RAINFALL

Topics to be covered:

- Forms of Precipitation
- Mechanisms for Production of Rainfall
- Types of Precipitation
- Temporal and Spatial Variation of Rainfall
- Rainfall Measurement
- Rainfall Measurement Errors
- Raingauge Network

Forms of Precipitation:

- Precipitation occurs in many forms e.g. drizzle, rain, glaze, sleet, snow, hail, dew and frost, depending upon the causes and temperature at the time of formation.

- Dew is condensation on the ground of atmospheric vapor caused by radiational cooling of the lower layers of atmosphere, usually at night.

- Frost is dew formed under freezing conditions.

Dew and frost are quantitatively unimportant and rarely measured.

Forms of Precipitation:

- **Drizzle**: Drop size < 0.5 mm in dia and intensity is usually < 1 mm/h and generally occurs in conjunction with warm frontal lifting.

- **Rain**: Drop size is between 0.5 to 6 mm in dia. Drops bigger than 6 mm tend to break up as they fall. It is formed by condensation and coalescence of cloud droplets at temperatures above the freezing point.

  - The rainfall is classified into
    - Light rain – if intensity is trace to 2.5 mm/h
    - Moderate – if intensity is 2.5 mm/h to 7.5 mm/hr
    - Heavy rain – above 7.5 mm/h

- **Glaze**: It is the ice coating formed when drizzle or rain freezes as it comes in contact with cold objects on the ground.

Forms of Precipitation:

- **Sleet**: It is frozen raindrops cooled to ice stage while falling through air at sub-freezing temperature.

- **Snow**: It is a precipitation in the form of ice crystals resulting from desublimation, i.e., directly from water vapor to ice.

- **Snow Flake**: It is made of a number of ice crystals fused together.

- **Hail**: It is precipitation in the form of balls or lumps of ice over 5 mm diameter formed by alternate freezing and melting as they are carried up and down in highly turbulent air currents.

Mechanisms for Production of Rainfall

The following four conditions are necessary for the production of rainfall.

- **Mechanism to produce cooling of the air** – The pressure reduction due to ascending air from surface to upper levels in the atmosphere is the only known mechanism capable of producing large drops in the temperature.
- **Mechanism to produce condensation** – Condensation in the atmosphere takes place on "hygroscopic nuclei" small particles of substances that have an affinity for water.

Mechanisms for Production of Rainfall

- **Mechanism for droplet growth** – A tendency for the droplets to remain small and therefore to resist falling is called "colloidal stability". Most effective processes for droplet enlargement are;
  - (i) the difference in speeds between large and small droplets, and
  - (ii) the co-existence of ice crystals and water droplets.

- **Mechanism to produce accumulation of moisture of sufficient intensity to account for the observed rates of rainfall** – Regardless of whether or not the other conditions for precipitation are fulfilled, continuity considerations demand that there must be a good amount of moisture present in the atmosphere so that evaporation losses between ground and cloud be compensated, if there is to be appreciable rain.

Types of Precipitation

There are three major types of precipitation:

1. Cyclonic,
2. Convective, and
3. Orographic.

Each type represents a different method of lifting an air mass, resulting in cooling and condensation of atmospheric water vapor.

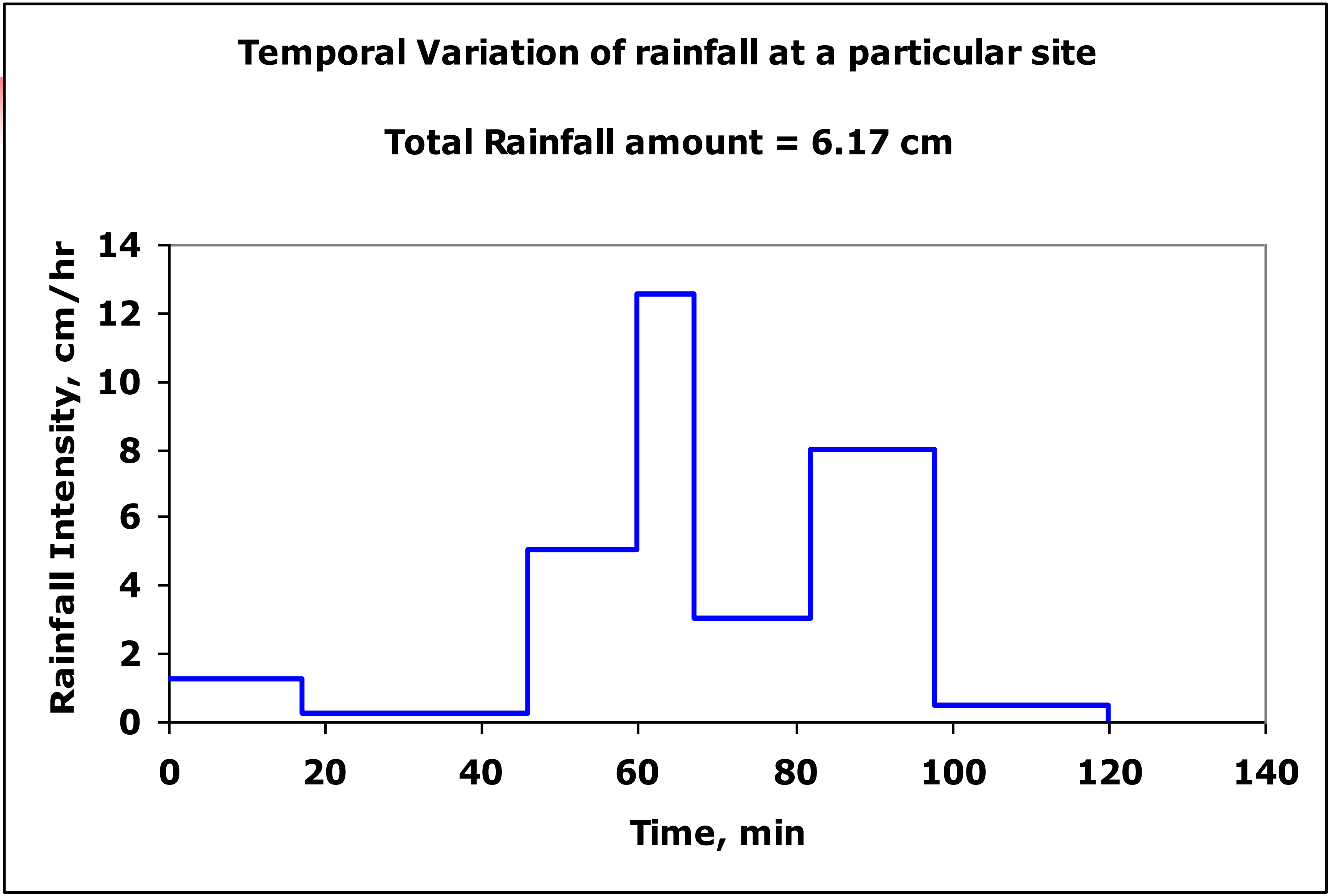
Rainfall

- **Principal component of the hydrological cycle**
  - **Measured rainfall is useful in variety of hydrological applications**
  - **Varies in space and time**

Temporal and Spatial Variation of Rainfall

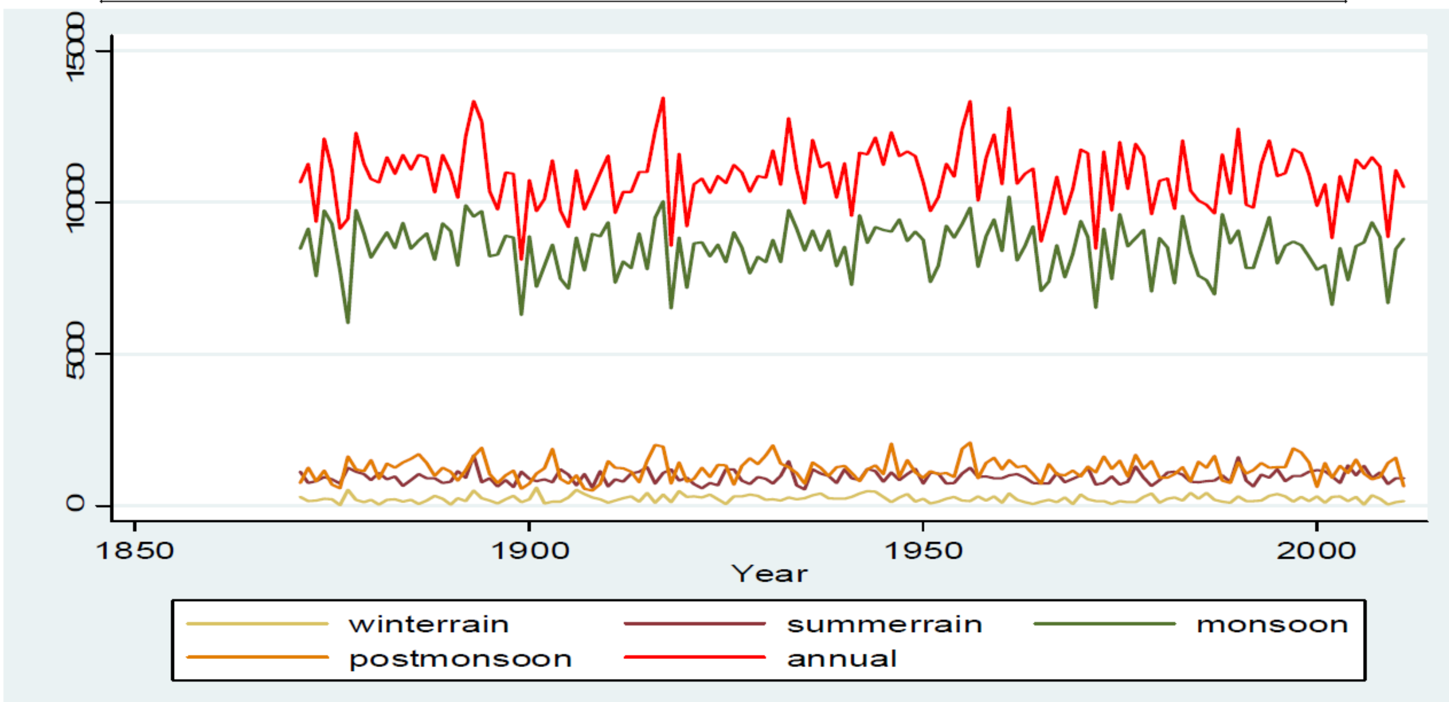
- Rainfall varies greatly both in time and space
  - With respect to time – temporal variation
  - With space – Spatial variation

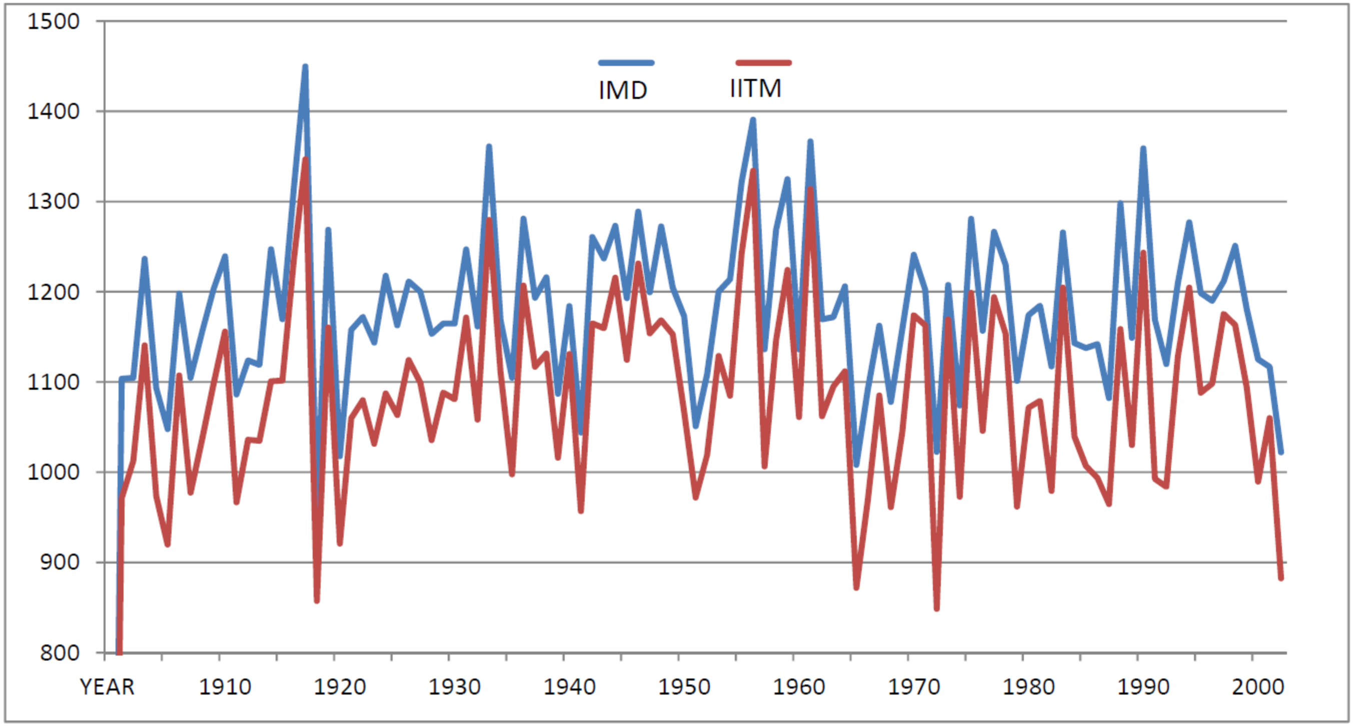
- The temporal variation may be defined as hourly, daily, monthly, seasonal variations and annual variation (long-term variation of precipitation)


Temporal Variation of rainfall at a particular site
Total Rainfall amount = 6.17 cm
Rainfall Intensity, cm/hr
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120
140
Time, min

Seasonality : Rainfall In 1/10 mm As Per IITM Series

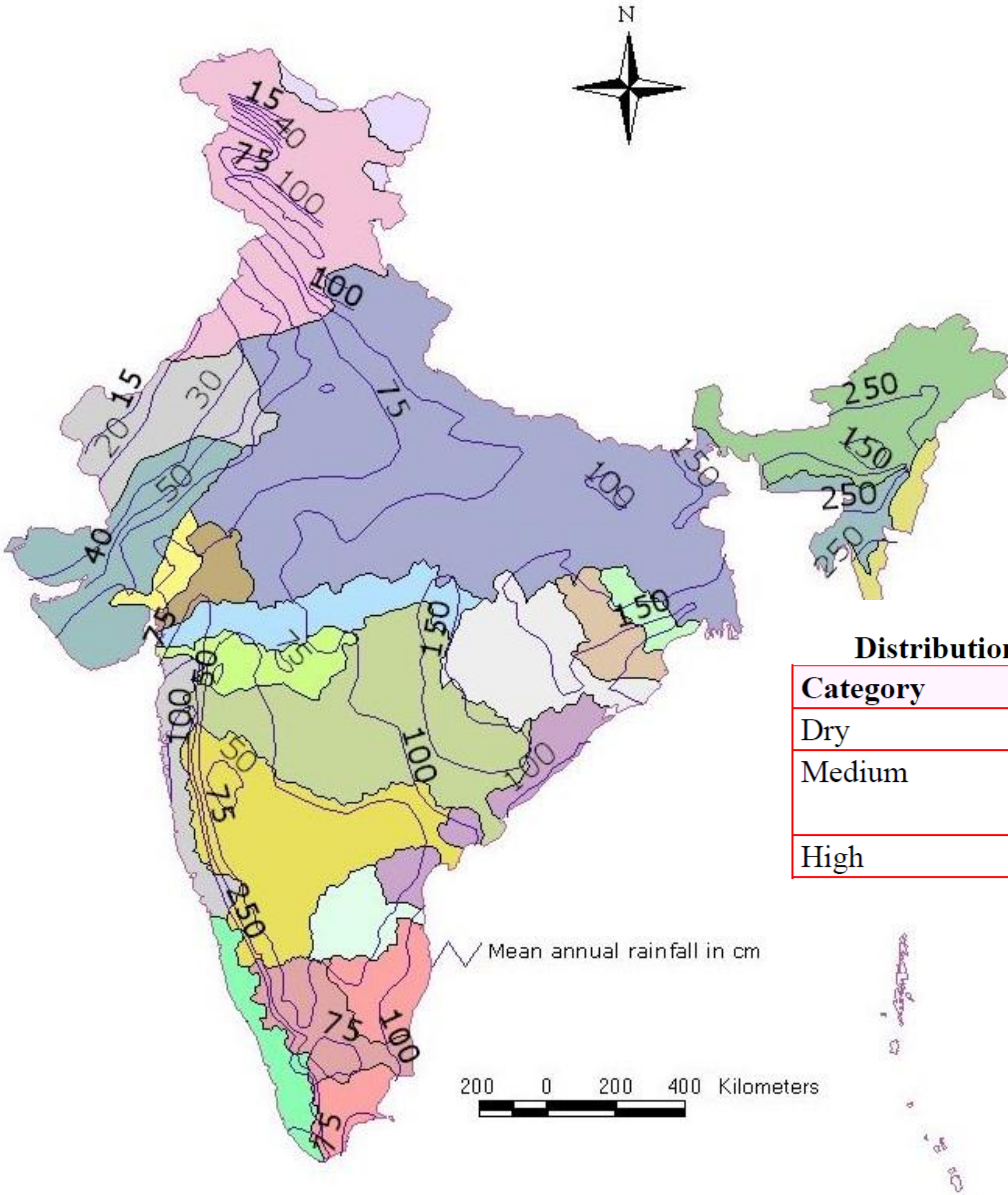
Jan-Feb : Winter rain, Mar-May :Summer rain, June-Sep: Monsoon, Oct-Dec : Post Monsoon





- The All-India area-weighted mean summer monsoon rainfall, based on a homogeneous rainfall data set of 306 rain gauges in India, developed by the Indian Institute of Tropical Meteorology (IITM),Pune (www.tropmet.res.in) (Average = 1086 mm)

- Rainfall time series of 36 meteorological sub Divisions of India using 1476 rain gauge stations has also been constructed by India Meteorological Department, IMD Pune since 1901. This series includes hilly regions also. (Average = 1183 mm)



Distribution of Area According to Annual Rainfall

Category	Rainfall (mm)	Area (%)
Dry	0–750	30
Medium	750–1150	42
	1150–2 000	20
High	> 2 000	8

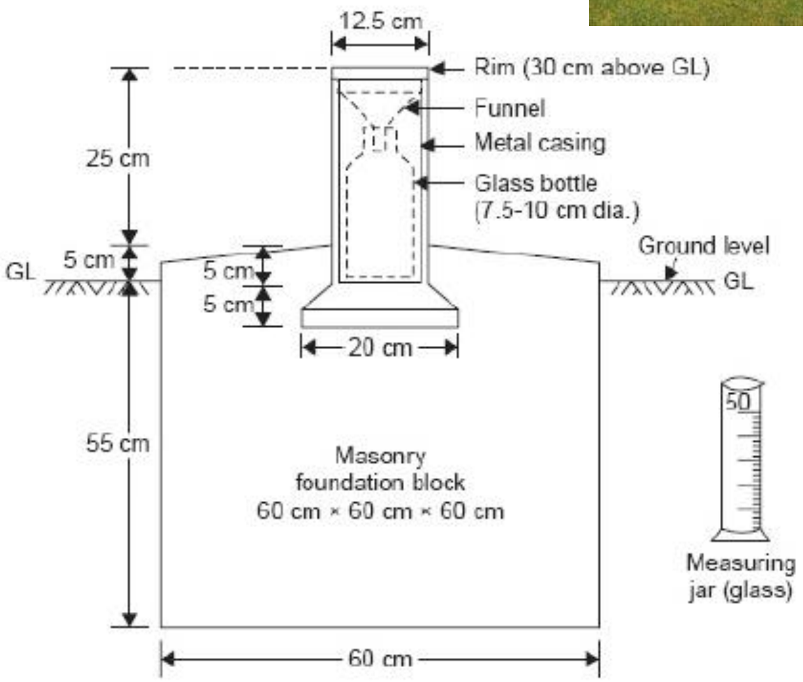
Rainfall Measurement

- Raingauge
  - to measure the depth and intensity of rainfall

- Types of Raingauge
  - Non-recording
    - Symon's gauge
  - Recording
    - Weighing Bucket Type
    - Tipping Bucket Type
    - Siphon or Floating Type

Symon's Raingauge (Non-recording Gauge)

- The standard raingauge, known as Symon's gauge is recommended and installed by the India Meteorological Department.
- This is a vertical, cylindrical container with top opening 127 mm in diameter.
- A funnel shaped hood is inserted to minimize evaporation losses.
- The water is funneled into an inner cylinder.



Symon's Raingauge (Non-recording Gauge)

Considerations for Installation:

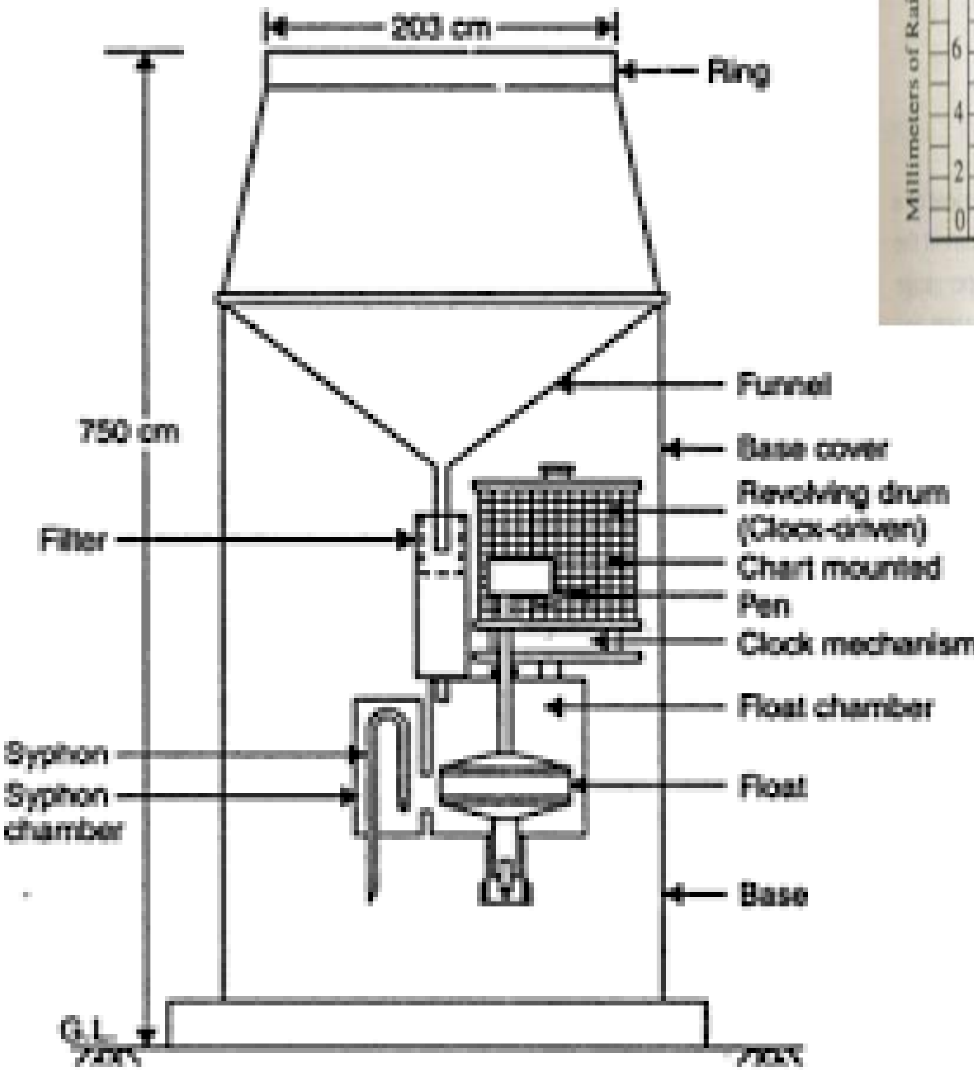
- The site should be an open place,
- The distance between the raingauge and the nearest object should be at least twice the height of the object,
- As far as possible it should be a level ground,
- In the hills, the site should be so chosen where it is best shielded from high winds and wind does not cause eddies, and
- If a fence is erected, it should be at least at a distance of twice the height.

Recording or Automatic Gauge

A. Syphon Type Automatic Rainfall Recorder –

- In the Syphon gauge, also known as the float type of recording raingauge, the rain is fed into a float chamber containing a light, hollow float.
- The vertical movement of the float, as the level of water rises, is transmitted by a suitable mechanism into the movement of the pen on a revolving chart.
- By suitably adjusting the dimensions of the receiving funnel, float and float chamber, any desired scale value on the chart can be obtained.
- Syphoning arrangement is provided for emptying the float chamber quickly whenever it becomes full, the pen returns to the bottom of the chart.

Siphon/Float Raingauge



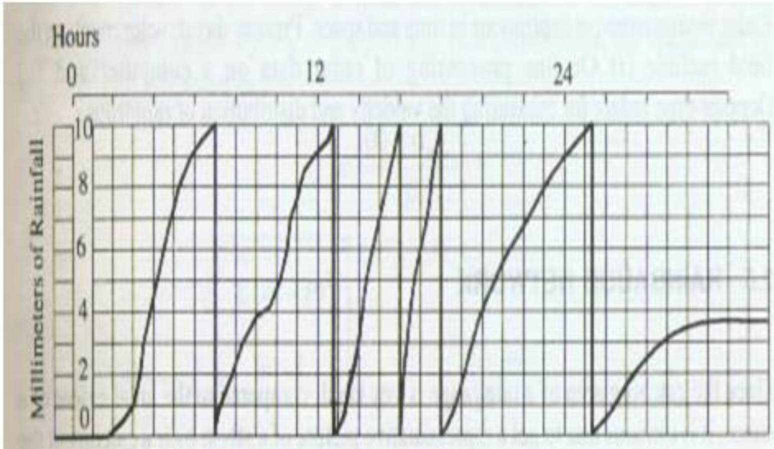
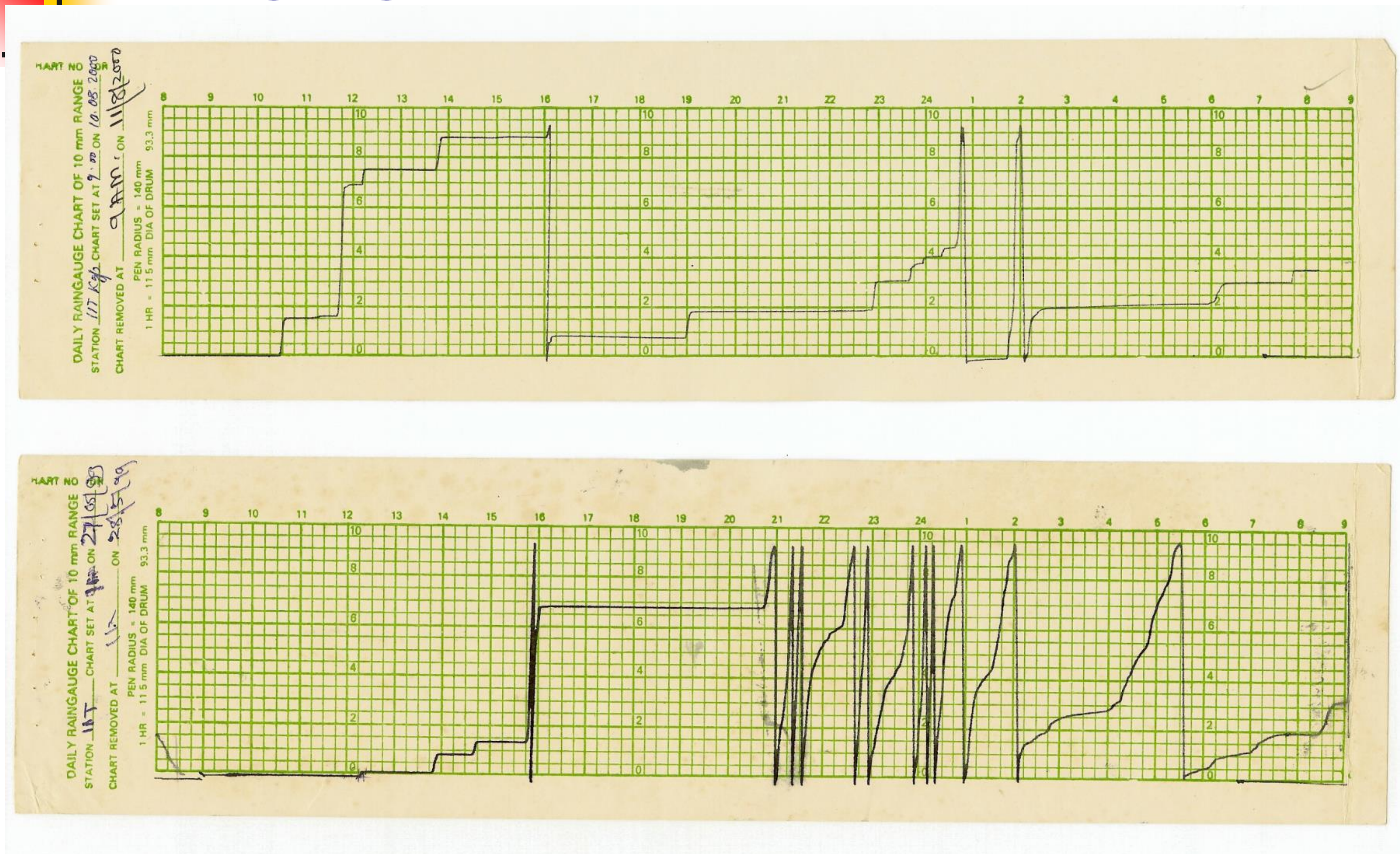
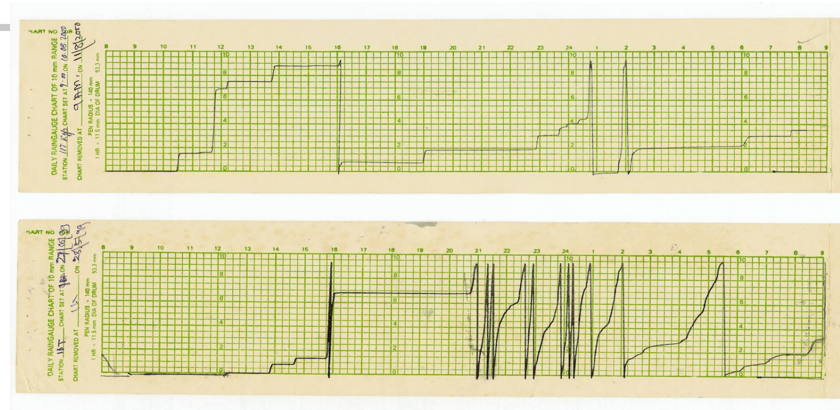


Fig. 2.6 Recording from a natural syphon-type gauge (schematic)

Raingauge Chart



Siphon/Float Raingauge

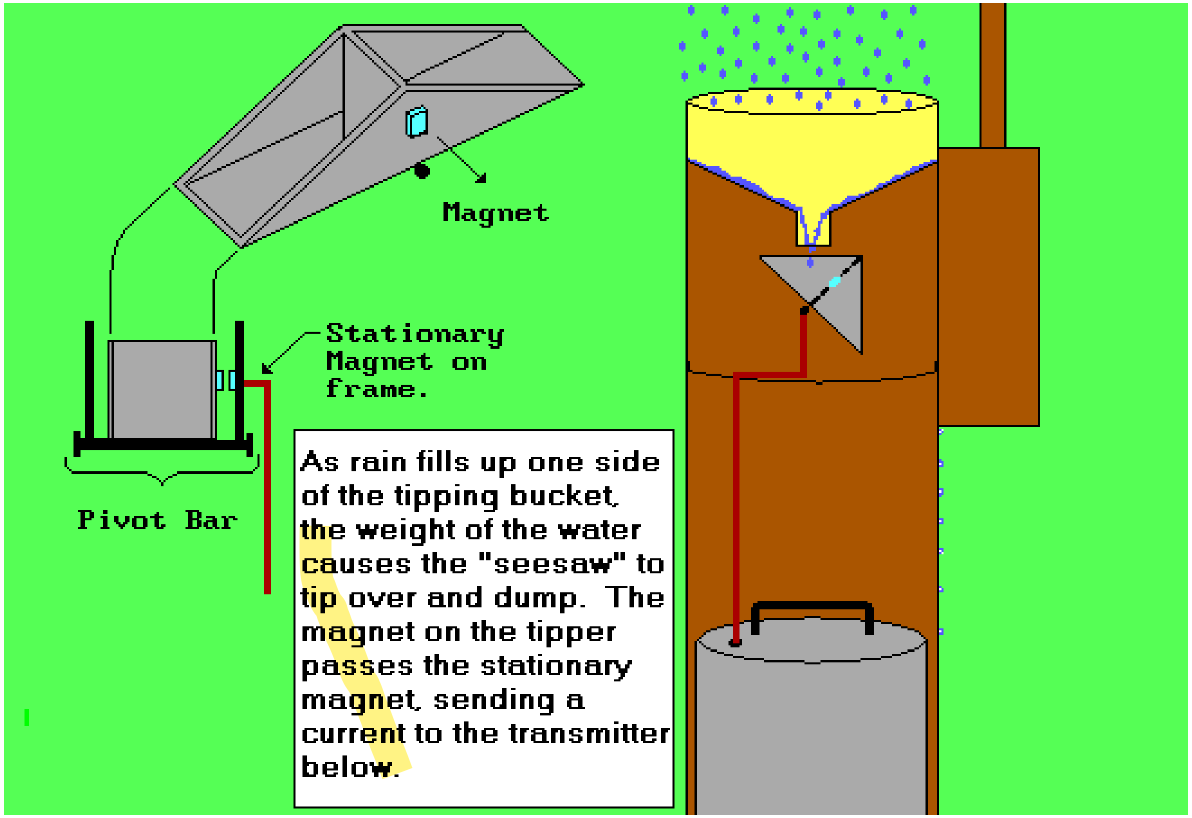


- Hollow Float
- Collecting chamber
- Clock-work mechanism
- Daily/Weekly chart

Tipping Bucket

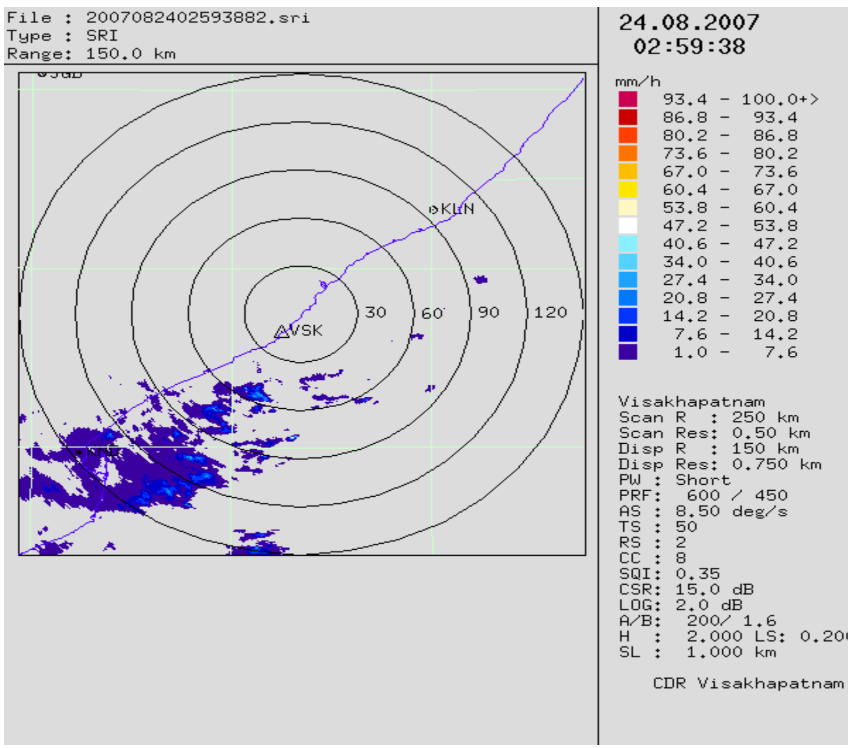
- Two containers on balance beam form a “tipping bucket”
- Rain fills one container until its threshold weight reached
- Bucket then tips over, emptying collected water into total container and continues to collect rainfall in other container
- Magnet generates electric pulse which is recorded
- Problems
  - Evaporation from buckets
  - Discontinuous record in light rain
  - Susceptible to freezing

Tipping Bucket

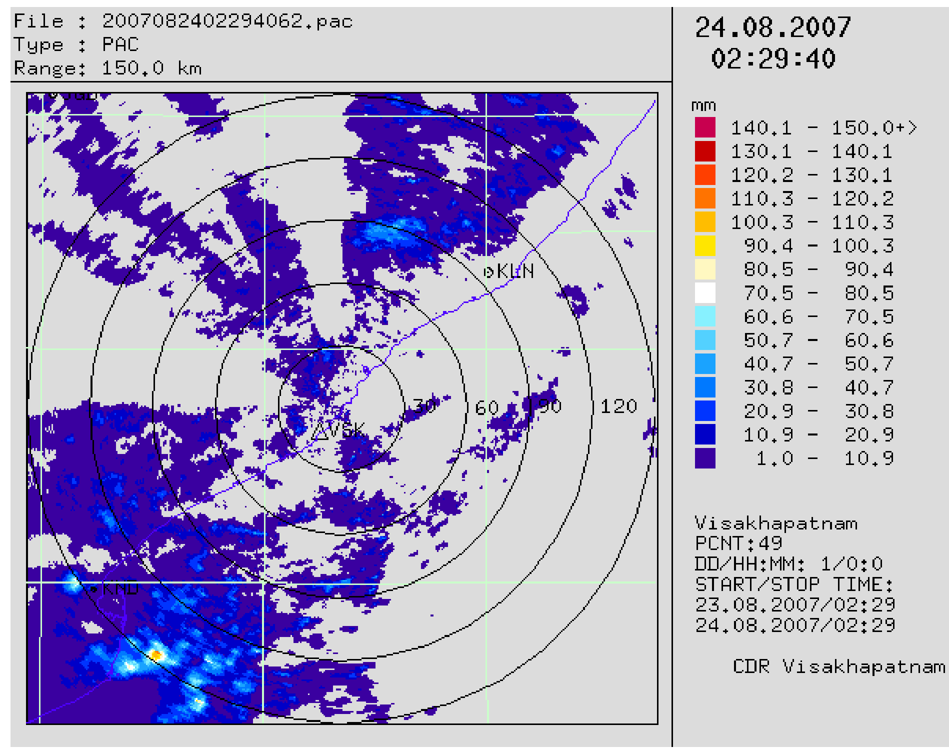


Radar Measurement of Precipitation

Rainfall Intensity

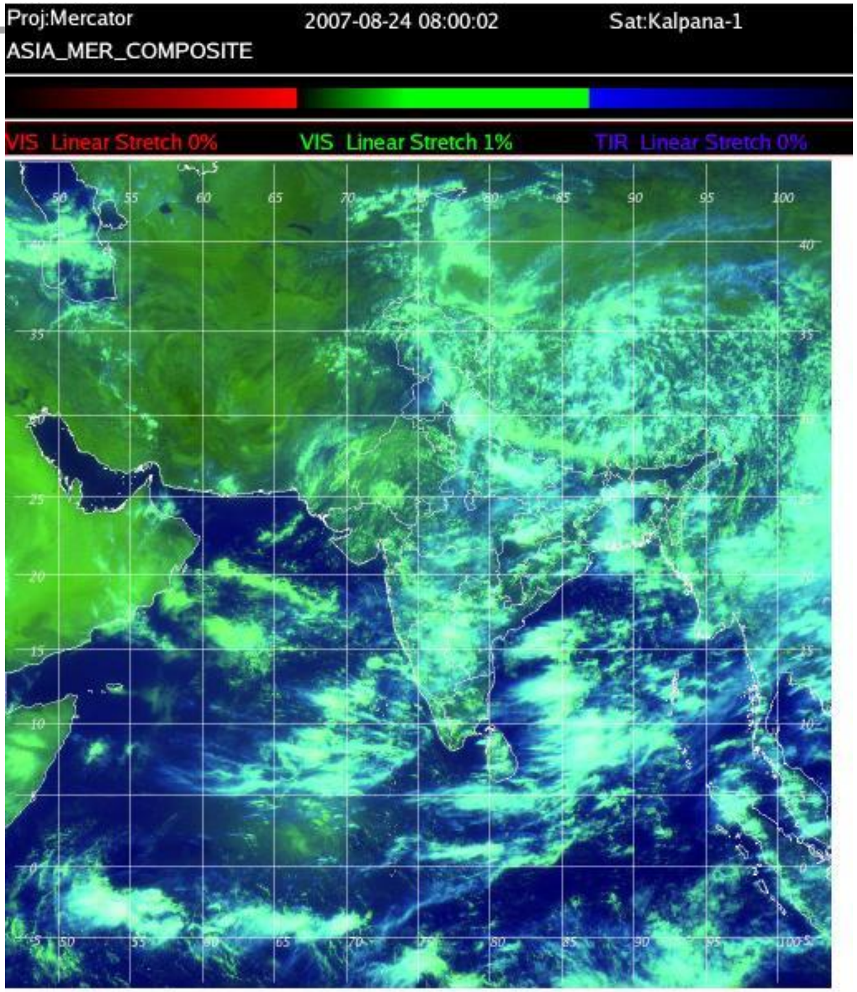


Accumulated Rainfall in 24 hrs



Satellite Estimates of Precipitation

METSAT: KALPANA-1



Rainfall Measurement Errors

- Two types of errors
  - Random
    - Random errors are due to
      - storm characteristics
      - raingauge density
      - ability of a raingauge to represent the area that it is supposed to represent
  - Systematic
    - Systematic errors are due to
      - measurement errors
      - improper siting
      - poor exposure
      - change in observer
      - Change in gauge

WMO Recommended Precipitation Network Density

- One station per 600 to 900 km^2 - in flat regions of temperate, Mediterranean and tropical zone
- One station per 100 to 250 km^2 – in mountainous regions of temperate, Mediterranean and tropical zone
- One station per 25 km^2 – in small mountainous land with irregular precipitation
- One station per 1500 to 10,000 km^2 – arid and polar zones

Indian Standard Recommendation

- One station per 520 km^2 - in plains
- One station per 260 - 390 km^2 – in regions of average elevation of 1000 m
- One station per 130 km^2 – in predominantly hilly areas with heavy rainfall

Raingauge Network

- In general, the sampling errors of rainfall tends to
  - decrease with increasing network density, duration of rainfall, and areal extent

- Accordingly, larger average errors are produced by a particular network for storm rainfall than for monthly, seasonal or annual rainfall

- The adequacy of an existing raingauge network of a watershed is assessed statistically

Raingauge Network

- The optimum number of raingauges corresponding to an assigned percentage of error in estimation of mean areal rainfall can be obtained as

$$N = \left(\frac{C_v}{\epsilon}\right)^2$$

where

N = optimal number of raingauge stations

C_V = coefficient of variation of the rainfall values at the existing 'm' stations (in %)

ε = assigned percentage of error in estimation of mean areal rainfall (usually 10 %)

Raingauge Network

If there are m stations in a catchment, each recording rainfall values P_1, P_2, P_3…,P_m at a known time,

$$C_v = \frac{100 \times \sigma_{m-1}}{\overline{P}} \qquad \sigma_{m-1} = \sqrt{\left[\frac{\sum_{1}^{m}(P_i - \overline{P})^2}{m-1}\right]} \qquad \overline{P} = \frac{1}{m}\left(\sum_{1}^{m} P_i\right)$$

For the existing system of 'm' raingauge stations,

$$m = \left(\frac{C_v}{\epsilon_{ex}}\right)^2$$

The standard error in the estimation of mean rainfall,

$$\epsilon_{ex} = \left(\frac{C_v}{\sqrt{m}}\right)$$

Example

- A catchment has six raingage stations. In a year, the annual rainfall recorded by the gages are as follows

Stations	A	B	C	D	E	F
Rainfall (cm)	82.6	102.9	180.3	110.3	98.8	136.7

(i) Determine the standard error in the estimation of mean rainfall in the existing set of raingauges.

(ii) For a 10% error in the estimation of mean rainfall, calculate the optimum number of stations in the catchment

Solution

- Number of stations (m) = 6,
- Mean precipitation $(\bar{P})$ =118.6 cm
- Standard deviation of precipitation (S) = 35.04
- Error (ε) =10%

$$CV = \frac{100\,(35.04)}{118.6} = 29.54$$

Standard error = $(C_v/\sqrt{m})$ = 12.06%

$$N = \left(\frac{29.54}{10}\right)^2 = 8.7 \cong 9 \text{ stations}$$

Exercise

- A catchment has seven raingauge stations. In a year, the annual rainfall recorded by the gages are as follows:

Stations	P	Q	R	S	T	U	V
Rainfall (cm)	130.0	142.1	118.2	108.5	165.2	102.1	146.9

- Determine the standard error in the estimation of mean rainfall in the existing set of raingauges.
- For a 5% error in the estimation of mean rainfall, calculate the minimum number of additional stations to be established in the catchment.

Solution

- Number of stations (m) = 7,
- Mean precipitation $(\bar{P})$ =130.4 cm
- Standard deviation of precipitation (S) = 22.54
- Error (ε) =5%
- CV = 17.285
- Standard error in estimation of mean areal rainfall = 6.53%
- N = 11.95 = 12
- Additional gauges = 5