PRINCIPLES OFCLIMATOLOGY CODE - 18KP1G02

UNIT IV: Atmospheric Humidity: Evaporation – Condensation - Clouds: formation and Types - Air mass – Front -Precipitation Types - Classification of World Climates: Koppen's andThornthwaite's schemes.

Atmospheric Humidity

Within the atmosphere, water exists in all three forms: i) water vapor, ii) liquid (i.e. cloud droplets, raindrops), and iii) solid (i.e. ice crystals). Within the usual range of temperature and pressure, all three phases of water coexist (equilibrium). Out of which, the amount of water vapor present in the atmosphere is referred as humidity. There are five different methods to express humidity:

1. Absolute humidity
2. Mixing ratio
3. Vapor pressure
4. Relative humidity
5. Dew point

Absolute humidity: is the mass of water vapor in a given volume of air (usually grams/meter^3)

Since temperatures and pressures change constantly and they change from place to place, meteorologists usually prefer mixing ratio.

Mixing ratio: mass of water vapor in a unit of air compared to dry air. E.g., mass of water vapor (in grams)/mass of dry air (kilograms). Not affected by changes in temperature or pressure. Also known as specific humidity.

Vapor pressure: that part of the total atmospheric pressure attributable to water vapor. In chemistry we would call this the partial pressure. We could also measure, or calculate, the partial pressures of all the other gasses in the atmosphere (e.g., N_2, O_2, Ar, CO_2, etc.) - they should all add to the total atmospheric pressure. This is temperature dependent.

We can actually measure the number of molecules (by way of the pressure) leaving water, or entering water. When the number of molecules leaving water is the same as the number entering, we call that saturation, and the pressure is the saturation vapor pressure.

(Pressure: Pressure is defined as a force per unit area. That force is caused by air molecules striking your skin because they are in motion. That's why the air pressure is lower at great altitudes - fewer air molecules. Air pressure is dependent on the kinetic energy of the air molecules (temperature), the mass of the molecules, and gravity. In meteorology we use units of millibars to measure air pressure. Sea level is ~1013 mb.)

Relative humidity: the ratio of the air's actual water vapor content compared with the amount of water vapor required for saturation (at that temperature and pressure). In effect, its a measure of how close to being saturated the air is.

The amount of water vapor required to saturate air at various temperatures is variable. That's why on a very cold day the relative humidity may be close to 100 percent but it doesn't feel like a muggy 70 percent relative humidity day when it's 95°F outside.

If the amount of water vapor is constant:

Increasing temperature decreases RH
Decreasing temperature increases RH

If temperature is held constant:

Adding water vapor increases RH
Removing water vapor decreases RH

This is why usually relative humidity higher at night. Since relative humidity is easily changed by temperature or amount of water vapor.

Dew Point: temperature to which the air would have to be cooled, without changing pressure or moisture content, to reach saturation. The drier the air, the more is must be cooled to reach saturation.

High dew points indicate a large amount of moisture in the air. Low dew points indicate small amounts of moisture in the air.

Frost (hoar frost, white frost) is caused when the temperature is below freezing and the air is saturated with moisture.

Dew points are directly related to the amount of moisture in the air, so is a much better indicator of humidity.

Dew point depression, $T_{dd} = T - T_d$
Small T_{dd} indicate high RH
Large T_{dd} indicate low RH.

Evaporation

The amount of humidity found in air varies because of a number of factors. Two important factors are evaporation and condensation. At the water/atmosphere interface over our planet's oceans large amounts of liquid water are evaporated into atmospheric water vapor. This process is mainly caused by absorption of solar radiation and the subsequent generation of heat at the ocean's surface. Evaporation is the process by which water changes from a liquid to a gas or vapor. Evaporation is the primary pathway that water moves from the liquid state back into the water cycle as atmospheric water vapor. Studies have shown that the oceans, seas, lakes, and rivers provide nearly 90 percent of the moisture in the atmosphere via evaporation, with the remaining 10 percent being contributed by plant transpiration. Heat (energy) is necessary for evaporation to occur. Energy is used to break the bonds that hold water molecules together, which is why water easily evaporates at the boiling point (212° F, 100° C) but evaporates much more slowly at the freezing point. Net evaporation occurs when the rate of evaporation exceeds the rate of condensation. A state of saturation exists when these two process rates are equal, at which point the relative humidity of the air is 100 percent. Condensation, the opposite of evaporation, occurs when saturated air is cooled below the dew point.

Significance of Evaporation

Evaporation from the oceans is the primary mechanism supporting the surface-to-atmosphere portion of the water cycle. After all, the large surface area of the oceans (over 70 percent of the Earth's surface is covered by the oceans) provides the opportunity for large-scale evaporation to occur. On a global scale, the amount of water evaporating is about the same as the amount of water delivered to the Earth as precipitation. This does vary geographically, though. Evaporation is more prevalent over the oceans than precipitation, while over the land, precipitation routinely exceeds evaporation. Most of the water that evaporates from the oceans falls back into the oceans as precipitation. Only about 10 percent of the water evaporated from the oceans is transported over land and falls as precipitation. Once evaporated, a water molecule spends about 10 days in the air. The process of evaporation is so great that without precipitation runoff, and groundwater discharge from aquifers, oceans would become nearly empty.

Process of Condensation

The process of change of state from water vapour to water is known as condensation. It takes place due to cooling of moist air upto dew point. It is the temperature at which saturation takes place and water vapour starts changing into water droplets. Some kind of cooling process is generally required to initiate and sustain condensation or sublimation. In general, the cooling is associated with two broad processes:

Adiabatic processes:

a. Rising and expanding air, resulting into clouds, because of
   - (i) Convection
   - (ii) Convergence of winds
   - (iii) Convergence of air masses
   - (iv) Orographic lifting

b. A decrease in barometric pressure at surface, may result into fog

Non-adiabatic or Diabatic processes

a. Cooling due to loss of heat by radiation. Direct radiation from moist air may result into fog or clouds.

b. Contact cooling with cold surface (conduction). Dew, frost, or fog may form.

c. Contact cooling associated with the movement of air across a cold surface (Advection).

d. Mixing of warm air with colder air. It depends on sufficient moisture and cooling upto dew point. Fog and clouds will develop on hygroscopic nuclei.

Forms of Condensation

Freezing point is the temperature at which a liquid becomes a solid. The dew point is the temperature at which the air is saturated with respect to water vapor over a liquid surface. When the temperature is equal to the dew point then the relative humidity is 100%. The air at any given temperature is capable of holding a certain amount of water vapor. When that maximum amount of water vapor is reached, that is referred to as saturation. This is also known as 100% relative humidity. When this is achieved, the temperature of the air has reached the dew point temperature. It is also called the condensation temperature where the condensation begins in the form of clouds, dew, fog, mist, frost, rain, or snow. The forms of condensation can be classified on the basis of temperature at which the dew point is reached. i.e lower than the freezing point or higher than the freezing point.

Dew: During night time surface cooling occurs due to radiation from earth surface. When, the cooling is so intense that the temperature of the moist air touching the surface falls below dew point. It results into dew formation or water droplets formation on features such as – stones, blades of grass and leaves of plants. The favourable conditions required for this non adiabatic cooling of surface by radiation includes long nights, clear sky, calm and moist air.

Frost: Frost occurs when the dew point of air drops below the freezing point. It means white frost is result of sublimation or crystallization or deposition that is direct transformation from water vapour to ice crystal. The favourable conditions for frost formation are the same as for dew except that the dew point is below freezing point.

Fogs are mainly formed near surface by nonadiabatic cooling like radiation, conduction and mixing of airs and air masses. Fog represents microscopic water droplets suspended in air with base at or near surface. It reduces horizontal visibility to less than one km. Fog has great similarity with clouds only difference is of location and process of formation. Clouds are result of adiabatic cooling caused by lifting processes. Generally, following types of fogs are predominant.

Radiation Fog: During night time surface cooling takes place due to loss of heat by terrestrial radiation. This cooling results into dew point temperature in adjacent moist air. Light winds, clear sky and moist air are the favourable conditions required for radiation fog Radiation fog occurs on lands instead of seas, and especially in interior lands and valleys.

Advection Fog: Advection fog develops due to the horizontal movement of moist and warm air over a cold surface. It becomes chilled due to contact cooling and achieves dew point and forming a blanket of fog. The ideal locations for their occurrence are sea coasts, large inland water bodies like and the convergence areas of warm and cold ocean currents.

Upslope Fog: Upslope fog is produced due to cooling by adiabatic expansion of upslope rising air. It is also called hill fog or orographic fog.

Evaporation Fog: It occurs when a cold air mass moves over a warm water surface. As the cold air comes in contact with warm water, evaporation takes place due to heating. After saturation, condensation occurs in the form of steam fog in cold air. Evaporation fogs are also known as 'steam fogs'. Usually, evaporation fog is very shallow. In Arctic and Antarctic areas, it appears as 'sea smoke' when very cold air moves over the warm waters along the edge of ice.

Frontal Fog: Fogs formed along the front of two different types of air masses are known as frontal fogs. Warm and moist air rises on frontal slope and due to contact and adiabatic cooling gets condensed as fog.

CLOUDS

Clouds represent a visible aggregate of minute droplets of water, or tiny ice crystals or a mixture of both. Clouds are usually product of condensation or sublimation caused by lifting process or adiabatic cooling, They are very useful indicators of various weather phenomena and flying conditions. The International Cloud Atlas WMO (World Meteorological Organisation, 1956) has classified the infinite variety of clouds into ten main types of genera on the basis of height. High clouds (base above 6 km), middle clouds (2-6 km) and low clouds (base below 2 km).

High Clouds

The high clouds are usually found in the altitude zone of 6 to 12 km from the earth surface. Three cloud types, namely cirrus, cirrocumulus and cirrostratus constitute the family of high clouds. All these clouds are composed of mainly ice crystals because at greater heights amount of moisture is less and dew point is achieved at low temperatures in supersaturated situation. They appear white. These high clouds are generally associated with fair weather conditions, but occasionally warn of impending stormy weather.

a) Cirrus: These are detached clouds composed of white, delicate, ice filaments. These clouds have a fibrous appearance like ‘mares tails’ or a silky sheen or both. Irregular arrangement of these clouds indicates fair weather conditions. But occasionally, when arranged systematically in bands or connected with cirrostratus and altostratus, they indicate weather disturbance like a storm.

b) Cirrostratus: These clouds represent a thin, milky or whitish sheet of fibrous appearance covering the sky totally or partially. They are composed of tiny ice crystals. They are easily recognized when they produce halo around moon or sun. They usually indicate about approaching storm.

c) Cirrocumulus: These clouds are patches of small white flakes or small globules which are arranged in ripples or wavelike form. Wavelike regular pattern forms a ‘mackerel sky’. These clouds are least common in high clouds.

Middle Clouds

The middle clouds are in the altitudinal range of 2 to 6 km and have prefix alto in their names.They are composed of water droplets, ice crystals or both.

a) Altocumulus: These clouds consist of layer or patches of white or grey globular clouds, generally arranged in fairly regular pattern of lines, groups or waves. They are generally composed of supercooled water droplets. Altocumulus clouds differ from cirrocumulus as cirrocumulus clouds are smaller and less dense. They differ from stratocumulus because stratocumulus clouds are larger and have shadows.

b) Altostratus: Altostratus clouds appear as fibrous sheet of gray or blue-grey, covering the sky totally or partially. They are thicker than the higher cirrostratus. They are usually associated with warm fronts. These clouds are associated with infrequent precipitation either in the form of light snow or drizzle.

Low Clouds

Stratus, stratocumulus, nimbostratus cumulus and cumulonimbus clouds come under the category of low clouds. Cumulus and cumulonimbus clouds have their base in the range of low clouds, but they extend upward into the middle or higher altitude. On the basis of height of their base they come under the category of low clouds, but some scholars classify them in a separate category, as clouds of vertical development also.

a) Stratus: Stratus clouds generally represent grey coloured uniform layer covering much of the sky. They are composed of many uniform layers. These are dense and low-lying fog-like clouds. The uniform of these clouds indicate a temperature inversion.

b) Stratocumulus: These are large globular masses or rolls of grey or whitish or both. These globular masses are usually arranged in lines, groups or waves. They are usually associated with fair weather but occasional rain and snow may occur.

c) Nimbostratus: The Latin word nimbus means 'rain cloud' and stratus stands for layered. Therefore, these are rainy clouds. These clouds bring light to moderate rainfall for long durations over widespread areas. These are thick very low clouds which bring complete darkness and precipitation. The rain, snow and sleet are associated with these clouds but are never accompanied by thunder, lightning or hail.

d) Cumulus: These clouds are dense, widespread, dome-shaped like a cauliflower and have flat bases. These clouds predominantly represent the top of the effective convective currents. The vertical extent depends on the power of vertical currents and amount of release of latent heat of condensation. If both are intense they may grow to emerge as cumulonimbus clouds. The cumulus clouds of limited vertical extent usually represent fair weather. Convergence of a large group of cumulus clouds becomes stratocumulus and inversely breaking apart of stratocumulus forms cumulus.

e) Cumulonimbus: These clouds show great vertical extent, from a few hundred meters above the ground upward to 14 to 18 km. They have a flat base and flat spreading out top as an 'anvil head' of cirrus. These are dark and dense thunderstorm clouds associated with heavy rain, snow and hail (occasionally) usually accompanied by lightning, thunder and gusty winds. These clouds are common in equatorial low pressure belts and in tropical cyclones.

Distribution of Clouds: During summer of northern hemisphere, due to monsoon onset and shifting of pressure belts, high cloudiness is observed over southeast Asia, West Africa, northwestern South America and low cloudiness over the southern hemisphere landmasses, southern Europe, North Africa and the Near East. In the northern winter, the tropical areas of southern hemisphere experience high cloudiness.

AIR MASSES AND FRONTS

Introduction

An air mass is defined as a large body of air with fairly uniform temperature and moisture characteristics. It can be several kilometers across and extend upward to the top of the troposphere. A given air mass is characterised by a combination of surface temperature, environmental temperature lapse rate and surface specific humidity from extreme hot to icy cold as well as moisture content. There is an uneven distribution of solar radiation on the earth's surface. The amount of insolation is more in the tropical regions as compared to temperate and polar regions. These zones have different types of air masses with different thermal characters. An air mass is often approximately homogeneous in its horizontal extent with reference to temperature, humidity and air pressure. Although temperature, humidity and pressure change vertically across the length and breadth of the air mass, there is very little change in horizontal direction.

Genesis and Source Regions

The idea of air mass was first of all introduced into the subject of meteorology by Norwegian scientist, meteorologist Bergeron in 1928. Favourable conditions for the development of air masses are the areas of subsiding and divergent air and these areas lie in the semi-permanent high pressure belts. In the belt of low pressure along the equator, however, there is a weak equatorial convergence and stagnated air produce equatorial air masses, the development of the high pressure is seasonal.

Favorable region: Air masses originate in the areas where conditions promote the development of vast bodies of uniform and horizontal air. Such areas are homogeneous and physically large. The source region should have uniform and flat topography with calm conditions. Also in such areas there must be a sufficient stagnation of the atmospheric circulation so that upper air gets the properties of the underlying surface.

Unfavorable region: Areas of uneven topography or where the land and water are present is the unfavorable for the formation of air masses. Similarly, areas with convergent winds cannot serve as the source region.

The important source regions of the world are:

1. The snow covered arctic plains of N. America, Europe, Asia and Antarctica,

2. The sub-tropical and tropical oceans,

3. The Sahara desert of Africa, and

4. The continental interiors, Asia, Europe and N. America.

Classification of Air Masses

Trewartha (1967) conducted a study of air masses based on geographical position. The air masses can be classified into two main categories:

(1) Tropical air mass (T) and (2) Polar air mass (P)

He emphasised that the Equatorial, Arctic and Antarctic air masses may be taken as the modified form of tropical and polar air masses. These air masses can be further sub-divided on the basis of their source regions. Small letters are used to indicate continental and maritime air masses by ‘c’ and ‘m’, respectively.Continental and maritime air masses are found over land and sea, respectively. Continental air masses are dry, whereas maritime air masses contain large amount of moisture. Based on the source region and nature of the surface, the air masses can be divided into four categories:

(a) Continental Tropical air mass (cT)

- The source-regions of the air masses include tropical and sub-tropical deserts of Sahara in Africa, and of West Asia and Australia.
- These air masses are dry, hot and stable and do not extend beyond the source.
- They are dry throughout the year.

(b) Maritime Tropical air mass (mT)

- The source regions of these air masses include the oceans in tropics and sub-tropics such as Mexican Gulf, the Pacific and the Atlantic oceans.
- These air masses are **warm, humid and unstable.**
- The weather during winter has mild temperatures, overcast skies with fog.
- During summer, the weather is characterized by high temperatures, high humidity, cumulous clouds and convectional rainfall.

(c) Continental Polar air mass (cP)

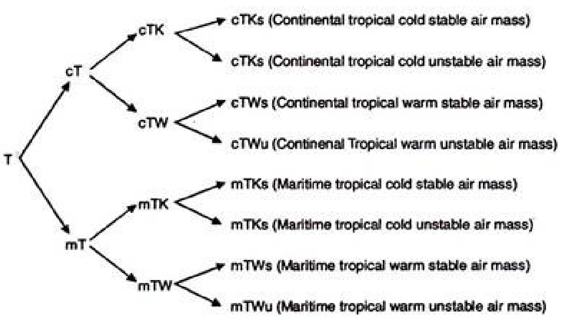
- Source regions of these air masses are the Arctic basin, northern North America, Eurasia and Antarctica.
- These air masses are characterized by **dry, cold and stable conditions.**
- The weather during winter is frigid, clear and stable.
- During summer, the weather is less stable with lesser prevalence of anticyclonic winds, warmer landmasses and lesser snow.

(d) Maritime Polar air mass (mP)

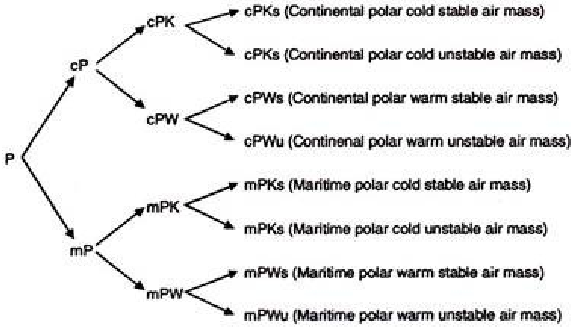
- The source region of these air masses are the oceans between **40° and 60° latitudes**.
- These are actually those continental polar air masses which have moved over the warmer oceans, got heated up and have collected moisture.
- The conditions over the source regions are **cool, moist and unstable**. These are the regions which cannot lie stagnant for long.
- The weather during winters is characterized by high humidity, overcast skies and occasional fog and precipitation.
- During summer, the weather is clear, fair and stable.

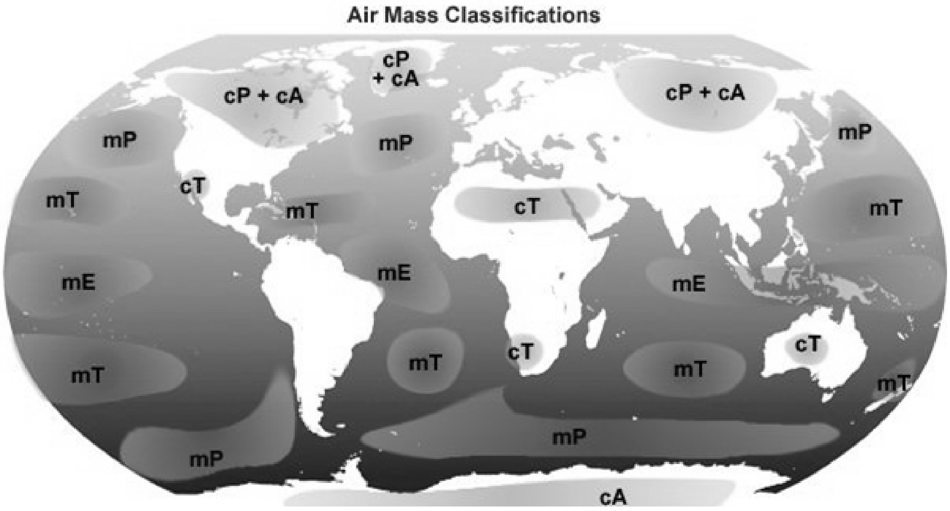
Apart from the above classification, thermodynamic and mechanical modifications can also be considered. Capital letter 'K' stands for cold and letter ' W' stands for warm. Similarly small letter 'u' stands for unstable air mass and letter's' stands for stable air mass. The air masses can be classified into the following categories by using all letters:

(1) Tropical Air Mass (T):



(2) Polar Air Mass (P):





AIR FRONTS

Different air masses originate and move out from different sources, but they all eventually meet in a region of convergence zone of low pressure. At the interface zone, both cold and warm air masses meet, and it results only marginal mixing. The air masses primarily retain their own characteristics in the upper layers, it is unaffected and un-disturbed. The instability and turbulence occur in the lower atmosphere, near to the earth surface. These phenomena of meeting and mixing of different air masses by called air fronts. The ascent and convergence of fronts results in condensation and precipitation.

Frontal Formation

The process of formation of a front is known as Frontogenesis, and dissipation of a front is known as Frontolysis . Frontogenesis involves convergence of two distinct air masses. Frontolysis involves overriding of one of the air mass by another. In northern hemisphere Frontogenesis (convergence of air masses) happens in anti-clockwise direction and in southern hemisphere, clockwise direction. This is due to Coriolis effect. Mid-latitude cyclones or temperate cyclones or extra-tropical cyclones occur due to frontogenesis.

General Characteristics of Fronts

The temperature contrast influences the thickness of frontal zone in an inversely proportional manner, i.e., two air masses with higher temperature difference do not merge readily. So the front formed is less thick.With a sudden change in temperature through a front, there is a change in pressure also. Front experiences wind shift, since the wind motion is a function of pressure gradient and Coriolis force.

Classification of Fronts

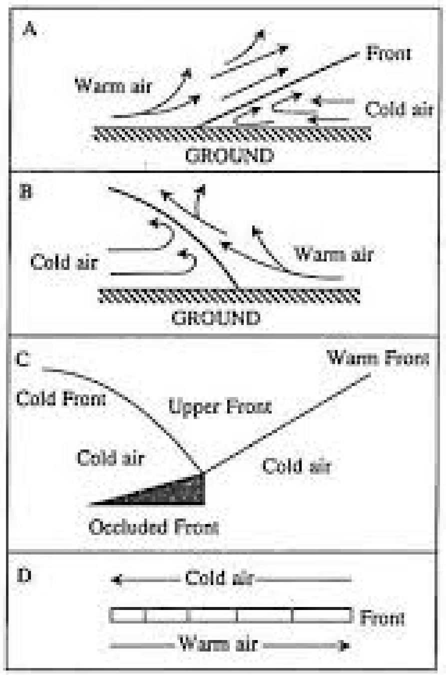
Based on the mechanism of frontogenesis and the associated weather, the fronts can be studied under the following types**.**

A. Warm Front: It is a sloping frontal surface along which active movement of warm air over cold air takes place (warm air mass is too weak to beat the cold air mass). Frontolysis (front dissipation) begin when the warm air mass makes way for cold air mass on the ground, i.e. when the warm air mass completely sits over the cold air mass.As the warm air moves up the slope, it condenses and causes precipitation but, unlike a cold front, the temperature and wind direction changes are gradual. Such fronts cause moderate to gentle precipitation over a large area, over several hours.

B. Cold Front: Such a front is formed when a cold air mass replaces a warm air mass by advancing into it or that the warm air mass retreats and cold air mass advances (cold air mass is the clear winner). In such a situation, the transition zone between the two is a cold front. Cold front moves up to twice as quickly as warm fronts. Frontolys is begin when the warm air mass is completely uplifted by the cold air mass. The weather along such a front depends on a narrow band of cloudiness and precipitation. Severe storms can occur. During the summer months thunderstorms are common in warm sector. In some regions like USA tornadoes occur in warm sector.

C. Occluded Front: Occlusion: Meteorology a process by which the cold front of a rotating low-pressure system catches up the warm front, so that the warm air between them is forced upwards.Such a front is formed when a cold air mass overtakes a warm air mass and goes underneath it. Frontolysis begin when warm sector diminishes and the cold air mass completely undertakes the warm sector on ground.

Thus, a long and backward swinging occluded front is formed which could be a warm front type or cold front type occlusion. Weather along an occluded front is complex—a mixture of cold front type and warm front type weather. Such fronts are common in west Europe.



D. Stationary Front: When the surface position of a front does not change (when two air masses are unable to push against each other; a draw), a stationary front is formed. The wind motion on both sides of the front is parallel to the front. Warm or cold front stops moving, so the name stationary front. Once this boundary resumes its forward motion, becomes a warm front or cold front, where Cumulonimbus clouds are formed. Overrunning of warm air along such a front causes frontal precipitation. Cyclones migrating along a stationary front can dump heavy amounts of precipitation, resulting in significant flooding along the front.

PRECIPITATION - FORMS AND TYPES

Introduction

Clouds as aggregates of water droplets and ice crystals are a form of condensation and a precondition for precipitation. The process of precipitation represents falling down of this condensed material in the form of rain, snow, hail, sleet or some other forms. Sometimes precipitation takes place from clouds but it gets evaporated in the atmosphere and fails to reach at surface. Therefore, clouds themselves are not enough for precipitation. The process of precipitation depends on fulfillment of certain conditions mainly size of the droplet. a typical rain drop has size about 100 times of that of the average size of cloud droplet and its volume is a million times of cloud droplet. Thus, millions of tiny cloud droplets constitute a single raindrop.

Forms of Precipitation

Due to spatial and temporal variations of atmospheric conditions, a variety of forms of precipitation occur. Precipitation occurs in many forms or phases, such as:

Liquid precipitation: Drizzle and rain,

Freezing precipitation: freezing drizzle, freezing rain and sleet

Rain: Rain is the most common form of precipitation. The term is used for raindrops which have diameter in the range of 0.5 to 5 mm. Larger than this range raindrop fail to reach surface because while descending, the frictional drag exceeds the surface tension and large droplets breaks apart into smaller drops. In tropical areas, rain associated with cumulus clouds, in temperate areas, it is by cumulonimbus and nimbostratus clouds. In temperate areas and in cumulonimbus clouds most of the rainfall begins.

Drizzle: Drizzle represents light liquid precipitation in the form of uniform water droplets of diameter less than 0.5 mm. It is usually associated with stratus, nimbostratus and stratocumulus clouds. Precipitation in the form of drizzle continues for several hours or occasionally for days, but rate is about a millimeter per day or less. It is the most frequent form of precipitation over subtropical oceans.

Freezing Rain and Freezing Drizzle: Freezing rain occurs when raindrops pass through the subfreezing air near the surface, the raindrops become supercooled and freeze when they strike on surface features like plants and power lines etc. Similarly, in case of small size droplets (less than 0.5 mm diameter), this supercooling produces freezing drizzle.

Snow: Snow represents precipitation in the solid form of water i.e. as white grains of ice or snowflakes. Snowfall takes place from ice clouds. In winter season, under subfreezing temperatures ice crystals fall from clouds and reach the surface as snow without melting.

Sleet: In Commonwealth countries, including Canada, precipitation composed of rain and partially melt snow is known as sleet. Sleet occurs in the presence of an above-freezing air layer overlying a subfreezing layer near the surface. Sleet is predominantly a wintertime phenomenon, in middle and higher latitudes.

Snow Pellets: Snow pellets consist of small, white and opaque compact grains of ice. The grains are mostly spherical and have a diameter of 2-5 mm. Snow pellets are also known as soft hail, the grains are brittle and bounce and break after striking surface. They are commonly associated with convective storms of winter and spring seasons.

Hail: Hail represents precipitation in the form of hard and rounded pellets of ice, mostly diameter between 1 cm and 5 cm. Strong, repeated ascend and descent as convective currents in cumulonimbus clouds results in the formation of nearly concentric layers of differing densities and degrees of opaqueness. Hailstones are common in violent summer thunderstorms.

Types of Precipitation

The process of adiabatic cooling plays the most significant role in process of condensation, especially cloud formation and precipitation. The atmospheric instability is enhanced by three mechanisms which force the moist and warm air to ascend above the level of condensation and form clouds. The three mechanisms resulting into lifting of warm and moist air are:

(i) Thermal heating of surface and adjacent air and formation of convectional currents;

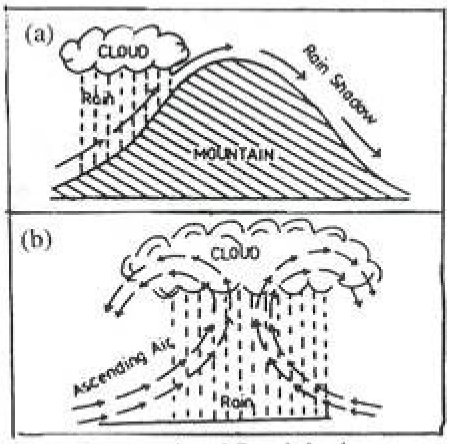
(ii) Forced uplift of air over an orographic barrier; and,

(iii) Frontal ascent or wedging associated with convergence of different types of air masses in mid-latitude and in tropical areas formation of low pressure cyclonic disturbances.

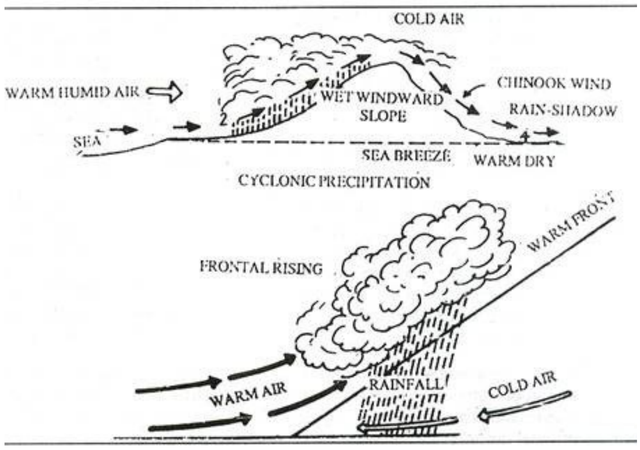
It is noteworthy that all these three mechanisms of lifting are not necessary independent of one another rather more than one functions, simultaneously. But the type of precipitation is identified on the basis of dominant mechanism. The three major types of precipitation are following:

Convectional Precipitation: In this type of precipitation, the principal lifting force for the ascending warm and moist air is thermal convection produced by heating of surface and adjacent air by solar radiation. The two pre-conditions for convectional precipitation are: (i) Intense heating of the surface by insolation so that the air in contact gets heated, expands and rises up; and (ii) Ant supply of moisture to the ascending air to maintain high relative humidity. These conditions result into upward movement of warm and moist air which initially cools at dry adiabatic rate. The adiabatic cooling increases relative humidity and saturation stage or level of condensation is achieved at some height. Further updraft of air occurs at wet adiabatic rate and cloud formation takes place. Which results into heavy showers hailstones, drizzle and rain in case of cumulus clouds. Thus, convectional precipitation is basically a warm weather phenomenon.

Orographic Precipitation: Orographic precipitation occurs when mountains or physical barriers force the flow of air to rise and cool adiabatically. It may results into condensation and precipitation as rain or snow, depending on level of instability. This type of precipitation predominantly occurs on the windward sides and leeward sides generally remain rain shadow areas. On the windward side, adiabatic cooling of warm and moist air results into condensation and precipitation, but after crossing the crest no lifting takes place and air becomes dry, asmost of the moisture is already precipitated.



(a) Convectional Precipitation
(b) Orographic Precipitation



c. Frontal and Cyclonic rainfall

Therefore, the descending air gets adiabatically heated due to compression. Afterwards, condensation and precipitation remain negligible or low on the leeward side and it is called rain shadow region The location of line of maximum rainfall depends on latitude, distance from sea, moisture content in air, type of slope, season and exposure. It is noteworthy that orographic precipitation is not entirely due to the direct forced uplift by the physical barrier but it involves indirect effects of day time convective cells and cyclones also.

Frontal and Cyclonic Precipitation

This type of precipitation is associated with tropical and temperate cyclones and fronts. In temperate regions, when two different types of air masses with sharp contrasts in temperature and humidity come together by converging forces, zone of mixing or frontogenesis or front formation takes place. Lifting mechanism at fronts produces instability, resulting into condensation and precipitation. Extra-tropical cyclones or temperate cyclones or wave cyclones originate at polar fronts. These fronts have a great variety of clouds and also a great variety of forms of precipitation

Along a cold front, the cold air invades the warm-air zone. The colder air mass being denser remains in contact with surface and forces the warmer air mass to rise over it. Depending upon level of instability cumulonimbus clouds and thunderstorms may develop along a line known as squall line. The precipitation associated with cold front is confined to narrow zone and is of short duration at a particular place.

In case of warm front, the warmer and moist air is forced to rise, as if it were ascending a long and gentle slope. Contact cooling and adiabatic cooling produces instability and precipitation. On the basis of level of instability of the slowly rising warm and moist air, convective clouds or even cumulonimbus thunderstorms may occur. Nimbostratus and altostratus clouds are also common at lower levels. Although the precipitation is moderate to gentle, it is widespread and of longer duration.

Precipitation

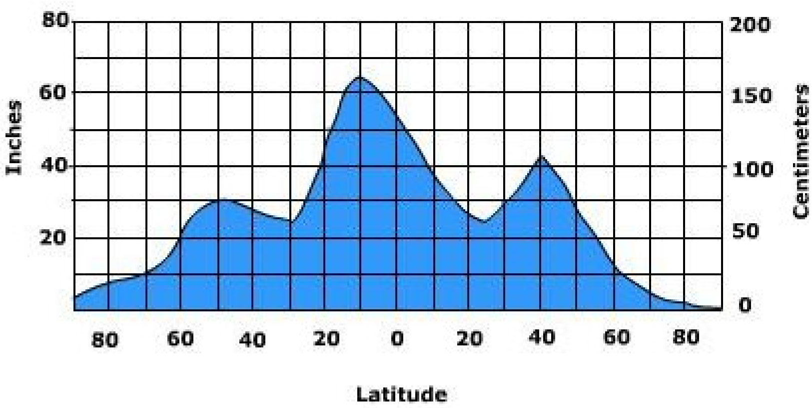
Gaseous
1. **Dew**
2. **Fog**
3. **Smog**

Liquid
1. **Drizzle**
2. **Mizzle**
3. **Rainfall**
    1. **Orographic rain**
    2. **Cyclonic rain**
    3. **Convectional rain**
    4. **Advectional rain**

Solid
1. **Snowfall**
2. **Hailstorm**
3. **Sleet**

Distribution of Precipitation

The distribution of precipitation in the world is highly uneven. The average annual precipitation in the world is 97 cm. At Mawsynram and Cherrapunji the average annual precipitation is 1,221and 1,102 cm respectively. On the other hand, about one-third area of landmasses is arid and semi-arid in the form of subtropical hot deserts and cold deserts. The equatorial zone receives maximum rainfall with a mean annual of 175 to 200 cm. The monsoon region also receives more than world average rainfall, mainly in summer season. For instance, average annual rainfall in India is 118 cm. The mid latitude region also receives high precipitation due to onshore westerlies and temperate cyclones associated with polar fronts. On shore, westerlies also result into winter precipitation in Mediterranean climate regions. The subtropical high pressure and polar zones receive minimum precipitation. The hot deserts of subtropics receive less than 25 cm average annual precipitation. Likewise, polar areas are cold deserts, with limited precipitation mainly as snowfall.



CLASSIFICATION OF WORD CLIMATE
KOPPEN'S AND THORNTHWAITE'S

Introduction

Thus climate may be defined simply as 'average weather'. The term climate denotes a description of aggregate weather conditions it also includes common deviations from the average as well as the extreme. Therefore, climate may be defined as the sum of all statistical weather information of a particular area during a specified interval of time, usually several decades. The World Meteorological Organization has suggested a standard period of 31 years for calculating the climate average of different weather elements. In general, climatic elements include temperature, precipitation, humidity, sunshine, wind direction and velocity and potential evapotranspiration.

Classification of Climates

The first map of mean monthly temperature over the earth had been published by Dove (1848) and the earliest modern studies in climatic classification utilizing climatic data sought to redefine the original zones of the Greeks in terms of the of measured values. In connection with a special study on the evolution of plants from the geologic past through fossil records de Condole (1875) employed a scheme of classification comprising six vegetation division. In 1884 Koppen published an article with a map dividing the earth's surface into temperature belts. They were defined in terms of the number of month of the year below or above certain specified mean temperatures.

Koppen's Climatic Classification

The concepts of devising climate classes that combine temperature and precipitation characteristics, but of setting limits and boundaries fitted into known vegetation and soil distributions were actually carried out in 1918 by Dr. Wladimir Koppen of the University of Graz, in Austria. Koppen was both a climatologist and a plant geographer, so his main interest lay in finding climate boundaries that coincided approximately with boundaries between major vegetation types. Although he was not entirely successful in achieving his goal, his climate system has appealed to geographers because it is strictly empirical and allows no room subjective decisions.

Basis For The Classification: The Koppen system is strictly empirical. This is to say that each climate is defined according to fixed values of temperature and precipitation, computed according to the averages of the year or of individual months. In such a classification, no concern whatsoever is given to the causes of the climate in terms of pressure and wind belts, air masses, fronts, or storms. It is possible to assign a given place to a particular climate sub-group solely on the basis of the records of the temperature and precipitation of that place, provided, of course, that the period of record is long enough to yield meaningful averages. Air temperature and precipitation are the most easily obtainable surface weather data, requiring only simple equipment and a very elementary observer education. A climate system based on these data has a great advantage, in that the area covered by each sub-type of climate can be delineated (outlined, profiled) for large regions of the world.

Limitations: As with any regional classification, this system is not universally applicable. It utilizes, for example, only the data or mean monthly temperature and precipitation. There is not provision for variations in the strength or constancy of winds, temperature extremes, precipitation intensity and range, amount of cloud cover, or the net radiation balance. Its greatest inadequacies perhaps lie in its application to humid dry boundaries, and it should not be considered for land management and planning purposes, where more precise and varied factors should be utilized.

Advantages: Despite these and other disadvantages, this system has been used mainly because of four reasons that have special value.

1. It has precise definitions that can be applied easily to standardize data that are available for locations throughout the world.
2. There is a reasonable correlation globally with major vegetation regions.
3. It requires a minimum amount of calculation.
4. It is widely used in educational circles throughout the world.

The classification was subsequently revised and extended by his students to become the most widely used of climatic classifications for geographical purposes.

13.3 MAJOR GROUPS
Five major climate groups are designated by capital letters as follows:

A–Tropical Rainy Climate: Average temperature of every month is above 64.4oF (18oC). These climates have no winter season. Annual rainfall is large and exceeds annual evaporation.

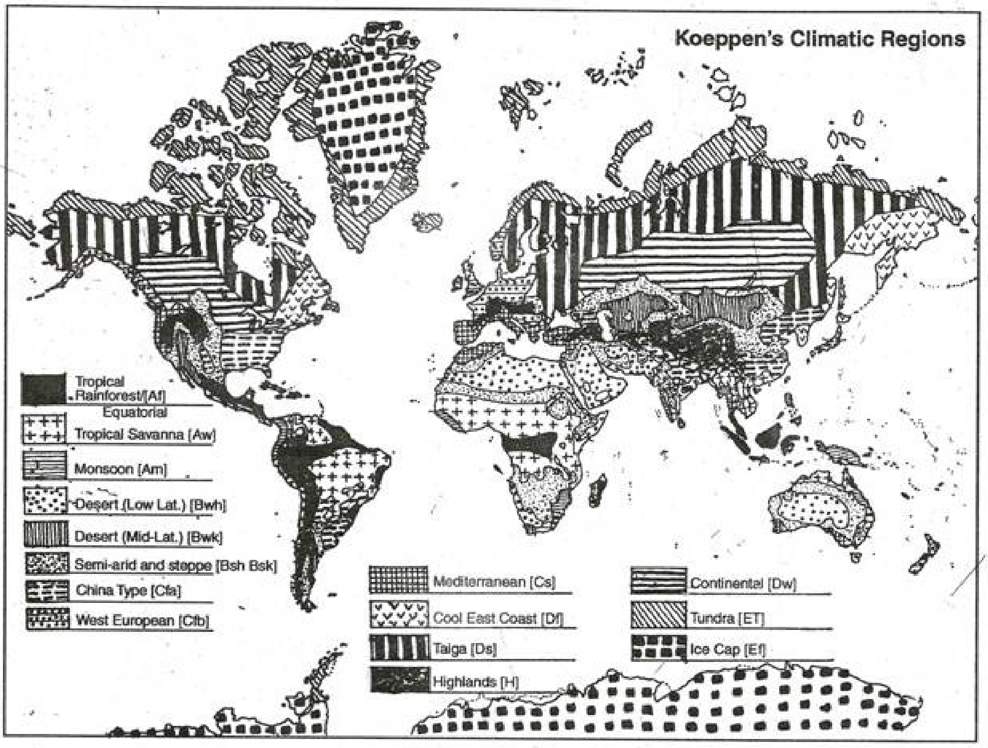
B–Dry Climate: Potential evaporation exceeds precipitation on the average throughout the year. No water surplus; hence no permanent streams originate in B Climate Zones.

C–Mild, Humid (Mesothermal) Climates: Coldest month has an average temperature under 64.4oF (18oC), but above 26.6oF (-3oC); at least one month has an average temperature above 50oF (10oC). The sea climates have both a summer and a winter season.

D– Snowy Forests (Microthermal) Climates: Coldest month has an average temperature under 26.6oF. Average temperature of warmest month is above 50oF.

E–Polar Climates: The average temperature of warmest month is blow 50^{o}F. The climates have no true summer.

Four of these five groups (A, C, D and E) are defined by the temperature averages, whereas one (B) is defined by the precipitation to evaporation ratios. This procedure may seem to be of fundamental inconsistency. Groups A, C and D have sufficient heat and precipitation for both of high trunk trees, e.g., forest and woodland vegetation.



Köppen climate classification scheme symbols description table

1st	2nd	3rd
A (Tropical)	f (Rainforest)	
	m (Monsoon)	
	w (Savanna, Wet summer)	
	s (Savanna, Dry summer)	
B (Arid)	W (Desert)	
	S (Steppe)	
		h (Hot)
		k (Cold)
C (Temperate)	s (Dry summer)	
	w (Dry winter)	
	f (Without dry season)	
		a (Hot summer)
		b (Warm summer)
		c (Cold summer)
D (Continental)	s (Dry summer)	
	w (Dry winter)	
	f (Without dry season)	
		a (Hot summer)
		b (Warm summer)
		c (Cold summer)
		d (Very cold winter)
E (Polar)	T (Tundra)	
	F (Eternal winter (ice cap))	

Classification by Thornthwaite:

C. W. Thornthwaite, an American climatologist, presented his first scheme of classification of climates of North America in 1931 when he published the clamatic map of North America. Later he extended his scheme of climatic classification for world climates and presented his full scheme in 1933. He further modified his scheme and presented the revised second scheme of classification of world climates in 1948. Instead of vegetation, as done in 1931 classification, he based his new scheme of climatic classification on the concept of potential evapotranspiration (PE). The PE (Potential Evapotranspiration) for a 30-day month (a day having only the length of sunshine i.e. 12 hours) is calculated as follows:

PE (in cm) = $1.6(10t/I)^{a}$
where PE = Potential Evapotranspiration
I = the sum for 12 months of $(t/5)^{1.514}$
a = a further complex function of I
t = temperature in °C

Thornthwaite developed four indices to determine boundaries of different climatic types e.g.:

(i) Moisture index (Im),

(ii) Potential evapotranspiration or thermal efficiency index (PE),

(iii) Aridity and humidity indices, and

(iv) Index of concentration of thermal efficiency or potential evapotranspiration.

(i) Moisture Index (Im):

Moisture index refers to moisture deficit or surplus and is calculated according to the following formula: Im = (100s – 60D)/PE

Where Im = monthly moisture index

S = monthly surplus of moisture

D = monthly deficit of moisture

The sum of the 12 monthly values of Im gives the annual moisture index.

$$\text{Annual Moisture Index} = \sum_{i=1}^{12} (100S - 60D)/PE$$

(ii) Thermal Efficiency Index: Thermal efficiency is simply the potential evapotranspiration expressed in centimetres as expressed above. It is, thus, apparent that the thermal efficiency is derived from the PE value because PE in itself is a function of temperature. The method of the calculation of PE is given above.

(iii) Aridity and Humidity Indices: These indices are used to determine the seasonal distribution of moisture adequacy.

These are calculated as follows:

Aridity Index = in moist climates annual water deficit taken as a percentage of annual PE becomes aridity index.

Humidity Index = in dry climates annual water surplus taken as a percentage of annual PE becomes humidity index.

(iv) Concentration of Thermal Efficiency: Concentration of thermal efficiency refers to the percentage of mean annual potential evapotranspiration (PE) accumulating in three summer months.

On the basis of moisture index (Im) Thornthwaite identified 9 moisture or humidity provinces:

Moisture Index	Humidity province
(1) 100 and above	A perhumid
(2) 80 to 100	B_4 Humid
(3) 60 to 80	B_3 Humid
(4) 40 to 60	B_2 Humid
(5) 20 to 40	B_1 Humid
(6) 0 to 20	C_2 Moist subhumid
(7) -33.3 to 0	C_1 Dry subhumid
(8) -66.7 to -33.3	D Semiarid
(9) -100 to -66.7	E Arid

On the basis of thermal efficiency (potential evapotranspiration) 9 thermal provinces were recognized**:**

Thermal Efficiency Index (cm)		Thermal Province (Type)
(1) 114 and above	A'	Megathermal
(2) 99.7 to 114.0	B'_4	Mesothermal
(3) 85.5 to 99.7	B'_2	Mesothermal
(4) 71.2 to 85.5	B'_2	Mesothermal
(5) 57.0 to 71.2	B'_1	Mesothermal
(6) 42.7 to 57.0	C'_2	Microthermal
(7) 28.5 to 42.7	C'_1	Microthermal
(8) 14.2 to 28.5	D'	Tundra
(9) Below 14.2	E'	Frost

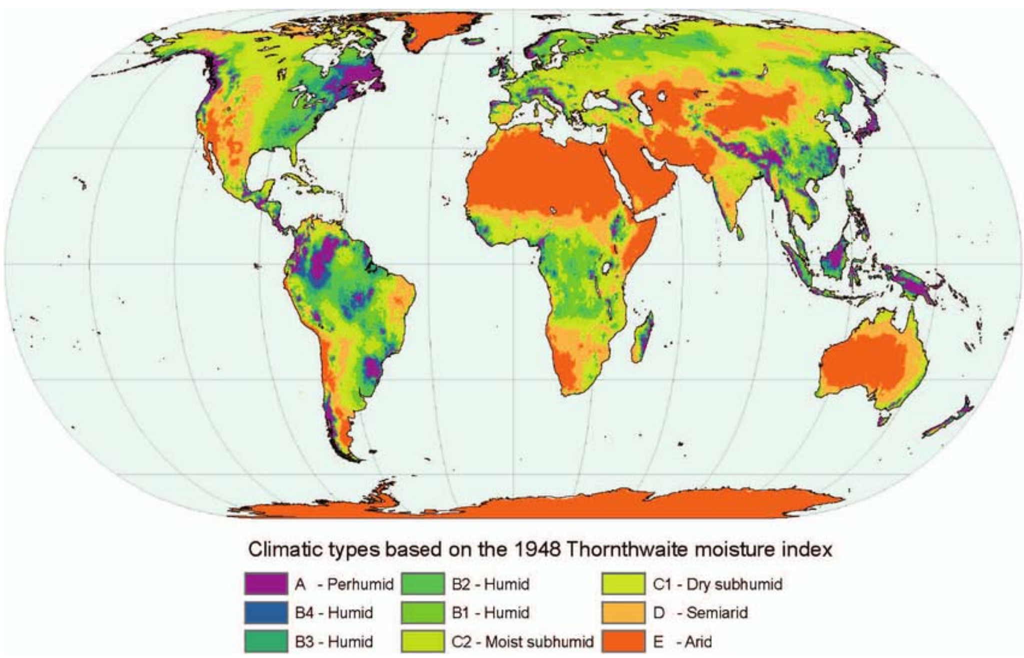
On the basis of summer concentration of thermal efficiency the world was further divided into 8 provinces:

Summer Concentration of Thermal Efficiency (%)	Type
(1) below 48.0	a'
(2) 48.0-51.9	b'
(3) 51.9-56.3	b'_3
(4) 56.3-61.6	b'_2
(5) 61.6-68.0	b'_1
(6) 68.0-76.3	c'_2
(7) 76.3-88.0	c'_1
(8) above 88.0	d'

On the basis of seasonal moisture adequacy 2 major and 10 sub-climatic types were identified:

Moist Climates (A, B, C_2)		Aridity Index
(1) r	little or no water deficit	0 to 10
(2) s	moderate summer deficit	10 to 20
(3) w	moderate winter deficit	10 to 20
(4) s_2	large summer deficit	above 20
(5) w_2	large winter deficit	above 20
Dry Climates (C_1, D, E)		**Humidity Index**
(6) d	little or no water surplus	0 to 16.7
(7) s	moderate winter surplus	16.7 to 33.3
(8) w	moderate summer surplus	16.7 to 33.3
(9) s_2	large winter surplus	above 33.3
(10) w_2	large summer surpuls	above 33.3

The climate of a place, thus, is determined by combining the aforesaid elements of the climatic classification e.g.. moisture index, thermal efficiency index, summer concentration of thermal efficiency, and seasonal moisture adequacy (aridity and humidity indices). Thus, the climate of a place is represented by four letters.For example- A A' a'r climate = Perhumid (A) megathermal (A') climate with summer concentration of annual thermal efficiency (PE in cm) of less than 48 per cent (a') and little or no water deficit (r) etc. On the basis of above indices the classification system becomes so complex due to large number of climatic types that it becomes difficult to represent them carto- graphically.



Climatic types based on the 1948 Thornthwaite moisture index

UNIT V: Applied Climatology: Agro-climatology - Human Comfort Zone – UrbanClimate - Micro climate – Weather Stations - Role and functions of IndianMeteorological Department (IMD) - Meteorological Satellites – Weatherforecasting.

- **Applied climatology:-**

-- This branch of climatology is concerned with the application of the climatological knowledge to practical problems

-- It analyses the relationship of climatology to other sciences

--The main purpose is to find out the ways and means to make use of our knowledge of climatic elements for the betterment of human life on the Earth

AGROCLIMATOLOGY

- Term describes the interrelationship between elements of climate and agriculture
- Branch of science which deals with the study of climate and effects on crop and livestock productivity

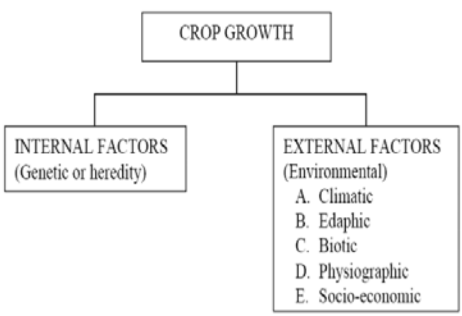
- *Agroclimatology deals* with the effect of climate on crops. It includes especially the length of the growing season, the relation of growth rate and crop yields to the various climatic factors.
- It also deals with the optimal and limiting climates, the availability of moisture / irrigation, and the effect of weather conditions on the development and spread of crop diseases.
- This discipline is primarily concerned with the space occupied by crops, the soil and the layer of air up to the tops of the plants, in which conditions are governed largely by the microclimate.

More specifically it deals with

1.Understand climatological and surface hydrological processes and their impacts

2. Describe climatological factors and their effect on agriculture

3. Analyze climatological factors using Geospatial tools with weather and climate datasets, computer models for optimizing management and decision-making.



A

1. Precipitation
2. Temperature
3. Atmospheric humidity
4. Solar radiation
5. Wind velocity
6. Atmospheric gases

B

1. Soil moisture
2. Soil air
3. Soil temperature
4. Soil mineral matter
5. Soil organic matter
6. Soil organisms
7. Soil reactions

C. BIOTIC FACTORS

Beneficial and harmful effects caused by other biological organism (plants and animals)

Agroclimatic Elements

1.Crop Seasons

Kharif Crops

- As cultivation of these crops happens in the monsoon season, another name for Kharif crop is *monsoon crop*. The Kharif season differs in every state of the country but is generally from June to September. We sow the crop at the beginning of the monsoon season around June and harvest by September or October. Rice, maize, bajra, ragi, soybean, groundnut, cotton are all Kharif crops.

Rabi Crops

- As these crops harvest in the springtime hence the name. The Rabi season usually starts in November and lasts up to March or April. Cultivation of Rabi crop is mainly through irrigation since monsoons are already over by November. Wheat, barley, mustard and green peas are some of the major rabi crops that grow in India.

Zaid Crops

- This is a short season between Kharif and Rabi season in the months of March to July. Also, these grow on irrigated lands. So we do not have to wait for monsoons to grow them. Some examples of Zaid crops are pumpkin, cucumber, bitter groud.

2. Length of Growing Period (LGP)

- Length of growing period is defined as the period during the year when average temperatures are greater than or equal to 5^{o}C and precipitation plus moisture stored in the soil exceed 50 % of the potential evapotranspiration

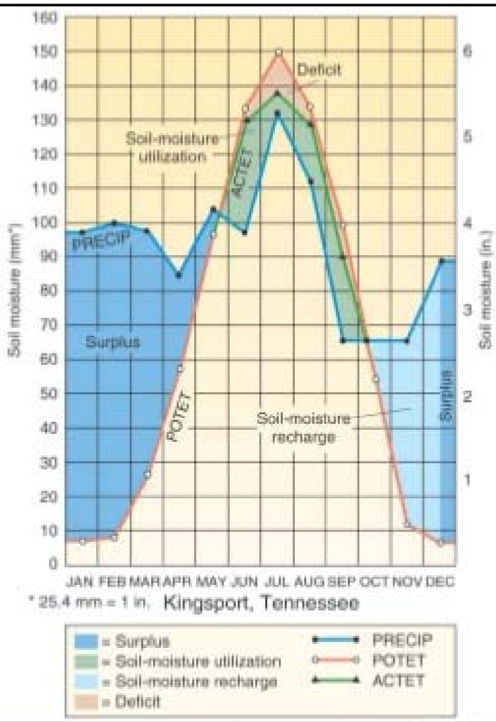
The spatial distribution of crops and farming systems in any region is determined by the LGP.

3.Evaporation and Evapotranspiration

- Evaporation (E) is the amount of water moved from the leaf surfaces of plants. Soil evaporation and plant transpiration occur simultaneously.
- Evapotranspiration (ET) is a combination of evaporation of water remaining on the surfaces of vegetation after precipitation and transpiration (water lost from plant’s surface).
- Potential evaporation (PE) occurs when the soil moisture is greater than a critical value above which evaporation takes place.
- Actual evaporation (AE) occurs when soil moisture is less than the critical value resulting in the rate of evaporation itself far below PE (i.e. soil moisture is less than critical value)

4.Climatic waterbalance

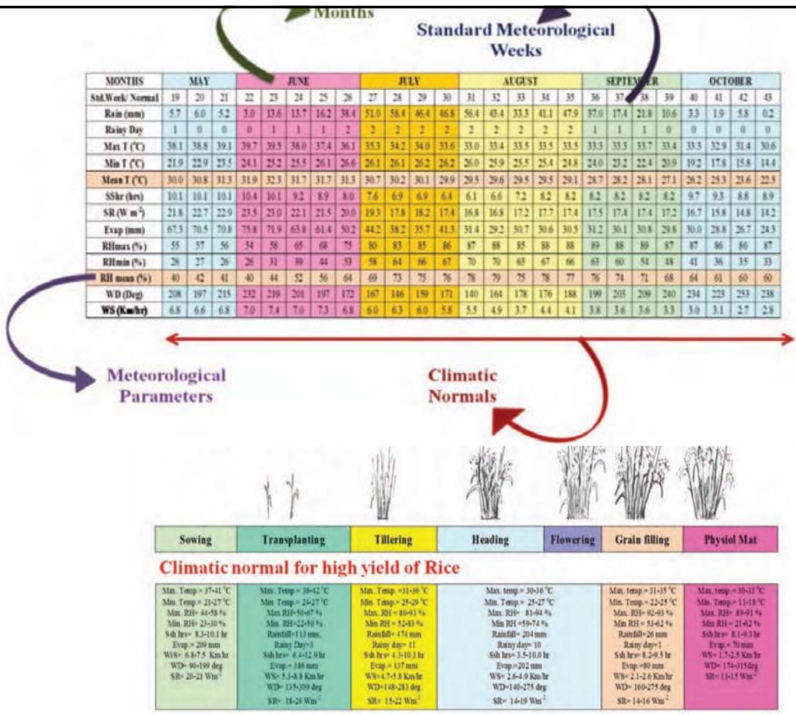
Temperature, Rainfall, PE and soil mositure are the only element of water balance,



5.Crop Calendar

- Crop weather calendar is a comprehensive guide for farmers. It is a tool that provides information on average weather of every week, planting, sowing and harvesting periods of locally adapted crops in a specific agro-ecological zone. Further, stage-wise pest disease infestation information can also be added.
- IMD prepared district-wise crop-weather calendars almost two decades ago using normal weather, crop water requirement for major cereals, pulses and oilseed crops.

.



MONTHS	MAY			JUNE					JULY				AUGUST					SEPTEMBER				OCTOBER			
Std.Week/ Normal	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Rain (mm)	5.7	6.0	5.2	3.0	13.6	13.7	16.2	38.4	51.0	58.4	46.4	46.8	56.4	43.4	33.3	41.1	47.9	37.0	17.4	21.8	10.6	3.3	1.9	5.8	0.2
Rainy Day	1	0	0	0	1	1	1	2	2	2	2	2	2	2	2	2	2	1	1	1	0	0	0	0	0
Max T (°C)	38.1	38.8	39.1	39.7	39.5	38.0	37.4	36.1	35.3	34.2	34.0	33.6	33.0	33.4	33.5	33.5	33.5	33.3	33.3	33.7	33.4	33.3	32.9	31.4	30.6
Min T (°C)	21.9	22.9	23.5	24.1	25.2	25.5	26.1	26.6	26.1	26.1	26.2	26.2	26.0	25.9	25.5	25.4	24.8	24.0	23.2	22.4	20.9	19.2	17.8	15.8	14.4
Mean T (°C)	30.0	30.8	31.3	31.9	32.3	31.7	31.7	31.3	30.7	30.2	30.1	29.9	29.5	29.6	29.5	29.5	29.1	28.7	28.2	28.1	27.1	26.2	25.3	23.6	22.5
SShr (hrs)	10.1	10.1	10.1	10.4	10.1	9.2	8.9	8.0	7.6	6.9	6.9	6.4	6.1	6.6	7.2	8.2	8.2	8.2	8.2	8.2	8.2	9.7	9.3	8.8	8.9
SR (W m⁻²)	21.8	22.7	22.9	23.5	23.0	22.1	21.5	20.0	19.3	17.8	18.2	17.4	16.8	16.8	17.2	17.7	17.4	17.5	17.4	17.4	17.2	16.7	15.8	14.8	14.2
Evap (mm)	67.3	70.5	70.8	75.8	71.9	63.8	61.4	50.2	44.2	38.2	35.7	41.3	31.4	29.2	30.7	30.6	30.5	31.2	30.1	30.8	29.8	30.0	28.8	26.7	24.3
RHmax (%)	55	57	56	54	58	65	68	75	80	83	85	86	87	88	85	88	88	89	88	89	87	87	86	86	87
RHmin (%)	26	27	26	26	31	39	44	53	58	64	66	67	70	70	65	67	66	63	60	54	48	41	36	35	33
RH mean (%)	40	42	41	40	44	52	56	64	69	73	75	76	78	79	75	78	77	76	74	71	68	64	61	60	60
WD (Deg)	208	197	215	232	219	201	197	172	167	146	159	171	140	164	178	176	188	199	205	209	240	234	223	253	238
WS (Km/hr)	6.8	6.6	6.8	7.0	7.4	7.0	7.3	6.8	6.0	6.3	6.0	5.8	5.5	4.9	3.7	4.4	4.1	3.8	3.6	3.6	3.3	3.0	3.1	2.7	2.8

Agro-climatic zones

An agro-climatic zone is a land unit uniform in respect of climate and length of growing period (LGP) which is climatically suitable for a certain range of crops and cultivars (FAO, 1983).

Classification by Planning Commission

Planning Commission of India (1989) made an attempt to delineate the country into different agro climatic regions based on homogeneity in rainfall, temperature, topography, cropping and farming systems and water resources. India is divided into 15 agro-climatic regions.

1	Western Himalayan Region	J&K, HP, UP, Utranchal
2	Eastern Himalayan Region	Assam Sikkim, West Bengal & North-Eastern states
3	Lower Gangetic Plains Region	West Bengal
4	Middle Gangetic Plains Region	UP, Bihar
5	Upper Gangetic Plains Region	UP
6	Trans-Gangetic Plains Region	Punjab, Haryana, Delhi & Rajasthan
7	Eastern Plateau and Hills Region	Maharastra, UP, Orissa & West Bengal
8	Central Plateau and Hills Region	MP, Rajasthan, UP
9	Western Plateau and Hills Region	Maharastra, MP & Rajasthan
10	Southern Plateau and Hills Region	AP, Karnataka, Tamil Nadu
11	East Coast Plains and Hills Region	Orissa, AP, TN,& Pondichery
12	West Coast Plains and Ghat Region	TN, Kerala, Goa, Karnataka, Maharastra
13	Gujarat Plains and Hills Region	Gujarat
14	Western Dry Region	Rajasthan
15	The Islands Region	Andman & Nicaobar, Lakshya Deep

The state of Tamil Nadu has been classified into seven distinct agro-climatic zones listed below.

1. North Eastern zone
2. North Western zone
3. Western zone
4. Cauvery Delta zone
5. Southern zone
6. High Rainfall zone
7. Hilly zone

Microclimate

- Microclimates are the local interplays between factors such as soil temperature, air temperature, wind directions, soil moisture and air humidity—affected by day-night effects and seasonal effects. They are determined by the particular landscape, soil conditions, vegetation, land use and water retention.
- A microclimate is the distinctive climate of a small-scale area, such as a garden, park, valley or part of a city.
- It is these subtle differences and exceptions to the rule that make microclimates so fascinating to study, and these notes help to identify and explain the key differences which can be noticed by ground-level observations.

Scope of Micro Climate

The importance of microclimate in influencing ecological processes such as plant regeneration and growth, soil respiration, nutrient cycling, and wildlife habitat

To a landscape ecologist, a microclimate may comprise the side of a mountain, or a section of desert tens or perhaps even hundreds of kilometers in extent.

To a reproductive ecologist interested in the life history of a mosquito breeding in a pitcher plant, the term microclimate refers to the inside of a plant only a few centimeters in diameter.

.

- Relationships between microclimate and biological processes are easy to visualize when one considers that temperature, solar radiation, and humidity affect plant growth by influencing physiological processes such as photosynthesis, respiration, seed germination, mortality, and enzyme activity.
- Therefore, it follows that ecosystem processes such as decomposition, nutrient cycling, succession, and productivity are partially dependent on microclimatic variables too.
- Many animals are also adapted to specific microclimatic conditions. Wind speed, air temperature, humidity, and solar radiation can influence migration and dispersal of flying insects.
- Soil microbe activity is affected by soil temperature and moisture. Fish have specific thermal ranges in which they are able to survive and reproduce,

To a **botanist, Microclimate can be of a single plant leaf, with its** temperature and moisture conditions, its population of insects and micro organisms, on the scale of a few centimetres.

To an **urban geographer, micro climate may mean the climate** of a whole **town.**

Factors Affecting Microclimate

Ground surface: (Whether natural or man-made): affect in terms of reflectance, permeability and the soil temperature as these affect the vegetation and this in turn affects the climate. (woods, shrubs, grass, paving, water, etc.)

- **Three dimensional objects: such as trees, tree belts, fences,** walls and buildings as these may influence air movement, cast a shadow, etc.

Phenomenal Examples of Microclimate

- Rain shadow effect
- Fog / Mist
- Local winds
- **Urban climate / Heat Island**
- Water body and its environment
- Sandy area / Rocky surface environment
- Vegetated environment
- Hill stations
- Impact of ocean currents over it viciniy

URBAN CLIMATE

Towns and cities are the most densely populated areas on Earth and will continue to be the artificial landscapes most widely used by the greater part of the Earth's population in the future.

In 2030 more than 60% of humans will live in cities. Changes in urban conditions have often caused deterioration in environmental quality and may result in damage to the health of city-dwellers.

The differences between the climate of a city and the climate of its surroundings are referred to as the "urban climate".

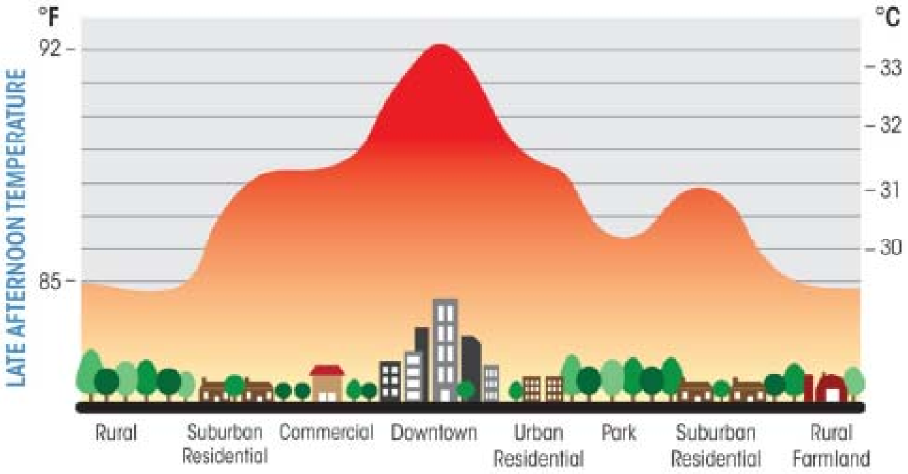
The most important features of urban climate include *higher air / surface temperatures*, changes in radiation balances, lower humidity, and restricted atmospheric exchange that causes accumulations of pollutants from a variety of sources.

Although these changes mainly affect local or regional conditions, persistent substances released into the atmosphere may also affect larger areas or even the global climate.

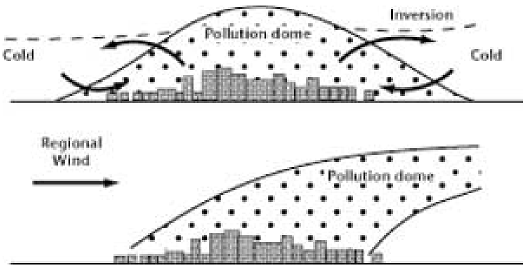
Heat Island

Causing factors:

- The release (and reflection) of heat from industrial and domestic buildings;
- The absorption by concrete, brick and tarmac of heat during the day, and its release into the lower atmosphere at night;
- The reflection of solar radiation by glass buildings and windows. The *central business districts of some urban areas can therefore have quite high albedo rates* (proportion of light reflected);
- The emission of **hygroscopic pollutants** from cars and heavy industry act as condensation nuclei, leading to the formation of cloud and smog, which can trap radiation. In some cases, a pollution dome can also build up;



- Pollution domes in urban area filters the incoming solar radiation, thereby reducing the buildup of heat during the day. At night, the dome may trap some of the heat from the day, so these domes might be reducing the sharp differences between urban and rural areas;
- the relative absence of water in urban areas means that less energy is used for evapotranspiration and more is available to heat the lower atmosphere;
- the absence of strong winds to both disperse the heat and bring in cooler air from rural and suburban areas. Indeed, urban heat islands are often most clearly defined on calm summer evenings, often under blocking anticyclones (High pressure)



The nature of the heat island varies from urban area to urban area, and it depends on the presence of large areas of open space, rivers, the distribution of industries and the density and height of buildings.

In general, the temperatures are highest in the central areas and gradually decline towards the suburbs. In some cities, a temperature cliff occurs on the edge of town.

IMPACTS

- Urban heat islands raise demand for electrical energy in summer. Companies that supply electricity typically rely on fossil fuel power plants to meet much of this demand, which in turn leads to an increase in air pollutant and greenhouse gas emissions.

- High pavement and rooftop surface temperatures can heat storm water runoff. Tests have shown that pavements that are 100ºF (38°C) can elevate initial rainwater temperature from roughly 70ºF (21ºC) to over 95ºF (35ºC).

Studied City	Method	Difference in temperature found in the city	Observations/ UHI Influencing factors
New Delhi	Thermal mapping of surface temperatures using MODIS data for 3 years	7˚C in the night time	Aerosol depth/ distribution, Presence of water bodies and rivers
Chennai	Mobile survey- air temperatures	2.48 ˚C in summer and 3.35 ˚C in winter	Density of builtup areas, presence of water bodies, thermal properties of materials and anthropogenic heat
Bangalore	LST maps using satellite data for a few decades	2.5 ˚C	Parks, lakes, vegetation
Pune	Mobile measurements (DBT and WBT)	2˚C	Heat island accompanied by moisture island, Topography, Katabatic winds
Colombo	LANDSAT satellite data for surface temperatures	Max 18˚C*	Population, floor area density, forest cover
Cochin	Filed measurements- Air temperatures	Average 2.4K during Winter	High water cover
Hong Kong	Fixed station	1.5ºC (during night)	Surface albedo, Sky view factor
Kaulalampur	Fixed station	6.5ºC	Building mass, green spaces
Singapore	Fixed stations	3ºC	Building mass, green spaces
Tokyo	Mobile measurements	8.1ºC (during night)	Wind movement
Seoul	Surface temperatures (fixed station)	Max 7ºC	Stronger on week days than week ends

Human Comfort Zone

- Human comfort is concerned, air temperature is undoubtedly of dominant significance; but also depends on other factors such as humidity, wind and sunshine.
- indices are have been developed and used evaluate the impact of heat stress on the individual and take into account temperature, humidity or a combination of the two. Hence the clear understanding over the relationship among the ***weather elements mainly temperature, humidity and evaporation with its diurnal and spatial dimension.***
- Some widely used index are : humiture, humidex, humisery, the weather stress index, apparent temperature, the discomfort index and the temperature humidity index.

Understanding Relative Humidity

➢The difference between the actual moisture present in the air and how much the air can hold maximum is known relative humidity.

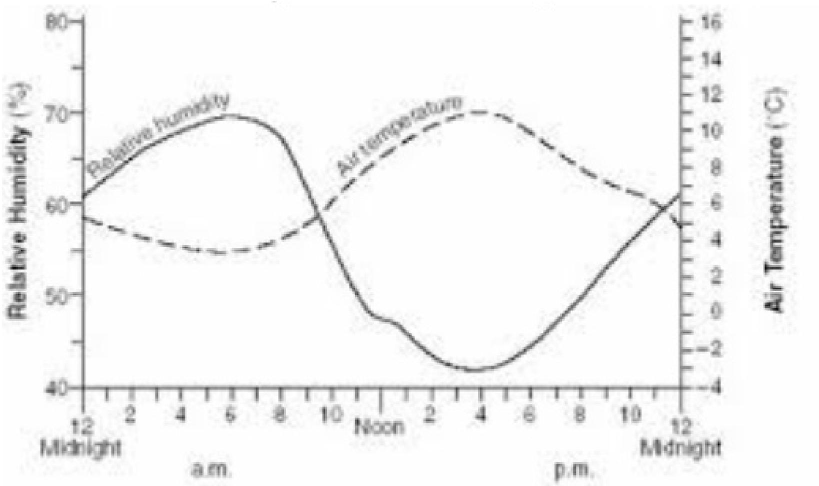
➢Measure using dry and wet bulb temperature reading. The difference in the readings shows the atmospheric moisture.

➢In general temperature increases relative humidity decreases and vice versa.

➢When the dew point temperature and air temperature are equal, the air is said to be saturated. When air temperature and dew point temperatures are very close, the air has a high relative humidity.

- **Relative humidity is greater over the oceans and least over the continents.** Because more moisture by the availability of water causes high absolute humidity and less temperature causes the low dew point temperature. Which causes sticky / sultry.
- **Where as over the continents t**he high temperature of the air and low moisture availability causes **lower Relative humidity. Similarly at night relative humidity is higher than the day. Too low less than 25 % causes dryness**

Diurnal Variation of Temperature and Humidity

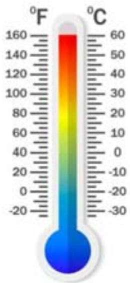


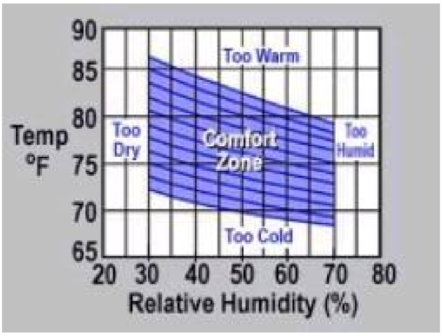
Relative Humidity and human comfort

- While temperature is the most important factor of thermal comfort, Relative humidity plays a large part in sense of discomfort.
- We cannot perceive differences in relative humidity levels within the range of 25% and 60%, this range is often cited as the baseline. If relative humidity falls outside this range, there are notable effects.
- When relative humidity gets too high, discomfort develops, either due to the feeling of the moisture itself, which is unable to evaporate from the skin, or due to increased friction between skin and clothing with skin moisture.

People "feel comfortable" over a wide range of temperatures and conditions, depending upon age, weight, sex, and level of physical activity.

A sedentary person could feel "cold" at 74° (23°C)F if the humidity is low, while a factory worker could feel warm at 65°F if they are performing heavy manual labor.



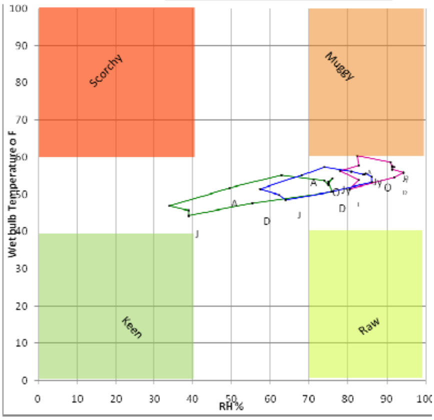


When relative humidity gets too low, skin and mucous surfaces become drier, leading to complaints about dry nose, throat, eyes, and skin. In particular, discomfort in working environments, which are prone to significant eyestrain with office equipments such as computer.

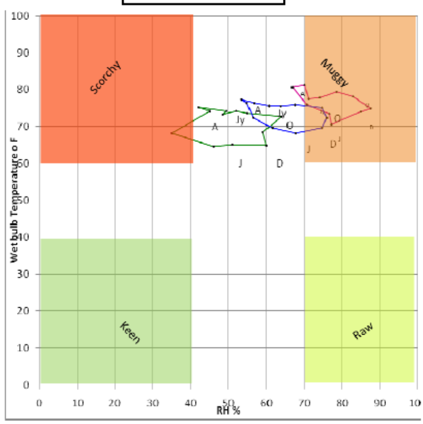
Human Comfort Zone Analysis

Thomas Griffith Taylor – regarded as one of the founders of modern Geography in Australia – who deployed a number of cartographic techniques (climograph) to reinforce his racial theorizations.

(G) Kodaikanal



(C) Vellore



- This graph represents two climatic variables at any one place, in which one variable (relative humidity)is plotted on abscissa and another (wet bulb temperature)is plotted on the ordinates.

- The four quadrants of the climographs i.e. NW, NE, SE and SW represent the climatic condition as Scorching, Muggy, Raw and Keen respectively. With the help of these four zones the comfortable climatic conditions for human beings are identified

In general the ideal climatic comfort will be towards the centre of the graph. The zone with low relative humidity (less than 40 %) and low wet bulb temperature (less than 40oF) makes the weather ***uncomfortable by dry air called 'keen'. On contrast to keen,***

excessive wet bulb temperature (above 60oF) *and higher relative humidity (above 70%)makes* ***sweaty and uncomfortable, being warm and damp weather with little or no stirring of the air known as 'muggy'.***

The weather can be termed as ***'raw' if the relative humidity is excessive (above 70%)*** *and low wet bulb temperature (less than 40oF)causes* ***unpleasantly cold and damp weather.***

Scorching is very hot and horrible weather caused by higher wet bulb *temperature (above 60oF)under low humidity (less than 40oF) condition.* ***The zone between, 40 o F and 60 o F of wet bulb temperature and the relative humidity, range between 40 % and 70 % will be ideal climatic comfort zone, which is highly dynamic with reference to spatial and temporal condition. However, this is not the threshold limit for the survival of the human.***

WEATHER STATIONS / OBSERVATORIES

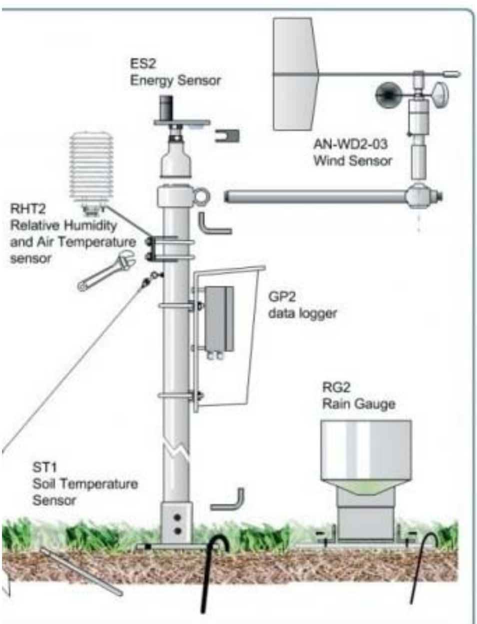
✓A weather station has a meteorological platform where most of the in struments are mounted which includes

hygrometers, wind speed and direction, precipitation gauges, soil the rmometers wet and dry bulb thermometer, pan evaporimeter solar radiation, cloud cover etc.,

✓IMD meteorological real time ***surface observatories*** are located almost one in each district (559 observatories) so as to meet the requirements of agricultural, transport and other operations.

✓In addition to that a network of 1000 ***Automatic Weather Station*** (AWS) and 3600 Automatic Rain Gauge Stations (ARG) across the county is operational which is recent development.

✓IMD's ***Upper air observational network*** comprises 39 radiosonde and 62 pilot balloon observatories spread all over the country. New GPS based sounding systems have been introduced in the observational network for the upper air observations at 10 locations.



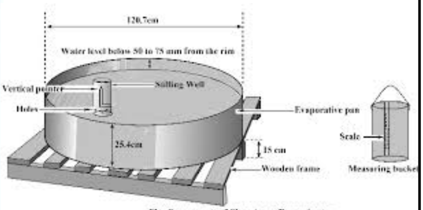


Fig: Components of Class A pan Evaporimeter

WEATHER FORECASTING

Weather forecasting, the prediction of the weather through application of the principles of physics, supplemented by a variety of statistical and empirical techniques.

In addition to predictions of atmospheric phenomena themselves, weather forecasting includes predictions of changes on Earth's surface caused by atmospheric conditions—e.g., snow and ice cover, storm tides, and floods.

The Forecasting Process: Making a weather forecast involves three steps:

A.Observation : from surface stations, radiosondes, ships at sea, aircraft, radar, and meteorological satellites.

B.Analysis: The data are printed, plotted, graphed and fed in forecast model.

C.Extrapolation : meteorologists rely on numerical models to extrapolate the state of the atmosphere into the future,

.

METHODS OF WEATHER FORECASTING

1.Synoptic

Forecast methods based upon analysis of a series of synoptic charts, these techniques usually contain elements of a physical, kinematic, and climatological nature

2.Numerical Weather Prediction (NWP)

Numerical Weather Prediction (NWP) uses the power of computers to make a forecast. Complex computer programs, also known as forecast models, run on supercomputers and provide predictions on many atmospheric variables such as temperature, pressure, wind, and rainfall. A forecaster examines how the features predicted by the computer will interact to produce the day's weather.

3. Statistical Methods

Statistical weather forecasting is based on the statistical procedure known as "least-squares regression."

RANGE OF WEATHER FORECASTING

Range	Time	Methods	Phenomena	Utility
Nowcasting	- 6hrs	Radars etc	Hailstorms, Squalls with high accuracy	Severe Weather Warnings (~ 500 m)
Short Range	2-3 days	Nested Atmospheric Models	Synoptic scale weather systems	Conventional Forecasting resolution (3-25 km)
Medium Range	7-10 days	Global Atmospheric Models	Synoptic scale weather systems	Conventional Forecasting resolution (25 – 50 km)
Extended Range	10–30 days	Coupled Atmospheric	Persistent systems • Blocking Highs • MJO • ITCZ	Droughts and Heat / Cold Waves

Satellite Meteorology

Satellite Meteorology refers to the study of the earth's atmosphere and oceans using data obtained from remote sensing devices flown onboard satellites orbiting the earth.

The international coordination of meteorological data is accomplished through the World Weather Watch (WWW) program of the World Meteorological Organization and the Coordination Group for Meteorological Satellites (CGMS).

Operational Meteorological Satellites

Geostationary:

GOES-15 USA NOAA
(Geostationary Operational Environmental Satellite)
METEOSAT - 11 EUROPE
INSAT-3C INDIA
KALPANA-1 INDIA
ELECTRO L N2 RUSSIA **(Roscosmos)**
FY 2E CHINA (NSMC)
COMS-1 (Chollian) S.KOREA
HIMAWARI 8 JAPAN (JMA)

Non Geostationary

NOAA-18 USA
JASON 3 USA,EUROPE
(Joint Altimetry Satellite Oceanography Network) - JASON

ORGANIZATIONAL REFERENCE

- The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) – EUROPE
- NOAA - National Oceanic and Atmospheric Administration, US
- The Roscosmos State Corporation for Space Activities, commonly known as Roscosmos, is a state corporation of the Russian Federation
- National Satellite Meteorological Center(**NSMC**) , China
- COMS-1 (Communication, Ocean and Meteorological Satellite-1) by **Korea Aerospace Research Institute**,
- Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA)

Scope of Meteorological satellites

Apart from weather and climate forecasting, satellite meteorology has broader scopes which includes ***sunami dynamics, El Niño Southern Oscillation, eddy dynamics, ocean boundary currents, coastal and shallow water tides, as well as sea level and climatic changes***

Types of Meteorological Satellite Data

Imagery: Visible (VIS), Infrared (IR), Water Vapor (WV), Shortwave Infrared (SWIR), Microwave (MW), Multispectral

- Satellite Atmospheric Winds
- Sea Surface Temperatures
- Ocean Surface Wind Speeds
- Precipitation Estimates

IMD is receiving and processing meteorological data from two Indian satellites namely Kalpana-1 and INSAT-3A. both have three channel Very High Resolution Radiometer provides the following data variables:

- Sea surface Temperatures (SSTs)
- Outgoing Longwave Radiation(OLR)
- Quantitative Precipitation Estimates (QPEs)
- Cloud motion vectors (CMVs)
- Water vapor winds (WVWs)

Role and Functions of Indian Meteorological Department (IMD)

India Meteorological Department (IMD) was established during 1875 in New Delhi. It is the National Meteorological Service provider of the country and the principal government agency in all matters relating to meteorology, seismology and allied disciplines and provides weather and climate services to different sectors. The roll and various functions of IMD are given under different operational cells.

A. Forecasting Cell

- Monitoring of weather situation over the country
- Facilitating short to medium range forecast with a outlook on extended range.
- Extended forecast for mountain region, sports, tourism and VIP movements etc
- Providing of meteorological sub-division wise weather warnings.
- Co-ordination with Regional and State Meteorological Centres for location specific forecasts

B. Aviation Cell

- Preparation of significant weather charts for analysis purpose.
- Monitoring of aviation weather through 17 Aerodrome Meteorological offices, 51 Aeronautical Meteorological Weather offices and Meteorological Watch offices (MWO).

C. Cyclone Warning & Marine Forecasting Cell

- Responsible for monitoring and prediction of cyclone disturbances over the north Indian Ocean.
- Issuance of warning and advisory to national and international disaster management agencies.
- Acts as Regional Specialized Meteorological Centre to issue tropical cyclone advisories to **World Meteorological Organisation**
- Also acts as Tropical Cyclone Advisory Centre to provide advisories for **International Civil Aviation Organization** .

D. Satellite and Radar Support Cells

- To facilitate the interpretation of satellite and radar products for forecasting
- Interpret the radar products and assist the forecasters in NWFC in issuance of weather advisories and Nowcasting of severe weather.
- Satellite application cell monitors and interprets satellite products and functions in the same manner as the radar cell.

Additional Readings

INDIA METEOROLOGICAL DEPARTMENT

India Meteorological Department (IMD) is the National Meteorological Service provider of the country. It is an agency of the Ministry of Earth Sciences of the Government of India in all matters relating to Meteorology, Satellite Meteorology, Agricultural Meteorology, Civil Aviation Meteorology, Cyclone watch, Marine Meteorology, Hydrometeorology, Seismology Meteorological Instrumentation and Telecommunication, Climatology, Training in all meteorological fields, Positional Astronomy, Forecasting at national & regional levels in these fields and allied subjects.

India Meteorological Department was established in the year 1875 with its headquarters at Calcutta. The headquarters was shifted to Shimla in 1905, to Pune in 1928 and then to Delhi in 1944.

IMD's main objective is to provide meteorological information for weather sensitive activities like -

- Aviation
- Shipping
- Agriculture
- Off shore fishing
- Oil exploration and
- Industries
- It also issues warning against severe weather conditions like cyclone, dust storm, heavy rainfall, cold and heat waves.
- The department records earthquakes and conducts research.

Uses of IMD Information

- Information provided by IMD is useful for general public to know about the weather forecast.
- It is vital for fishermen, civil aviation activities and farmers.
- IMD has high power radars and uses satellite system also.
- The seismological observatory systems under national network monitor seismic zones or activities in and around the nation for quick determination of natural calamities.
- The Oceansat provides data regarding shoals of fishes to IMD and it is very useful for the fishermen.
- IMD participates in various international research which studies monsoon mechanism.
- Various forecasting helps farmers to plan their agricultural activities.
- IMD has installed many digital receivers on east and west coast to disseminate information on cyclone and other oceanic phenomena.

Thus, IMD through its various activities certainly plays a significant role in creating awareness about importance of climate and weather in life and economy of India. IMD has certainly played vital role in India.

The mandate and functions of the IMD are discussed below-

1. Taking meteorological observations and providing current information and forecasting information for the most favorable operation of weather-dependent activities such as irrigation, agriculture, aviation, shipping, offshore oil exploration, and so on.
2. Giving warnings against severe weather phenomena such as tropical cyclones, dust storms, heat waves, cold waves, heavy rains, heavy snow, etc.

3. Providing met-related statistics needed for agriculture, industries, water resources management, oil exploration, and any other strategically important activities for the country.
4. Engaging in research in meteorology and allied subjects.
5. Detection and location of earthquakes and evaluation of seismicity in various parts of the country for developmental projects.

IMD's Services Provides the real time data and weather predictions like-

♣Issues warnings for Maximum temperature, Minimum Temperature

♣ Heat-wave warning Heat-alert,

♣ Thunderstorm/hailstorm Warnings with Gusty Winds, Lightning

♣ Heavy Rainfall

♣ Cold Wave

- 4 Meteorological Watch Offices (MWOs – Chennai, Delhi, Kolkata and Mumbai),
- 18 Aerodrome Meteorological Offices (including four MWOs) and
- 53 Aeronautical Meteorological Stations (AMS).

Central Aviation Meteorological Division (CAMD) at New Delhi is the nodal office designated for the provision of meteorological services to aviation in the country. It plans and executes the administrative and technical matters pertaining to the aviation meteorological services India Meteorological Department caters to the needs of upper air observational requirement through a network of RADARS and upper air observatories (RS/RW), governed through

•

technical supervision of Upper Air Instruments Division, a dedicated division under Director General of Meteorology.

IMD has its research and development unit at Pune headed by Additional Director General of Meteorology (Research).

WEATHER SATELLITES

The weather satellite is a type of satellite that is primarily used to monitor the weather and climate of the Earth. Because of weather satellite technology and communications satellite technology, we can find out the weather anywhere in the world any time of the day. There are television stations that carry weather information all day long.

Meteorologists use weather satellites for many things, and they rely on images from satellites. Here are a few examples of those uses:

- Radiation measurements from the earth's surface and atmosphere give information on amounts of heat and energy being released from the Earth and the Earth's atmosphere.
- People who fish for a living can find out valuable information about the temperature of the sea from measurements that satellites make.
- Satellites monitor the amount of snow in winter, the movement of ice fields in the Arctic and Antarctic, and the depth of the ocean.
- Infrared sensors on satellites examine crop conditions, areas of deforestation and regions of drought.
- Some satellites have a water vapour sensor that can measure and describe how much water vapour is in different parts of the atmosphere.
- Satellites can detect volcanic eruptions and the motion of ash clouds.

- Satellites receive environmental information from remote data collection platforms on the surface of the Earth. These include transmitters floating in the water called buoys, gauges of river levels and conditions, automatic weather stations, stations that measure earthquake and tidal wave conditions, and ships. This information, sent to the satellite from the ground, is then relayed from the satellite to a central receiving station back on Earth.
- El Niño and its effects on weather are monitored daily from satellite images. The Antarctic ozone hole is mapped from weather satellite data. Collectively, weather satellites flown by the U.S., Europe, India, China, Russia, and Japan provide nearly continuous observations for a global weather watch.

Types of Weather Satellites

There are two basic types of weather satellites: those in **Geostationary orbit** and those in **polar orbit**.

Geostationary satellites orbit around the earth over the equator at a height of about 36000 kms. They complete one orbit in 24 hours synchronized with earth's rotation about its own axis. Thus they remain over the same location on the equator. The main advantage of geostationary satellites lies in the high time-scale resolution of their data. A fresh image of the full earth's disc is available every 30 minutes. However they have limited spatial resolution as compared to the polar orbiting satellites in view of their distance from the earth. Useful information is restricted to the belt between 70 deg. N and south latitudes. Some of the examples of geostationary satellites are GMS(1400 E), GOES-W, GOES-E, INSAT-1 and INSAT-2 Series., GEOS, METEOSAT -5 (Positioned at 64 0 E), METEOSAT-6 etc.

Polar orbiting satellites pass approximately over the poles at a height of about 850 kms. The whole surface of the earth is observable by these satellites which follow orbits nearly fixed in space while the earth is rotating beneath them. The areas scanned on each pass (swath) are nearly adjacent at the equator with overlapping areas further poleward. The swaths are usually about 2600 km wide. These satellites complete 14 orbits per day and thus can provide global coverage twice in 24 hours. Some of the polar orbiting satellites are NOAA, IRS, ERS-1 &ERS-2, TRMM (low inclination), DMSP, Oceansat-1 etc

Satellite Sensor System

land-ocean atmosphere system.

(a) Spatial Information:

The examples are the extent and temperature of sea surface, clouds, vegetation, soil moisture, etc. The main objective here is to obtain the required information over a 2-dimensional plane. The best suited sensors for this class are imaging radiometers operating in visible, infrared or microwave frequencies. Active sensors like Synthetic Aperture Radar (SAR) are also put to effective use for the imaging applications

(b) **Spectral Information** :

For certain applications, the spectral details of an electromagnetic signal are of crucial importance. A particular object of interest, for example an atmospheric layer, or, the ocean surface, interacts differently with different wavelengths of electromagnetic (EM) spectra. In most cases, this may be due to the chemical composition of the object.

(c) Intensity Information :

The intensity of EM radiation can provide several clues about the object of interest. In most cases, the satellite sensors measure the intensity of the radiation reflected from the object to know the dielectric properties and the roughness of the object. By the use of suitable algorithms these parameters can be translated to the properties of geophysical parameters like soil moisture, ocean surface roughness, ocean surface wind speed, and wind direction etc. The sensors that use this information are radar, scatter meter, and polar meters.

As early as 1946, the idea of cameras in orbit to observe the weather was being developed. The first weather satellite to be considered a success was TIROS-1, (The acronym for Television and Infra Red Observation Satellite) launched by NASA on April 1, 1960. The first attempt to look at Earth's weather from space occurred early in the space program of the United States. In 1959, Vanguard II was launched with light-sensitive cells able to provide information about Earth's cloud cover. Unfortunately, the satellite tumbled in orbit and was unable to return any information. Explorer VI, also launched in 1959, was more successful and transmitted the first photographs of Earth's atmosphere from space.

Later versions of TIROS improved upon the original with television cameras that provided direct, real-time readouts of pictures to simple stations around the world.

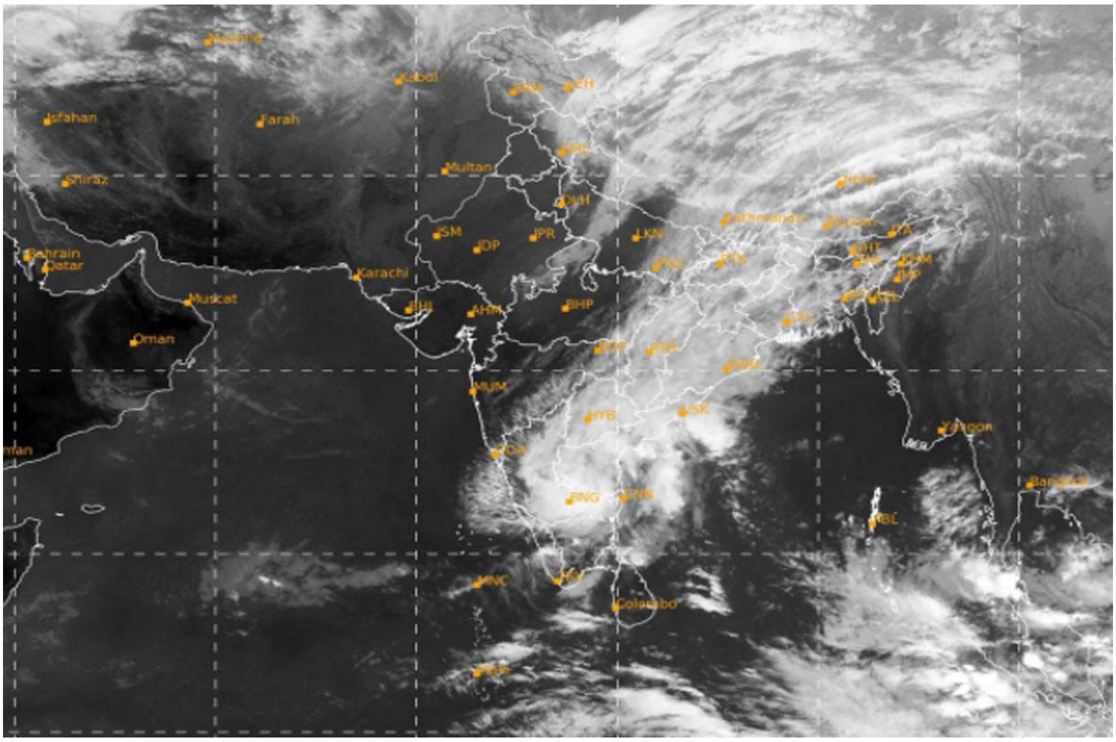
Another successful series was called NOAA after the National Oceanic and Atmospheric Administration. Some of these satellites were placed in geostationary orbit (moving at the same speed as Earth) and thus were able to continuously observe one area. This helped in the detection of severe storms and tornadoes and provided real-time coverage at an earlier stage of cloud and frontal weather movements. Other TIROS-type satellites, such as NIMBUS (1960s) and NOAA-9 (1980s–1990s), are in polar orbit, where their infrared sensors measure temperatures and water vapor over the entire globe.

Several GOES (Geostationary Operational Environmental Satellites) also cover the western and eastern hemispheres. These satellites are able to provide weather reports for places that have not been covered very well in the past: ocean regions, deserts, and polar areas. They also trace hurricanes, typhoons, and tropical storms, in the process save many lives. Their data are used to produce state-of-the-art charts showing sea-surface temperatures, information useful to the shipping and fishing industries. New satellites that probe Earth's atmosphere by day and night in all weather are being developed in many countries. Since the weather satellite is now an established tool of meteorologists all over the world, both developed and developing nations will continue to rely on these crafts.

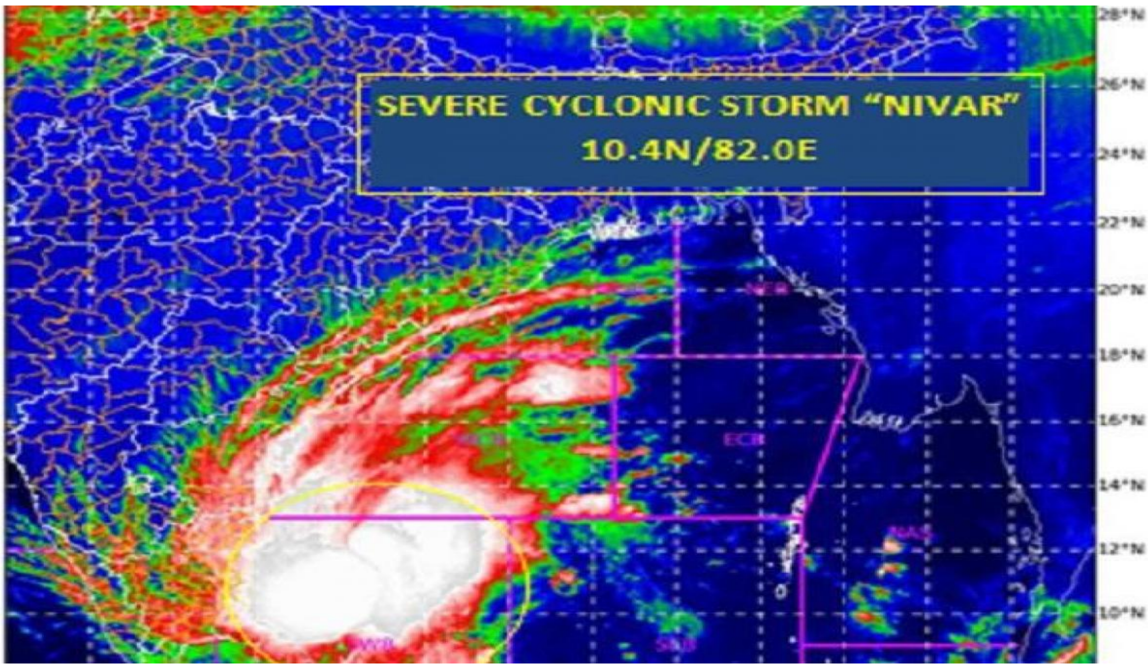
Weather Satellites of India

The prediction of weather in the tropical regions, like India, is a major challenge due to the complex and dynamic nature weather system. The day to day changes of weather elements such as rainfall, temperature, wind speed and humidity are the important meteorological parameters to be monitored on a continuous basis. The meteorological satellites provide a synoptic measurement of weather parameters at frequent intervals. The satellite images on cloud cover and various parameters such as winds, rainfall, sea surface temperature etc., have become an integral part of weather forecasting.

The **INSAT** series of satellites carrying **Very High Resolution Radiometer** (VHRR) have been providing data for generating cloud motion vectors, cloud top temperature, water vapour content, etc., facilitating rainfall estimation, weather forecasting, genesis of cyclones and their track prediction.



NIVAR CYCLONE



Source: https://www.business-standard.com

The INSAT series of satellites carrying Very High Resolution Radiometer (VHRR) have been providing data for generating cloud motion vectors, cloud top temperature, water vapour content, etc., facilitating rainfall estimation, weather forecasting, genesis of cyclones and their track prediction. These satellites have also carried Data Relay Transponders (DRT) to facilitate reception and dissemination of meteorological data from in-situ instruments located across vast and inaccessible areas.

Currently, there are three meteorological satellites Kalpana-1, INSAT-3A and INSAT-3D in the geosynchronous orbit. Quick visualization and analysis of data and products enable accurate weather assessments. Towards this, Space Applications Centre (SAC), ISRO, Ahmadabad has developed a weather data explorer application - Real Time Analysis of Products and Information Dissemination (RAPID) which is hosted in India Meteorological Department (IMD) website. This software acts as a gateway to Indian Weather Satellite Data providing quick interactive visualization and 4-Dimensional analysis capabilities to various users like application scientists, forecasters, and the common man.

This innovative application introduces the concept of next generation weather data access and advanced visualization capabilities. It provides access to the previous 7-day satellite data including images and geophysical parameters from Indian Satellites in near real time. More than 150 Products from Indian Weather Satellites are being hosted using this application. The scientific products which affect our daily lives like Fog, Rainfall, Snow, Temperature, etc., retrieved from INSAT-3D and Kalpana-1 are made available for the common man. It also provides animation of images based on start/end time. This feature is very useful in visualizing the movement of severe weather events like cyclones.

WEATHER FORECASTING

Weather forecasting is the application of science and technology to predict the conditions of the atmosphere for a given location and time. People have attempted to predict the weather informally for millennia and formally since the 19th century. Weather forecasts are made by collecting quantitative data about the current state of the atmosphere at a given place and using meteorology to project how the atmosphere will change.

The goal of weather prediction is to provide information people and organizations can use to reduce weather-related losses and enhance societal benefits, including protection of life and property, public health and safety, and support of economic prosperity and quality of life.

There is a vast variety of end users to weather forecasts. Weather warnings are important forecasts because they are used to protect life and property. Forecasts based on temperature and precipitation are important to agriculture, and therefore to traders within commodity markets. Temperature forecasts are used by utility companies to estimate demand over coming days. On an everyday basis, many use weather forecasts to determine what to wear on a given day. Since outdoor activities are severely curtailed by heavy rain, snow and wind chill, forecasts can be used to plan activities around these events, and to plan ahead and survive them.

The main ways the weather can be forecast include looking at current weather conditions, tracking the motion of air and clouds in the sky, finding previous weather patterns that resemble current ones, examining changes in air pressure and running computer models.

Significance of weather forecasting

Weather forecasting can help agricultural activities in the following ways:

- Selection of crops
- Efficient use of fertilizers
- Predicting pests and diseases
- Timing of weeds, pests and disease control.
- Planning for mitigating adverse effects of weather hazards,
- Adjustments in crop harvest timing to reduce the losses at harvest.

The synoptic observatories collect information on various weather elements on the basis of which daily forecasts, warnings and weather reports are prepared by five regional forecasting centres situated at Chennai, Nagpur, Mumbai, Delhi and Kolkata. The regional centres also prepare forecast of weather known as weather bulletins indicating the probable date to onset of monsoon, intensity, duration, breaks in rainfall and other adverse weather phenomenon. The bulletins are broadcasted in the regional languages through radio and television along with rural programmes.

Essentials of weather forecasting

Essential features of weather forecasting are: Proper recording of data, Careful study of synoptic charts. Search for similar situation from the historical data. Preparation of the weather condition chart as may be possible in next 24 hours, and Drawing quick, correct levels and definite conclusions regarding future weather phenomenon. Elements included in weather forecasting are-

- Sky coverage by clouds
- Precipitation Temperature (maximum, minimum and dew point)
- Relative humidity

- Wind Speed and direction
- Extreme events (heat and cold waves fog, frost, hail, thunderstorms, wind squalls and gales, low pressure areas, different intensities of depressions, cyclones, tornados, …)
- Bright hours of sunshine
- Solar radiation

Types of weather forecasting

Based on time or duration of forecasting period, the weather forecasting can be divided into six categories:

- Now-casting (NC) - Current weather variables and 0-6 hour's description of forecasted weather variables.
- Very short range weather forecasting - Up to 12 hours description of weather variables
- Short range weather forecasting - Short range weather forecasts are for a period of 12 hours to 72 hours.
- Medium range weather forecasting - Medium range weather forecasts are for periods of 3 to 10 days.
- Extended range weather forecasting - Extended range weather forecasts are for periods of 10 to 30 days. Forecast is usually restricted to Temperature and precipitation.
- Long range weather forecasting - The long range weather forecasts are issued thrice in year. Validity period of long range weather forecast is 10 to 30 days