UNIT –I

THE CLIMATE

Weather:

Weather only describes the particular day's surrounding environment atmosphere conditions of these variables in a given region. **Ex:** Temperature, rainfall, humidity, sky condition

Weather has only limited predictability. Meso scale convective systems are predictable over a period of hours only; Synoptic scale cyclones may be predictable over a period of several days to a week. Beyond a week or two individual weather systems are unpredictable.

Climate:

Climate is the average weather in a place over many years usually over a 30-year interval. It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time.

Climate varies from place to place, depending on latitude distance to the sea, vegetation, presence or absence of mountains or other geographical factors.

Climate varies also in time, from season to season, year to year, decade to decade or on much longer time-scales as the Ice Age.

Statistically significant variations of the mean state of the climate or of its variability, typical persisting for decades or longer are referred to as " Climate change"

FACTORS THAT DETERMINE CLIMATE:

Air temperature: ^{0}C

Air temperature is a measure of the energy of motion of the air's gas molecules.

The factors most responsible for the heating and cooling of the atmosphere are radiation arriving from the sun and radiation flowing from earth.

The air is made up of individual molecules just like any other physical material.

When exposed warm or hot temperatures, these molecules expand as they dry out. When this happens, the air becomes less able to hold moisture or water vapors.

When air becomes cold, its molecules contract, which allow them to better hold onto moisture. As a result rain, sleet or snow occurs when the temperature are cooler, while hot dry air produces little to no precipitation.

Wind near the surface of the earth:

Monsoon winds are good examples as they affect the climate of the countries over which they blow. Monsoons are sudden seasonal reversals in wind direction. They bring heavy rain. The strongest monsoons occur in southern Asia, Australia and Africa.

The climates of these countries are affected by these monsoons as heavy rain occurs during the monsoon period. The global winds (particularly, Hadley cell, ferner cell and Polar cell) regulate the global weather, help in moving the ocean currents which affect the climate of many countries and sometimes signal an El Nino formation which also affect the climate of many continents.

Precipitation: mm

Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change. Rainfall is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future.

A warmer atmosphere can hold more moisture, and globally water vapour increases by 7% for every degree centigrade of warming.

There's evidence to show that regions that are already wet are likely to get wetter, but details on how much wetter and what impacts there will be on a local scale are more difficult to ascertain. The dry regions of the subtropics are likely to get drier and will shift towards the poles. For much of Europe, wetter winters are expected, but with drier summers over central and southern Europe.

It is likely that in a warmer climate heavy rainfall will increase and be produced by fewer more intense events. This could lead to longer dry spells and a higher risk of floods.

So far, any impact that climate change may have had generally on regional rainfall cannot be distinguished from natural variations. However, for some specific cases a signal is starting to emerge.

Humidity: %

Humidity is the amount of water vapor in the air and can be described in different ways. Humidity is a key player in the weather.

Water vapor in the air, the humidity, plays an important part in global climate. Like carbon dioxide, water vapor is a greenhouse gas. Climate scientists have found that carbon- dioxide human activities is adding to the air is causing the Earth's average climate to warm. This, in turn, is almost surely affecting other aspects of global climate, and could have even bigger effects in the future.

As the climate warms, the humidity can increase. Since water vapor is a greenhouse gas, it should increase warming as it increases. Measuring how much global humidity is increasing and figuring out how it will increase, and the effects of such an increase are major challenges for climate scientists. (**Related: NASA report on warming and humidity)**

Absolute humidity (AH): is the mass of water vapor divided by the mass of dry air in a volume of air at a given temperature. The hotter the air is, the more water it can contain.

Relative humidity (RH): is the ratio of the current absolute humidity to the highest possible absolute humidity (which depends on the current air temperature). A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more, creating the possibility of rain. This doesn't mean that the relative humidity must be 100 percent in order for it to rain -- it must be 100 percent where the clouds are forming, but the relative humidity near the ground could be much less.

Wet bulb temperature (WBT): The lowest temperature that can be obtained by evaporating water into the air at constant pressure. The name comes from the technique of putting a wet cloth over the bulb of a mercury thermometer and then blowing air over the cloth until the water evaporates. Since evaporation takes up heat, the thermometer will cool to a lower temperature than a thermometer with a dry bulb at the same time and place. Wet bulb temperatures can be used along with the dry bulb temperature to calculate dew point or relative humidity.

Dry Bulb Temperature (DBT): The temperature of the air measured by the ordinary thermometer is called as the dry bulb temperature of air.

Cloud type and amount:

Climates have always been signs of the weather to come. Scattered white cumulus clusters sailing across a field of blue promise a dry summer afternoon. Massive dark thunderheads portend crop-damaging wind and rain. A blanket of light gray signals a temperate winter's night. A high sheet of see-through wisps signals a change in the weather tomorrow or the next day.

Their most important roles in climate are to modulate Earth's basic radiation balance and to produce precipitation. The law of conservation of energy requires that the energy absorbed by the Earth from the sun balance the energy radiated by the Earth back into space. Clouds both reflect incoming sunlight and inhibit the radiation of heat radiation from the surface, thereby affecting both sides of the global energy balance equation.

Clouds also produce precipitation from water vapor, releasing heat to the atmosphere in the process (evaporation of water vapor from the surface cools it, so that these two processes serve to transfer heat from the surface to the atmosphere). Thus, any changes in clouds will modify the radiative energy balance and water exchanges that determine the climate. The trouble is that clouds are produced by the climate, specifically the atmospheric motions (winds) that are produced by the radioactive and latent heating influenced by clouds. This connected loop of relations is called a feedback loop. The ways that clouds respond to changes in the climate are so complex that it is hard to determine their net effect on the energy and water balances and to determine how much climate might change.

Solar radiation:

Solar radiation powers the climate system. There are three fundamental ways to change the radiation balance of the Earth:

1. by changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself);
2. by changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation); and
3. by altering the long wave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations).

Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

Because the Earth is a sphere, more solar energy arrives for a given surface area in the tropics than at higher latitudes, where sunlight strikes the atmosphere at a lower angle. Energy is transported from the equatorial areas to higher latitudes via atmospheric and oceanic circulations, including storm systems. Energy is also required to evaporate water from the sea or land surface, and this energy, called latent heat, is released when water vapor condenses in clouds (see Figure 1).

Atmospheric circulation is primarily driven by the release of this latent heat. Atmospheric circulation in turn drives much of the ocean circulation through the action of winds on the surface waters of the ocean, and through changes in the ocean's surface temperature and salinity through precipitation and evaporation.

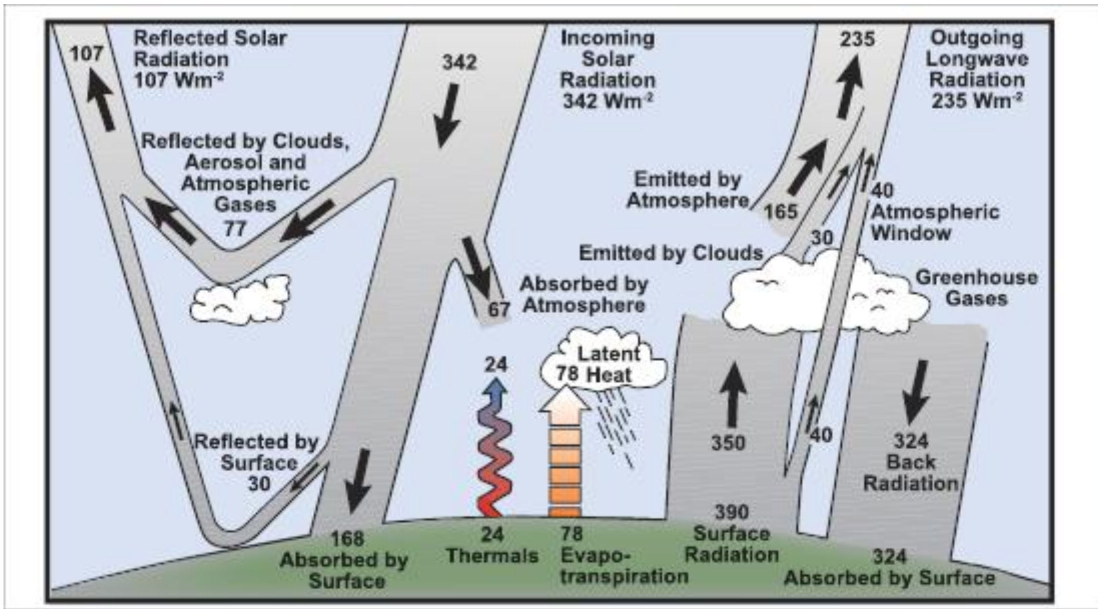


Figure 1 Solar Radiation

Structure of the Earth/Tilt of the Earth's Axis:

In early January each year, Earth reaches its closest distance to sun. At this time, the northern hemisphere experiences winter while the southern hemisphere experiences summer. The Earth travels to its farthest point from the sun at the beginning of July each year, when it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.

While it is true that Earth does have a perihelion, or point at which it is closest to the sun, and an aphelion, its farthest point from the sun, the difference between these distances is too minimal as to have any significant impact on the Earth's seasons and climate

it's easy to figure out that the Earth's orbit around the sun is not so much elliptical (oval) as it is circular, and that the Earth's distance from the sun remains relatively constant throughout its annual orbit.

The Earth is constantly changing its position with the sun. That's because the Earth tilts in relation to the sun. That is what creates the differences in the seasons and the annual warming and cooling cycles of the Earth's Northern and Southern Hemispheres.

The Earth is tilted 23.5 degrees on its axis, a straight line through the planet from the North Pole to the South Pole. The Earth spins around, or rotates, on this axis as it orbits the sun. The key here is that as the Earth orbits the sun, different regions on Earth tilt both towards and away from the sun, depending on the region's respective hemisphere. This causes the sun's light and energy to hit the different regions of the Earth at different angles throughout the course of one orbit, or one full year.

Earth's coldest temperature averages about minus 60°F (-45°F to -97°F) and its hottest temperature averages about 130°F-plus. While these extremes make most life impossible to naturally exist or thrive, they occur only in remote areas of the planet, such as the Antarctic (coldest average temperatures) or the Sahara Desert (hottest). Still, these temperatures are relatively warm (or cool) compared to other planets..

Atmospheric circulation:

THE HYDROLOGIC SYSTEM includes the entire cycle (hydrologic cycle) of water movement on the Earth (be it on the surface or in the air). The driving force behind this cycle is the energy input from the sun.

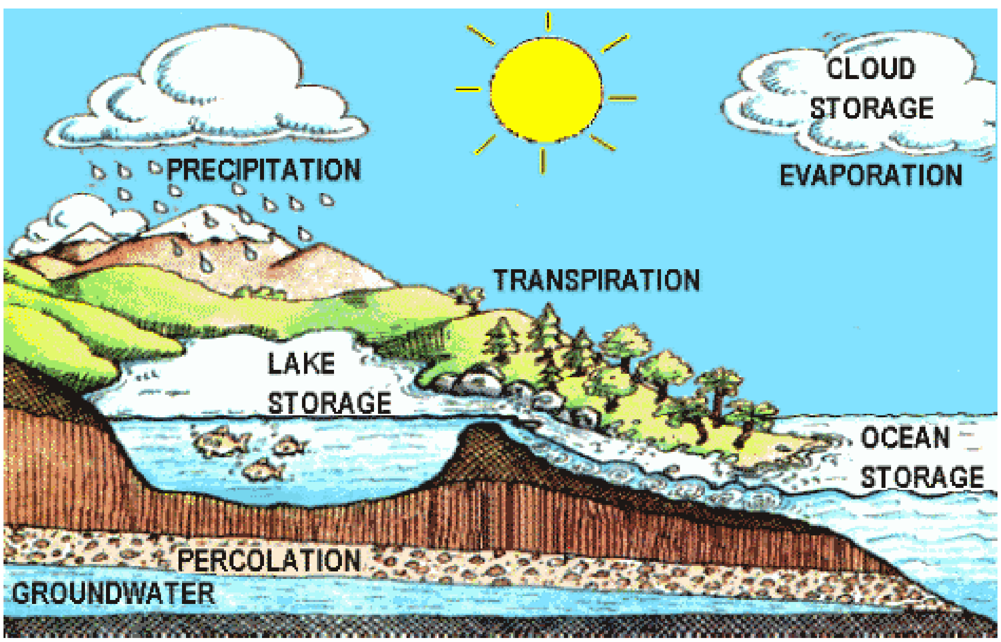


Figure-2 as shown in above diagram shows the various pathways of (1) water to the oceans (rivers, glaciers, precipitation); (2) water into the atmosphere by evaporation (from falling rain, rivers & lakes, soil, the oceans, transpiration by plants); and (3) onto the landmasses (by rain, snow). Water movement/transport occurs through movement of clouds, by rivers, ocean circulation, groundwater flow, and evaporation.

The bulk of the water is contained in the oceans, which contain about 30000 times more water than atmosphere and continents combined, cover approximately 70% of the Earth's surface and are on average 3800 m deep. The remainder of the water is found in ice caps & glaciers (3%), groundwater (1%), and rivers and lakes (0.01%). The latter two reservoirs constitute the terrestrial fresh water supply. Thus, only a very small fraction of the overall water supply is suitable and available for human use. The water transfer between these reservoirs is accomplished by the processes of evaporation, transpiration, precipitation, and flow of water (following gravity).

Every year about 30000 to 40000 cubic kilometers (a cube 30-35 km in size) of water move across the surface of the continents to the oceans, profoundly shaping the surface of the continents. Evaporation by the sun effects lifting of water into the atmosphere, and the counterforce to this process is gravity that forces rain to fall back on the earth and causes water move back to the oceans in streams (river systems), on the way eroding soils, cutting canyons, and transporting solids (silt, sand, clay) and dissolved salts to the oceans. The transfer of water vapor from the oceans to the atmosphere goes hand in hand with the transfer of tremendous amounts of thermal energy to the atmosphere and is very important for atmospheric circulation (see below). For this reason atmospheric circulation and winds can be considered part of the hydrologic cycle.

COMPONENTS OF CLIMATE:

Its components

The climate system is an interactive system consisting of five major components:

1. The atmosphere,
2. The hydrosphere,

3. The cryosphere,

4. The land surface and

5. The biosphere (forced or influenced by various external forcing mechanisms, the most important of which is the Sun)

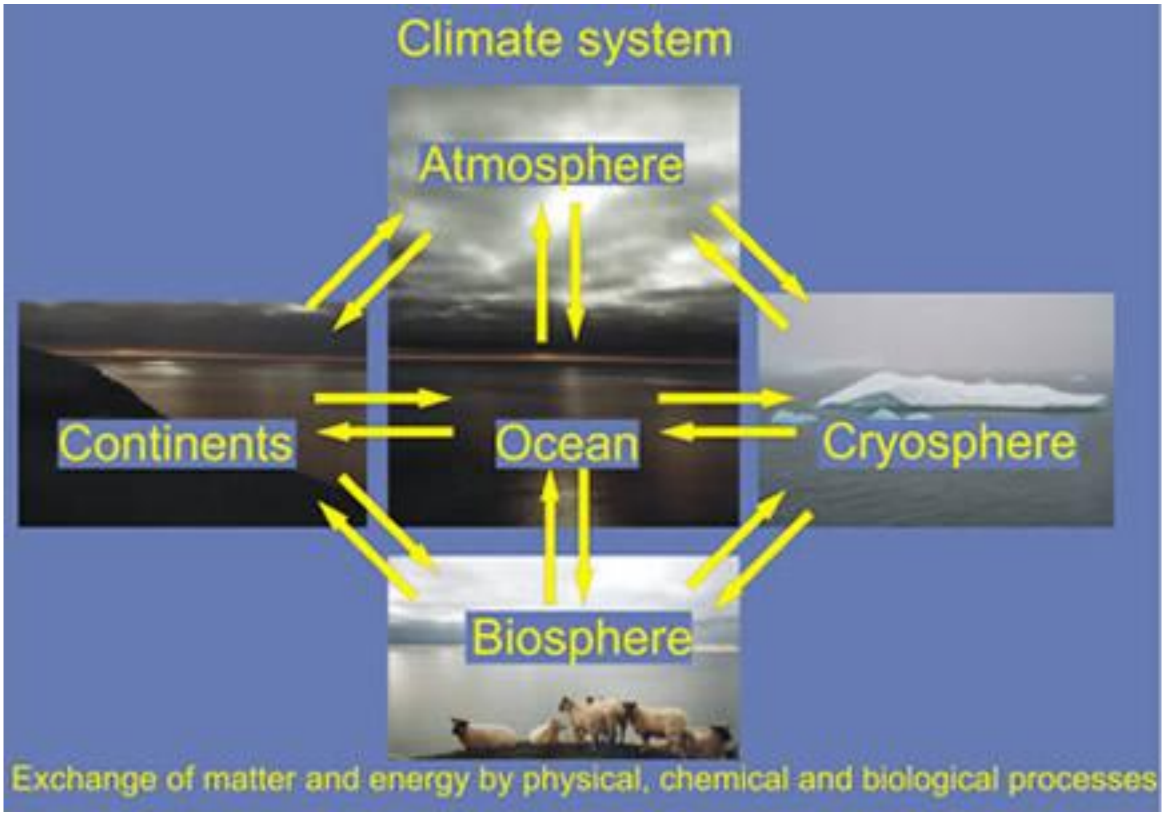


Figure-3 Components of Climate

1. The atmosphere:

The *atmosphere* is the most unstable and rapidly changing part of the system. Its composition, which has changed with the evolution of the Earth, is of central importance to the problem assessed in this Report. The Earth's dry atmosphere is composed mainly of nitrogen (N2, 78.1% volume mixing ratio), oxygen (O2, 20.9% volume mixing ratio, and argon (Ar, 0.93% volume mixing ratio). These gases have only limited interaction with the incoming solar radiation and they do not interact with the infrared radiation emitted by the Earth.

However there are a number of trace gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3), which do absorb and emit infrared radiation. These so called greenhouse gases, with a total volume mixing ratio in dry air of less than 0.1% by volume, play an essential role in the Earth's energy budget.

Moreover the atmosphere contains water vapour (H_2O), which is also a natural greenhouse gas. Its volume mixing ratio is highly variable, but it is typically in the order of 1%. Because these greenhouse gases absorb the infrared radiation emitted by the Earth and emit infrared radiation up- and downward, they tend to raise the temperature near the Earth's surface.

Water vapour, CO_2 and O_3 also absorb solar short-wave radiation. The atmospheric distribution of ozone and its role in the Earth's energy budget is unique. Ozone in the lower part of the atmosphere, the troposphere and lower stratosphere, acts as a greenhouse gas. Higher up in the stratosphere there is a natural layer of high ozone concentration, which absorbs solar ultra-violet radiation.

2. The Hydrosphere:

The hydrosphere is the component comprising all liquid surface and subterranean water, both fresh water, including rivers, lakes and aquifers, and saline water of the oceans and seas. Fresh water runoff from the land returning to the oceans in rivers influences the ocean's composition and circulation.

The oceans cover approximately 70% of the Earth's surface. They store and transport a large amount of energy and dissolve and store great quantities of carbon dioxide. Their circulation, driven by the wind and by density contrasts caused by salinity and thermal gradients (the so-called thermohaline circulation), is much slower than the atmospheric circulation.

Mainly due to the large thermal inertia of the oceans, they damp vast and strong temperature changes and function as a regulator of the Earth's climate and as a source of natural climate variability, in particular on the longer time-scales.

3. The Cryosphere:

The cryosphere, including the ice sheets of Greenland and Antarctica, continental glaciers and snow fields, sea ice and permafrost, derives its importance to the climate system from its high reflectivity (albedo) for solar radiation, its low thermal conductivity, its large thermal inertia and, especially, its critical role in driving deep ocean water circulation. Because the ice sheets store a large amount of water, variations in their volume are a potential source of sea level variations

4. The land surface:

Vegetation and soils at the land surface control how energy received from the Sun is returned to the atmosphere. Some is returned as long-wave (infrared) radiation, heating the atmosphere as the land surface warms. Some serves to evaporate water, either in the soil or in the leaves of plants, bringing water back into the atmosphere. Because the evaporation of soil moisture requires energy, soil moisture has a strong influence on the surface temperature.

The texture of the land surface (its roughness) influences the atmosphere dynamically as winds blow over the land's surface. Roughness is determined by both topography and vegetation. Wind also blows dust from the surface into the atmosphere, which interacts with the atmospheric radiation.

5. The biosphere

The marine and terrestrial biospheres have a major impact on the atmosphere's composition. The biota influence the uptake and release of greenhouse gases. Through the photosynthetic process, both marine and terrestrial plants (especially forests) store significant amounts of carbon from carbon dioxide. Thus, the biosphere plays a central role in the carbon cycle, as well as in the budgets of many other gases, such as methane and nitrous oxide.

Other biosphere emissions are the so-called volatile organic compounds (VOC) which may have important effects on atmospheric chemistry, on aerosol formation and therefore on climate. Because the storage of carbon and the exchange of trace gases are influenced by climate, feedbacks between climate change and atmospheric concentrations of trace gases can occur.

The influence of climate on the biosphere is preserved as fossils, tree rings, pollen and other records, so that much of what is known of past climates comes from such biotic indicators.

Interactions among the components:

Many physical, chemical and biological interaction processes occur among the various components of the climate system on a wide range of space and time scales, making the system extremely complex. Although the components of the climate system are very different in their composition, physical and chemical properties, structure and behavior, they are all linked by fluxes of mass, heat and momentum: all subsystems are open and interrelated.

As an example, the atmosphere and the oceans are strongly coupled and exchange, among others, water vapour and heat through evaporation. This is part of the hydrological cycle and leads to condensation, cloud formation, precipitation and runoff, and supplies energy to weather systems. On the other hand, precipitation has an influence on salinity, its distribution and the thermohaline circulation. Atmosphere and oceans also exchange, among other gases, carbon dioxide, maintaining a balance by dissolving it in cold polar water which sinks into the
deep ocean and by out gassing in relatively warm upwelling water near the equator.

Some other examples: sea ice hinders the exchanges between atmosphere and oceans; the biosphere influences the carbon dioxide concentration by photosynthesis and respiration, which in turn is influenced by climate change.
The biosphere also affects the input of water in the atmosphere through evapotranspiration, and the atmosphere’s radioactive balance through the
amount of sunlight reflected back to the sky (albedo).

SITE CLIMATE:

Site climate conditions are usually estimated based on historical weather data and computer models. The term "site climate" is also used to describe local climate at a research site, such as a field research station.

The term "site climate" is used mainly in the wind energy industry to describe typical variations in wind speed and potential power output at a current or planned wind generator site.

Local factors which affect the site climate:

Many factors influence site climate, such as the surrounding topography, direction of exposure (if the site is on a hill, for example), and tree cover.

Topography:

It concerns with slope, orientation, exposure, elevations, hills or valley, at or near the site

Ground Surface:

The surface is with natural or man -made , its reflectance, permeability and the soil temperature, a s these affect vegetarian an d this in turn affects the climate.

Three Dimensional objects:

It is such as trees, or tree belts, fences, walls and buildings, as these may influence air movement, may cast at shadow and may sub-divide the area into smaller units with distinguishable climatic features.

Climate Classification

The **Köppen Climate Classification System** is the most widely used system for classifying the world's climates. Its categories are based on the annual and monthly averages of temperature and precipitation. The Köppen system recognizes five major climatic types; each type is designated by a capital letter.

A - **Tropical Moist Climates**: all months have average temperatures above 18° Celsius.

B - **Dry Climates**: with deficient precipitation during most of the year.

C - **Moist Mid-latitude** Climates with Mild Winters.

D - **Moist Mid-Latitude** Climates with Cold Winters.

E - **Polar Climates**: with extremely cold winters and summers.

Tropical Moist Climates (A)

Tropical moist climates extend northward and southward from the equator to about 15 to 25° of latitude. In these climates all months have average temperatures greater than 18° Celsius. Annual precipitation is greater than 1500 mm. Three minor Köppen climate types exist in the A group, and their designation is based on seasonal distribution of rainfall.

Af or tropical wet is a tropical climate where precipitation occurs all year long. Monthly temperature variations in this climate are less than 3° Celsius. Because of intense surface heating and high humidity, cumulus and cumulonimbus clouds form early in the afternoons almost every day. Daily highs are about 32° Celsius, while night time temperatures average 22° Celsius.

Am is a tropical monsoon climate. Annual rainfall is equal to or greater than Af, but most of the precipitation falls in the 7 to 9 hottest months. During the dry season very little rainfall occurs.

The tropical wet and dry or savanna (Aw) has an extended dry season during winter. Precipitation during the wet season is usually less than 1000 millimeters, and only during the summer season.

Dry Climates (B)

The most obvious climatic feature of this climate is that potential evaporation and transpiration exceed precipitation. These climates extend from 20 - 35° North and South of the equator and in large continental regions of the mid-latitudes often surrounded by mountains.

Minor types of this climate include:

BW - dry arid (desert) is a true desert climate. It covers 12% of the Earth's land surface and is dominated by xerophytic vegetation. The additional letters h and k are used generally to distinguish whether the dry arid climate is found in the subtropics or in the mid-latitudes, respectively.

BS - dry semiarid (steppe). Is a grassland climate that covers 14% of the Earth's land surface. It receives more precipitation than the BW either from the intertropical convergence zone or from mid-latitude cyclones. Once again, the additional letters h and k are used generally to distinguish whether the dry semiarid climate is found in the subtropics or in the mid-latitudes, respectively.

Moist Subtropical Mid-Latitude Climates (C)

This climate generally has warm and humid summers with mild winters. Its extent is from 30 to 50° of latitude mainly on the eastern and western borders of most continents. During the winter, the main weather feature is the mid-latitude cyclone. Convective thunderstorms dominate summer months.

Three minor types exist:

Cfa - humid subtropical; **Cs** - Mediterranean; and **Cfb** - marine.

Moist Continental Mid-latitude Climates (D)

Moist continental mid-latitude climates have warm to cool summers and cold winters. The location of these climates is pole ward of the C climates. The average temperature of the warmest month is greater than 10° Celsius, while the coldest month is less than -3° Celsius. Winters are severe with snowstorms, strong winds, and bitter cold from Continental Polar or Arctic air masses. Like the C climates there are three minor types: Dw - dry winters; Ds - dry summers; and Df - wet all seasons.

Polar Climates (E)

Polar climates have year-round cold temperatures with the warmest month less than 10° Celsius. Polar climates are found on the northern coastal areas of North America, Europe, Asia, and on the landmasses of Greenland and Antarctica.

Two minor climate types exist.

ET or ***polar tundra*** is a climate where the soil is permanently frozen to depths of hundreds of meters, a condition known as permafrost. Vegetation is dominated by mosses, lichens, dwarf trees and scattered woody shrubs.

EF or ***polar ice caps*** has a surface that is permanently covered with snow and ice.

Climatic Region Descriptions

The following discussion organizes the climatic regions of the world into eight different groups. Categorization of these climates is based on their Köppen classification and seasonal dominance of air masses.

Tropical Wet, Tropical Wet and Dry, Subtropical Desert and Steppe, Mid-Latitude Desert and Steppe, Mid-Latitude Wet, Mid-Latitude Winter-Dry, Mid-Latitude Summer-Dry, Polar Tundra & Polar Ice Cap

<u>CHARACTERISTICS OF DIFFERENT CLIMATES</u>

Warm-humid climate

- Hot-dry desert, or semi-desert climate — subgroup: hot-dry maritime desert climate
- Composite or monsoon climate (combination of 1 and 2) — subgroup: tropical upland climate

  These groups are referred to throughout the text. Detailed description of each zone is given below

Warm-humid climates are found in a belt near the Equator extending to about 15°N. and S. Examples of cities in this zone: Lagos, Dar-es-Salam, Mombasa, Colombo, Singapore, Jakarta, Quito and Pernambuco. Figure 18 shows a climate, graph for Mombasa.

There is very little seasonal variation throughout the year, the only punctuation being that of periods with more or less rain and the occurrence of gusty winds and electric storms.

Air temperature, i.e. DBT, in the shade reaches a mean maximum during the day of between 27 and 32°C, but occasionally it may exceed the latter value. At night the mean minimum varies between 21 and 27°C. Both the diurnal and annual ranges of temperature are quite narrow.

Humidity, i.e. RH, remains high, at about 75% for most of the time, but it may vary from 55 to almost 100%. Vapor pressure is steady in the region of 2500 to 3000 N/m^2.

Precipitation is high throughout the year, generally becoming more intense for several consecutive months. Annual rainfall can vary from 2000 to 5000 mm and may exceed 500 mm in one month, the wettest month. During severe storms rain may fall at the rate of 100 mm/h for short periods.

Sky conditions are fairly cloudy throughout the year. Cloud cover varies between 60 and 90% Skies can be bright, a luminance of 7000 cd/m^2 or even more when it is thinly overcast, or when the sun illuminates white cumulus clouds without itself being obscured. When heavily overcast, the sky is dull, 850 cd/m^2 or less.

Solar radiation is partly reflected and partly scattered by the cloud blanket or the high vapor content of the atmosphere, therefore the radiation reaching the ground is diffuse, but strong, and can cause painful sky glare. Cloud and vapor content also prevents or reduces outgoing radiation from the earth and sea to the night sky, thus the accumulated heat is not readily dissipated.

Wind velocities are typically low, calm periods are frequent, but strong winds can occur during rain squalls. Gusts of 30 m/s have been reported. There are usually one or two dominant directions.

Vegetation grows quickly due to frequent rains and high temperatures and it is difficult to control. The red or brown laterite soils are generally poor for agriculture. Plant-supporting organic substances and mineral salts are dissolved and washed away by rain-water. The subsoil water table is usually high and the ground may be waterlogged. Little light is reflected from the ground.

Special characteristics: high humidity accelerates mould and algal growth, rusting and rotting. Organic building materials tend to decay rapidly. Mosquitoes and other insects abound. The thunder-storms are accompanied by frequent air-to-air electrical discharges.

Warm-humid island climate

Islands within the equatorial belt and in the trade-winds zone belong to this climate type. Typical examples are the Caribbeans, the Philippines and other island groups in the Pacific Ocean.

Seasonal variations are negligible.

Air temperature, i.e. DBT, in the shade reaches a day-time mean maximum between 29 and 32°C and rarely rises above skin temperature. Night-time mean minima can be as low as 18°C, but it is normally between this figure and 24°C. The diurnal range is rarely more than 8 degC and the annual range is only about 14 degC. Humidity, i.e. the RH, varies between 55 and almost 100%, the vapour pressure being between 1 750 and 2 500 N/m^2.

Hot-dry desert climate

Precipitation is high, 1250 to 1800 mm per annum, and 200 to 250 mm in the 27 wettest month. Up to 250 mm may fall in a single storm of a few hours' duration. Spray is driven nearly horizontally on windward coasts.

Sky conditions are normally clear or filled with white broken clouds of high brightness, except during storms, when the skies are dark and dull. Clear blue skies are of low luminance, between 1700 and 2500 cd/m^2.

Solar radiation is strong and mainly direct, with a very small diffuse component when the sky is clear, but varies with the cloud cover.

Winds: the predominant trade-wind blows at a steady 6 to 7 m/s and provides relief from heat and humidity. Much higher velocities occur during cyclones (see below).

Vegetation is less luxuriant and of a lighter green colour than in the warm-humid zones. It varies with the rainfall. Sunlight reflected from light colored coral, sand and rock can be very bright. The soil is often dry with a fairly low water-table.

Special characteristics are the tropical cyclones or hurricanes with wind veloci-ties from 45 to 70 m/s, which constitute a serious seasonal hazard the high salt content of the atmosphere encourages corrosion in coastal areas.

These climates occur in two belts at latitudes between approximately 15 and 30° north and south of the Equator. Examples of settlements in this zone: Assuan, Baghdad, Alice Springs, and Phoenix. Figure 19 shows a climate graph for the last-named.

Two marked seasons occur: a hot and a somewhat cooler period. Air temperature, i.e. DBT, in the shade rises quickly after sunrise to a day-time mean maximum of 43 to 49°C. The ever-recorded maximum temperature of 58°C was measured in Libya in 1922. During the cool season the mean maximum temperature ranges from 27 to 32"C. Night-time mean minima are between 24 and 30"C in the hot season and between 10 and 18'C in the cool season. The diurnal range is very great: 17 to 22 degC.

Humidity, i.e. the RH, varies from 10 to 55%, as the wet-bulb depression is large (rapid evaporation). The vapour pressure is normally between 750 and 1 500 N/m^2

Precipitation is slight and variable throughout the year, from 50 to 155 mm per annum. Flash-storms may occur over limited areas with as much as 50 mm rain in a few hours, but some regions may not have any rain for several years.

Sky conditions are normally clear. Clouds are few due to the low humidity of the air. The sky is usually dark blue, with a luminance of 1700 to 2500 cd/m^2. and further darkened during dust or sand-storms to 850 cd/m^2 or even less. Towards the end of the hot period, dust suspended in the air may create a white haze, with a luminance of 3500 to 10000 cd/m^2, which produces a diffuse light and a painful glare.

Solar radiation is direct and strong during the day, but the absence of cloud permits easy release of the heat stored during the day-time in the form of long-wave radiation towards the cold night sky. Diffuse radiation is only present during dust haze periods.

Winds are usually local. The heating of air over the hot ground causes a tempera-ture inversion, and as the lower warm air mass breaks through the higher cooler air, local whirlwinds are often created. Winds are hot, carrying dust and sand — and often develop into dust-storms.

Vegetation is sparse and difficult to maintain because of the lack of rain and low humidities. The soil is usually dusty and very dry. Strong sunlight illuminating a highly reflective light coloured and dry ground can create a luminance of 20000 to 25000 cd/m^2. Soils dry quickly after rain and would generally be fertile if irrigated. The subsoil water-table is very low.

Special characteristics: during certain months dust and sand-storms may he frequent. The high day-time temperatures and rapid cooling at night may cause materials to crack and break up.

Hot-dry maritime desert climate

Maritime desert climates occur in the same latitude belts as the hot-dry desert climates, where the sea adjoins a large land mass. These are regarded to be amongst the most unfavorable climates of the earth. Typical examples are Kuwait, Anto-fagasta and Karachi.

There are two seasons: a hot one and somewhat cooler one.

Air temperature, i.e. DBT, in the shade reaches a day-time mean maximum of about 38°C, but in the cool season it remains between 21 and 26°C. The night-time mean minimum temperatures of the hot season range from 24 to 30°C and of the cool season from 10 to 18 °C. The diurnal mean range varies between 9 and 12 degC, the larger diurnal variation occurring during the cool season.

Humidity, i.e. the RH, is steadily high, between 50 and 90%, with vapour pressures of 1500 to 2500 N/m^2, as the strong solar radiation causes strong evaporation from the sea. The moisture is, however, not precipitated but remains suspended in the air, creating intensely uncomfortable conditions.

Precipitation, as in other desert regions, is very low.

Sky conditions are as for hot-dry desert climates, a little more cloud may occur in the form of a thin, transparent haze, which is likely to cause glare.

Solar radiation is strong, with a higher diffuse component than in desert climates, due to the thin clouds and suspended moisture.

Winds are mostly local, coastal winds, caused by the unequal heating and cooling of land and sea surfaces. These tend to blow off the sea towards the land during the day and in the reverse direction during the night.

Vegetation is sparse, not more than some dry grass. The ground and rocks are brown or red; it is dry and dusty throughout the year. Ground glare can be intense.

Special characteristics: dust and sand-storms may occur. The salt laden atmosphere accelerates corrosion.

Composite or monsoon climate

These climates usually occur in large land masses near the tropics of Cancer and Capricorn, which are sufficiently far from the Equator to experience marked seasonal changes in solar radiation and wind direction. Examples of cities with composite climates: Lahore, Mandalay, Asuncion, Kano and New Delhi. The latter is shown as an example in Figure 20.

Two seasons occur normally. Approximately two-thirds of the year is hot-dry and the other third is warm-humid. Localities further north and south often have a third season, best described as cool-dry.

Air temperature, i.e. DBT, in the shade is as follows:

Seasons	hot-dry	warm-humid	cool-dry
Day-time mean max.	32-43°C	27-32°C	up to 27°C
Night-time mean min.	21-27°C	24-27°C	4-10°C
Diurnal mean range	11-22 degC	3-6 degC	11-22 degC

Humidity, i.e. the RH, is low throughout the dry periods at 20 to 55%, with a vapour pressure of 1300 to 1600 N/m^2. During the wet period it rises to 55 to 95%, with a vapour pressure of 2000 to 2500 N/m^2.

Precipitation: the monsoon rains are intense and prolonged; occasionally 25 to 38 mm can fall in an hour. Annual rainfall varies from 500 to 1300 mm with 200 to 250 mm in the wettest month. There is little or no rain during the dry seasons.

Sky conditions markedly vary with the seasons. The sky is heavily overcast and dull during the monsoons, and clear, with a dark blue colour, in the dry seasons. Towards the end of the hot-dry seasons the sky becomes brighter with frequent dust haze. The intensity of sky glare varies accordingly.

Solar radiation alternates between conditions found in the warm-humid and the hot-dry desert climates. Winds are hot and dusty during the dry period. Directional changes in the pre-vailing winds at the beginning of the warm-humid season bring rain-clouds and humid air from the sea. Monsoon winds are fairly strong and steady.

Tropical upland climate

Vegetation, which is sparse — characteristic of a hot-dry region — with brown and red barren ground, changes rapidly and dramatically with the rain. The landscape becomes green and fertile within a few days. Plants grow quickly. In the cooler period vegetation covers the ground, but diminishes as the temperature rises. The soil is damp during the rains but it dries out quickly. There is a risk of soil erosion during monsoons. In the dry season strong ground glare may be experienced.

Special characteristics: seasonal changes in relative humidity cause rapid weakening of building materials. Dust and sand-storms may occur. Termites are common. Occasional condensation problems.

Mountainous regions and plateaux more than 900 to 1200 m above sea-level experience such climates, between the two 20°C isotherms. Examples of cities in such regions: Addis Ababa, Bogota, Mexico City and Nairobi. A climate graph for Nairobi has been given in Figure 15.

Seasonal variations are small in upland climates near the Equator, but when further away from the Equator, the seasons follow those of the nearby lowlands.

Air temperature, i.e. the DBT, in the shade decreases with altitude. At an altitude of 1800 m the day-time mean maxima may range from 24 to 30`C and the night-time mean minima are around 10 to 13°C. At some locations it may fall below 4°C and ground frost is not uncommon. The diurnal range is great. The annual range depends on latitude: at the Equator it is slight; but at the tropics of Cancer and Capricorn it may be 11 to 20 degC.

Humidity, i.e. the RH, varies between 45 and 99% and the vapour pressure between 800 and 1600 N/m^2. Precipitation is variable, but rarely less than 1000 mm. Rain often falls in heavy concentrated showers, reaching an intensity of 80 mm per hour.

Sky conditions are normally clear or partly cloudy, to the extent of about 40%. During the monsoon rains the sky is overcast — and the clouds are heavy and low.

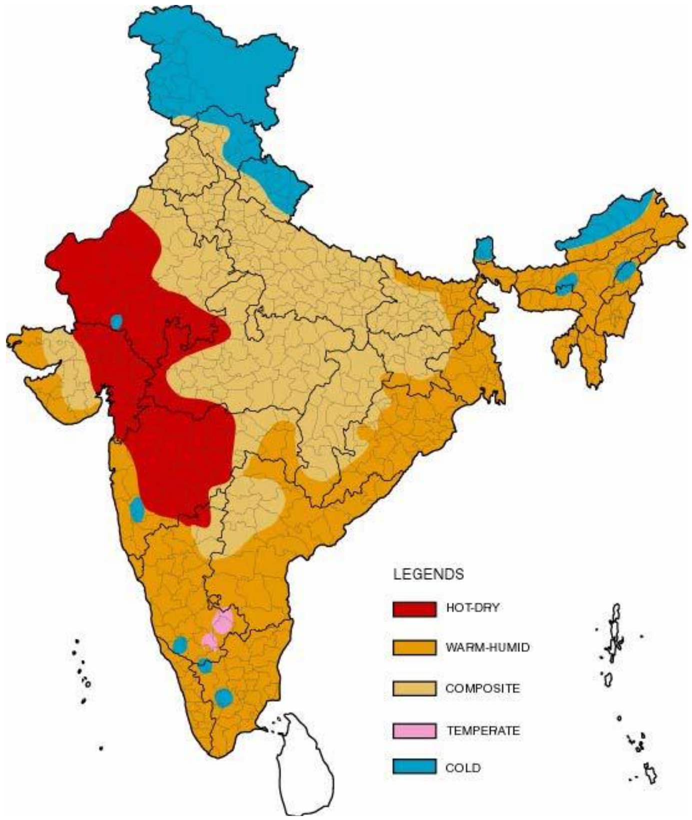
Solar radiation is strong and direct during the clear periods, stronger than at the same latitude, but at sea-level. Ultra-violet radiation especially is stronger than at lower altitudes. It becomes more diffuse as cloud cover increases.

Winds are variable, predominantly north-east and south-easterlies, but may be drastically deflected by local topography. Wind velocity rarely exceeds 15 m/s.

Vegetation is green although not very luxuriant during the wet season but it may wither in the dry season, when the ground can turn brown or red. The soil may be damp in the rains but dries quickly.

Special characteristics: heavy dew at night. Strong radiation loss at night during the dry season, which may lead to the formation of radiation fog. Thunder-storms with a fair proportion of electric discharges — air to ground. Hail may also occur.

CLIMATIC ZONES IN INDIA



Source: National Building Code 2005, Part 8

Regions having similar characteristic features of climate are grouped under one climatic zone. According to a recent code of Bureau of Indian Standards, the country may be divided into five major climatic zones:

Hot & Dry (mean monthly temperature >30 and relative humidity <55%);

Warm & Humid (mean monthly temperature >25-30 and relative humidity >55-75%);

Temperate (mean monthly temperature 25-30 and relative humidity <75%);

Cold (mean monthly temperature <25 and relative humidity – all values);

Composite (This applies, when six months or more do not fall within any of the other categories).

Brief Description

Buildings in different climatic zones require different passive features to make structures energy-efficient. Some features that can be adopted in particular zones are listed below.

Introduction - Climatic Zones of India

Regions having similar characteristic features of climate are grouped under one climatic zone. According to a recent code of Bureau of Indian Standards, the country may be divided into five major climatic zones: Hot & Dry (mean monthly temperature >30 and relative humidity <55%); Warm & Humid (mean monthly temperature >25-30 and relative humidity >55-75%); Temperate (mean monthly temperature 25-30 and relative humidity <75%); Cold (mean monthly temperature <25 and relative humidity – all values); Composite (This applies, when six months or more do not fall within any of the other categories).

Brief Description

Buildings in different climatic zones require different passive features to make structures energy-efficient. Some features that can be adopted in particular zones are listed below.

Hot and dry

Hot & Dry (mean monthly temperature >30 and relative humidity <55%); The hot and dry zone lies in the western and the central part of India; Jaisalmer, Jodhpur and Sholapur are some of the towns that experience this type of climate.

In such a climate, it is imperative to control solar radiation and movement of hot winds. The design criteria should therefore aim at resisting heat gain by providing shading, reducing exposed area, controlling and scheduling ventilation, and increasing thermal capacity. The presence of “water bodies” is desirable as they can help increase the humidity, thereby leading to lower air temperatures. The ground and surrounding objects emit a lot of heat in the afternoons and evenings. As far as possible, this heat should be avoided by appropriate design features.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Insulation of building envelope
- Massive structure
- Air locks, lobbies, balconies, and verandahs
- Weather stripping and scheduling air changes
- External surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees, ponds, and evaporative cooling

Warm and humid

Warm & Humid (mean monthly temperature >25-30 and relative humidity >55-75%); The warm and humid zone covers the coastal parts of the country, such as Mumbai, Chennai and Kolkata. The main design criteria in the warm and humid region are to reduce heat gain by providing shading, and promote heat loss by maximizing cross ventilation. Dissipation of humidity is also essential to reduce discomfort.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Roof insulation and wall insulation
- Reflective surface of roof
- Balconies and verandahs
- Walls glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Ventilated roof construction, courtyards, wind towers, and arrangement of openings
- Dehumidifiers and desiccant cooling

Moderate

Temperate (mean monthly temperature 25-30 and relative humidity <75%);Pune and Bangalore are examples of cities that fall under this climatic zone. The design criteria in the moderate zone are to reduce heat gain by providing shading, and to promote heat loss by ventilation.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Roof insulation and east and west wall insulation
- Walls facing east and west, glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards and arrangement of openings

Cold

Cold (mean monthly temperature <25 and relative humidity – all values);

Generally, the northern part of India experiences this type of climate. The design criteria are to resist heat loss by insulation and controlling infiltration. Simultaneously, heat gain needs to be promoted by admitting and trapping solar radiation within the living space.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation, wall insulation, and double glazing
- Thicker walls
- Air locks and lobbies
- Weather stripping
- Darker colours
- Sun spaces, greenhouses and trombe walls

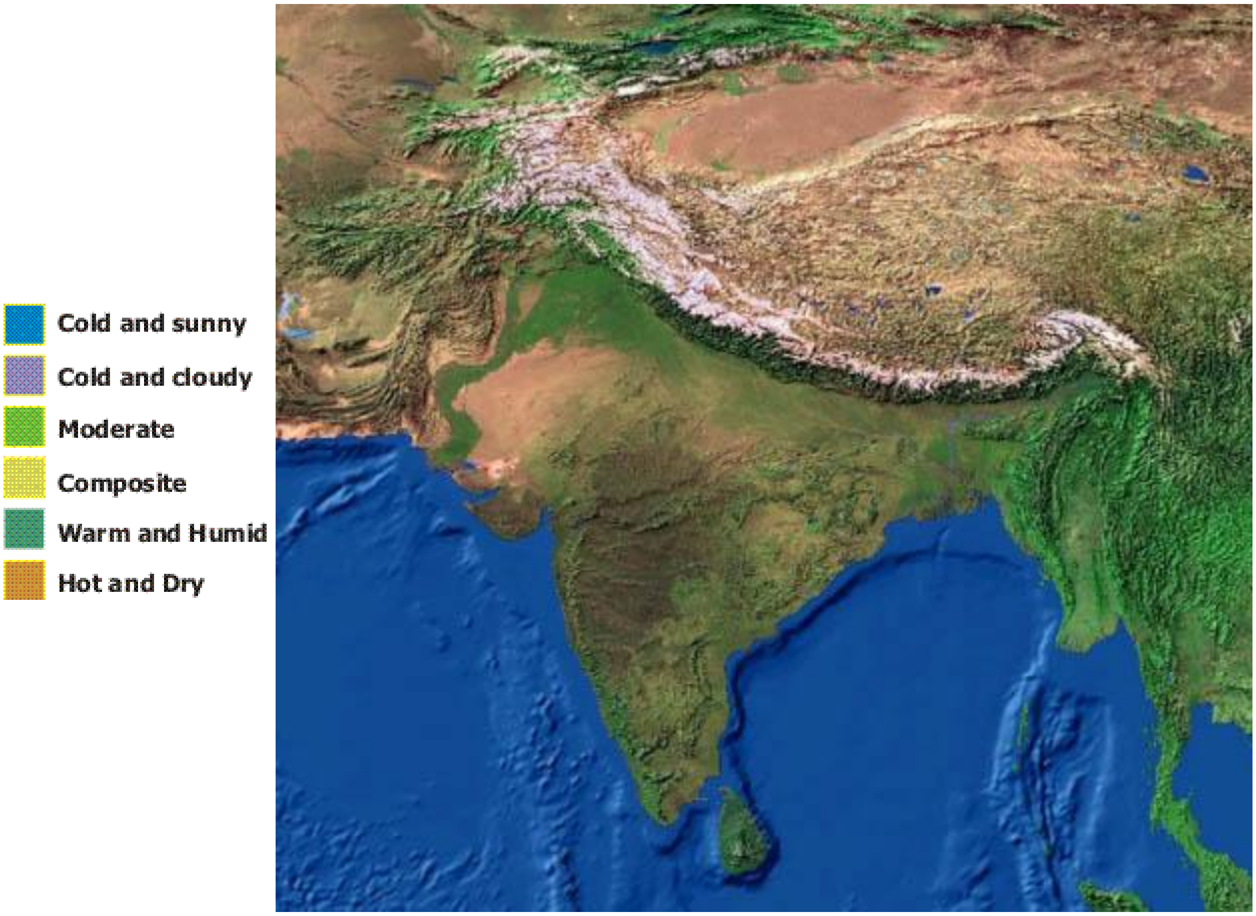
Composite

Composite (This applies, when six months or more do not fall within any of the other categories).

The composite zone covers the central part of India, such as New Delhi, Kanpur and Allahabad. The design criteria are more or less the same as for hot and dry climate except that maximizing cross ventilation is desirable in the monsoon period.

Some of the design features for buildings in this climate are:

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation and wall insulation
- Thicker walls
- Air locks and balconies
- Weather stripping
- Walls, glass surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees and ponds for evaporative cooling
- Dehumidifiers and desiccant cooling



ORIENTATION:

Orientation refers to the position and direction of a building on site, with respect to the path of the sun. Orientation strongly relates a building to the natural environment— the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle.

Energy conservation strategies relating to building orientation are:

- Maximizing north and south façade exposure for daylight harvesting to reduce lighting electrical loads
- Using southern exposure for solar heat gain to reduce heating loads in the heating season*
- Using shading strategies to reduce cooling loads caused by solar gain on south façades*

- Turning long façades toward the direction of prevailing breezes to enhance the cooling effect of natural ventilation
- Turning long façades in the direction parallel to slopes to take advantage of cool updrafts to enhance natural ventilation
- Shielding windows and openings from the direction of harsh winter winds and storms to reduce heating loads
- Orienting the most populated building spaces toward north and south exposures to maximize day lighting and natural ventilation benefit
- Determining building occupant usage patterns for public, commercial, institutional, or residential buildings, and how occupants will be affected by the building orientation, by time of day, on different exposures

FACTORS AFFECTING THE ORIENTATION:

The orientation of a building is influenced by following numerous environmental and built factors,

Sensory

- Thermal—solar exposure, wind direction, temperature
- Visual—varying daylight qualities in different locations and at different times of day
- Acoustical—direction of objectionable noises
- Environmental—smoke, dust, odors

Psychological

- Views
- Privacy
- Street activity

Local development patterns

- Street direction
- Spatial organization, land use, urban design
- Zoning
- Accessibility requirements—main/secondary entrances, parking

Other considerations

- Aesthetic
- Direction of storms
- Site conditions—topography, geotechnical, wetlands
- Site vegetation—mature trees
- View corridors, scenic easements

Designing for Building Orientation

- The designer must consider and prioritize all factors and site conditions affecting building orientation. For example, a building might have to take heed of multiple orientation factors depending on functional requirements: designing for cooling load or heating load. To take advantage of north–south day lighting, the building may be oriented along an east–west axis. But this may be counter to street lines and other site considerations. Orientation of the building entrance may have to respect street access, activity zones, and local urban design guidelines.
- For most regions, optimum façade orientation is typically south.* South-facing* glass is relatively easy to shade with an overhang during the summer to minimize solar heat gain. Light shelves also can work well with the higher sun in the southern exposure. North-facing* glass receives good daylight but relatively little direct isolation, so heat gain is less of a concern.
- East and west window orientations and horizontal orientation (skylights) all result in more undesired heat gain in the summer than winter. East and west sun glare is also more difficult to control for occupant comfort because of low sun angles in early morning and late afternoon.
- Wind will affect tall buildings more than low structures. Design for wind direction—admitting favorable breezes and shielding from storms and cold weather winds. Wind information is often available from airports, libraries, and/or county agricultural extension offices. In cold climates, locate pedestrian paths and parking lots on south and east sides of buildings to enable snow melting, but in southern climates locate these on the less sunny east or north sides of the building.

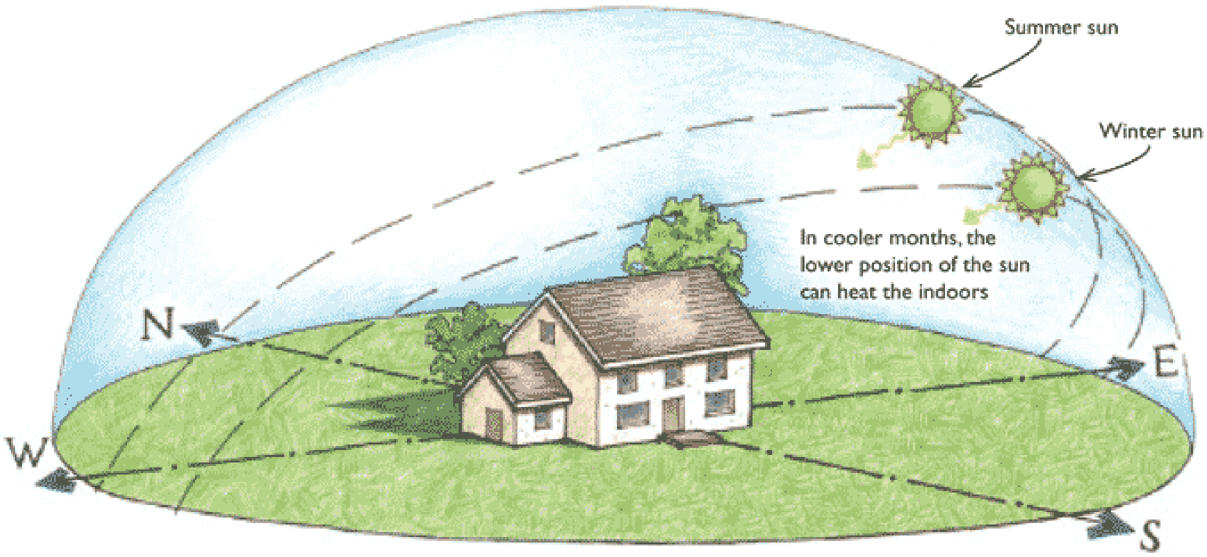


FIGURE-4 ORIENTATION OF THE BUILDING

- In temperate and northern climates, locate deciduous trees for south-side shading in the cooling season; in the heating season, the dropped leaves will permit desired solar gain. In urban settings, orientation may be strongly determined by local regulation, view easements, and urban design regulations. Be aware of unique local and site-specific conditions, such as lake or coastal exposures, effect of mountainous conditions, and special scenic easements.
- To minimize heat losses and gains through the surface of a building, a compact shape is desirable. This characteristic is mathematically described as the "surface-to-volume" ratio of the building. The most compact orthogonal building would be a cube. This configuration, however, may place a large portion of the floor area far from perimeter day lighting. Contrary to the cube, a building massing that optimizes day lighting and ventilation would be elongated along its east–west axis so that more of the building area is closer to the perimeter. Although this may appear to compromise the thermal performance of the building, the electrical load and cooling load savings achieved by a well-designed day lighting system will more than compensate for the increased surface losses.

Orientation criteria for Tropical climate:

In cold and temperate climates, long rectangular buildings, with their longer walls facing the winter sun are excellent solutions in terms of energy efficiency.

Obviously, in hot and tropical climates, the basic rule is different, and direct sun-exposure of the building should be avoided. In hot humid climates the long axis of the house should be oriented for cross-ventilation as well as for sun-protection...

Orientation and shape

Well oriented home, with a proper shape and properly placed windows can cut your energy bills by 30 percent or more.

We shouldn't forget the very basics about the sun's path in the sky: sun rises in the east and sets in the west and is higher in the summer sky and lower in winter. These basic facts, and the several particulars of each site and climate, should be taken into account when building a new home.

Hot climates

In hot climates (either humid or dry) with no winter heating needs, orientation should exclude sun exposure, and look for exposure to cooling breezes.

Orientation

In temperate and cold climates, in the north hemisphere, the longer walls of the building should face south (the north, in southern hemisphere countries). Southern exposure is crucial to get maximum solar benefits (Northern exposure in southern hemisphere courtiers).

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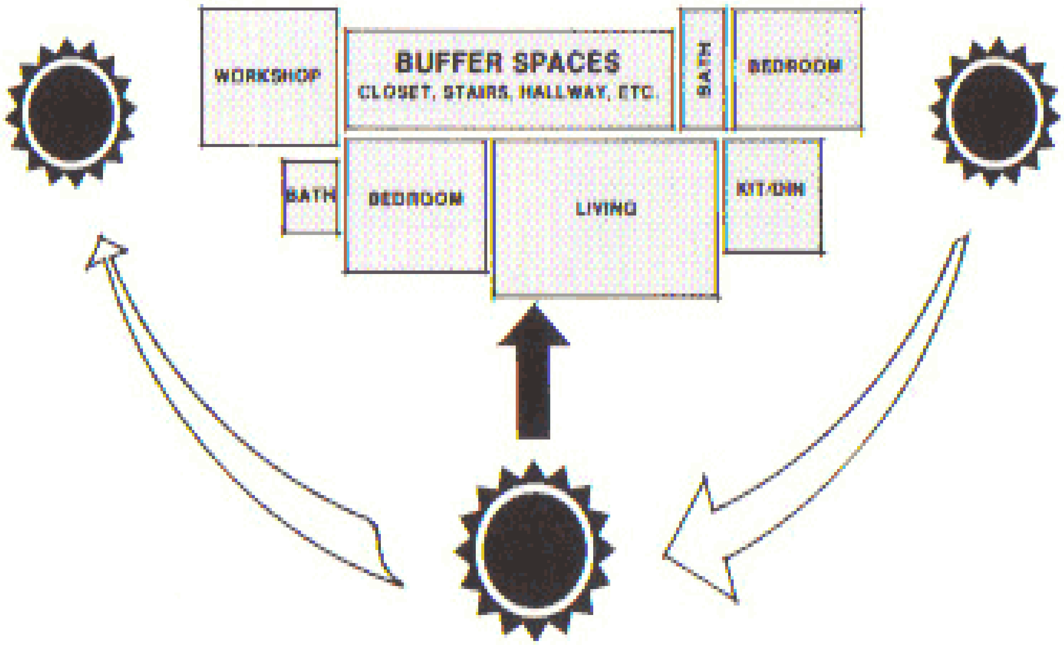
Image: a suggestion of



Building shape and axis

Rectangular-compact buildings, with their longer walls facing the winter low sun (to profit from it), are excellent solutions. In this case, the longer axis of the building (its ridge line) is oriented east/west.

Such orientation and shape allow maximum winter solar gains and will reduce unwanted summer sun (that will strike the east and the west sides of the house).

Most frequently used rooms facing the winter's low sun

The most used areas of the house should be located on the winter side of the building (cold and temperate climates), where sunlight can enter through conveniently located windows, high clerestories windows, or skylights.

South-exposure should incorporate well sized overhangs and the shadow of trees, to limit sun radiation in the hotter months.

Less frequently used rooms on the east/west short side of the house

Other rooms and divisions (namely garages, storage rooms, laundry rooms...) should be located on the home's east/west and shorter sides, where they can act as an extra thermal buffer.

Avoid glass in the east and west sides of the house, since it is a common cause of unwanted energy losses and glare.

Shading the house & landscape

Landscape features such as trees, hills or the predominant orientation of the winds are also important while considering the energy needs.

Study on the prevailing winds and their patterns in order to use windbreaks or walls to direct breezes into the house or to channel cold winter winds away from it is necessary.

In the summer, when the sun is higher in the sky, trees with adequate tree-top can help to shade the building and keep it cooler.