Engineering Hydrology
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Module: 02 Lecture 18
Measurement of Rainfall

Hello everyone, welcome back. We were talking about different forms of precipitation. Out of that we have seen rainfall is the major important type of precipitation, which gives us water. We are mainly depending on rainfall for water. So, let us move on to the measurement of rainfall in this lecture.

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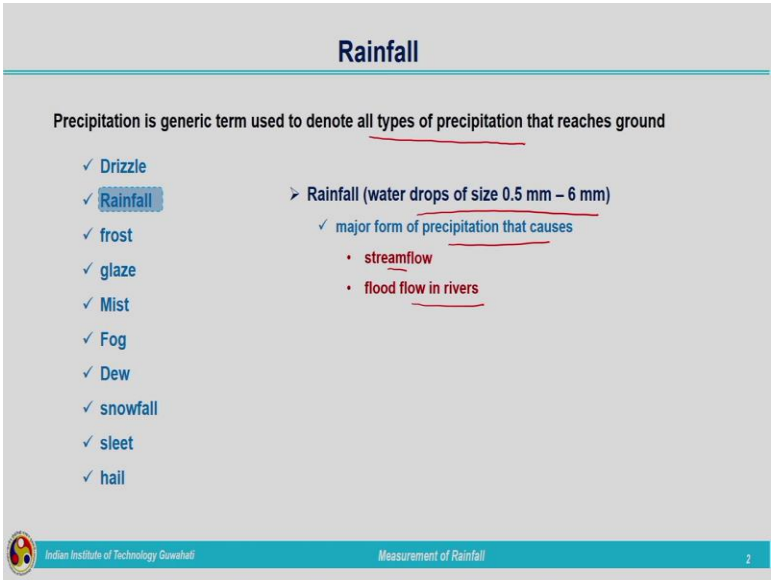

So, that is the precipitation we have seen. It is the generic term which is used to denote all types of precipitations that reaches on the ground. So, we have seen different forms as drizzle, rainfall, frost, glaze, mist, fog, dew, snowfall, sleet and hail. Out of that major important one is rainfall. So, in this lecture, we will see the measurement of rainfall. Rainfall consists of water drops of size 0.5 to 6 millimetres.

This is the major form of precipitation, because of this we are experiencing streamflow, we are getting flood flow in rivers. So, all these things are mainly due to rainfall. So, that is why it is very important to have knowledge about rainfall. So, first we need to have an understanding related to the measurement of rainfall.

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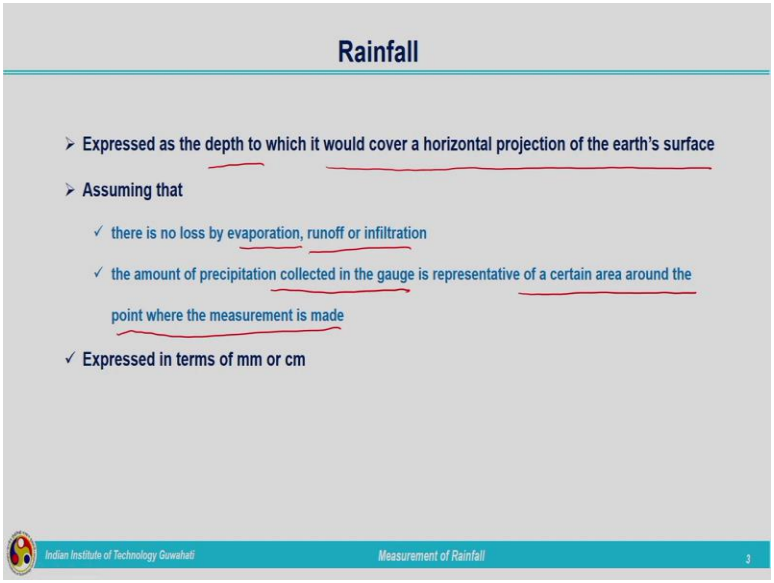

It is expressed in terms of depth, depth of rainfall. We will be talking about rainfall, this much of depth of rainfall, this much of millimetres of rainfall or centimetres of rainfall. So, expressed as depth of rainfall to which it would cover a horizontal projection of Earth's surface. As we all know Earth's surface is having certain curvature.

So, this depth is representing if we are projecting on a horizontal Earth's surface, how much will be the depth of rainfall, that is what is representing the amount of rainfall which we are experiencing. Indian Meteorological Department, IMD is reporting a rainfall of 10 centimetres. So, that 10 centimetre of rainfall is the depth of rainfall on the horizontal surface that is the projected area of Earth without considering the curvature.

So, rainfall will be expressed in terms of units of depth. We are assuming that there is no loss by evaporation, runoff or infiltration. Different losses which are taking place from the rainfall we have seen. So, here the assumption which we are making is that whatever rainfall depth is coming it is not having any loss, there is no loss from this rainfall.

So, the amount of precipitation collected in the gauge, that is the rain gauge is the instrument which is used for measuring the rainfall depth that is representative of certain area under the point where the measurement is made. So, we will be having the instrument installed at a particular point, in that point what is the depth of rainfall attained that is the amount of precipitation which we are experiencing at that point that we are assuming for a particular area

for the entire area this much is the depth of rainfall. Now, it is expressed in terms of millimetres or centimetres, depth unit will be used. Now, we need to say sometimes we will be telling we are experiencing heavy rain, very heavy rain. So, what is the classification for getting a heavy rain or light rain that we need to understand.

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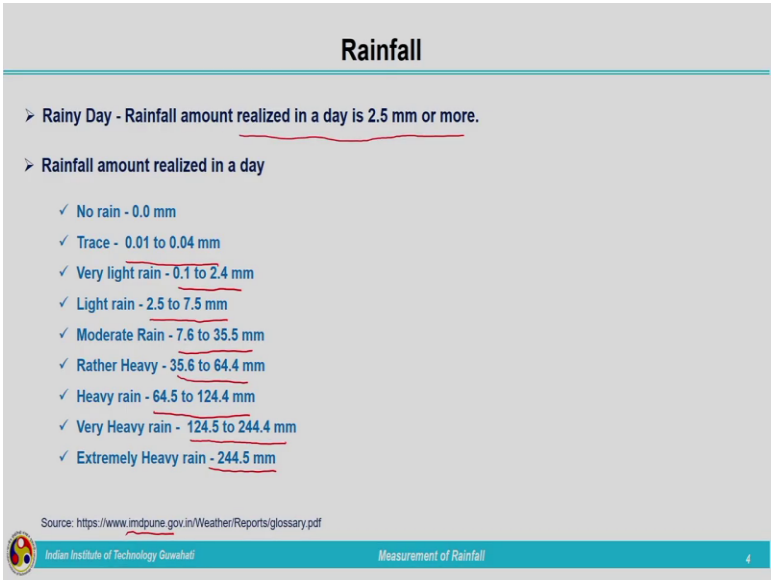

According to IMD, the classification is like this that is we will be calling a day as rainy day, if the rainfall amount is realised to around 2.5 millimetres or more. In a particular day if we are getting a rainfall of 2.5 millimetres or above we will be considering it as a rainy day. This is based on IMD reports and rainfall amount is realised in a day, we need to see whether we are experiencing heavy rainfall or light rainfall. The classification is like this: zero rain, no rain is there, so that will be, it is not a rainy day. Trace is the one which is considered as the rainfall between 0.01 to 0.04 millimetres. It is very small amount, it is not a measurable amount.

So, sometimes we will be seeing in the reports very trace of rainfall. So, that means it is between 0.01 to 0.04 millimetres. Then very light rain, next classification is very light rain, the range varies from 0.1 to 2.4 millimetres. Then comes the light rain, light rain is the rain which is having a rainfall depth around 2.5 to 7.5 millimetres in a day and for a light rain the intensity of rainfall is 2.5 to 7.5 millimetres per day or if we are talking in terms of depth of rainfall in a particular day the rainfall is in between 2.5 to 7.5 millimetres of depth, then we will be calling it as light rain.

Then comes moderate rain, moderate rain ranges between 7.6 to 35.5 millimetres in a day. Next is rather heavy rain that is 35.6 to 64.4 millimetres. So, we are moving from no rain to heavy rain. So, rather heavy rain is having a range between 35.6 to 64.4 millimetres. Now comes heavy rain, it is a high value that is 64.5 to 124.4 millimetres.

Next is very heavy rain, very heavy rain is ranging between 124.5 to 244.4 millimetres. Next is extremely heavy rain that is around 244.5 millimetres. So, beyond that it happens. So, it is exceptionally very high rainfall. So, this is the ranges which we consider the rain: from trace to extremely heavy rain.

So, it has gone beyond 244.5 mm also, during heavy flooding day we have experienced even around up to 1 metres of rainfall with complete flooding in city areas in Mumbai. So, I am not going up to that level. So, this is the range which we are considering when we are talking about the rainfall. So, it varies from 0.01 to 244.5. It does not mean that we are experiencing a maximum rainfall of 244.5, we can have rainfall beyond that also but it is an exceptionally very rare event.

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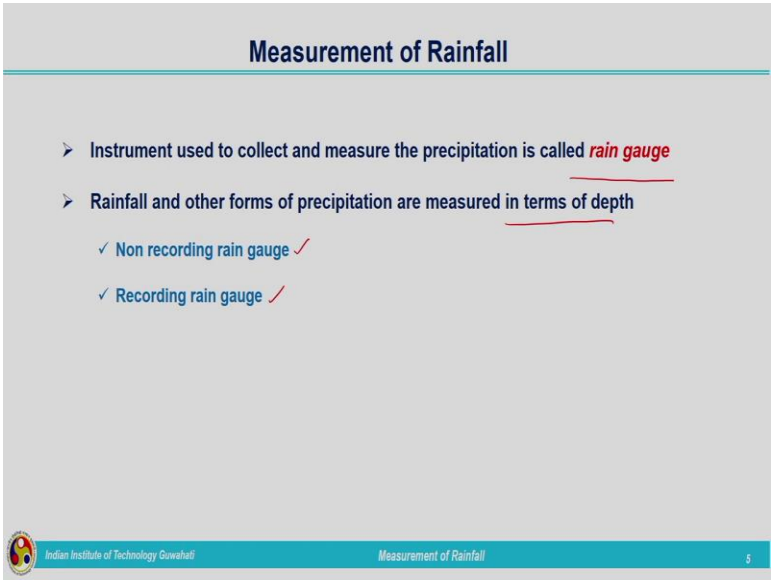

Now, coming to the measurement of rainfall. The instrument which is used to collect and measure precipitation is called rain gauge. Rain gauge is the instrument which we are using for measuring the rainfall. So, rainfall and other forms that is other forms of precipitation are

measured in terms of depth. That we have seen rainfall we are expressing in terms of millimetres or centimetres.

Different types of gauges are there, one is non-recording rain gauge and other one is the recording rain gauge, non-recording and recording rain gauge. As the name indicates one is of recording type, it will be automatically recording how much is the rainfall depth, other one is non-recording it will not be recording we have manually measure how much is the rainfall. So, let us see these one by one. Non recording type of rain gauge, we were using earlier days, but now as the technology is advancing, we are making use of the recording rain gauges.

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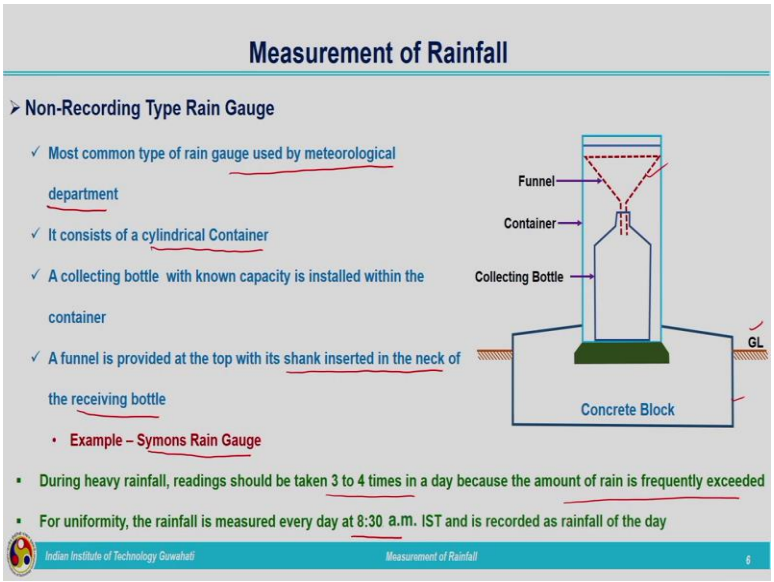

So, non-recording type of rain gauge that is the one which is most common type of rain gauge IMD, Indian Meteorological Department was using, but now majority of these rain gauges have been replaced by the recording type of rain gauges, but we need to have an idea of what is non-recording type of rain gauge.

So, it consists of a cylindrical container that is installed inside the concrete block. So, this is our ground surface we are having a concrete block like this it is already constructed within that it is already installed that is the cylindrical container which is installed in the concrete block and a collecting bottle is installed within this container.

The capacity of this bottle is known to us. So, this is a collecting bottle which is installed within the container which is installed in the concrete block and a funnel is present at the top that is here

you can see the funnel. So, a funnel is provided at the top with its shank inserted in the neck of the receiving bottle just a funnel is kept inside the bottle.

So, when we are experiencing rainfall, it will be collected in the bottle. During the rainy days it will be exceeding beyond the capacity of this collecting bottle. So, in such days during heavy rainy days, we need to take the readings 3 to 4 times in a day because the amount of rainfall will be exceeding the capacity of the rain gauge.

So that time in between with the approximate calculation from our side manually we need to replace the bottle. Usually the rainfall measurements will be done by 8:30 am for uniformity at 8:30 am it is recorded every day. But during rainy season, we need to increase the frequency or the number of measurements. The example of this non recording type of rain gauges is the Simon's rain gauge.

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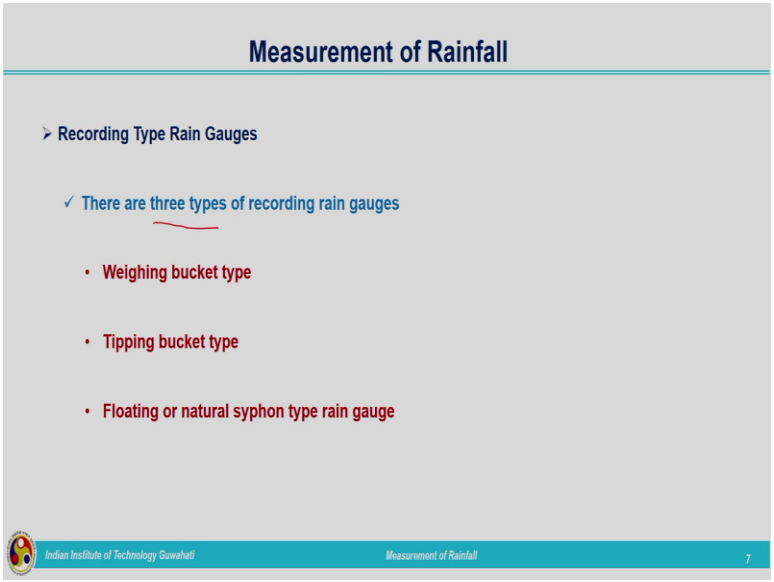

Now, second one is the recording type of rain gauges. There are three types of recording type of rain gauges, one is the weighing bucket type, second one is tipping bucket type and floating or natural syphon type rain gauge is the third one. So, recording type are of different types that is weighing bucket, tipping bucket, and floating type rain gauge.

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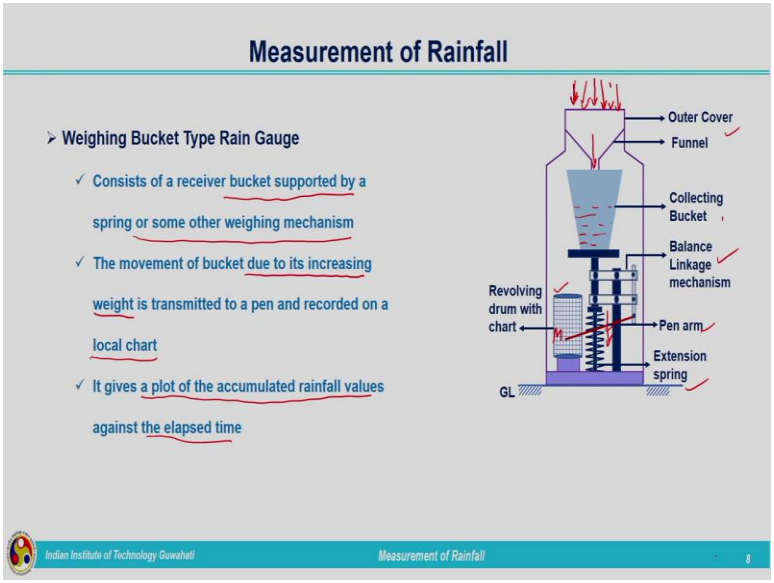

Let us see one by one. First one is the weighing bucket type of rain gauge. So, here in this case also you can see we are having the ground surface, this rain gauge is installed at the particular location where we need to measure the rainfall. This is the outer cover of the rain gauge and it consists of a receiver bucket supported by a spring or some other weighing mechanism. So, the working principle is based on the spring action. So, here we are having the spring provided, as the weight on this is increasing, spring will be compressed, that spring action will be determining how much is the rainfall which is occurring.

Let us, see how it is working. So, this is the extension spring and above the spring we have installed our collecting bucket. So, this collecting bucket is initially empty. The initial position of the spring is adjusted in such a way that the bucket is empty and we are having a funnel at the top, at the mouth of the outer cover there is a mechanism.

So, the mechanism is connected to the spring unit that is a balanced linkage mechanism. We need to measure the depth of rainfall. So, for that we need to have some recording system. How it is we will see now. So, a balanced linkage mechanism is provided which is connected to the spring and the bucket and there is a revolving drum with a chart. This is a revolving drum that is the cylindrical drum on that one chart is attached.

So, on this chart the rainfall readings will be marked. Along with the balance linkage mechanism, a pen is attached that is marked with the red colour, this is the pen arm. So, when the

rainfall is occurring that is the movement of bucket due to its increasing weight, that is transmitted to the pen and recorded on the chart.

When pen is recording the details, it will be giving us a plot of the accumulated rainfall values against the elapsed time. So, here you can see we are having the bucket here we are getting the rainfall collected through this and that will be entering through the funnel into the bucket. As the weight of the bucket is increasing, the spring will be coming down and what will happen because of that we will be having the movement of the pen, it will be marking the rainfall depth, how much depth it has come down that markings will be shown on this chart.

So, that way it can be used until this thing is fully filled, after that water will be removed from that and again water is allowed to fill inside. So, the movement of spring action depends on the water which is filled in the bucket that is the representation of the rainfall which we are experiencing. So, this movement will be marked on the chart that represents the rainfall depth.

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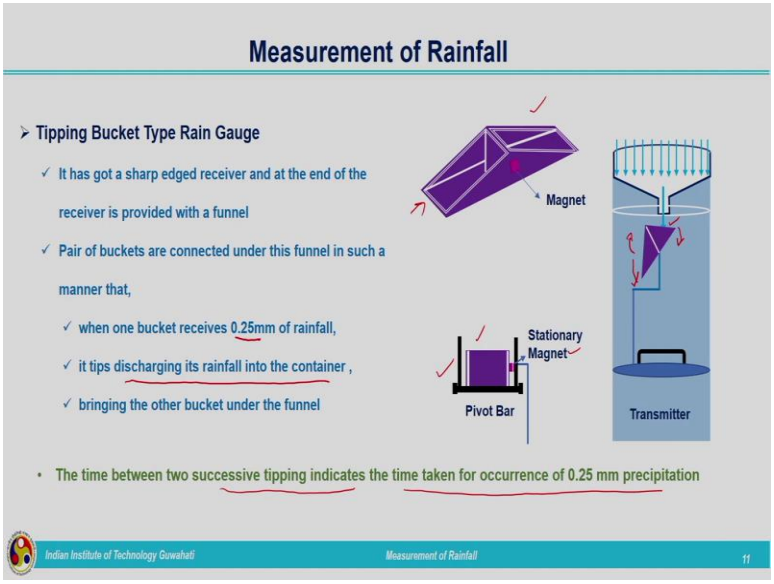

Next is the tipping bucket rain gauge. This is a very common recording type of rain gauge which we are using nowadays. Tipping bucket rain gauge let us see how it is working. So, this is the representation of tipping bucket rain gauge. In order to understand what is there inside the tipping bucket rain gauge, it is made it in a transparent way otherwise it will not be visible from outside. Let us see the parts one by one.

Tipping bucket rain gauges having a funnel at the top that is it such a sharp edge receiver and at the end of the receiver is provided with a funnel, this is a receiver its end is provider with the funnel like this, below that the collecting system is there. A pair of buckets, the name itself is tipping bucket. So, here it is installed with a pair of buckets conducted under this funnel.

These are the pair of buckets this is 1, this is 2. So, pair of buckets are there and when rainfall is occurring, it will be collected in the funnel and it will be directed towards the buckets. So, this way, rainwater will be entering into the bucket. So, when one bucket receives 0.25 millimetres of rainfall in this bucket, what will happen it will be tipping that is it will be moving in this direction and the other bucket will be located beneath the funnel, this way.

So, what will happen the water from the first bucket will be emptied into the receiver. When one bucket receives 0.25 millimetres of rainfall it tips, whatever rainfall is collected in the bucket that will be discharged into the container. So, after that the second bucket will be filled and when it is filled, it will be moving in the other direction.

The first bucket will be taking the initial position beneath the funnel and this process will be continuously happening, there is a seesaw mechanism which is taking place there. This is the close view of the tipping bucket and here is a magnet which is connected to the tipping bucket. This tipping bucket recording is taking place based on this magnetic action. So, the close view that is from this side if you are looking at the tipping bucket we can get a figure like this. So, here we are having the tipping bucket, the magnet is here and this is installed over a pivot bar.

Here there is a stationary magnet that will be transmitting the signal. Whenever this tipping is occurring, the signal will be transfer to the transmitter or sometimes there will be a data logger, the data will be collected in the data logger, different mechanism, different technologies are the behind the data collection.

So, the main basic principle happening is that tipping of buckets. So, a pair of buckets are there, one bucket is getting filled up, that is the 0.25 millimetres of rainfall is collected in one bucket means that is filled, that the seesaw action will be taking place that bucket will be tipping and discharging the water to the container, second bucket will be coming under the funnel.

And how the readings taken whenever each tipping is taking place, it is noted down by this transmitter. This stationary magnet will be transferring the readings to the transmitter or data

logger or whatever procedure is there for recording the rainfall data. The time between two successive tipping indicates the time taken for the occurrence of 0.25 millimetres of precipitation.

So, it is not a fixed time we are recording, it is the fixed amount of rainfall we are recording, how much is the time taken for also will be noted. So, we will be getting a graph or we will be getting the readings corresponding to every 0.25 millimetres of rainfall and the time taken for rainfall of 0.25 millimetres to occur. So, once, this is continuously acting, we do not have to manually record this thing, data logger will be giving us the complete details about the rainfall.

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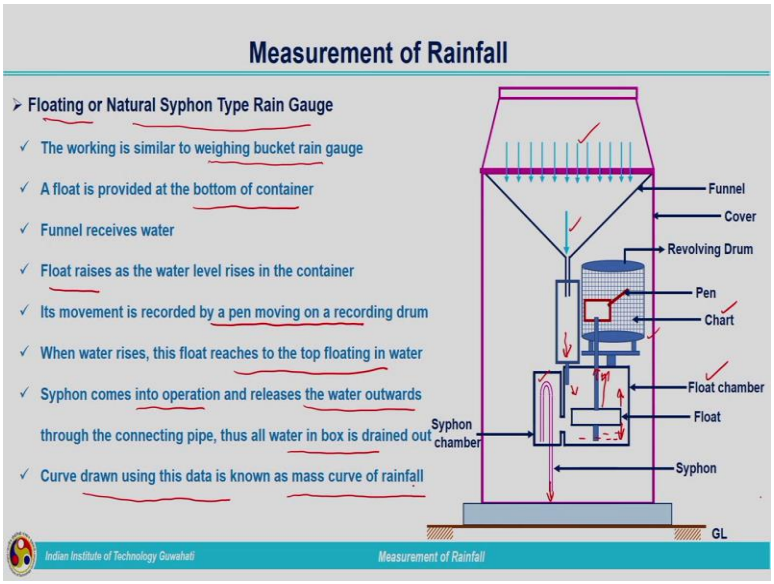

Next one is the floating or natural syphon type rain gauge. The working is similar to that of weighing bucket rain gauge. Let us see the pictorial representation of these floating type rain gauge. Here we are having the ground surface. Above the rain gauge is installed. So, this is the cover and here we are having the funnel, funnel we will be collecting the rainfall and it will be transferred to a float chamber.

So, here the measurement is based on the floating mechanism. So, we need to have a float, the float is installed within the float chamber like this. The float is provided at the bottom of the container. And beside the float chamber we are having a syphon chamber syphon is also installed near to the float.

As in the case of recording type of rain gauge with the chart we are having a chart here also. So, this is the revolving drum and revolving drum is having the recording chart. When funnel receives the rainfall, rainfall will be collected that is transferred through the funnel and it will be collected in this way, it will be reaching the float chamber.

When the water level in the float chamber rises the float also will be rising. This float will be rising like this. So, water is collected whenever rainfall is occurring it is collected through the funnel and it is entering the float chamber. And when the water level is increasing here in the float chamber what will happen this float will be rising.

So, it can go up to this level. And here there is a mechanism which is connected to a pen, that pen will be marking the rising and lowering of the float on the chart paper. This pen will be making the marking on the chart. When this water is rising in the float chamber float reaches to the top of the float chamber. It is floating only, it will be reaching up to the top and then what will happen? Then the role of syphon comes into picture. So, when the float reaches to the highest level, so syphon will be coming into operation and it releases the water outside, through this syphon the water will be sent outside through the connecting pipe.

So, all the water will be allowed to drain out from the float chamber and the syphon chamber. Then what will happen? The float will be coming down, it will be lowering and again as the water is increasing, it will be rising syphon action will be taking place for emptying the container, emptying the chamber, then according to the movement of this float, float is coming up, coming down this moment will be marked on the chart by means of the pen.

So, finally, we can make use of these recorded readings for getting the details about the precipitation. So, a curve is drawn using the data that is the data which we are getting a curve is drawn that curve is known as mass curve of rainfall. So, rainfall representation we will see later. Different ways of representation of rainfall is there, the data which we are getting from here can be plotted with respect to time that is what is termed as the mass curve of rainfall. So, this is the working principle of floating or natural syphon type rain gauge.

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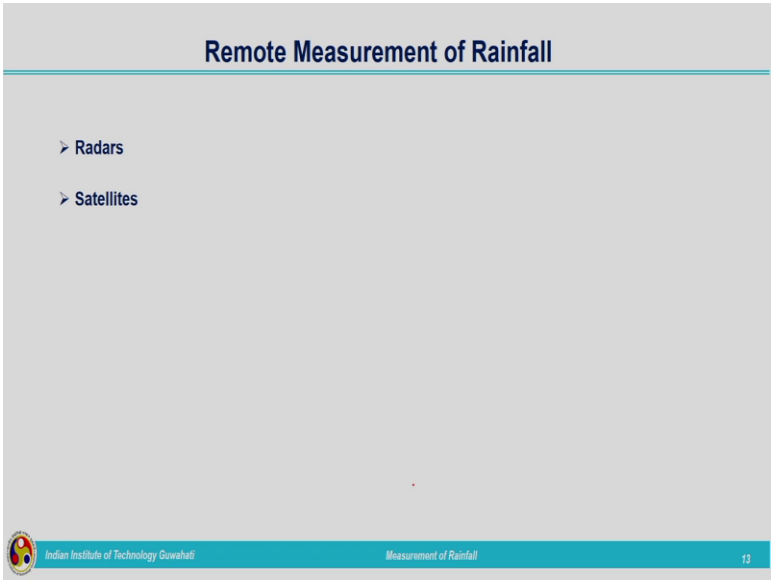

So, next is the remote measurement of rainfall. So, when we were talking about the measurement of rainfall, we have seen two types of rain gauges: recording type and the non-recording rain gauge. So, it is installed at a particular point, point measurements we are doing whether it is recording or non-recording based on that we are assuming it is the same rainfall which we are experiencing over any area.

Now, next one is the remote measurement of rainfall. Why do we want this remote measurement of rainfall? From the name itself it is clear that it is not the direct manual measurement. So, it is really good to have such measurements because during heavy rainfall, we will not be able to collect rainfall data going to the field, that is in the case of non-recording type in between we have seen we need to empty the bottle two to three times a day, so that we can get the exact representation of the rainfall happening in a particular day if it is heavily raining. So, that may not be possible in all the cases. So, that can be sorted out in the case of recording type of rain gauges. It is giving us continuous readings or continuous details about the rainfall which is occurring at a particular point. Now, let us say what is meant by this remote measurement of rainfall. Remote measurement of rainfall can be done either through radars or through satellites. Two techniques which we are following that is radar rainfall data is available to us, satellite rainfall data are also available to us.

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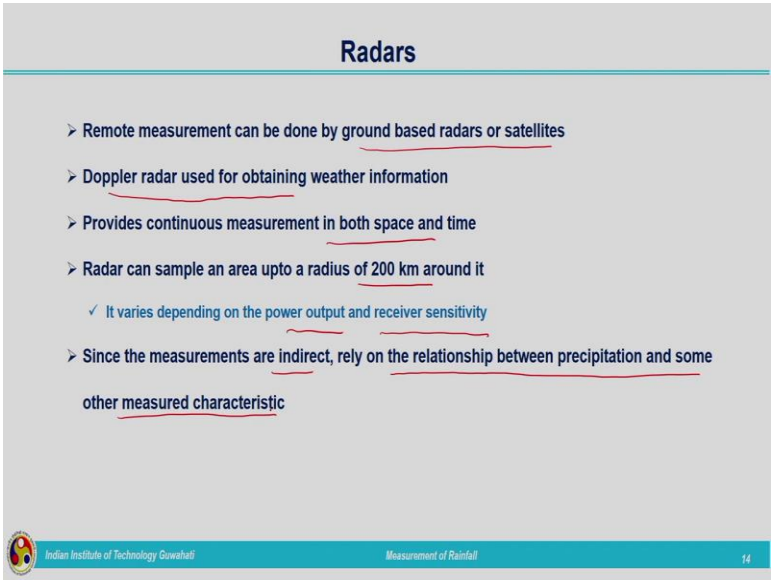

Let us, see one by one. First one is radars. Remote measurement can be done by ground based radar or satellites. So, first one is the radar. So, in the case of radar, Doppler radar is used for obtaining weather information. It gives the continuous measurement of rainfall not directly the rainfall certain relationship we have to make use of but still it gives the continuous measurement which varies with respect to time and also space, that is the temporal variation and the spatial variation is captured by means of these radars.

Around 200 kilometres of radius we can get the data from the radars. Beyond that we will be getting by using radars it depends on the power output and the receiver sensitivity approximately up to 500 kilometres also there are readers but as the radius is increasing the accuracy of the results will be reducing.

So, that is why approximately up to 200 kilometres we can make use of radar rainfall data. Since the measurements are indirect, we need to depend on the relationship between precipitation and some other measured characteristics. So, these radars are not measuring directly the rainfall data as our rain gauges were doing.

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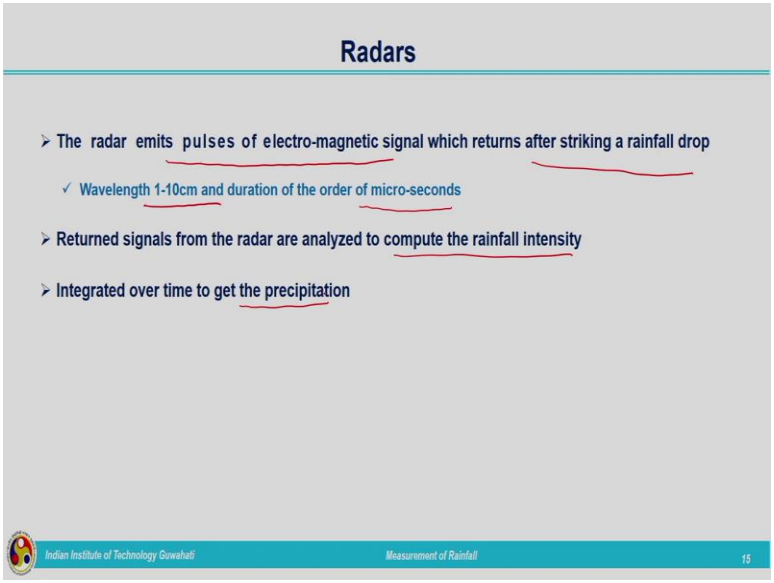

So, the radar emits pulses how it is working, it emits pulses of electromagnetic signal which returns after striking the raindrop. Whenever these pulses are hitting the raindrop it will be returned back. So, the wavelength of the signal varies between 1 to 10 centimetre and the duration is very very short interval of time, it is in the order of microseconds.

So, the return signals from the radar will be analysed to compute the rainfall intensity. Based on the signal, this signal will be converted to the rainfall intensity and once we get the rainfall intensity it can be integrated over time to get the precipitation depth. So, this is the principle of radar.

So, by making use of the radar data, we are getting the temporal as well as the spatial variation of the rainfall, but it depends on the radius with which it is measuring and it depends on the accuracy, details about the each and every radar. Those details you will be getting when you are collecting the data from the relevant agencies. Here Indian meteorological department is having so many radars installed all over India. So, based on that we can collect data and that can be used for getting the precipitation data corresponding to particular region. That much about radars.

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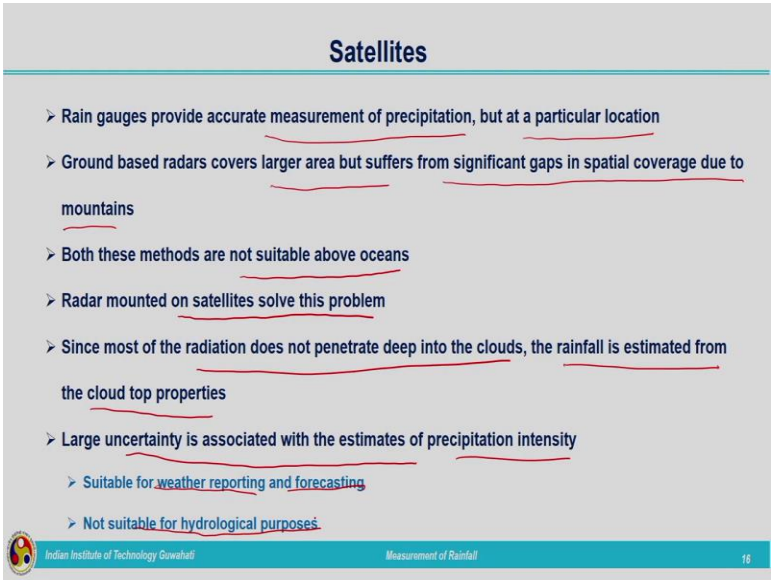

Next is the satellite rainfall data. So, we have seen rain gauges now and also radars. So, rain gauges provide accurate measurement of precipitation, but at a particular location. At a particular location this much is the depth of rainfall for different interval of time, maybe it is 15 minutes or lesser than that also we will be getting.

And radar data also very small interval of time and the spatial variability also available. But the problem is that in the case of rain gauges, it gives at a particular location, particular point it is not giving us the spatial variability of the rainfall. So, ground based radars covers larger area but suffers from significant gaps in spatial coverage due to mountains. If mountains hills present in between it will be affecting the data.

Both these methods are not suitable above oceans, you can imagine how it will be working. So, the installation of rain gauge is not possible. So, both these methods are not suitable in the case of oceans. But, if we are mounting a radar on a satellite, we can get the rainfall for that particular area whether there is a mountain, whether there is an ocean, it does not matter.

Most of the radiation does not penetrate deep into the clouds that is if you are installing the radar on satellite, what is the issue is that we are not getting the readings related to the ground surface. The radiation does not penetrate deep into the clouds, the rainfall is estimated from the top of the cloud, based on the cloud top properties.

Here also we are not directly using the getting the rainfall data it is measured above the top of the cloud based on those properties we will be getting the rainfall detail. So, depending on the height of the cloud, it will be moving spatially and temporarily also changes will be taking place. So, there need to have a proper bias correction when we make use of these rainfall data from the satellite rainfall data for our purposes. So, proper correct way of bias correction should be done, otherwise it will not be suitable for our studies. That is why this large uncertainty is associated with the estimates of precipitation intensity in case of satellite rainfall data. So, this can be used for weather reporting and forecasting.

So, if we are going for weather reporting and forecasting, it is fine, we can make use of these data, but if we are specifically making use of this data for some hydrological studies, in order to determine a flood, flooding details or calculate the flood depth in an urban area, if you are depending on this particular rainfall data from satellites, it will be giving you some flood data, but it will not be representing the actual flooding which is happening on that particular location. So, it is not suitable for hydrological purposes. It can be used for weather reporting and forecasting, but it cannot be used for these hydrological studies especially in the urban area and all.

If we are having a suitable bias correction with respect to spatial and temporal way, then it can be utilised. Otherwise you can imagine cloud is at a particular height and it is moving time to time. So, the spatial variability and the temporal variability is huge in the case of satellite rainfall products. So many satellites are there which are providing us the satellite rainfall data, but before directly using that data suitable bias corrections need to be done, after that only we can make use of that. So much of uncertainties are involved with this satellite rainfall data. So, that much about the rainfall measurement.

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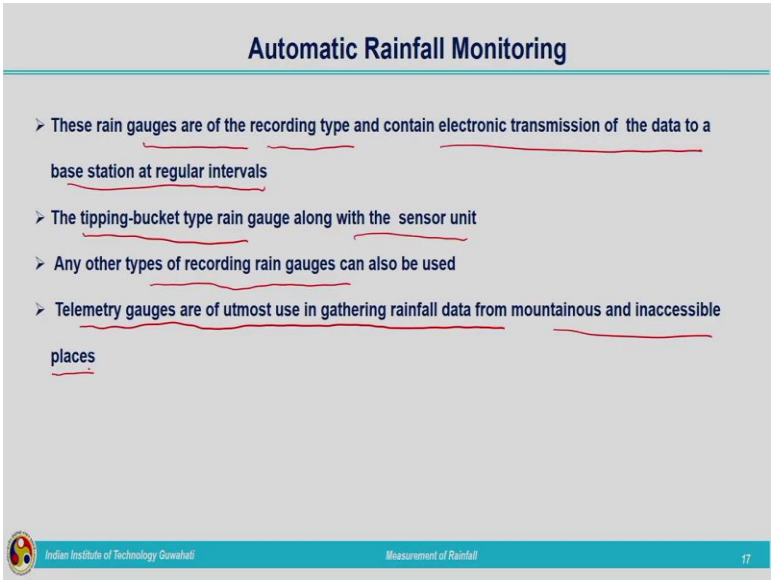

Next one is the automatic rainfall monitoring. This is very important, majority of our cities are installed with automatic rain gauges or automatic weather monitoring systems. What is it, let us see. In this we are making use of rain gauges of recording type and mainly we are using the tipping bucket rain gauges.

This will be recording the rainfall data and we will be getting the electronic transmission of the data to a base station at regular intervals. Tipping bucket how it is working we have seen, with that interval that data will be transmitted to a base station. So, there from all the network of automatic rain gauges or automatic weather stations different equipment's are there. So, it will be having a tipping bucket, rain gauge and other atmospheric parameters such as temperature measurement will be the.

So, those parameter measurements will be given by this automatic weather station. So, how it is it is working on the principle like a tipping bucket rain gauge only in the case of rainfall. So, that data will be transmitted that is the electronic transmission of that data will be taking place to a base station at regular time intervals. As I told tipping bucket rainfall is an example with a sensor unit. It will be having a proper sensor unit; data logger will be connected to it and by making use of that we can get the real time rainfall data in the base station. Not only tipping bucket any other kind of recording rain gauges can be used because only the thing is that it should be automatically recorded, manual measurement will not work in this case. So, this will be very

useful even during the time of heavy rainfall. So, the telemetry gauges are of utmost use in gathering rainfall data from mountainous and in accessible places. As in the case of non-recording and recording rain gauges, point measurements it is giving to us.

So, if we are having an automatic rainfall monitoring for an entire area, different number of automatic weather stations will be installed at different different locations, it is inclusive of the tipping bucket rain gauge for example tipping bucket rain gauge, and that will be recording the precipitation which is occurring at a particular location, that way at different different locations it will be recording and that data will be transferred to the base station.

So, we are getting the spatial variation of the rainfall data at different different locations for different times. So, these gauges, telemetry gauges are very much useful if we are going to study the flooding of an urban area or a particular location there is heavy rain is occurring and, in the areas, where we are not in a position to access mountainous regions and in accessible places these are of utmost importance. So, that much about the rainfall measurement.

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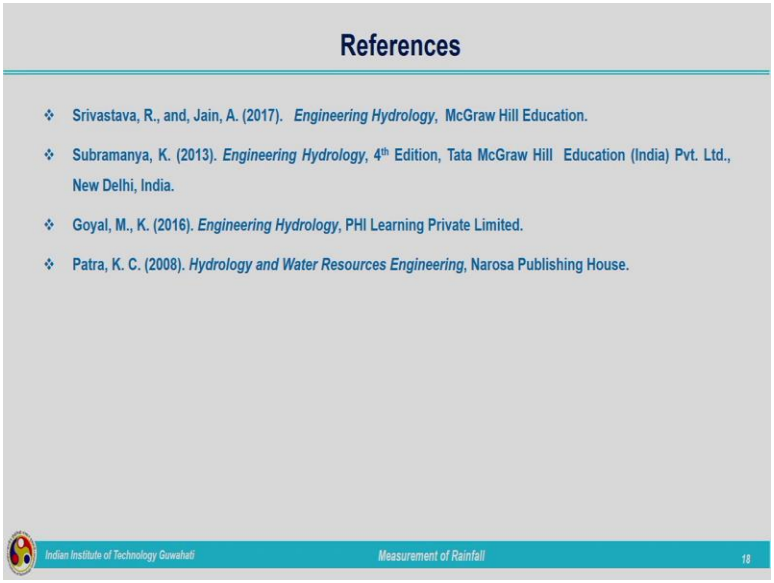

For getting detailed knowledge about these rain gauges and the remote measurement of rainfall data you can have a look into these textbooks. So, in this lecture, we have seen different rain gauges, recording, non-recording. Recording ones three types we have seen; out of that we are making use of tipping bucket rain gauges very commonly.

So, that is installed in the case of telemetric rain gauges also, so that telemetric rain gauges or the automatic weather stations installed at different different locations in urban areas or inaccessible area like mountainous areas, we will be getting all the data from these areas at a base station. So, continuous spatial variability of rainfall data can be obtained at the particular base station on real time basis.

Other one which we have seen is the remote measurement of the rainfall data. You have seen rain gauge is giving us the point gauge data at a particular location and we are assuming that data to be uniformly distributed over a certain area that is an approximation. But if you are having the spatial variability of rainfall, it will be giving us the detailed knowledge about the rainfall which is occurring in a particular area that can be attained by making use of the remote measurement of precipitation data by making use of radars or satellite.

But in the case of radars and satellites also disadvantages are there. Radar depend upon the spatial extent, that is how much is the radius it can be covered. Beyond that if you are making use of that data it will not be giving you accurate results. And also, it is not directly giving you the rainfall data we are depending on certain relationship, based on relationship we are finding out the precipitation data in the case of radars and while coming to the satellite rainfall products, above the top of the cloud we are measuring the details and that data is converted back to the rainfall data.

So much of uncertainties are involved with the satellite rainfall products. So, before using those data for any type of studies, we need to do the bias correction and we need to validate it with the point gauge data, then only we can make use of that data for further studies. So, for the urban studies and all we need to make use of these telemetric rain gauge data for different different locations these rain gauges or the automatic weather stations will be installed and that will be transmitting the data to the control station or the base station, from there on real time basis we will be getting the temporal as well as spatial variability of these rainfall data. So, here I am stopping today's lecture. Thank you.