THE NEOTIA UNIVERSITY
ज्ञानम् आत्म प्रदीपाय

Introductory Agro-meteorology and Climate change Practical Manual
Course Code:CC –AGP 234 Credits:2(1+1)

Under the Guidance of Prof. S. K. Kothari, Director

Department of Agronomy
School of Agriculture and Allied Sciences
The Neotia University
Sarisha, Jhinga - 743368, D. H. Road South 24 Parganas, West Bengal

Compiled by

Mr. Argha Ghosh

Contents

Practical -1

Visit to principal agrometeorological observatory

The agrometeorological observatory is a piece of land where observing instruments are installed for continuous monitoring of weather elements essential for agricultural activities.

Site selection for agrometeorological observatory

1. A flat rectangular plot with 55 m in N-S direction and 36 m in E-W direction
2. Representative of the soil and crop conditions of the area
3. Free from water logging
4. Away from hills, buildings and trees to avoid shade
5. Should be away from steep slope
6. The soil of the station and the surrounding area should have a green grass cover/ short crop cover.
7. The station should be fenced by barbed wire up to 1-1.5m height.

Agrometeorological observatories are of three types based on availability of instruments as described as follows

Auxiliary Observatory (Class C)	Ordinary observatory (Class B)	Principal observatory (Class A)
Essential instruments: 1. Single stevenson's screen having Dry bulb, wet bulb, maximum & minimum thermometer 2. Non-recording/ ordinary rain gauge	**Essential instruments:** 1. Single stevenson's screen having Dry bulb, wet bulb, maximum & minimum thermometer 2. Non-recording/ ordinary rain gauge 3. Soil thermometers at 5, 15 & 30 cm soil depth 4. Evaporimeter 5. Wind vane and Anemometer	**Essential instruments:** 1. Single stevenson's screen having Dry bulb, wet bulb, maximum & minimum thermometer 2. Non-recording/ ordinary rain gauge 3. Soil thermometers at 5, 15 & 30 cm soil depth 4. Evaporimeter 5. Wind vane and Anemometer
Optional instruments: 1. Wind vane and Anemometer 2. Dew gauge	**Optional instruments:** 1. Dew gauge 2. Sun shine recorder 3. Self-recording rain gauge 4. Thermograph and Hygrograph	**Optional instruments:** 1. Dew gauge 2. Sun shine recorder 3. Self-recording rain gauge 4. Thermograph and Hygrograph

Recording time of instruments

The observation from rain gauge and evaporimeter is taken at 8:30 IST. The time of recording for other instruments is scheduled at fixed local mean time (LMT) at 0700 or 1400 or at both as recommended for the specific instrument. The local mean time for any station is estimated from longitude of that place. To estimate local mean time for any location the following formulae is used

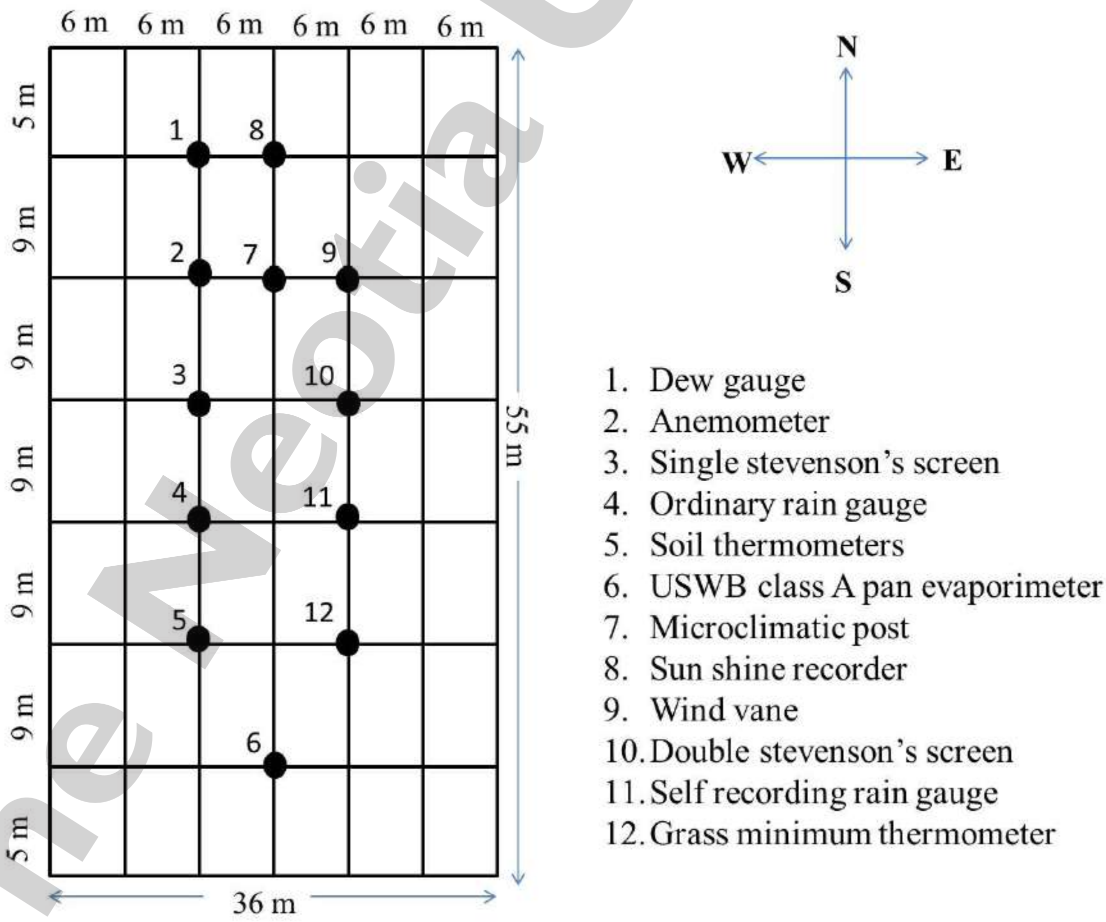
$IST = LMT + 4\ (\lambda_S - \lambda_L)$

λ_S = Standard Time Longitude (82°30'E) for India passing through Allahabad

λ_L= Longitude of the station for which local time is calculated

The stations at east of the standard longitude will have LMT ahead of IST and vice versa.

Recommended layout of a Principal agrometeorological observatory



Reference Video link:

https://youtu.be/JapT2XDOSAE

Exercise

1. **Write down the time of observation and purpose of the following instruments**
    a. Maximum thermometer
    b. Minimum thermometer
    c. Dry bulb thermometer
    d. Wet bulb thermometer
    e. Evaporimeter
    f. Thermograph
    g. Hygrograph
    h. Sun shine recorder
    i. Wind vane
    j. Anemometer
    k. Rain gauge
    l. Soil thermometer

2. **Calculate, at what IST maximum temperature is conventionally measured in the following meteorological observatories**

    A. Mumbai (Longitude = 72°51' E) B. Chennai (Longitude = 80°14' E)

    C. Bhubaneswar (Longitude = 85° 52' E) D. Ludhiana (Longitude = 75° 54' E)

Conclusion:

Practical -2

Calculation of Global radiationusing Pyranometer

Global radiation is the total short-wave radiation from the sky falling onto a horizontal surface on the ground. It includes both the direct solar radiation and the diffuse radiation resulting from reflected or scattered sunlight.

Global solar radiation measurements are used in several applications for different purposes:

- Solar energy to determine how efficiently solar panels are converting the sun's energy into electricity and when the panels need to be cleaned. Sensors used for this purpose usually measure radiation in the plane of the solar panel array.
- Utilities to predict gas and electricity energy usage
- Research as one parameter to predict or quantify plant growth or production
- Agriculture, as well as golf and park maintenance, as one parameter to predict plant water usage and to schedule irrigation
- Meteorology as one factor in weather prediction models

Pyranometer:A pyranometer is a sensor that converts the global solar radiation it receives into an electrical signal that can be measured. Pyranometers measure a portion of the solar spectrum. As an example, the CMP21 Pyranometer measures wavelengths from 0.285 to 2.8 µm. A pyranometer does not respond to long-wave radiation.Pyranometers must also account for the angle of the solar radiation, which is referred to as the cosine response. The most common types of pyranometers used for measuring global solar radiation are thermopiles and silicon photocells.

- **Thermopile pyranometers**: Thermopile pyranometers use a series of thermoelectric junctions (multiple junctions of two dissimilar metals—thermocouple principle) to provide a signal of several µV/W/m2 proportional to the temperature difference between a black absorbing surface and a reference. The reference may be either a white reflective surface or the internal portion of the sensor base. The thermopile pyranometer's black surface uniformly absorbs solar radiation across the solar spectrum. The thermopile pyranometer accurately captures the sun's global solar radiation because its special black absorptive surface uniformly responds to most of the solar spectrum's energy. The sensing element is usually enclosed inside one or two specialty glass domes that uniformly pass the radiation to the sensing element. The advantages of thermopile pyranometers relate to their broad usage and accuracy. A thermopile pyranometer's black surface uniformly absorbs solar radiation across the short-wave solar spectrum from 0.285 to 2.800 μm. The uniform spectral response allows thermopile pyranometers to measure the following: reflected solar radiation, radiation within canopies or greenhouses, and albedo (reflected:incident) when two are deployed as an up-facing/down-facing pair.

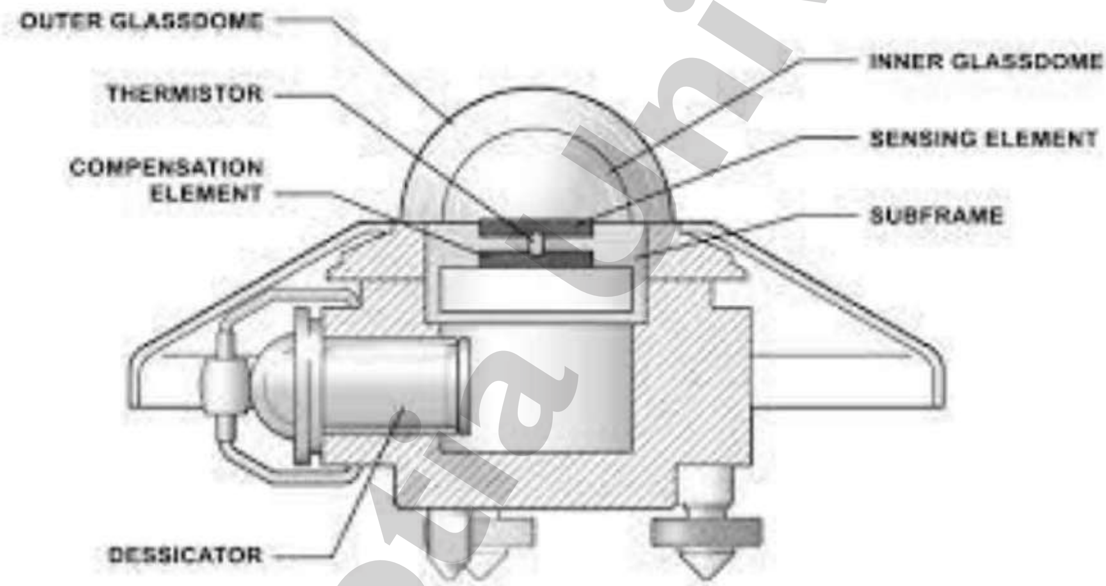


Figure: Thermopile pyranometer

Reference video link:

https://youtu.be/xQopheOsIpc

https://youtu.be/PPICpKYnJs0

Exercise

1. Note the radiation amount from the thermopile pyranometer under sunny, partly shade and full shade conditions.

Conclusion:

Practical -3

Measurement of sunshine duration

Sunshine duration is defined as "the period during which direct solar irradiance exceeds a threshold value of 120 watts per square meter (W/m2)" (WMO 2003). This value is equivalent to the level of solar irradiance shortly after sunrise or shortly before sunset in cloud-free conditions.

Sunshine duration or sunshine hours is a climatological indicator. Sunlight provides the energy plants need to convert carbon dioxide and water into carbohydrates and oxygen. The carbohydrates produced by photosynthesis are used for vegetative and reproductive growth and to increase crop biomass. Because solar energy is needed for photosynthesis, it only occurs during daylight. Day length affects how much light is available to plants for photosynthesis, which defines how much energy they can produce. However, day length can serve as an indicator of the season for plants. Day length helps plants to regulate their internal clock.

Measurement

The sunshine is measured by means of the Campbell-Stokes Sunshine Recorder. This consists of a glass sphere of which the diameter is 10 cm and is designed to focus the rays from the sun onto a card mounted at the back and is set on a stand. The card is held in place by grooves of which there are three overlapping sets, to allow for the altitude of the sun during different seasons of the year. The recording of each day goes onto one card.The sunshine recorder is installed on a masonry pillar. There should not be any obstruction having an elevation of 3° above the horizon.

In the northern hemisphere, the unit is set in a stand facing south to enable the maximum amount of sun to be recorded. It is important to place the unit in an area where the sun will not be blocked by buildings, trees or flagpoles.

While inserting the new sunshine card, its 12-hr. line should be adjusted to coincide with the noon line engraved on the bowl. The card is subdivided into hourly intervals. As the sun moves across the sky, its focussed image burns a trace on the card, so that by measuring the trace for the whole day, the duration of sunshine during the day can be accurately recorded. For this purpose, a special plastic scale is provided in which the subdivisions of the hour are also marked. By keeping the plastic scale on the trace, the total duration of the intermittent burns of the card within an hour can be added up and thus, the total duration of sunshine can be obtained correct to 0.1 of an hour. The hours marked in the sunshine card refer to local mean time (LMT) of the station. Thus sunshine is measured in number of hours per day. For each day's observation, sunshine cards should be inserted in the recorder before sunrise and removed after sunset.

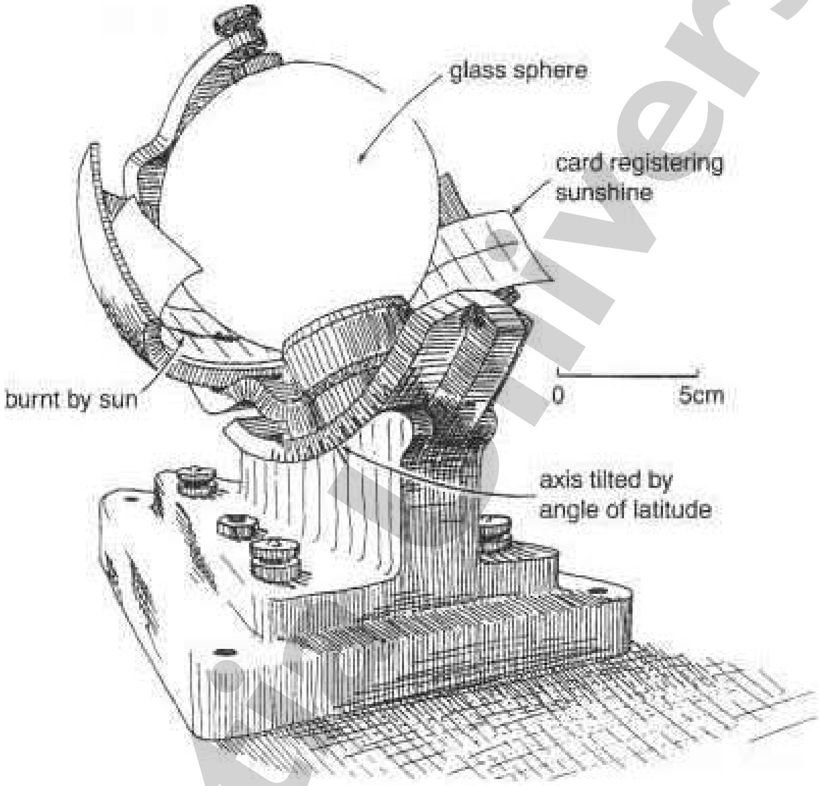


Figure: Campbell-Stokes Sunshine Recorder

Three types of cards as per following details are used in the instrument.

Card	Groove location	Period	
		Northern hemisphere	Southern hemisphere
Long curved	Lower	11-April to 31-August	11-October to 28-February
Straight	Middle	1-September to 10-October	1-March to 10-April
Short curved	Upper	11-October to 28-February	11-April to 31-August
Straight	middle	1-March to 10-April	1-September to 10-October

Procedure

a) Select the appropriate new card corresponding to the season concerned.

b) Insert the new sunshine card in the appropriate groove of the recorder and adjust it so that its 12-hr. line coincides with the noon mark engraved on the bowel.

c) Remove the burnt card in the evening after sunset and mark the date of observation on the reverse of the card.

d) Tabulate the amount of sunshine recorded during each hour of the day from sunrise to sunset using the special plastic scale.

e) Add up the values for all the hours and determine the total duration of sunshine hours of the day.

Precautions

a) Do not clean the glass bowl of the sunshine recorder with any cloth or material that may abrade the surface. Avoid excessive vigour in polishing.

b) Remove immediately any deposit such as dew, frost, snow or bird droppings.

c) If the trace is not parallel to the central line of the card, or if the intensity of the trace is too high or too low, carry out leveling and other adjustments of the recorder.

d) Use the sunshine cards appropriate for the season.

Reference video link:
https://youtu.be/tTEPjinivls

Exercise: Find out the sunshine duration to one decimal of hour from the card of the date……………..

Break-up	5-7	7-9	9-11	11-13	13-15	15-17	17-19	19-21
Sunshine duration (hr)								
Total of the day								

Conclusion:

Practical -4

Determination of radiation intensity using BSH

The utilization of solar energy, like any other natural resources,requires detailed information on availability. Detailed information about the availability of solar radiation onhorizontal surface is essential for the optimum design and studyof solar energy conversion system.When solar radiation enters the atmosphere, a part of theincident energy is removed through the process of absorption,scattering and reflection.The global solar radiation varies from latitude to latitude. Thus, a solar radiation measurement parameter is obtained and defined as the ratio of the actual number of hours of sunshine received at a site to the day length. The ratio is known as fraction of sunshine hours n/N. It is found to vary daily and seasonality. The amount of global solar radiation H_0 is the extraterrestrial radiation which is found at the top of the atmosphere of the site. Similarly H_g is global solar radiation which is the fraction of the extraterrestrial radiation at the ground surface after scattering, reflection and absorption in the atmosphere. The ratio of H_g/H_0 is a possible measure of the transparency of the atmosphere to the solar radiation. It is also called clearness index or coefficient of transmission.

Monthly mean radiation intensity of a particular place can be estimated using Angstrom-Prescott Equation which is as follows:

$$\frac{H_g}{H_0} = a + b\,\frac{n}{N}$$

H_0 = Monthly mean Extra-terrestrial radiation

H_g= Monthly Mean Earth Surface radiation

n= Bright Sunshine Hour

N= Monthly average daylength

a,b = Empirical Constants

Reference video link:

https://youtu.be/ur5muGY5Gy4

Exercise

1. Calculate the average solar radiation of Kalyani for November month, when average monthly BSS is 9.7 hours. Assume that the Extra-terrestrial radiation for this period is 720 $cal/cm^2/day$. [Consider: N= 10.9 hours for November, a=0.3143 and b=0.4476 for Kalyani Station]

Conclusion:

Practical -5

Measurement of Photosynthetically active radiation (PAR) distribution in a crop canopy

Photosynthetically active radiation (PAR): Photosynthetically active radiation (PAR) is light of wavelengths 400-700 nm and is the portion of the light spectrum utilized by plants for photosynthesis. Photosynthetic photon flux density (PPFD) is defined as the photon flux density of PAR (µmol $s^{-1}m^{-2}$).PAR changes seasonally and varies depending on the latitude and time of day. Levels are greatest during the summer at mid-day.PAR measurement is used in agriculture, forestry and oceanography. One of the requirements for productive farmland is adequate PAR, so PAR is used to evaluate agricultural investment potential. PAR sensors stationed at various levels of the forest canopy measure the pattern of PAR availability and utilization. Photosynthetic rate and related parameters can be measured non-destructively using a photosynthesis system, and these instruments measure PAR and sometimes control PAR at set intensities. PAR measurements are also used to calculate the euphotic depth in the ocean.

Line quantum sensor: Photosynthetically Active Radiation or PAR light lies in the range 400-700nm and is the part of the sun's spectrum used by plants for photosynthesis. The PAR line quantum sensor consists of 33 individual sensors evenly spaced along an 850mm length. The design and diffusing cover ensures the average of PAR light falling along the whole length is measured.This sensor is designed to give an integrated value of the PAR inside plant canopies.

Figure: Line quantum sensor

Specifications:

Materials:	AnodisedAluminium, Acrylic. IP65 sealed.
Cable:	5mEnhanced polyethylene screened twin 18 x 0.1mm
Sensor:	33, GaAsP Photodiodes. 350 - 680nm. peak at 640nm.
Sensitivity:	1 mV/10 mmol / m2/s
Temperature Sensitivity:	±0.15%/°C at peak response, from 0 - 50°C
Linearity:	1% over 0 - 2000μmol/m2/s
Uniformity of sensing surface:	better than 2% over 0.85 sensing length
Response time:	2μs. 10 - 90%
Output:	200mV / 2,000μmol / m2 / s
Operating temperature range:	-20°C - + 50°C

Procedure:

- Go to the crop field
- Hold the instrument across the rows
- Fix the glass index properly
- Note the reading from the data logger
- Invert the instrument and hold over the canopy
- Insert the instrument inside the crop canopy and take the reading keeping the instrument straight and inverted.
- Calculate the incident, reflected, transmitted and absorbed PAR

Reference video link:

https://youtu.be/-JXvD02fNOc

Exercise:

Note the incident, reflected PAR over the top of the crop canopy and in the middle of the crop canopy. Calculate the absorbed PAR.

Conclusions:

Practical -6

Measurement of maximum and minimum air temperature from Stevenson's screen

Air temperature is the temperature of the air recorded by the thermometer exposed in a standard type of screen called Stevenson screen. The objective of the screen is to shield the thermometers from radiation from the sun, ground and neighbouring objects, and from losing heat by radiation at night. The screen also protects the thermometer from precipitation while at the same time allowing free circulation of air. It is usually made in the shape of a box with louvered sides at the bottom and double roof having 2-3 inches air space. The shelter is painted white and is usually mounted on an open wooden support. The floor of the screen is 4 ft. above the ground. The shelter is set up with its door facing north side in the Northern Hemisphere so that only minimum sunlight would enter while the observer is reading the instruments.

Single Stevenson screen: A single Stevenson screen is a wooden box with certain specifications and it is available in standard sizes. It houses the following thermometers:[1' X 1 ½ ' X 2']. It contains maximum, minimum, dry bulb and wet bulb thermometers.

Double Stevenson screen: It houses some autographic instruments like thermograph and hygrograph for continuous record of temperature and relative humidity, respectively. [1' X 1 ½ ' X 4']

Dry bulb thermometer: Dry bulb thermometer is installed towards left in vertical position with bulb end down. This is an ordinary Hg in glass thermometer graduated from - 35°C to 55°C. This has a capillary stem of which end is bulb containing mercury and the other end is sealed after removing air from the same. Reading times are 7:00 LMT and 14:00 LMT.

Wet bulb thermometer: It is an ordinary thermometer similar to the dry bulb thermometer. Its bulb is wrapped by a piece of muslin cloth just sufficient to cover the bulbe. The other end of the muslin cloth is dipped in a small container or bottle having distilled water or rain water to keep the muslin cloth moist round the clock. Distilled water or rain water is used to avoid salt deposition on bulb and muslin cloth. Dust from the atmosphere may be deposited on muslin and bulb of the thermometer. So muslin cloth should be changed at frequent intervals. Reading times are 7:00 LMT and 14:00 LMT. Graduation is from - 35°C to 55°C.wet bulb thermometer is placed towards the right side in the screen.

Maximum thermometer: It is a Hg thermometer with a constriction in the stem near the bulb. When the temperature falls after reaching the maximum value, Hg does not return to the bulb. The range of maximum thermometer graduation is from - 35°C to 55°C. Reading time is 7: 00 LMT. Maximum thermometer is installed horizontally on the upper side in between dry bulb and wet bulb thermometer. It is placed horizontally with bulb downwards at an angle of about 2°.

Minimum thermometer: It is a spirit thermometer, commonly used liquid is absolute ethyl alcohol. Within the liquid, there is a very light dark glass index which moves freely within the alcohol due to surface tension. The reading time is 14:00 LMT and the range of graduation is from - 40°C to 50°C. Reading is taken from the one end of the glass index which is farthest from the bulb. The minimum thermometer is with bulb end slightly at lower position by about 2° to the horizon.

Figure: Maximum, minimum, dry bulb and wet bulb thermometers in Single Stevenson's screen

Figure: Double Stevenson's screen with thermograph and hygrograph

Procedure

1) Open the Stevenson screen

2) Note the reading of the dry bulb thermometer, correct to 0.1°C.

3) Note reading of the maximum thermometer correct to 0.1°C.

4) Reset the maximum thermometer after recording the temperature.

5) Note the reading of the minimum thermometer corresponding to the end of the index away from the bulb. correct to 0.1°C.

6) Reset the minimum thermometer after recording the temperature.

Precautions

2. Take the temperature reading as quickly as possible, so that it is not affected by your presence.
3. After taking temperature readings, index corrections of the thermometers, obtained by calibration done with the standard thermometers earlier, should be applied.

4. Avoid parallax error while reading the thermometers.
5. After reading the thermometer, verify once again whether the whole number of degrees has been read correctly.
6. Do not keep the door of the Stevenson screen open for a longer time than is necessary.
7. Use distilled water or rainwater for the wet bulb thermometer and keep the container bottle clean.
8. Cover the bulb with only one fold of muslin cloth tied with strands of darning cotton and trim the excess muslin cloth.
9. The bottle should have a small neck so that air inside the screen may not be moistened by evaporation of water from the vessel.
10. Place the bottle on one side of the wet bulb away from the dry bulb and not directly below the dry bulb.
11. Keep muslin and cotton thread clean and free from dust or grease.
12. Change muslin cloth and threads immediately after a dust storm.
13. Inspect wet bulb periodically and if the wet bulb develops a white coating due to incrustation of salts, clean it with a lemon or dilute acid.

Reference video link:

https://youtu.be/taHCJj1gdnw

Exercise:

1. Write down the names of the instruments present in single and double Stevenson Screens.
2. Note the air instantaneous air temperature (during observation), maximum air temperature and minimum air temperature.
3. Differentiate maximum and minimum thermometer.

Conclusions:

Practical -7

Measurement of soil temperature

Soil temperature is the factor that drives germination of seeds. Soil temperature directly affects plant growth. Most soil organisms function best at an optimum soil temperature. Soil temperature impacts the rate of nitrification.

Soil temperature at specified depth is measured by means of soil thermometer. For measuring soil temperature, mercury thermometers are. In a principal agrometeorological observatory the soil thermometers is fixed in the soil in three different depths viz. 5cm, 15 cm and 30 cm.

The front portion of the soil thermometers should face towards south in the northern hemisphere. Soil thermometers should be installed with increasing depth from the West to the East i.e. soil thermometer of 5 cm in the West followed by the soil thermometer of 15 cm and 30 cm . The reading times are 7:00 LMT and 14.00 LMT.

While observing the soil thermometer, care should be taken so that the shadow of the observer is not cast on the thermometers.

Figure: Soil thermometer

Reference video link:

https://youtu.be/cQOvAG6Rp_4

Exercise

1. Note the soil temperatures at 3 different depths.
2. Estimate the trend of soil temperature with decreasing soil depth.

Conclusions:

Practical -8

Computation of soil heat flux

Soil heat flux (G) is a critical component of the surface energy balance along with the net radiation (R_N), latent heat flux (L), sensible heat flux (H), and in some cases, canopy storage and photosynthesis (Cobos and Baker 2003). Soil heat flux can be defined by the amount of heat energy transferred to one point to another point in the soil per unit area per unit time. Movement of heat from one point to another point in the soil depends on the temperature difference between those two points, distance between those two points and the thermal conductivity of the soil. Soil heat flux (q_h) is directly proportional to the temperature difference (ΔT) and inversely proportional two the distance (Δx) between two points.

$$q_h \propto \frac{\Delta T}{\Delta x}$$

$\frac{\Delta T}{\Delta x}$ is known as the temperature gradient (T_i) between two points.

$q_h = -K_T T_i$ (-ve sign denotes the heat flow from higher temperature to lower temperature)

This is called as the Fourier's 1st law which is applicable in homogenous media.

Reference video link:

https://youtu.be/bmf91uQy_K0

Exercise

1. Compute the magnitude of the heat flux between point A and point B with the following specifications:

   A = 2.5 cm soil depth; 14°C and B = 15 cm soil depth; 13°C

   Given: The heat carrying capacity of the soil is 0.50 W $m^{-1}K^{-1}$.

Conclusions:

Practical -9

Determination of vapour pressure, relative humidity and dew point temperature

Vapour pressure

The vapour pressure of water is the pressure at which water vapour is in thermodynamic equilibrium with its condensed state.Actual vapor pressure is a measurement of the amount of water vapor in a volume of air and increases as the amount of water vapor increases. Air that attains its saturation vapor pressure has established equilibrium with a flat surface of water.

The vapor pressure of a system, at a given temperature, for which the vapor of a substance is in equilibrium with a plane surface of that substance's pure liquid or solid phase; that is, the vapor pressure of a system that has attained saturation

The difference between the saturation vapour pressure and actual vapour pressure is known as the vapour-pressure deficit (VPD). VPD is simply the difference (deficit) between the amount of moisture in the air and how much moisture the air can hold when it is saturated. Once air becomes saturated, water will condense out to form clouds, dew or films of water over leaves. It is this last instance that makes VPD important for greenhouse regulation. If a film of water forms on a plant leaf, it becomes far more susceptible to rot. On the other hand, as the VPD increases, the plant needs to draw more water from its roots. In the case of cuttings, the plant may dry out and die.

Computation of vapour pressure and saturation vapour pressure deficit

For this purpose a table of saturation vapour pressure values (either in mb. or in mm. of Hg.) corresponding to air temperature will be required. Since the actual vapour pressure is the saturation vapour pressure at the dew point temperature, the vapour pressure can be computed by noting from the saturation vapour pressure table, the values corresponding to the dew point temperature. Saturation vapour pressure can be determined from the observed dry bulb temperature.

Humidity

Humidity is the amount of water vapor in the air. If there is a lot of water vapor in the air, the humidity will be high. Relative humidity is the amount of water vapor actually in the air, expressed as a percentage of the maximum amount of water vapor the air can hold at the same temperature.

Humidity depends on the temperature and pressure of the system of interest. The same amount of water vapor results in higher humidity in cool air than warm air. A related parameter is the dew point. The amount of water vapor needed to achieve saturation increases as the temperature increases. As the temperature of a parcel of air decreases it will eventually reach the saturation point without adding or losing water mass. The amount of water vapor contained within a parcel of air can vary significantly.

Dew point temperature is defined as the temperature to which the air would have to cool (at constant pressure and constant water vapor content) in order to reach saturation. A state of saturation exists when the air is holding the maximum amount of water vapor possible at the existing temperature and pressure.

Calculation of dew point temperature and relative humidity

From the dry bulb and wet bulb temperature readings the dew point temperature and relative humidity can be obtained using hygrometric tables. If the altitude of the place of observation is less than 1500 ft., 1000 mb Hygrometric tables are to be used and for higher station elevation, 900 mb Hygrometric tables are to be used. Dew point temperature and relative humidity corresponding to specified values of dry and wet bulb temperature are given in the abovementioned tables at intervals of 0.2°C. While using the tables, interpolation to the nearest 0.1°C has to be done, wherever necessary. During interpolation it is to be noted if any digit is followed by 0.5, it should be rounded off to the next higher digit only when the digit is even, and when the digit is odd, it remains the same. This procedure is followed in order to avoid systematic overestimation during rounding off.

Procedure

a) Open the Stevenson screen.

b) Note the reading of the dry bulb thermometer correct to 0.1°C.

c) Note the reading of the wet bulb thermometer correct to 0.1°C.

d) Read from the Hygrometric tables dew point temperature and relative humidity values, corresponding to observed dry bulb and wet bulb temperature readings after carrying out necessary interpolation.

e) Compute vapour pressure from the dew point temperature obtained, by using the saturation vapour pressure table.

f) Compute the saturation vapour pressure corresponding to the dry bulb temperature from the same table.

g) Calculate the saturation vapour pressure deficit, by the method given already.

Actual vapour pressure can be calculated by using a mathematical equation as proposed by Regnault and as modified by August (for wet bulb temperature greater than 0°C)

$$X = f' - \frac{0.480-(T-T')}{610-T'} . P$$

Where, X = Actual vapour pressure of air (mb)

f ' = Saturation vapour pressure at temperature T'°C of the wet bulb (mb.) – obtained from table

T = Temperature of the dry bulb thermometer in °C (recorded from observatory)

T' = Temperature of the wet bulb thermometer in °C (recorded from observatory)

P = Pressure of air (consider 1000 mb.)

Relative humidity (RH) is measured by the following equation:

$$\text{RH (\%)} = \frac{\textit{Actual vapour pressure (X)}}{\textit{Saturation vapour pressure corresponding to the dry bulb temperature (from table)}}$$

Vapour pressure deficit (VPD) is measured by the equation:

VPD = (Saturated vapour pressure corresponding to dry bulb temperature – Actualvapour pressure)

Reference video link:

https://youtu.be/kAjQUDrRVhc

https://youtu.be/FNzGGvCKsOs

Exercise

1. Note the dry bulb and wet bulb temperature and find out the dew point temperature, relative humidity and vapour pressure deficit using hygrometric table.

Conclusion:

Practical -10

Measurement of wind

Wind is the air in horizontal motion caused due to difference in atmospheric pressure. Wind has to be specified by its direction and speed. The movement of wind is almost horizontal and its vertical component is very small, being about $1/100^{th}$ of the horizontal component. So by wind, we generally mean only the horizontal component of the wind.

Wind related to the motion and is associated with direction and speed. It is a vector quantity and its measurement involves both direction and speed. For agrometeorological purposes, wind speed and direction are measured at a height of 10 ft. in the principal agrometeorological observatory, wind speed and direction are measured by using cup counter anemometer and wind vane respectively.

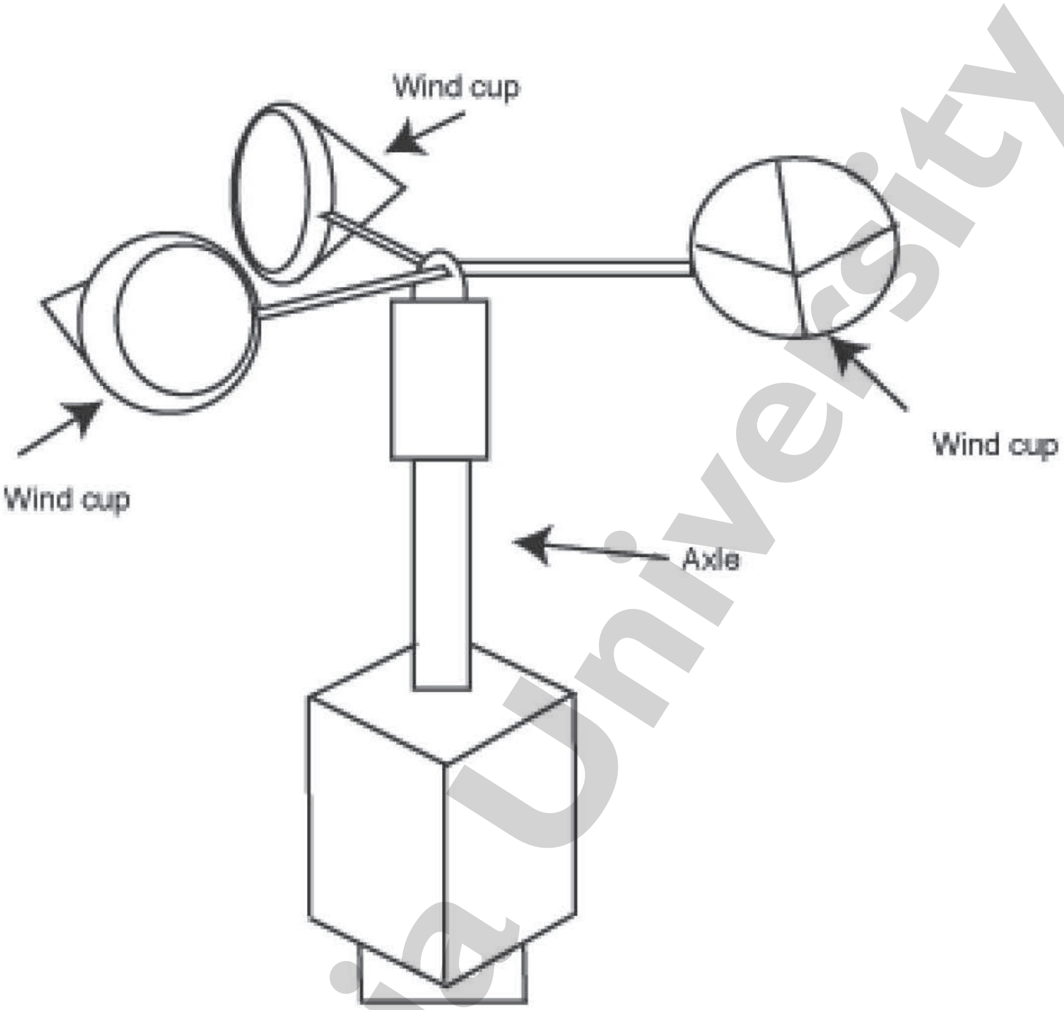


Figure: Counter cup Anemometer

Measurement of wind speed

The instrument used to measure the surface wind is called anemometer which is a mechanical arrangement converting the rotational motion into linear motion. Taking two subsequent readings in an interval and division by difference of time interval gives average wind speed during that interval.

Wind speed = $\frac{WR2-WR1}{T2-T1}$

Where, WR2 is the wind run at time T2 and WR1 is the wind run at time T1.

The cup counter anemometer consists of 3 cups mounted at right angles to a vertical axis. The force exerted by winds is greater on the inside of cups than on the outside of the cups and so the cups rotate. The anemometer is installed at a height of 10 ft. Wind speed is recorded at 7:00 and 14:00 LMT.

Measurement of wind direction

Wind direction is a direction from which the wind blows. It is expressed in degrees, measured clockwise from geographical North. It is normally expressed in codes from 00 to 36 where 00 represents calm, 09 – easterly, 18- southerly, 27- westerly and 36-northerly. The direction of wind is expressed in 8 or 16 points of compass expressing north, east, south and west by N, E, S and W, respectively. The directions represented by 8 and 16 point of compass as follows:

8 points of compass: N, NE, E, SE, S, SW, W, NW and N.

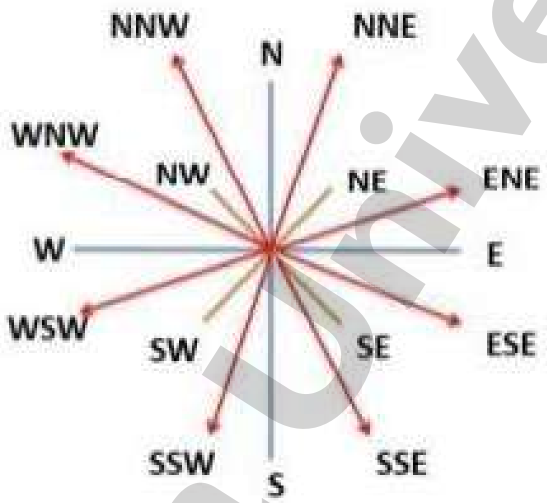


Figure: Different wind direction measured by Wind vane

16 points of compass: N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW and N.

Wind direction is measured with the help of wind vane. It consists of an arrow head installed on a metal frame free to rotate in the horizontal plane with the direction of the arrow pointing towards the direction of the wind. Below this arrow frame, another frame indicating 4 directions (N, E, S, W) are fixed to the frame to facilitate the estimation of wind direction. The instrument is installed at a height of 10 ft. and wind direction is recorded at 7:00 and 14:00 LMT.

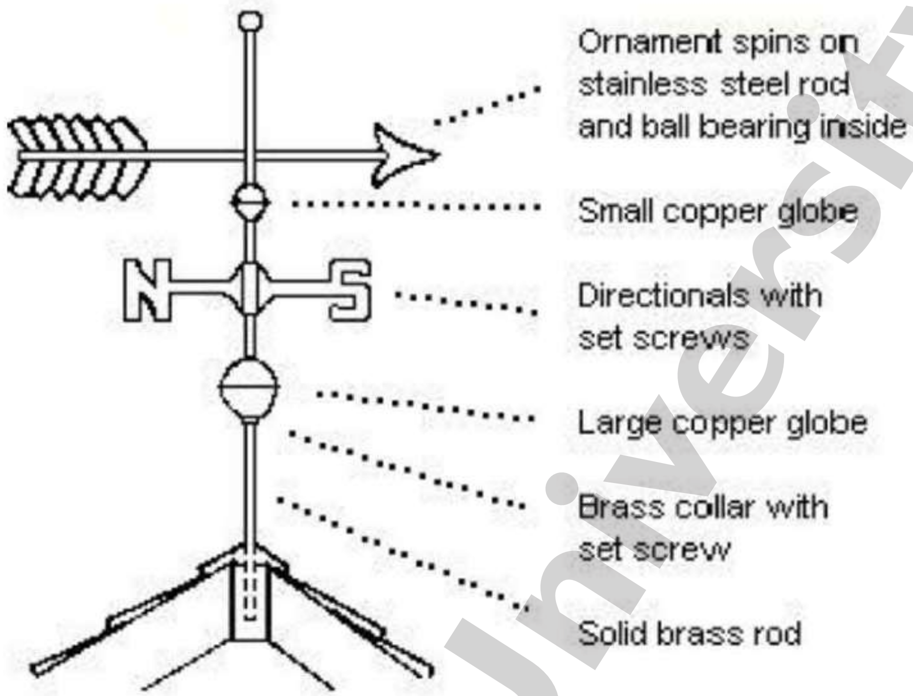


Figure: Wind vane

The direction reported is the average direction. Wind vane reading is recorded by standing exactly in the line of the arrow of the instrument. Since we record 16 directions and the distance between two directions is less, the nearest possible direction is recorded alphabetically and in degree. It may be noted that we report windward side that is from where the wind is coming. In case the wind vane is static, wind may be calm and in that case the direction is reported as 00.

Important conversion factors for calculating wind speed

1 mile = 1.69 km, 1 Nautical mile = 1.85 km

1 KNOT = 1 Nautical mile per hour = 1.85 km per hour = 0.5142 m/s

1 km/hr = 0.2778 m/s, 1mile per hour = 0.4694 m/s

1 m/s = 3.6 km/hr = 1.945 KNOT

Procedure

1. Note the initial reading of the Anemometer as well as the time accurately.
2. Note the final reading of the Anemometer after 3 minutes. 5. Subtract the initial reading from the final reading and multiply by 20 to get the instantaneous wind speed at the time of observation in kmph (if the instrument is calibrated in km).

3. Subtract the Anemometer reading at 7 hrs. LMT of the previous day from that at 7 hrs. LMT of the observation date and divide the difference by 24. This will give the mean daily wind speed for the observation date.
4. Watch the wind vane for a few minutes and identify the direction.
5. Read the direction to which the arrowhead points, nearest to the sixteen points of the compass.

Precautions

1. Make sure that the wind vane moves freely before taking the reading.

2. During occasions of light wind when wind vane does not respond readily, give a slight turn to wind vane by hand and allow it to take up the direction of wind.

3. In order to verify the direction given by the wind vane; compare the same with the appropriatedirection determined either by facing the direction of wind or by letting of small bits of paper.

Reference video link:

https://youtu.be/dfB3jxvi0LY

https://youtu.be/HFRwoPhDDAE

Exercise

1. Calculate the mean wind speed in KNOT given that the wind run at 0700 LMT 16May is 05862.5 km and that at 0700 LMT 17May is 09785.3 km.
2. Note the wind run twice during observatory visit at 15 minutes interval and calculate the wind speed in kmph.
3. Express the following wind direction in terms of degree angle
   NW, NNE, WNW, SSW, SSE and ENE.

Conclusions:

Practical -11

Measurement of rainfall

Rain is the liquid form of precipitation and it is the most important climatological factor affecting agricultural activities. The purpose of rainfall measurement is to obtain the information about the amount of precipitation occurring in a given period and its distribution over space and time. It is expressed in mm. Rainfall is commonly measured by using ordinary or non-recording rain gauge. This is also called as Fiber reinforced polyester (FRP) rain gauge.

Different parts of Ordinary rain gauge:

1. Funnel with brass rim of 159.6 mm diameter
2. Cylindrical body on which the funnel is supported
3. Receiver with narrow neck and usually with a handle
4. Base which is partly fixed in the ground and supports the cylindrical body
5. Measuring cylinder

The cross sectional area of the funnel is 200 cm^2. So it is called 200 cm^2 rain gauge. Measuring cylinder is rain gauge specific.

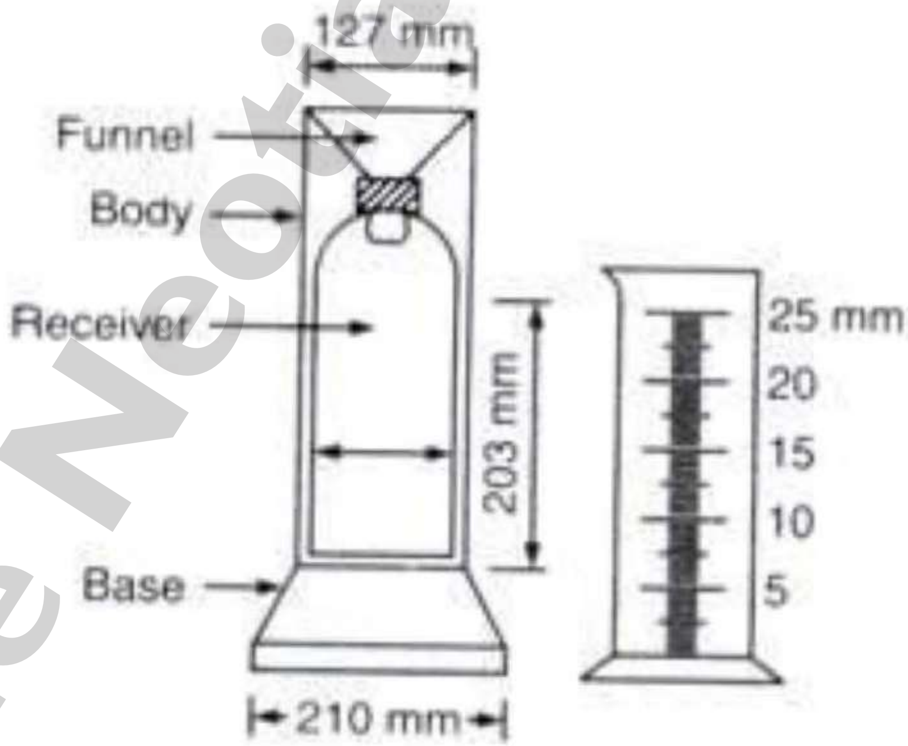


Figure: Ordinary FRP raingauge

Rainfall is measured at 8.30 IST. It is assumed that the rainfall collected per unit area of funnel aperture is the same which falls on each unit area surrounding the station. The graduation of the measuring cylinder must be consistent with the train gauge used. Measuring cylinder is made of clear glass and it is clearly marked with the size of rain gauge for which it is used. The graduation should be in units of rainfall in mm. In general every 0.2 mm should be marked.

Main sources of errors in rainfall measurement

1. Use of incorrect measuring cylinder
2. Loss of rainfall when transferring from receiver to measuring cylinder
3. Inability to transfer all water from the receiver to the measuring cylinder
4. Evaporation loss

Measurement of rainfall

The rain falling into the funnel of the raingauge is collected in the receiver kept inside the body and is measured by means of a special measuring glass cylinder graduated in millimeters. Ten millimeters of rain means that if that rainfall is allowed to be collected on a flat surface, the height of the water collected would be 10 mm. In case the above mentioned special measuring glass cylinder is not available rainwater may be measured by commonly available measuring glass graduated in ml. In such cases volume-area relationship has to be adopted to obtain depth of rainfall. If "d" be the diameter of the funnel (cm) and "v" is the volume of water collected (ml) then depth (D) of rainfall.

$$D = \frac{V}{\pi d^2/4} = \frac{V}{200}$$

Procedure

a) Remove the funnel of the raingauge.

b) Take out the receiver containing rainwater collected.

c) Place the measuring cylinder in a basin and transfer the content of the receiver into measuring cylinder.

d) Keep back the receiver and funnel in position after the transfer of rainwater.

e) Hold the measuring cylinder in an upright position or keep it on a table or a horizontal surface.

f) Read the water level in the measuring cylinder correct to 0.1 mm (since the water level would be slightly concave due to surface tension the level of the lower meniscus should be read avoiding parallax error.

Precautions

a) Avoid spilling of the rainwater while transferring from raingauge receiver to the measuring cylinder.

b) Avoid parallax error while reading the level of water in the measuring cylinder. For this the observer should keep his eye at the level of water in the cylinder while measuring.

c) Use appropriate measuring glass cylinder provided with the raingauge.

d) If during heavy rainfall, water in the receiver has overflown and fallen into the outer cylinder, the quantity of water collected in the receiver as well as in the outer cylinder should be added.

e) Alternatively, on days of heavy rainfall, more frequent measurements should be made in order to avoid overflow and all these amounts should added up

Reference video link:

https://youtu.be/JVOxLrMaWA8

Exercise

1. Write down the components of a FRP rain gauge.
2. Calculate the amount of rainfall when the receiver amounts to be 1.16 litre.

Conclusions:

Practical -12

Measurement of open pan evaporation

Evaporation is one of the important aspects of the hydrologic cycle by which water from the earth's surface is transferred to the atmosphere in the form of water vapour. Measurement of evaporation is of great importance in agricultural and hydrological studies. The rate of evaporation is defined as the amount of water lost by evaporation from a unit area of a surface in unit time and is expressed in depth units (mm/day) just like rainfall. Evaporation is dependent on a number of factors such as (a) total radiation (b) temperature of the evaporating surface and that of air, (c) wind speed (d) vapour pressure deficit and (e) nature of surface etc.

Pan evaporimeter

Evaporation is measured by means of pan evaporimeter. The class'A' pan evaporimeter which is commonly used in India, consists of a large cylindrical pan made of copper with 120-cm diameter and 25 cm depth. The pan is made of copper sheet tinned inside and painted white outside. A still well is provided inside the pan so that there would be undisturbed water surface inside that well and ripples will be broken. It consists of a brass cylinder mounted on a heavy circular base provided with three circular holes at the bottom. The reference point is provided by a brass rod fixed at the center of the still well. The top of the rod tapers to a point and is exactly 190 mm above the base of the pan. The pan is filed up with clean water till the water level just touches the tip of the rod. The pan rests on a white painted wooden grill so that the bottom of the pan would be above the surface of water in rainy weather. The wooden grills also help in reducing the conduction of heat from the surrounding soil. The pan is provided with a standard wire mesh to prevent the loss of water from the pan by external agents such as birds, animal etc. The water temperature of the pan is measured by means of a thermometer that is just immersed below the water level in the pan.

For measuring evaporation a graduated measuring cylinder made of brass is also provided with the instrument. It has a scale 0-20 cm. engraved inside it along its height. The cross sectional area of the measuring cylinder is exactly $1/100^{th}$of the area of the pan. The evaporimeter should be installed in an open site with no obstruction lasting shadow of the pan. The site should be free from flooding and water logging even during heavy rains. The pan should be placed on a wooden grill kept on a firm foundation so that the edge of the pan is level and is exactly at 36 cm above the ground. The observation of evaporation should be made daily at 0830 hrs. IST.

Figure: USWB Class A Pan Evaporimeter

Procedure

1. Note the bottom level in the still well of the pan.
2. If water level is below the tip of the rod add sufficient water slowly with the help of measuring cylinder, so that the water level again coincides with the reference level.
3. Note the amount of water added by taking into account the numbers of cylinder of water added and parts thereof.
4. Divide the amount of water (which is measured in cm) by 100 and record the quotient as the evaporation (in mm) for the 24 hrs. ending at 0830 hrs. IST of the day.
5. If rainfall has occurred during last 24 hrs. ending 0830 hrs. IST and still the water level has fallen below the reference point and water has to be added to bring the water level to the reference level, mm equivalent of this amount of water should be added to the rainfall amount in mm to get the total evaporation of the day.
6. If, however, the rainfall has been heavy and the water level has gone above the reference point at the time of observation, remove water with the help of the measuring cylinder, in

order to bring the water level back to the reference point. Subtract from the rainfall the mm equivalent of the removed water in order to get the total evaporation for the day.

7. If on any day, due to occurrence of very heavy rainfall, the water level has risenupto the rim of the pan and some water has overflown, evaporation for that day cannot be determined. So entry "overflown" should be made in the evaporation register.

Precautions

1. Inspect the pan periodically for leaks.
2. Check periodically and ensure that the wooden platform and the bottom of the tank are perfectly horizontal and the height of the rim is 36 cm above the ground level.
3. Clean the pan at least every fortnight and fill it up with fresh water.
4. When there is a likelihood of heavy rain that may cause overflowing of the pan, remove enough water and make entries regarding the same in the observation book.
5. Paint the outside of the pan with white paint and do tinning inside once every year.
6. Use water that has been stored in a reservoir for refilling so that its temperature will be as that of the pan.

Reference video link:

https://youtu.be/v3iBHPAPA4M

Exercise

1. Write down the components of the USWB class A pan evaporimeter.
2. Estimate the amount of evaporation in mm under following situations
   a. The water added to the evaporimeter to bring water to reference level = 3.1 mm. Rainfall amount = 5.8 mm
   b. The water removed to the evaporimeter to bring water to reference level = 4.6 mm. Rainfall amount = 6.1 mm
   c. The water of the evaporimeter remains at the reference level. Rainfall amount = 4.1 mm

Conclusions:

Practical -13

Computation of Potential evapotranspiration

Thornthwaiteestimated monthly potential evapotranspiration (PET) using readily available climatological data such as mean air temperature. The general equation derived by him was as follows:

$e = 1.7(\frac{10T}{I})^a$

Where, e = Unadjusted PET in cm per month (a month consisting of 30 days each and hours a day)

T = Mean air temperature (°C)

I = Annual or seasonal heat index. It is the summation of 12 values of monthly heat indices i

$i = (\frac{T}{5})^{1.514}$

a = An empirical exponent component by the following expression:

$a = 6.75 \times 10^{-7} I^3 - 7.7 \times 10^{-5} I^2 + 1.792 \times 10^{-2} I + 0.49239$

Reference video link:

https://youtu.be/9pu7iNMxpb8

Exercise

Compute the unadjusted potential evapotranspiration in cm per month by Thornthwaite method from the following data

Month	Maximum temperature (°C)	Minimum temperature(°C)	Month	Maximum temperature (°C)	Minimum temperature(°C)
January	10.6	5.5	July	21.5	11.3
February	12.8	7.2	August	21.4	11.2
March	15.9	7.8	September	21.1	11.0
April	18.1	9.2	October	20.8	11.0
May	19.6	9.6	November	18.9	9.0
June	21.3	10.2	December	15.2	7.9

Conclusions:

Practical -14

Calculation of Actual evapotranspiration

Actual evapotranspiration or AET is the quantity of water that is actually removed from a surface due to the processes of evaporation and transpiration. Scientists consider these two types of evapotranspiration for the practical purpose of water resource management. AET can be calculated by the following formula:

$AET = PET \times K_c$

The expression can also be written as: $ET_c = ET_o \times K_c$

Where,

ET_c = Crop evapotranspiration

ET_o = Reference crop evapotranspiration (Reference evapotranspiration is that from a grass surface that is well-watered)

K_c = Crop coefficient expressing the difference in evapotranspiration between the cropped and reference grass surface. Crop coefficient values are different during different crop growth stages.

Reference video link:

https://youtu.be/x9JxV5ERfd0

https://youtu.be/YO5Lf3xdsLc

https://youtu.be/x8p6JSLbI-E

Exercise:

1. Calculate the value of total AET of a crop having a crop coefficient value of 0.85. Provided: the seasonal PET value of that region is 900 mm.

Conclusion:

Practical -15

Analysis of temperature trend

The detection, estimation and prediction of trends and associated statistical and physical significance are important aspects of climate research. Given a time series of (say) temperatures, the trend is the rate at which temperature changes over a time period. The trend may be linear or non-linear.

For a given dataset containing year wise temperature data the procedure of analyzing temperature trend is as follows

1. In MS-Excel Worksheet enter the year in column "A" and corresponding temperature in column "B".
2. Select the entire range of data, from menu bar select "insert" and then select "Line Chart."
3. A line diagram is produced. Right click any data point on the diagram and select "Add trend line."
4. Select Regression type as "linear"
5. In the same window, check the boxes "Display Equation on Chart" and close the window.
6. Graphs with trend lines, respective regression equations are shown in the Spreadsheet.

Reference video link:

https://youtu.be/nnO-b2t21nQ
https://youtu.be/MzGyerXpDW0
https://youtu.be/YnAod3vLQM8
https://youtu.be/S_QmRD3CyNo

Exercise

1. Estimate the linear trend of the average temperature of a station for the last 40 years using MS Excel

Year	Temp (°C)	Year	Temp (°C)	Year	Temp (°C)	Year	Temp (°C1
1981	26.9	1991	28.5	2001	28.7	2011	29.2
1982	26.3	1992	28.0	2002	28.9	2012	29.1
1983	26.8	1993	28.4	2003	28.7	2013	29.1
1984	27.5	1994	28.6	2004	28.7	2014	29.0
1985	26.8	1995	28.0	2005	28.8	2015	28.8
1986	27.2	1996	28.8	2006	29.2	2016	28.9
1987	27.9	1997	28.5	2007	29.2	2017	29.2
1988	27.7	1998	28.5	2008	29.0	2018	29.0
1989	27.6	1999	28.4	2009	28.9	2019	29.2
1990	28.1	2000	28.9	2010	29.0	2020	29.1

Conclusions:

Practical -16

Analysis of rainfall by Ranking Order Method

Rainfall is one of the most important factors influencing the vegetation. Rain water is the source of soil moisture essential for growth of crops. It is a fact that crop water needs can be fully or partly met by rainfall. Rainfall for each period varies and means monthly rainfall data give only a certain pattern. In the rainfed agriculture one is interested in the question; how much rainfall can be expected, at least in a time interval, in three out of four years or four out of five years? This can be known by using "Ranking Order Method". The main assumption in this method is that the rainfall is more or less normally distributed. The main steps involved are:

a) Minimum thirty years of rainfall data for a month in question should be presented in the descending magnitude. This may be made into a column and name it "Rain" or any convenient term.

b) Assign a number to each record in the ascending order. This is called Ranking Number 'm'. Always for highest value No.1 is given and the last number for the lowest rainfall.

c) Give probability numbers Fa(m) to these ranking numbers.

d) The ranking numbers should be calculated as follows:

Fa(m) = $\frac{100\,m}{n+1}$; Where, n = Number of records; m = rank number

Thus, m = $\frac{(n+1)Fa(m)}{100}$

Reference video link:

https://youtu.be/2s3siU9jf6g