PRECIPITATION MEASUREMENT

BY

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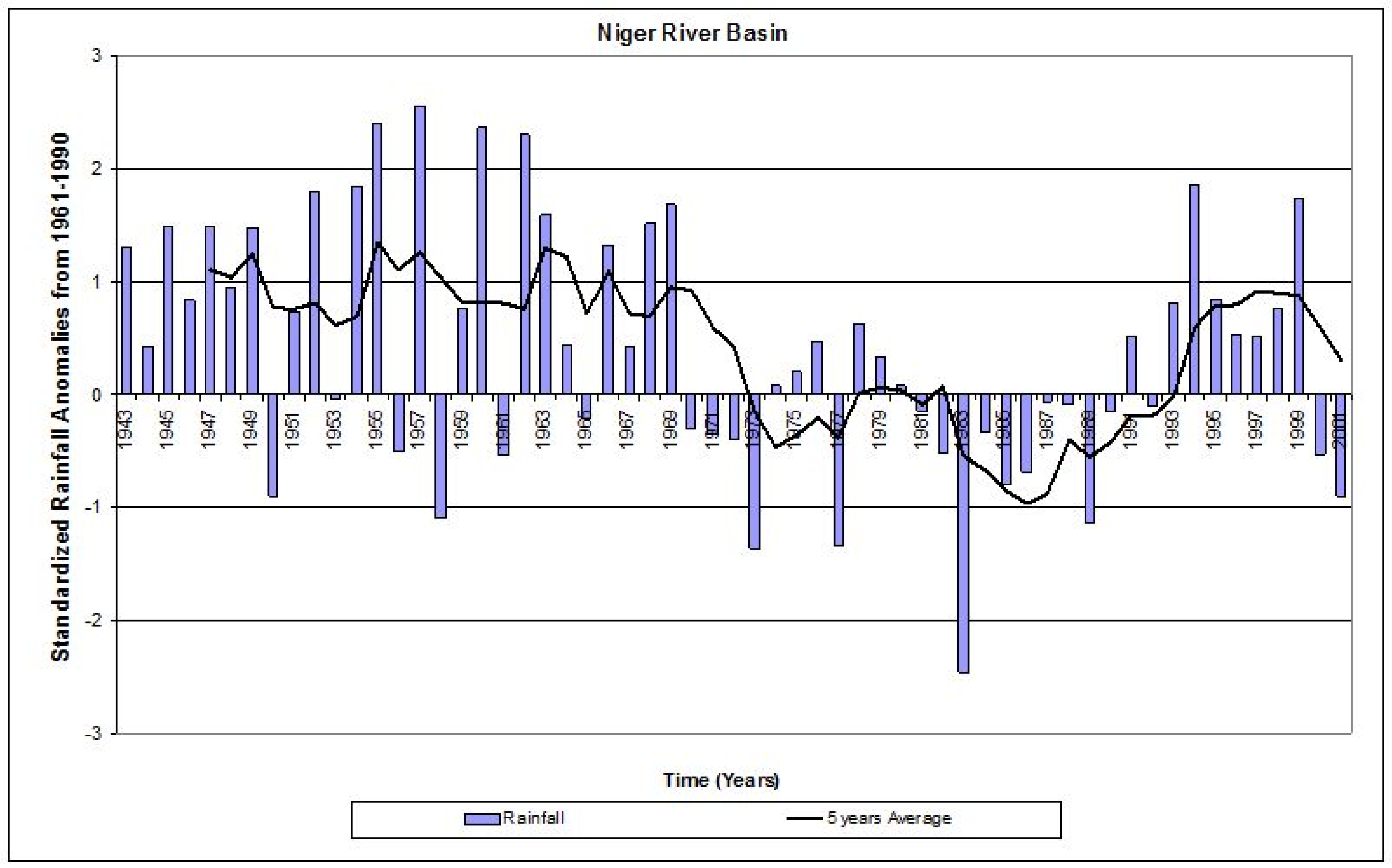
Precipitation

Precipitation is any product of the condensation of atmospheric water vapor that falls under gravity.

The main forms of precipitation include drizzle, rain, snow and hail.

Precipitation is a major component of the water cycle, and is responsible for depositing the fresh water on the planet.

Rainfall Variability



MORE RAIN

MORE RAIN

MORE RAIN

NO RAIN

NO RAIN

NO RAIN

NO RAIN

What do we Measure?

1- Amount of rain water.

2- Intensity of rainfall: water amount per unit of time (1 hour or I minute)

Rainfall Intensity

Light rain — when the precipitation rate is < 2.5 mm per hour

Moderate rain — when the precipitation rate is between 2.5 mm - 10.0 mm or 10 mm per hour.

Heavy rain — when the precipitation rate is between 10 mm and 50 mm per hour.

Violent rain — when the precipitation rate is > 50 mm per hour

RAIN

HAIL

SNOW

IGLOO

IGLOO VILLAGE

Standard Instrument

The standard rain gauge is a circular funnel with a diameter of 203mm which collects the rain into a graduated and calibrated cylinder.

The top of the rain gauge is 0.3m above the ground.

The measuring cylinder can record up to 25mm of precipitation.
Any excess precipitation is captured in the outer metal cylinder.

Types of Rain Gauges

and Klem estimate that there are over 50 different manual gauges in use worldwide.

Fate of Rain Water

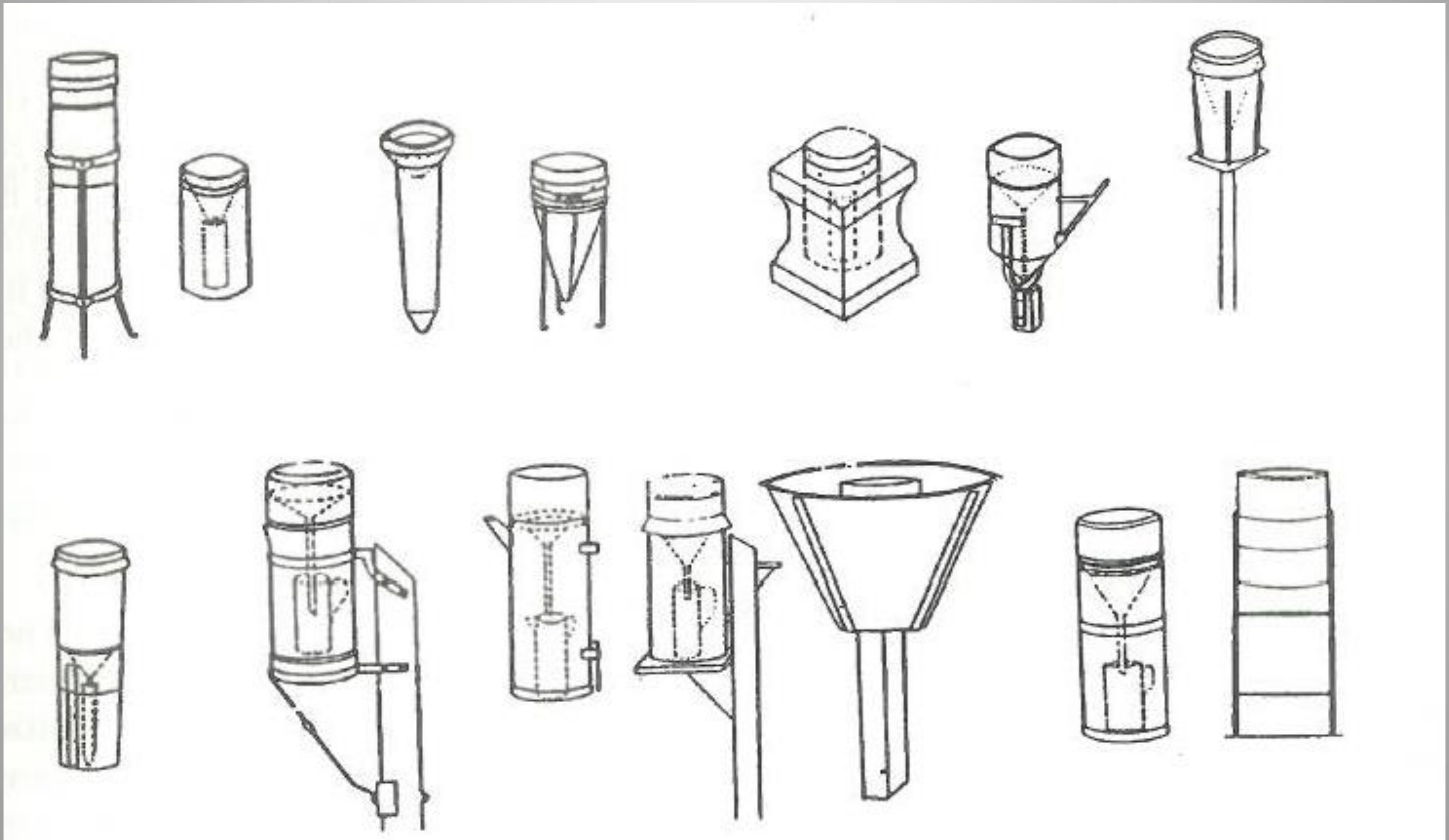
The total amount of rainfall over a given period is expressed as the depth of water which would cover a horizontal area.

1- No runoff,

2- No infiltration and

3- No evaporation.

Different Types of Rain Gauges

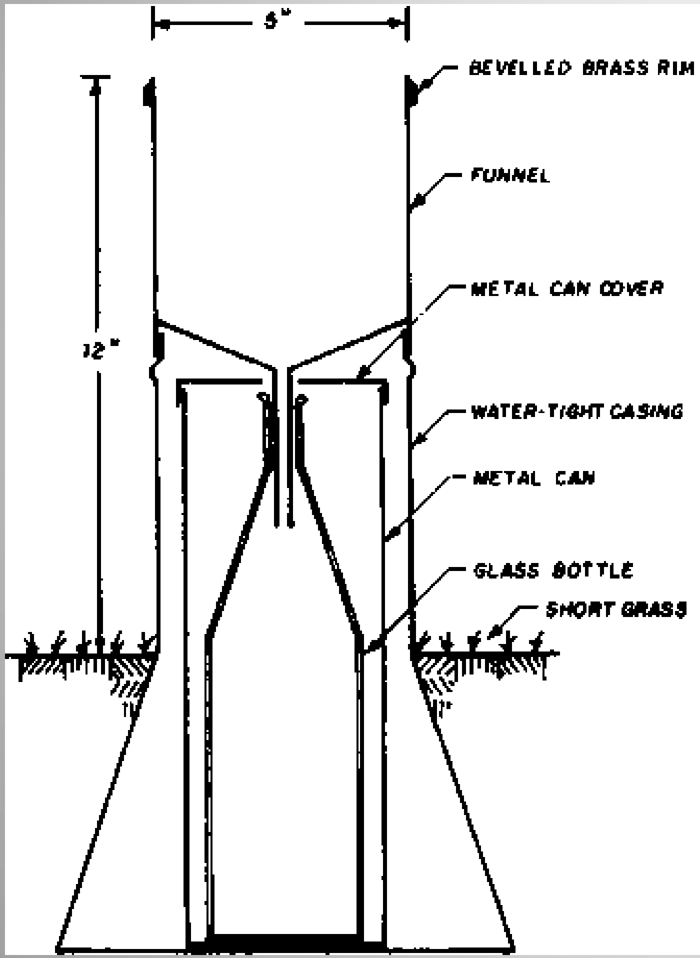


Types of Rain Gauges

The Standard Rain Gauge

The standard rain gauge, developed at the start of the 20th century, consists of a funnel emptying into a graduated cylinder, 2 cm in radius, which fits inside a larger container which is 20 cm in diameter and 50 cm tall.

Installation of Rain Gauge



1-The ground should preferably be grassed or loose earth.

2-No object such as another instrument, building or trees should be closer than four times their height.

3-Very exposed sites, such as on the top of a hill, should be avoided.

Recording Rain Gauge

The recording rain gauge consists of a rotating drum that rotates at constant speed, this drum drags a graduate sheet of cardboard, which has the time at the x axis while the y axis indicates the height of rainfall in mm of rain.

This height is recorded with a pen that moves vertically, driven by a buoy, marking on the paper the rainfall over the time (the cardboard sheet is usually for one day).

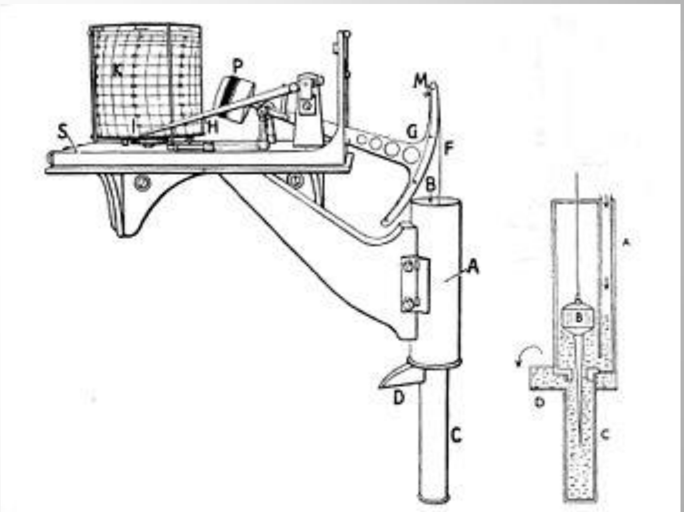
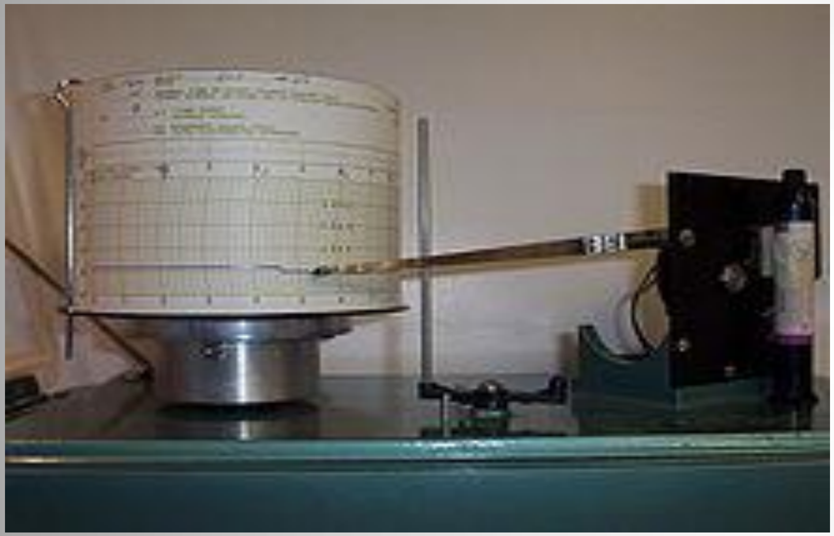
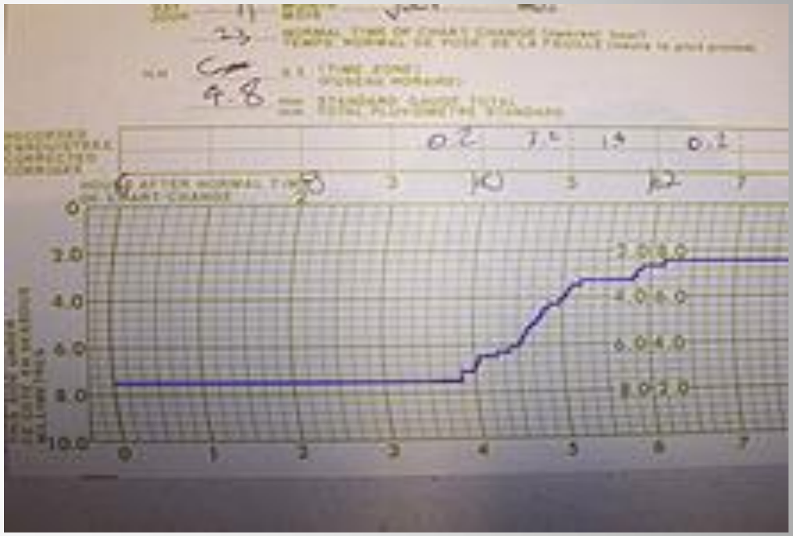
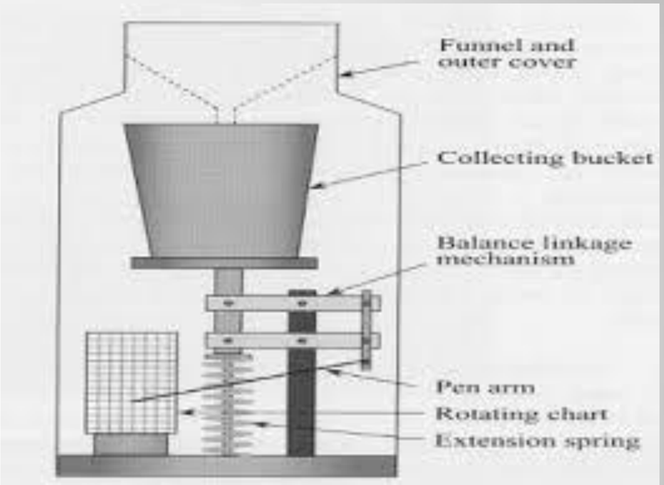


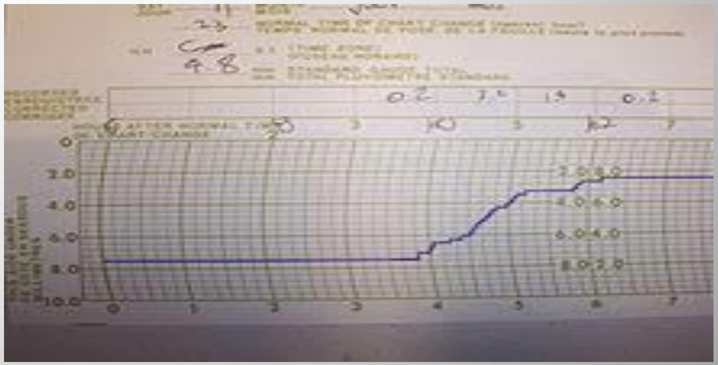
Chart of a Recording Rain Gauge



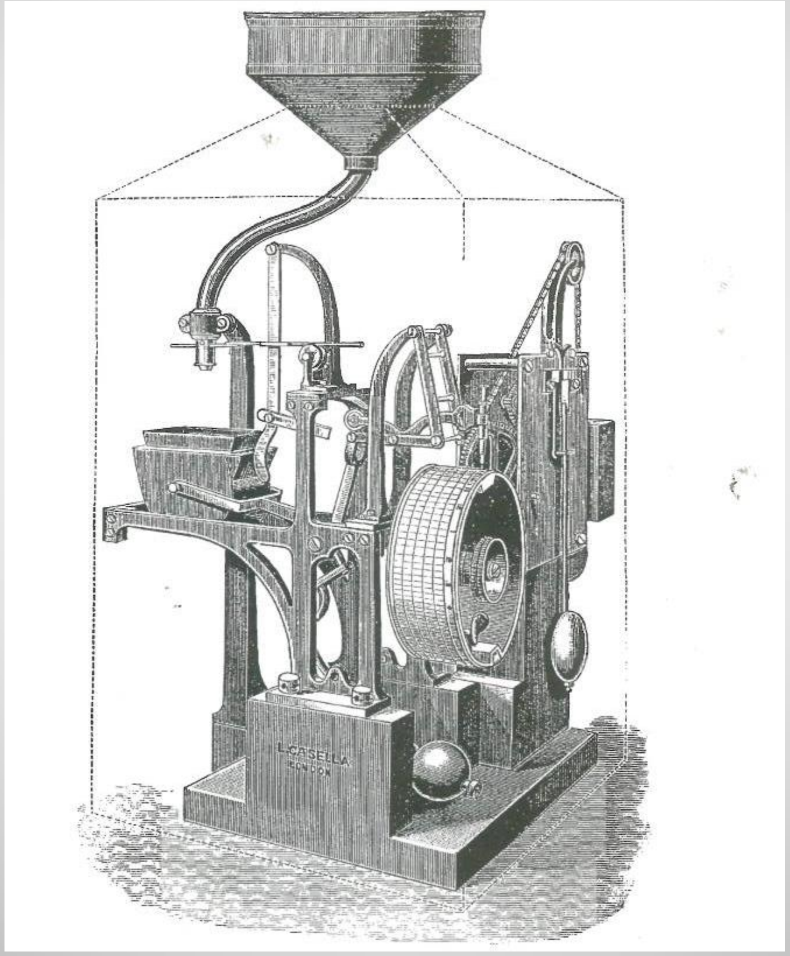


Recording Rain Gauge





First Recording Rain Gauge



Tipping Bucket Rain Gauge

In modern automatic weather stations a Tipping Bucket Rain Gauge (TBRG) is employed, which also has an aperture of 203mm.

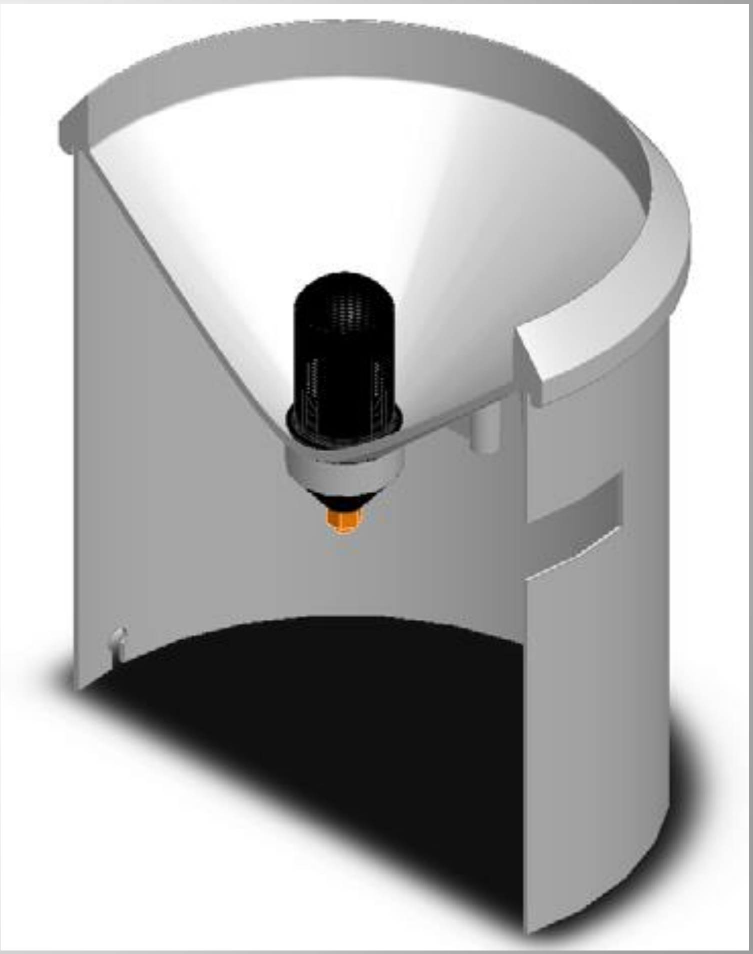
There are two advantages of this type of rain gauge.

Firstly, it never needs to be emptied, and

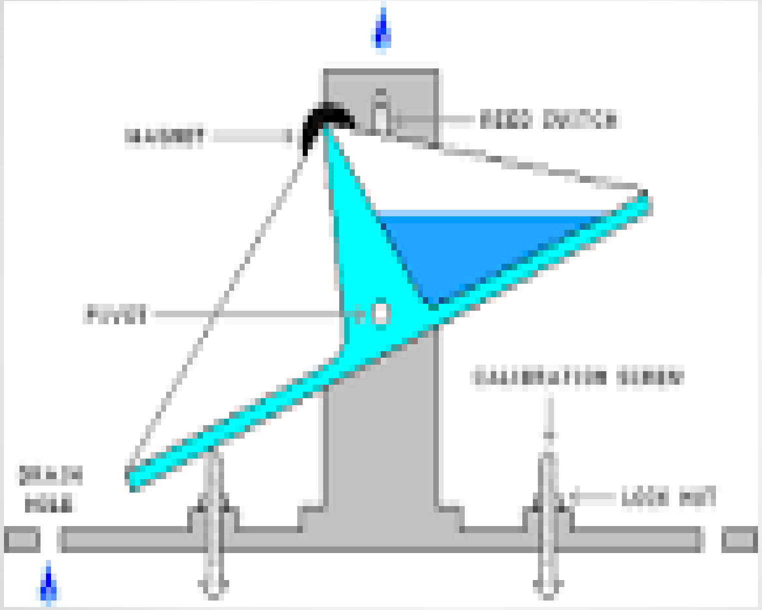
Secondly the amount of rainfall can be read automatically.

An electronic pulse is generated each time the volume of water collected in one of the small buckets causes the bucket to tip. This is equivalent to 0.2mm of precipitation.

Tipping Bucket Rain Gauge



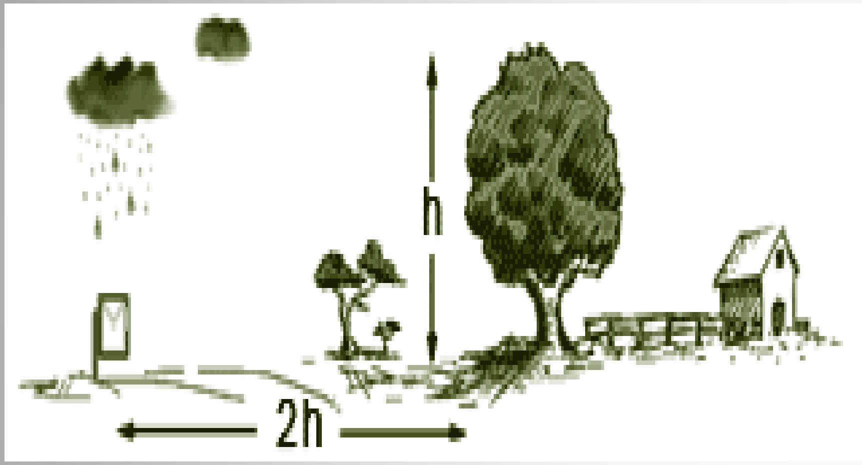
Tipping Bucket



TBRG

Range up to 250mm/hour. Accuracy 2%

Installation of Rain Gauge



The distance of the gauge from buildings, trees or other objects should be at least twice the height of the obstruction, and preferably four times the height.

For instance, the gauge should be more than 10 m from a house 5 m high and more than 30 m from the nearest branches of a tree 15 m high.

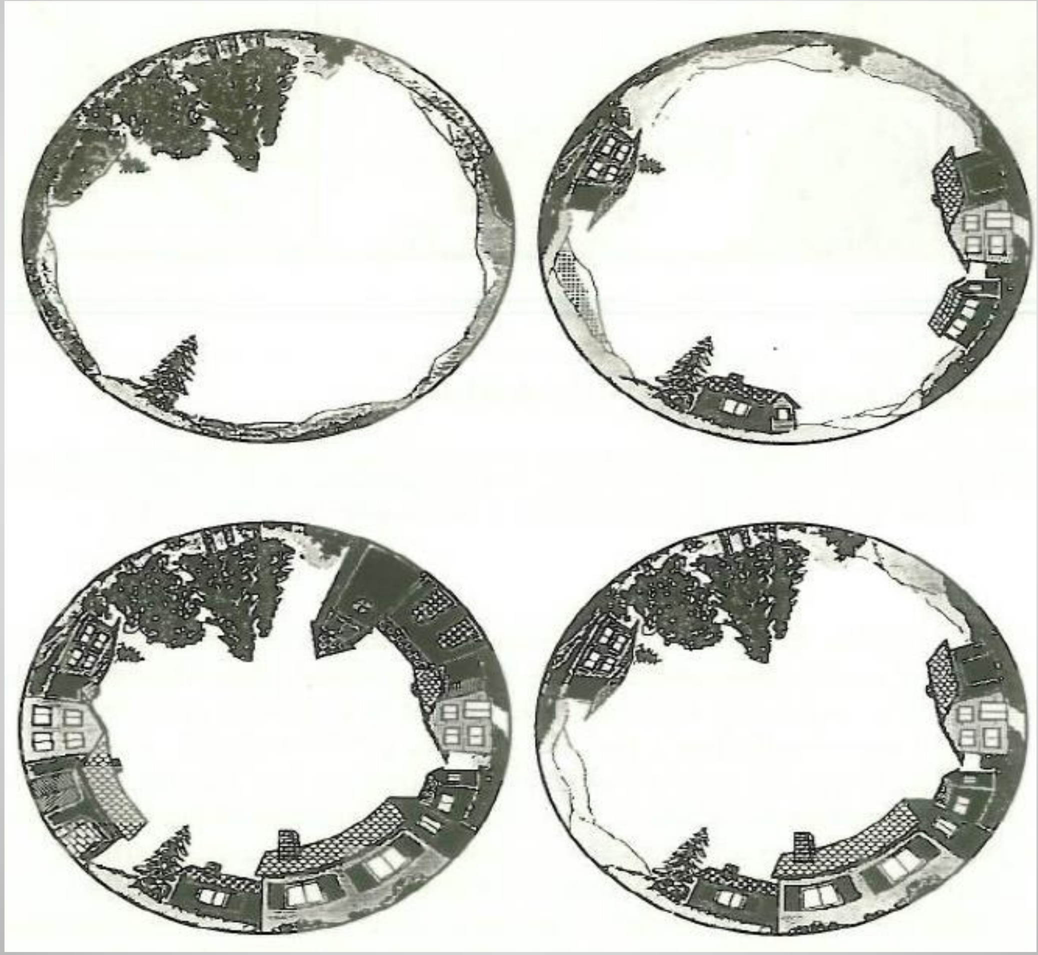
The gauge should also be in a place where it will not be disturbed by people, animals or vehicles.

Installation of Rain Gauge

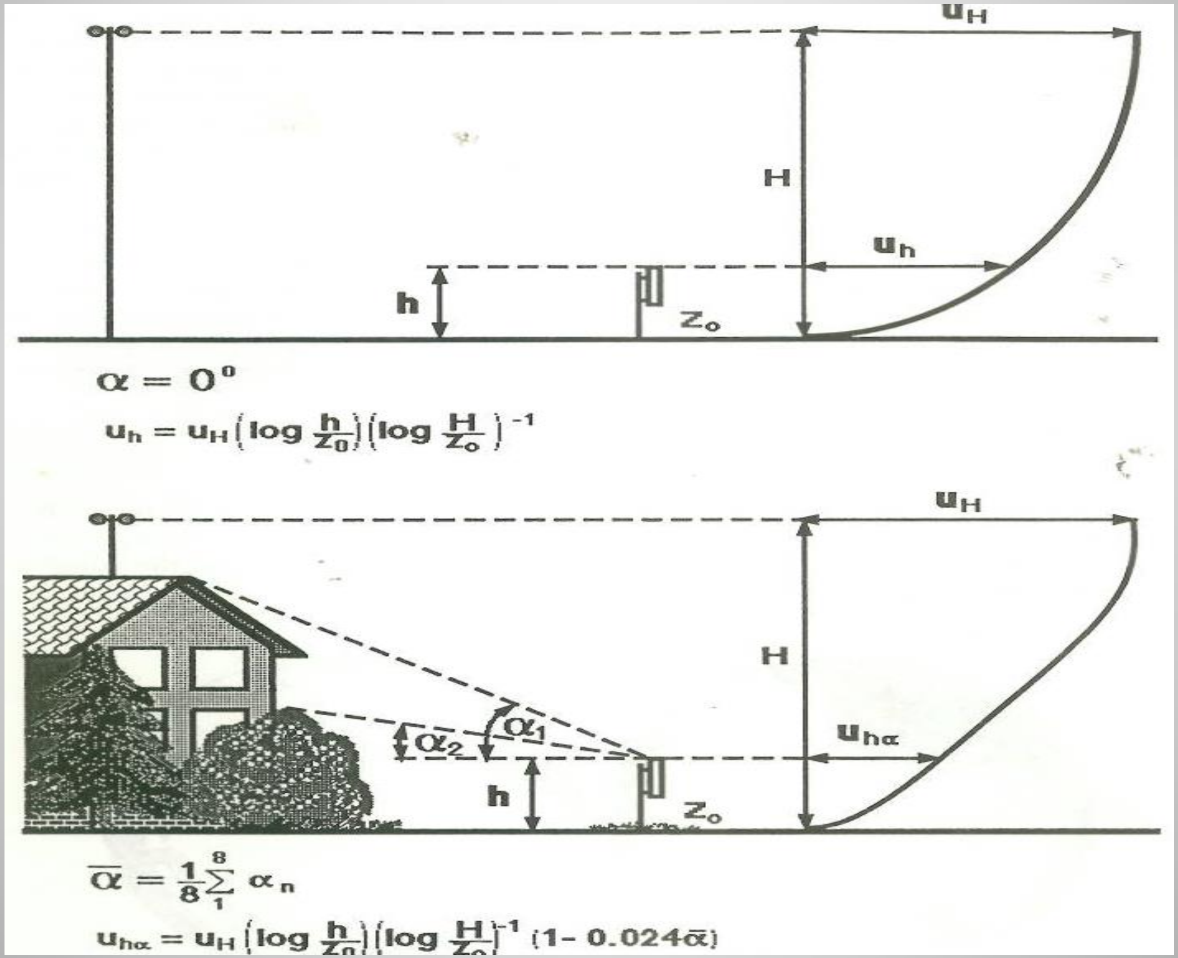
The WMO recommend that a rain gauge be placed away from any nearby obstacle a distance of at least twice the height of the obstacle.

Gauges sited near buildings, solid fences and trees can have serious errors in rainfall totals.

Rain Gauge Exposure
A fish-eye camera was used



Wind Speed and Shelter



Error

Accuracy of rainfall measurement is mainly affected by:

1- Wind.

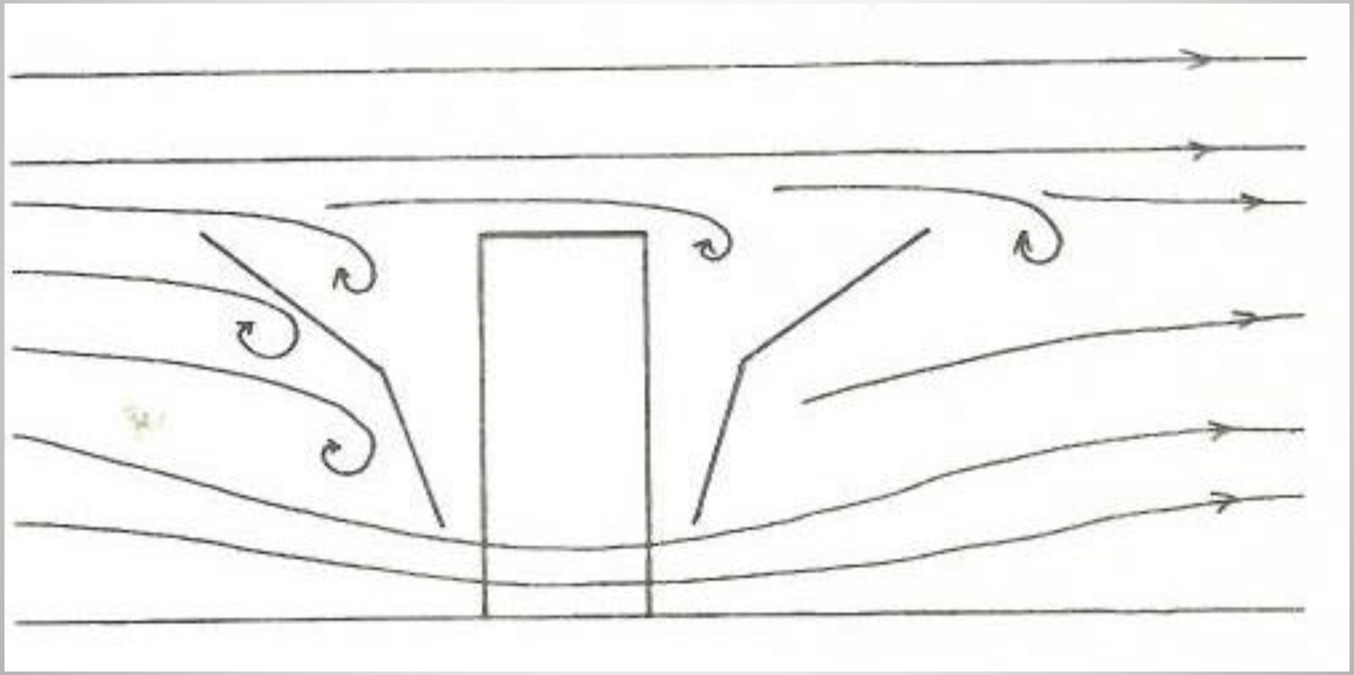
2- Height of the gauge.

3- Exposure.

4- Type of precipitation.

Wind and exposure errors can be very large, even more than 50 percent.

Wind around Rain Gauge



Type of Precipitation: Snow or Hail

Wind Induced Errors

Wind induced errors depend on 3 groups of variables:

A) Instrumental:

1- wind shield.

2- shape of gauge

3- shape and thickness of orifice.

B) Observational:

1- Height of gauge.

C) Environmental

1- Meteorological: wind speed, form and intensity of precipitation.

2- degree of protection

Ideal Network

1 Station per 600 – 900 squared kilometer.

Acceptable 1 per 900 – 3000 squared km.

10% of rain gauge stations should be equipped with self-recording rain gauges.

RADAR

Another method of measuring precipitation is through the use of radar.

Radars are active devices, emitting radiation at wavelengths ranging between 1 and 10 cm, and receiving the echo from targets such as raindrops.

The maximum range of radars is only about 300 km.

Radars are expensive.

RADAR

RADAR

The actual measurement taken by the radar is of backscattered power of the echo returns.

This return power is used to calculate a reflectivity factor, Z.

The Z reflectivity factor is then used in an equation referred to as a "Z-R relationship" to determine rainfall rate.

The radar precipitation estimates for an area of 4 by 4 km square grid resolution.

RADAR

One of the main uses of weather radar is to be able to assess the amount of precipitations fallen over large basins for hydrological purposes.

Radar-derived rainfall estimates compliment surface station data which can be used for calibration.

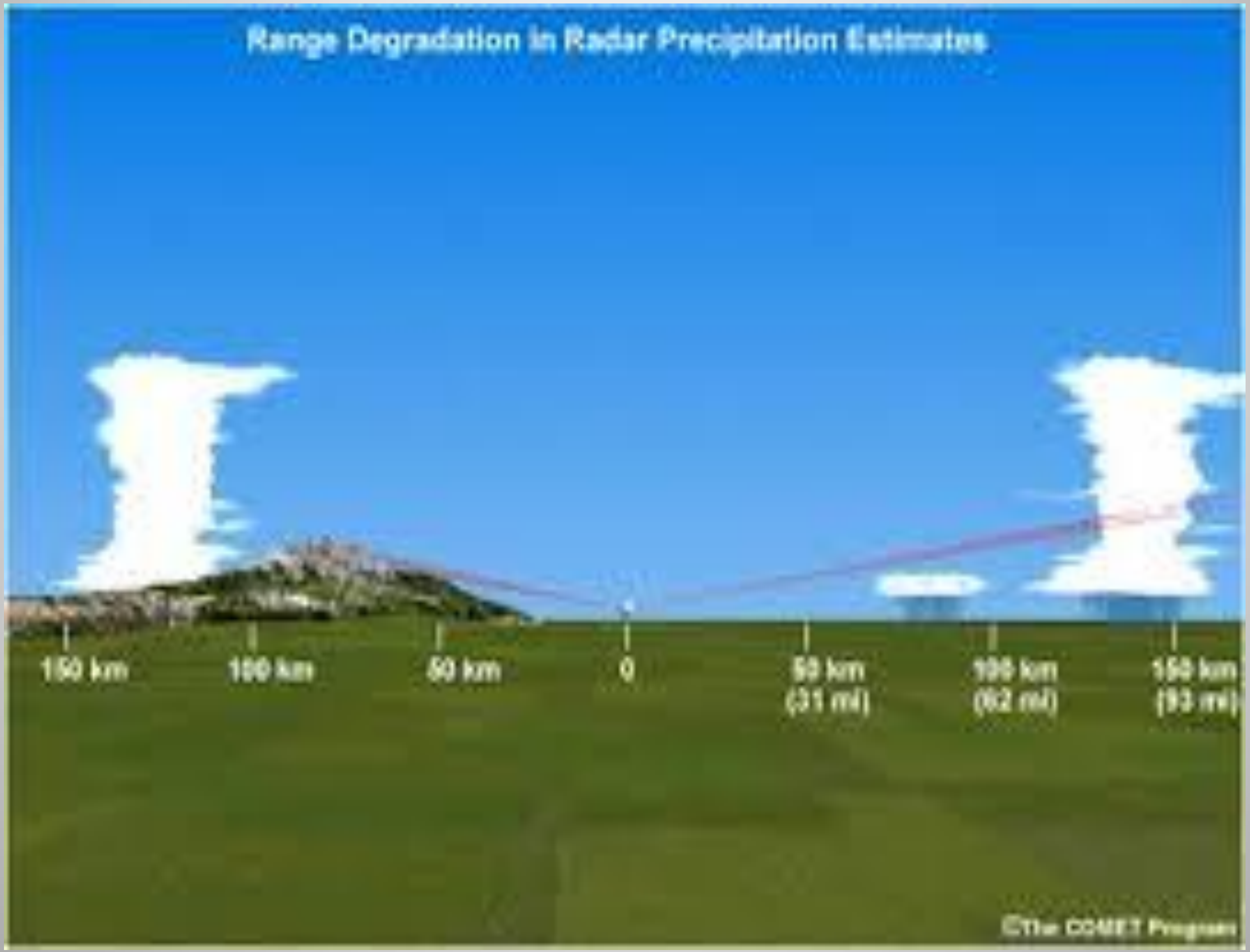
To produce radar accumulations, rain rates over a point are estimated by using the value of reflectivity data at individual grid points.

A radar equation is then used, which is,

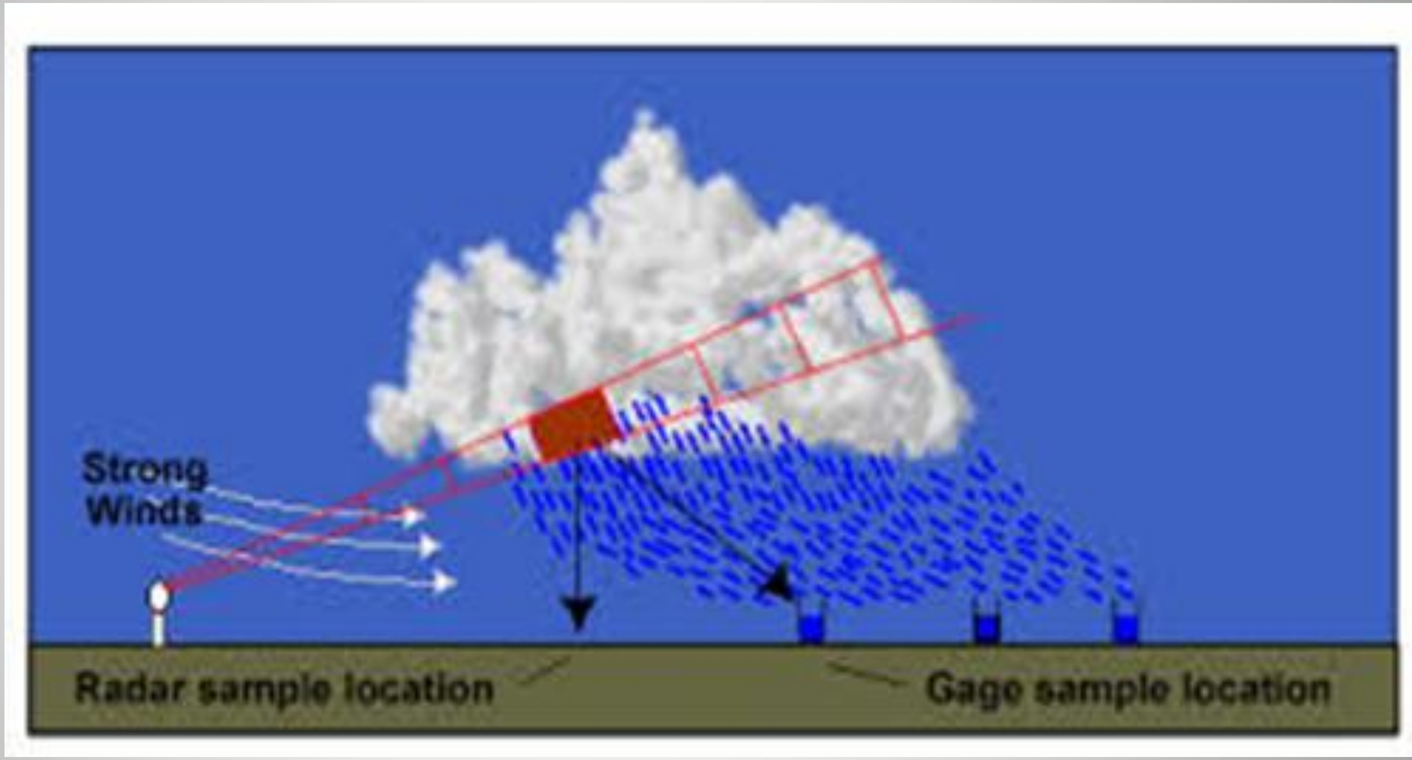
$$Z = AR^b$$

where Z represents the radar reflectivity, R represents the rainfall rate, and A and b are constants

RADAR/MOUNTAIN



RADAR/WIND



Satellite

Satellite derived rainfall estimates use passive microwave instruments aboard polar orbiting as well as geostationary weather satellites to indirectly measure rainfall rates.

If one wants an accumulated rainfall over a time period, one has to add up all the accumulations from each grid box within the images during that time.

Wide Coverage

Satellite-based measurements offer global coverage or a good part thereof.

Satellite

1- The rainfall rate (R mm/h) depends on the cloud-top temperature (T degrees Kelvin) thus:

2- $R = 1.1183 \times 10^{11} \times \exp(-3.6382 \times 10^{-2} \times T^{0.5})$

3- Adjustments are then made according to the precipitable water and surface relative humidity.

4- The rate of change of cloud-top temperature can be used as well. It indicates the speed of cloud growth, and hence the areas of heavy rainfall.

Satellites

Estimates of instantaneous area average rain rate 〈*R*〉 in millimeters per hour) are obtained with 5–10% accuracy over a large domain simply by measuring:

(1) the fraction of the area, $F(\tau)$, covered by rain intensity greater than a selected threshold τ and

(2) the average precipitating cloud top heights.

GOES Precipitation Index (GPI)

Simple threshold method:

R = 3.0 mm/hr * (fraction of pixels with $T_B \leq 235$K)

Satellites

Satellite precipitation estimates are widely used to measure global rainfall on monthly timescales for climate studies.

Near real time satellite precipitation estimates are becoming increasingly available to the wider community.

These precipitation estimates are potentially very useful for applications such as:

1- NWP Data Assimilation,

2- Nowcasting

3- Flash Flood Warning,

4- Tropical Rainfall Potential,

5- Water Resources Monitoring.

Water Cycle

Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth.

Tropical Rainfall Measuring Mission (TRMM

- **The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration (JAXA) Agency to study rainfall for weather and climate research.**

- **The TRMM satellite ended collecting data on April 15, 2015 Launched in late November 1997, with a design lifetime of 3 years, the TRMM satellite produced over 17 years of valuable scientific data.**

TRMM

TRMM observed rainfall rates over the tropics and subtropics, where two-thirds of the world’s rainfall occurs.

TRMM carried the first precipitation radar flown in space, which returned data that were made into 3-D imagery, enabling scientists to see the internal structure of storms for the first time.

Tropical Rain Measuring Mission (TRMM)

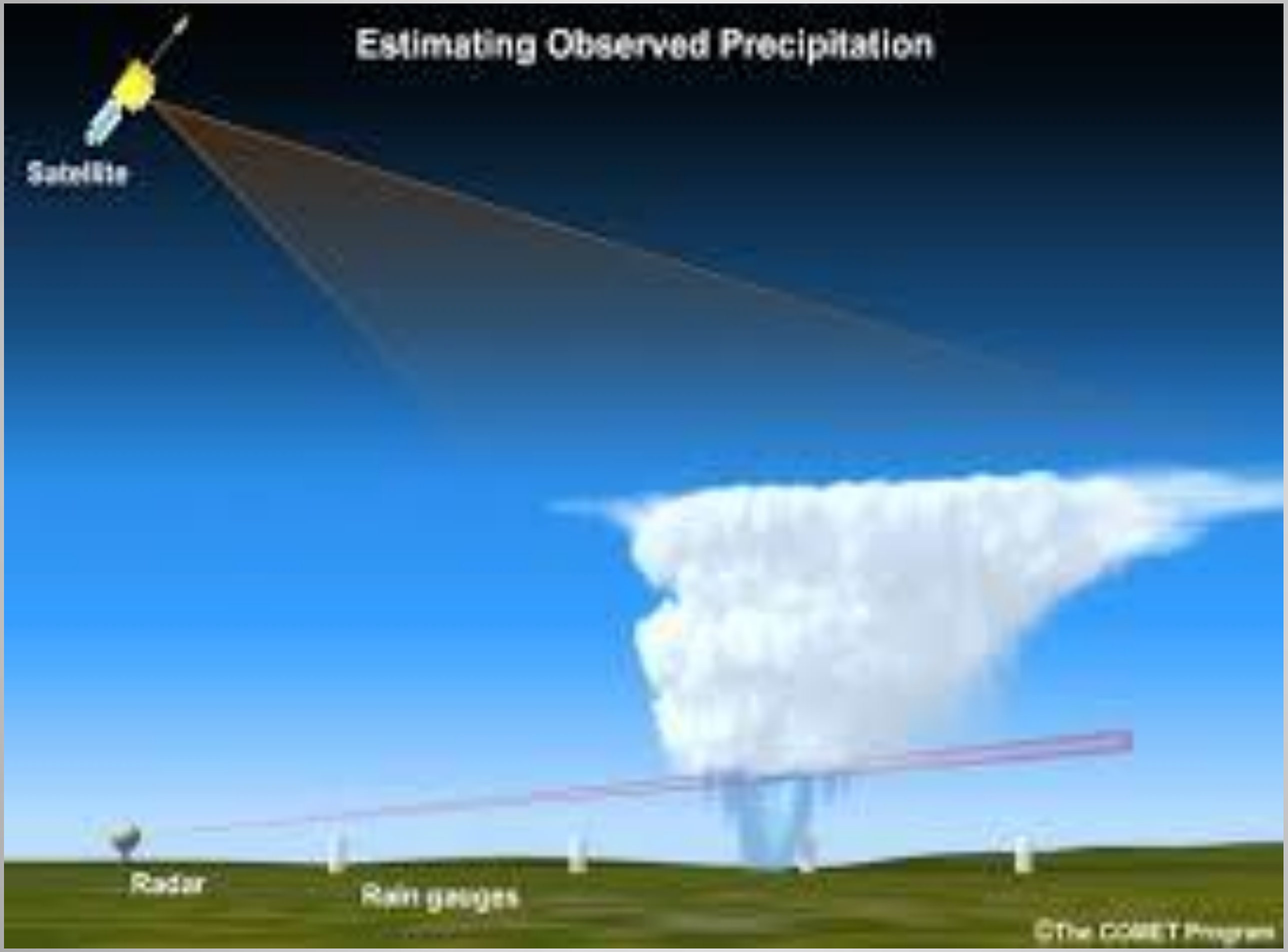
TRMM Microwave Imager (TMI), 780 km swath:

Band	Frequency (GHz)	Polarization	Horiz. Resol. (km)
1	10.7	V, H	38.3
2	19.4	V, H	18.4
3	21.3	H	16.5
4	37.0	V, H	9.7
5	85.5	V, H	4.4

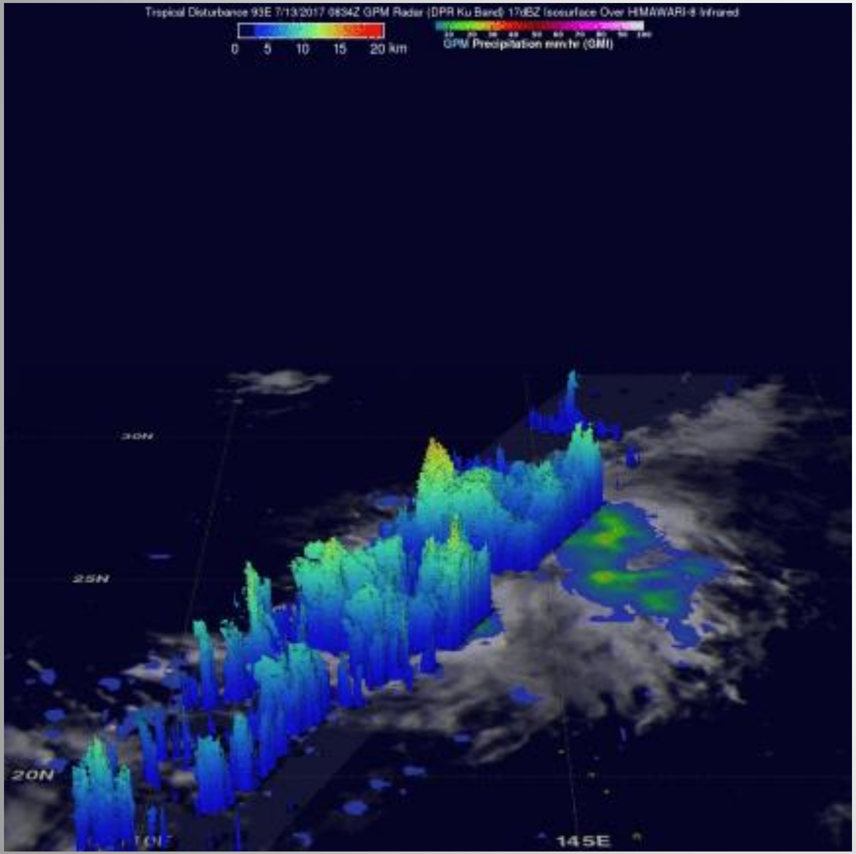
- Precipitation Radar, 220 km swath:
- Horizontal resolution of 4 km
- Profile of rain and snow from surface to ~20 km altitude

» Use precipitation radar to tune TMI rain

Radar on Board Satellite



TRMM



Data from the satellite's radars was used to perform a 3-D examination of precipitation in the area of possible tropical cyclone development.

Storm top heights in the tallest convective storms were found to reach heights above 15 km.

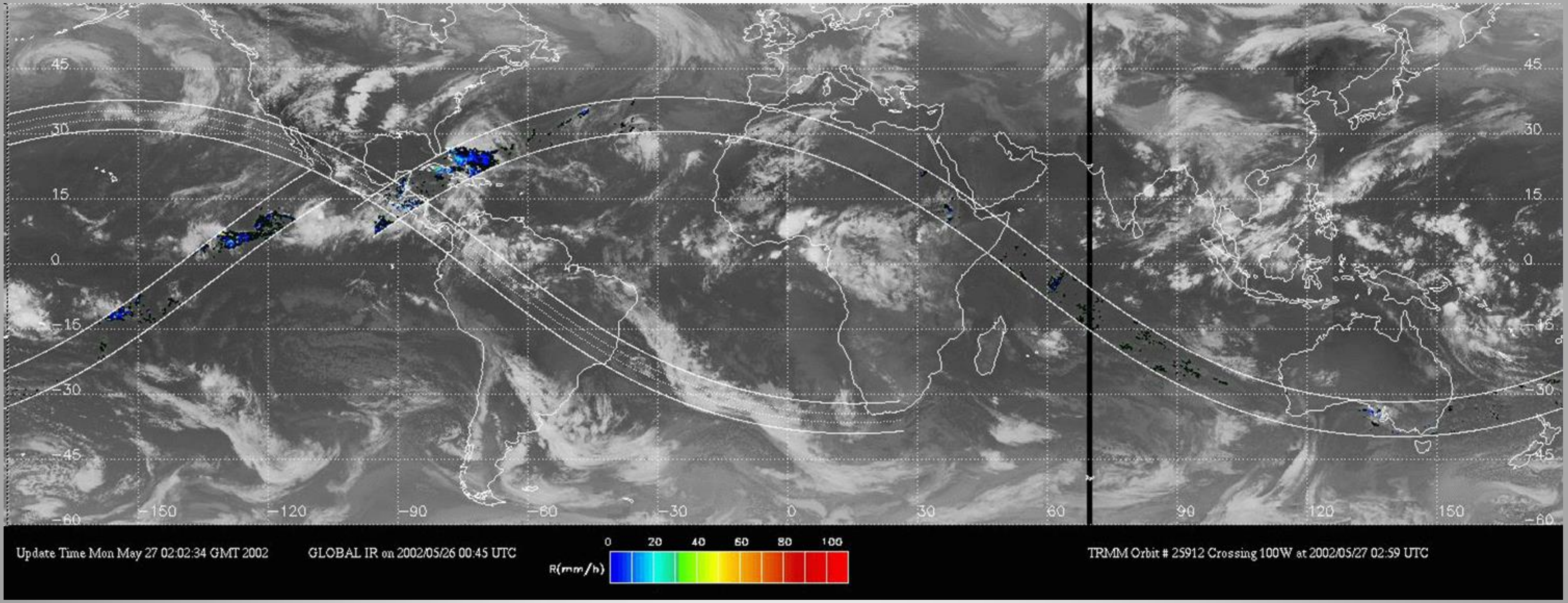
TRMM

- **The original goal was to provide monthly averages of rainfall over Earth's surface divided into large grid boxes, roughly 500 km square.**

- **TRMM eventually generated rainfall estimates at a higher resolution and in near-real time, every three hours.**

Tropical Rain Measuring Mission (TRMM

Instantaneous” rain rate



Applications

Hydrology

Civil Defence

Irrigation

Domestic uses

NWP

Rainfall- Runoff Modelling

The average rainfall over an area may be considered as the main input on watershed modeling process, especially of those which deal with surface runoff

Index of wetness

Index of wetness = Actual rainfall/ Normal amount of rainfall

If the index

- = 60%, the deficiency is 40%.
- = 30 – 45% Large deficiency.
- = 45- 60% Serious deficiency.
- More than 60%, disastrous.

Estimation of Areal Precipitation

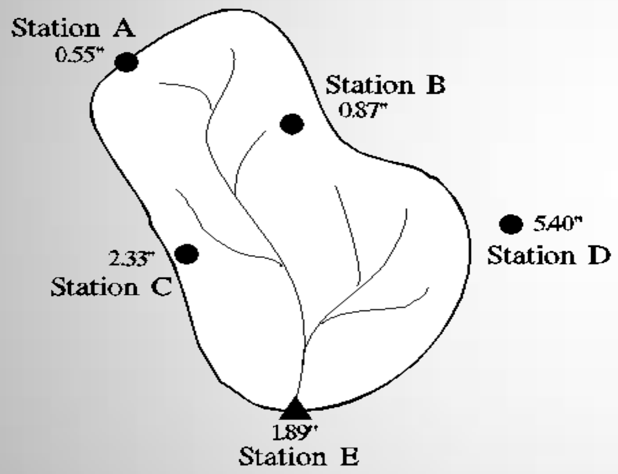
A single point precipitation measurement is quite often not representative of the volume of precipitation falling over a given catchment area.

A dense network of point measurements and/or radar estimates can provide a better representation of the true volume over a given area.

A network of precipitation measurements can be converted to areal estimates using any of a number of techniques which include the following:

1- Arithmetic Mean

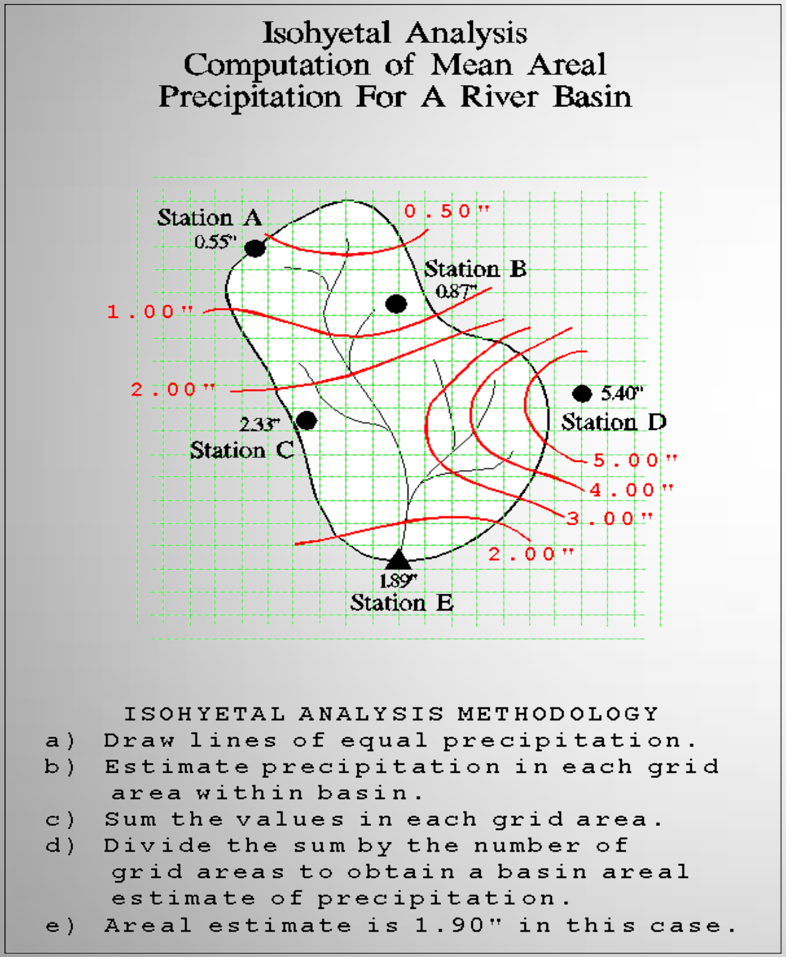
Arithmetic Mean of Point Values
Computation of Mean Areal
Precipitation For A River Basin



The areal precipitation estimate is calculated with this method as the arithmetic mean of the five station point measurements considered in this example. I.e., ((0.55+0.87+2.33+5.40+1.89)/5)=2.21"

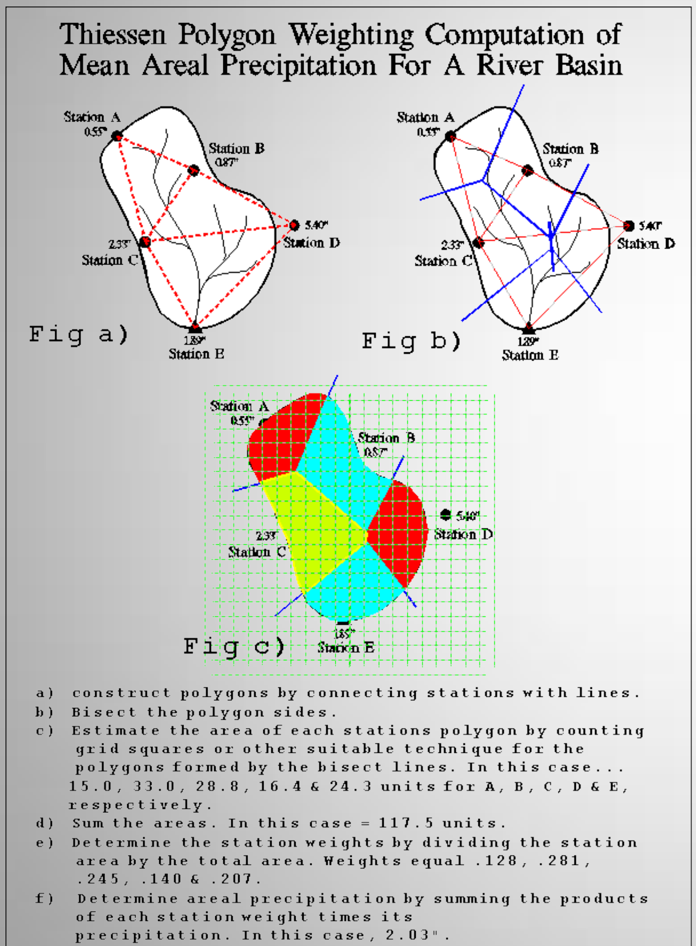
This technique calculates areal precipitation using the arithmetic mean of all the point or areal measurements considered in the analysis.

2- Isohyetal Analysis



This is a graphical technique which involves drawing estimated lines of equal rainfall over an area based on point measurements.

3- Thiessen Polygon

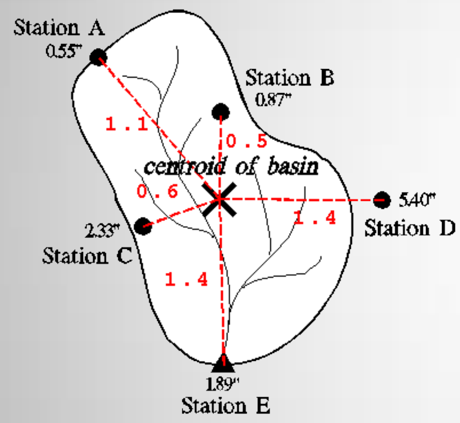


This is another graphical technique which calculates station weights based on the relative areas of each measurement station in the Thiessen polygon network.

The individual weights are multiplied by the station observation and the values are summed to obtain the areal average precipitation.

4- Distance Weighting/Gridded

Distance Weighting
Computation of Mean Areal
Precipitation For A River Basin



Sta	Dist	$1/D^2$	weight	precip	weighted precip
A	1.1	0.826	0.096	0.55"	0.05"
B	0.5	4.000	0.462	0.87"	0.40"
C	0.6	2.778	0.322	2.33"	0.75"
D	1.4	0.510	0.059	5.40"	0.32"
E	1.4	0.510	0.059	1.89"	0.11"
TOTALS		8.624		areal val=1.63"	

A grid of point estimates is made based on a distance weighting scheme.

Each observed point value is given a unique weight for each grid point based on the distance from the grid point in question.

The grid point precipitation value is calculated based on the sum of the individual station weight multiplied by observed station value.

Once the grid points have all been estimated they are summed and the sum is divided by the number of grid points to obtain the areal average precipitation.

How much Rain Water

- When we say the rain amount is 1mm that means it has a depth of 1mm over a flat surface.
- 1 mm of rain over an area of 1 squared meter is equivalent to 1 litre.
- 1 mm of rain over a house of an area of 400 square meters equals 400x1/1000 = 0.4 cubic meters.
- As the density of water is 1000 kg per cubic meters this means that the weight of the rain water of 1 mm is equal to 400 kg.
- Last weeks rainfall (75 mm) at a similar house in Al Kalakla = 0.4x75 = 30 cubic meters.

Energy of Rain Water

The heat of vaporization of water is about 2,260 kJ/kg.

1 mm of rain over an area of 1 squared metre is equivalent to I litre of water.

This is equivalent to 1 kg of water.

This means that each one mm of rain water leaves 2260 KJ of energy in a column of atmosphere with an area of 1 squared metre.

Extreme Rainfall

Duration	Amount mm	Place	Date
1 minute	38	Barot, Guadeloupe	26 Nov 1970
1 hour	401	Shangdi, China	03 Jul 1975
1 day	1825	Foc Foc, La Reunion	7-8 Jan 1966
1 month	9300	Cherrapunji, India	Jul 1861
1 year	26461	Cherrapunji, India	Aug 1860- Jul 1861

Rain

Thank You