CE 361A : Engineering Hydrology

Precipitation

Lecture -5

Revision

Measurement of Precipitation

- Rainfall
  - Doppler or land-based radars
  - Satellites
  - Rain gauge : (a) non-recording & (b) recording
    - Effects of winds, drop size and ground turbulence on rainfall catch
    - Measurement of rainfall over India

Assimilation of various sources

Measurement of Snow

1. Gauges (Total precipitation or snow gauges)

Non-recording type

Measurement of Snow

1. Gauges

Snowflakes melt, trickle into tipping bucket

Evaporation/sublimation from gauge funnel

Intense snowfall overflows gauge funnel

Recording type

Source: The COMET program

Measurement of Snow

2. Snow core or tubes

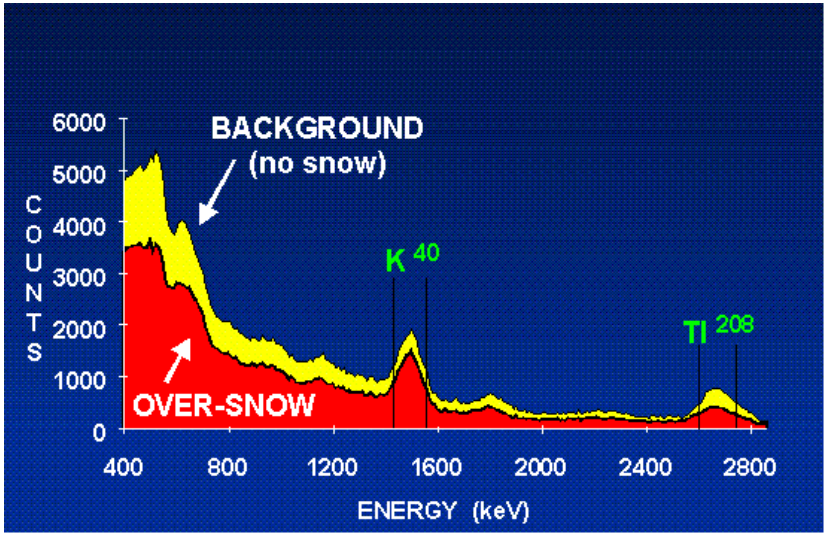
Measurement of Snow

3. Snow pillow

Source: The COMET program

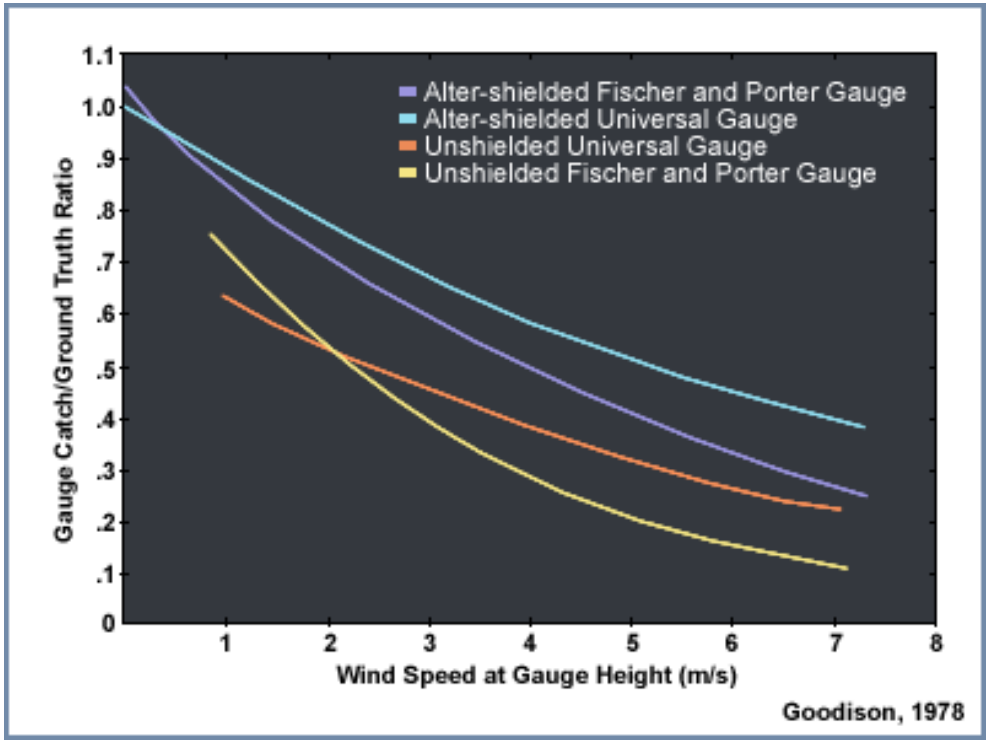
Measurement of Snow

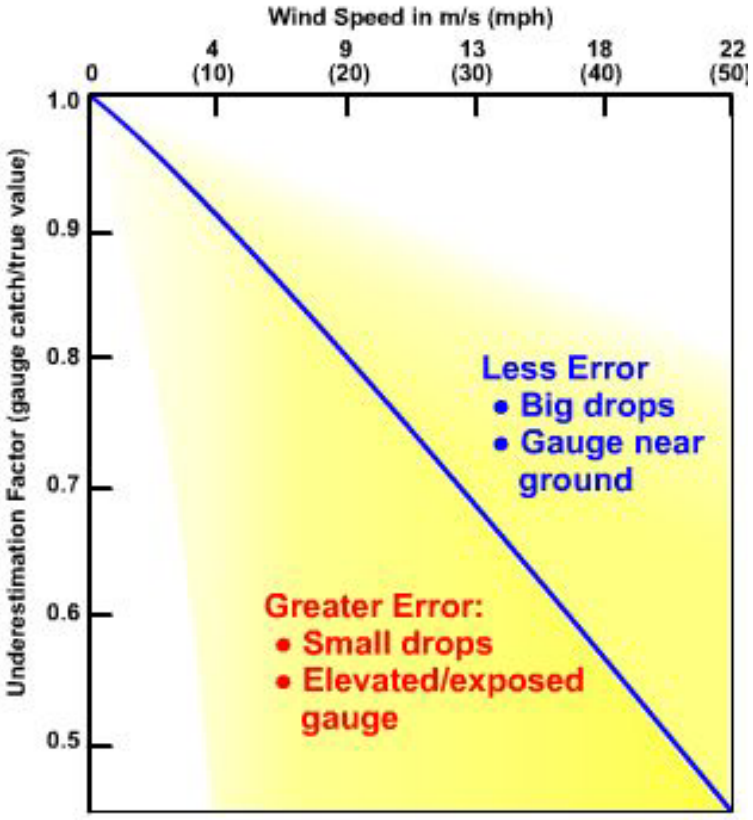
4. Airborne gamma radiation survey



Source: National operational hydrologic remote sensing centre

Effect of Wind





Winds have more affect on snow than rainfall measurements. Why?

Source: The COMET program

Analysis of Rainfall Data

Analysis of Rainfall Data

Data collected from rain gauges

1. Present rainfall data
2. Check consistency
3. Estimate missing values
4. Adequacy of raingauge
5. Areal average rainfall
6. Depth-area-duration relationships
7. Frequency analysis: Intensity-duration-frequency (IDF) curves
8. Probable maximum precipitation
9. Variability, Periodicity and Trends

Presentation of Rainfall Data

Hyetographs

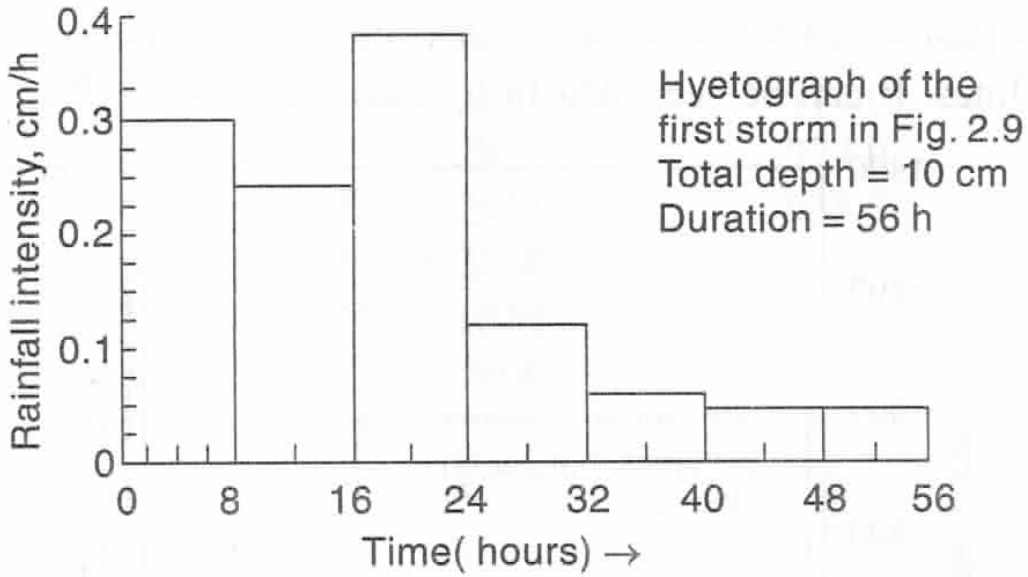


Fig. 2.10 Hyetograph of a Storm

Area under the curve represents?

Sometimes plotted as a smooth curve

Source: Subramanya (2008)

Presentation of Rainfall Data

Mass curve

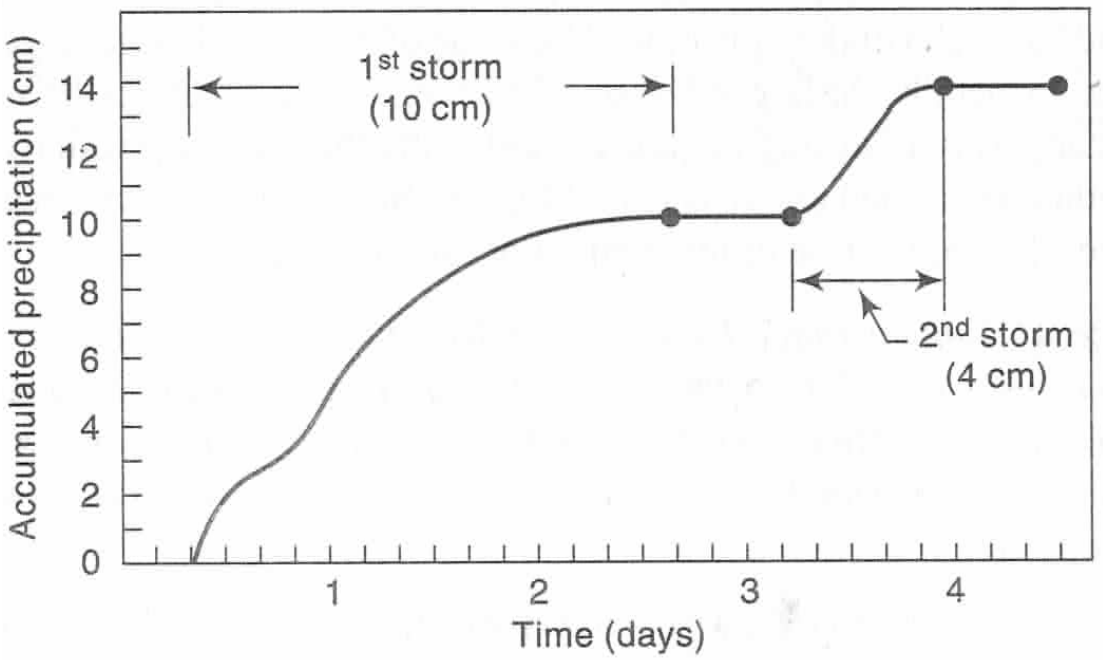


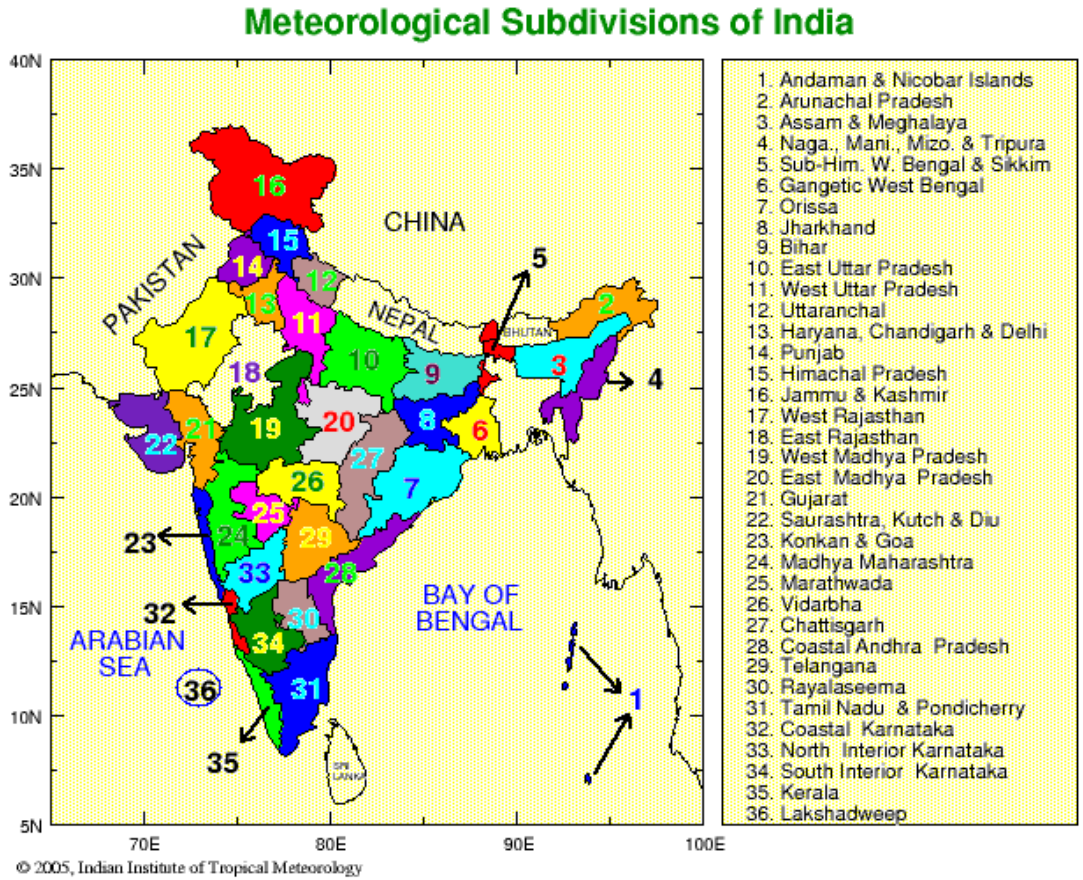
Fig. 2.9 Mass Curve of Rainfall

Useful for extracting the information on duration and magnitude of a storm event

Source: Subramanya (2008)

Presentation of Rainfall Data

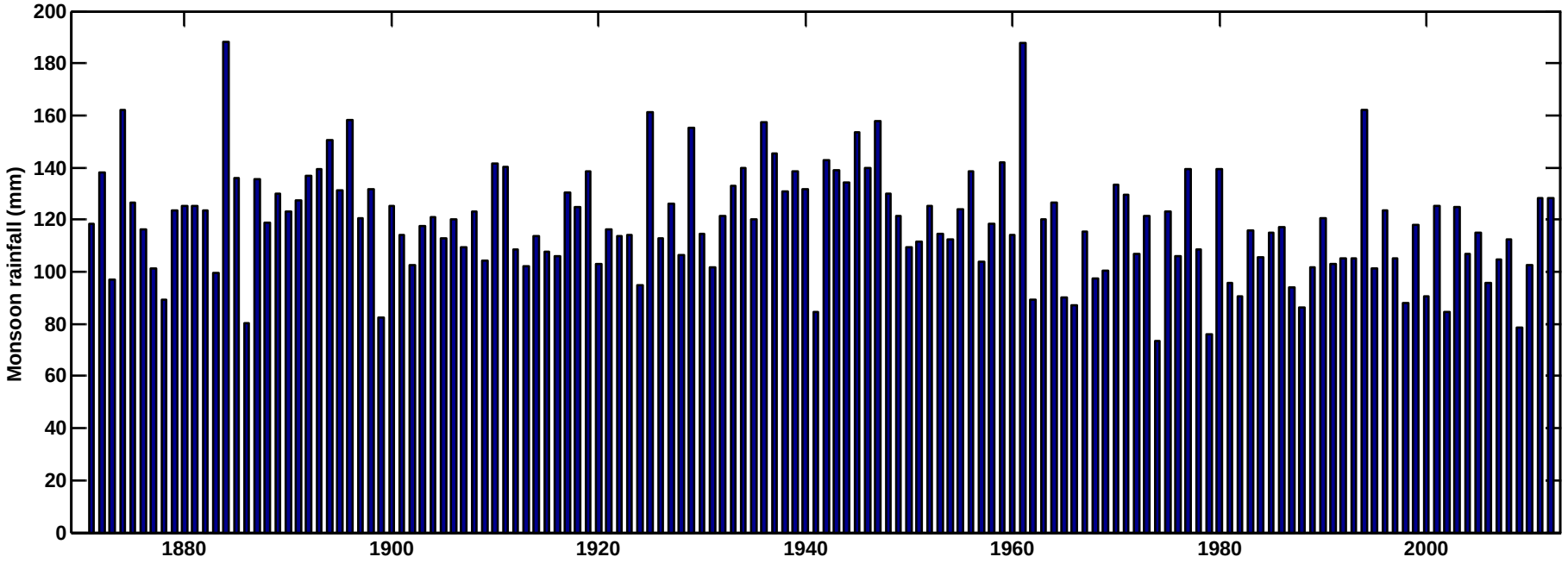
Time series : Annual, seasonal & daily



Example: Chattisgarh (27) Monsoon rainfall for 1870 to 2012

Presentation of Rainfall Data

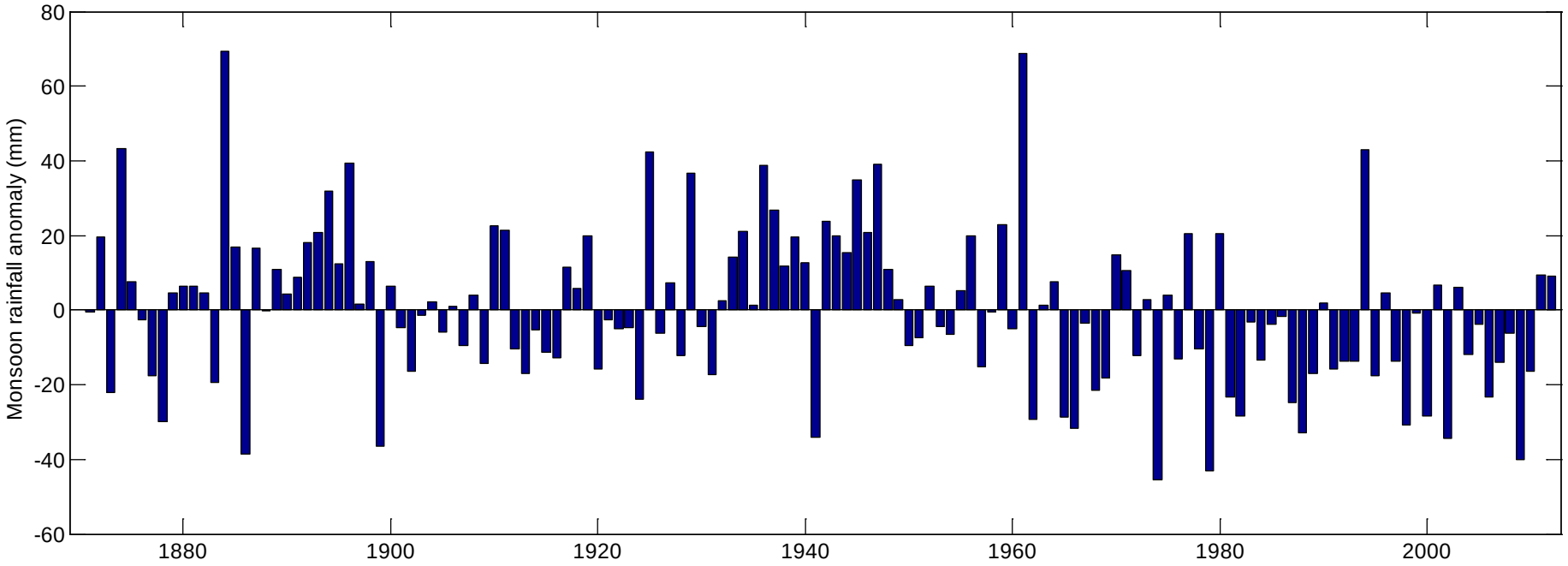
Time series (Point rainfall)



$$x_i \quad i = 1 \; to \; 142$$

Presentation of Rainfall Data

Time series of anomaly

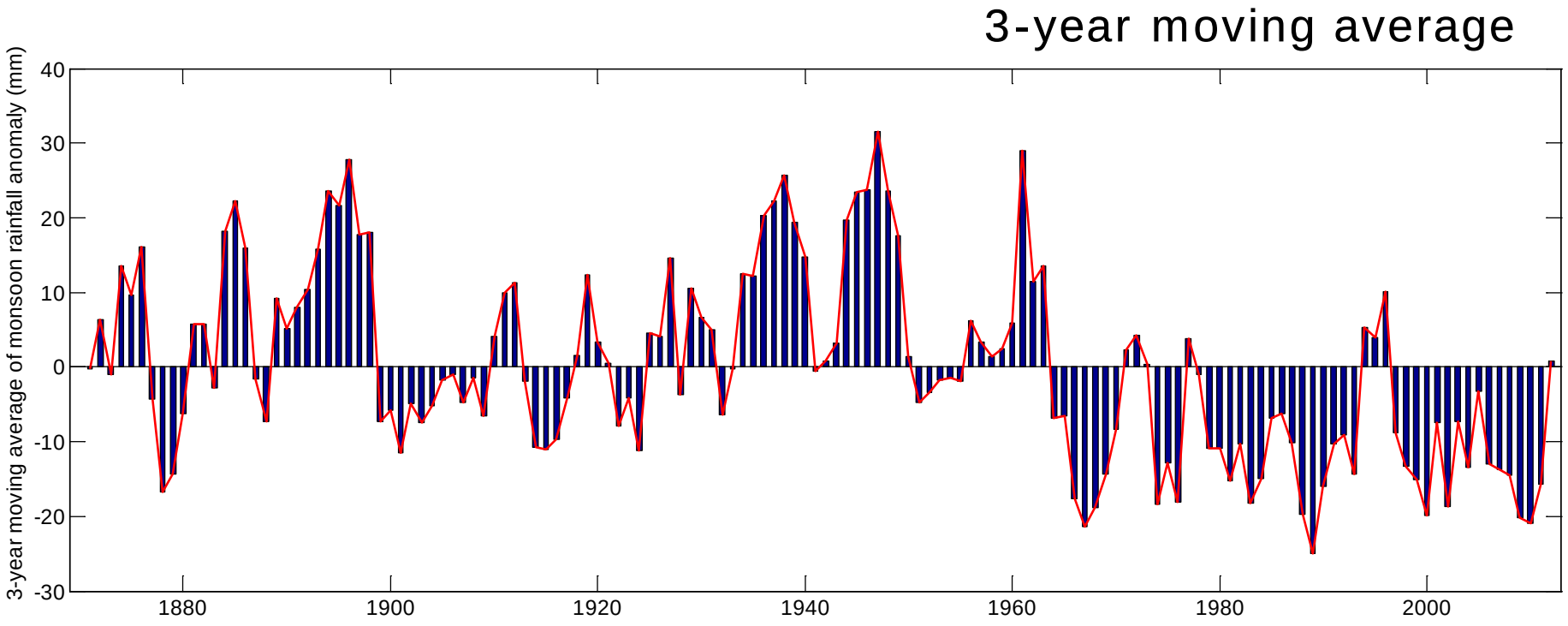


$$z_i = x_i - \bar{x} \quad i = 1 \; to \; N$$

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Presentation of Rainfall Data

Moving average : window of length m; m≥3

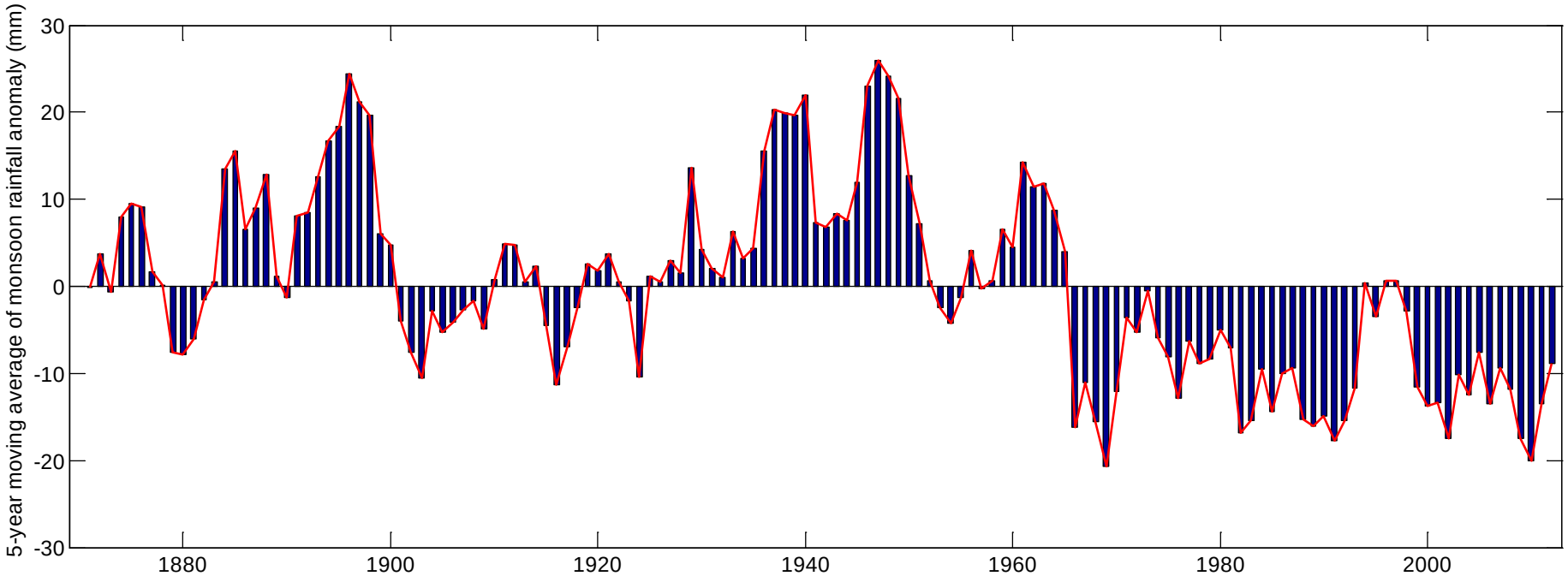


$$\acute{z}_i = \frac{1}{3}\sum_{i=1}^{i+2} z_i \qquad i = 1\ to\ N-2$$

Presentation of Rainfall Data

Larger the window more would be the smoothening

5-year moving average



$$\acute{z}_i = \frac{1}{5}\sum_{i=1}^{i+4} z_i \qquad i = 1\ to\ N-4$$

Summary: Presentation of Rainfall Data

- Hyetograph
- Mass curve
- Time series
  - Rainfall depth
  - Anomalies
  - Moving averages

Consistency of raingauge record

Reasons for inconsistency of raingauge record

- Shifting of raingauge station
- Changes in the neighborhood or the ecosystem
- Observational error from a certain date

Double mass curve

Based on the assumption that the neighboring raingauge stations form a homogeneous set

Consistency of raingauge record

Steps in preparing double mass curve

- Select a group of base stations (5 to 10 ?) in the neighborhood of the problem station X covering the same time period
- Estimate the average rainfall of the group of base stations and arrange it in reverse chronological order (Why?)
- Plot accumulated rainfall at X against accumulated rainfall of the average of the base stations
- Change in the slope of the curve indicates change in the precipitation regime at X
- Adjust the older records so that they are consistent with the new regime

Consistency of raingauge record

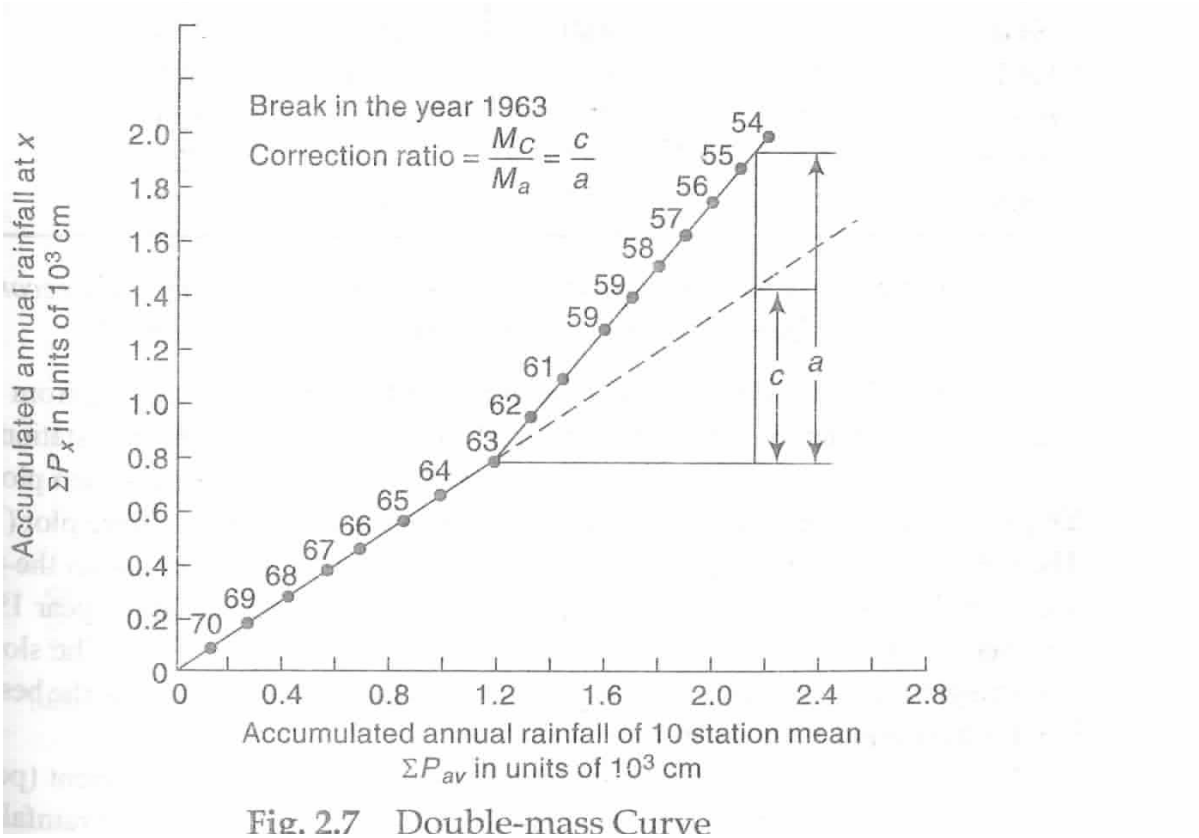


Fig. 2.7 Double-mass Curve

Source: Subramanya (2008)

Consistency of raingauge record

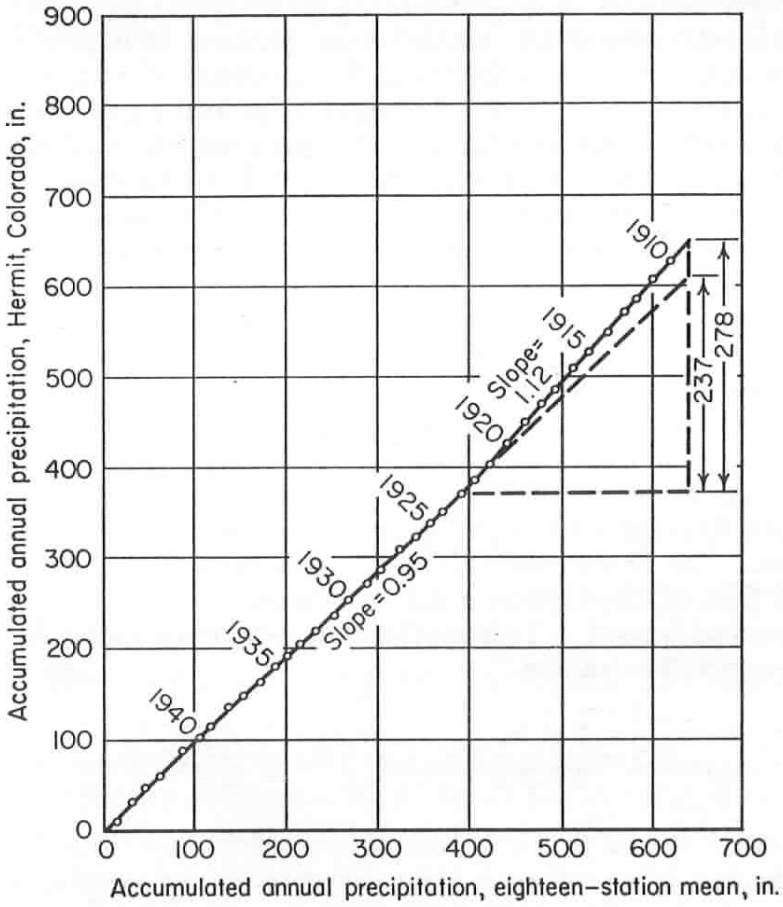


FIG. 9-19. Double-mass curve. (*After Linsley, Kohler, and Paulhus* [14].)

Station shifted in 1923 by several kilometers

Source: Handbook of Applied Hydrology, Chow (1964)

Consistency of raingauge record by Double Mass

- Not recommended for storm or daily rainfall amounts
- Can be applied to monthly, seasonal or annual
  - Seasonal scale is recommended for stations having pronounced seasonal variation (Monsoon)
- Change in slope should not be considered significant unless it persists for more than 5 years
- Always find an independent evidence of a change in location or exposure to corroborate results of double mass curve

Estimate missing values

Normal Rainfall

It is the average value of rainfall at a particular day, month, season or year over a specified period of 30-years (*1981-2010*)

Two methods for estimating missing values

- Arithmetic average method
- Normal ratio method

Estimate missing values

Arithmetic Average Method

Applicable if the *normal annual rainfall* at the station under consideration is within 10% of the normal annual rainfall at the adjoining stations.

Example

Stations	Normal annual rainfall (N, mm)	Rainfall in 2012 (P, mm)
A	95	90
B	92	102
C	105	99
D	100	?

Estimate missing values

Arithmetic Average Method

Applicable if the *normal annual rainfall* at the station under consideration is within 10% of the normal annual rainfall at the adjoining stations.

Example

Stations	Normal annual rainfall (N, mm)	Rainfall in 2012 (P, mm)	% difference in normal annual rainfall w.r.t D
A	95	90	05
B	92	102	08
C	105	99	05
D	100	97	-

$$P_D = \frac{1}{3}(P_A + P_B + P_C) = \frac{1}{3}(90 + 102 + 99) = 97\ mm$$

Estimate missing values

Normal ratio method

Applicable if the normal annual rainfall at the station under consideration and the normal annual rainfall at the adjoining stations differs by more than 10%.

Example

Stations	Normal annual rainfall (N, mm)	Rainfall in 2012 (P, mm)	% difference in normal annual rainfall w.r.t D
A	95	90	05
B	**88**	102	**12**
C	105	99	05
D	100	?	-

Estimate missing values

Normal ratio method

Applicable if the normal annual rainfall at the station under consideration and the normal annual rainfall at the adjoining stations differs by more than 10%.

Example

Stations	Normal annual rainfall (N, mm)	Rainfall in 2012 (P, mm)	% difference in normal annual rainfall w.r.t D
A	95	90	05
B	**88**	102	**12**
C	105	99	05
D	100	101.6	-

$$P_D = \frac{N_D}{3}\left(\frac{P_A}{N_A} + \frac{P_B}{N_B} + \frac{P_C}{N_C}\right) = \frac{100}{3}\left(\frac{90}{95} + \frac{102}{88} + \frac{99}{105}\right) = 101.6\,mm$$

Estimate missing values

Can we apply the two methods to estimate missing values in the daily rainfall data ?