Agro-Meteorology and Climate Change

NRM 314

Practical Manual

College of Horticulture

CENTRAL AGRICULTURAL UNIVERSITY, IMPHAL

Bermiok, South Sikkim-737134

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Sunil Kumar Chongtham

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FOREWORD

In India, agriculture supports the livelihood of about two-thirds of the population directly or indirectly. Agriculture is the main source of food, fodder, fiber, and fuel and forms the basic foundation of economic development. Weather and farming are integral components of agriculture. Agro-meteorology plays a vital role in agriculture as weather and climate decide the success of all agricultural activities. During the era of global warming and climate change, the role of agro-meteorology in agriculture has become more crucial in mitigating the repercussions of climate change induced challenges. This manual has been prepared to help students and other users to comprehend the measurement of weather elements, their interpretation, and role in agriculture and allied subjects. I congratulate the author for bringing out this manual for the benefit of students, teachers, readers, and all those who are involved in the measurement of weather data and its application in agriculture.

Anupam Mishra

PREFACE

Weather and climate play a crucial role in regulating the success of any agricultural pursuits. The impact of weather and climate on crop production has been well-demonstrated by several studies. However, climate affects all components of crop production, including cropping area and cropping intensity. The vital atmospheric variables that impact crops are solar radiation, air temperature, humidity, wind, and precipitation. Change in these parameters directly impacts the quality and quantity of agricultural produce.

Weather refers to the state or condition of the atmosphere at a given place and at a given instant of time. Weather extremes at critical stages of the crop life cycle could severely affect its yield, productivity, and quality. Crop response to the various weather variables is quite complex and difficult to describe. Generally, crop responds to the particular weather variable that is farthest from the optimum, while other variables are non-limiting. The generalized weather or summation of weather conditions over a given region during a comparatively longer period is known as climate. Climate change could significantly influence farming in numerous ways, including through alterations in average temperatures, rainfall, extreme events (like drought, heat waves, floods, etc.), changes in pests and diseases, and the nutritional quality of some foods.

This manual has been prepared for the fifth-semester students of B.Sc. (Hons.) Horticulture according to the recommendation of the Fifth Dean's Committee Report. The manual contains the practices and procedures for measuring weather parameters, instruments used, and computation of various weather variables, and their interpretations.

Sunil Kumar Chongtham

SYLLABUS

Site selection for Agromet observatory; Measurement of temperature; Measurement of rainfall; Measurement of evaporation (atmospheric/soil); Measurement of atmospheric pressure; Measurement of sunshine duration and solar radiation; Measurement of wind direction and speed and relative humidity; Study of weather forecasting and synoptic charts. Visit to Meteorological observatory, Visit to IMD meteorological observatory-Lay out plan of standard meteorological observatory. Recording of air and soil temperature. Measurement of radiation and components, Measurement of rainfall-different types of raingauges, Measurement of wind speed and direction and atmospheric humidity, Recording of evaporation. Synoptic charts and weather reports, symbols, etc.

CERTIFICATE

This is to certify that Mr./Ms …………………………………….…………….......……….

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B. Sc. (Hons) Agriculture in the Course No……….……………………………………….

Title…………………………………………………………..………………………………

During the academic year…………………………

He/She has performed……………………. practical out of ……………………

US ID:………………………..

Course Teacher

CONTENT

Exercise No. 1 **Date:**

STUDY OF METEOROLOGICAL OBSERVATORIES, SITE SELECTION AND LAYOUT

Objective:
- To study different types of meteorological observatories
- To study the criteria of site selection and layout of agrometeorological observatory

The weather has a direct and indirect effect on the quality and quantity of crop production. For investigating precisely and quantitatively the relationships between crop and weather, detailed development observations of the crop and regular observations of the weather are essential. Recording weather variables namely solar radiation, air temperature, precipitation, wind speed, and relative humidity are important as these factors determine the growth development and yield of the crop. The suitability of these parameters for increasing crop production and economical gains in a given area needs to be assessed thoroughly. A meteorological observatory is a place where all the necessary instruments are exposed for measuring weather phenomena.

1.1. Types or classes of meteorological observatories:

Four types of weather stations are recognized depending on the number of weather elements measured, the frequency of measurement, the status of the observer, and the location. These four types of weather stations are as follows.

- *Synoptic stations*: These are stations managed by a full-time observer who maintains continuous weather watch and makes hourly instrumental observations of the weather elements on which information is required for the compilation of the synoptic charts or weather maps used in weather forecasting.
- *Agricultural stations*: These are stations managed by a part-time observer making at least twice daily instrumental observations of the major weather elements. Evaporation, grass minimum, and soil temperatures, and solar radiation are also usually measured in view oftheir obvious importance in agriculture.
- *Climatological Stations*: These are stations managed by part-time observers making only once or twice daily instrumental observations of temperature, humidity, rainfall, and wind.
- *Rainfall stations*: These are stations managed by part-time observers who take the daily reading of rainfall only.

Surface meteorological observatories of the India Meteorological Department are divided into six classes:

Sl. No.	Category	Description
1.	Class I	These are observatories equipped with both eye - reading and self-recording instruments
2.	Class II	Most of these observatories are equipped with only eye-reading instruments. Regular observations are taken at least twice daily
3.	Class I I I	These observatories have the same instrumental equipment as Class II observatories, but observations are recorded only once a day.
4.	Class IV, V	These observatories have a lesser number of instrumental equipment

	and VI	or take non- instrumental observations only

1.2. Selection of site for Agrometeorological Observatory:

An agrometeorological observatory is a place where all meteorological as well as biologicalobservations are recorded simultaneously.

- ❖ The site should be representative of the crop-soil-climate conditions of the area.
- ❖ An agrometeorological observatory is generally installed ideally in an area of dimensions 15 m x 12 m, with proper meteorological exposure conditions. In places where such an extent of land is not available, an area of 10 m x 10 m is also sufficient.
- ❖ The site should be enclosed with barbed wire fencing and should be easily accessible during rain.
- ❖ The site of an observatory should be fairly level and under no circumstances should it lie on concrete, asphalt, or crushed rock. Wherever the local climate and soil do not permit a grass cover, the ground should have natural cover common to the area, to the extent possible.
- ❖ Waterlogging should be avoided.
- ❖ The site should be well exposed i.e., away from high buildings, trees, main channels, and drains, etc.

1.3. Location of instruments: Generally, every agro meteorological observatory is provided with given below instruments.

- ❖ Sunshine recorder
- ❖ Anemometer
- ❖ Wind vane
- ❖ Stevenson screen
- ❖ Double size Stevenson screen
- ❖ Ordinary rain gauge
- ❖ Self-recording rain gauge
- ❖ Soil thermometers
- ❖ Grass minimum thermometer
- ❖ U.S.W.B. Class 'A' Pan
- ❖ M.C.P. (micro climatic pole)
- ❖ Dew gauge
- ❖ Soil moisture plot

All these instruments are fixed in observatories in a given sequence (see layout). The temperature and humidity sensor is mounted at 1.5 to 2m height and wind sensor at 10 m height as per the standards prescribed by World Meteorological Organisation. Rain gauge is installed at least at a distance of 3 m from the centre of the mast where the datalogger enclosure is mounted. Sensor for measurement of atmospheric pressure is mounted within the enclosure where the other equipments like solar charge controller, transmitter, battery etc. are kept.

1.4. Order of Observations:

The instruments at the observatory should be read in the following order commencing from 10 minutes preceding the hour

(1) Wind instruments

(2) Rain gauge
(3) Thermometers, and
(4) Barometer.

Non-instrumental observations (e.g. clouds, visibility etc.) should be taken in the interval of 5 min between the first and second readings of the anemometer or if that is not possible, before commencing the instrumental observations.

1.5. Local mean time (LMT):

The local mean time (LMT) corresponding to Indian Standard Time (IST) varies from place to place depending upon the longitude of a place. LMT at a place is the mean time determined with reference to the sun. When the sun rises at any place it is said to be 7° clock locally. As corresponding to each degree longitude local mean time (LMT) is higher by 4 minutes on the east and lower to the west, therefore, for determining LMT from IST, following formula may be used:

$$\mathbf{IST = LMT + 4\ (L_1 - L_2)}$$

or

$$\mathbf{LMT = IST - 4\ (L_1 - L_2)}$$

Where

IST = The Indian Standard Time is the L.M.T. of longitude 82 ½° East (Allahabad). It is 5. 30 hours ahead of the 'Universal Time of coordinated' (U.T.C).

L_1 = Longitude of Allahabad

L_2= Longitude of the station

1.6. Time of observations:

- At meteorological observatories, the hours are numbered consecutively from mid-night 00 hours to midnight 24 hours, the hours after noon being 13 hours, 14 hours, and so on. Time as 2:30 p.m. and 2:30 a.m. are expressed as 1430 and 0230 hours IST, respectively.
- Meteorological observations (except rainfall and evaporation) are taken at 0700 and 1400 hours LMT, which is converted into IST.
- Rainfall and evaporation observations are taken at 0830 hours IST. The setting of automatic instruments like thermograph, hydrograph, evaporigraph, and barographs, etc., are done at 0830 IST.

Example: Calculate the IST for the location Bermiok (longitude 88.18° East) for LMT 0700 and 1400 hours.

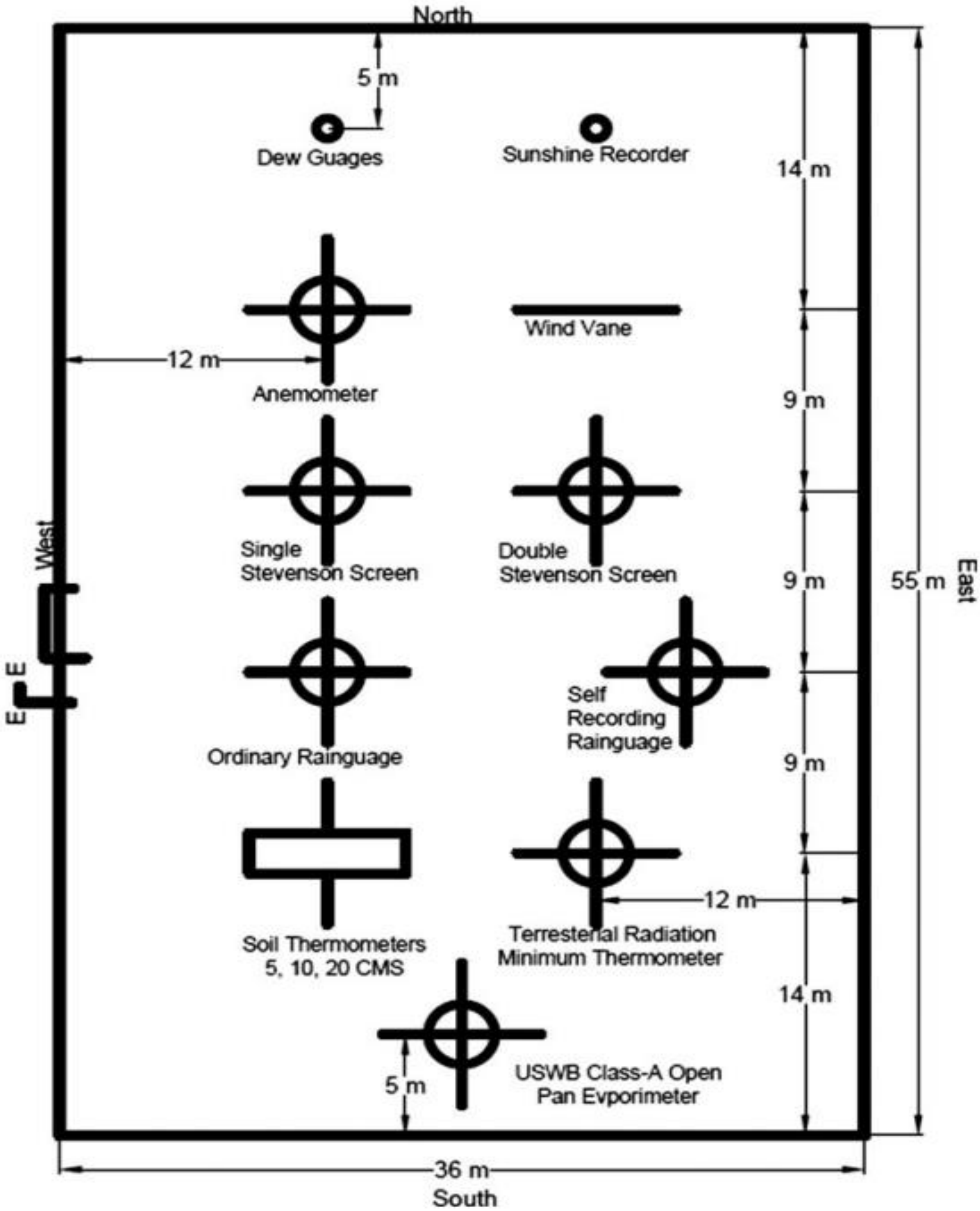


Fig. 1.1.: Layout of Agro-meteorological Observatory

Exercise No. 2 **Date:**

MEASUREMENT OF SUNSHINE DURATION

Objective: ❖ To study sunshine duration and its measurement

The energy in the form of electromagnetic waves received from the sun by the earth is called as solar radiation/insolation. The sun emits about a constant amount of solar radiation (1.94 cal/ cm^2/ min) continuously. This is known as solar constant. Solar radiation is one of the most vital factors influencing photosynthesis and transpiration of crops. Since its measurement involves advanced and costly instruments, indirect estimation of the same from sunshine duration data is useful. Hence, the measurement of bright sunshine hour is important for studying the impact of weather on crop production.

Sunshine duration is the length of time that the ground surface is irradiated by direct solar radiation (i.e., sunlight reaching the earth's surface directly from the sun). According to WMO, it is the period during which direct solar irradiance exceeds a threshold value of 120 watts per square meter. This value is equivalent to the level of solar irradiance shortly after sunrise or shortly before sunset in cloud-free conditions.

2.1 Measurement of bright sunshine duration

For the measurement of bright sunshine duration, the following instrument and accessories are used:

- Campbell-Stokes sunshine recorder
- Sunshine cards
- Sunshine plastic scale

2.1.1. Campbell-Stokes sunshine recorder:

The sunshine is measured by means of Campbell-Stokes sunshine recorder. This consist of a glass sphere of 10 cm diameter, mounted concentrically in a section of spherical bowl, the diameter of which is such that the sunrays are focused sharply on a card held in the grooves cut into the bowl. Three overlapping pairs of grooves are provided in the bowl to take cards suitable for different seasons of the year. Long curved cards are used in summer, short curved cards in winter and straight cards in equinoxes. The time indicated by a correctly adjusted sunshine recorder is the true solar time or local apparent time.

2.1.2. Sunshine cards:

Three types of cards namely, the short-curved card (13th October to 28th February), the long curved card (13th April to 31st August) and straight card for other seasons (during equinoxes) are used in grooves. These cards are subdivided into hourly intervals. While inserting the new cards its 12-hour line should be adjusted to coincide with noon line on the bowl. As the sun moves across the sky, its focused 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.

2.1.3. Sunshine scale:

A sunshine scale measures the burning hour. It is made of celluloid. A special plastic scale is provided in which the subdivisions of the hour are marked. There are 10 parts in scale each part consists of 0.1 hour (6 minutes). The parallel sunshine scale is used for straight cards and the trapezoidal scale is used for long and short curved cards. The duration of sunshine can be obtained correctly to 0.1 of an hour. The hours marked in the sunshine card refer to the local mean time (LMT) of the station. The sunshine is measured in the units of bright sunshine hours per day.

Installation:

The sunshine recorder is installed on a masonry pillar of 5" (1.52 m) or 10" (3.04 m). Thereshould not be any obstruction having an elevation of 3° above the horizon.

Procedure:

- ❖ Select the appropriate card as per the season.
- ❖ Insert the card in the appropriate groove of the recorder after sunset.
- ❖ Remove the burnt card in the evening after sunset and mark the date of observation onthe reverse of the card.
- ❖ Tabulate the duration of sunshine recorded during each hour of the day.
- ❖ Calculate the bright sunshine duration using the special plastic scale.
- ❖ Estimate the total amount of clouds in the sky in Oktas.

Precautions:

- ❖ Avoid excessive vigour in polishing the glass sphere. Avoid cleaning the glass bowlwith any cloth.
- ❖ Remove any deposits of dew, frost, snow, or bird droppings immediately.
- ❖ If the trace is not parallel to the central line of the card, carry out leveling and otheradjustments of the recorder.
- ❖ Use appropriate cards for the season.

2.3. Radiation instruments:

- ❖ **Pyrheliometer**: To measure direct solar beam on a plane surface at normal incidence.
- ❖ **Pyranometer**: The instrument used to measure total incoming radiation (total short wave radiation) is called pyranometer. Principle of working is temperature differentials between two surfaces (black & white) is directly proportional to difference in solar radiation incident upon them.
- ❖ **Albedometer**: It is used to measure the reflectivity of short-wave radiation is called albedometer. (Principle: as same as pyranometer).
- ❖ **Net radiometer**: Net radiometer is measure net radiation. It has two pyranometers, the sensors of which are exposed to the earth and the sky. The sensor exposed to the sky measures the incoming radiation and the other facing toward the earth's surface measures outgoing radiation. The sensor is shielded with plastic domes, which are transparent to both short- and long-wave radiations.
- ❖ **Quantum sensor**: It measures the photosynthetically active radiation (visible radiation). This instrument is most useful because it measures a portion of solar radiation, which is essential for photosynthesis.
- ❖ **Spectro-radiometer**: This instrument measures solar radiation in narrow wave bands. This has been developed by ISRO in the wave bandwidth between 400 and 1010 nano micron.
- ❖ **Luxmeter**: For measurement of the intensity of radiation.

Units of measurement: solar radiation is expressed as watt per square metre. Inmeteorology, it is measured in cal/ cm^2/min and Langley /min

1 watt = 1 joule/s

1 $cal/cm^2/min = 697.93\ watt/m^2$

Precautions:

- ❖ Pyranometers should be kept horizontal while in use.
- ❖ Observation should be repeated to check for accuracy.
- ❖ Any shading on sensors should be avoided.
- ❖ While taking an observation, the plastic dome should be in a fully inflated state.
- ❖ The instrument is usually held 50- 100 cm above the surface over which observation isto be recorded.
- ❖ Plastic dome should be clean and free from wrinkles and deposits of foreign matter.

Fig 2.1: Sunshine Recorder

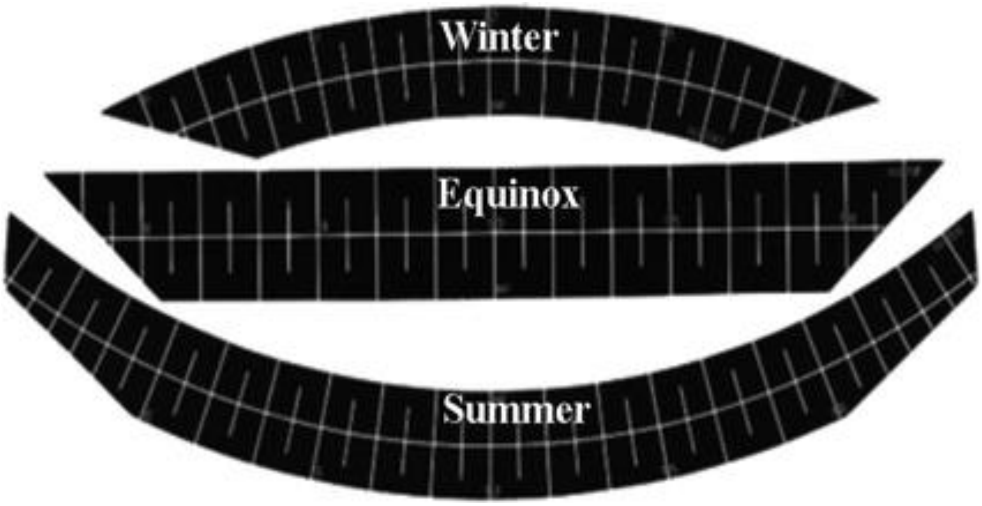


Fig 2.2: Sunshine Cards

Exercise No. 3 **Date:**

Measurement of total shortwave and longwave radiation estimation

Objective: ❖ To study shortwave and longwave radiations and their measurement

Global radiation is defined as the total of direct and indirect radiation (diffused, scattered radiation). The amount of radiation at the top of the atmosphere (R_a) is dependent on latitude and the time of year (Table Value). Radiation while passing through the atmosphere is scattered and absorbed by the atmosphere constituents and clouds. Hence, the amount of radiation reaching the earth's surface is identified as solar radiation or global radiation (R_a). This is largely dependent on cloud cover. This radiation when falls on soil, crop, or water surface are reflected back and lost to the atmosphere. This reflection depends on the nature of the surface.

3.1. Estimation by Angstrom's formula:

$$R_s = R_a (0.25 + 0.50 \ n/N)$$

where

n = actual duration of sunshine (hour)

N = Maximum possible duration of sunshine (hour)

R_a = Extraterrestrial radiation (radiation at the top of the atmosphere) (MJ m^{-2} day^{-1})

R_s = Solar radiation actually received on the earth's surface (MJ m^{-2} day^{-1})

3.2. Estimation of net shortwave radiation:

The net shortwave radiation resulting from the balance between incoming and reflected solar radiation is given by:

$$R_{ns} = (1 - \propto) R_s$$

where

R_{ns} = net shortwave radiation (MJ m^{-2} day^{-1})

$\propto$ = albedo or canopy reflection coefficient, which is 0.25 for crop surface and 0.05 for water

R_s = Solar radiation actually received on the earth's surface (MJ m^{-2} day^{-1})

3.3. Estimation of net longwave radiation and total net radiation:

Data required: (i) Latitude (ii) Altitude (iii) Mean Air temperature
(iv) Mean Relative Humidity (v) Sunshine hours

Tables required:

(1) R_a = Extra-terrestrial radiation

(2) N = Maximum sunshine hours for different months and latitudes

3.4. Determination of net longwave radiation (R_{n1}):

The rate of longwave energy emission is proportional to the absolute temperature of the surface raised to the fourth power. This relation is expressed quantitatively by the Stefan-Boltzmann law. The net energy flux leaving the earth's surface is, however, less than that emitted and given by the Stefan-Boltzmann law due to the absorption and downward radiation from the sky. Water vapour, clouds, carbon dioxide and dust are absorbers and emitters of longwave radiation. Their concentrations should be known when assessing the net outgoing flux. As humidity and cloudiness play an important role, the Stefan-Boltzmann law is corrected by these two factors when estimating - the net outgoing flux of longwave radiation. It is thereby assumed that the concentrations of the other absorbers are constant:

$$R_{nl} = \sigma \left(\frac{T_{max} + T_{min}}{2} \right) (0.34 - 0.14\sqrt{ea}) \left(1.35 \frac{R_s}{R_{so}} - 0.35 \right)$$

where

R_{nl} = net outgoing longwave radiation (MJ m^{-2} day^{-1})
s = Stefan-Boltzmann constant (4.903 10^{-9} MJ K^{-4} m^{-2} day^{-1}),
$T_{max,}$ = maximum absolute temperature during the 24-hour period (in kelvin)
T_{min} = minimum absolute temperature during the 24-hour period (in kelvin)
e_a = actual vapour pressure (kPa)
R_s/R_{so} relative shortwave radiation (limited to ≤ 1.0)
R_s measured or calculated solar radiation (MJ m^{-2} day^{-1})
R_{so} calculated clear-sky radiation (MJ m^{-2} day^{-1})

An average of the maximum air temperature to the fourth power and the minimum air temperature to the fourth power is commonly used in the Stefan-Boltzmann equation for 24-hour time steps. The term (0.34-0.14$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$ e_a) expresses the correction for air humidity and will be smaller if the humidity increases. The effect of cloudiness is expressed by (1.35 R_s/R_{so} - 0.35). The term becomes smaller if the cloudiness increases and hence R_s decreases. The smaller the correction terms, the smaller the net outgoing flux of longwave radiation. Note that the R_s/R_{so} term in the above equation must be limited so that $R_s/R_{so} \leq 1.0$.

Where measurements of incoming and outgoing short and longwave radiation during bright sunny and overcast hours are available, calibration of the coefficients in the above equation can be carried out.

3.5. Estimation of Net radiation:

$$R_n = R_{ns} - R_{n1}$$

$$= Rs\ (1-\propto)\ (A + B\ n/N) - \sigma\ T_a^4\ (1 - a - b\sqrt{e_a}\ )\ (l + m\ n/N)$$

The net radiation is the algebraic sum of net short radiation (R_{ns}) and net longwave radiation (R_{nl}). The net longwave radiation always represents a loss and it is a negative term. $Rn = R_{ns} - R_{nl}$

This gives a net radiation for a given place and for a given month in terms of depth (mm) of evaporable water (1 mm of water = 58 cal of heat energy)

Example: Calculate net radiation of a crop surface (∝ =0.25) of a station having latitude 21.30’N, altitude 61 m with the following data for the month of February.

Mean temperature = 30^0 C
Mean RH = 50%
Sunshine = 9.5 hrs

Exercise No. 4 **Date:**

Measurement of air and soil temperatures

Objective:
- ❖ To study air temperature and its measurement
- ❖ To study soil temperature and its measurement

Temperature can be defined as a physical quantity characterizing the mean random motion of molecules in a physical body. The direction of the net flow of heat between two bodies determines the value of temperature. For meteorological purposes, temperatures are measured for a number of media. The most common variables measured in agriculture are air temperature (at various heights), and soil temperature. The temperature is usually expressed as degrees Celsius (°C) or degrees Fahrenheit (°F). The SI unit of temperature is Kelvin (K).

Air temperature plays a vital role in crop growth and development. Crop water use increases with the increase in temperature. There are three cardinal temperatures (viz. maximum, minimum, and optimum temperature ranges) for germination, flowering, and other crop developmental processes. The range of temperatures presents also determines final grain yields during the crop-growing season and hence, the observations of air temperatures at different hours of the day as well as maximum and minimum values for the day are important.

Soil temperature in simple words is the measurement of the warmth in the soil. Soil temperature is an important factor for plant growth and development. Soil temperature affects the water movement within the soil and plays a vital role in the germination of seeds and root system development. The activity of the soil micro-flora, decomposition of organic material, and absorption capacity of roots depend on the soil temperature. An increase in soil temperature results in the increased solubility of some major salts.

4.1. Instruments for measuring air temperature

4.1.1. Stevenson Screen (Single size):

It is a wooden box in which (1) Dry bulb (2) Wet bulb (3) Maximum thermometer and (4) Minimum thermometer are exposed. It provides all the essential conditions for the exposure of the thermometers i.e., Free access of air to the bulb of the thermometers Protects the thermometers from direct exposure to sunrays and raindrops. It is a double-louvered wooden box, with a dimension being 2‟X 2.5‟ X 3.0‟ with a double roof. The upper one projects 2” beyond the sides of the screen and slopes from front to back. The front of the screen is hinged as a door and can be opened downwards. The Stevenson screen is to be erected on four iron posts with the door opening to the north. The bottom of the screen should be kept at 120cm. above the ground level.

4.1.2. Maximum Thermometer:

- ❖ It is a mercury-in-glass type thermometer ranging from –35°C to +55°C.
- ❖ It has a constriction in the bore between the bulb and the beginning of the scale. This

constriction prevents the mercury column from receding with falling temperatures.

- ❖ It records the highest air temperature attained during a day.
- ❖ The thermometer is to be set at 0700 hours LMT by brisk shaking.

4.1.3. Minimum thermometer:

- ❖ It indicates the **lowest temperature** reached during the last 24 hours.
- ❖ It is an alcohol/spirit in glass type thermometer ranging from –40°C to +50°C, having a light narrow index.
- ❖ Reading is taken from the end of the index, which is away from the bulb.
- ❖ It is set at 1400 hrs. LMT by tilting the thermometer with the bulb upwards.

4.1.4. Dry bulb Thermometer:

- ❖ It is an instantaneous instrument, which gives the current temperature of the air. It is mercury in glass type thermometer.
- ❖ It is just like an ordinary mercury thermometer ranging from -35°C to +55°C,
- ❖ It is used for calculating the relative humidity, dew point temperature and vapour pressure.
- ❖ The least count of the thermometer is 0.5°C but reading is recorded up to 0.1°C.

4.1.5. Wet bulb Thermometer:

- ❖ It is same as the dry bulb thermometer except that the bulb of this thermometer acts as an evaporating surface.
- ❖ The bulb is enclosed with muslin, which is connected with a thread dipped in distilled water container.
- ❖ The water flow is maintained through the thread and keeps the bulb of the thermometer wet.
- ❖ The adiabatic evaporation of water from the thermometer bulb results in the cooling effect and thus the "wet bulb temperature" is lower than the "dry bulb temperature" in the air.
- ❖ The rate of evaporation from the muslin cloth on the bulb and the temperature difference between the dry bulb and wet bulb depends on the humidity of the air.
- ❖ The evaporation from the wet muslin is reduced when the air contains more water vapour. When the air is saturated, both the dry bulb and wet bulb temperatures would be the same. This temperature is used to find out dew point temperature, vapor pressure, and humidity.

(N.B.: Maximum and Minimum thermometers are kept inside the screen horizontally whereas dry and wet bulbs are hung vertically.)

4.1.6. Double Size Stevenson Screen:

Its construction is similar to that of single-size Stevenson Screen except that it is double in length. In this screen self-recording instruments like Thermograph, Hygrograph or Thermo hygrograph, Evaporigraph, Barograph etc. are kept.

4.1.7. Thermograph:

It is an instrument used for recording continuously the temperature of air. Common type of thermograph is Bourdon tube, which has a flattened, curved metal tube filled with liquid, sealed and fastened rigidly at one end. With change of temperature, there is unequal expansion or contraction of the liquid and the metal, producing a change of curvature in the tube thus moving the free end. This movement is communicated to a pen, which is caused to moving up and down on a drum that is being rotated by a clockwork arrangement within it. In this manner a continuous record of temperature is traced on the graph sheet surrounding the rotating drum.

4.1.8. Thermo hygrograph: It is an instrument used for recording continuously temperature and relative humidity both on a single graph paper.

4.2. Instrument for measuring soil temperature

4.2.1. Soil thermometer:

Soil thermometers are used for recording the variation of soil temperature with time and depth in the layers which are affected by diurnal variation and with which crops are primarily concerned. The diurnal range of soil temperature is the highest at the surface and this range decreases rapidly with depth and becomes practically negligible at a depth of 1 feet. These thermometers are held by the iron stands in an inclined position making 60° angle with the soil surface. Soil thermometers commonly used are of three depths 5, 10 and 20 cm. Thermometers should face south direction. These are placed 45 cm apart in a plot of size 120 cm x 180 cm. The soil temperature readings are taken read daily at 07.00 and 14.00 h LMT. The following points should be kept in mind while taking the observations:

I. The line joining the observer's eye and the top of the mercury column should be at the right angle to the instrument.
II. The observer should stand at some distance from the instrument so as not to shadow the ground surface in the vicinity of the instrument.
III. Reading should be taken correctly to 0.10 °C

4.2.2. Grass Minimum Thermometer (The Terrestrial Radiation Thermometer):

This instrument is used to measure the actual minimum temperature experienced by the plant near the ground surface. The grass minimum temperature is lower than the air temperature at screen height. The readings of the thermometer indicate the possibility of the occurrence of ground frosts**.** A ground frost is likely to have occurred when the instrument records 0^{o}C (32°F) or below it. Its construction and working are similar to that of the minimum thermometer. The thermometer is exposed 1" above ground surface on its support over the grass plot in the evening and its reading is noted before sunrise the next morning. After reading the instrument in the morning, it should be removed from the observatory room or some shady place (indoors) to avoid direct exposure to solar radiation.

Fig. 4.1: Maximum Thermometer

Fig. 4.2: Minimum Thermometer

Fig. 4.3: Dry Bulb Thermometer

Fig. 4.4: Wet Bulb Thermometer

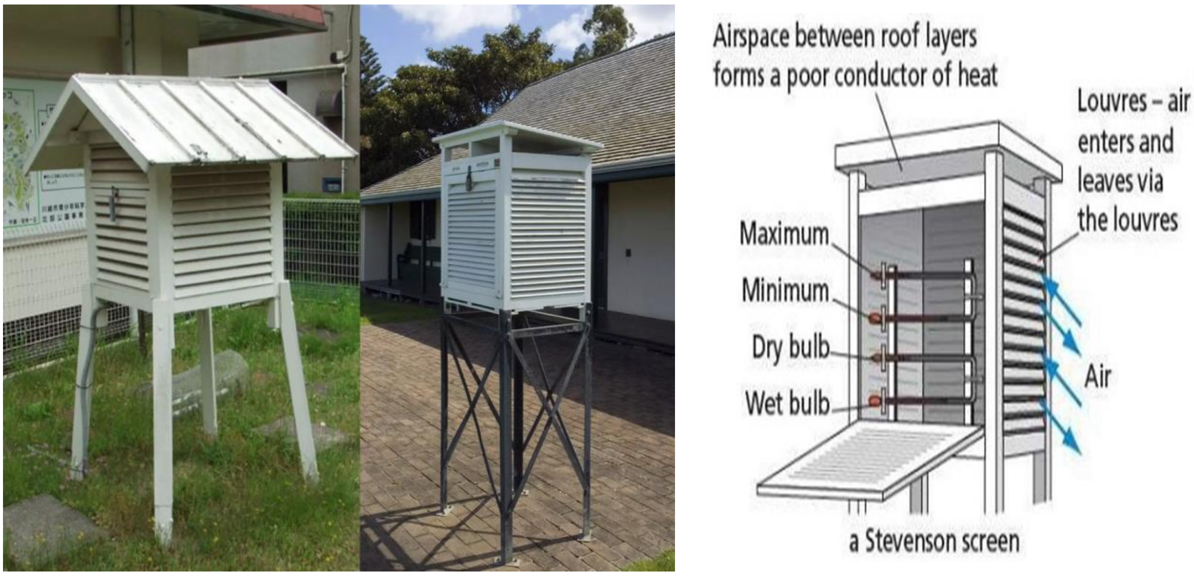


Fig. 4.5: Stevenson screen

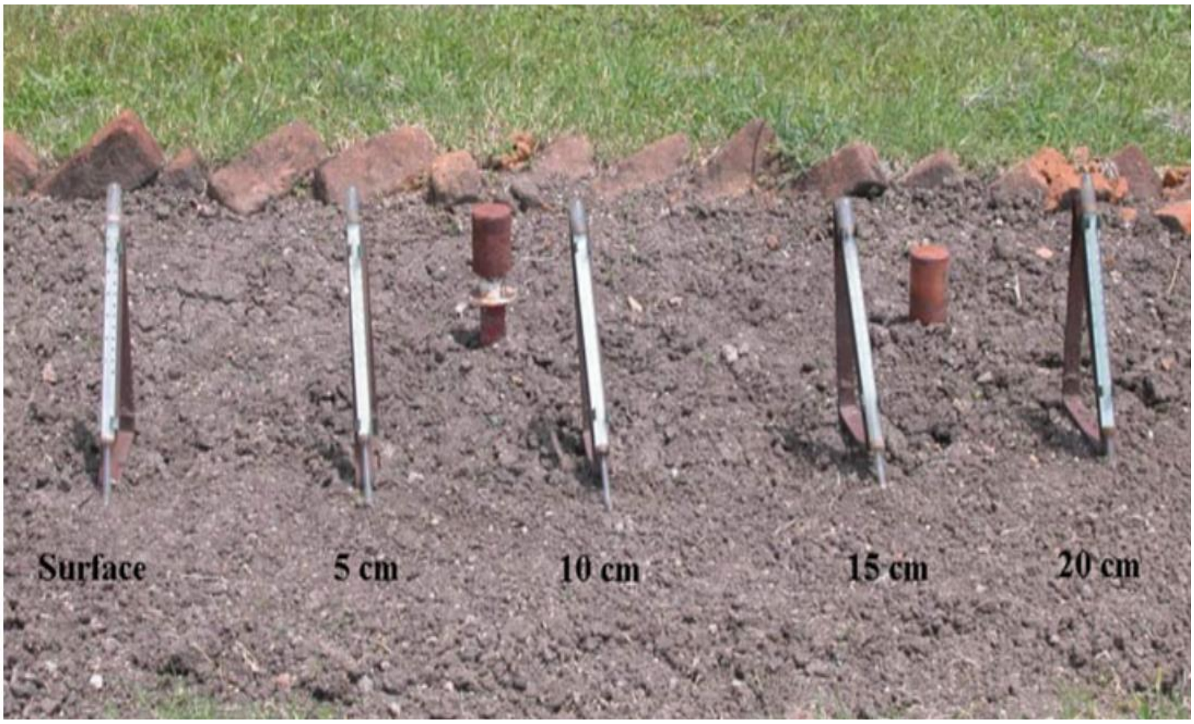


Fig. 4.6: Soil thermometers

Exercise No. 3 **Date:**

MEASUREMENT OF WIND SPEED AND WIND DIRECTION

Objective

- ❖ To study wind direction and wind speed and their measurement

Air expands when heated and gets compressed when cooled. This results in variations in atmospheric pressure. The differences in atmospheric pressure cause the movement of air from high pressure to low pressure, setting the air in motion. Atmospheric pressure also determines when the air will rise or sink. Air in horizontal motion is known as wind. The wind redistributes the heat and moisture across latitudes, thereby, maintaining a constant temperature for the planet as a whole. The vertical rising of moist air forms clouds and bring precipitation.

5.1. Instruments for measuring wind direction and wind speed:

- ❖ Wind vane
- ❖ Anemometer

5.1.1. Wind Vane:

The common instrument to determine wind direction is the wind vane. This instrument indicates the direction from which the wind blows. It is a balanced lever that turns freely about a vertical axis. One end of the lever exposes a broad surface to the wind, while the other end which isin the form of an arrowhead points to the direction from which the wind blows. This narrow end is in the form of an arrowhead. Under this movable system, there are eight fixed rigid bars that are set to the eight cardinal directions i.e. North, North-East, South-East, South, South- West, West and North-West.

Installation:

It is installed over a wooden plank, and is fixed on a wooden post. The height between the pointer and ground level is exactly 10 feet (3.05m). The north indicator should bese to true north and not to the magnetic north. The axis of the wind vane should be exactly vertical

Units: There are two ways of expressing wind direction

- **By sides**: In sixteen points of a compass as N, NNE, NE, ENE, E, ESE, SE, SSE, S,SSW, SW, WSW, W, WNW, NW, NNW.
- **By degrees** (from the north, measured clockwise as 360, 20, 50, 70, 90, 110, 140, 160,180, 200, 230, 250, 270, 290, 320, 340,)

5.1.2. Anemometer:

Wind speed is measured by means of an anemometer. There are two types of rotating anemometers: the cup anemometer, which has three or four cup wheels attached to the rotating axis, and the propeller anemometer, which has propeller blades. Both types rely on the principle that the revolution speed of the cup or propeller rotor is proportional to the wind speed. The height from the centre of the anemometer cups is 10 ft. above the ground level. Propeller anemometer measures wind direction and wind speed, and can indicate/record the instantaneous wind direction and wind speed in remote locations.

Installation:

In an agro-meteorological observatory, wind instruments are installed at an open site. It is installed on pillars or wooden posts so that the height of the centre of anemometer cup or the arrow head should be 10" (3.05 m) above the ground. The minimum exposure criterion for the wind instruments is that any obstruction should be away by at least 10 times the height of the obstruction.

Units of measurement: The wind speed is directly measured in terms of kilometers per hour (km/h), miles per hour (mph), feet per second (ft./s), and knots (kt). However,the wind speed in synoptic charts is given in knots.

The conversion of different units:

1 knot = 0.515 m/s = 1.853 km/h = 1.152 mph = 1.689 ft./s.

Maintenance:

- The screw cap of the wind vane should be lubricated with clock oil every fortnight.
- Anemometer should be lubricated every week.
- Every six months the bearing should be washed and lubricated thoroughly.

Procedure:

- Watch the wind vane for a few minutes and identify the direction.
- Read the direction to which the arrowhead points, nearest to the sixteen prints of the compass.
- Note the initial and final reading of the anemometer after 3 minutes. Subtract the initial reading and multiply by 20 to get the instantaneous wind speed at the time of observations inkilometer per hour.
- Subtract the anemometer reading at 7:00 hrs. LMT of the observation date and divide the difference by 24 to get the main daily wind speed for the observation dates.

Observations & calculation of wind speed:

- **Instantaneous wind speed**: Note down two readings from the anemometer at an interval of three minutes. Multiply the difference by 20 to get wind speed at thetime of observation in km/h.
- **Mean daily wind speed**: Subtract the Anemometer reading at 0700 LMT of the previous day from that at 0700 LMT of the observation day and divide the difference by 24 to get the mean daily wind speed for the observation day.

Exercise: Take the reading of wind vane and cup anemometer. Calculate wind speed at the time of observation and mean daily wind speed.

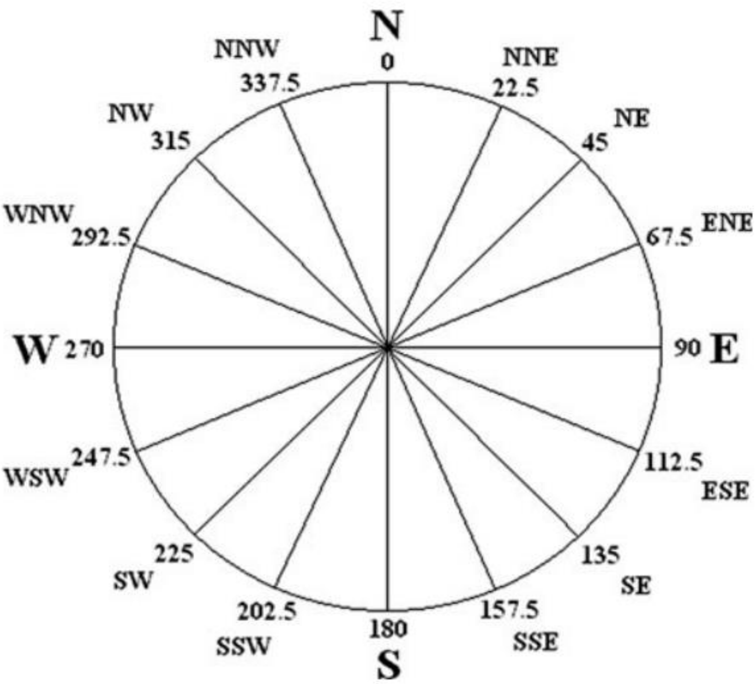


Fig. 5.1: Wind direction in sides and degrees

Fig. 5.2: Cup Anemometer

Fig. 5.3: Propeller anemometer

The Beaufort Wind Scale:

If a measuring instrument becomes faulty or is not available, wind can be estimated by visual means such as observing smoke as a guide to wind speed and using the Beaufort Scale (Table). The Beaufort scale was first developed by Admiral Francis Beaufort in 1806. It emphasizes more on the observed effect of the wind, rather than the actual wind speed.

Beaufort scale number and description	**Wind speed equivalent at a standard height of 10 m above open flat ground**				**Specifications for estimating speed over land**
	(kt)	**(m/s)**	**(km/h)**	**(mph)**	
0 (Calm)	<1	0-0.2	<1	<1	Calm; smoke rises vertically
1 (Light air)	1-3	0.3-1.5	1-5	1-3	Direction of wind shown by smoke-drift but not by wind vanes
2 (Light breeze)	4-6	1.6-3.3	6-11	4-7	Wind felt on face, leaves rustle; ordinary vanes moved by wind
3 (Gentle breeze)	7-10	3.4-5.4	12-19	8-12	Leaves and small twigs in constant motion, wind extends light flags
4 (Moderate breeze)	11-16	5.5-7.9	20-28	13-18	Raises dust and loose paper, small branches are moved
5 (Fresh breeze)	17-21	8.0-10.7	29-38	19-24	Small trees in leaf begin to sway, crested wavelets form on inland waters
6 (Strong breeze)	22-27	10.8-13.8	39-49	25-31	Large branches in motion, whistling heard in telegraph wires; umbrellas used with difficulty
7 (Near gale)	28-33	13.9-17.1	50-61	32-38	Whole trees in motion, inconvenience felt when walking against the wind
8 (Gale)	34-40	17.2-20.7	62-74	39-46	Breaks twigs off trees, generally impedes progress
9 (Strong gale)	41-47	20.8-24.4	75-88	47-54	Slight structural damage occurs (chimney-ports and slates removed)
10 (Storm)	48-55	24.5-28.4	89-102	55-63	Seldom experienced inland, trees uprooted, considerable structural damage occurs
11 (Violent storm)	56-63	28.5-32.6	103-117	64-72	Very rarely experienced; accompanied by widespread damage
12 (Hurricane)	64 and over	32.7 and over	118 and over	73 and over	-

Exercise No. 6 **Date:**

Measurement of relative humidity and dew point temperature

Objective ❖ To study relative humidity and dew point temperature and their measurement

The humidity in the atmosphere is of great physical as well as biological importance. It influences the internal water potential of plants and the rate at which plants transpire into the atmosphere. Humid conditions affect the growth and development of many pathogens, especially fungi. Humidity measurements at the Earth's surface are required for meteorological analysis and forecasting, climate studies, and special applications in hydrology, agriculture, aeronautical services, and environmental studies, in general. They are particularly important because of their relevance to the changes in the state of water in the atmosphere.

6.1. Psychrometer:

The instrument which contains both dry bulb and wet bulb thermometers for the measurement of dry bulb and wet bulb temperatures is called a psychrometer. The depression of the wet bulb gives an idea about the relative humidity of the air at a particular time.

6.2. Different measures of humidity parameters

The atmospheric humidity is measured in various units. The important measures of humidity are vapour pressure, relative humidity, dew point temperature, etc.

- **Vapour pressure:** Air contains different gases and water vapour also behaves as a gas. The pressure of air is the sum of the partial pressures of its component gases. The partial pressure due to presence of water vapour in air is called vapour pressure. The vapour pressure is expressed in c.g.s. Units of pressure viz. milli bars or milli meters of mercury (mm of Hg). The M.K.S unit of pressure is Pascal. The pressure exerted by the water vapour under saturated conditions is called as the saturation vapour pressure (S.V.P.). The saturation vapour pressure depends on the temperature of the air. It increases nearly exponentially with the air temperature. The pressure exerted by water vapour actually present in the air is called as actual vapour pressure of the air or simply, the vapour pressure of air.
- **Saturation deficit**: It is the difference between saturated vapour pressure and the actual vapour pressure present in the atmosphere.
- **Relative humidity:** The ratio of actual vapour pressure to saturation vapour at the prevailing air temperature is called as relative humidity. It is normally expressed in percentage.
- **Dew point temperature:** Dew point temperature is the temperature at which air would become saturated if it is cooled at constant pressure without addition or removal of water vapour. Thus, the actual vapour pressure is equal to the saturation vapour pressure at the dew point temperature. If the dew point temperature is close to the air temperature it means that the air is nearly saturated.

6.3. Relative humidity:

When the air is saturated no evaporation takes place and therefore there is no difference between the temperature in the wet and dry bulb thermometers. The relative humidity (R.H.) is therefore said to be 100%. On the other hand, when the air is not saturated evaporation takes place in the wet bulb thermometer. As this takes up heat energy from the mercury contained in the wet bulb consequently the temperature goes down. The greater the evaporation, the lower will be the temperature and hence the greater the difference between the temperature of the wet and the dry bulb thermometer. The R.H. is obtained by calculation or by using ready-made tables like Hygrometric and SVP tables from which one can find the relative humidity and dew point temperature corresponding to wet and dry bulb temperatures. One of the following instruments can be used for the measurement of relative humidity

- ❖ Simple or stationary psychrometer
- ❖ Assmann psychrometer
- ❖ Whirling psychrometer
- ❖ Hair hygrometer

6.3.1. Simple or stationary psychrometer:

It is a set of dry bulb and wet bulb thermometers of identical form and size exposed in a Stevenson’s Screen. The relative humidity is then estimated from the hygrometric tables.

6.3.2. Assmann psychrometer:

A pair of vertically fixed dry and wet bulb thermometers with cylindrical bulbs form this psychrometer. The bulbs are protected from external radiation by means of two polished coaxial tubes. The temperature and RH of both open and inside crops are measured by this psychrometer.

6.3.3. Whirling psychrometer:

It consists of a set of two thermometers attached horizontally to a rectangular wooden frame that can be rotated with a handle. The psychrometer is designed to measure the temperature and Relative Humidity of both inside and outside crops

6.3.4. Hair hygrometer:

It uses the characteristic of the hair that its length expands or shrinks in response to the relative humidity. The length of human hair from which liquid is removed increases by 2–2.5% when relative humidity changes by 0–100%. The hair hygrograph is a hair hygrometer to which a clock-driven drum is installed to record humidity on a recording chart.

Hour of Observation:

Observation of dry bulb and wet bulb thermometers are recordedat 0700 and 1400 hours LMT.

6.4. Estimation of relative humidity and vapour pressure

Relative humidity (RH)

$$\mathbf{RH} = \frac{e_a}{e_s} \times 100$$

Where, e_a = AVP at dry bulb temperature or SVP at dew point temperature, mmHg

e_s = SVP at dry bulb temperature, mmHg

SVP at dew point temperature = e_a = E' – AP (Td- Tw)

Where, E'' = SVP at wet bulb temperature in mmHg

A= Psychrometric constant (0.0008)

P= Atmospheric pressure (1013 mb or 760 mmHg)

AP = 0.6 mmHg or 0.8 mb

Vapour pressure (VP)

$$e_a = e_w - 0.0006\, P\, (T_d - T_w)\, (1+0.00115\, T_w)$$

Where, e_a = Actual Vapour pressure (mb)

e_w =Saturation vapour pressure at wet bulb temperature

P =Atmospheric pressure (mb),1013 mb

T_d = Dry bulb temperature (°C)

T_w = Wet bulb temperature (°C)

$$e_a = e_w = \frac{0.480(T_d - T_w)}{610 - T_W} \times P$$

6.4.1. Solved example for given data:

Date	Time (hrs)	Temperature (°C)		Atmospheric pressure (mb)	SVP (e_s)	SVP* (e_w)
		(T_d)	(T_w)		(mm)	
21/01/2013	0738	14.0	12.4	999.4	12.0	10.8
	1438	18.4	16.4	992.7	15.9	14.0

* SVP values to be obtained from the Hygrometric table

(i) Convert SVP into mb units to make the pressure value balanced, i.e. taking 1 mm = 1.333 mb

At 0738 hours e_s = 1.333 x 12 = 16.00 mb

e_w = 1.333 x 10.8 = 14.4 mb

Calculation of VP at 0738 hrs

$$e_a = 14.4 - \frac{0.480(14.0-12.4)}{610-12.4} \times 999.4$$

$$= 14.4 - 1.28 = 13.12 \text{ mb}$$

$$\text{RH (\%)} = \frac{e_a}{e_s} \times 100 = \frac{13.12}{16.0} \times 100 = 82\ \%$$

6.5. Dew point temperature

It is defined as the temperature at which air becomes saturated when it is cooled at constant pressure without removal or addition of moisture.

It can be seen from hygrometric tables directly.

6.6. Calculation of dew point temperature and dew point depression

Example: Calculate dew point temperature, if air temperature and relative humidity (RH) are 15.0^0 C and 58 % respectively.

Tdp = T- (100-RH)/5

Where

Tdp= Dew point temperature (^{0}C)

T= Air temperature(^{0}C)

RH = Relative humidity (%)

Tdp = 15-(100-58)/5

=15-(42)/5

= 15-8.4

= 6.6 ^{0}C

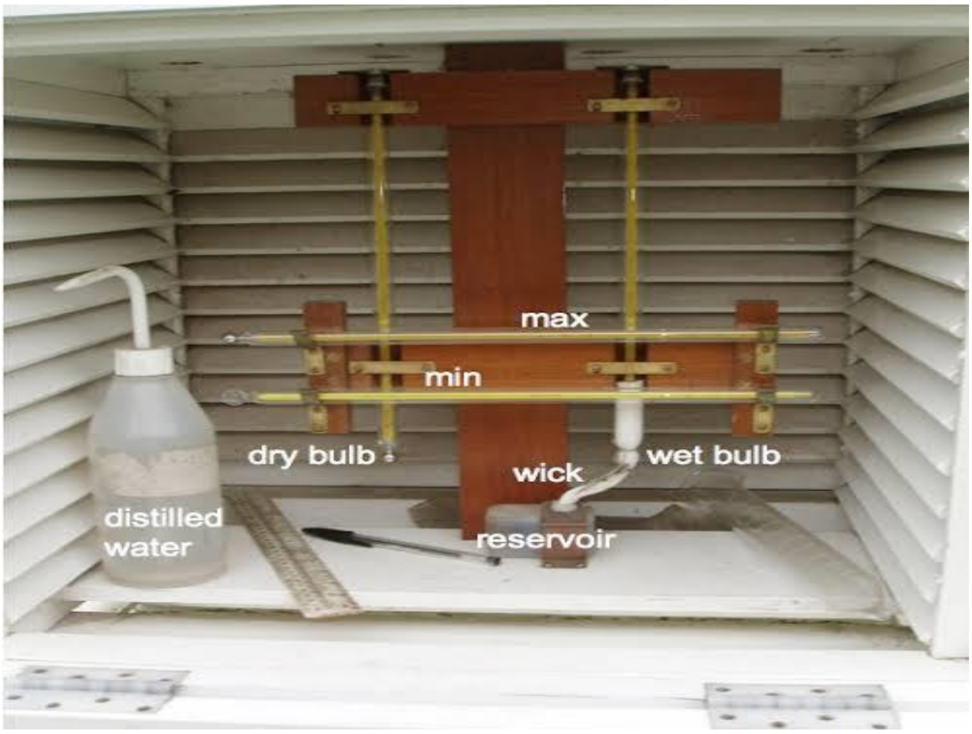


Fig. 6.1: Simple or stationary psychrometer

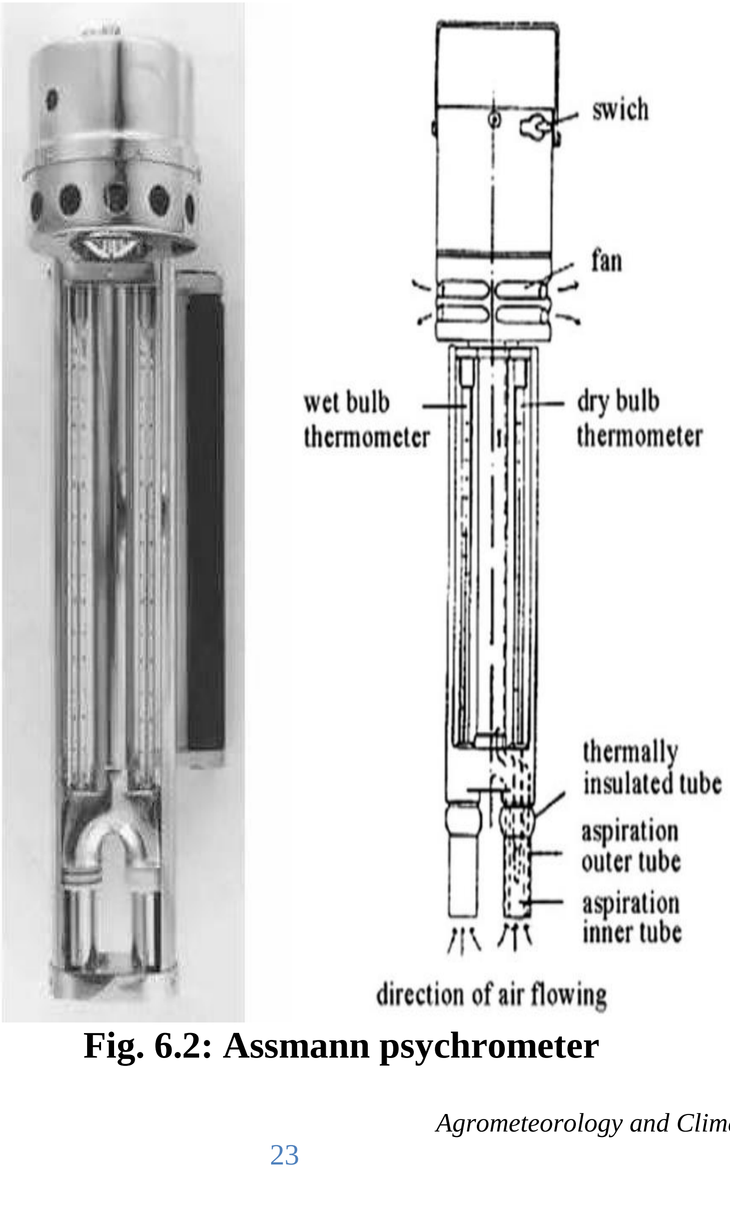


Fig. 6.2: Assmann psychrometer

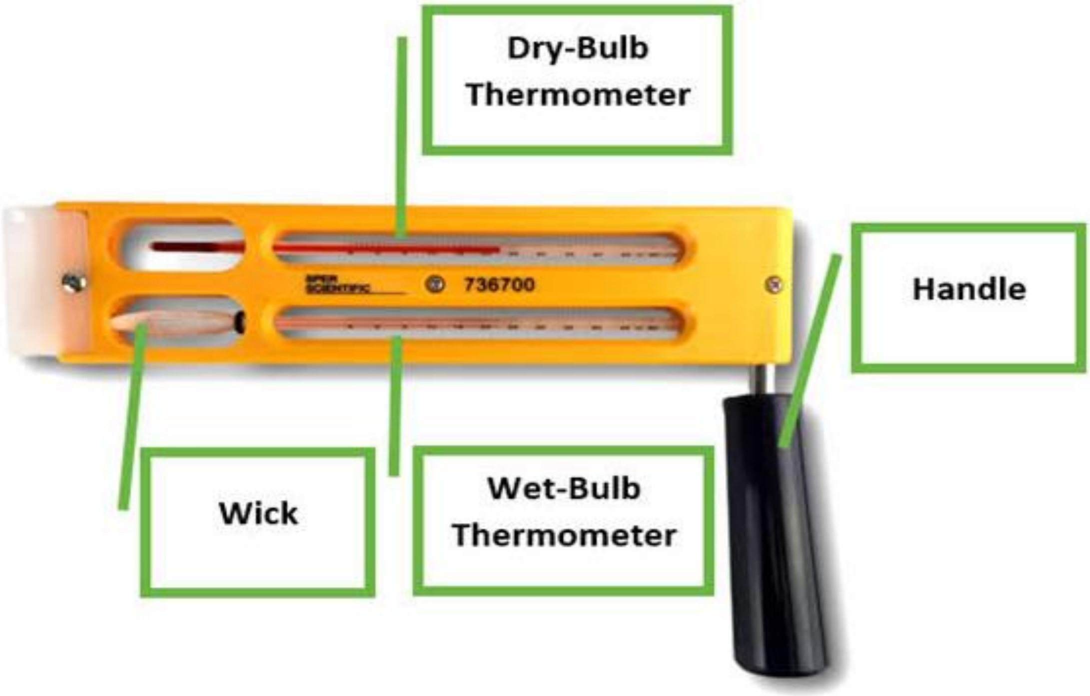


Fig. 6.3: Whirling psychrometer

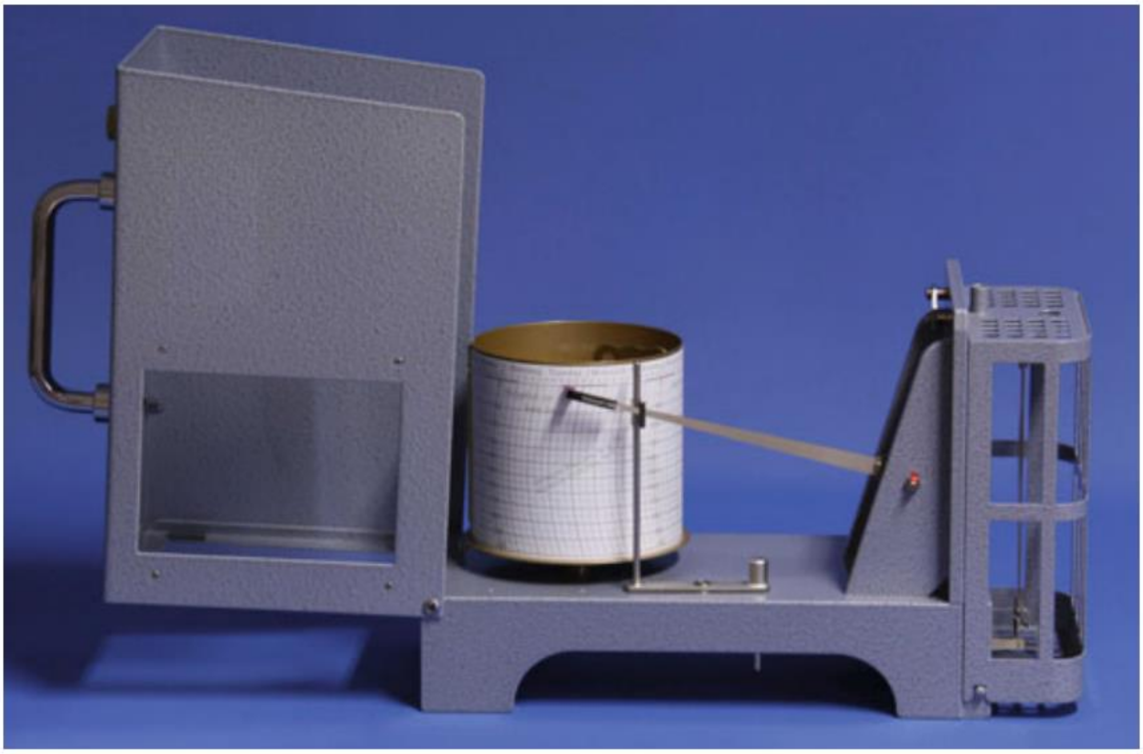


Fig. 6.4: Hair hygrometer

Exercise No. 7 **Date:**

Measurement of rainfall

Objective ❖ To study rainfall and its measurement

The terms precipitation and rainfall are used as synonyms with each other. Precipitation canbe defined as “the earthward falling of water droplets or ice particles that have formed by rapid condensation in the atmosphere and are too large to remain suspended in the atmosphere". In condensation, the water droplets remain suspended in the atmosphere in different forms. Condensation is the first step of precipitation. But in precipitation, those condensed droplets areso big so that they cannot remain in the atmosphere but fall down to the earth’s surface.

7.1. Instruments for measuring rainfall:

- ❖ Ordinary rain gauge with measuring cylinder
- ❖ Self-recording rain gauge

7.1.1. Ordinary Rain Gauge:

It is an instrument used for measuring the amount of rainfall. It consists of five parts (1) Funnel (2) Receiver (3) Body (4) Base (5) Measuring cylinder. The funnel is provided with a brass rim, which is truly circular and exactly 5” (127 mm) in diameter. The rim of the rain gauge should be 12” above ground level and 10” above the cemented platform. The rain is collected in the receiver and is measured by a standard measuring cylinder provided with the instrument.

Installation:

The rain gauge should be fixed on masonry or a concrete foundation of 60 cm x 60 cm x 60cm sunk in the ground. The base of the gauge is cemented into the foundation so that the rim of the rain gauge is exactly 30 cm above ground level. The height is chosen in order to minimize water splashing into the rain gauge. If the height of the rim is more, the rainwater collected would decrease because of the change in the wind structure near the rain gauge. The top of the rim of the rain gauge should be perfectly horizontal. A rain gauge should be installed on a lev ground, not upon a slope or terrace, or never on a wall or roof. In order to avoid the loss of raindrops due to obstruction, the distance of any object should be at least twice the heightof the object above the rim of the rain gauge.

Measurement of Rainfall:

The rain falling into the funnel of the rain gauge is collected in the receiver kept inside the body and is measured by means of a special measuring glass cylinder graduated in milli meters. Ten millimetres of rain means that if that rainfall is allowed to be collected on a flat surface, the height of water collected would be 10 mm. In case, the special measuring glass cylinder is not available, rainwater can be measured by commonly available measuring glass graduated in ml. In such cases, 126.7 ml of water measured is equal to 10 mm of rainfall. Thisconversion is applicable to a rainfall spell.

7.1.2. Self-recording Rain Gauge:

The instrument is designed to measure the duration, amount, and rate of rainfall. It consists of a float chamber containing a light hollow float. As the watercollected by the outer funnel is led into this chamber, the float rises along with the water level, and the vertical movement of the float is recorded on a pen on a chart fixed on a rotating clock drum. This chart has a range of 10 mm or 25 mm. As soon as 10 mm or 25 mm of rain falls, the pen reaches the top line of the chart. But the instrument has a siphoning arrangement so, the water in the chamber gets emptied and the pen and float come to the initial position immediately. If there is further rain, the pen continues to rise and record the rainfall in the manner. If there is no rain the pen traces the horizontal line from where it leaves off rising. Some of the commonly used rain gauges are: (a) Tipping Bucket type and (b) Natural Siphon type self-recording rain guages.

Intensity of Rainfall Spell:

The intensity of a rainfall spell is defined as the ratio of the total amount of rainfall recordedduring the spell to the total duration of the spell. It is expressed in mm per hr.

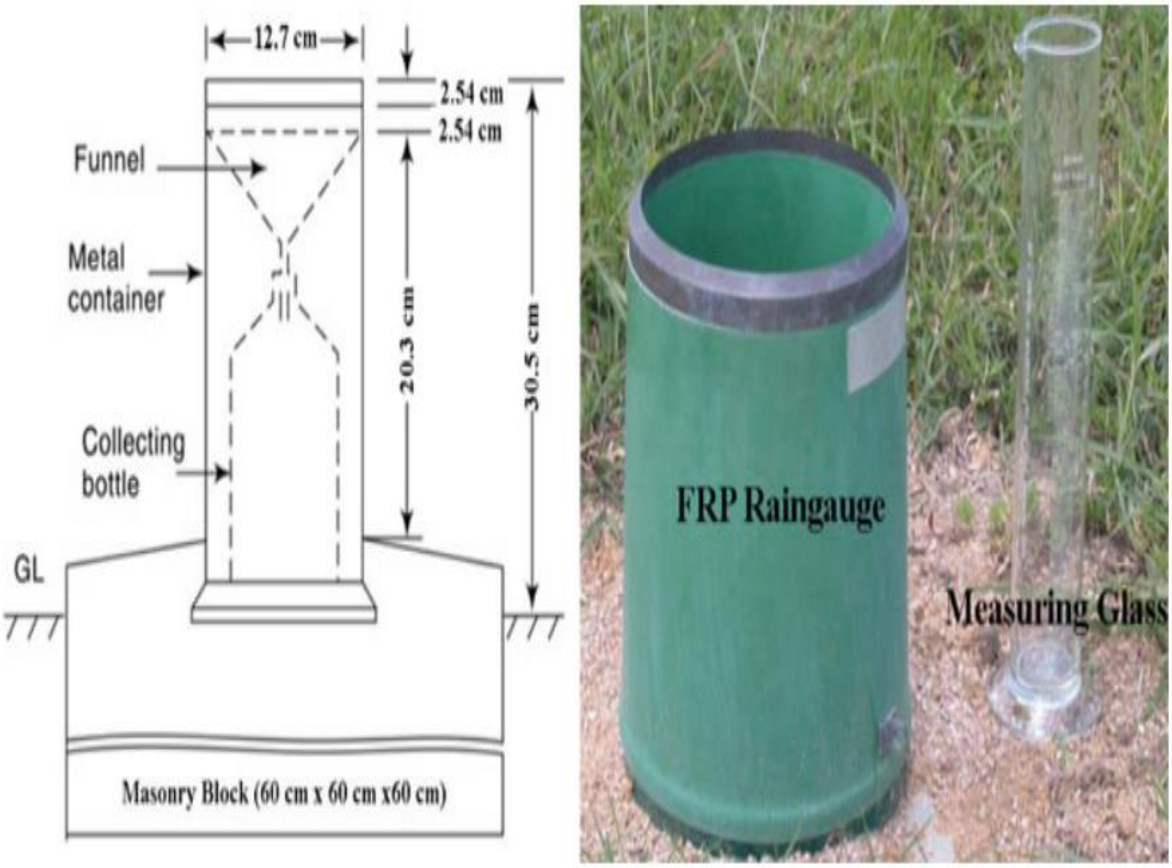


Fig. 7.1: Ordinary Rain Gauge (Fibre Reinforced Plastic rain gauge)

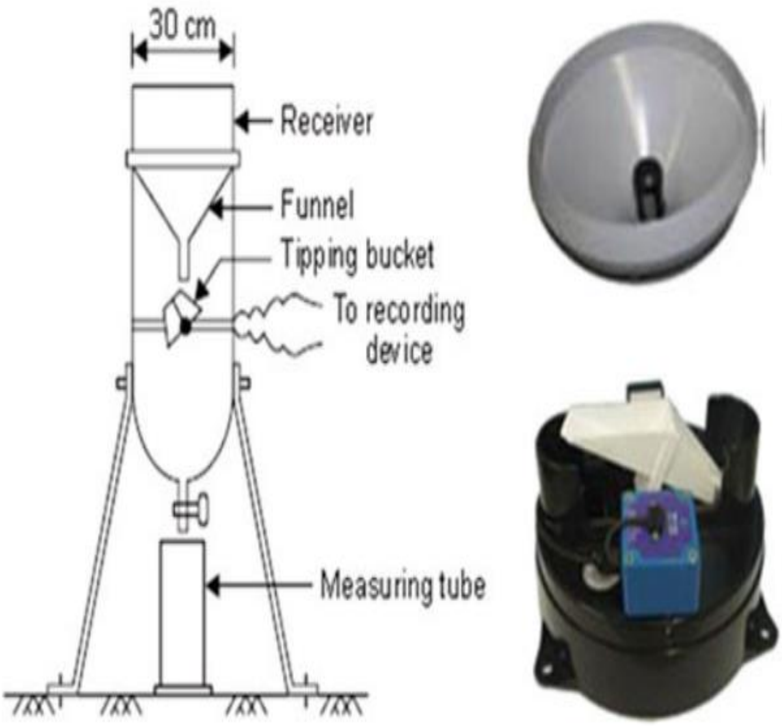


Fig. 7.2: Tipping Bucket Type Self-Recording Rain Guage

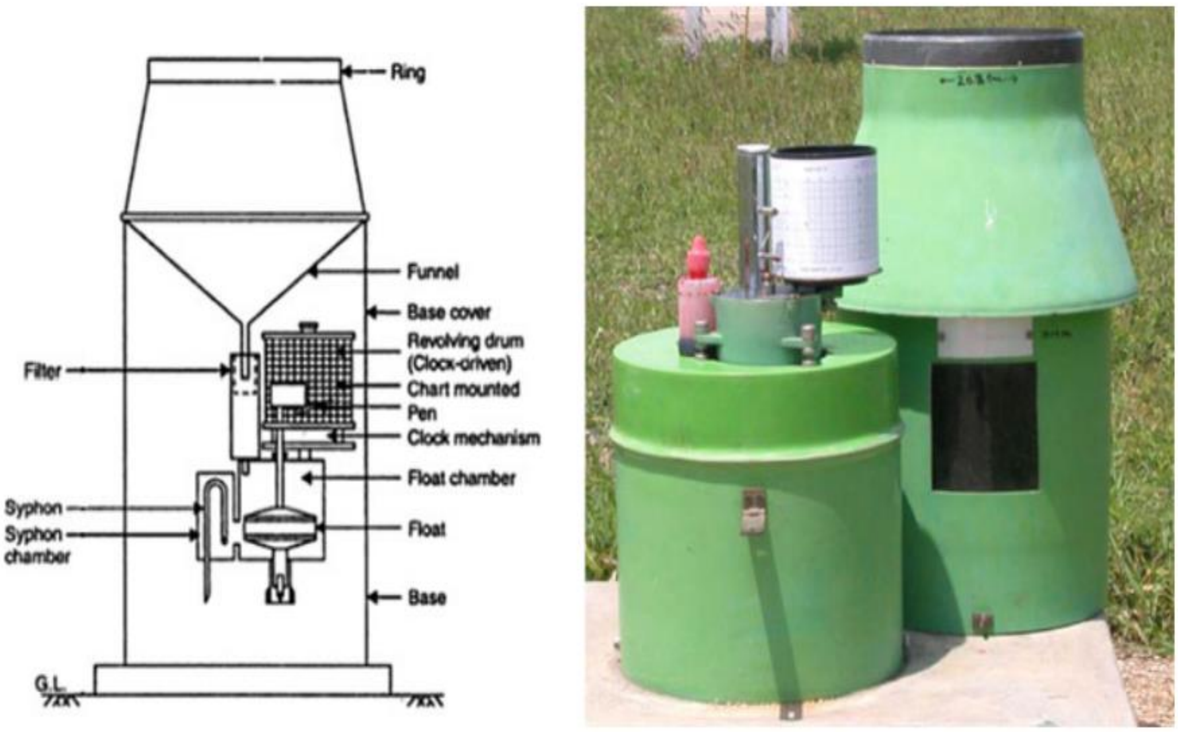


Fig. 7.3: Natural Siphon Type Self-Recording Rain Guage

Exercise No. 8 **Date:**

Measurement of evaporation

Objective ❖ To study evaporation and its measurement

Evaporation is measured by means of a pan evaporimeter. This instrument is used to measure the evaporation of water near the ground. The class A pan evaporimeter which is commonly used in India consists of a large cylindrical pan made of copper or tin with a 120 cm diameter and 25 cm depth. The pan is made of 20 gauge copper sheet tinned inside and painted outside. A still well is provided inside the pan so that there would undisturbed water surface inside the well and ripples would be broken. It consists of a brass cylinder mounted on a heavy circular base provided with three circular holes at the bottom. The reference pointed is provided by a brass rod fixed at the centre of a still well.

For measuring evaporation, a graduated measuring cylinder made of brass is also provided with the instrument. It has a scale of 0.20 cm engraved inside it along its height. The reservoir of the Evaporimeter rests on a wooden platform120 cm x 120 cm, placed on the ground. The height of the wooden platform is 10cm so the rim of the reservoir is 40 cm above the ground. The reservoir is covered with wire mesh to check water loss by birds etc.

8.1. Part of Pan evaporimeter:

1. Class 'A' pan evaporimeter	2. Still well	3. Measuring cylinder
4. Thermometer	5. Wooden frame	6. Wire mesh

Procedure:

- ❖ Note the water temperature is correct at 0.1 ^{O}C.
- ❖ If the water level is below the tip of the rod, add sufficient water slowly with the help of the measuring cylinder so that the water level again coincides with the reference level.
- ❖ Note the amount of water added by taking into account the number of cylinders of water added and parts thereof.
- ❖ If rainfall has occurred during 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, this amount of water should be added to the rainfall amount in mm to get the total evaporation for the day. If however, the rainfall has been heavy and the waterlevel 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 referencepoint. Subtract from the rainfall the amount of water removed in order to get the total evaporation for the day.
- ❖ If on any day, due to the occurrence of very heavy rainfall, the water level has risen up to the rim of the pan and some water overflown. So, the entry **"**over flown**"** should be made in the observation register.

Observations to be recorded:

- Temperature of water in the pan.
- Amount of water added or removed to bring back the water level to the reference point.
- Amount of rainfall, of any, during the past 24 hours.

Installation:

The evaporimeter should be installed at an open sight with no obstruction casting shadow on the pan. The pan should be placed on the wooden grill kept on a fixed foundation so that the edge of the pan is on level and is exactly at 30 cm above the ground. The rate of evaporation is measured daily at 0830 hours IST.

Evaporigraph:

This instrument is used for recording continuously the evaporatingpower of the air.

Time of Observation:

Ordinary rain gauge and self-recording rain guage and Open pan Evaporimeter observationsare recorded and set at 0830 hours IST (Indian Standard Time).

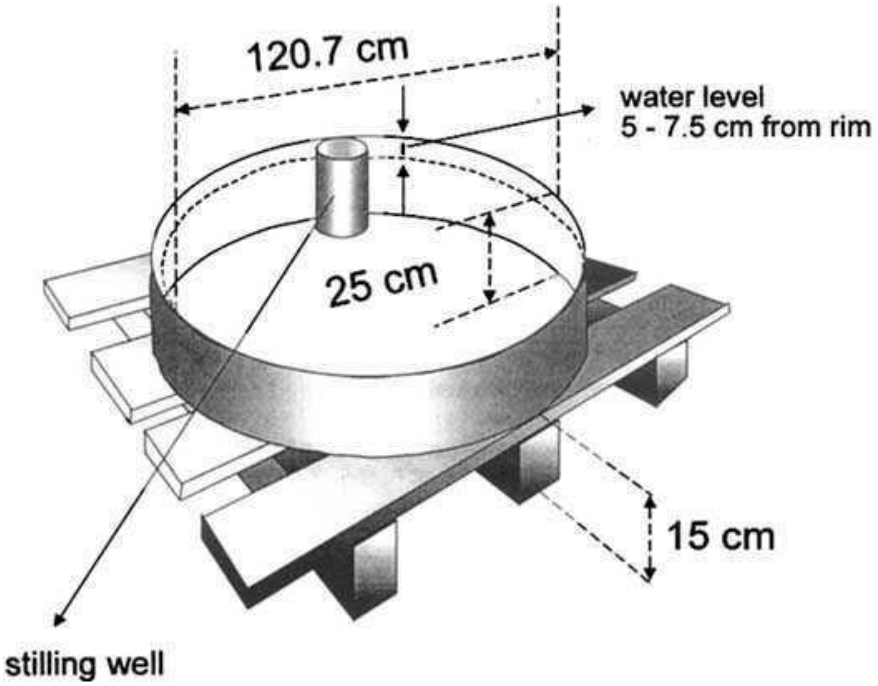


Fig. 8.1: U. S. W. B. Class 'A' pan evaporimeter

Exercise No. 9 **Date:**

Measurement of atmospheric pressure and analysis of atmospheric conditions

Objective
- ❖ To study atmospheric pressure and analyse atmospheric conditions

Technically, pressure is defined as the force per unit area. But the pressure exerted by the atmosphere on the earth's surface is called atmospheric pressure. It is defined as the pressure exerted by a column of air with a cross-sectional area of a given unit extending from the earth's surface to the uppermost boundary of the atmosphere. The standard sea level pressure is given as 1013 MB or 76 cm or 29.92" at a temperature of 15^{o}C and 45^o north latitudes. Atmospheric pressure does not have a direct influence on crop growth. It is, however, an important weather parameter in weather forecasting.

9.1. Instruments for measuring atmospheric pressure:

- ❖ Fortin's barometer
- ❖ Kew pattern barometer
- ❖ Aneroid barometer
- ❖ Barograph

The standard instruments for measuring atmospheric pressure are aneroid barometer and barograph.

9.1.1. Fortin's barometer:

This barometer is a standard and accurate instrument for measuring pressure. It consists of a small cistern vessel containing mercury with a flexible leather bag and a screw at its bottom. The mercury level can be raised or lowered with the help of a screw. In the cistern vessel, a glass tube filled with mercury is kept inverted. In this vessel, there is a pouted ivory pointer. from the lower tip of this pointer, the zero of the scale starts and therefore while taking the reading, the mercury level in the cistern vessel must touch the lower tip. There are two scales on two sides of the tube, one in centimeters and the other in inches. Vernier calipers are also attached for an accurate reading. To take a pressure reading the height of the mercury column is measured on the main scale and then the Vernier scale is read.

Atmospheric pressure = MSR + VSR x Vernier constant

The metal scale and the mercury expand differently at different temperatures. They are, therefore transformed to one common temperature which is zero degree centigrade or 273^{o}K. The gravitational pull changes according to latitude. Hence, the gravitational correction is applied and all the readings are transformed into one common latitude i.e., 45^o N. All the readings are transformed to sea level height. Thus, three corrections such as temperature, gravity and latitude are applied.

9.1.2. Kew pattern barometer:

This is also similar to Fortin's barometer where the cistern vessel is fixed and has no adjusting screw. The divisions are made unequal in order to allow the rise or fall of the mercury column in the cistern. In this barometer initial adjustment of the cistern is not required.

9.1.3. Aneroid barometer:

This barometer does not contain any liquid. It consists of an evacuated box with a corrugated sheet of metal lid held in position by means of a spring to avoid collapse of the top and bottom. This box is called a siphon cell and is sensitive to changes in pressure. When the pressure increases the cell is compressed and when it decreases the cell is expanded. These variations are magnified with the help of levers and are communicated through chain and pulley to the pointer, which moves on a graduated scale. This pointer gives direct pressure reading. This is not an accurate instrument.

9.1.4. Barograph:

This instrument is used for automatic and continuous recording of atmospheric pressure. It is a special type of aneroid barometer with having recording system. It consists of several vacuum boxes like an aneroid barometer placed one above another. The combined motion of these vacuum boxes becomes appreciable and communicates to a level system. The changes are marked on a chart paper fixed on the clock-driven rotating drum. The chart is calibrated in cm or inches on one axis and hrs/days of the week on another axis. Thus, a continuous record of atmospheric pressure is obtained. Before use, the instrument must be standardized with the help of Fortin's barometer. This instrument does not give correct pressure readings. However, it helps record the barometric tendencies.

Use of barometer:

It is used for approximate forecasting, to measure atmospheric pressure and to measure height of a given station above mean sea level.

Weather and pressure:

- ❖ Falling barometer indicates rain or storm (bad weather).
- ❖ Rising barometer indicates fair weather (clear and stable).
- ❖ Steady barometer indicates steady or settled weather.
- ❖ A continually rising pressure indicates fine and settled weather and a steadily falling pressure indicates occurrence of unsettled and cloudy weather.

Units of pressure:

The pressure is measured in the following units.

1 atmospheric pressure = 29.92" = 76 cm = 760 mm

= 1013 mill bar

= 101.32 kilopascal (kpa)

= 14.7 lbs/inch^2

= 1.014 x 10^6 dynes /cm^2

= 1 bar

- Height of mercury column in inches or cm or mm
- Bar is a force equal to 10^6 dynes /cm^2. This is a big unit and is therefore divided into smaller units1 bar = 1000 mb
- In the standard international unit of pressure is

  Pascal1 Pascal = force of 1 Newton/ sq.m.

9.2. Calculation based on air density and atmospheric pressure

Example: Calculate the standard sea level air density, if the standard sea level pressure is 1013 hPa and temperature is 25.0^0C

Absolute temperature = C+273
= 25.0+273.0
= 298 ^{0}K
Air density = P/RT
Where P = Atmospheric pressure at msl
R = Gas constant = 2.87
T = Absolute temperature

Air density (kg/m^3) = 1013/(2.87*298)
= 1013/826.56
= 1.18

Exercise No. 10 **Date:**

Measurement of clouds

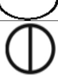
Objective ❖ To measure cloud cover

Cloud is an aggregate of very small water droplets, ice crystals, or a mixture of both, with its base above the Earth's surface, which is perceivable from the observation location. The limiting liquid particle diameter is of the order of 200 µm; drops larger than this comprise drizzle or rain

10.1. Estimation of Cloud Cover

- There is no instrument for measuring the cloud amount in the sky. Cloud amount is expressed in terms of "Okta" or one-eighth of the sky.
- The assessment of the total amount of clouds, therefore, consists of estimating how much the total area of the sky nearest to the earth is covered with clouds.
- The observer assumes the sky to be divided into four quadrants.
- The clouds scattered in different parts of the sky are supposed to be present together.
- The observer then estimates the number of quadrants the clouds occupy. Cloud amount is reported in oktas.
- Scale of cloud cover measured in oktas (eighths) with the meteorological symbol for each okta is shown in table 10.1.

Table. 10.1. Scale for measurement of cloud cover in oktas (eighths) with the meteorological symbols.

Sky cover (Oktas)	Symbol	Name	Abbreviation	Sky cover (tenths)
0		Sky clear	SKC	0
1		Few* clouds	FEW*	1
2				2-3
3		Scattered	SCT	4
4				5
5		Broken	BKN	6
6				7-8
7				9
8		Overcast	OVC	10
9		Sky obscured		Unknown
(/)		Not measured		Unknown

Exercise No. 11 **Date:**

Determination of heat indices

Objective ❖ To study heat indices

The accumulated heat unit system or degree-day concept can be used for the prediction of crop maturity dates in a region. The concept assumes that there is a direct and linear relationship between growth and temperature. The assumption is that a crop requires a definite amount of accumulated heat energy for the completion of its life cycle.

11.1. Definitions

11.1.1. Phenology:

The periodic biological events and their dates of occurrence in plant life in relation to the influence of weather are called phenology. It is the branch of science that studies the periodical biological events with respect to calendar days.

11.1.2. Growing Degree day (GDD):

The degree-day or heat unit is the departure from the mean daily temperature above the minimum threshold or base temperature or critical temperature. It is the difference between the daily mean temperature and base temperature.

11.1.3. Base temperature (Tb):

The temperature below which growth does not take place is known as the base temperature. The value for the majority of the plants ranges from 3.5 to 12.0^{o}C.

Table. 11.1. Base temperature of some crops (in degree Celsius)

Crop	Base Temperature (^{o} C)	Crop	Base Temperature (^{o} C)
Pea	1 – 2	Oats	4 – 5
Wheat	3.0 - 4.5	Groundnut	8 - 10
Barley	3.0 - 4.5	Tobacco	13-14
Sugar beet	4 – 5	Pumpkin	12
Rice	10-12	Lentils	4 - 5
Sorghum	8 - 10	Carrot	4 - 5
Maize	8 - 10		

11.1.4. Photo-thermal unit (PTU):

The product of GDD and maximum bright sunshine hours of any day is called photo thermal unit (PTU).

11.1.5. Helio-Thermal Unit (HTU):

The Product of GDD and the number of actual bright sunshine hours on the day is called helio-thermal unit (HTU).

11.1.6. Hydrothermal unit (HYTU): The product of GDD and relative humidity is calledHYTU.

11.2. Materials:

Data on daily maximum temp; daily minimum temp., day length and daily number of actual bright sunshine hours during the growing period of the crop and base temperature of crop (Tb).

11.3. Methodology:

$$GDD = \sum \frac{(T_{max} + T_{min})}{2} - T_b$$

Where, T^b is base temperature of crop

PTU = GDD x Day length (hours) or max. possible bright sunshine hours.

HTU= GDD x No. of actual bright sunshine hours

$$T_{range} = T_{max} - T_{min}$$

$$\text{Heat Use Efficiency (HUE)} = \frac{\text{Yield (kg/ha)}}{\text{GDD (Degree-day)}}$$

$$\text{Radiation Use Efficiency (RUE)} = \frac{\text{Yield (Kg/ha)}}{\text{PTU (Degree-day) (in hrs)}}$$

$$\text{Heliothermal Use Efficiency} = \frac{\text{Yield (kg/ha)}}{\text{HTU (Degree-day) (in hrs)}}$$

$$\text{Hydrothermal use efficiency (HYTUE)} = \frac{\text{Yield (kg/ha)}}{\text{HYTU } (^{o}\text{C day \%})}$$

11.4. Exercise:

From the given data calculate mean, SD, CV%, GDD, PTU, and HTU for the pea crop on Nov.1st (Taking T_b= 2° C)

Date	T_{max} (°C)	T_{min} (°C)	Day length (hrs.)	Sunshine hours (No.)
1				
2				
3				
4				
5				
6				
7				
8				
9				

Exercise No. 12 **Date:**

Study synoptic charts and weather reports

Objective ❖ To study synoptic charts and weather reports

After collection of data with various devices, the data need to be transferred to an appropriate place for analysis. In this regard, it is proper to know a little about synoptic climatology. The term synoptic climatology is applied to investigations of regional weather and circulation types. It is also used to refer any climatological analysis which makes some reference to synoptic weather phenomena. This field is concerned with obtaining an insight into local or regional climates by examining the relations hip of weather elements individually or collectively to atmospheric circulation processes. Synoptic climatology is defined as the description and analysis of the totality of weather at a single place or over a small area, in terms of the properties and motion of the atmosphere over and around the place or area. There are essentially two stages to a synoptic climatological study:

1. The determination of categories of atmospheric circulation type
2. The assessment of weather elements in relation to these categories.

Besides agricultural meteorological observatories, synoptic weather stations also record weather data such as rainfall, temperature, radiation, low level wind and evaporation etc. The surface observatories collect information on various weather elements and based on these, daily forecasts, warnings and weather reports are prepared by weather forecasting centres at Chennai, Nagpur, Mumbai, Delhi and Kolkatta. The weather bulletins are being broadcast in regional languages through All India Radio and Television.

12.1. Synoptic report:

Observed weather conditions are marked in brief coded form as a synopsis of the conditions. Such a brief report on weather conditions is known as synoptic report.

12.2. Synoptic chart/weather map:

The regular observatories record weather elements at scheduled time and send these readings through a telegram to the main observatory at Pune. They reach Pune within an hour of observation and they are charted on outline map of India, using the international code of signals and abbreviations. These are called synoptic charts or weather maps. In synoptic charts different weather phenomena and atmospheric characters are marked with different symbols as mentioned below.

S.no.	Symbols	Weather element/character
1.	Narrow block items	Isobars
2.	Number at ends of isobars	Pressure values in millibars
3.	Shading	Precipitation
4.	Arrows	Wind direction
5.	Feathers in the arrows	Wind velocity
6.	Small circles with shading	Amount of clouds

Besides, different symbols are also used for recording weather phenomena, in relevant columns of the pocket register and the Monthly Meteorological Register by the observer. The duties of the observer: The routine duties of the observer include:

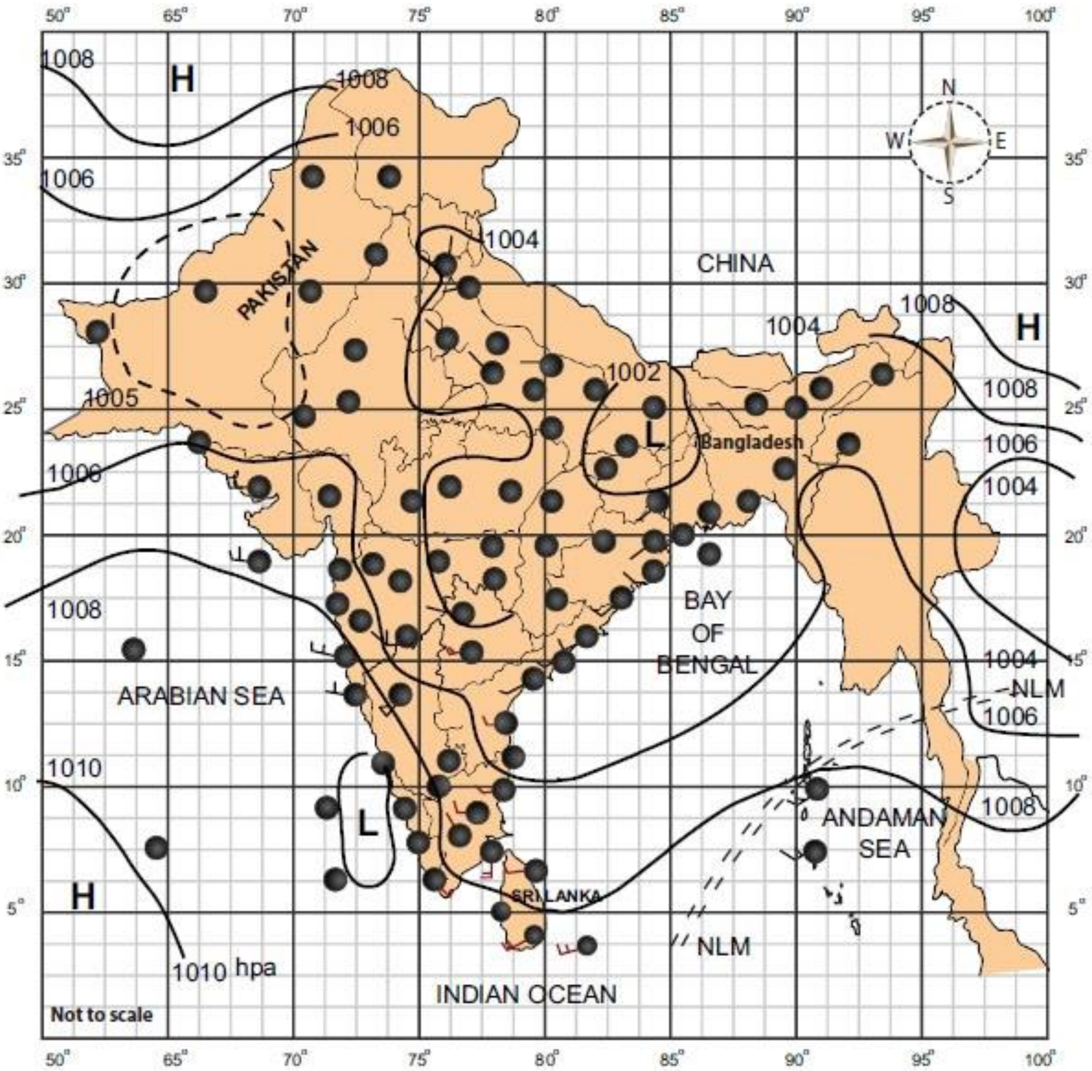
1. To make regular and careful observations and to note the general character of the weather and record in the pocket register.
2. To prepare and dispatch the weather telegram as per the instructions to the different forecasting centers, immediately after the observations are taken.
3. To send, heavy rainfall telegrams to the various offices on warning list.
4. To prepare and post monthly meteorological and pocket registers, for each month to the controlling meteorological office.
5. To keep the instruments clean and maintain them property.

After sending the data by the observer, it should be decoded and the weather observations for each station must be plotted at the appropriate location in a systematic manner following the international station model. Only weather maps in first-class forecasting c enters approach the completeness of the model. Printed maps and maps used for plotting usually have an appropriately numbered circle corresponding to each reporting land station and observations are plotted about this location in the appropriate position regardless of the number of observations shown. It must be, emphasized again that the weather pattern affecting a locality is an integral part of the much larger hemispheric weather pattern. It is necessary to plot a map over a large area. Even if observations are not to be plotted, it is necessary to know the plotting scheme in order to read and interpret weather charts already plotted.

INDIAN DAILY WEATHER REPORT

WEATHER MAP AT 08.30 HRS .I.S.T. (0300 HRS. G.M.T)

Monday 1 June 1992 (11 Jyaistha 1914 Saka)



Exercise No. 13 **Date:**

Visit at Agro-meteorology observatory

Objective

- To study the layout of the meteorological observatory, the installed instruments, their working principles and time of observations for various weather variables

13.1. Exercise:

1. **Draw the layout plan of agrometeorological observatory you visited.**

2. **Enlist the instruments/devices that you have observed as follows:**

Sl. No.	Name of instrument/ device	Weather variable measured	Time of observation