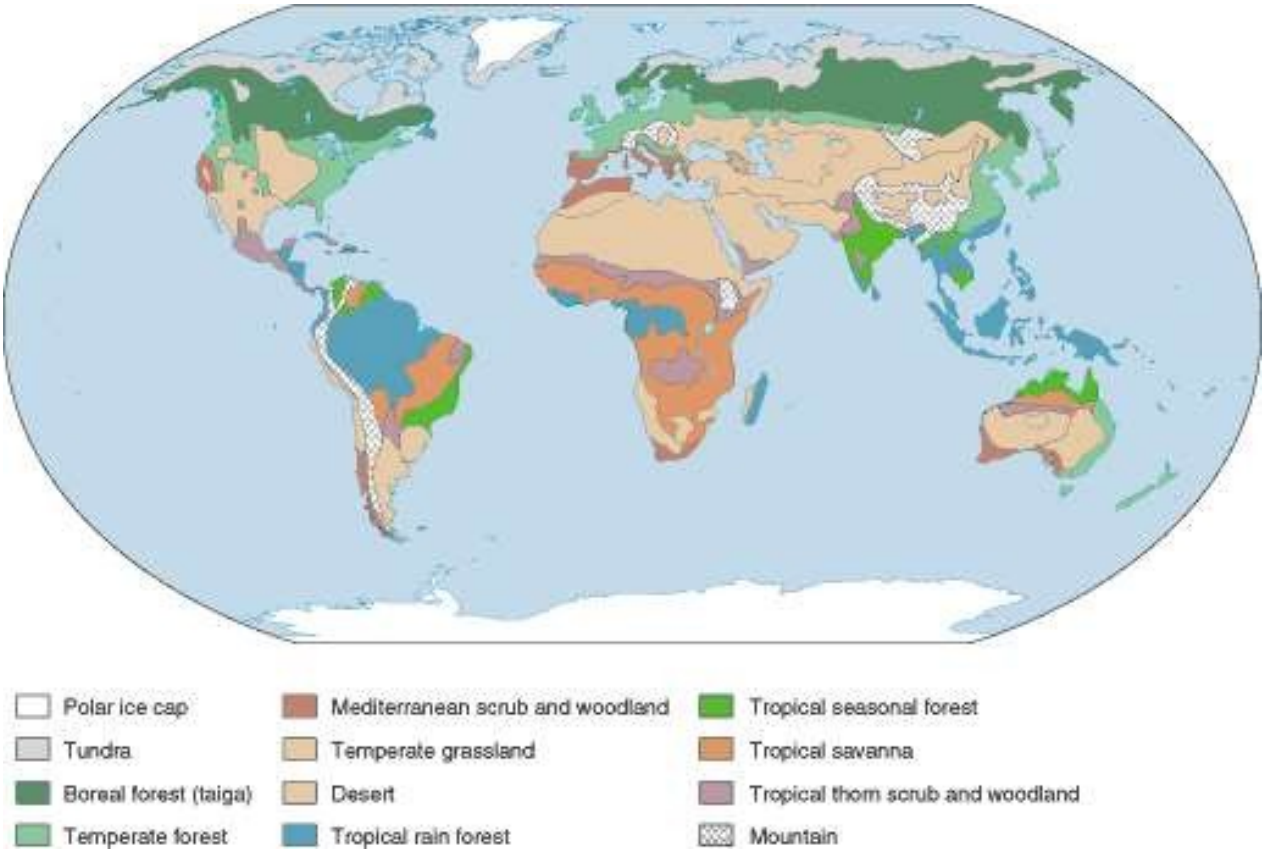
**Climate Types and Biomes**

It is well elaborated above about different types of climate all over the globe. Their types and sub-types are very clearly dealt in numerous previous paragraphs. As explained above that the vegetation is very well correlated with annual average temperature and annual average precipitation. It is apt place to at least say a little about the outcome of temperature and precipitation in the form of vegetation. Though we are not dealing here about the vegetation, but

still you can have a glance on the world map in Figure 3 showing the distribution of different types of vegetation.

In very short, it is quite evident that the good amount of temperature as well as precipitation is pre-requisite for proper growth of vegetation apart from other factors like soil types and fertility. Therefore, wherever higher annual average temperature is associated with good amount of precipitation, very dense vegetation type is seen like in equatorial region. Higher temperature but lesser amount of precipitation results into hot desert and semi-desert is found associated with less vegetation (Figure 3). Very low temperature is a retarding factor for the growth of vegetation. Wherever very low temperature is found, the vegetation growth is less and hence, it is a cold desert. Intermediary conditions very clearly show the biotic life accordingly. Therefore, the climate types and types of biomes are very closely correlated.

**Figure 3: Different Climate Types and Related Biomes**



**Criticisms of Koppen's Climate Classification**

Some of the weaknesses of Koppen's climatic classification are as under:

1. Climatic elements such as air pressure, air masses, humidity, etc. have not been considered despite their effective role in the characterization of climate.
2. Mathematical calculations using computers could have offered more reliable results.
3. Landforms play a decisive role in the distribution of vegetation and climatic characterization. Landforms have not been included in the scheme of climatic classification.
4. Direction of wind and distribution of water and land bodies exercises considerable influence on the climatic conditions. The inclusion of these factors would have improved the climatic classification qualitatively.
5. Aspects of climate change and occurrence of extreme events deserve to have found some space in the classification because of its increasing consequences.

Despite some of the weaknesses, Koppen's classification of climates is considered to be the most scientific, as it is based on the empirical data and inductive approach. It is widely used classification of climate. It is easy to decode the climate type and understand its thermal, locational as well as seasonal characteristics.

**Summary and Conclusions**

Koppen's classification is based on the empirical relationship between climate and vegetation. The classification provides an efficient way to describe climatic conditions defined by precipitation and temperature and their seasonality. Climatic conditions identified through Koppen's scheme of classification are relevant both for plant as well as animal life. Therefore, the Koppen's scheme of classification is significant ecologically also. The classification is widely used to map long term climate and associated ecological conditions. It is simple and easy to work out the type of climate if alphabetical (letter)) codes are known. Similarly, if data on temperature, precipitation and seasonality is available, it is easy to code the climate type.

With the increasing incidence of extreme climate events, there has been an increasing interest in using the classification to identify changes in climate and potential changes in vegetation, animal and human life forms. The most useful significance of Koppen's climate classification is that it

helps to predict the dominant vegetation type based on climatic data and vice versa. From different scientific reports it has been established that more than 5% of all the land area worldwide had moved from wetter and colder classifications to drier and hotter classifications.