Weather and Climate Forecasts for Agriculture

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A deterministic definition states that **"weather forecast describes the anticipated meteorological conditions for a specified place (or area) and period of time"**; an alternative and more probabilistic definition states that **"weather forecast is an expression of probability of a particular future state of the atmospheric system in a given point or territory"**

- Weather plays an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop, incidence of pests and diseases, water needs and fertilizer requirements in terms of differences in nutrient mobilization due to water stresses and timeliness and effectiveness of prophylactic and cultural operations on crops
- Weather aberrations may cause **(i) physical damage to crops and (ii) soil erosion**
- The quality of crop produce during movement from field to storage and transport to market depends on weather
- Bad weather may affect the quality of produce during transport and viability and vigor of seeds and planting material during storage

The Role of Weather—and Weather Forecasting—in Agriculture

- **Crop Growth/Irrigation:** Crop growth, or crop yield, requires appropriate amounts of moisture, light, and temperature. Detailed and accurate historical, real-time and forecast weather information can help farmers better understand and track the growth status/stage to make informed decisions. Having access to this data can guide farmers in making significant and potentially costly decisions, such as whether, when and how much to irrigate

- **Fertilizer Timing and Delivery:** One of the many decisions that farmers have to make is determining the proper time to apply fertilizer, as well as the application rate and fertilizer form to use. A misapplied application caused by weather can wipe away the entire field's profits. Weather forecasts can be used to ensure that fertilizer is applied in the right conditions—when it's dry enough so that it doesn't wash away (which would create a waste of resources and money) but moist enough so that it gets worked into the soil

- **Pest and Disease Control:** Certain weather conditions encourage the development and growth of pests and diseases, which can destroy crops. Forecast guidance incorporated into pest and disease modeling can help determine whether—and when—it's appropriate to apply pest or disease controls. Wind forecasts also play a role in this decision, as crop dusters, aircraft that spray fungicidal or insecticidal chemicals on plants from above, must be utilized when wind conditions are not apt to cause sprayed chemicals to miss their targets

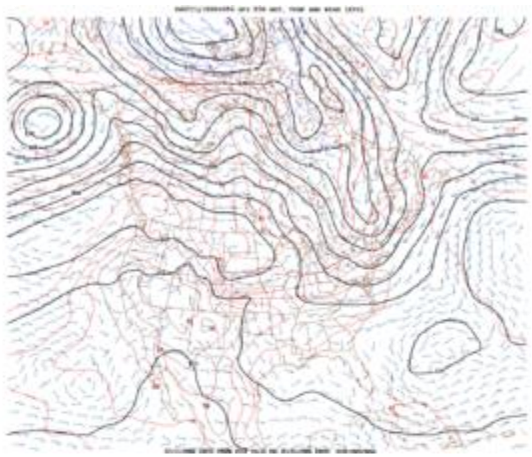
- **Field Workability:** Field workability refers to the availability of days that are suitable for fieldwork. It's primarily dependent upon soil moisture and soil temperature. Accurate field-level weather information can

In weather forecasting we now have a very wide range of operational products that traditionally are classified in the following groups:

- Now-casting (NC)
- Very Short Range Forecast (VSRF)
- Short Range Forecast (SRF)
- Medium Range Forecast (MRF)
- Long Range Forecast (LRF)

Numerical weather prediction (**NWP**) uses mathematical models of the atmosphere and oceans to predict the weather based on current weather conditions. Though first attempted in the 1920s, it was not until the advent of computer simulation in the 1950s that numerical weather predictions produced realistic results. A number of global and regional forecast models are run in different countries worldwide, using current weather observations relayed from radiosondes, weather satellites and other observing systems as inputs

Ensemble forecasting is a method used in or within numerical weather prediction. Instead of making a single forecast of the most likely weather, a set (or ensemble) of forecasts is produced. This set of forecasts aims to give an indication of the range of possible future states of the atmosphere



Type of weather forecast	Acronym	Definition	Characters of output	Dominant technology	Other aspects	Time and space resolution of typical products
Now-casting	NC	A description of current weather variables and 0 - 2 hours description of forecasted weather variables	A relatively complete set of variables can be produced (air temperature and relative humidity, wind speed and direction, solar radiation, precipitation amount and type, cloud amount and type, etc.)	Analysis techniques, extrapolation of trajectories, empirical models, methods derived from forecaster experience (rules of thumb). Basic information is represented by data from networks of Automatic Weather Stations, maps from meteorological radar, images from meteorological satellites, local and regional observations and so on)	A fundamental prerequisite for NC is the operational continuity and the availability an efficient broadcasting systems (eg: very intense showers affecting a given territory must be followed with continuity in provision of information for final users.	Typical time resolution is 1 hour; typical space resolution is of the order of gamma mesocale (20-2 km).
Very short-range forecast	VSRF	Up to 12 hours description of weather variables	A relatively complete set of variables can be produced (see nowcasting)	Analysis techniques, extrapolation of trajectories, interpretation of forecast data and maps from NWP (LAM and GM), empirical models, methods derived from forecaster experience (rules of thumb). The basic information is represented by data from networks of Automatic Weather Stations, maps from meteorological radar, images from meteorological satellites, NWP models, local and regional observations and so on)	A fundamental prerequisite for VSRF is the availability an efficient broadcasting systems (eg: frost information must be broadcasted to farmers that can activate irrigation facilities or fires or other systems of protection).	Typical time resolution is 1-3 hours; typical space resolution is of the order of beta mesocale (200-20 km).

Short-range weather forecast (*)	SRF	Beyond 12 hours and up to 72 hours description of weather variables	A relatively complete set of variables can be produced (see nowcasting)	Interpretation of forecast data and maps from NWP (LAM and GM), empirical models, methods derived from forecaster experience (rules of thumb). The basic information is represented by data from networks of Automatic Weather Stations, maps from meteorological radars, images from meteorological satellites, NWP models, local and regional observations and so on)	In SRF the attention is centred on mesoscale features of different meteorological fields. SRF can be broadcasted by a wide set of media (newspapers, radio, Tv, web, etc.) and can represent a fundamental information for farmers.	Typical time resolution is 6 hours; typical space resolution is of the order of alfa or beta mesoc (2.000-20 km).
Medium-range weather forecast (*)	MRF	Beyond 72 hours and up to 240 hours description of weather variables	A relatively complete set of variables can be produced (see nowcasting)	Interpretation of forecast data and maps from NWP (GM), empirical models derived from forecaster experience (rules of thumb). The basic information is represented by NWP models. Techniques of "ensemble forecasting" are adopted in order to overcome the problem of depletion of skill typical of forecasts founded on NWP models. Instead of using just one model run, many runs with slightly different initial conditions are made. An average, or "ensemble mean", of the different forecasts is created. This ensemble mean will likely have more skill because it averages over the many possible initial states and essentially smoothes the chaotic nature of climate. In addition, it is possible to forecast probabilities of different conditions.	In MRF the attention is centred on synoptic features of different meteorological fields. MRF can be broadcasted by a wide set of media (newspapers, radio, Tv, web, etc.) and can represent a fundamental information for farmers.	Typical time resolution is 12-24 hours; typical space resolution is of the order of alfa mesocale (2.000-200 km).

Long-range forecast	LRF	From 12-30 days up to two years	Forecast is usually restricted to some fundamental variables (temperature and precipitation); other variables like wind, relative humidity and soil moisture are sometimes presented. Information can be expressed in absolute values or in term of anomaly.	Statistical (e.g.: teleconnections), and NWP methods. Coupling of atmospheric models with ocean general circulation models is sometimes adopted in order to enhance the quality of long-range predictions.	An Extended-range weather forecast (ERF), beyond 10 days and up to 30 days, is sometimes considered.	Typical time resolution is 1 month; typicall space resolution is of the order of the beta macroscale (10.000 – 2.000 km)

(1) It is recently observed that SRF and MRF are converging toward a unique kind of forecast, due to the fact that Numerical Weather Prediction (NWP) models are the base for SRF and MRF too. It could be more correct to distinguish between forecasts based on Global Models - GM & Limited Area Models - LAM((from now to h + 72 h) and forecasts based only on GM (from h+72 to h + 7-15 days).

Type of weather forecast	Accuracy (*)	Usefulness		Main limitations
		Real	Potential	
Nowcasting	Very high	Very low	Low	Unsuitability of broadcasting system; insufficient flexi agricultural technology.
Very short-range forecast	Very high	Low	Moderate	Unsuitability of broadcasting system; insufficient flexi agricultural technology; farmer's doesn't know how to most use of available forecasts.
Short-range weather forecast	High	Moderate	High	Further adaptation of forecasts to farmer's requireme needed; farmer's doesn't know how to make the most available forecasts.
Medium-range weather forecast	High or moderate until 5 days; lower after.	High	Very high	Further adaptation of forecasts to farmer's requireme needed; farmer's doesn't know how to make the most available forecasts.
Long-range forecast	Very low	High in warning of delays in arrival of weather systems. Very low otherwise	Poor	Reliability (the reliability of LRF is higher for the trop mid latitudes. This is because tropical areas have a mo amount of predictable signal, whereas in the mid-latitu random weather fluctuations are usually larger than t predictable component of the weather).

(*) Subjective judgement of a weather forecaster working at mid latitudes. The judgement is referred to cloud coverage, air temperature and precipitation occurrence.

Elements of agricultural weather forecasts

An agricultural weather forecast should refer to all weather elements, which immediately affect farm planning or operations. The elements will vary from place to place and from season to season. Normally a weather forecast includes the following parameters.

- amount and type of coverage of sky by clouds
- rainfall and snow
- maximum, minimum and dew point temperatures
- relative humidity
- Wind Speed and Direction
- Extreme events like heat and cold waves fog, frost, hail, thunderstorms, wind squalls and gales, low pressure areas, different intensities of depressions, cyclones, tornados

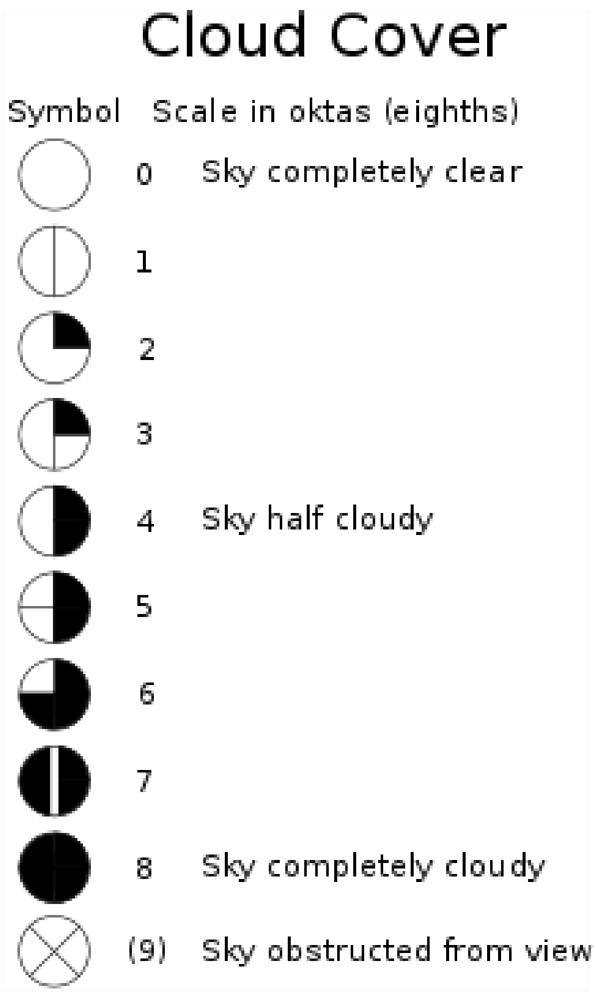
An agricultural weather forecast should contain the following information also:

- bright hours of sunshine
- solar radiation
- Dew
- leaf wetness
- pan evaporation
- soil moisture stress conditions and supplementary irrigation for rainfed crops
- advice for irrigation timing and quantity in terms of pan evaporation
- Specific information about the evolution of meteorological variables into the canopy layer in some specific cases
- Micro-climate inside crops in specific cases

A) Sky Coverage Forecast of sky coverage can be defined adopting some standard classes like sky clear (0-2 octas), partly cloudy (3-5 octas), most cloudy (6-7 octas), overcast (8/8). It is also important to give information about the character of prevailing clouds. For example high clouds produce a depletion of global solar radiation quite different from that produced by mid or low clouds. It is also important to give an idea of the expected variability of sky coverage in space and time. A probabilistic approach can be also adopted in order to increase the usefulness of this kind of information

B) Bright Sunshine Sun shining though clouds will not affect crop performance as in such a case the reduction will be in diffuse radiation from the sun-lit sky and the latter is only a fraction of Total Global Solar Radiation. So in cloud cover forecast the fraction of cloud covering the sun should also be specified in addition to the total cloud cover

C) Solar Radiation The main parameters, extraterrestrial radiation, Ra and possible sunlight hours, N required to derive solar radiation, Rs from bright hours of sunshine, n, are readily available on a weekly basis for any location and period



D) Precipitation Snow and rainfall are probably two of the most difficult forecasted variables. Quantitative forecasting of rainfall, especially of heavy downpours, is extremely difficult and realizable only within a couple of occurs of their occurrence and using highly sophisticated **Doppler Radars**. However, for crop operations quantitative forecast of rain is not half as important as forecast of

(i) non-occurrence of rains (dry spells)

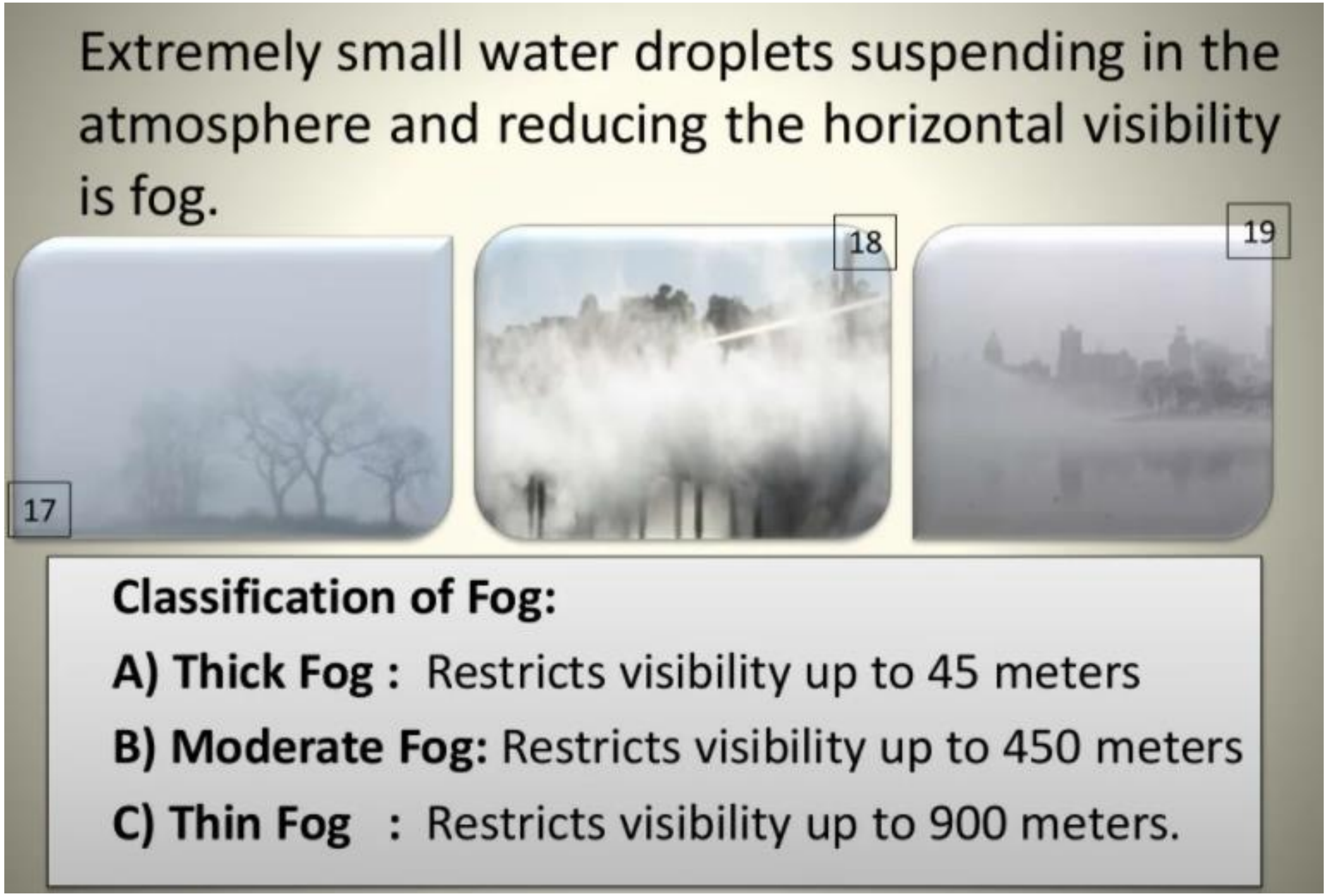
(ii) type of rain spell that can be expected

Forecasts of rain can be defined adopting some standard classes (Table 4) that could be defined in function of the climate and the agricultural context of the selected area. A probabilistic approach (Table 4) is quite important in order to maximise the usefulness of this forecast. Adopting the scheme of Table 4 it is possible to produce daily information like this:

- Most cloudy or overcast with rainfall (class 3, high probability)
- Partly cloudy with improbable rainfall (class 2, very low probability)
- Sky clear with absence of precipitation.

Quantity: class 1: <1 mm (absent); class 2: 1-10 mm (low); class 3: 10-50 mm (abundant); class 4: >50 mm (extreme)
Probability per the defined class of quantity: <1%=very low; 1-30%=low; 30-70%=moderate; >70%=high

Fog can contribute significantly to crop water needs and can be measured by covering the funnel of a raingauge with a set of fine wires. Quantitative data on fog precipitation may not be available. However, nomograms for predicting occurrence of fog at airports are available with forecasters and the same can be adopted for use in agricultural weather forecasts



2. Frost:

When the temperature of air falls below 0 °C before the dew point is reached, the water vapor is directly converted into crystals of ice, and this is called as frost. It is frequently called as a form of sublimation, Forts is injurious to vegetation.

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- Dew is an important parameter influencing leaf-wetness duration and hence in facilitating entrance of disease spores into crop tissues
- Dew is beneficial in contributing to water needs of crops in winter and in helping survival crops during periods of soil moisture stress, as the quantum of Dew collected per unit area of crop surface is many times more than that recorded with Dew Gauges
- Dew is also desirable for using pesticides and fungicides in form of dust
- The meteorological conditions required for dew formation are the same as those for fog formation except for the need for absence of air-turbulence in the air layers close to the ground and crop-canopy temperature being lower than the screen temperatures
- Thus, **nomograms used by forecasters for predicting fog can be used to predict dew in absence of low-level air turbulence and by factoring into the temperature criteria the expected depression of crop-minimum temperatures below the screen minimum**

E) Temperature

- Forecast of air temperature is important for many agrometeorological applications
- Forecasts of temperature of soil, water, crop canopies or specific plant organs are also important in some specific cases. Crop species exhibit the phenomenon of Thermoperiodicity, which is the differential response of crop species to daytime, nocturnal and mean air temperatures (examples: Solanaceae to Night temperatures; Papillionaceae to Daytime temperatures and Graminaceae to mean air temperatures)
- It is possible to derive mean day and night time temperatures from data of maximum and minimum temperatures. Forecasts of temperature are generally expressed as range of expected values (e.g.: 32-36°C for maximum and 22-24°C for minimum)
- If forecast is referred to mountainous territories, temperature ranges could be defined for different altitudinal belts, taking into account also the effects of aspect

thermoperiodicity, also called **thermal periodicity**, the growth or flowering responses of plants to alternation of warm and cool periods. Daily temperature fluctuations produce dramatic effects on the growth or flowering of most plants

F) Humidity For the day as a whole Dew Point temperature is a conservative parameters and is easier to forecast as changes in **Dew Point temperatures** are associated with onset of fresh weather systems. From maximum, minimum and dew point temperatures, minimum, maximum and average humidities can be arrived at. The user-interests understand the implications of the term Relative Humidity much better than other measures of moisture content of air like vapour pressure and precipitable water. So ultimate forecast has to be in terms of Relative Humidity. Forecast of relative humidity can be important in some specific cases. Probability of critical values (very high or very low) could be also important

Absolute humidity

Absolute humidity is the total mass of water vapor present in a given volume or mass of air. It does not take temperature into consideration. Absolute humidity in the atmosphere ranges from near zero to roughly 30 g (1.1 oz) per cubic metre when the air is saturated at 30 °C (86 °F).

$$AH = \frac{m_{H_2O}}{V_{net}}.$$

Relative humidity [edit]

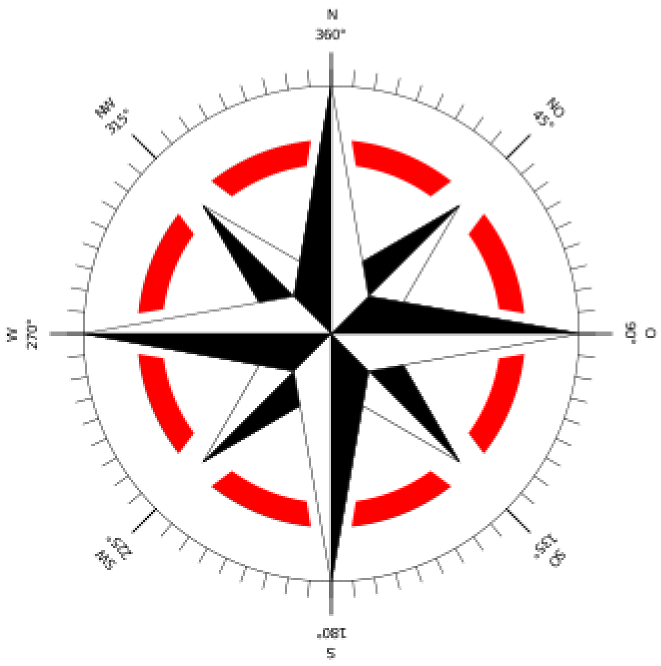
The relative humidity $(RH$ or $\phi)$ of an air-water mixture is defined as the ratio of the partial pressure of water vapor (p_{H_2O}) in the mixture to the equilibrium vapor pressure of water $(p^*_{H_2O})$ over a flat surface of pure water[10] at a given temperature:[11][12][4]

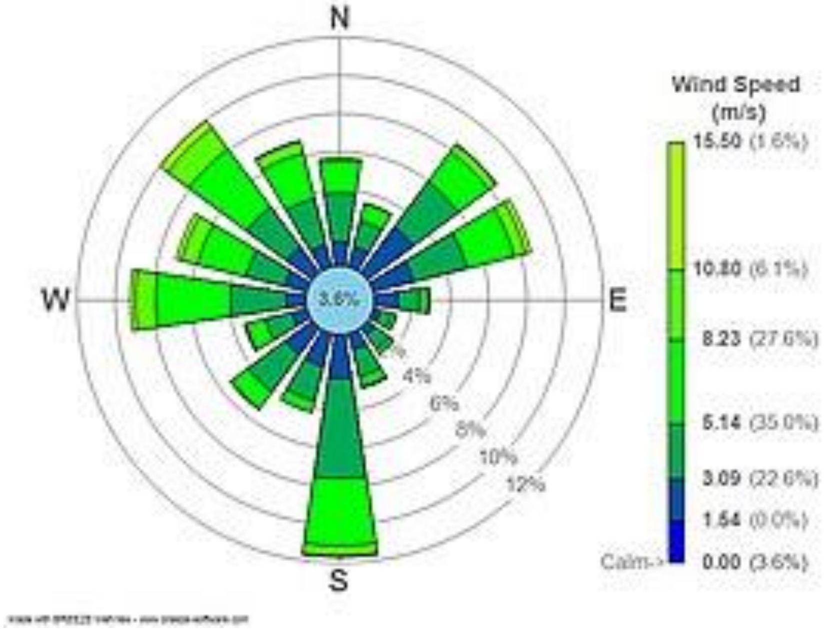
$$\phi = \frac{p_{H_2O}}{p^*_{H_2O}}$$

G) Wind speed and direction

- Forecast of wind speed is important for many different agricultural activities
- Wind direction could be defined too. It is important to give an idea of the expected variability in speed and direction of wind
- The monthly Wind Roses at a station is a climatological presentation which indicates the frequency of occurrence of wind from each of the 8 accepted points of the compass and frequencies of occurrence of defined wind speed ranges in each of the 8 directions

A **wind rose** is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. Historically, wind roses were predecessors of the compass rose (found on charts)





H) Leaf Wetness Leaf wetness is produced by rainfall or dew, or fog. Duration of this phenomenon can be important in order to plan different activities like distribution of pesticides, harvest of crops and so on. Leaf wetness is a parameter that is scarcely recorded

I) Evapotranspiration Forecast of evapotranspiration can be important in order to improve the knowledge of water status of crops. This kind of forecast is founded on correct forecast of solar radiation, temperature, relative humidity and wind speed

J) Water Balance A quantitative forecast of (i) the probability of water excess or stress for rainfed crops and (ii) the timing and amount of irrigation for irrigated crops are very highly useful. This kind of forecast for rainfed crops is founded on correct forecast of precipitation and evapotranspiration. The water balance approach to arrive at soil moisture excess or deficiency would require daily forecasts of rain in the first month of crop growth and on a short-period basis thereafter

Meteorological Instruments

INSTRUMENT	PARAMETER MEASURED
Standard Raingauge	Rainfall
Automatic Raingauge	Continuous record of rainfall, storm
Aneroid/Mercury Barometer	Atmospheric Pressure
Cup-counter Anemometer	Wind-run, Wind Speed
Campbell-Stokes Sunshine Recorder	Sunshine hours
Evaporation Pan	Evaporation
Stephenson Screen	Housing for instruments
Dry & Wet bulb Thermometer	Dry & Wet bulb temperature
Thermo-hygrograph	Temperature & Humidity
Wind Vane	Wind Direction

Instruments for Measuring Weather Elements

S. No	Element	Instrument	Unit
1	Temperature	Thermometer	°C/°F
2	Atmospheric Pressure	Barometer	Millibars
3	Wind (Direction)	Wind Vane	Cardinal points
4	Wind (Velocity)	Anemometer	Km/hr
5	Rainfall	Rain Gauge	mm/cm

Thermometer

stevenson screen

- The Stevenson screen is designed to protect thermometers from precipitation and direct sunlight while allowing air to circulate freely around them
- It is made from wood with louvered sides to allow free and even flow of air
- It is painted white to reflect radiation
- It stands on four legs and is about 3 feet 6 inches above the level of the ground
- The legs must be sufficiently rigid and be buried sufficiently in the ground to prevent shaking
- The door of Stevenson screen is always towards the north in the northern hemisphere and towards the south in the southern hemisphere because direct sunrays also affect mercury
- The purpose of the Stevenson screen is to create a uniform temperature enclosure that closely represents the same temperature as the air outside

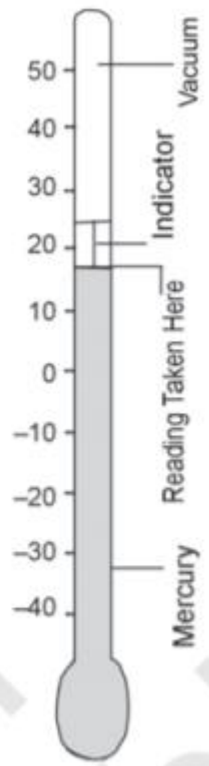


Figure 8.1 Maximum Thermometer

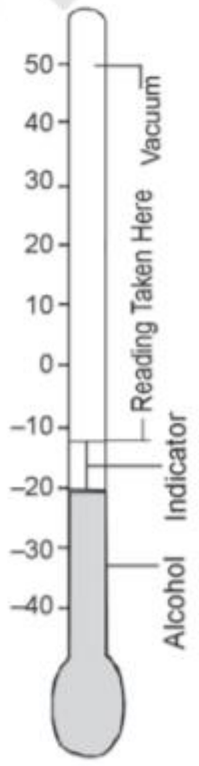
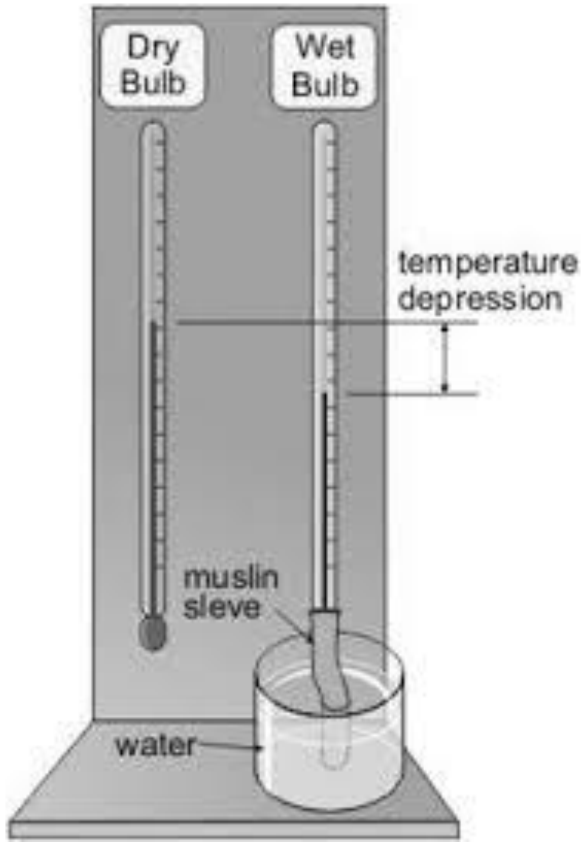


Figure 8.2 Minimum Thermometer

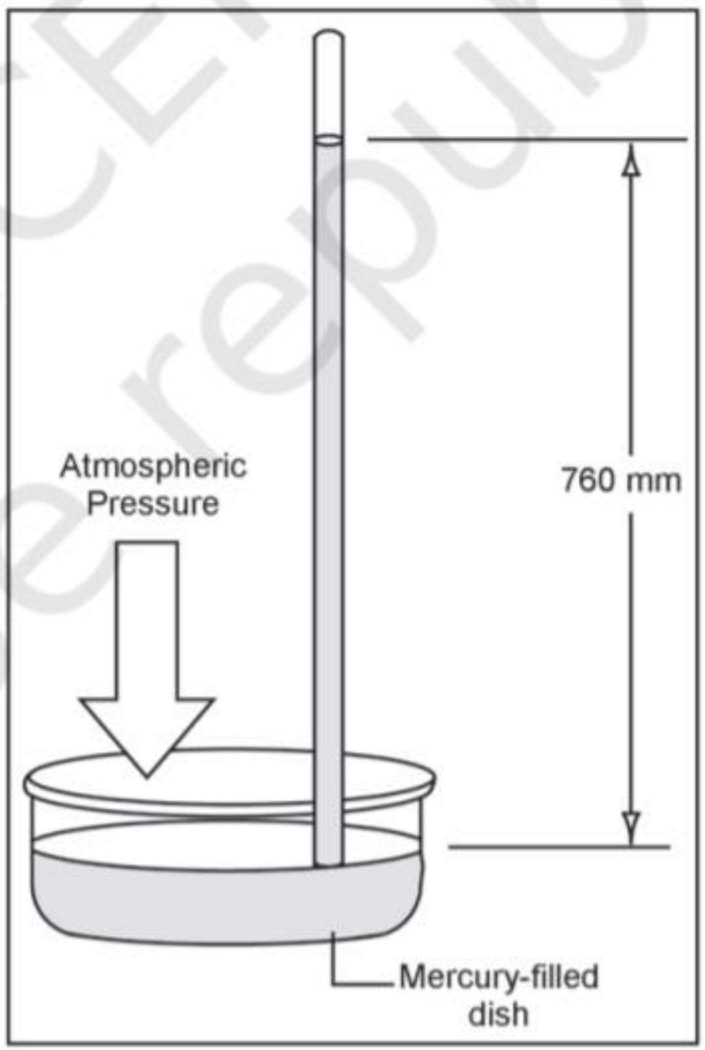


mercury

alcohol

Barometer

The air around us has weight, and it exerts great pressure on the earth's surface. At the sea level, under normal conditions, the pressure of air is 1.03 kg per square centimetre. Due to constant movement of air, change in temperature and variation in its vapour content, the weight of the air changes continuously with time and place



Aneroid barometer gets its name from the Greek work, aneros (a- 'not', neros – 'moisture', meaning without liquid). It is a compact and portable instrument. It consists of a corrugated metal box made up of a thin alloy, sealed completely and made airtight after partial exhaustion of air. It has a thin flexible lid, which is sensitive to changes of pressure

Rain Gauge

The amount of rainfall is measured with the help of a rain gauge. The rain gauge consists of a metal cylinder on which a circular funnel is fitted. The diameter of the funnel’s rim is normally 20 cm. The rain drops are collected and measured in a measuring glass. Normally, rainfall is measured in the units of millimetres or centimetres. Snow is also measured in a similar manner by turning it into liquid form

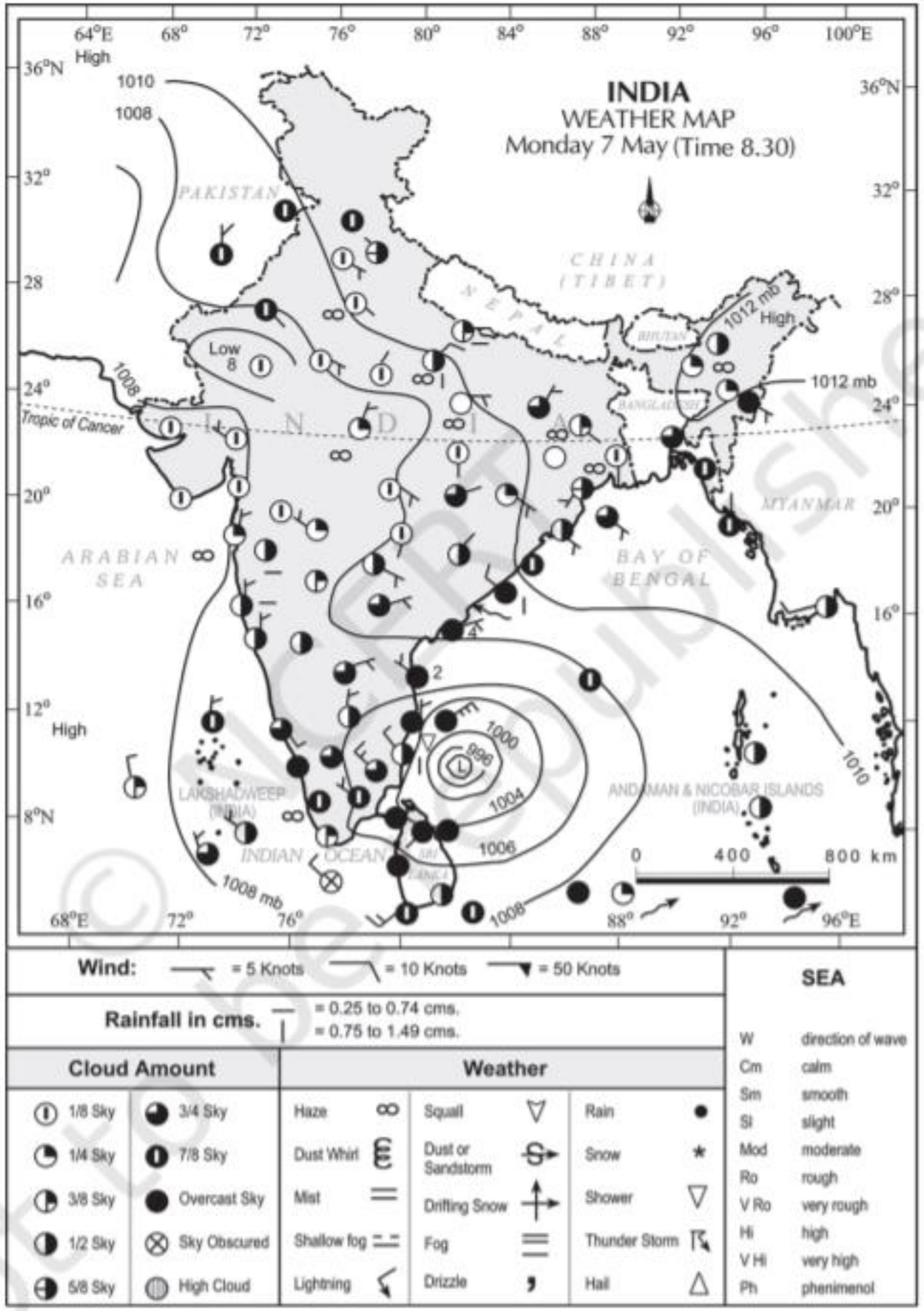
Wind Vane

Wind vane is a device used to measure the direction of the wind. The wind vane is a lightweight revolving plate with an arrowhead on one end and two metal plates attached to the other end at the same angle. This revolving plate is mounted on a rod in such a manner that it is free to rotate on a horizontal plane. It responds even to a slight blow of wind. The arrow always points towards the direction from which the wind blows

THE ROBINSON ANEMOMETER.

An **anemometer** is a device used for measuring wind speed and direction. It is also a common weather station instrument. The term is derived from the Greek word *anemos*, which means wind, and is used to describe any wind speed instrument used in meteorolog

1 knots = 1 nautical/hr = 1.1508 mile/hr in ocean
1.15 mile/hr in plains


INDIA
WEATHER MAP
Monday 7 May (Time 8.30)
64°E
68°
72°
76°
80°
84°
88°
92°
96°
100°E
36°N
32°
28
24°
20°
16°
12°
8°N
High
1010
1008
PAKISTAN
CHINA (TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR
1012 mb
Low 8
Tropic of Cancer
I N D I A
ARABIAN SEA
BAY OF BENGAL
1000
996
1004
1006
1008 mb
LAKSHADWEEP (INDIA)
ANDAMAN & NICOBAR ISLANDS (INDIA)
INDIAN OCEAN
SRI LANKA
0 400 800 km
68°E
72°
76°
88°
92°
96°E
Wind: = 5 Knots = 10 Knots = 50 Knots
Rainfall in cms. = 0.25 to 0.74 cms. = 0.75 to 1.49 cms.
Cloud Amount
1/8 Sky
1/4 Sky
3/8 Sky
1/2 Sky
5/8 Sky
3/4 Sky
7/8 Sky
Overcast Sky
Sky Obscured
High Cloud
Weather
Haze
Dust Whirl
Mist
Shallow fog
Lightning
Squall
Dust or Sandstorm
Drifting Snow
Fog
Drizzle
Rain
Snow
Shower
Thunder Storm
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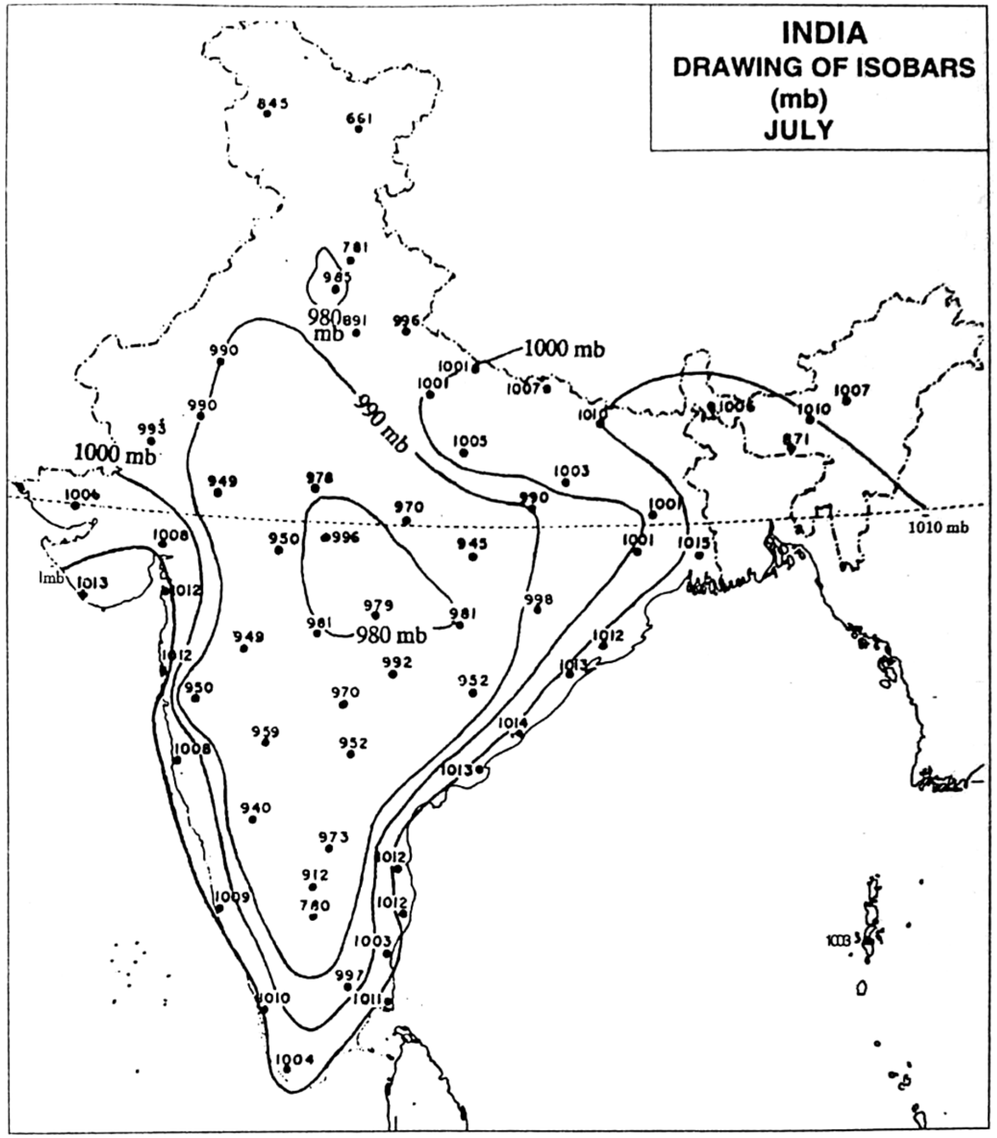
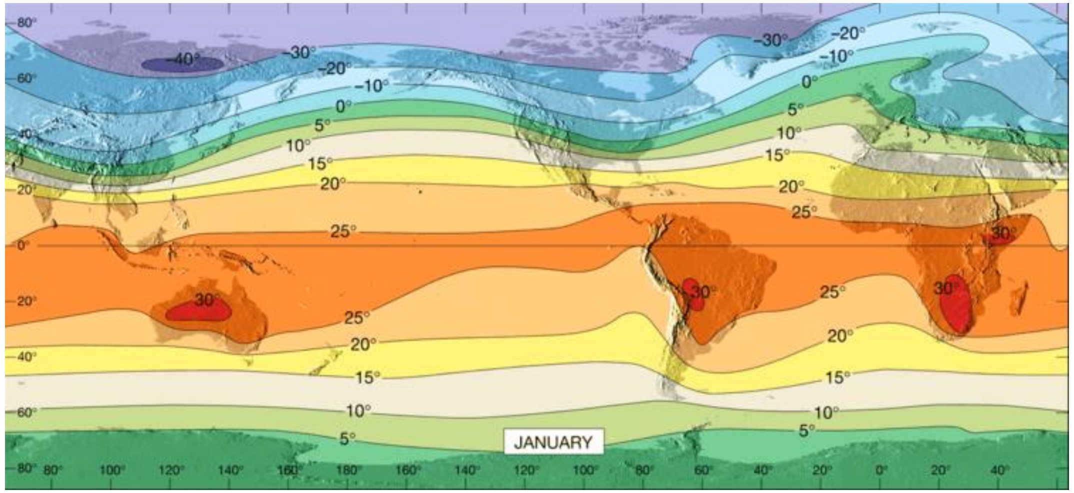
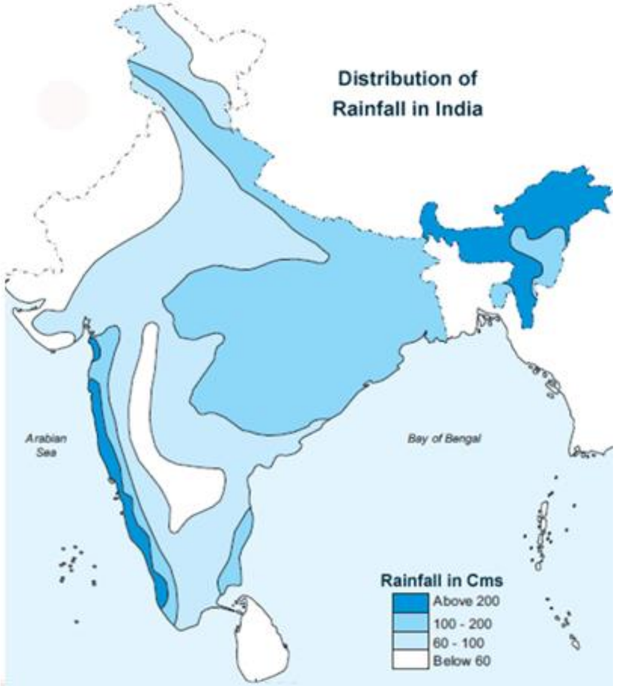


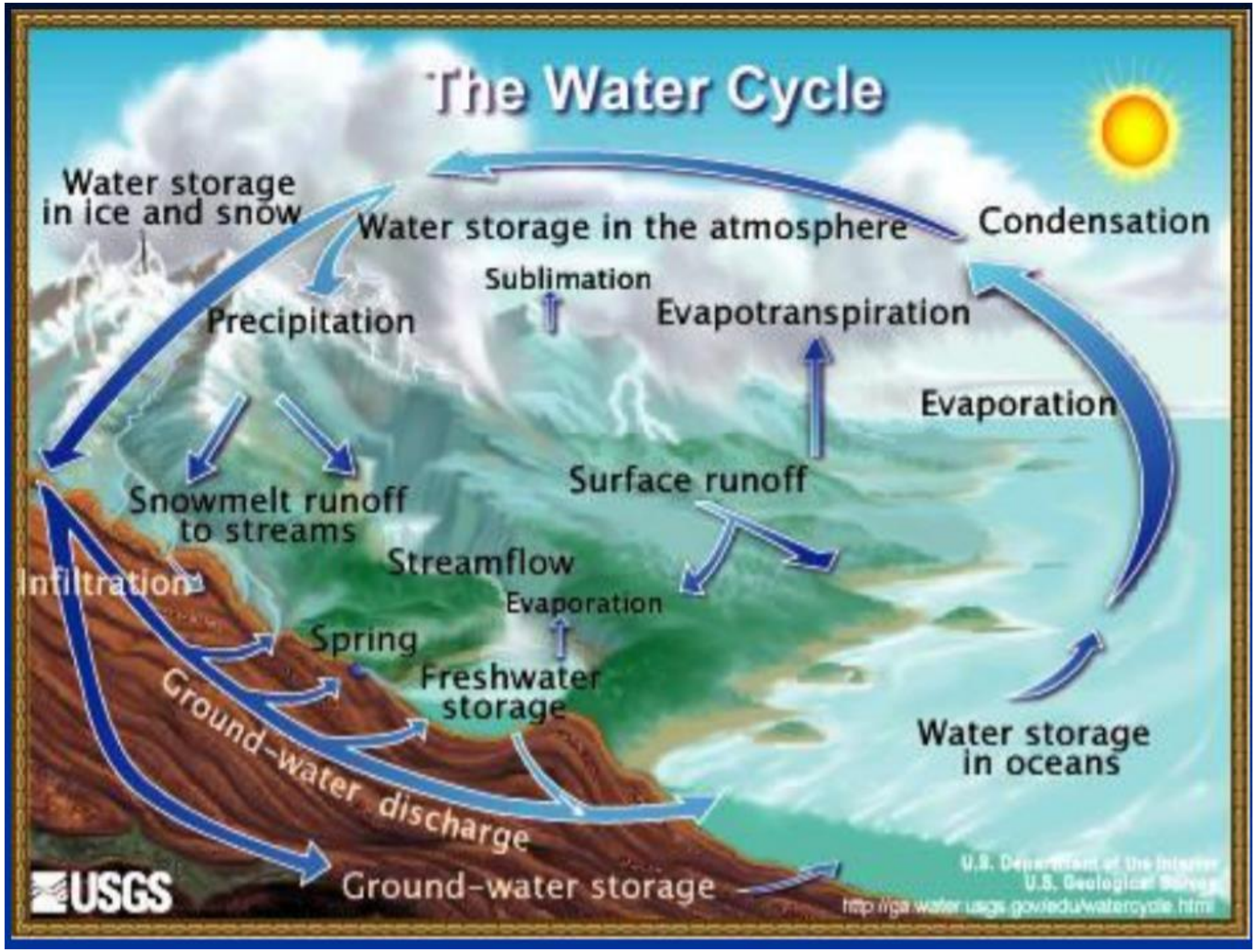


isotherm



isohyte

Hydrologic Cycle



2.1 Condensation

Definition 2.1. Condensation is the cooling of water vapor until it becomes a liquid.

As the dew point is reached, water vapor forms tiny visible water droplets. When these droplets form in the sky and other atmospheric conditions are present, clouds will form. As the droplets collide, they merge and form larger droplets and eventually, precipitation will occur.

Condensation generally occurs in the atmosphere when warm air rises, cools and looses its capacity to hold water vapor. As a result, excess water vapor condenses to form cloud droplets. The upward motions that generate clouds can be produced by convection in unstable air, convergence associated with cyclones, lifting of air by fronts and lifting over elevated topography such as mountains.

Precipitation

Definition 2.2. The moisture that falls from the atmosphere as rain, snow, sleet, or hail.

Precipitation varies in amount, intensity, and form by season and geographic location. These factors impact whether water will flow into streams or infiltrate into the ground. In most parts of the world, records are kept of snow and rainfall. This allows scientists to determine average rainfall for a location as well as classify rain storms based on duration, intensity and average return period. This information is crucial for crop management as well as the engineering design of water control structures and flood control.

2.2 Evaporation

Definition 2.3. Evaporation is the phase change of liquid water into a vapor.

Evaporation is an important means of transferring energy between the surface and the air above. The energy used to evaporate water is called "latent energy". Latent energy is "locked up" in the water molecule when water undergoes the phase change from a liquid to a gas. Eighty-eight percent of all water entering the atmosphere originates from the ocean between 60 degrees north and 60 degrees south latitude. Most of the water evaporated from the ocean returns directly back to the ocean. Some water is transported over land before it is precipitated out.

The conversion of water from a liquid into a gas. Approximately 80% of all evaporation is from the oceans, with the remaining 20% coming from inland water and vegetation. Winds transport the evaporated water around the globe, influencing the humidity of the air throughout the world.

Most evaporated water exists as a gas outside of clouds and evaporation is more intense in the presence of warmer temperatures. This is shown in the image above, where the strongest evaporation was occurring over the oceans and near the equator (indicated by shades of red and yellow).

2.3 Evapotranspiration

Definition 2.4. Evapotranspiration is the combined net effect of evaporation and transpiration.

Evapotranspiration uses a larger portion of precipitation than the other processes associated with the hydrologic cycle.

Evaporation is the process of returning moisture to the atmosphere. Water on any surface, especially the surfaces of mudholes, ponds, streams, rivers, lakes, and oceans, is warmed by the sun's heat until it reaches the point at which water turns into the vapor, or gaseous, form. The water vapor then rises into the atmosphere.

2.4 Infiltration and percolation

Definition 2.5. Infiltration is the entry of water into the soil surface.

Infiltration constitutes the sole source of water to sustain the growth of vegetation and it helps to sustain the ground water supply to wells, springs and streams. The rate of infiltration is influenced by the physical characteristics of the soil, soil cover (i.e. plants), water content of the soil, soil temperature and rainfall intensity. The terms infiltration and percolation are often used interchangeably.

As water reaches the surface in various forms of precipitation, it is intercepted by plants or falls directly to the surface. Precipitation that collects on the leaves or stems of plants is known as interception. The amount of water intercepted by a plant largely depends on plant form. Water is held on the leaf surface until it either drips off as through fall or trickles down the leaf stem finally reaching the ground as stem flow. Interception of falling rain buffers the surface against erosion. Coniferous trees tend to intercept more water than deciduous trees on an annual basis because deciduous trees drop their leaves for a period of time.

Definition 2.6. Percoloation is the downward movement of water through soil and rock.

Percolation occurs beneath the root zone. Ground water percolates through the soil much as water fills a sponge, and moves from space to space along fractures in rock, through sand and gravel, or through channels in formations such as cavernous limestone. The terms infiltration and percolation are often used interchangeably.

2.5 Runoff

Definition 2.7. Runoff is the movement of water, usually from precipitation, across the earth's surface towards stream channels, lakes, oceans, or depressions or low points on the earth's surface.

2.6 Transport

Definition 2.8. Transport is the movement of water through the atmosphere, specifically from over the oceans to over land.

Some of the earth's moisture transport is visible as clouds, which themselves consist of ice crystals and/or tiny water droplets. Clouds are propelled from one place to another by either the jet stream, surface-based circulations like land and sea breezes, or other mechanisms. However, a typical 1 kilometer thick cloud contains only enough water for a millimeter of rainfall, whereas the amount of moisture in the atmosphere is usually 10-50 times greater.

Most water is transported in the form of water vapor, which is actually the third most abundant gas in the atmosphere. Water vapor may be invisible to us, but not to satellites, which are capable of collecting data about the moisture content of the atmosphere. From this data, visualizations like this water vapor image are generated, providing a visual picture of moisture transport in the atmosphere.

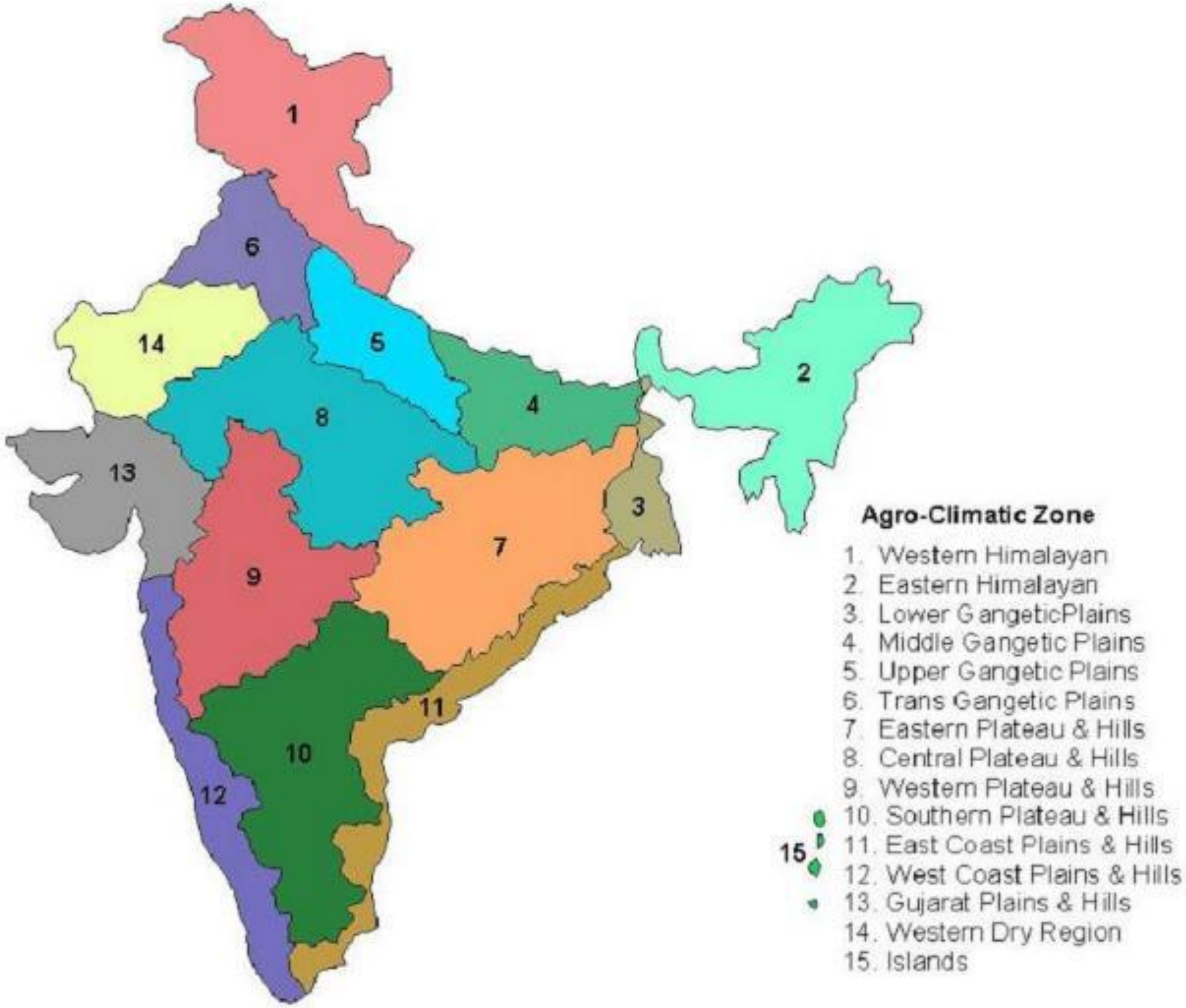
Agro-climatic Regions of India

Regionalisation has been used for planning at various levels. Several methodologies have been used for regionalisation depending on the purpose and ends. An important objective of most of these efforts was to evolve agro-ecological regional maps for the country in order to delineate comparable resource regions, for generating and transferring agro-technology to meet the country's needs of food, fodder and fibre. Most early attempts at regionalisation were on the basis of broad natural regions, existing cropping patterns, as well as a broad framework of climatic variations at a macro scale

The main objectives of agro-climatic regions are:

(i) to optimise agricultural production
(ii) to increase farm income
(iii) to generate more rural employment
(iv) to make a judicious use of the available irrigation water
(v) to reduce the regional inequalities in the development of agriculture

Agro-climatic zones of India



Zone 1- Western Himalayan Region: Jammu and Kashmir, Uttar Pradesh

Zone 2 - Eastern Himalayan Region: Assam, Sikkim, West Bengal and all North-Eastern states

Zone 3 - Lower Gangetic Plains Region: West Bengal

Zone 4 - Middle Gangetic Plains Region: Uttar Pradesh, Bihar

Zone 5 - Upper Gangetic Plains Region: Uttar Pradesh

Zone 6 - Trans-Gangetic Plains Region: Punjab, Haryana, Delhi and Rajasthan

Zone 7 - Eastern Plateau and Hills Region: Maharastra, Uttar Pradesh, Orissa and West Bengal

Zone 8 - Central Plateau and Hills Region: MP, Rajasthan, Uttar Pradesh

Zone 9 - Western Plateau and Hills Region: Maharastra, Madhya Pradesh and Rajasthan

Zone 10 - Southern Plateau and Hills Region: Andhra Pradesh, Karnataka, Tamil Nadu

Zone 11 - East Coast Plains and Hills Region: Orissa, Andhra Pradesh, Tamil Nadu and Pondicherry

Zone 12 - West Coast Plains and Ghat Region: Tamil Nadu, Kerala, Goa, Karnataka, Maharashtra

Zone 13 - Gujarat Plains and Hills Region: Gujarat

Zone 14 - Western Dry Region: Rajasthan

Zone 15 - The Islands Region: Andaman and Nicobar, Lakshadweep