Weather and Climate

The difference between weather and climate is a measure of time.

Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time.

Weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Climate, however, is the average of weather over time and space.

In short, climate is the description of the long-term pattern of weather in a particular area.

Some scientists define climate as the average weather for a particular region and time period, usually taken over 30-years. It's really an average pattern of weather for a particular region.

When scientists talk about climate, they are looking at averages of precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms, and other measures of the weather that occur over a long period in a particular place.

Precipitation

Precipitation

Precipitation: the single strongest variable driving hydrologic processes.

The term precipitation denotes all forms of water that reaches the earth's surface from the lower atmosphere (about 15 km).

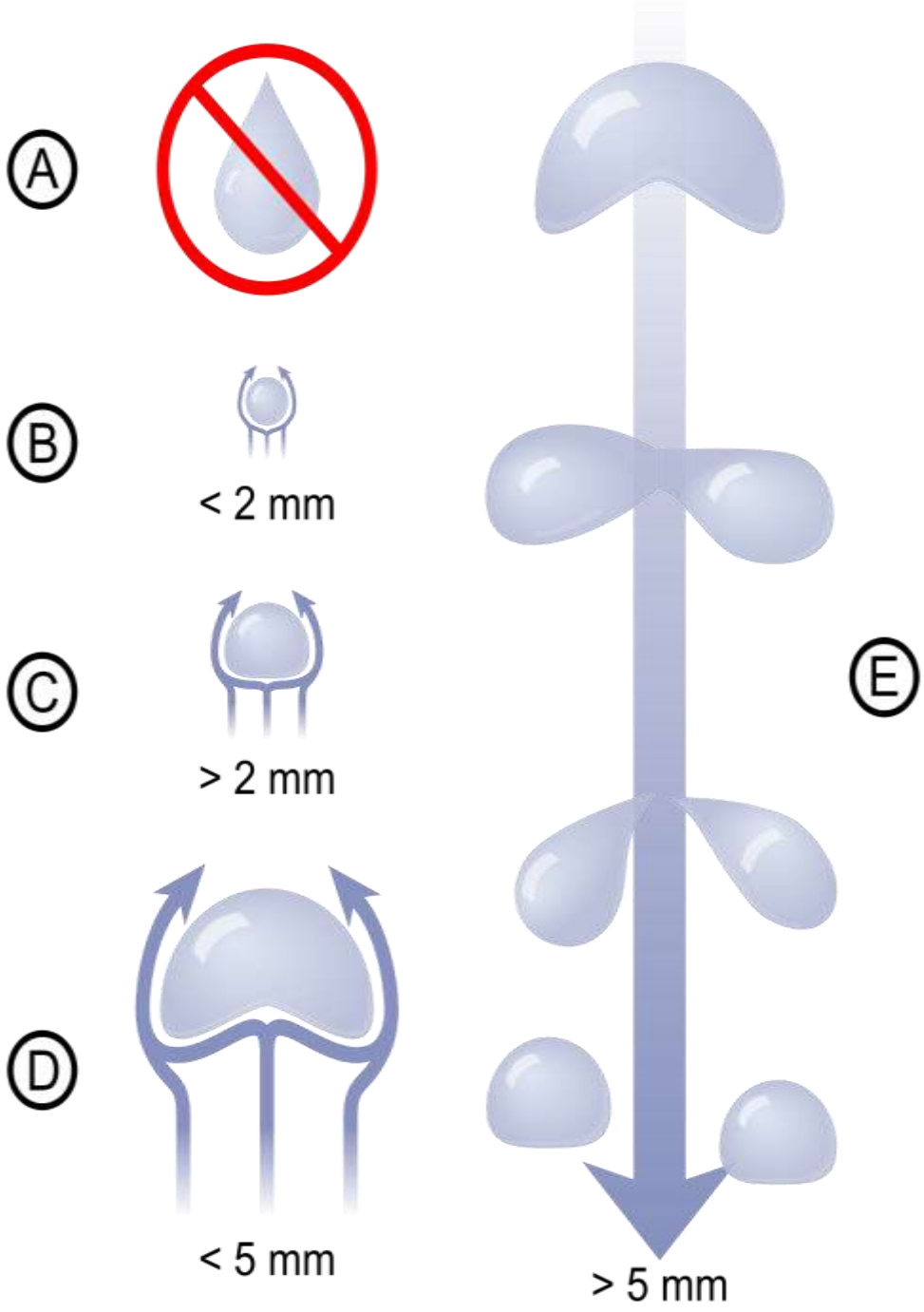
The usual forms of precipitation are rainfall, snowfall, hail and dew.

Formation of Precipitation

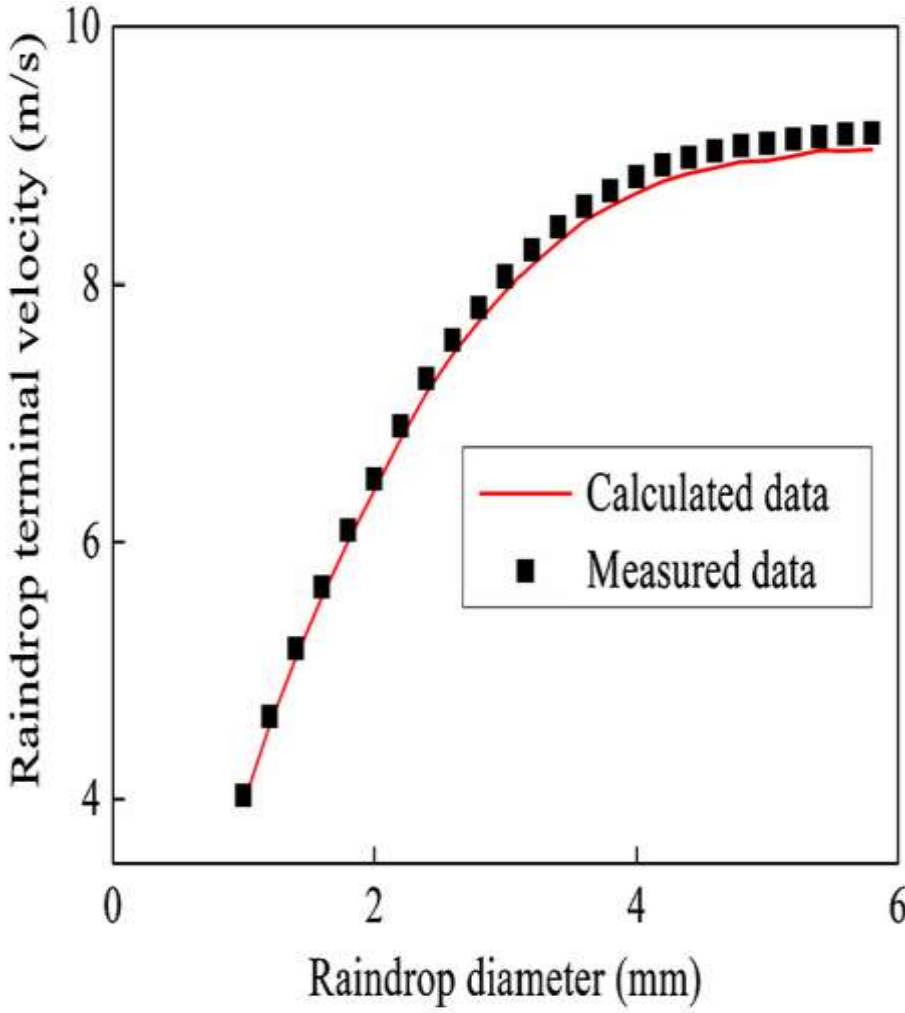
Moisture present in the atmosphere condenses into droplets in presence of nuclei. The nuclei are small particles of various substances (0.1 to 10 μm in diameter). After nucleation the droplets grow in size through diffusion of water vapour to it. Wind speed facilitates the movement of the cloud while its turbulence retains the water droplets in suspension.

For the precipitation to occur, the cloud elements must increase in size until their falling velocity exceeds the ascensional velocity of the air. Collision and coalescence of cloud are the important factors leading to precipitation. As the particles collide they usually coalesce to form larger particles and drop to the earth when they exceed the terminal velocity.

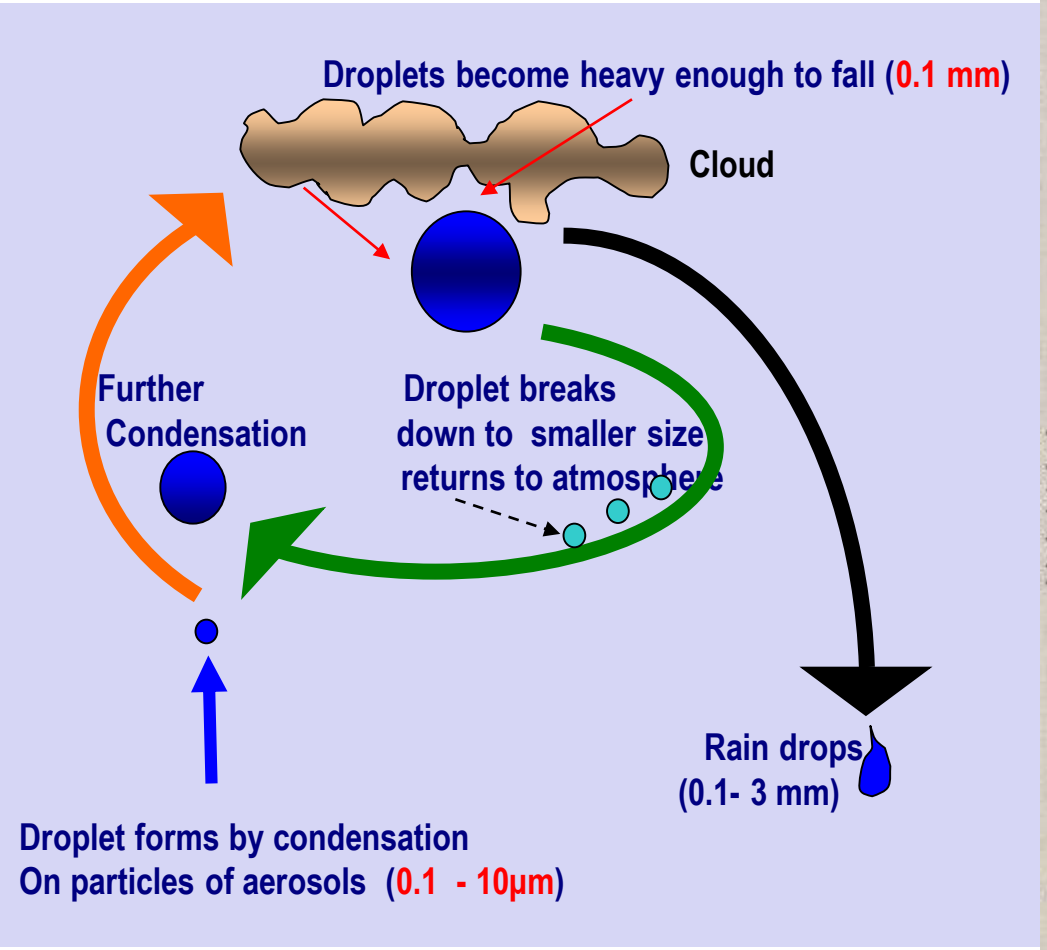
For droplet diameter of 2 mm, the terminal velocity > 20 km/hr

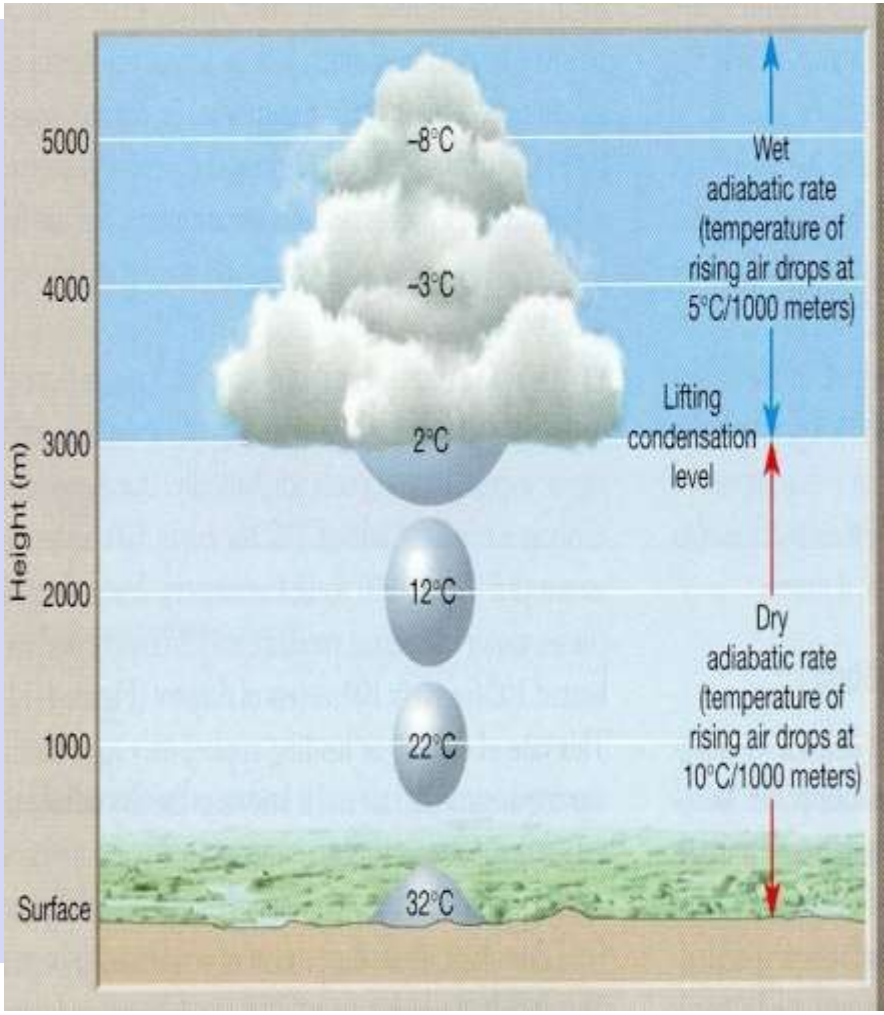

A
B
< 2 mm
C
> 2 mm
D
< 5 mm
> 5 mm

E


Raindrop terminal velocity (m/s)
10
8
6
4
0
2
4
6
Raindrop diameter (mm)
Calculated data
Measured data

Formation of Rain





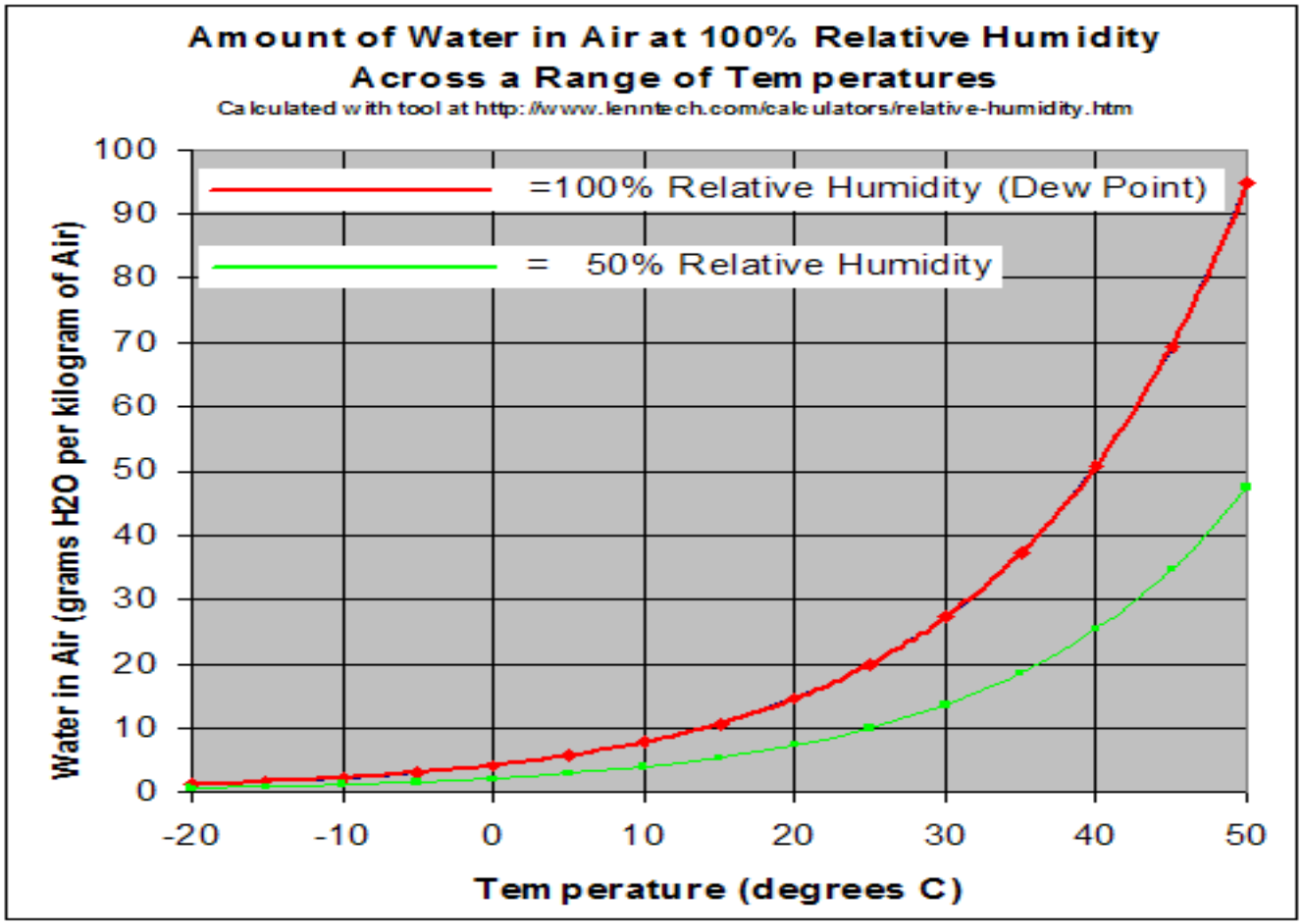
Moisture in the Atmosphere

Precipitation is formed from water vapor
As air cools → capacity to hold water decreases

Saturated (100% relative humidity)

Saturated at 70 °F vs. 32 °F
4 times more water at 70 °F!

As the temperature decreases



Precipitation

Forms of Precipitation

Drizzle – also called mist consists of water particles between 0.1-0.5 mm in diameter and falling at an intensity of less than 1 mm/hour.

Rain – consists of water particles larger than 0.5 mm to about 6 mm. The rainfall is:

light: rates < 2.5 mm/hr

moderate: rates between 2.5 – 7.5 mm/hr

heavy: > 7.5 mm/hr

Snow: is composed of ice crystals which usually combine to form flakes resulting from de-sublimation. The average density of snow is 0.1 g/cc and 125 to 500 mm of snow is generally required to equal 25 mm of water.

Hail: balls or irregular lumps of ice 5-125 mm in diameter.

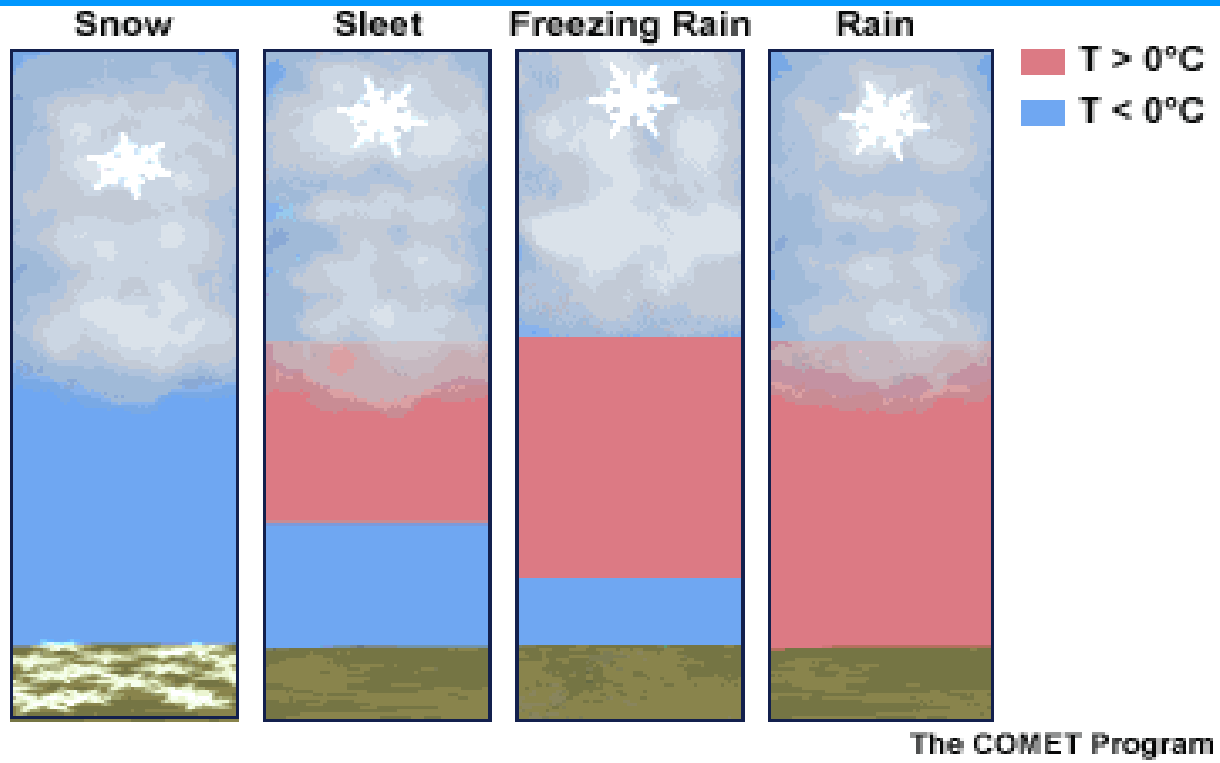
Dew: moisture condensed from the atmosphere in small drops upon cool surfaces.

Fog: a thin cloud of varying size formed at the surface of the earth by condensation of the atmospheric vapour. Visibility > 1 km - Mist

Sleet: frozen raindrops falling through subfreezing air near the earth's surface.



Forms of Precipitation



HAIL

- Hail is created when moisture and wind are together. Inside the cumulonimbus clouds ice crystals form, and begin to fall towards the surface of Earth. When this starts to happen wind gusts start to pick up the ice crystals pushing them up high into the clouds. As they start to fall down again they continue to grow in size. A wind gust might catch the hail stone again which will push it back up into the cloud. This whole process gets repeated several times before the hail stone becomes so big that it is too heavy for the wind to carry so it must fall towards Earth.

Shapes of hail particles

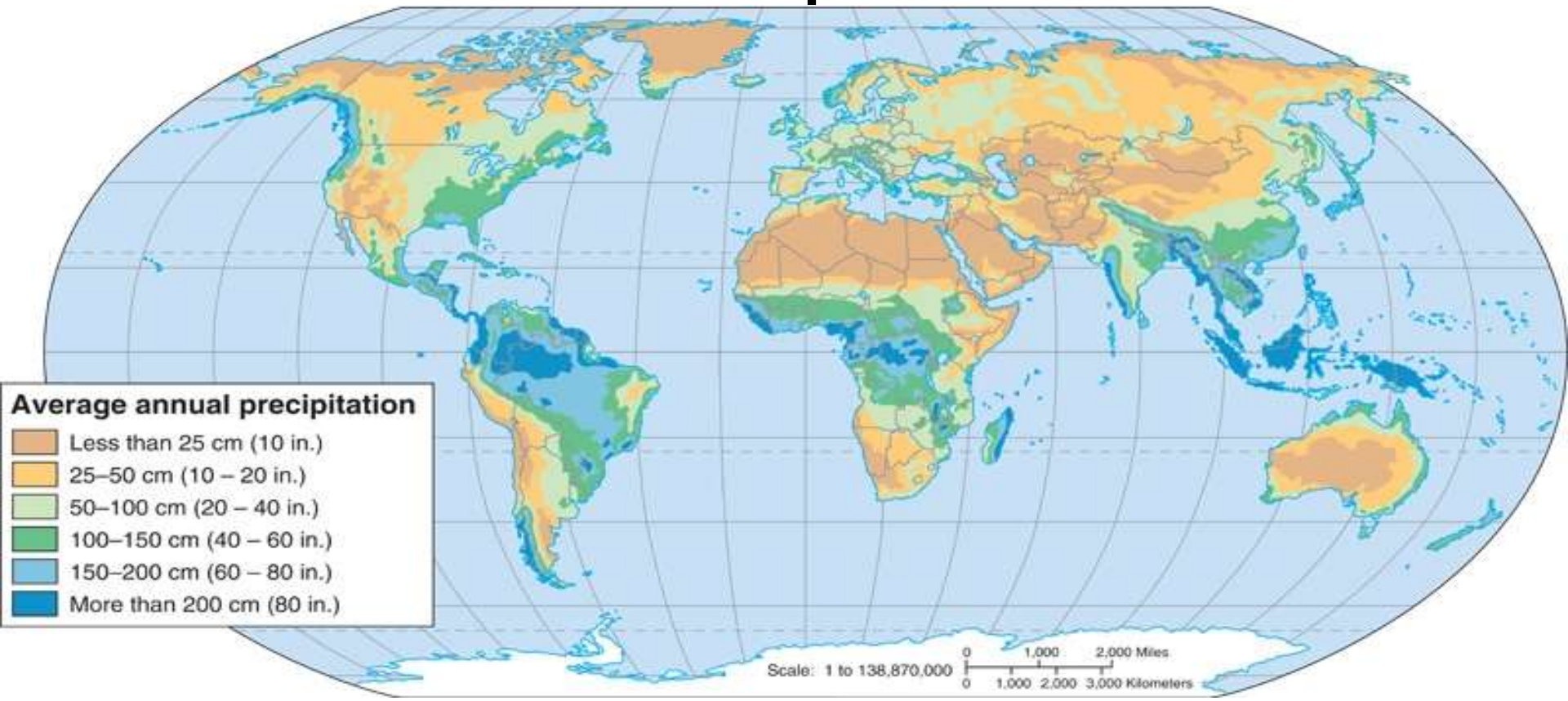
1. **Spherical**
2. **Conical**
3. **Irregular**

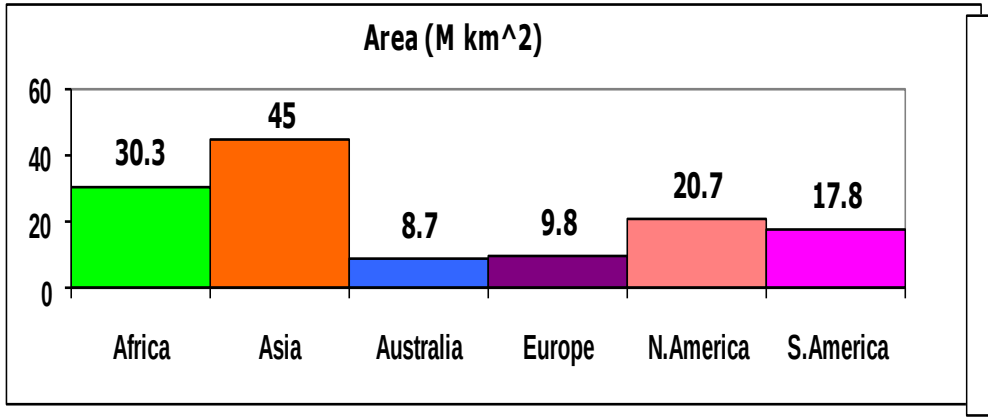
Diameter range 5 to 125 mm
Specific gravity = 0.8

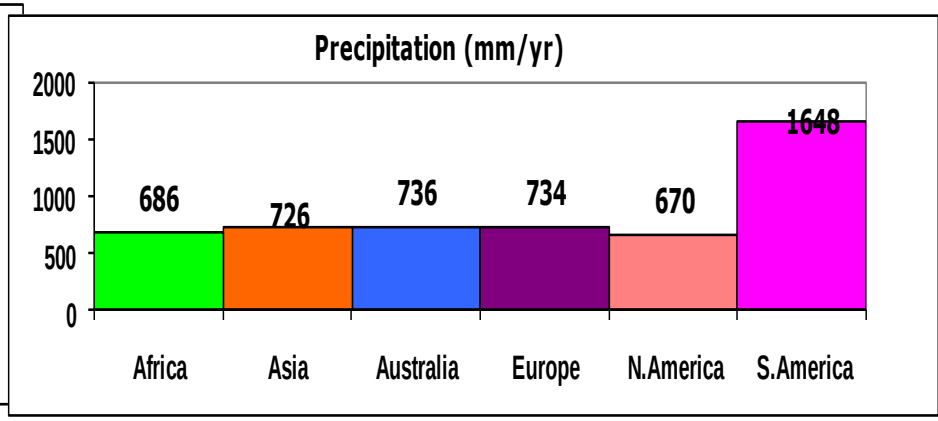




Global Precipitation







The global average annual precipitation is about 1m

Precipitation

Types of Precipitation

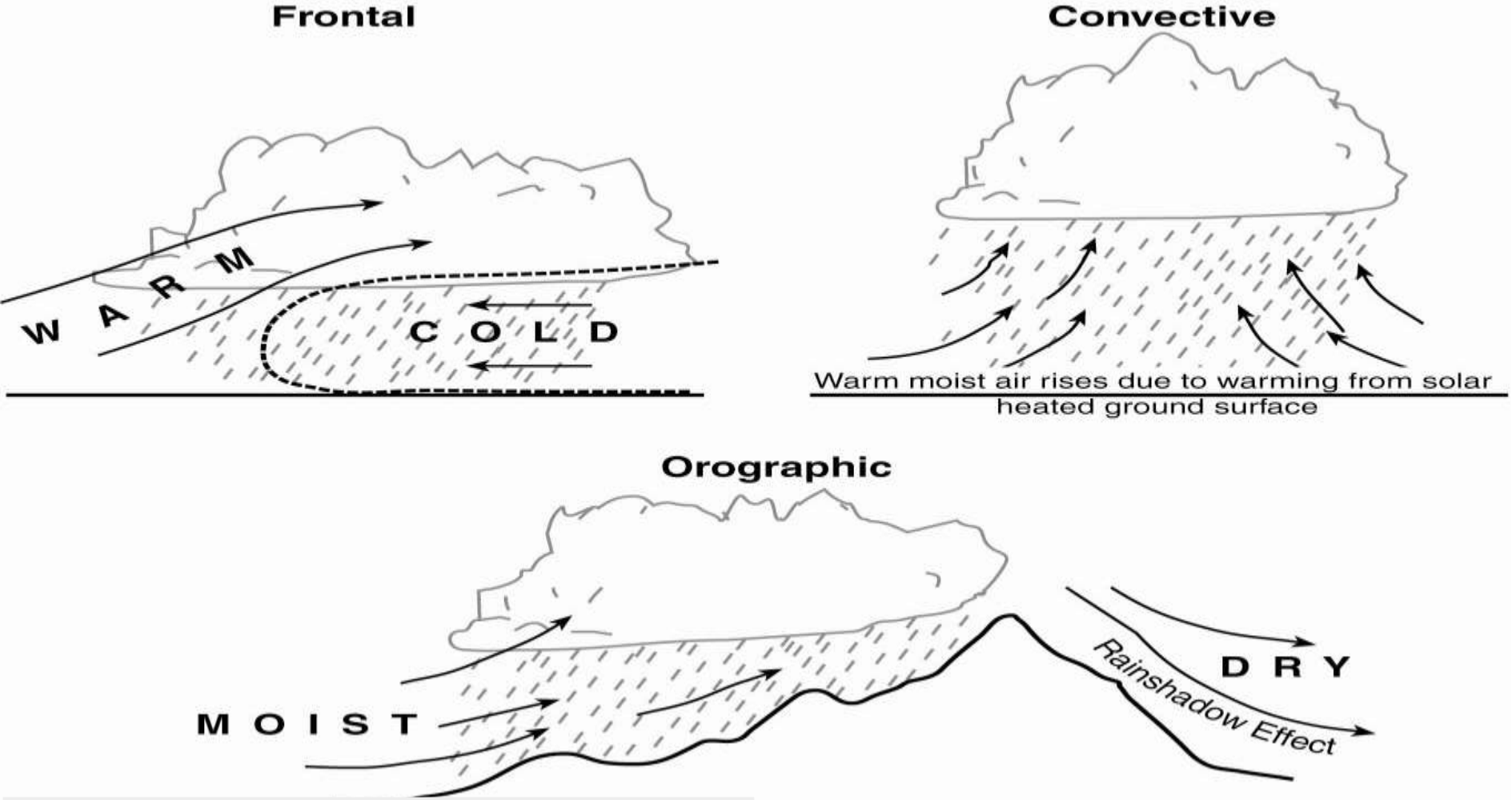
When the moist air is lifted to higher altitudes it cools and condenses – the process is called adiabatic cooling. The rate of change of temperature with height is called lapse rate. The mean lapse rate is a decrease of 0.7^0C per 100 m increase in height.

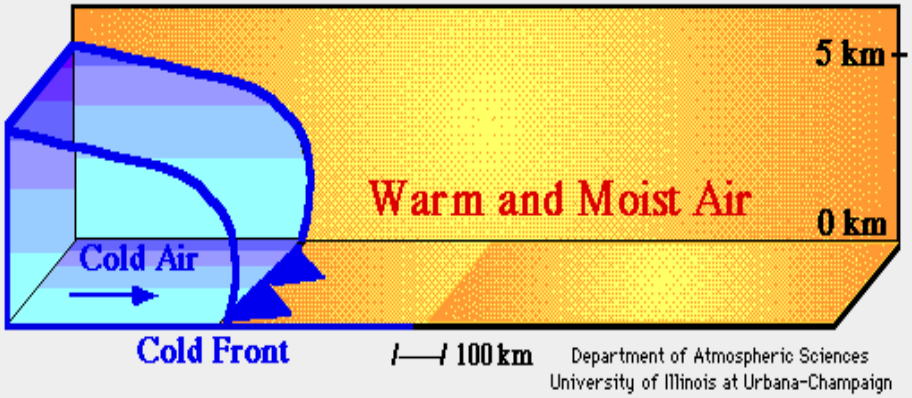
Convective: caused by rising of warmer and lighter air due to heating during the day into colder and denser surroundings. This is common in the tropics during the evenings.

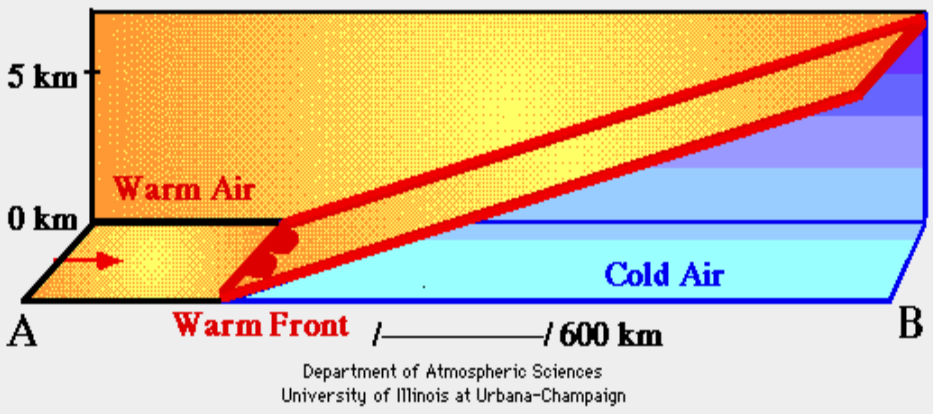
Orographic : moist air being lifted to higher altitudes due to presence of natural barriers (mountains) causing cooling, condensation and rain in the windward side (no or little rain in the leeward side).

Cyclonic/Frontal: lifting of air converging into low pressure areas. Cyclonic rainfall may be frontal (warm front moving into colder air or cold front moving into warmer air).

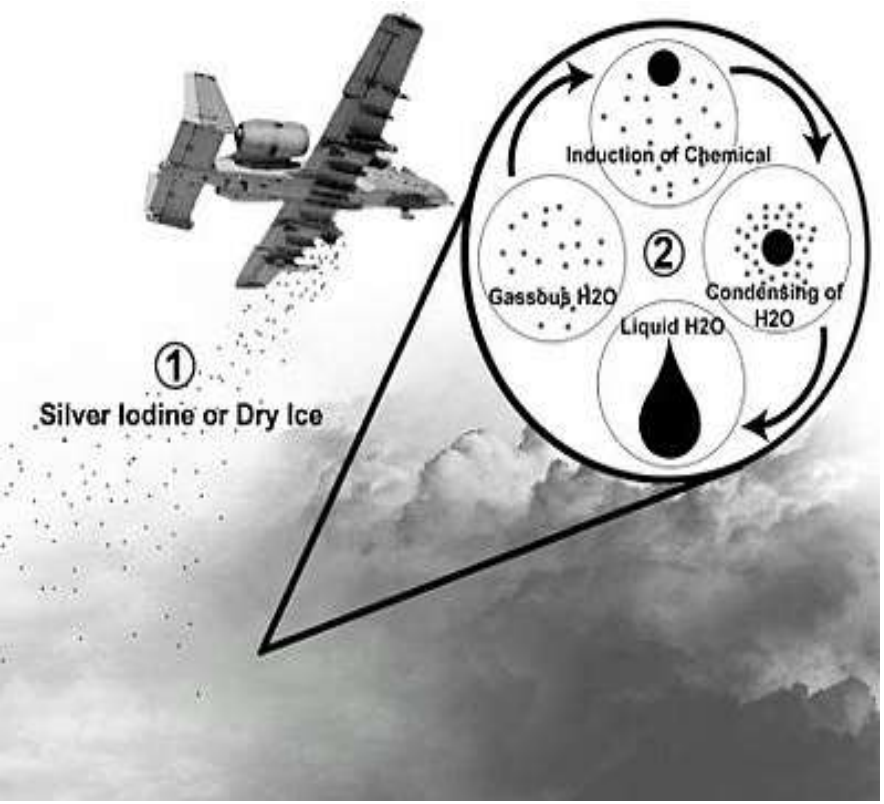
Artificial: providing the clouds with nuclei (solid carbon dioxide also called dry ice or silver iodide) by airplane to help formation of droplets.


Frontal
W A R M
C O L D
Convective
Warm moist air rises due to warming from solar heated ground surface
Orographic
M O I S T
D R Y
Rainshadow Effect


5 km
Warm and Moist Air
0 km
Cold Air
Cold Front
100 km
Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

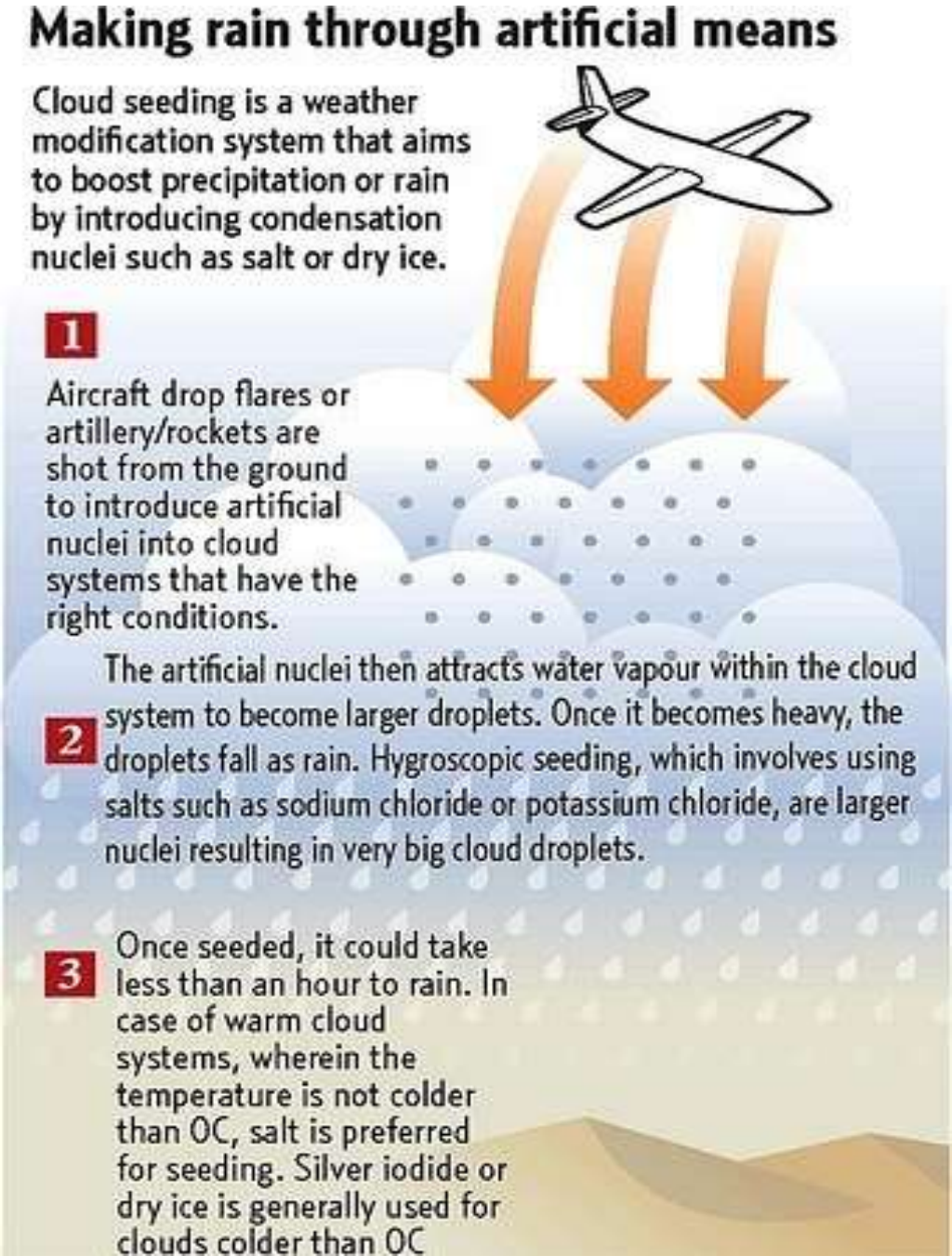

5 km
0 km
Warm Air
Cold Air
A
Warm Front
600 km
B
Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

Artificial Rain/Cloud Seeding



Limitations:

1. Expensive: $1/m^3$
2. Toxicity
3. Regional conflict
4. Chances of failure



Rainfall Characteristics

Depth: amount of rainfall at a point or over an area (usually in mm)

Duration: the period of time during which rain fell (hours)

Intensity: depth of rainfall per unit time i.e. depth/duration (mm/hr)

Time distribution of rainfall or **hyetographs**: are plots of rainfall intensity (mm/hr) or amount/depth (mm) as a function of time.

Hyetographs are usually plotted as a bar chart of gross rainfall.

Rainfall Mass Curve: cumulative rainfall hyetographs are called mass curve.

The slope of the mass curve (at any point) is the rainfall intensity.

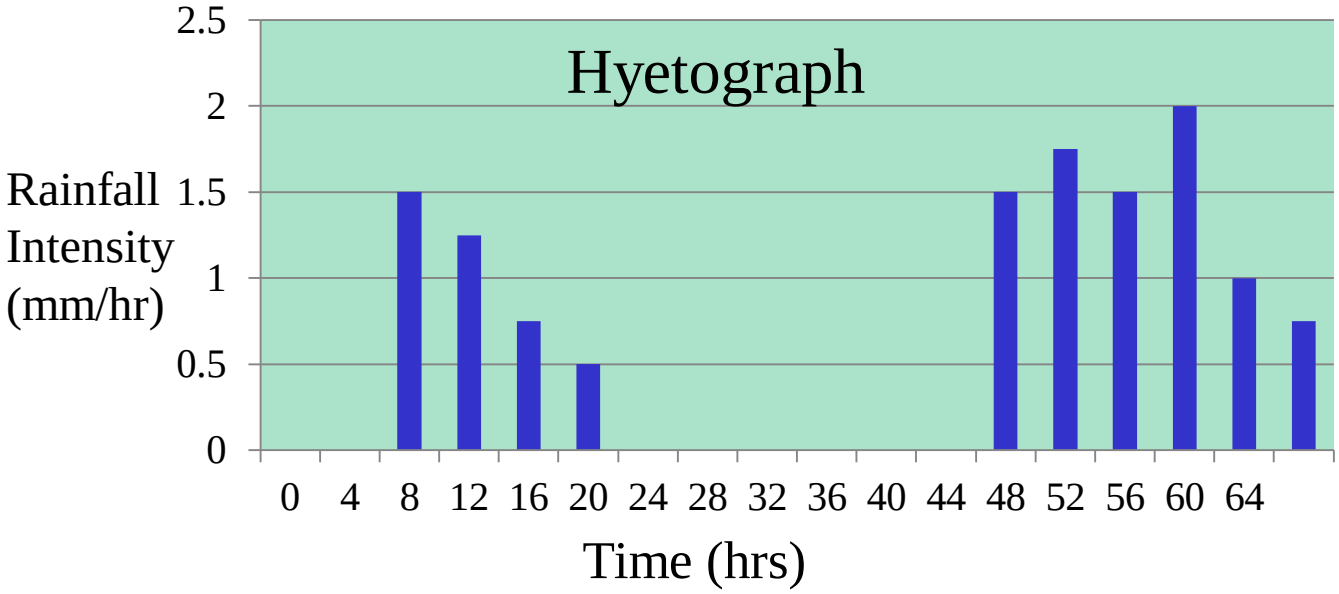
Thus, zero slope means zero rainfall and the maximum slope is the maximum intensity.

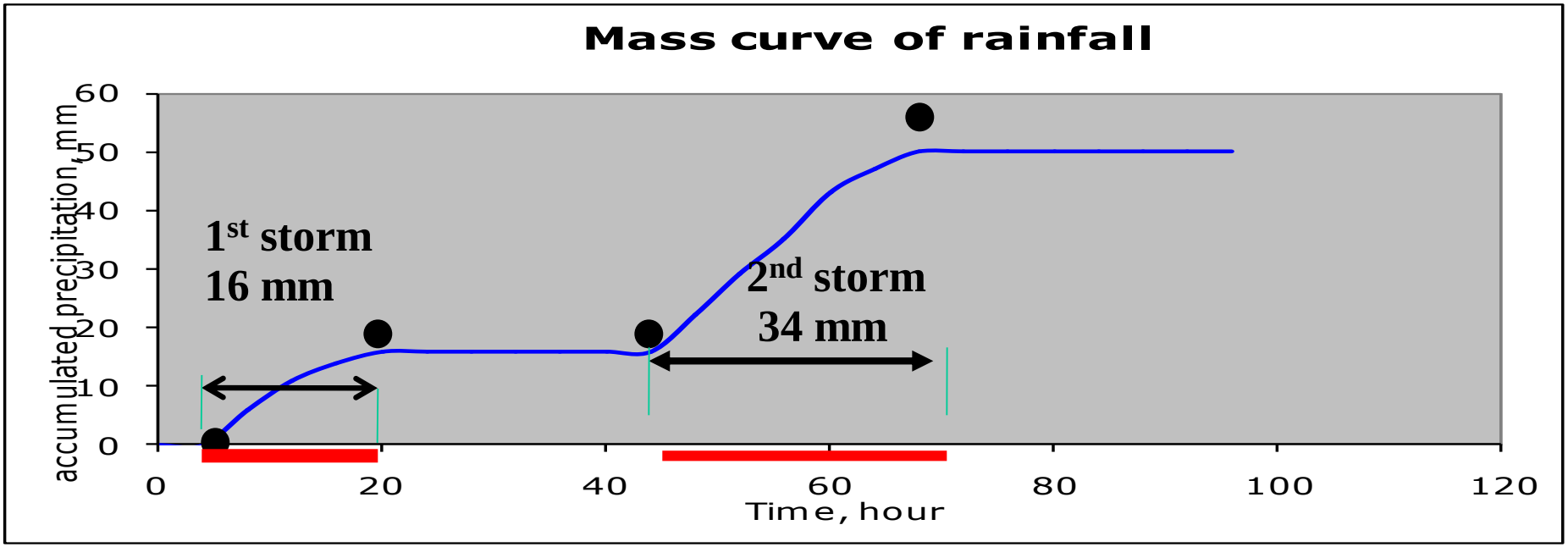
Isohyets: are contours of constant rainfall and can be drawn to develop isohyetal maps of rainfall depth.

Temporal and Spatial Variation of Rainfall: Rainfall varies greatly both in time and space

- With respect to time – Temporal variation
- With space – Spatial/Areal variation

Mass Curves & Rainfall Hyetographs





Measurement of Rainfall:

There are two types of rainfall measurement:

1. Point measurement – Recording and non-recording gauge (very accurate but small area coverage)

2. Non-point measurement or areal measurement – (less accurate as estimate based on cloud cover but large area coverage; accuracy is acceptable for hydrologic analysis and design)

   - Radar
   - Satellite

Rainfall

Point Measurement

Precipitation is measured on the basis of vertical depth of water that would accumulate on a level surface if the precipitation remained where it fell.

Precipitation is measured in mm and tenths.

One millimeter of precipitation represents the quantity of water needed to cover the land with a 1 mm layer of water, taking into account that nothing is lost through drainage, evaporation or absorption.

Precipitation is measured by gauges which can be either non-recording (no record but collect the rain) or recording (or automatic gauge).

There are three types of recording gauges: tipping bucket gauge, the weighing gauge and float gauge.

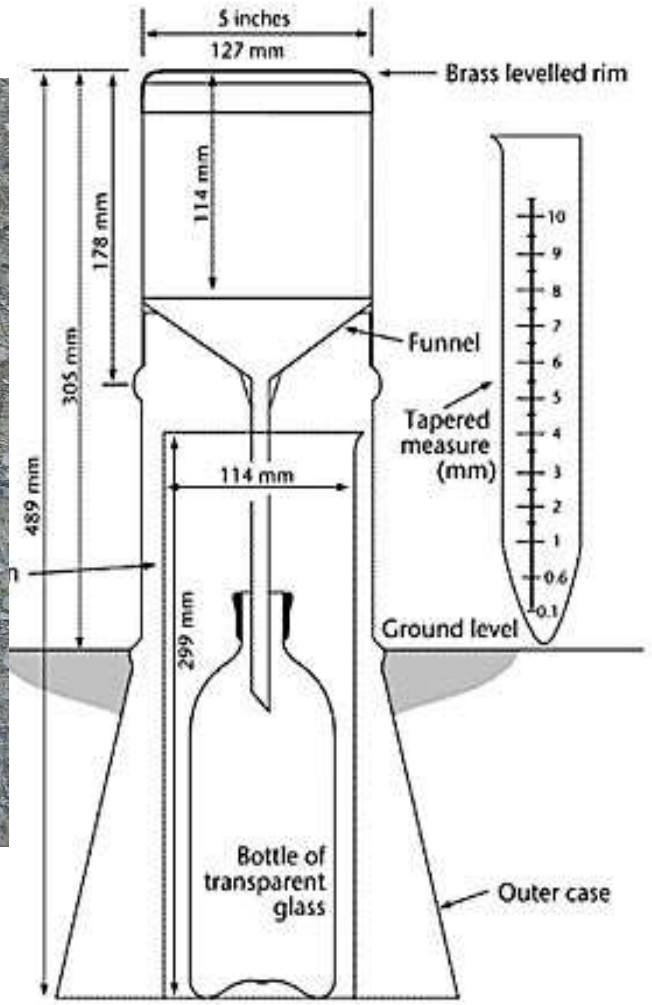
The rain gauge should be located such that:

1. The ground is level with horizontal catch surface.
2. The gauge must be near the ground to reduce wind effect.
3. Surrounded by an open fenced area of 5.5 x 5.5 m.
4. No object should be nearer to the gauge than 30 m or twice the height of the obstruction (whichever is larger).

Non-recording Rain Gauge

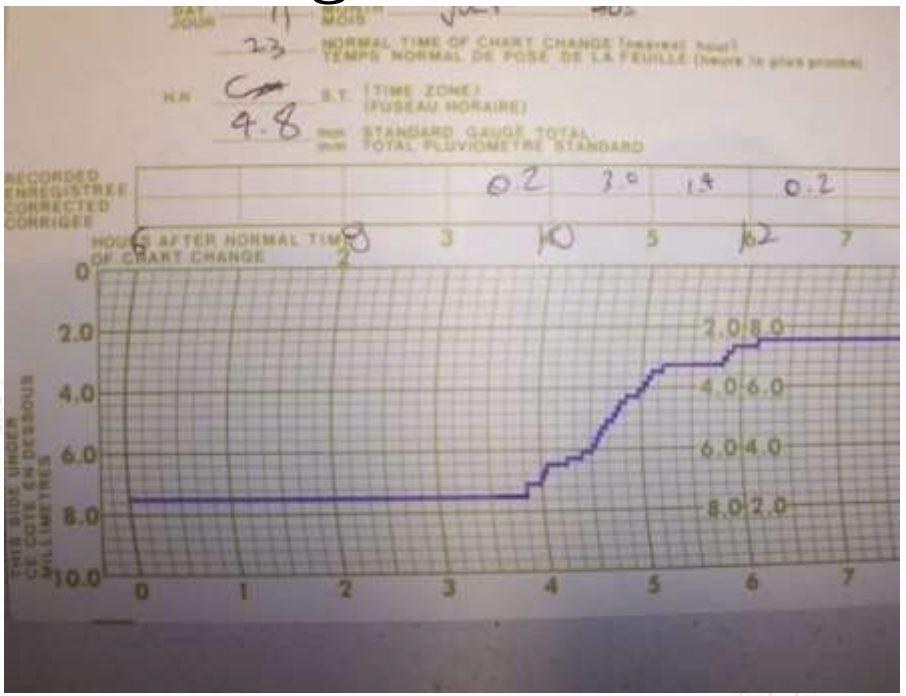


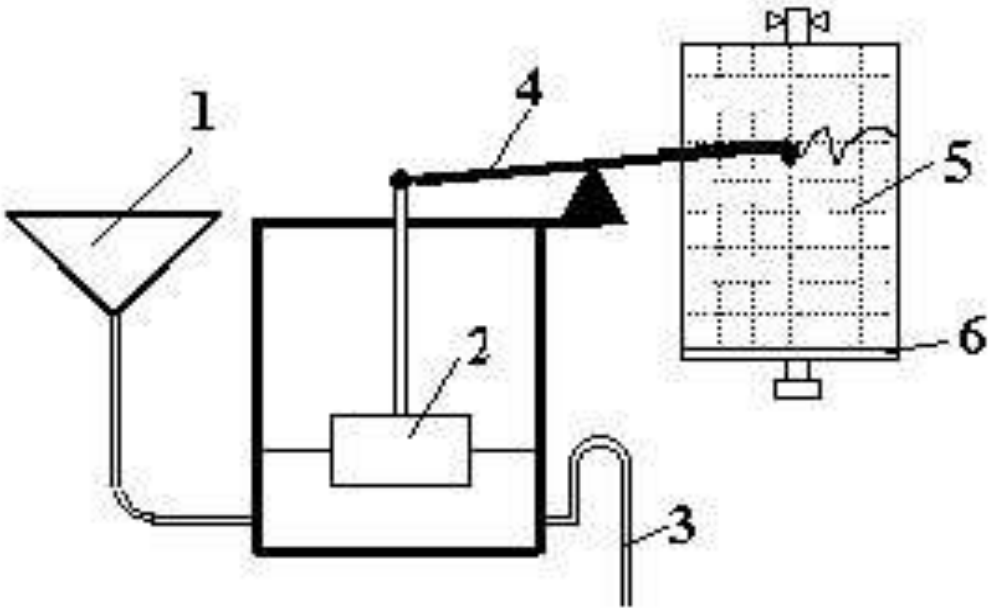




Recording Rain Gauge







Areal Rainfall Estimates: RADAR

Radar (Radio Detection and Ranging) is the "art of detecting by means of radio echoes (electromagnetic waves) the presence of objects, determining their direction and range, recognizing their characteristics and employing the data thus obtained".

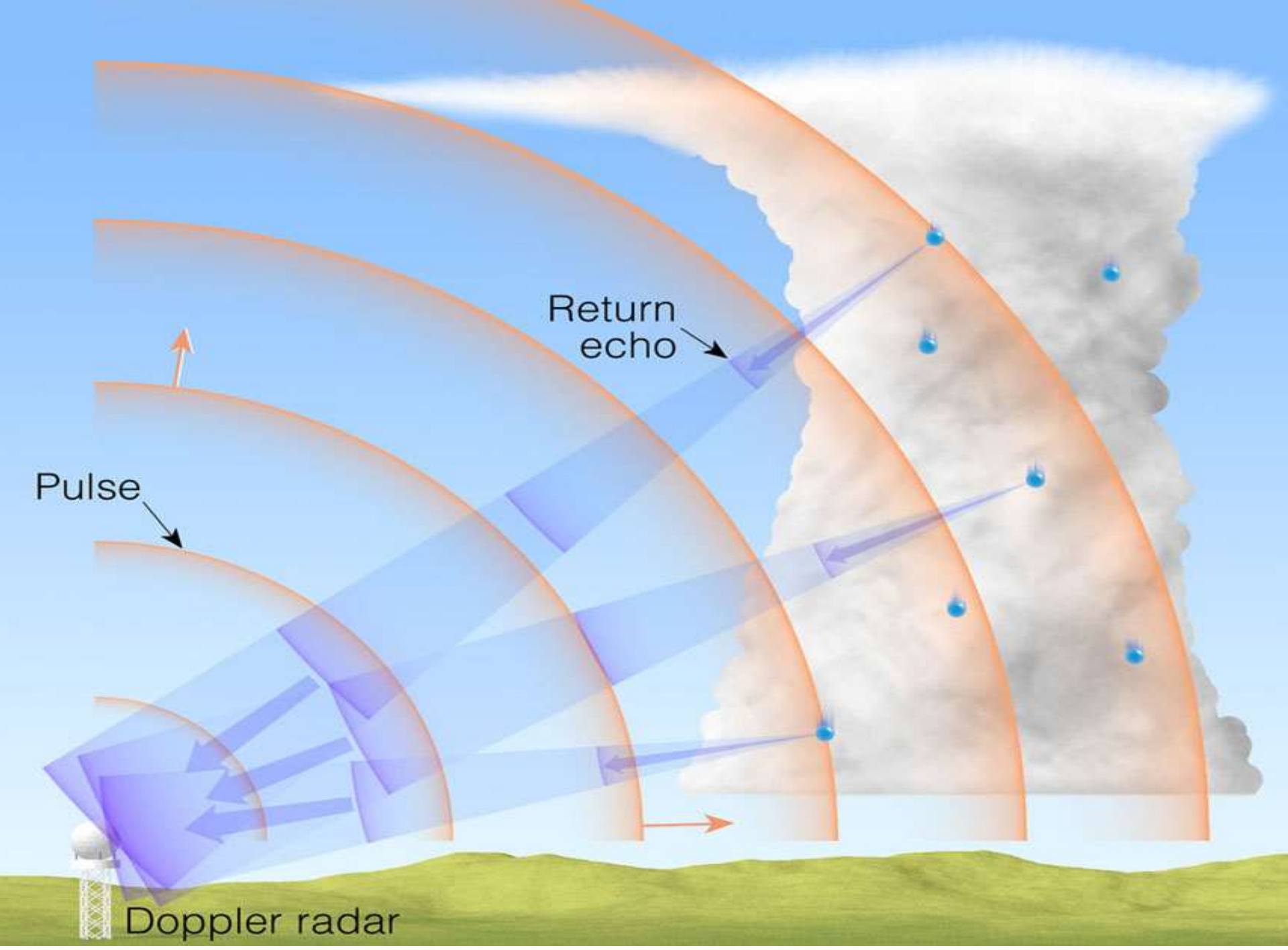
The meteorological radar is the powerful instrument for measuring the area extent, location and movement of rainstorm. Unlike gages (which measure point rainfall), the rainfall over large area can be determined through the radar with a good degree of accuracy.

The radar emits a regular succession of pulse of electromagnetic radiation in a narrow beam so that when the raindrops intercept a radar beam, it is partially reflected back to the radar. The **reflectivity mainly depends upon the drop-size distribution and the number of drops per unit volume**. In general, the more intense the precipitation, the higher the reflectivity.

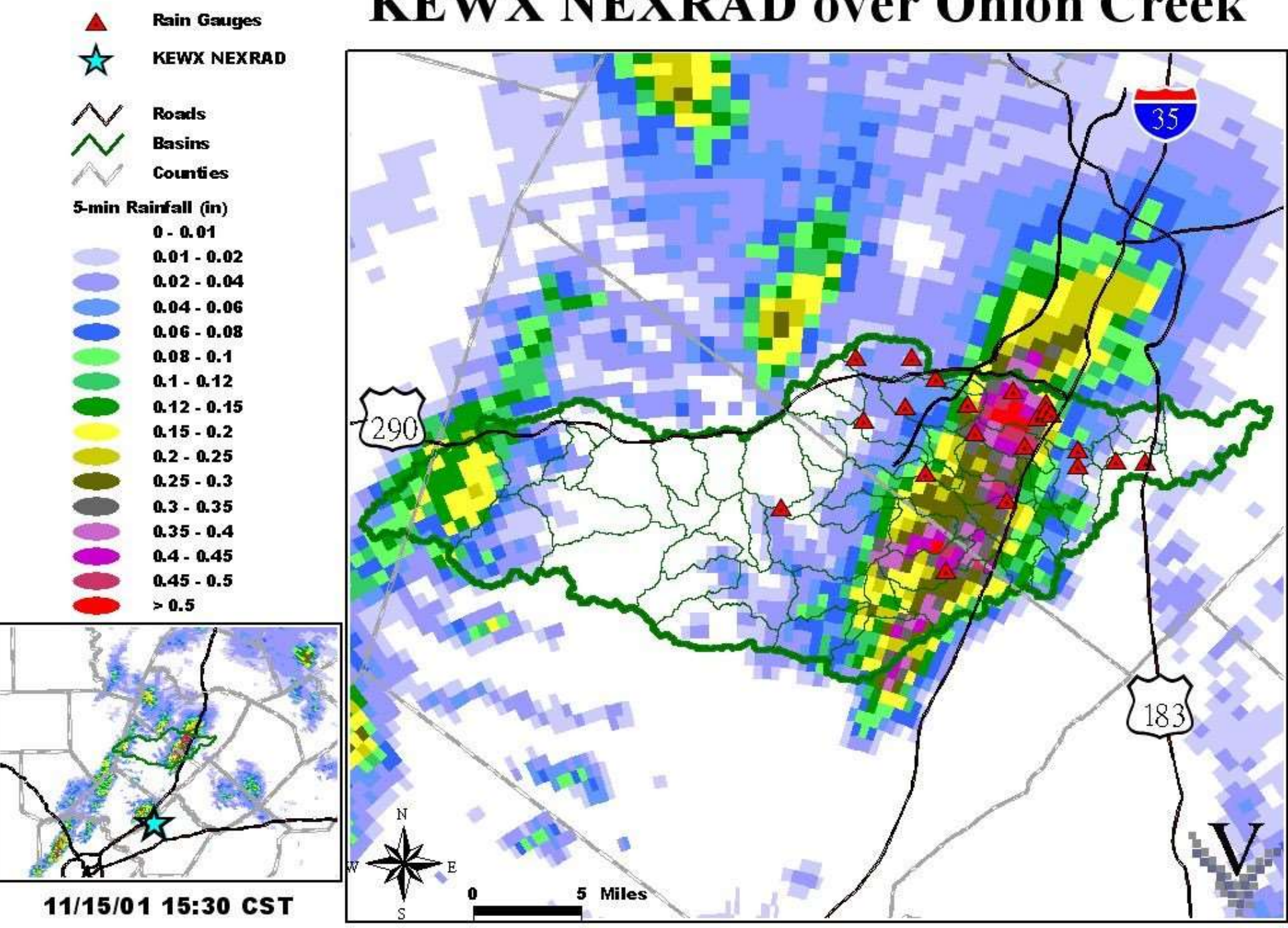
The major problem with radar measurement of rainfall is that the radar measures the rainfall in the atmosphere and gages measure the rainfall in ground (effect of wind, obstruction and evaporation). Moreover, hydrologists are more interested in rainfall amounts during a period (hours or day) rather than the instantaneous rates available from the radar data. But, cumulative rainfall can be obtained from radar data.



The accuracy of radar measurement varies between 90-98%.


Return
echo
Pulse
Doppler radar

KEWX NEXRAD over Onion Creek



Areal Rainfall Estimation by Satellites

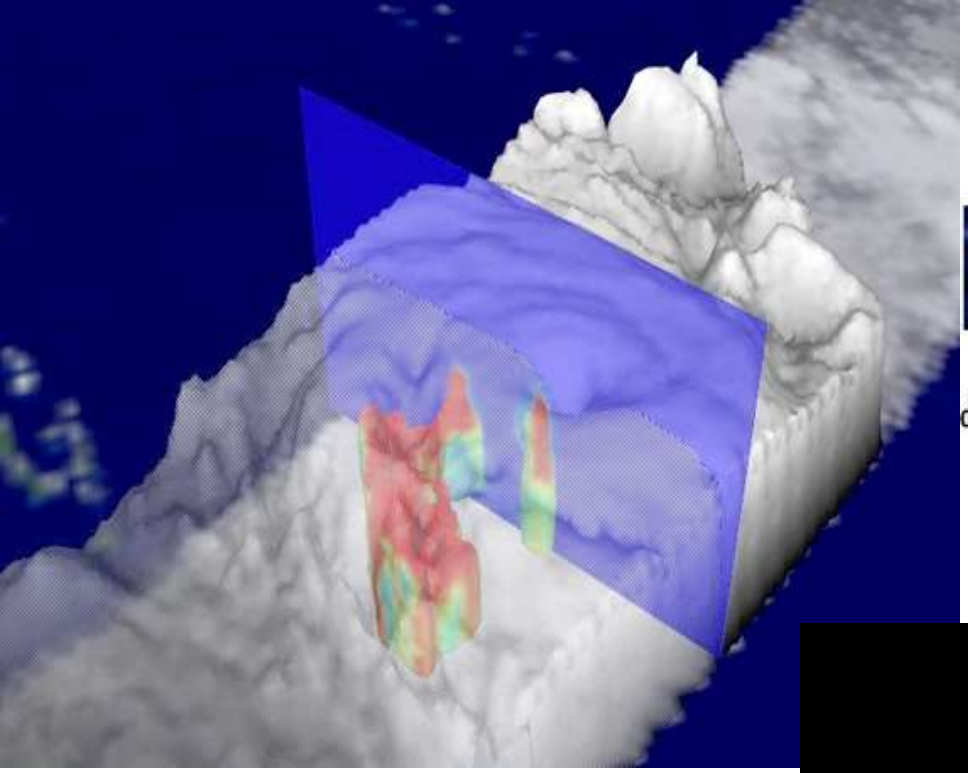
Non-homogeneity of temporal and spatial distribution of rainfall combined with the lack or the sparse presence of ground measurement makes it one of the most difficult parameters to quantify over a large area for hydrological analysis.

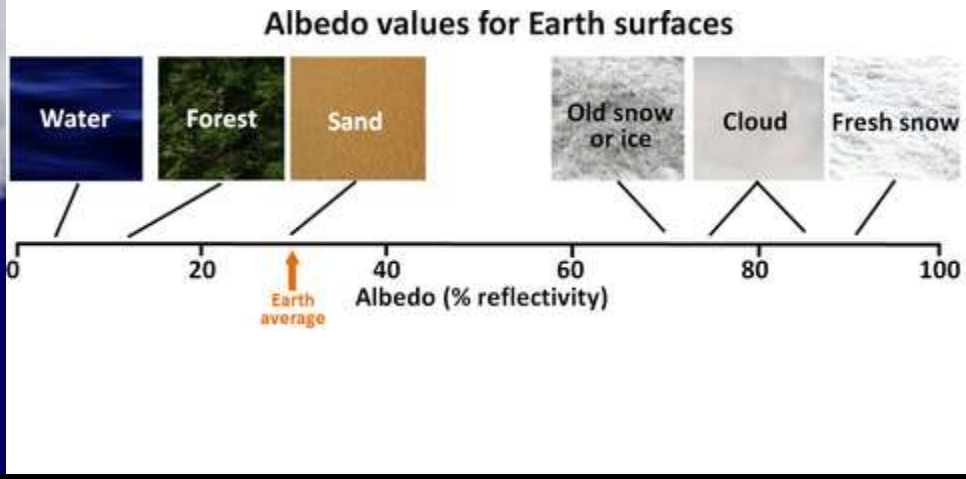
The maximum range of radars vary from 100 to 300 km and also, radars are prohibitively expensive. So, satellite-based measurements offer much cheaper and wider coverage over larger basins.

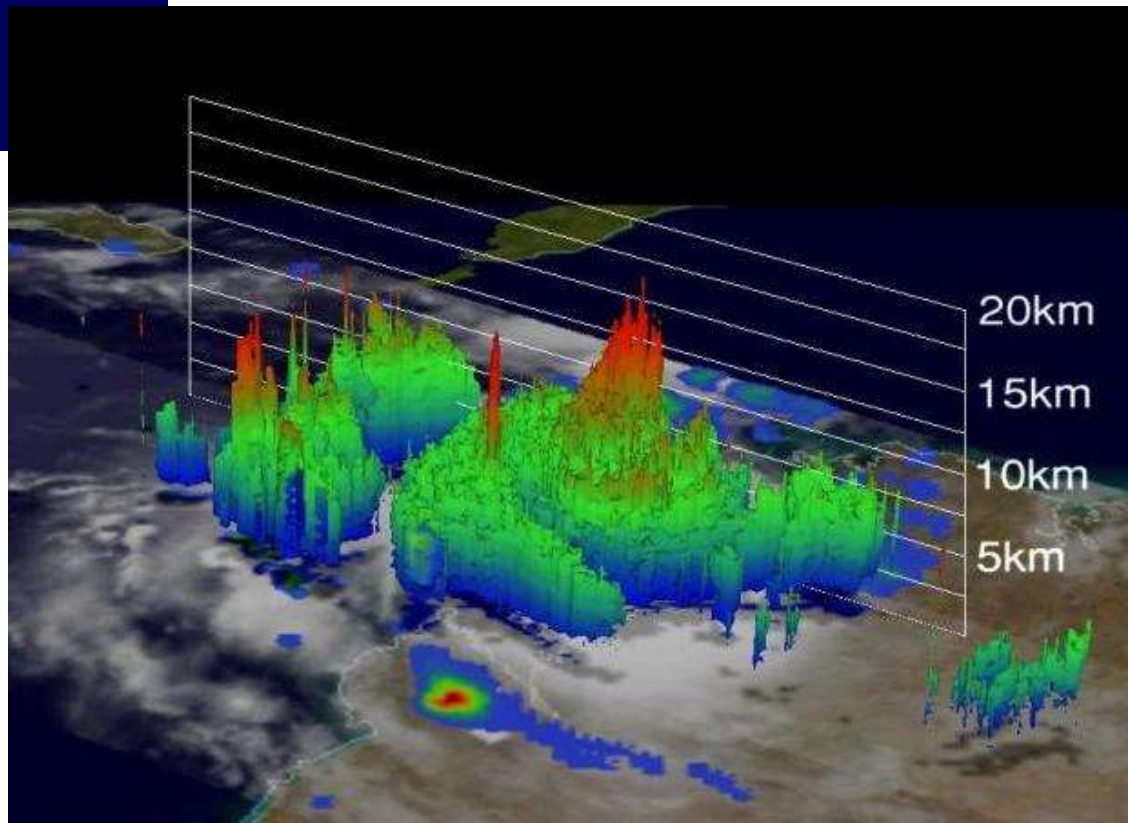
Meteorological satellite provide a unique opportunity for monitoring the precipitation for regions where ground measurement is limited and the accuracy of estimation is acceptable to the hydrologists. Satellites carry instruments designed to observe specific atmospheric characteristics such as cloud temperatures and precipitation particles.

The higher the cloud albedo (reflected solar energy), the more droplets and/or ice crystals it contains and the deeper it tends to be, so the more likely rainfall is on the ground. And the lower the top infrared brightness temperature, the higher the cloud top, and the more likely the rainfall.

TRMM (Tropical Rainfall Measuring Mission) satellite is the most widely used satellite for measurement of rainfall.





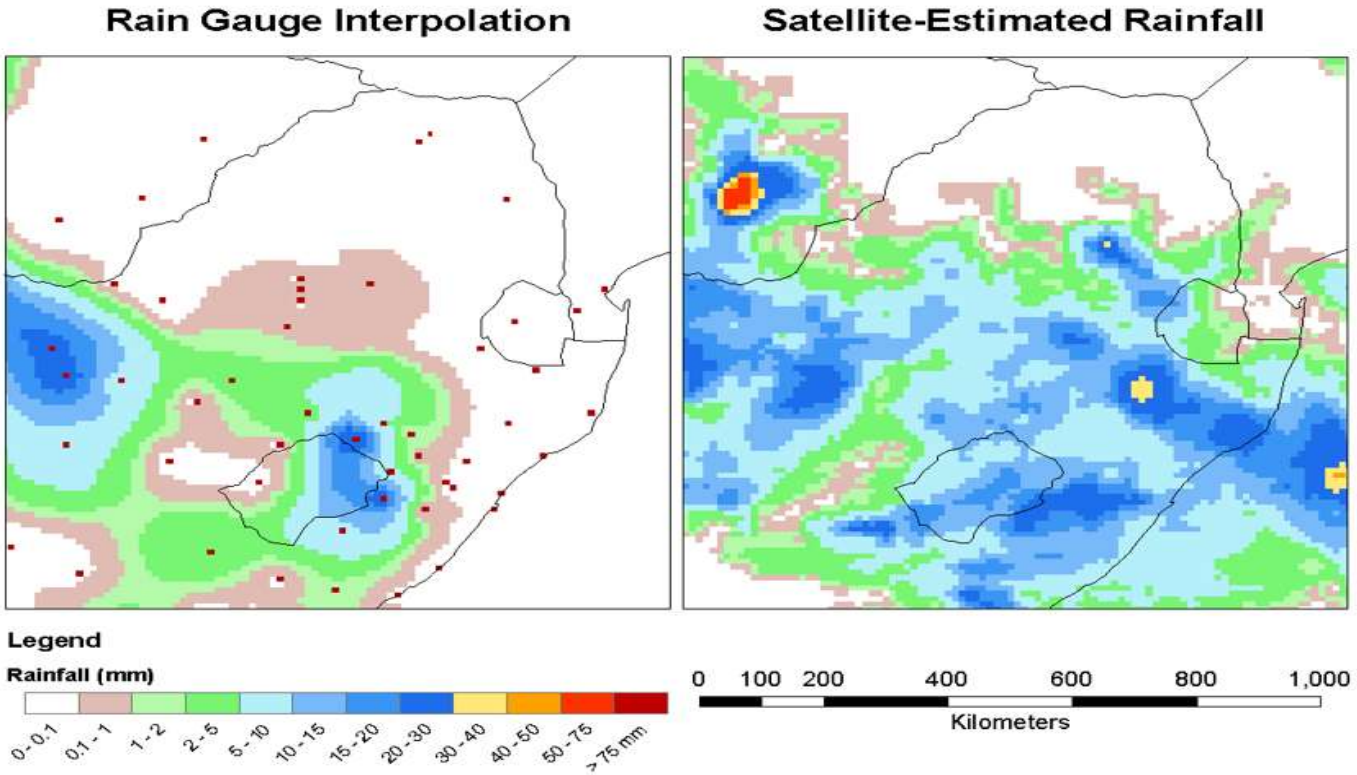


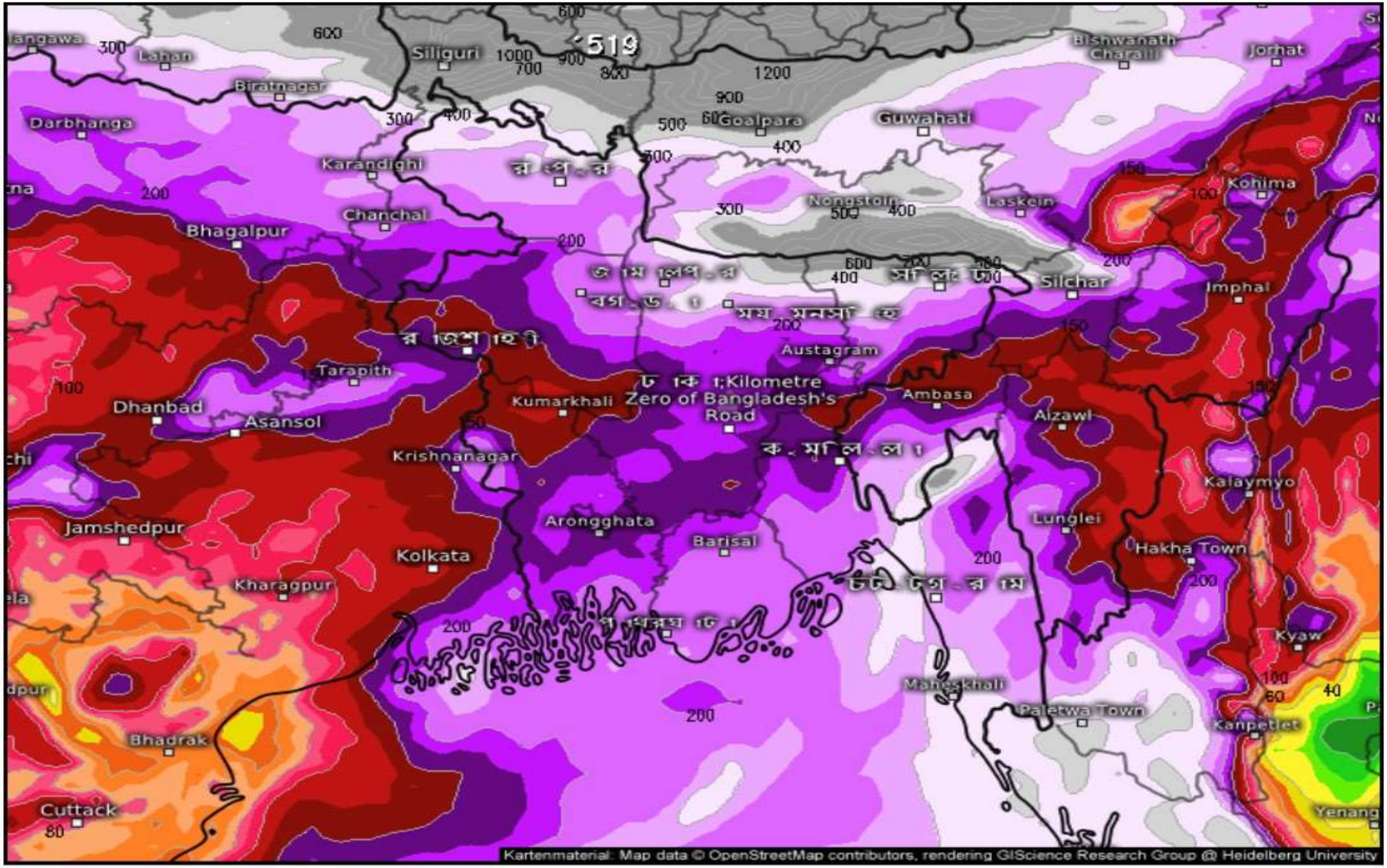
Satellite images used for rainfall predictions

Rainfall Estimation by Satellites

Advantages:

1. Better estimation of spatial and temporal distribution of observed precipitation for large areas
2. Data on precipitation in areas of poor coverage of radars and rain gauges
3. Availability of data with adequate lead time for input to river and flash flood models, analysis of floods and droughts, water resources assessments
4. Availability of data in absence of data sharing across transboundary catchments.





Accumulated Total Precipitation (mm)

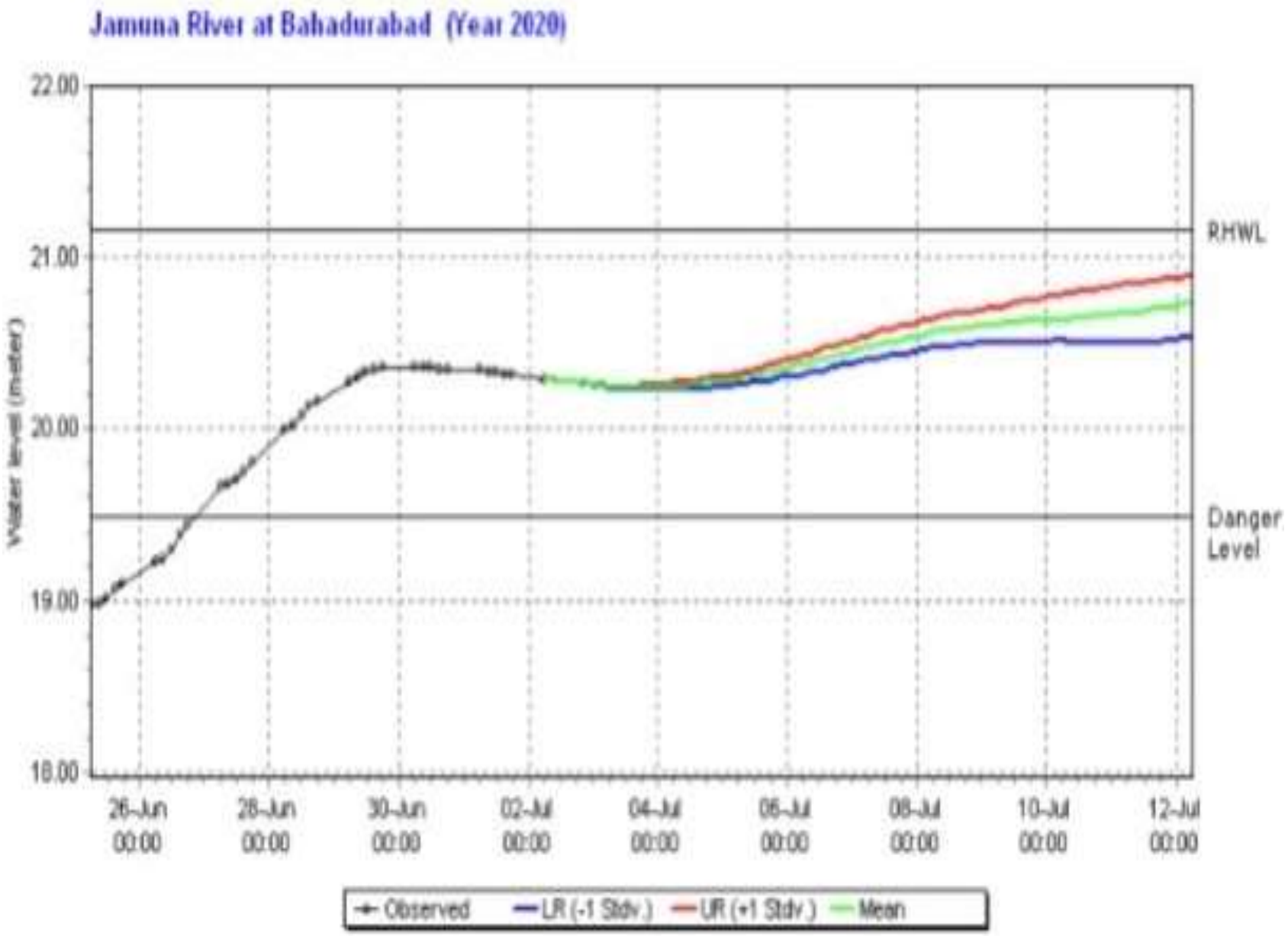
From Fri 07/03/2020, 06:00am GMT+06
to Mon 07/13/2020, 06:00am GMT+06

0.1 1 2 3 5 7 10 15 20 25 30 40 50 60 70 80 90 100 125 150 175 200 250 300 400 500

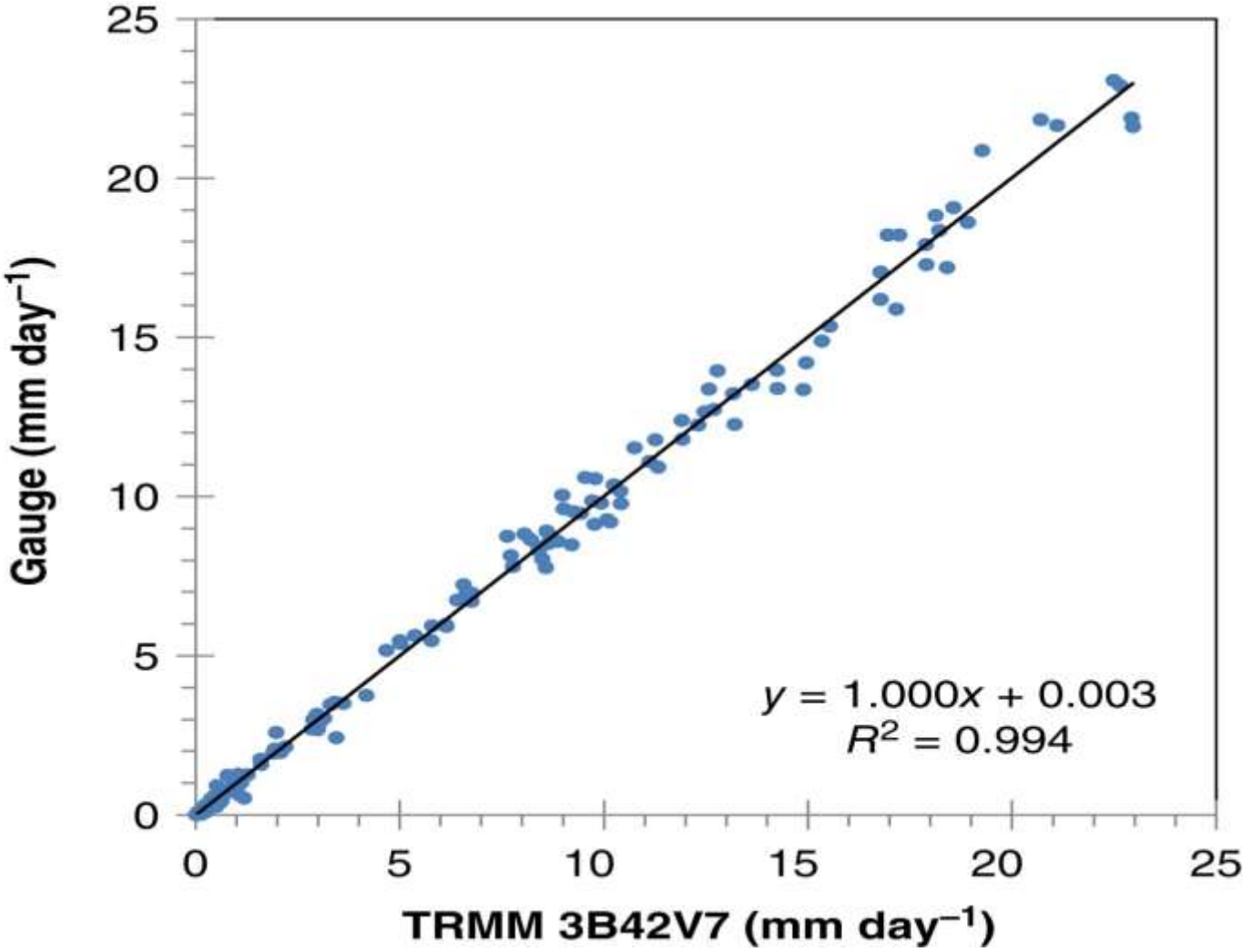
Bangladesh
ECMWF IFS HRES from 07/03/2020/00z

ECMWF meteologix.com SWISS QUALITY WEATHER FORECASTING

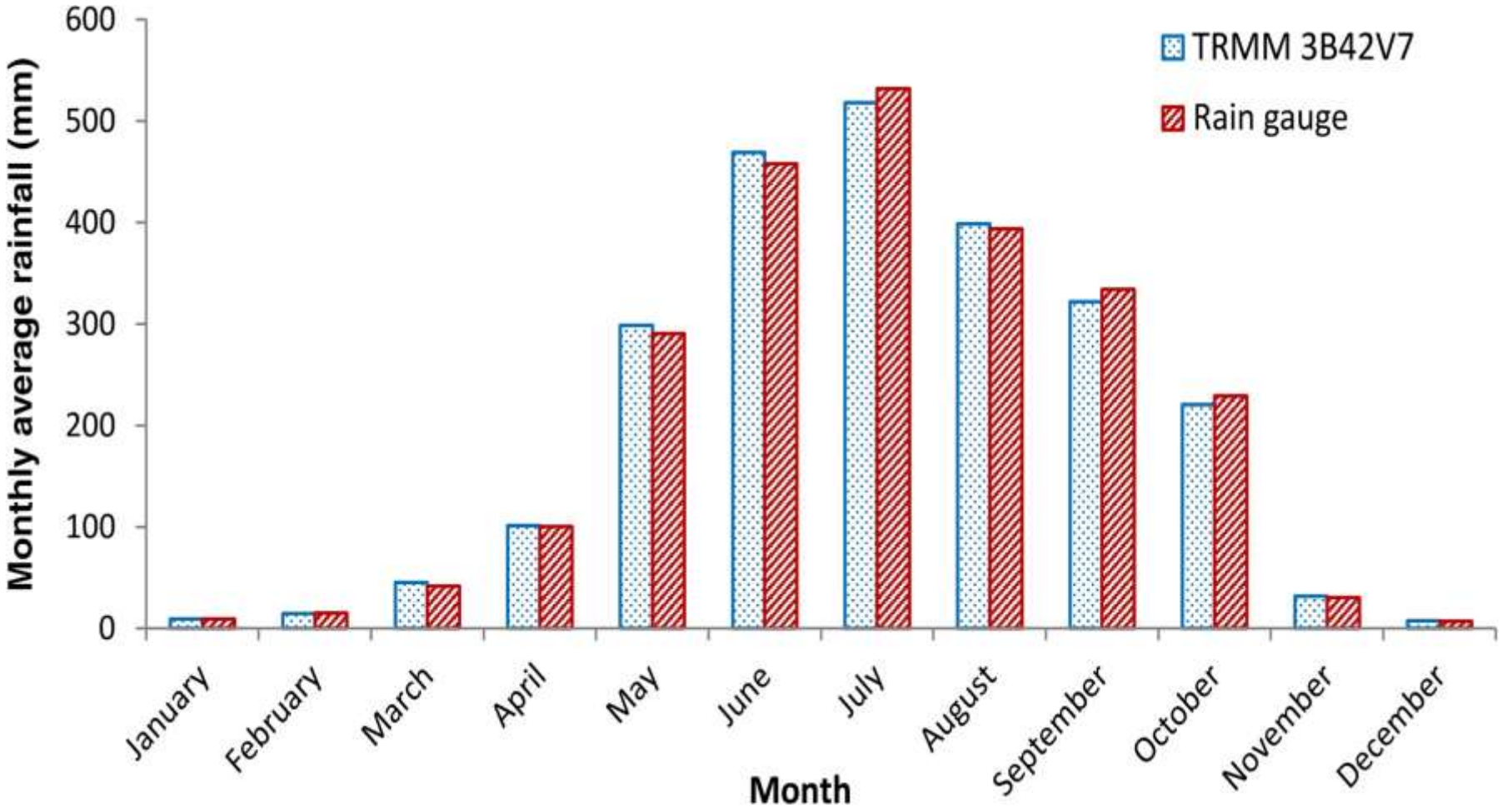
Use of Satellite Rainfall Data



Accuracy of Satellite Data



Scatter plot of the average monthly accumulated rainfall for gauge data versus Tropical Rainfall Measuring Mission (TRMM) 3B42V7 data.



Average monthly rainfall derived from Tropical Rainfall Measuring Mission (TRMM) 3B42V7 data and gauge data for the period 1998–2010.

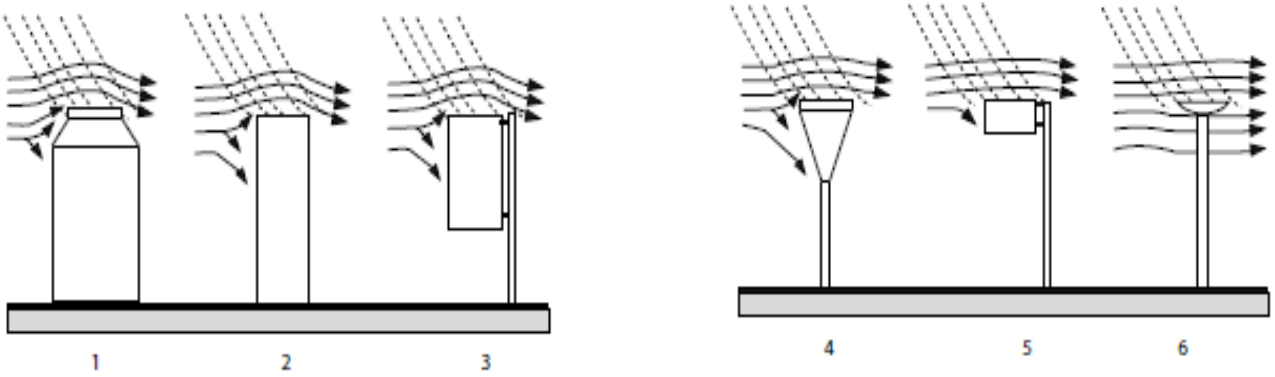
Accuracy is more than 90% for a lead time of up to 5 days.

Rainfall

Factors Affectng Accuracy of Rainfall Measurement

The accuracy of rainfall measurement is mainly affected by wind, by the height of the gauge and exposure. Wind and exposure errors can be very large, even more than 50 percent.

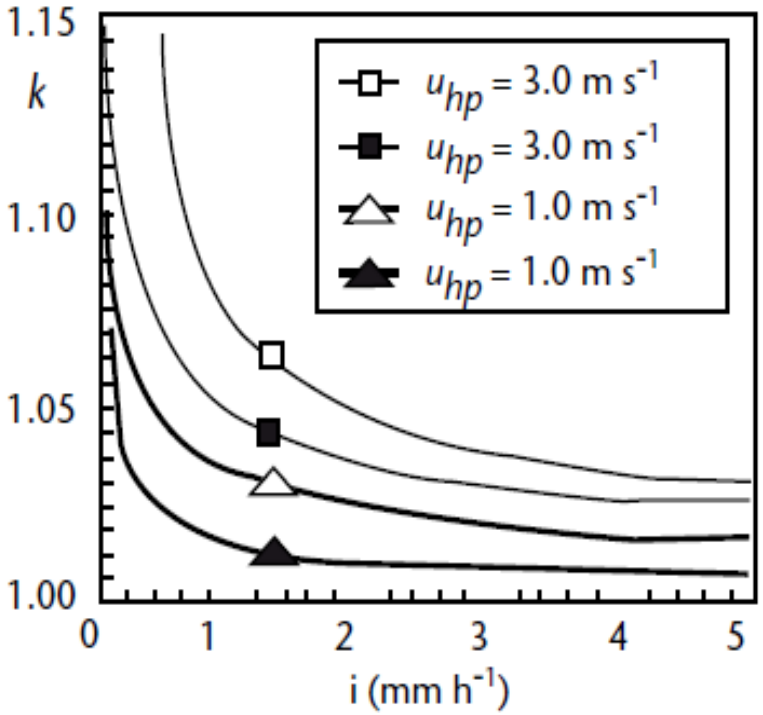
1. Human Error: faulty scale reading and water displacement (spilling of water).
2. Instrumental Defect: water to moisten the gauge; speed at which mechanical devices work (such as tipping bucket gauges); and leakage.
3. Improper Siting: height above the ground of the gauge orifice and exposure angle.
4. Wind Error: error due to systematic wind field deformation above the gauge orifice: typically 2 to 10 per cent.

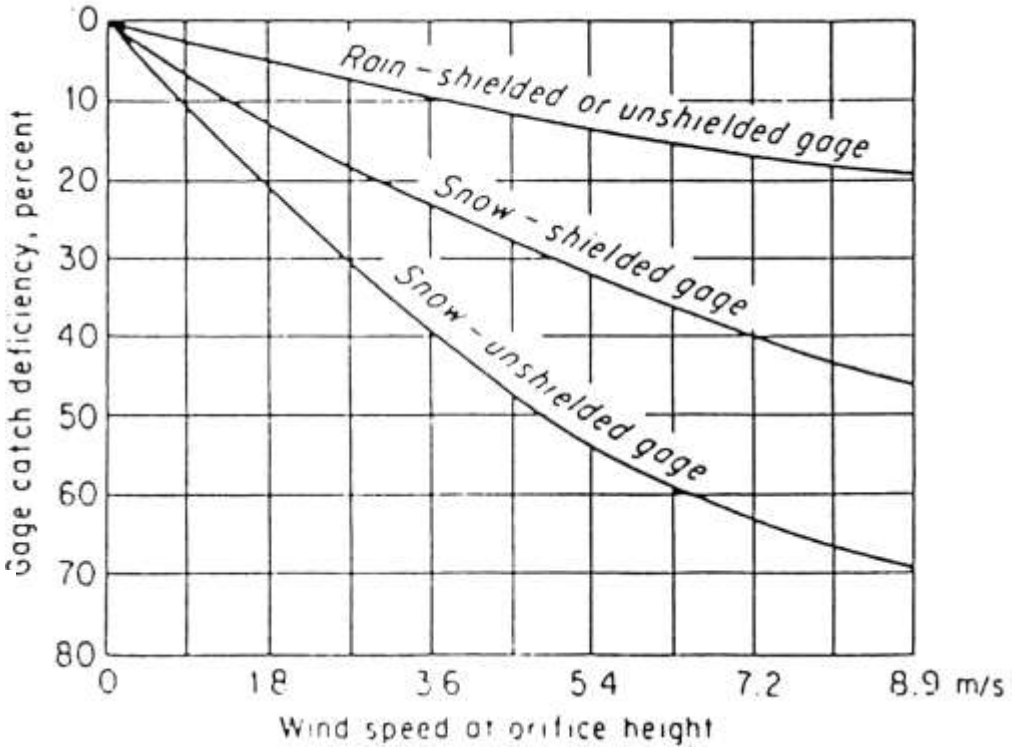


Wind deformation is largest for (1) and smallest for (6).

Effect of wind on rainfall

P = kPc
k is the correction factor
P is the corrected rainfall and
Pc is the catch.





Higher intensity lower *k* and higher wind speed higher *k*.

Rainfall

Rain Gauge Network

A gauge network should be planned such that a representative picture of the areal distribution of rainfall is obtained. The gauge density depends upon the purpose, accuracy, topography, accessibility and cost involved in measurement. The following are some of the criteria set by WMO:

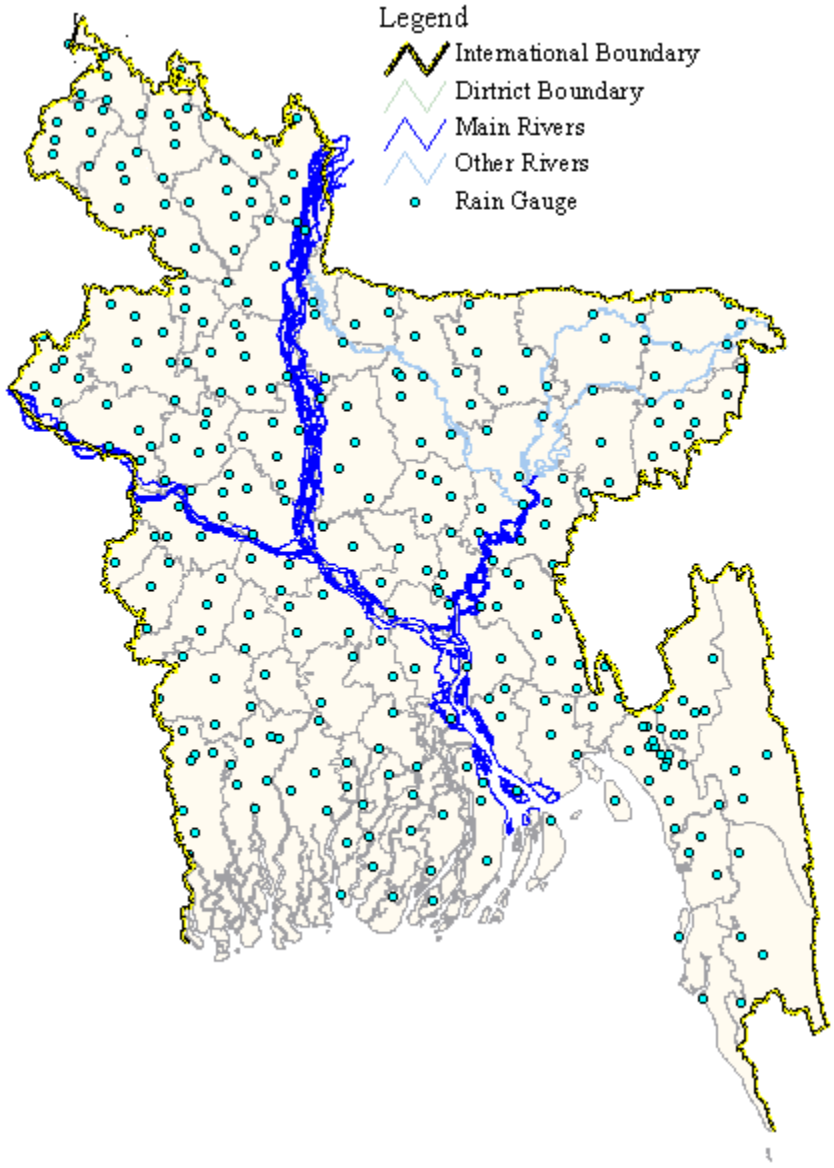
1. For flat regions: 600-900 km^2 per station.
2. For mountainous regions: 100-250 km^2 per station.
3. For arid regions: 1500-10,000 km^2 per station.

In Bangladesh, rain gauge networks are maintained by Bangladesh Water Development Board (BWDB) and Bangladesh Meteorological Department (BMD).

BWDB has 290 rainfall stations spread all over Bangladesh and BMD maintains 33 rainfall stations (mainly at district headquarters).

Rain gauge network of Bangladesh Water Development Board (BWDB)

Considering the area of Bangladesh the rain gauge network can be considered as good;
(147,500 / 290 = 508 km^2 gauge).



Adequacy of Rain Gauge Stations

The minimum number of raingauges (*N)* required to achieve a desired level of accuracy for the estimation of area-average rainfall can be determined by the **Coefficient of Variation Approach.**

If there are already some raingauge stations in a catchment, the optimal number of stations that should exist to have an assigned percentage of error in the estimation of mean rainfall is obtained by statistical analysis as:

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

where N = optimal number of stations,

ε = allowable degree of error in the estimate of the mean rainfall, (generally taken as 10%) and

Cv = coefficient of variation of the rainfall values at the existing number of stations (in per cent).

The higher the level of accuracy, the higher would be the gauge number.

If there are m stations in a watershed each measuring rainfall values P_1, P_2, P_3,…. .. P_m in a known time, the C_V can be calculated as:

$$C_V = \frac{100\,\sigma_{m-1}}{\overline{P}}$$

$$\sigma_{m-1} = \sqrt{\left[\frac{\sum_1^m (P_i - \overline{P})^2}{m-1}\right]} \qquad \overline{P} = \frac{1}{m}\left(\sum_1^m P_i\right)$$

Example

The annual rainfall recorded by 5 gauges in a catchment are as follows. For a 10% error in the estimation of mean rainfall, calculate the optimum number of stations (N) in the catchment.

Station	A	B	C	D	E
Rainfall (mm)	82.6	102.9	180.3	98.8	136.7

For the given data:

$m = 5$

$\overline{P} = 118.6mm$

$\sigma_{m-1} = 35.04mm$

$\varepsilon = 10\%$

$$C_v = \frac{100 * 35.04}{118.6} = 29.54\%$$

$$N = \left(\frac{29.54}{10}\right)^2 = 8.7, say 9$$

Hence, 4 more gauges are required.

Rainfall Analysis

Before analysing rainfall data, it is necessary to check the data for continuity and consistency.

Estimation of Missing Data

1. Average Method: If the normal rainfall of the surrounding stations is within 10% of the missing station, a simple average of the surrounding stations is taken as the estimated rainfall.
2. Normal Ratio Method: If the normal rainfall is more than 10%, then the rainfall (P_x) at station X, is:

$$P_x = \frac{N_x}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \ldots + \frac{P_m}{N_m}\right]$$

Where, P_1, P_2, P_3,… P_m are annual (monthly or of a storm) precipitation values at neighboring M stations 1, 2, 3, … & m respectively. The normal annual precipitations are given by N_1, N_2, N_3,…, N_m. (including station X).

Example:

The following data were taken from 5 gage stations. What is the missing rainfall at station X?

Gage	Average Annual Rainfall (cm)	Monthly Rainfall (cm)
A	32	2.2
B	28	2.0
C	25	2.0
D	35	2.4
X	26	?

Check whether the rainfall of the surrounding stations are within 10% of the missing station. For this case:

Mean of surrounding stations is 30 cm > 10% [30 > 26 ± 10% of 26]

Solution:

$$P_x = (N_x / M) [P_A / N_A + P_B / N_B + P_C / N_C + P_D / N_D]$$

$$= (26 / 4) [2.2 / 32 + 2.0 / 28 + 2.0 / 25 + 2.4 / 35] = 1.877 \text{ cm}$$

Then: P_x = 1.877 cm

Rainfall Analysis

Consistency of Rainfall Data

Changes in gauge location, instrumental errors, observational errors etc. would result in change in rainfall data. Such inconsistency in data are verified by Double Mass Analysis.

Double Mass Analysis tests the consistency of the record of a station by comparing the accumulated rainfall of a station with that of the mean accumulated rainfall of the surrounding stations. Corrections are applied by adjusting the slopes of the double mass curve.

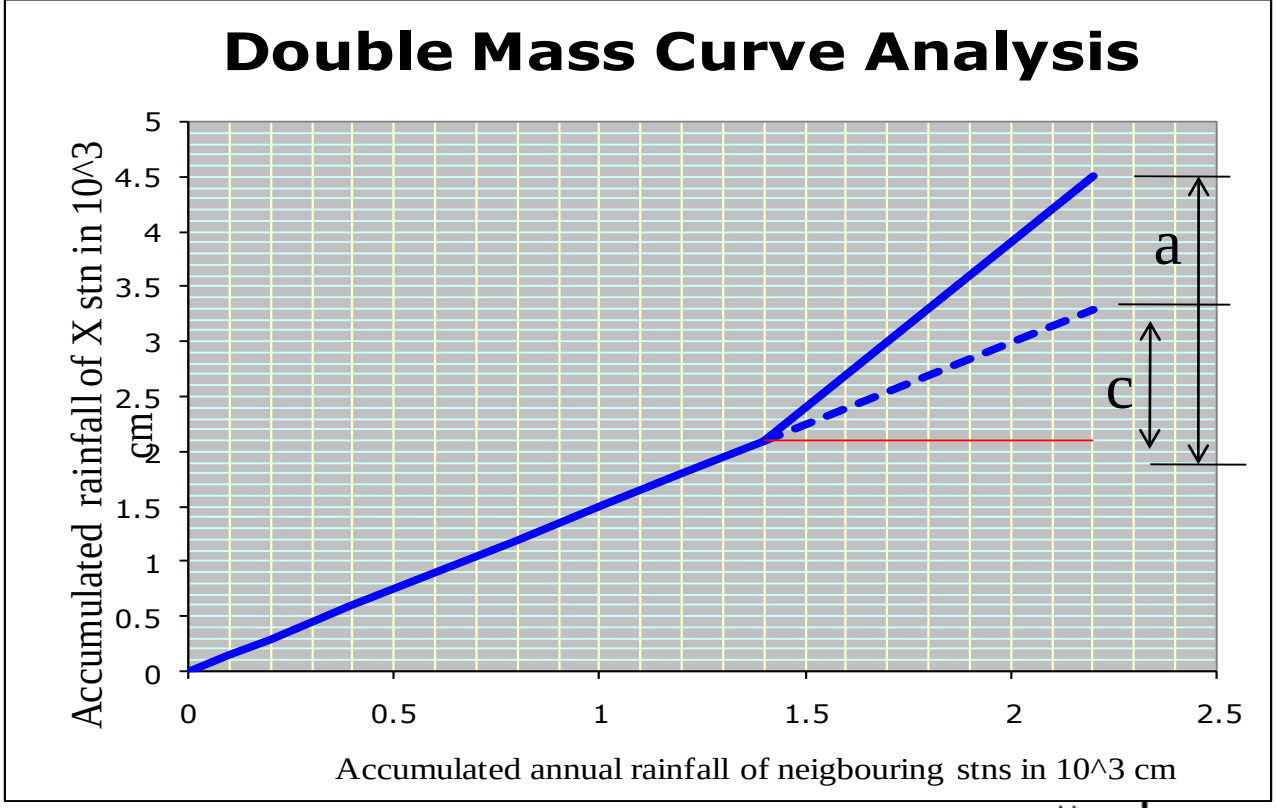
Let a group of 3 to 10 base stations in the neighbourhood of the problem station X is selected.

Arrange the data of station X and the average of the neighbouring stations.

Accumulate the precipitation of station X $(\sum P_x)$ and the average values of the group base stations $(\sum P_{avg})$.

Plot the $(\sum P_x)$ against $(\sum P_{avg})$ as shown on the next figure.

A break in the slope of the resulting plot indicates a change in precipitation regime of station X, i.e inconsistency.



$$\frac{M_c}{M_a} = \frac{c}{a}$$

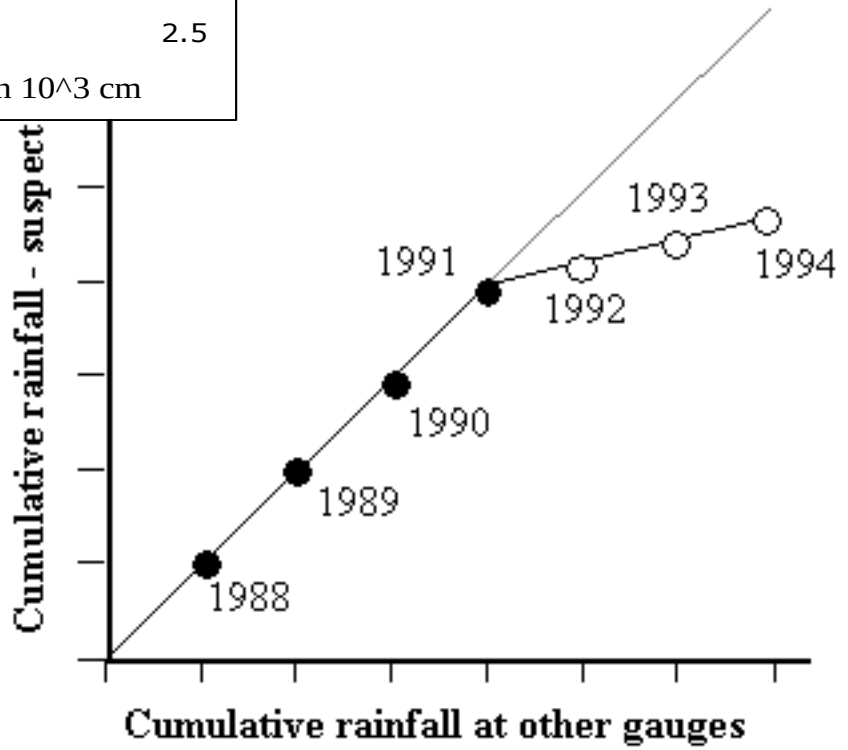
$$P_{cx} = P_x \frac{M_c}{M_a}$$

P_{cx} – corrected rainfall at station X

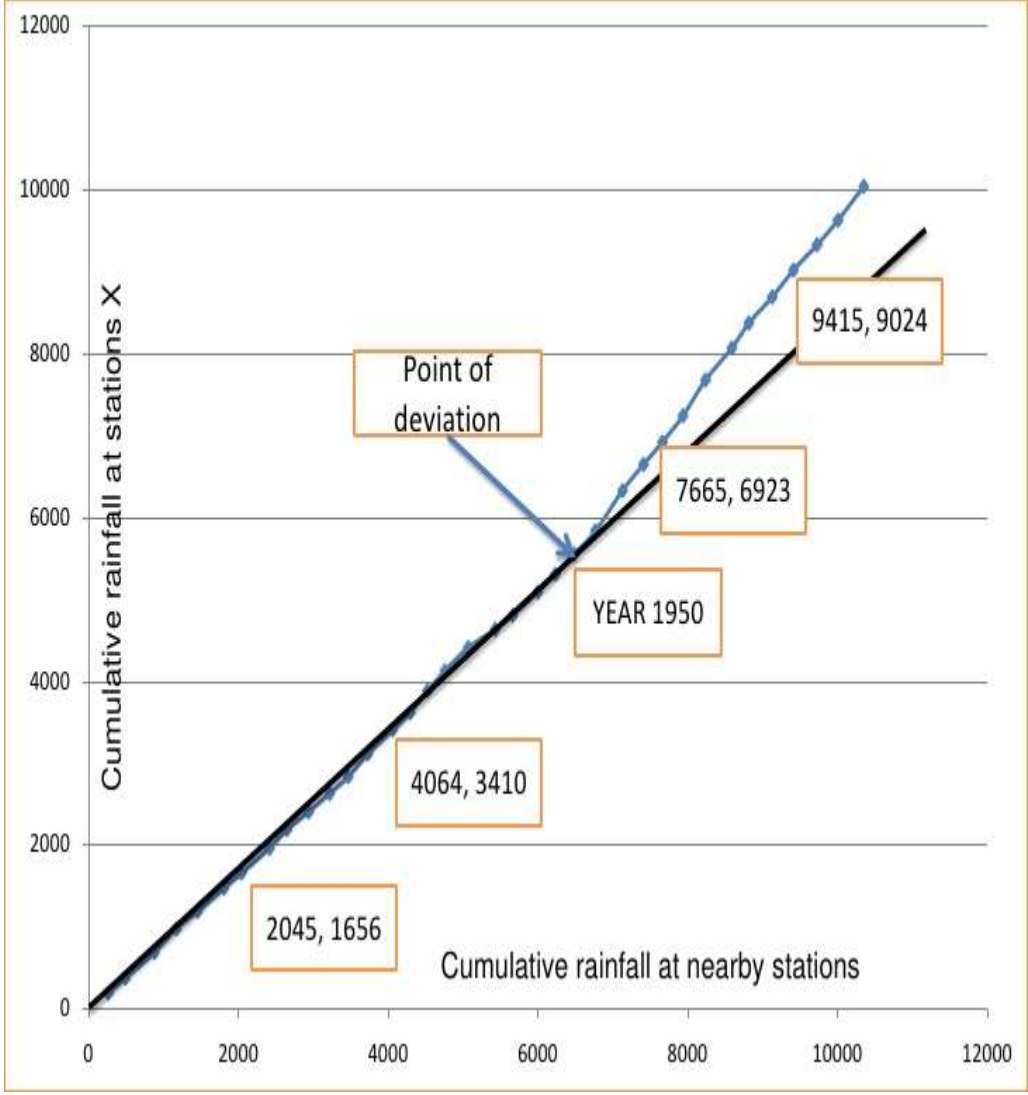
P_x – Original rainfall at time t_1 at station X

M_c – corrected slope of the double mass curve

M_a – original slope of the mass curve



year	annual rain at station X (mm)	Cumulative rainfall at station X	avg annual rainfall at nearby station (mm)	cumulative avg annual rainfall at nearby stations
1972	188	188	264	264
1971	185	373	228	492
1970	310	683	386	878
1969	295	978	297	1175
1968	208	1186	284	1459
1967	287	1473	350	1809
1966	183	1656	236	2045
1965	304	1960	371	2416
1964	228	2188	234	2650
1963	216	2404	290	2940
1962	224	2628	282	3222
1961	203	2831	246	3468
1960	284	3115	264	3732
1959	295	3410	332	4064
1958	206	3616	231	4295
1957	269	3885	234	4529
1956	241	4126	231	4760
1955	284	4410	312	5072
1954	223	4633	360	5432
1953	173	4806	234	5666
1952	282	5088	333	5999
1951	218	5306	236	6235
1950	246	5552	251	6486
1949	284	5836	284	6770
1948	493	6329	361	7131
1947	320	6649	282	7413
1946	274	6923	252	7665
1945	322	7245	274	7939
1944	437	7682	302	8241
1943	389	8071	350	8591
1942	305	8376	228	8819
1941	320	8696	312	9131
1940	328	9024	284	9415
1939	308	9332	315	9730
1938	302	9634	280	10010
1937	414	10048	343	10353



$$S_a = \frac{3410 - 1656}{4064 - 2045}$$

$$S_a = \frac{1754}{2019} = 0.868$$

$$S_o = \frac{9024 - 6923}{9415 - 7665}$$

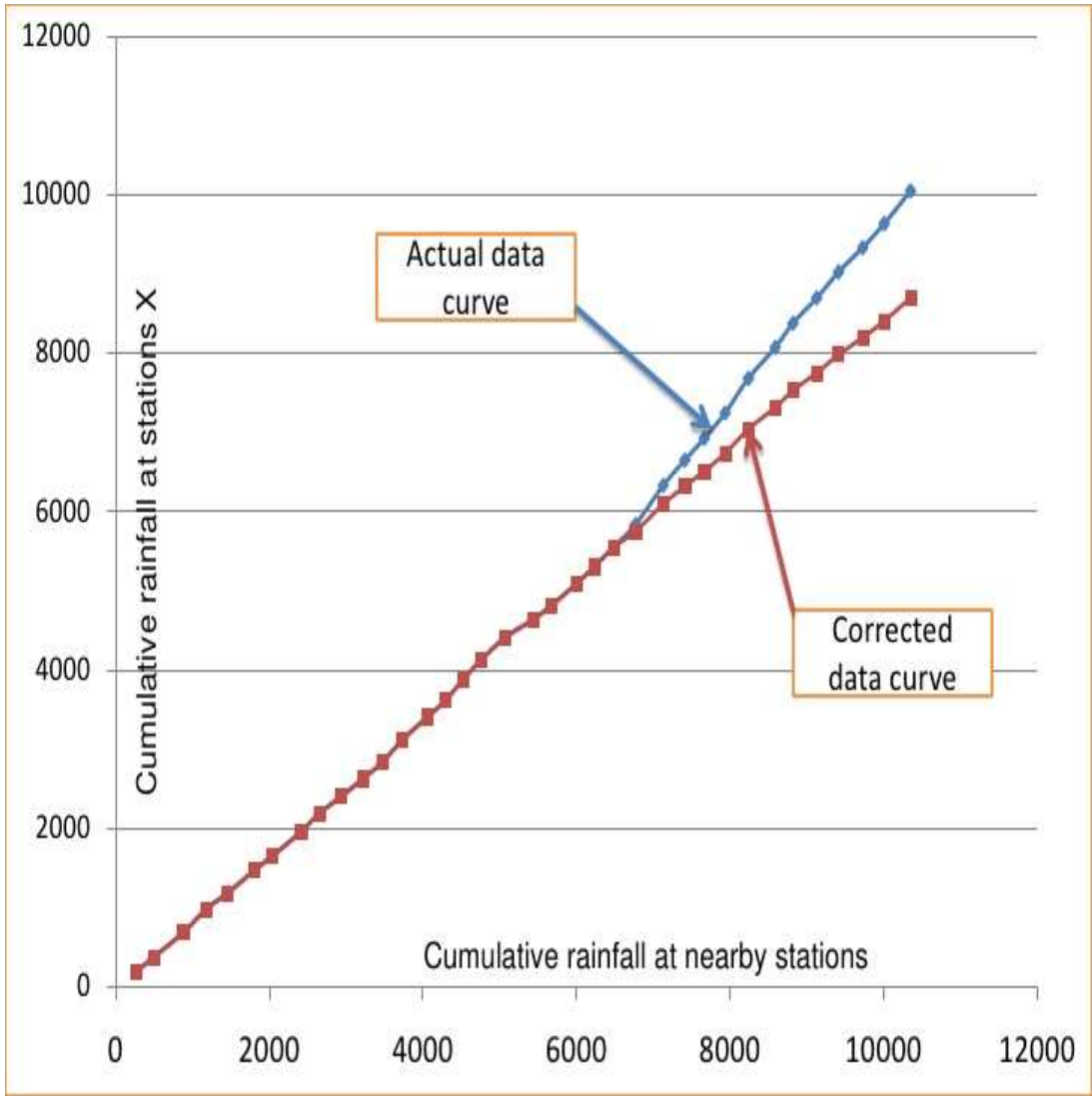
$$S_o = \frac{2101}{1750} = 1.20$$

Correction factor

$$cf = \frac{0.868}{1.20} = 0.72$$

Corrected precipitation

Year	Corrected Value (mm)
1949	205
1948	356
1947	231
1946	198
1945	232
1944	315
1943	289
1942	221
1941	231
1940	237
1939	223
1938	216
1937	299



Example: Double Mass Analysis

TABLE 7.3 CUMULATIVE ANNUAL PRECIPITATION

Year	Annual precipitation (in.) Station X	Annual precipitation (in.) 25-Station Ave.	Cumulative annual precipitation (in.) Station X	Cumulative annual precipitation (in.) 25-Station Ave.
1941	41.4	34.3	41.4	34.3
1942	30.2	27.9	71.6	62.2
1943	30.7	31.5	102.3	93.7
1944	32.8	28.2	135.1	121.9
1945	32.0	31.2	167.1	153.1
1946	30.5	22.9	197.6	176.0
1947	38.9	35.1	236.5	211.1
1948	43.7	30.2	280.2	241.3
1949	32.3	27.43	312.5	268.73
1950	27.4	27.2	339.9	295.93
1951	32.0	28.2	371.9	324.13
1952	48.3	36.1	420.2	360.23
1953	28.4	28.4	448.6	388.63
1954	24.6	25.1	473.2	413.73
1955	21.8	23.6	495.0	437.33
1956	28.2	33.3	523.2	470.63
1957	17.3	23.4	540.5	494.03
1958	22.4	36.1	562.9	530.13
1959	28.5	31.2	591.4	561.33
1960	24.1	23.1	615.5	584.43
1961	27.0	23.4	642.5	607.83
1962	20.6	23.1	663.1	630.93
1963	28.5	33.3	692.6	664.23
1964	28.5	26.4	721.1	690.63
1965	20.3	24.84	741.4	715.27
1966	22.35	28.2	763.75	743.47
1967	21.6	29.0	785.35	772.47
1968	22.9	23.4	808.25	795.87
1969	30.5	37.1	838.75	832.97
1970	18.3	23.6	857.05	856.57
1971	28.7	35.1	885.75	891.67
1972	20.8	28.4	906.55	920.07
1973	29.5	28.7	936.05	948.77
1974	31.0	38.6	967.05	988.37
1975	18.5	22.86	985.55	1011.23
1976	18.8	26.4	1004.35	1037.63

Adjusted Annual Precip.

Same as before

Col. (2) $\times \frac{S_1}{S_2}$

$= \text{col.}(2) \times 1.300$

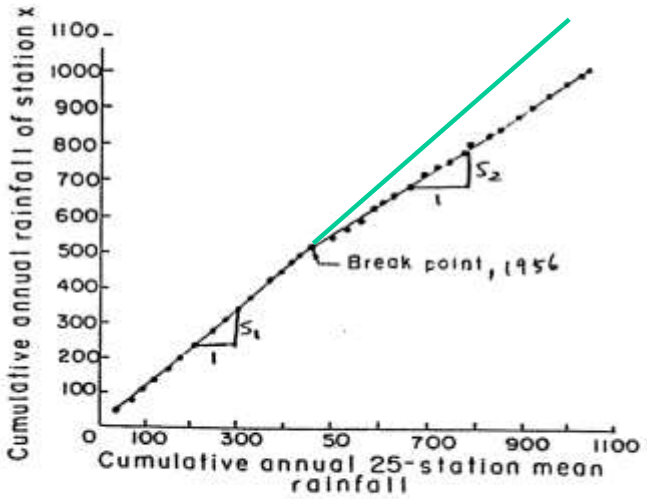


Figure 7.17 Double-mass curve for testing the homogeneity of the precipitation (inches) record at station X.

$S_1 = \frac{523.2 - 41.4}{470.63 - 34.3} = \frac{481.8}{436.33} = 1.104$

$S_2 = \frac{1004.35 - 523.2}{1037.63 - 470.63} = \frac{481.15}{567} = 0.849$

$\Delta S = \frac{|S_2 - S_1|}{S_1} = \frac{|0.849 - 1.104|}{1.104} = 23\%$

Rainfall Analysis

Estimation of Average Rainfall

Arithmatic Average Method: For only very small catchments. The method is accurate when C_v (standard deviation / mean) < 0.10.

Thiessen Polygon Method: Gauge stations are plotted on a map and each gauge is connected to the adjoining gauges by a line. Perpendicular bisectors of these lines are drawn to form a polygon around each gauge. The area of each gauge is assumed to be the area representing the gauge. Weighted average rainfall of the area is computed by multiplying the rainfall in each station by the area (or percentage of the area) and then totaling.

Advantage: - Ease of computation for other rainfall events

Disadvantages: - New polygons required with additional new stations

- Spatial variation of rainfall not considered

Isohyetal Method: Contours of equal rainfall (isohyets) are drawn with contour interval depending upon the variation of rainfall and accuracy. The mean rainfall is computed by multiplying the area between contours with the mean rainfall between contours and totaling. The total is divided by total area to get the average rainfall.

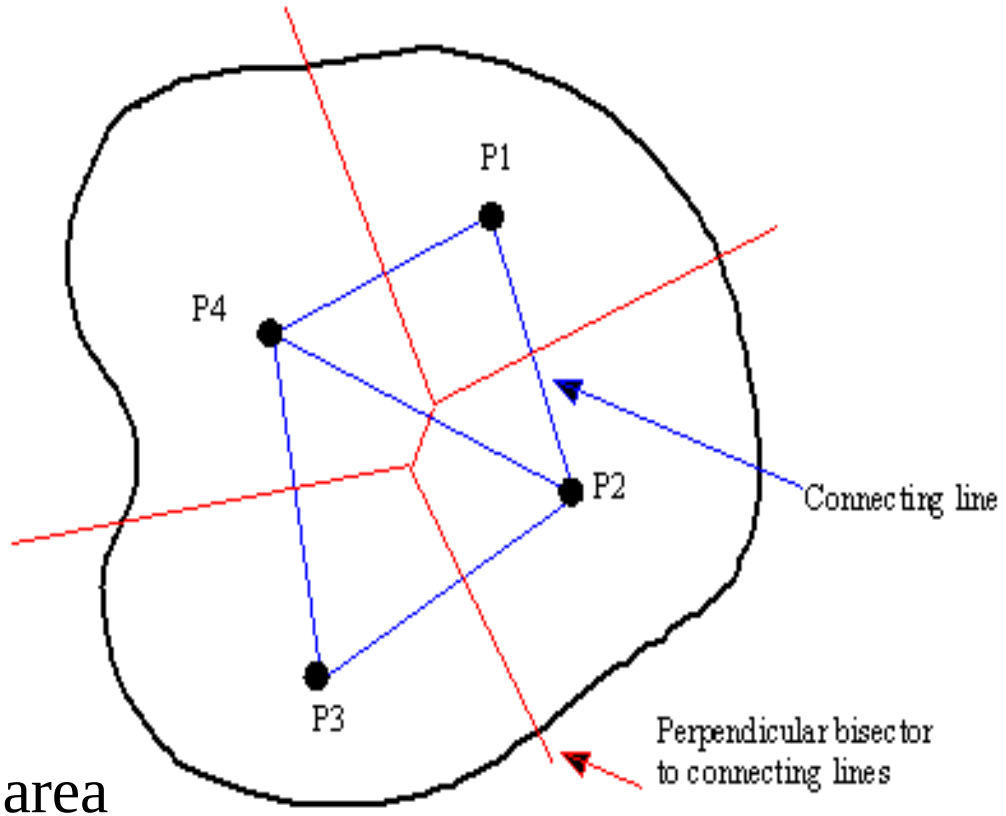
Advantage: - Accurate as spatial variations of rainfall are taken into consideration

- Accurate when a catchment has large number of gages

Disadvantage: - Isohyets needed for each new rainfall event.

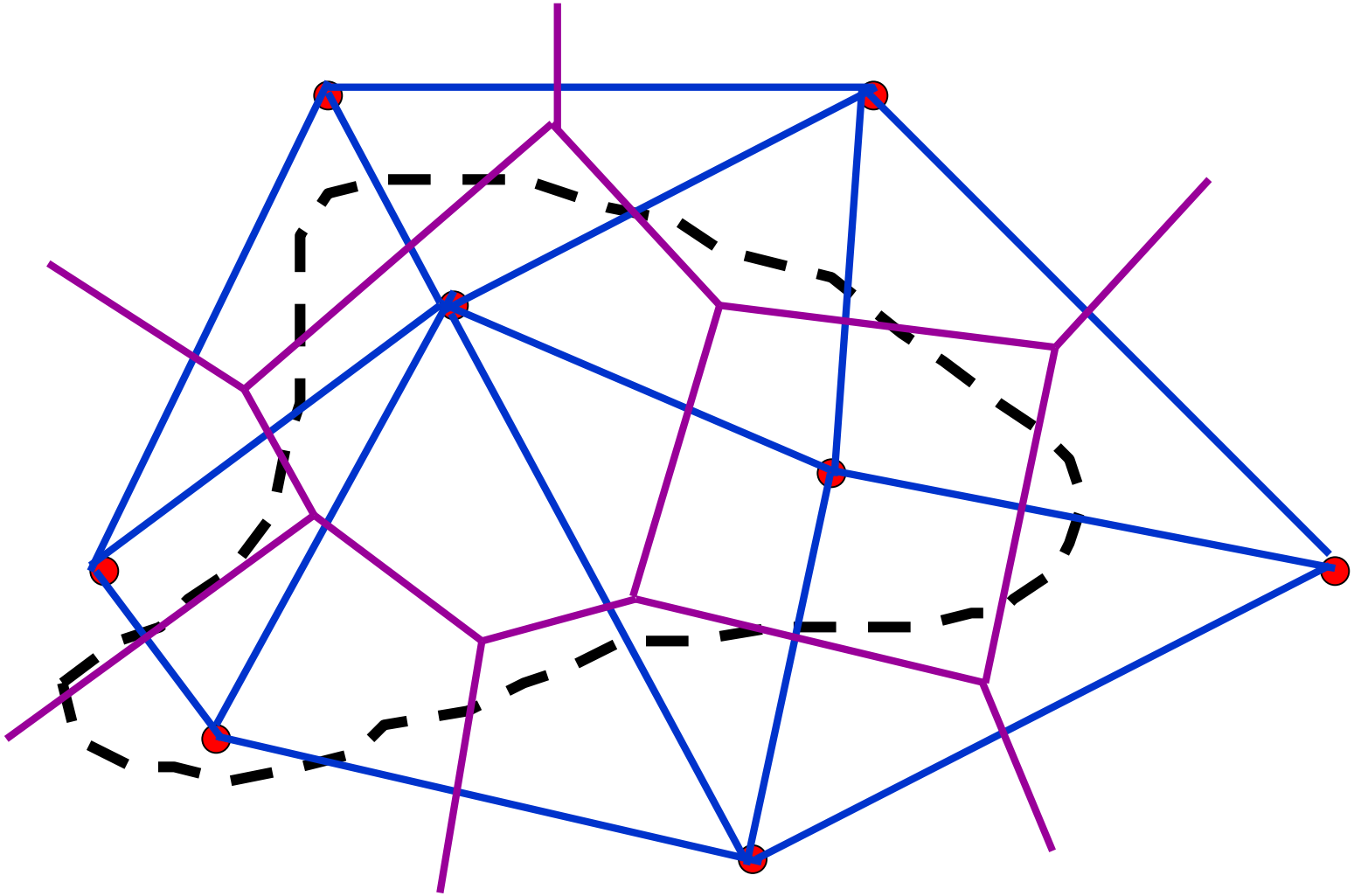
Thiessen Polygon Method

$$\overline{P} = \frac{\sum A_i P_i}{\sum A_i}$$

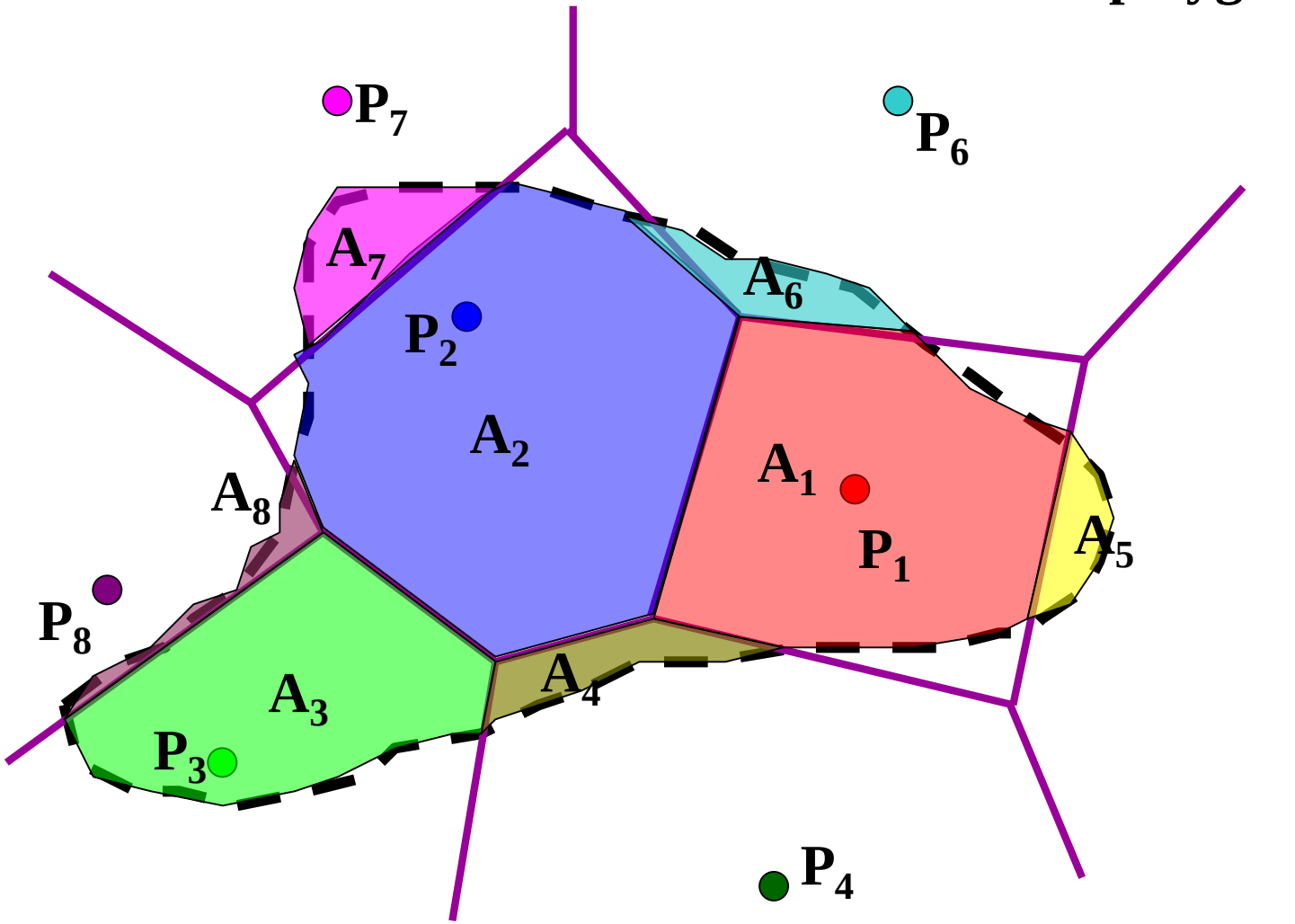


A can be polygon area or % area

Thiessen polygons …….



Thiessen polygons .....



$$\overline{P} = \frac{\sum A_i P_i}{\sum A_i}$$

Thiessen Polygon Weighting Computation of Mean Areal Precipitation For A River Basin

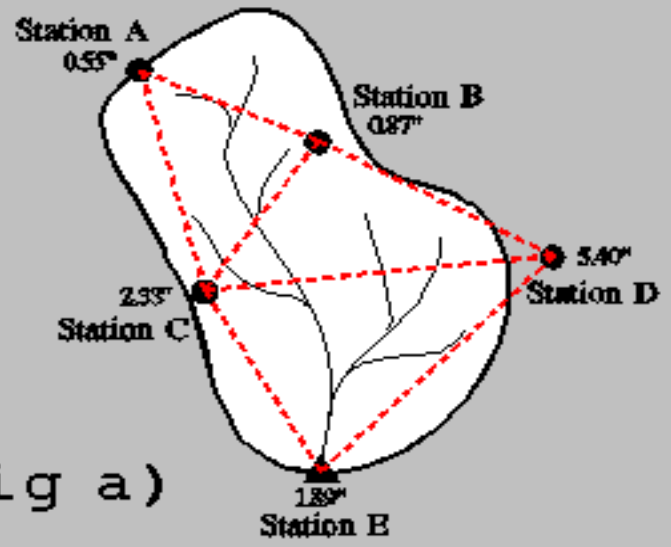


Fig a)

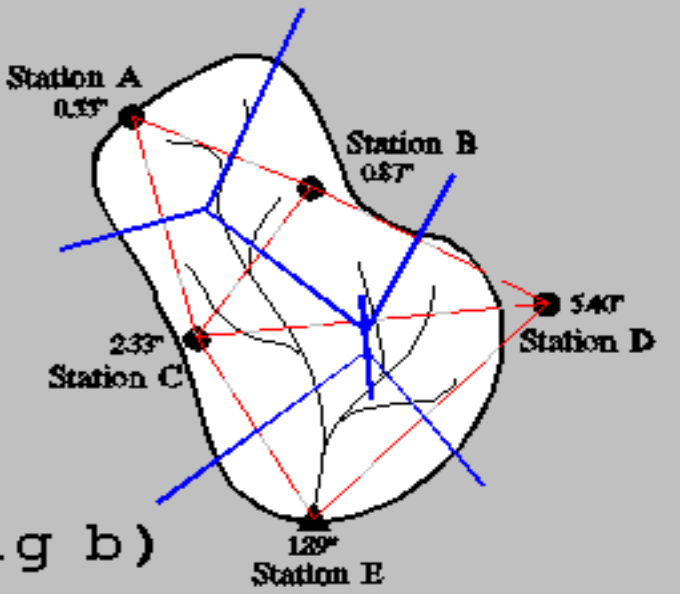


Fig b)

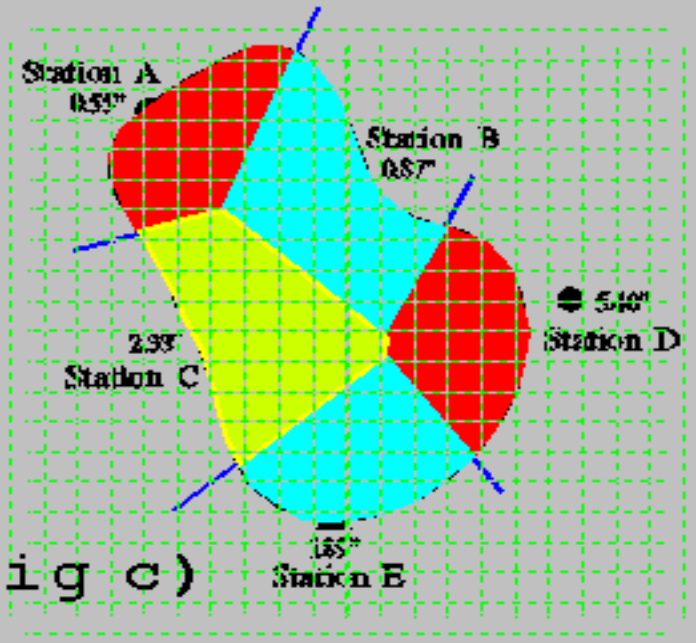


Fig c)

a) construct polygons by connecting stations with lines.

b) Bisect the polygon sides.

c) Estimate the area of each stations polygon by counting grid squares or other suitable technique for the polygons formed by the bisect lines. In this case... 15.0, 33.0, 28.8, 16.4 & 24.3 units for A, B, C, D & E, respectively.

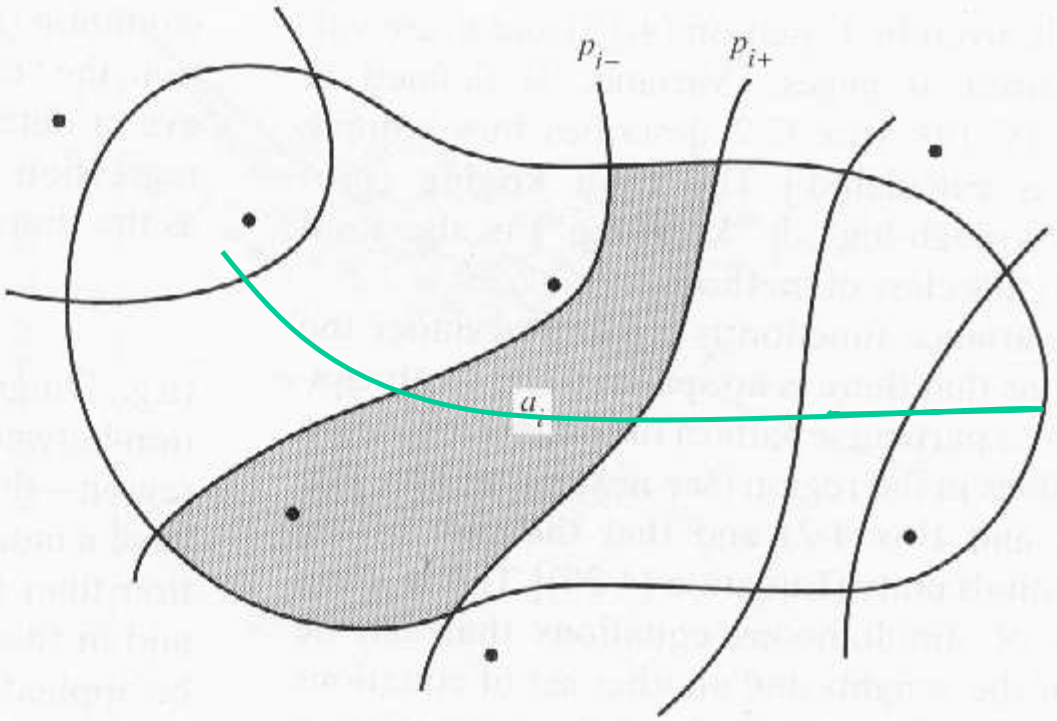
d) Sum the areas. In this case = 117.5 units.

e) Determine the station weights by dividing the station area by the total area. Weights equal .128, .281, .245, .140 & .207.

f) Determine areal precipitation by summing the products of each station weight times its precipitation. In this case, 2.03".

Isohyetal Method

FIGURE 4-26
The isohyetal method of integration. Dots are precipitation-gage locations; thin lines are isohyets; shaded zone is the area a_i between the p_{i-} and p_{i+} isohyets.



Isohyetal Method

- $P_1, P_2, P_3, \ldots, P_n$ – the values of the isohytes
- $a_1, a_2, a_3, \ldots, a_4$ – are the inter isohytes area respectively
- A – the total catchment area
- $\overline{P}$ - the mean precipitation over the catchment

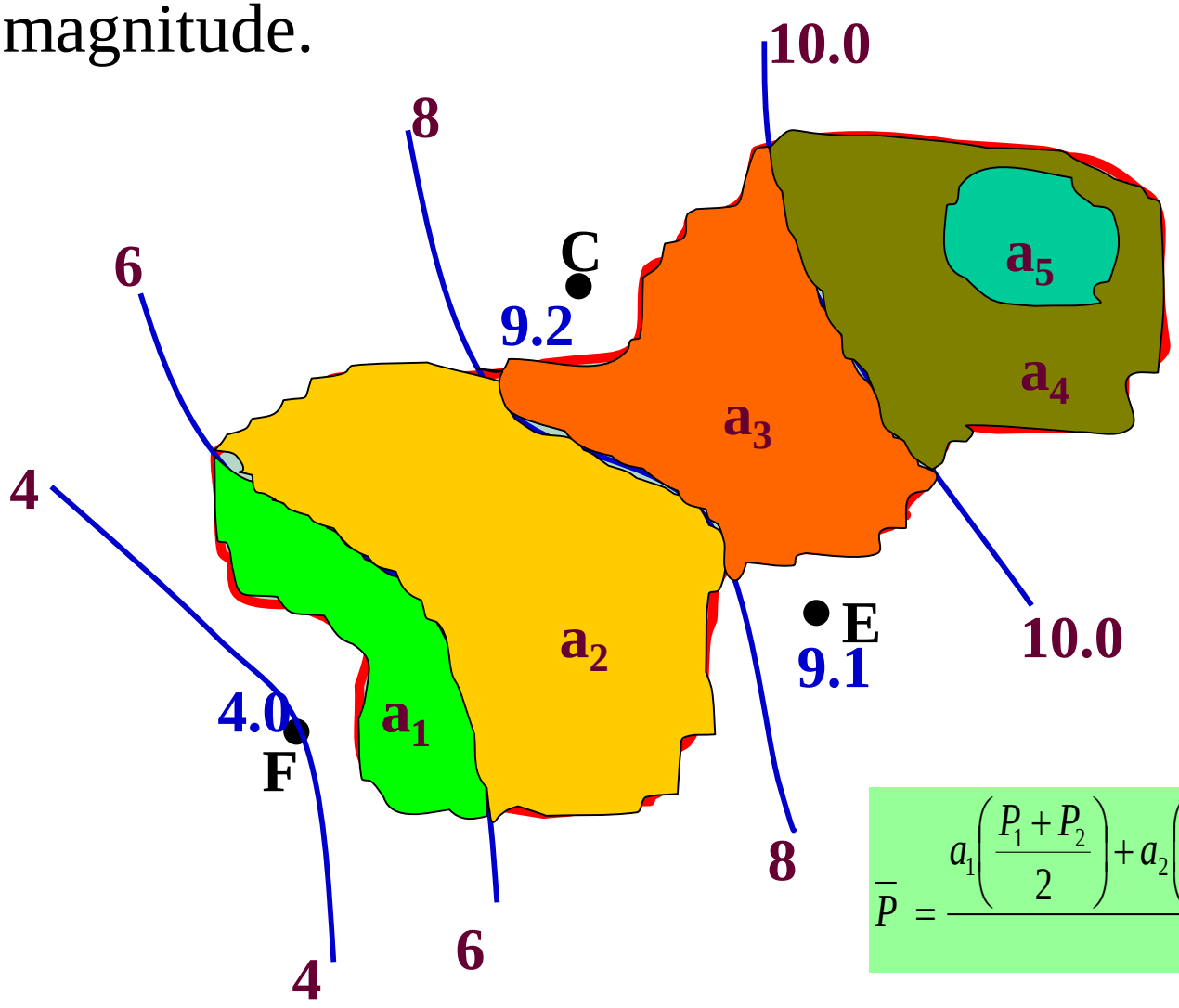
$$\overline{P} = \frac{a_1\left(\frac{P_1 + P_2}{2}\right) + a_2\left(\frac{P_2 + P_3}{2}\right) + \ldots + a_{n-1}\left(\frac{P_{n-1} + P_n}{2}\right)}{A}$$

NOTE

The isohyet method is superior to the other two methods especially when the stations are large in number.

Isohyetal Method

- An isohyet is a line joining points of equal rainfall magnitude.



$$\overline{P} = \frac{a_1\left(\frac{P_1+P_2}{2}\right)+a_2\left(\frac{P_2+P_3}{2}\right)+\ldots+a_{n-1}\left(\frac{P_{n-1}+P_n}{2}\right)}{A}$$

Isohyetal Method

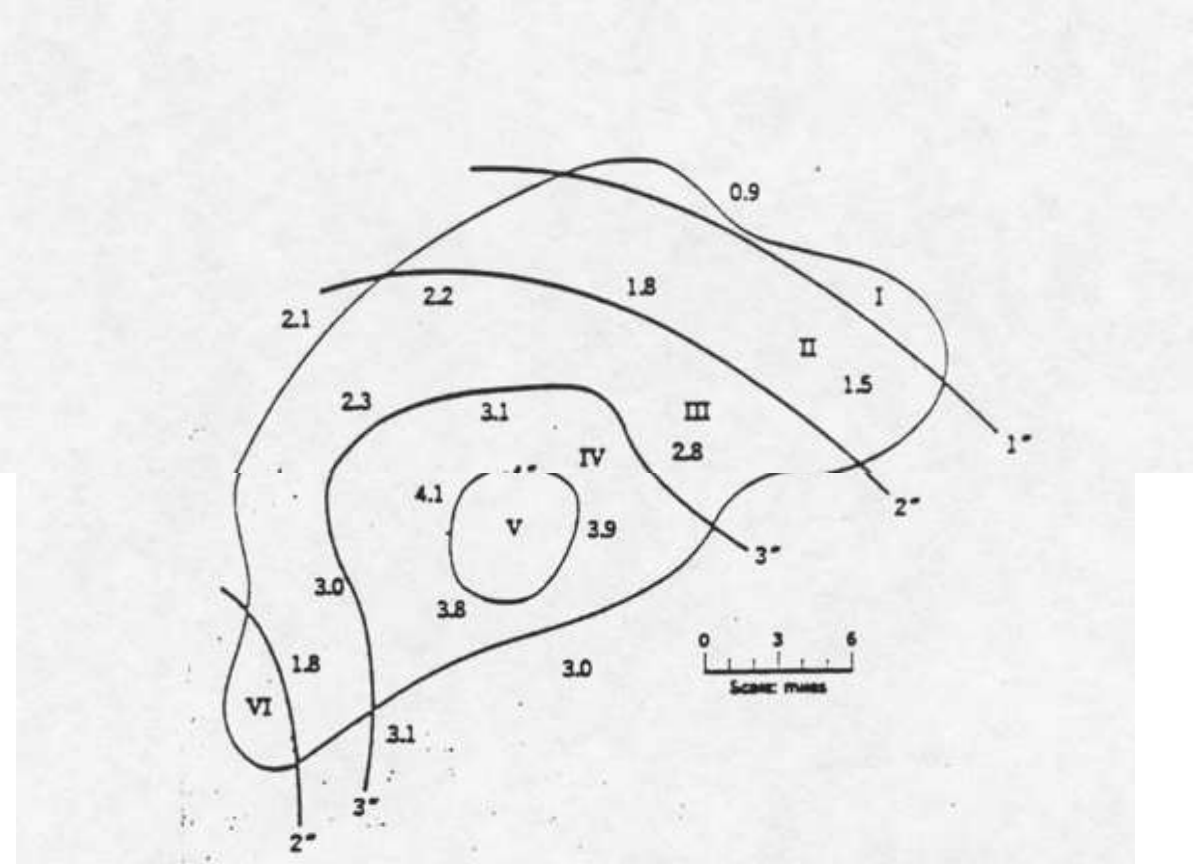


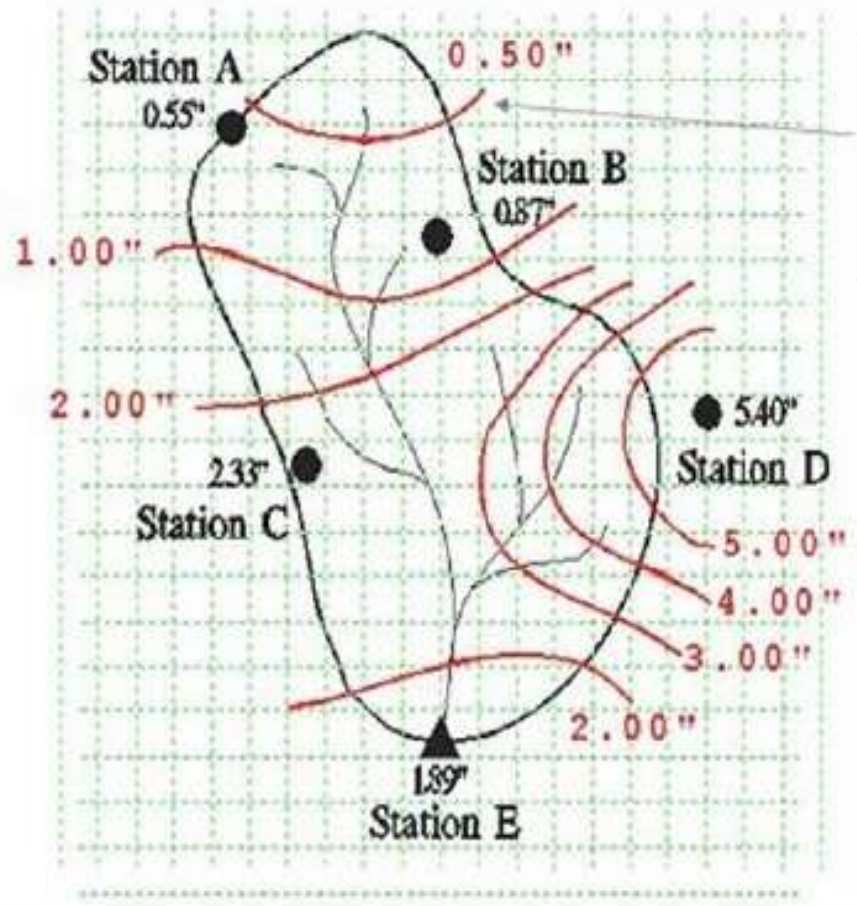
Fig. 2-13 Isohyetal method for average precipitation.

Zone	Area (sq mi)	P_{ave} (in.)	
I	21.24	0.95	20.18
II	84.96	1.50	127.44
III	150.12	2.50	375.30
IV	107.28	3.50	375.48
V	24.48	4.10	100.37
VI	12.60	1.80	22.68
	$A_t = 400.68$		$\Sigma P_{ave}A = 1{,}021.45$

Average precipitation on basin

$$\frac{\Sigma P_{ave} \times A}{A_t} = 2.55 \text{ in.}$$

Isohyetal Method



Isohyets
Lines of equal precipitation

om: WW 2010 Project University of Illinois, Point Precipitation
asurements, Areal Estimates and Relationships to Hydrologic
deling, via ABRFC Home Page - http://info.abrfc.noaa.gov/)