Surface Water Hydrology
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Lecture – 08
Precipitation Data Quality and Presentation

In this week 2 we are learning hydrological analysis of precipitation. In today's lecture, we will see the precipitation data quality and its presentation.

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The major two concepts we will cover in this lecture. The first one is the evaluation of the quality of rainfall data, and then a presentation of rainfall data.

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The outline goes like this, we will see the rain gauge stations when we install in a catchment whether the number of any station is adequate or not for that particular catchment. Second thing, we will see the data quality, whether that data quality is sufficient or not to measure things we will see one is that continuity and the other one is consistency that we mentioned in the last class. So, far as the continuity is concerned, we will see the estimation of the missing data. And so far as the consistencies will test for consistency will try to correct the inconsistent data in a consistent manner. And finally, we will see the presentation of rainfall data generally in three main parts one is the mass curve, hydrograph, and point rainfall.

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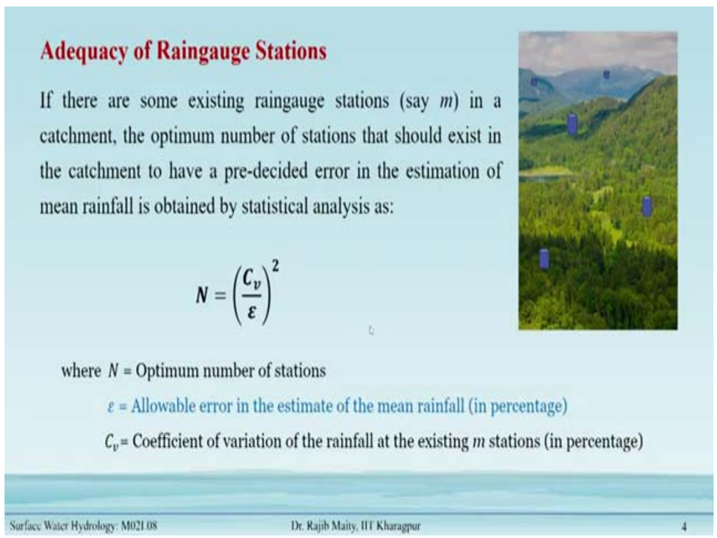

Adequacy of Rain gauge Stations

If there are some existing rain gauge stations (say m) in a catchment, the optimum number of stations that should exist in the catchment to have a pre-decided error in the estimation of mean rainfall is obtained by statistical analysis as:

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

Where, N = Optimum number of stations

ε = Allowable error in the estimate of the mean rainfall (in percentage)

C_v= Coefficient of variation of the rainfall at the existing m stations (in percentage.

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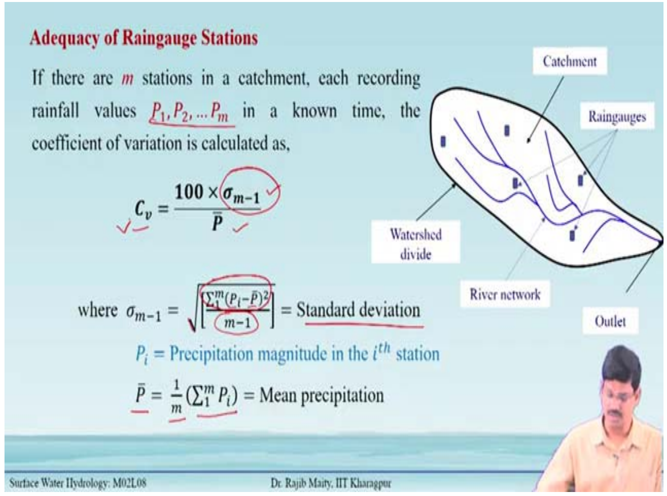

If there are m stations in a catchment, each recording rainfall values P_1, P_2, $\ldots P_m$ in a known time, the coefficient of variation is calculated as,

$$C_v = \frac{100 \times \sigma_{m-1}}{\bar{P}}$$

Where, $\sigma_{m-1} = \sqrt{\left[\frac{\sum_1^m (P_i - \bar{P})^2}{m-1}\right]}$ = Standard deviation

P_i= Precipitation magnitude in the ith station

$\bar{P} = \frac{1}{m}\left(\sum_1^m P_i\right)$ = Mean precipitation

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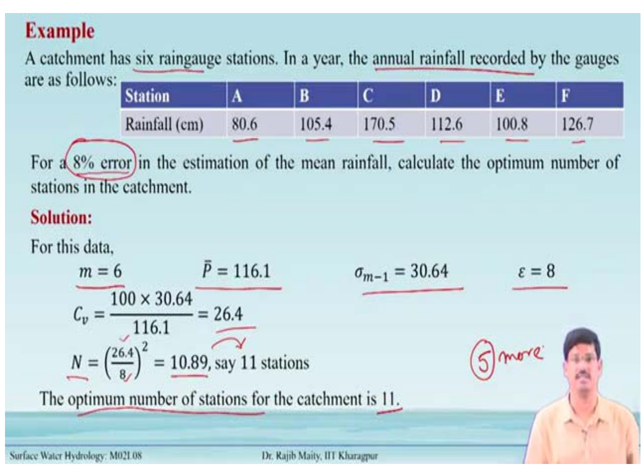

Example

A catchment has six rain gauge stations. In a year, the annual rainfall recorded by the gauges are as follows:

Station	A	B	C	D	E	F
Rainfall (cm)	80.6	105.4	170.5	112.6	100.8	126.7

For an 8% error in the estimation of the mean rainfall, calculate the optimum number of stations in the catchment.

Solution:

For this data,

$$m = 6 \qquad \bar{P} = 116.1 \qquad \sigma_{m-1} = 30.64 \qquad \varepsilon = 8$$

$$C_v = \frac{100 \times 30.64}{116.1} = 26.4$$

$$N = \left(\frac{26.4}{8}\right)^2 = 10.89, \text{ say 11 stations}$$

The optimum number of stations for the catchment is 11.

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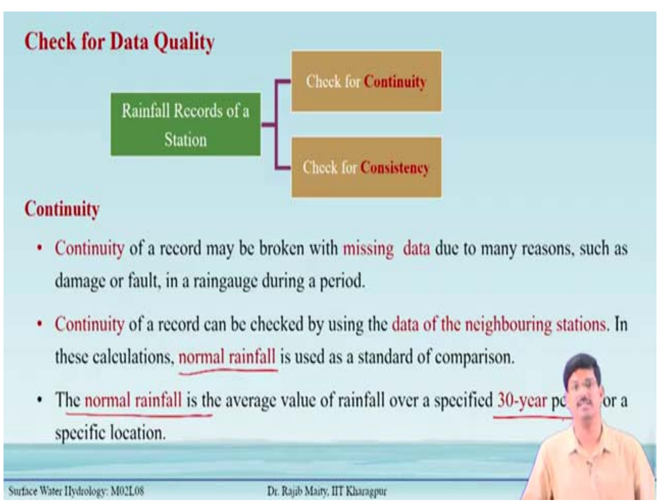

Check for Data Quality

Next, to check the data quality so far as the data quality is concerned, we take that rainfall record of a station and we check for two different things one is the continuity and the other one is the consistency.

Continuity: Continuity of a record may be broken with missing data due to many reasons, such as damage or fault, in a rain gauge during a period. The continuity of a record can be checked by using the data of the neighboring stations. In these calculations, normal rainfall is used as a standard of comparison. The normal rainfall is the average value of rainfall over a specified 30-year period for a specific location

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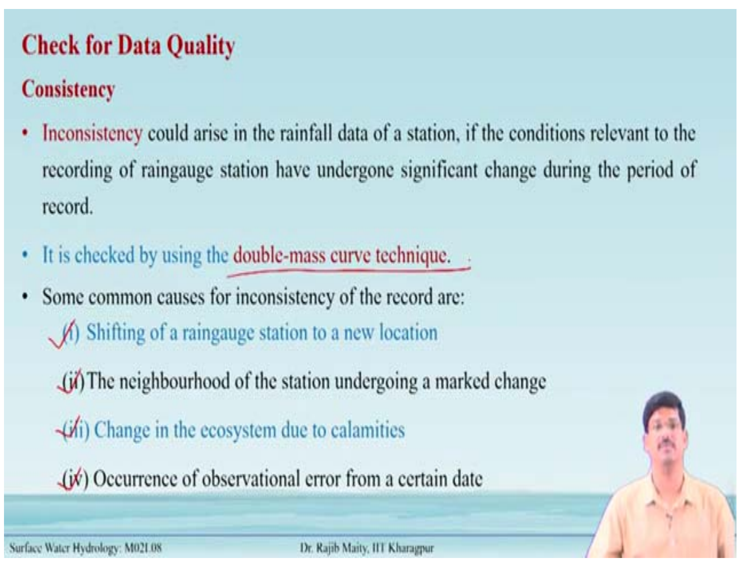

Consistency: Inconsistency could arise in the rainfall data of a station if the conditions relevant to the recording of rain gauge station have undergone significant change during the period of record. It is checked by using the double-mass curve technique.

Some common causes for the inconsistency of the record are:

(i) Shifting of a rain gauge station to a new location

(ii) The neighborhood of the station undergoing a marked change

(iii) Change in the ecosystem due to calamities

(iv) Occurrence of observational error from a certain date

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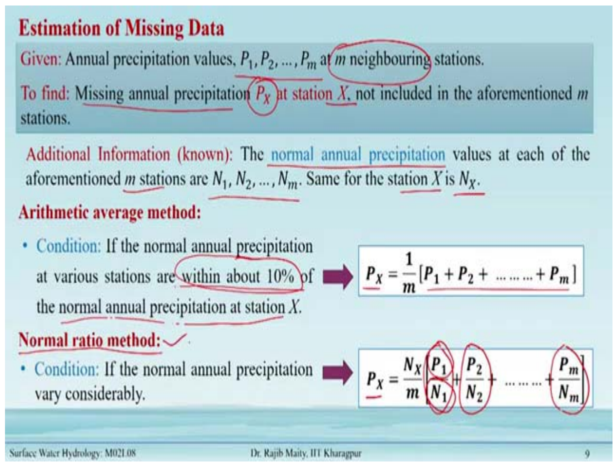

Estimation of Missing Data

Given: Annual precipitation values, P_1, P_2… P_m at m neighboring stations.

To find: Missing annual precipitation P_X at station X, not included in the aforementioned m stations.

Additional Information (known): The normal annual precipitation values at each of the aforementioned m stations are N_1, N_2…N_m. Same for the station X is N_x.

Arithmetic average method:

Condition: If the normal annual precipitation at various stations are within about 10% of the normal annual precipitation at station X.

$$P_X = \frac{1}{m}[P_1 + P_2 + \ldots\ldots\ldots + P_m]$$

Normal ratio method:

Condition: If the normal annual precipitation vary considerably.

$$P_X = \frac{N_X}{m}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \ldots\ldots\ldots + \frac{P_m}{N_m}\right]$$

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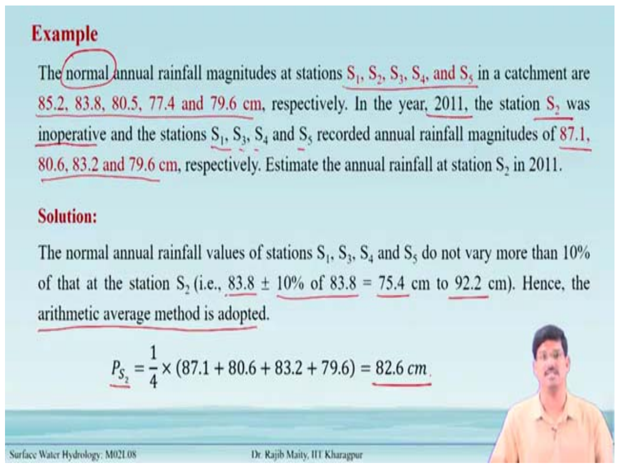

Example

The normal annual rainfall magnitudes at stations S_1, S_2, S_3, S_4, and S_5 in a catchment are 85.2, 83.8, 80.5, 77.4, and 79.6 cm, respectively. In the year, 2011, station S_2 was inoperative and stations S_1, S_3, S_4, and S_5 recorded annual rainfall magnitudes of 87.1, 80.6, 83.2, and 79.6 cm, respectively. Estimate the annual rainfall at station S_2 in 2011.

Solution:

The normal annual rainfall values of stations S_1, S_3, S_4, and S_5 do not vary more than 10% of that at the station S_2 (i.e., 83.8 ± 10% of 83.8 = 75.4 cm to 92.2 cm). Hence, the arithmetic average method is adopted.

$$P_{S_2} = \frac{1}{4} \times (87.1 + 80.6 + 83.2 + 79.6) = 82.6\ cm$$

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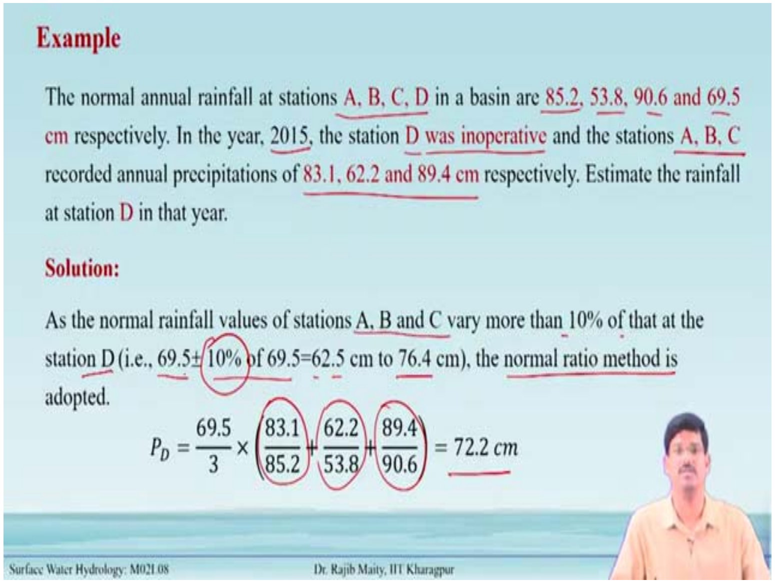

Example

The normal annual rainfall at stations A, B, C, and D in a basin is 85.2, 53.8, 90.6, and 69.5 cm respectively. In the year, 2015, station D was inoperative and the station's A, B, C recorded annual precipitations of 83.1, 62.2, and 89.4 cm respectively. Estimate the rainfall at station D in that year.

Solution:

As the normal rainfall values of stations A, B and C vary more than 10% of that at station D (i.e., 69.5± 10% of 69.5=62.5 cm to 76.4 cm), the normal ratio method is adopted.

$$P_D = \frac{69.5}{3} \times \left(\frac{83.1}{85.2} + \frac{62.2}{53.8} + \frac{89.4}{90.6}\right) = 72.2\ cm$$

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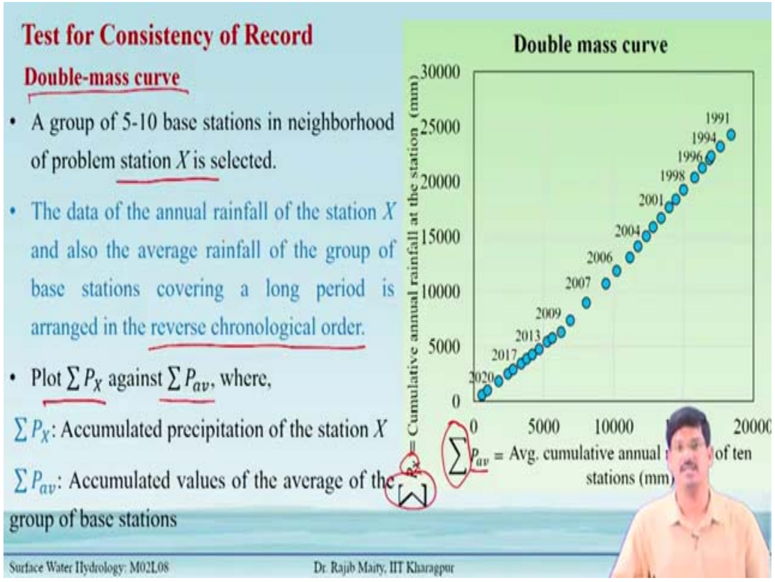

Test for Consistency of Record

Double-mass curve

A group of 5-10 base stations in the neighborhood of problem station X is selected.

The data of the annual rainfall of station X and also the average rainfall of the group of base stations covering a long period is arranged in reverse chronological order.

Plot $\sum P_x$ against $\sum P_{av}$, where,

$\sum P_x$: Accumulated precipitation of the station X

$\sum P_{av}$: Accumulated values of the average of the group of base stations.

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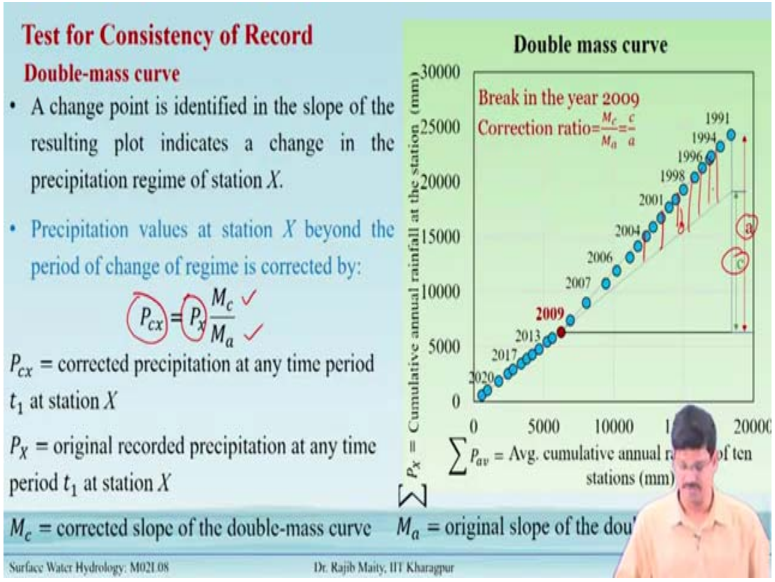

A change point is identified in the slope of the resulting plot indicates a change in the precipitation regime of station X.

Precipitation values at station X beyond the period of change of regime is corrected by:

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

P_{cx}= corrected precipitation at any time period t_1 at station X

P_x= original recorded precipitation at any time period t_1 at station X

M_c= corrected slope of the double-mass curve

M_a= original slope of the double-mass curve

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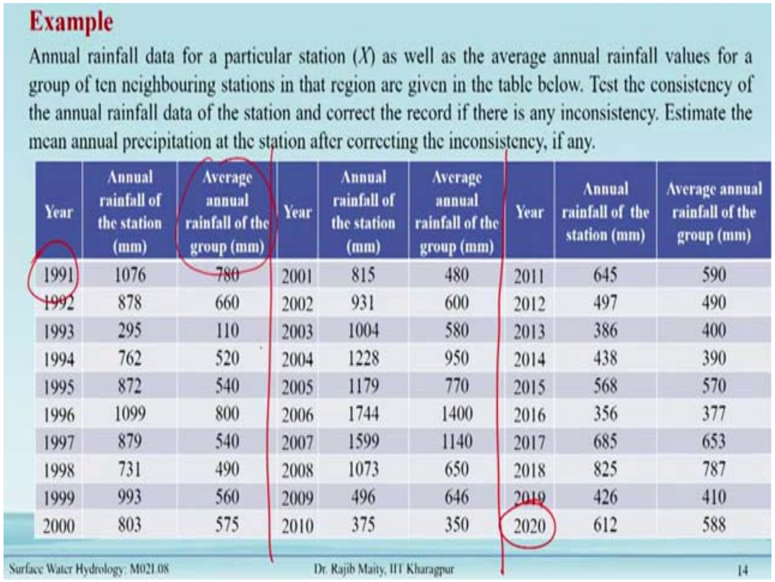

Example

Annual rainfall data for a particular station (*X*) as well as the average annual rainfall values for a group of ten neighboring stations in that region are given in the table below. Test the consistency of the annual rainfall data of the station and correct the record if there is any inconsistency. Estimate the mean annual precipitation at the station after correcting the inconsistency, if any.

Year	Annual rainfall of the station (mm)	Average annual rainfall of the group (mm)	Year	Annual rainfall of the station (mm)	Average annual rainfall of the group (mm)	Year	Annual rainfall of the station (mm)	Average annual rainfall of the group (mm)
1991	1076	780	2001	815	480	2011	645	590
1992	878	660	2002	931	600	2012	497	490
1993	295	110	2003	1004	580	2013	386	400
1994	762	520	2004	1228	950	2014	438	390
1995	872	540	2005	1179	770	2015	568	570
1996	1099	800	2006	1744	1400	2016	356	377
1997	879	540	2007	1599	1140	2017	685	653
1998	731	490	2008	1073	650	2018	825	787
1999	993	560	2009	496	646	2019	426	410
2000	803	575	2010	375	350	2020	612	588

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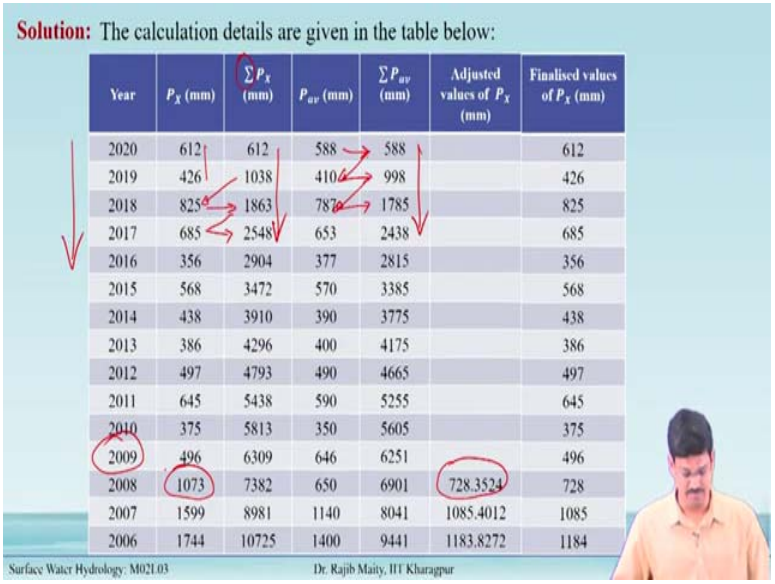
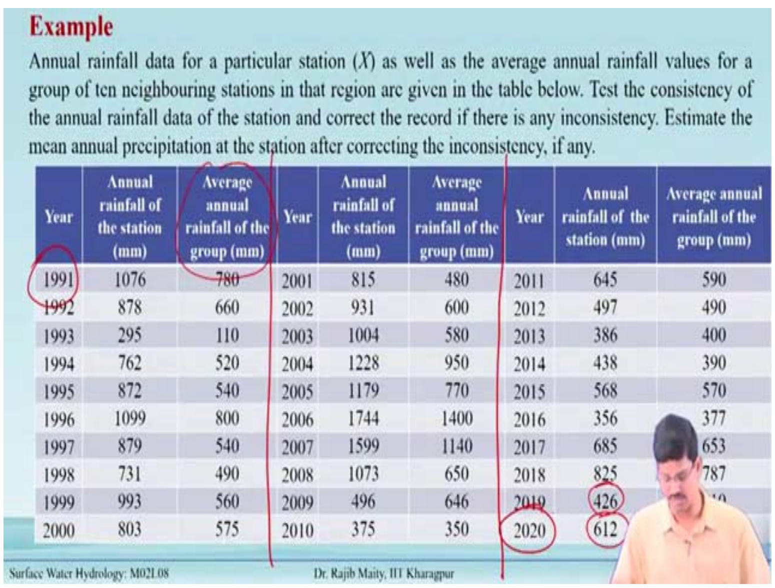


Solution: The calculation details are given in the table below:

Year	P_X (mm)	$\sum P_X$ (mm)	P_{av} (mm)	$\sum P_{av}$ (mm)	Adjusted values of P_X (mm)	Finalised values of P_X (mm)
2020	612	612	588	588		612
2019	426	1038	410	998		426
2018	825	1863	787	1785		825
2017	685	2548	653	2438		685
2016	356	2904	377	2815		356
2015	568	3472	570	3385		568
2014	438	3910	390	3775		438
2013	386	4296	400	4175		386
2012	497	4793	490	4665		497
2011	645	5438	590	5255		645
2010	375	5813	350	5605		375
2009	496	6309	646	6251		496
2008	1073	7382	650	6901	728.3524	728
2007	1599	8981	1140	8041	1085.4012	1085
2006	1744	10725	1400	9441	1183.8272	1184



Example

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1995	872	540	2005	1179	770	2015	568	570
1996	1099	800	2006	1744	1400	2016	356	377
1997	879	540	2007	1599	1140	2017	685	653
1998	731	490	2008	1073	650	2018	825	787
1999	993	560	2009	496	646	2019	426	[illegible]
2000	803	575	2010	375	350	2020	612	

Solution: The calculation details are given in the table below:

Year	P_X (mm)	$\sum P_X$ (mm)	P_{av} (mm)	$\sum P_{av}$ (mm)	Adjusted values of P_X (mm)	Finalised values of P_X (mm)
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2014	438	3910	390	3775		438
2013	386	4296	400	4175		386
2012	497	4793	490	4665		497
2011	645	5438	590	5255		645
2010	375	5813	350	5605		375
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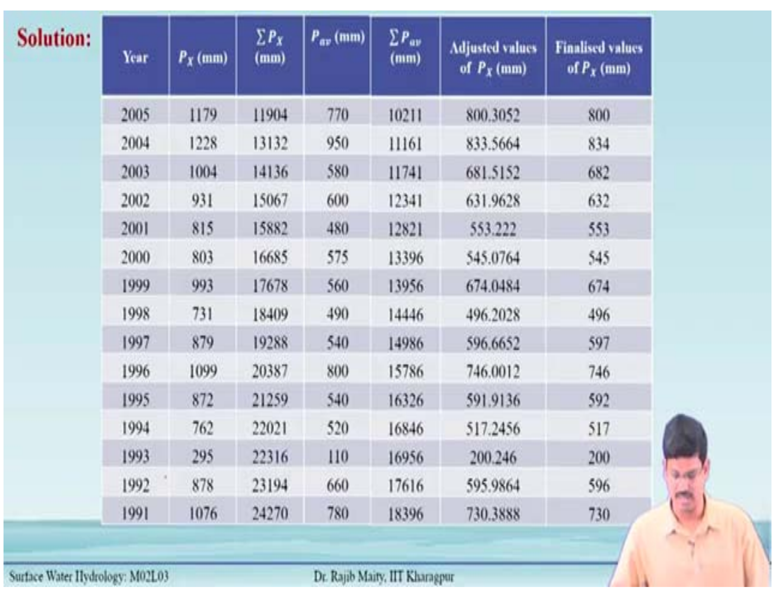

Year	P_X (mm)	$\sum P_X$ (mm)	P_{av} (mm)	$\sum P_{av}$ (mm)	Adjusted values of P_X (mm)	Finalised values of P_X (mm)
2005	1179	11904	770	10211	800.3052	800
2004	1228	13132	950	11161	833.5664	834
2003	1004	14136	580	11741	681.5152	682
2002	931	15067	600	12341	631.9628	632
2001	815	15882	480	12821	553.222	553
2000	803	16685	575	13396	545.0764	545
1999	993	17678	560	13956	674.0484	674
1998	731	18409	490	14446	496.2028	496
1997	879	19288	540	14986	596.6652	597
1996	1099	20387	800	15786	746.0012	746
1995	872	21259	540	16326	591.9136	592
1994	762	22021	520	16846	517.2456	517
1993	295	22316	110	16956	200.246	200
1992	878	23194	660	17616	595.9864	596
1991	1076	24270	780	18396	730.3888	730

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Σ=18501

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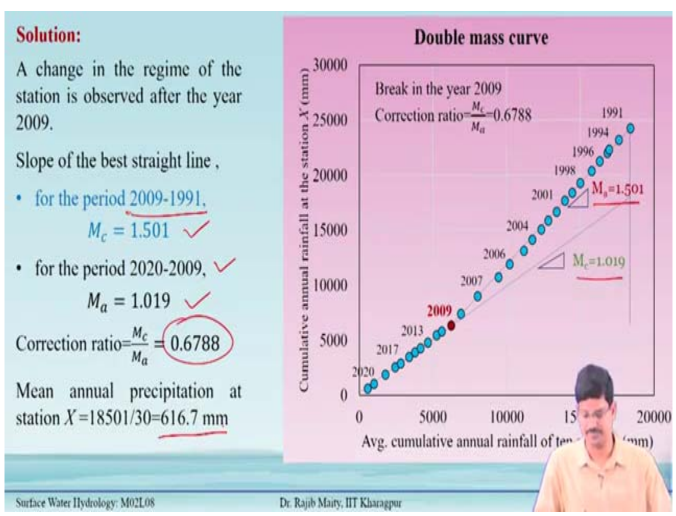

Solution: The calculation details are given in the table below:

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2016	356	2904	377	2815		356
2015	568	3472	570	3385		568
2014	438	3910	390	3775		438
2013	386	4296	400	4175		386
2012	497	4793	490	4665		497
2011	645	5438	590	5255		645
2010	375	5813	350	5605		375
2009	496	6309	646	6251		496
2008	1073	7382	650	6901	728.3524	728
2007	1599	8981	1140	8041	1085.4012	1085
2006	1744	10725	1400	9441	1183.8272	1184
2005	1179	11904	770	10211	800.3052	800
2004	1228	13132	950	11161	833.5664	834
2003	1004	14136	580	11741	681.5152	682
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1991	1076	24270	780	18396	730.3888	730
						Σ=18501

A change in the regime of the station is observed after the year 2009.

Slope of the best straight line,

For the period 2009-1991, Mc=1.501

For the period 2020-2009, Ma=1.019

Correction ratio=Mc/Ma =0.6788

Mean annual precipitation at station X =18501/30=616.7 mm

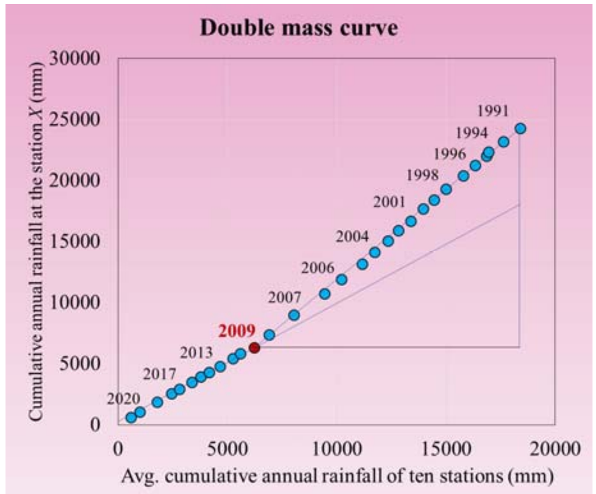

Fig.1 shows the double mass curve

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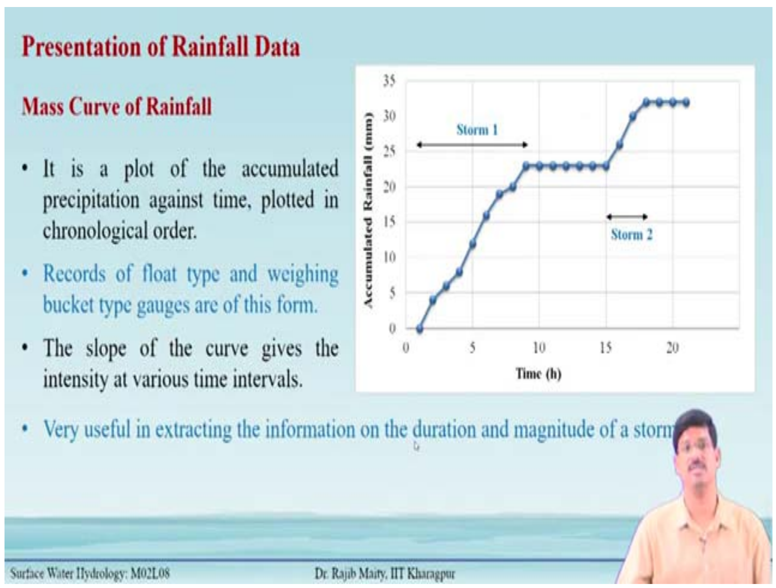

Presentation of rainfall data

Mass Curve of Rainfall: First one we take up the mass curve of rainfall, it is a plot of the accumulated precipitation against time plotted in chronological order. In the fig. 2 you can see that in the x-axis it shows the time in an hour and the Y axis shows the accumulated rainfall over time. So, if we just keep on adding we see the plot and there are sometimes it is horizontal which means, there is no surge rain.

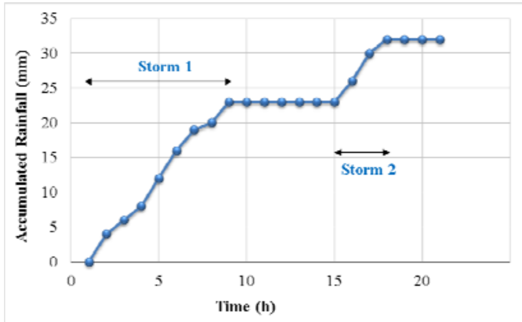

Fig.2 shows the mass curve of the rainfall

Records of float type and weighing bucket type gauges are of this form. The slope of the curve gives the intensity at various time intervals. It is very useful in extracting the information on the duration and magnitude of a storm..

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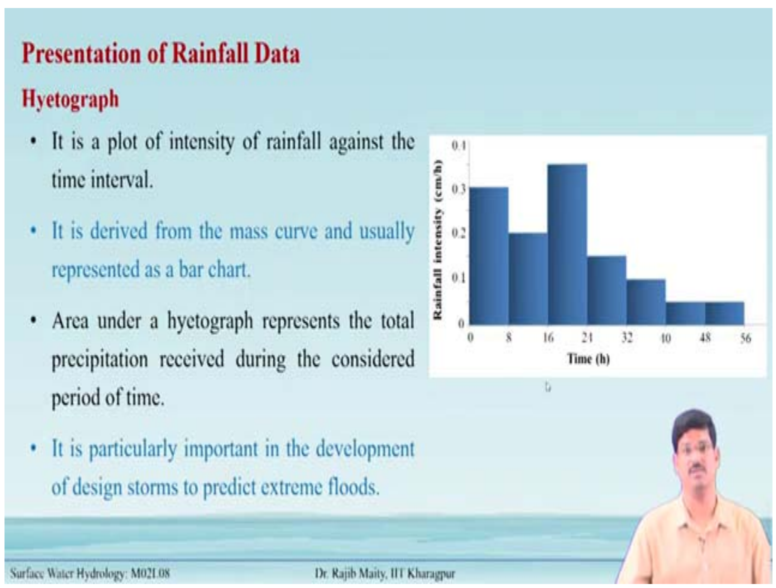

Hyetograph: Hyetograph is a plot of the intensity of rainfall against the time interval. It is derived from the mass curve and is usually represented as a bar chart. The area under a hyetograph represents the total precipitation received during the considered period of time. It is particularly important in the development of design storms to predict extreme floods

A typical example shows in fig.3, the x-axis is shown as a time and y-axis is the rainfall intensity in centimeter per hour here it is not accumulated. So, there from 0 to 8 as you can see here, this is the total amount 0.3 is indicates the rainfall intensity, the area under the hyetograph represents the total precipitation received during the considered period of time.

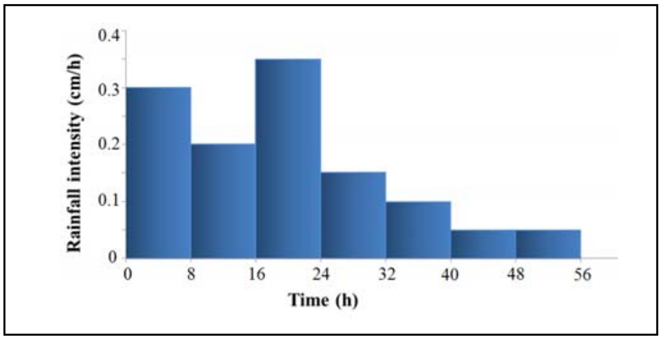

Fig.3 shows the hyetograph of the rainfall data

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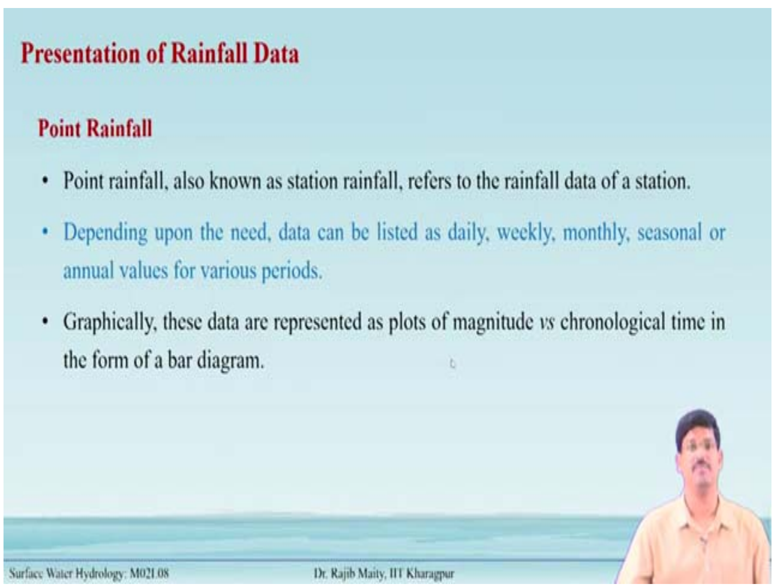

Point Rainfall: Point rainfall, also known as station rainfall, refers to the rainfall data of a station. Depending upon the need, data can be listed as daily, weekly, monthly, seasonal, or annual values for various periods. Graphically, these data are represented as plots of magnitude vs. chronological time in the form of a bar diagram.

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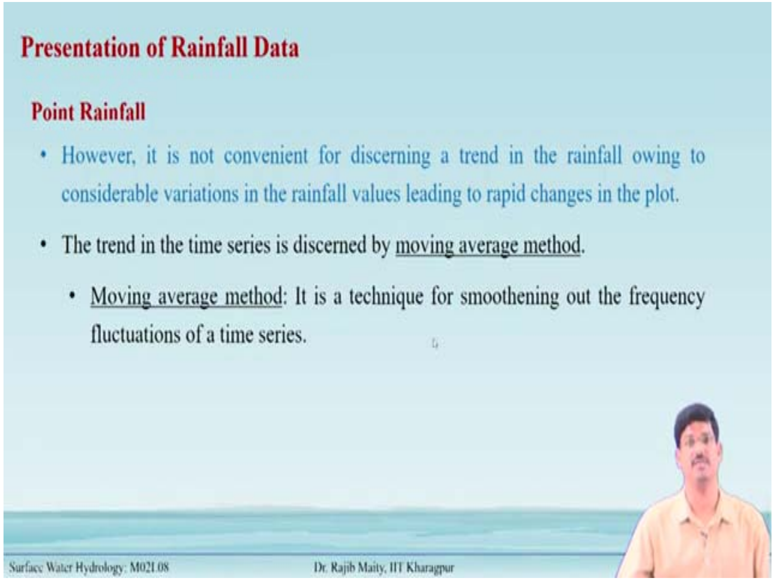

However, it is always not convenient for discerning the trend in the rainfall owing to a considerable variation in the rainfall values leading to the rapid change in the plot. So, the trend in the time series is discerned by the moving average method.

The moving average method is the technique of smoothing out the frequency of the fluctuation of a time series.

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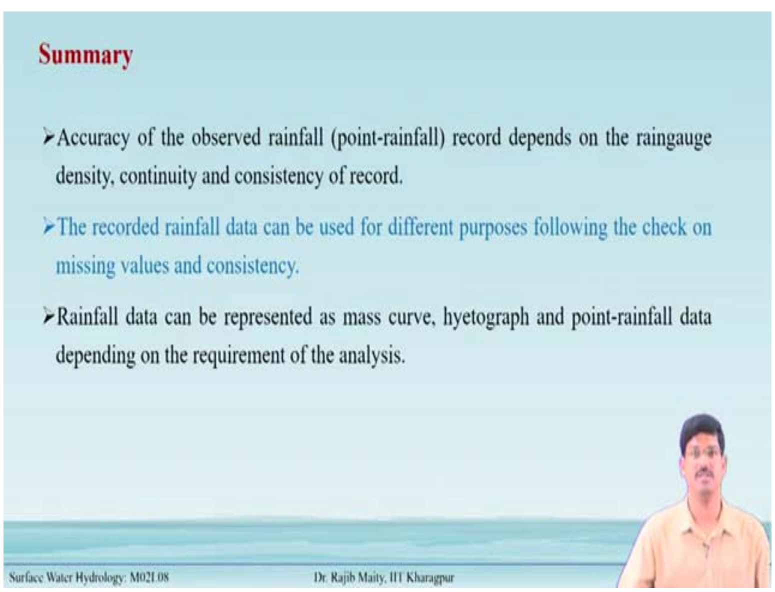

Summary

In summary, we learned the following points from this lecture

- The accuracy of the observed rainfall (point-rainfall) record depends on the rain gauge density, continuity, and consistency of record.
- The recorded rainfall data can be used for different purposes following the check on missing values and consistency.
- Rainfall data can be represented as a mass curve, hyetograph, and point-rainfall data depending on the requirement of the analysis.