Engineering Hydrology
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Module: 2 Lecture: 13
Precipitation

Hello all, welcome back. In the previous lecture, we were discussing about water vapor dynamics,

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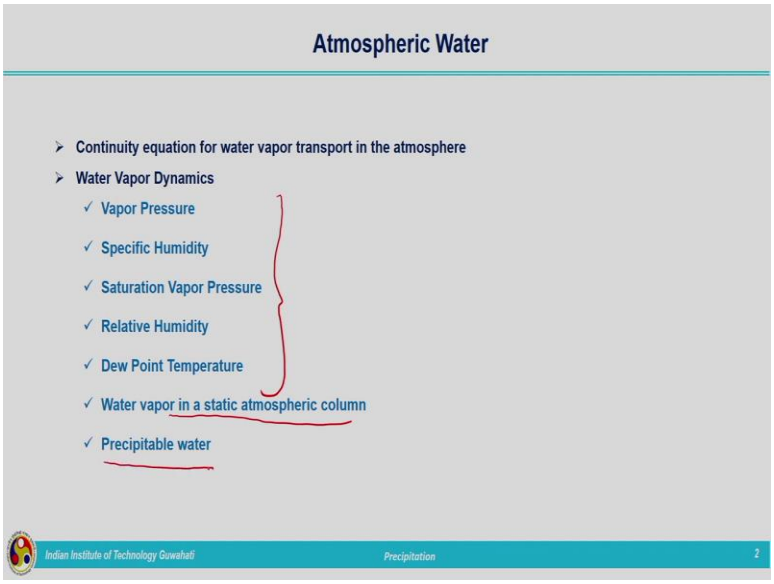

That is, we have seen the continuity equation for the vapor transport in the atmosphere and in that we have seen the extensive property is the mass of the water vapor and the corresponding intensive property as the specific humidity. So, we wanted to understand all these atmospheric parameters in detail and we have seen different, different atmospheric characteristics in detail in the previous lecture. That is what is meant by vapor pressure, specific humidity, saturation vapor pressure, relative humidity, dew point temperature?

Then after knowing all these atmospheric parameters, we have seen the expression for water vapor in the static atmospheric column. Then, we could understand if we know all these parameters, we can find out what will be the precipitable water in an atmospheric column. And after that, we have solved some of the numerical examples. And now, we will move on to the

topic of precipitation. So, precipitation is a term which is very much familiar to all of us, mainly rainfall.

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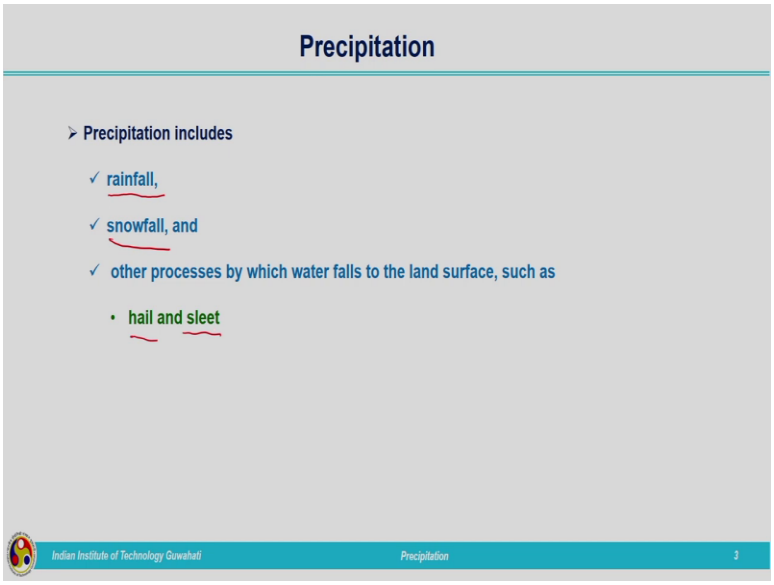

So, precipitation includes rainfall, snowfall, and other forms of precipitation are hail and sleet. So, rainfall we know we are getting precipitation in the form of rainfall, majority of the portion of our country is getting rainfall. Sometimes at certain locations it will be in the form of snowfall and sometimes we experience hail and sleet at different locations. Hail storms, you might have experienced. Hail storm is the rainfall, that is the water will be getting converted to ice balls in the atmosphere itself due to the very low temperature and that will be falling on the earth. And as far as sleet is concerned, when this precipitation water is falling on the surface as ice crystals that is the temperature will be very, very low and this precipitable water will be converted to the solid ice crystals and that will be forming the precipitation which are known as sleet.

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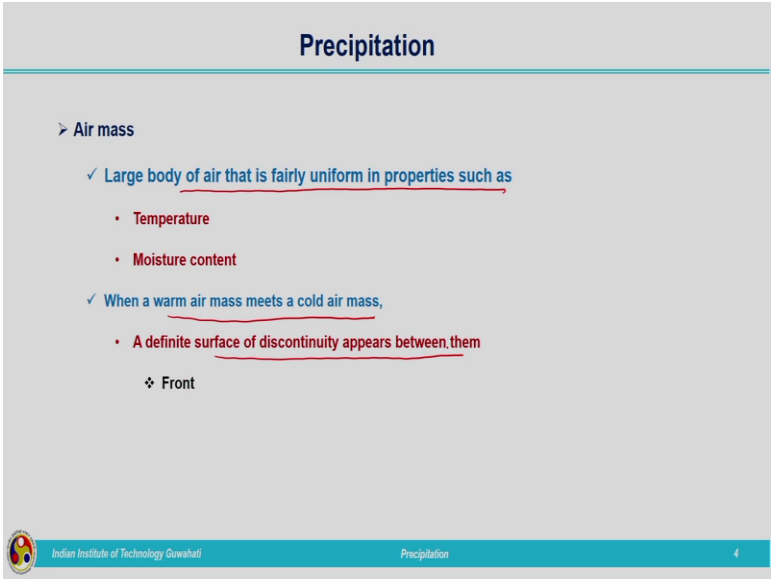

Now, let us see how precipitation is occurring. So, before that we need to have an understanding about air mass. What is meant by Air mass? Air mass is large body of air that is fairly uniform in properties. Fairly uniform in properties means that is the water vapor properties. Water vapor dynamics we have seen different properties related to atmospheric water also we have seen.

So, it may be temperature, it may be moisture content, and it may be vapor pressure. So, these large body of air mass which we are talking about will be having the uniform properties that is what is known as air mass and when a warm air mass meets a cold air mass we will be having a definite discontinuity or definite boundary is formed between them.

So, that definite surface of discontinuity appears between these warm air mass and cold air mass that is known as front. So, these terms should be familiar to you when we talk about the formation of rainfall. So, what is an air mass? Air mass is the large body of air which will be having uniform properties. These properties maybe temperature, moisture content, so it may be cold or it may be warm. So, when a warm air mass is meeting a cold air mass or cold air mass meets a warm air mass, there will be a definite boundary form, that boundary is termed as front.

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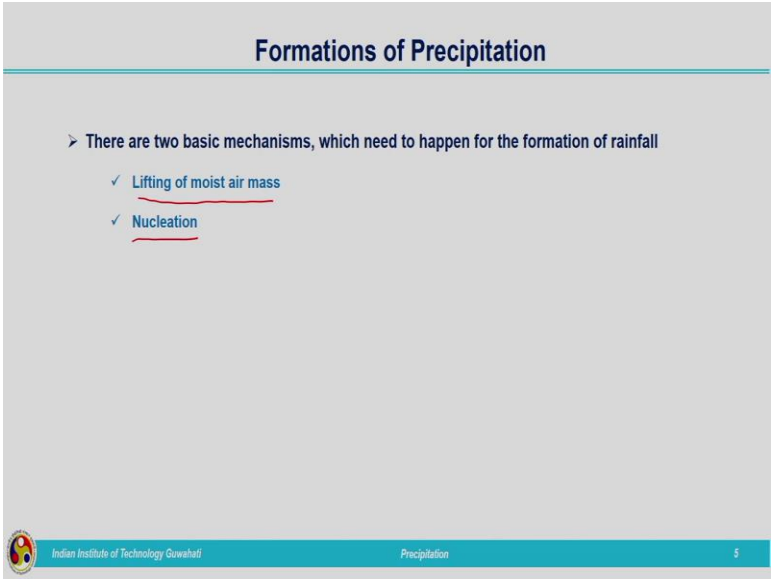

Now, let us move on to the different mechanism behind the formation of rainfall. There are two basic mechanisms, one is lifting of moist air mass and second one is nucleation.

What is meant by air mass? That is, it is moist air mass because, when the water is getting evaporated, the air will be containing water vapor, so it will be moist. So, behind the formation of rainfall, we are having two processes, one is known as the lifting of air mass and second one is the nucleation. Let us see one by one.

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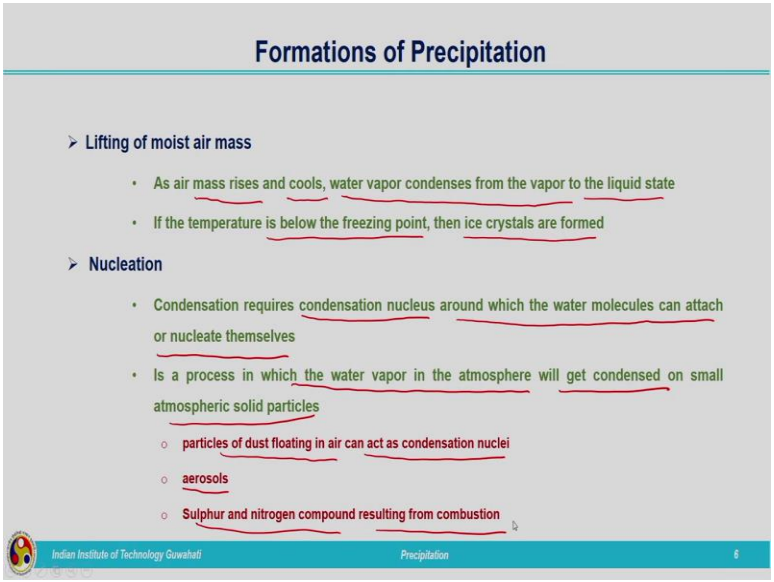

Lifting of moist air mass means, the air rises that is when the water vapor is produced, it will be warm and it will be lesser in density. So, that air mass will be lifted up into the atmosphere due to wind action, that we have seen when we were talking about atmospheric circulation. So, air mass rises and once it is rising the temperature reduces, it becomes cool. Because of that what will happen? water vapor condenses from the water vapor state to liquid state. As the air mass is rising, it will be cooled and condensation of this water vapor will be taking place, thus producing the liquid. It may not be always liquid, because if the temperature is below the freezing point, then ice crystals may be formed.

Second mechanism behind the formation of precipitation is termed as nucleation. Before going to nucleation, let me explain some points to you. You are getting a particular rainfall or precipitation on a particular day and you might be having the details related to atmospheric properties, pressure is this much, temperature, specific humidities, all these and on another day, we are having same atmospheric properties, but we are not experiencing any rain. We cannot expect, we cannot tell that that day since all these atmospheric properties are same we will get rainfall on that particular day on which we are having the same type of atmospheric properties.

Why? Because, there should be a process termed as nucleation to be taken place for the process of condensation to take place, that is condensation requires condensation nucleus, so that around

that condensation nucleus the water molecules can attach or nucleate themselves, that is it will be acting as a catalyst during the condensation process.

It is a process in which water vapor in the atmosphere will get condensed on small atmospheric solid particles. This is the process of nucleation. So, if we are not having the nucleation taking place on that particular day, even though we got rainfall with the similar atmospheric properties on a particular day, that on the other day we cannot expect rainfall because nucleation has to take place.

So, how this nucleation will be taking place, what are the things which are acting as this catalyst. So, particles of dust floating in air can act as condensation nuclei. Aerosols are some source of nucleation and Sulphur and nitrogen compounds resulting from combustion.

So, some polluted material will be present in that atmosphere and these aerosols are very common and some dust particles which are very very, very small in size, that is tiny solid particles, which are present in the atmosphere is acting as a catalyst and these are acting as the condensation nucleus. So, these particles should be present in order to have the condensation to take place.

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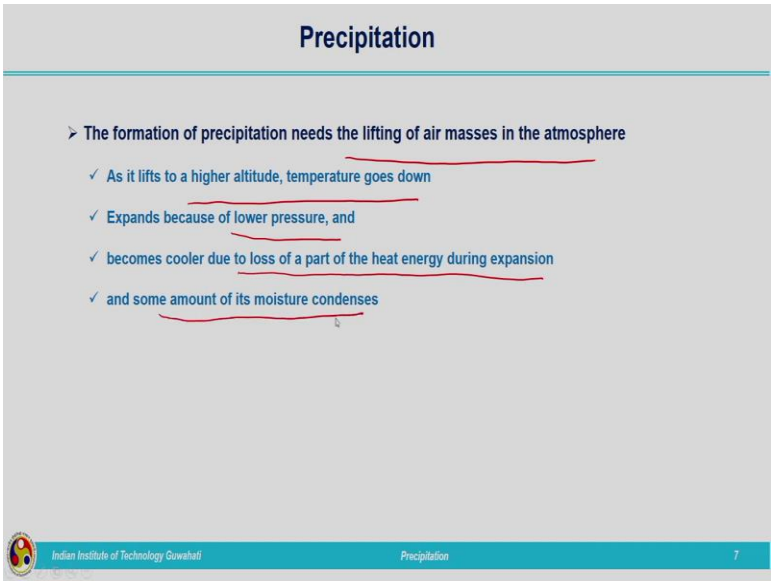

And the formation of precipitation needs the lifting of air masses in the atmosphere, that we have seen, first mechanism and as it lifts to higher altitude temperature goes down and it expands

because of lower pressure. When it is expanding, it becomes cooler due to loss of some amount of heat energy during the expansion, at that time some amount of its moisture condenses that is the water vapor will be converted to liquid form, depending on the temperature it may be converted to ice crystals also.

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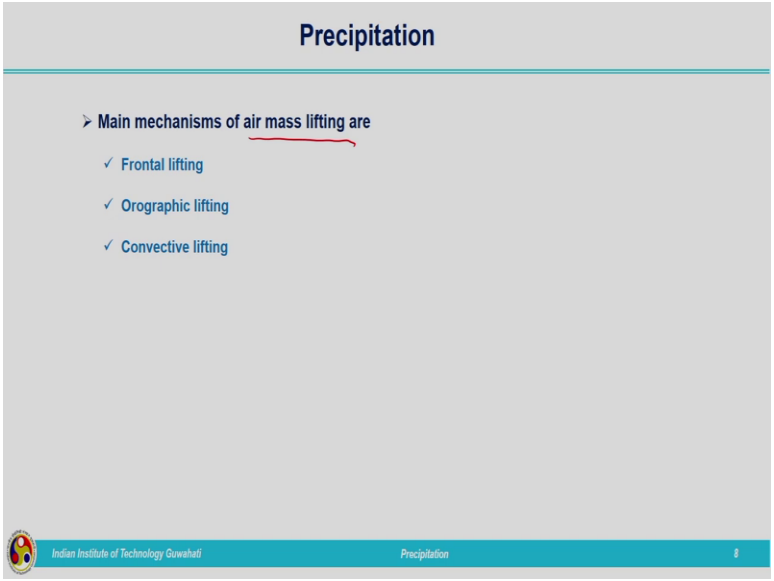

Now, we need to understand how this lifting taking place. Main mechanisms of air mass lifting are Frontal lifting, Orographic lifting and Convective lifting. So, based on these types of lifting, we will be calling that particular precipitation as Frontal precipitation, Orographic precipitation and Convective precipitation.

So, the first process which we have seen as the lifting of air mass. Lifting of air mass can be due to different mechanisms, those mechanisms are frontal, orographic and convective lifting. Let us see one by one.

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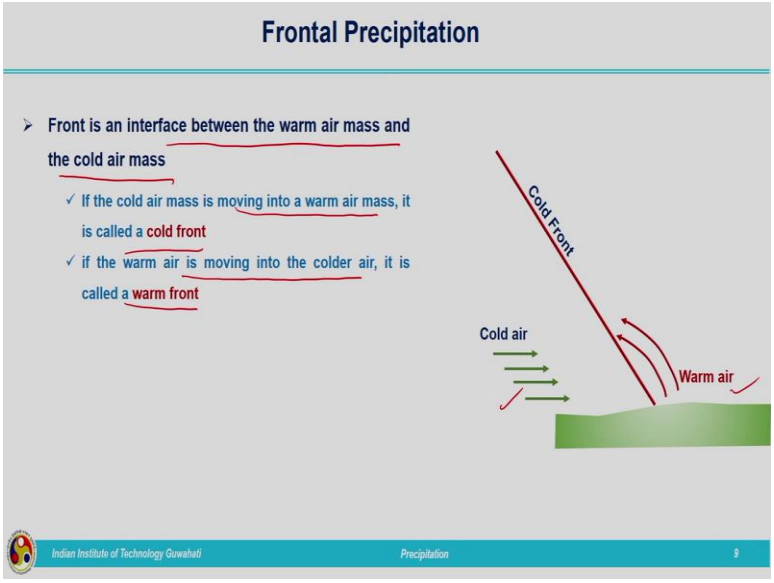

First one is frontal lifting. So, this is our land surface, from the land surface this air masses will be moving. We are having the warm air and also, we are having the cold air. We have seen when a warm air meets the cold air or cold air meets warm air there will be a definite boundary which is formed, that boundary is known as a front.

So, here we are having the cold air and also warm air. So, these two when meets a definite boundary is formed, that is what is termed as the front. The front is the interface between the warm air mass and called air mass. If the cold air mass is moving into warm air mass it is called cold front.

So, here you can see, the cold air masses moving towards the warm air and this front is cold front. If it is on the other hand, that is if the warm air is moving into the colder air, it is called a warm front. Anything can happen, sometimes cold air will be moving towards the warm air or some other cases warm air will be moving towards the cold air. So, depending on that the front which is formed will be calling as the cold front, warm front etcetera.

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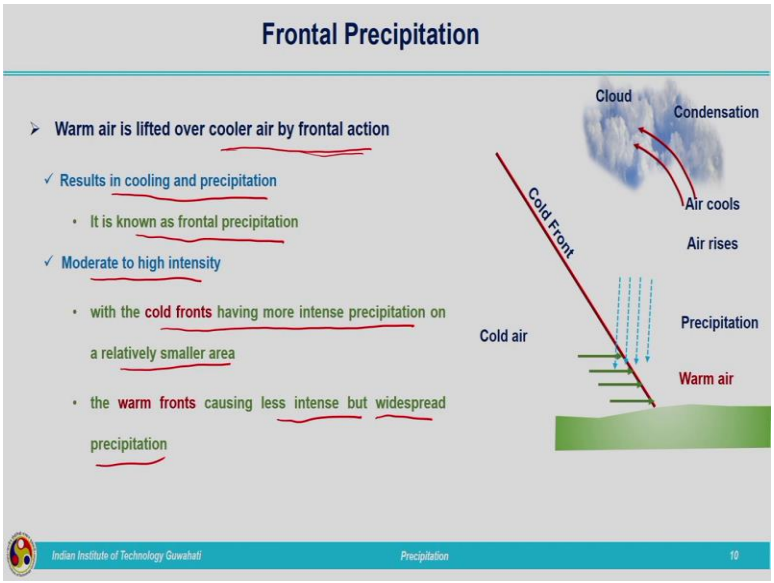

So, here in this case the cold air is moving towards the warm air. So, because of that what will happen, the warm air will get lifted up. When it is getting lifted up, warm air is lifted over the cool air due to frontal action. As it rises what will happen, the temperature reduces, it becomes cool, air cools and condensation of this water vapor will be taking place with the formation of cloud and we will be getting the precipitation. How this precipitation is formed we will see later on. So, here in this case cold air mass was moving towards the warm air and when the cold air is pushing the warm air, this warm air will get lifted up, when it is getting lifted up, the temperature is less at the higher altitude and it will become cold and also some of the heat energy absorbed by the water vapor will be lost to the atmosphere when it expands. So, as it rises it cools and condensation of this water vapor will be taking place by which the formation of clouds will be taking place and after that we will be getting the precipitation.

So, what will happen when the moisture has come down as precipitation we will be having the dry air present. Thus, which results in cooling and precipitation. It is known as the frontal precipitation. Because very clear, well defined boundary is formed, that front is formed, due to this the airlifting is taking place that is why this type of precipitation is termed as frontal precipitation.

These types of precipitation are of moderate to high intensity, with the cold fronts having more intense precipitation on relatively smaller area. Cold fronts mean, cold air is meeting warm air and the front is formed is the cold front, because of that lifting of the warm air is taking place. If the precipitation is due to the formation of cold front, it will be having more intense precipitation on a relatively smaller area.

On the other hand, if there is a formation of warm front in that case, it will be producing less intense, but widespread precipitation. In the case of cold front formation, our precipitation will be more intense and in the case of warm front, the precipitation will be of less intense, but it will be on the widespread area.

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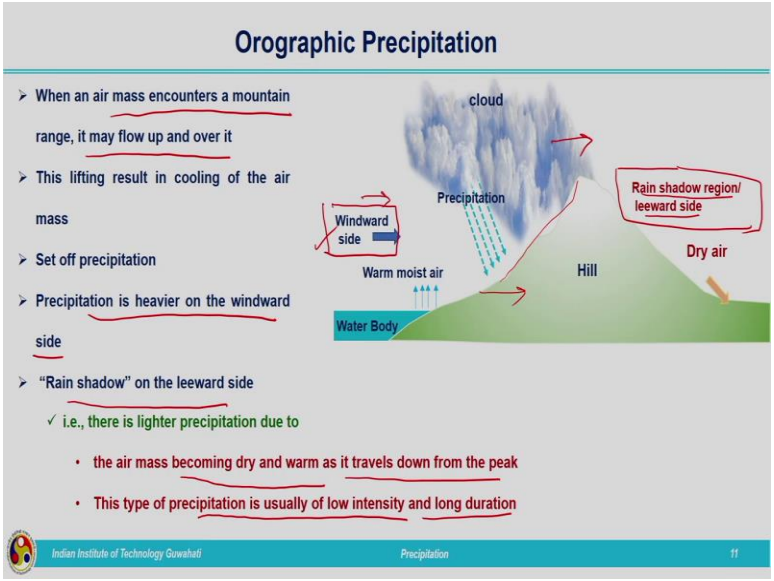

Now, second one is Orographic precipitation. Orographic precipitation is the precipitation which are occurring at the mountainous region or at some obstruction is present, at those locations will be experiencing the orographic precipitation. We have seen the movement of air mass, if there is no obstruction it is having a free movement. But in the case of mountainous region, it cannot go through the mountains or hills, it has to move above that. So, because of that sometimes in the locations where we are having hills or mountains we will be experiencing a precipitation different from the frontal precipitation that is what is termed as the orographic precipitation.

Let us see how it is occurring with the help of a figure. We are having a hill here and we are having a water body, by absorbing the heat energy from the sun, the water from the water body will be getting evaporated. So, this evaporated vapor will be mixing up with the dry air that is we will be having the moist air present just near the water body.

Warm moist air and this will be when air mass encounters a mountain it may flow up over it, that is it has to flow over this mountain region, it cannot go in this way. So, what will happen, due to the presence of wind action it will be moving along the side of the hill. So, this side from where we are having wind occurring that side is termed as the windward side. Because of the wind action these moist air masses will be getting lifted up and we will be having the cloud formation, that is this moist air getting lifted up it will be becoming cool and the condensation taking place with the formation of clouds and after that will be getting the precipitation on this side of the hill. So, once the water vapor converted to liquid, that is due to condensation what is taking place, the water vapor is converted into liquid form.

So, that liquid we are experiencing as the precipitation. Remaining air will be dry warm air and that air will be moving towards the other side of the hill. Because we are having the wind coming from this windward side and the precipitation is heavier on the windward side. On the other side we may experience rainfall but it may be of very, very less intensity.

So, this region is on the other side of the mountain, we will be calling it as rain shadow region or leeward side, there we won't be experiencing any rain or sometimes very less intensity rainfall will be there. And this dry air after the precipitation has taken place on the windward side, that dry air will be moving on the rain shadow region or the leeward side towards the downhill side.

So, rain shadow is on the other side of the windward side and because of the presence of the hill or mountain ranges, we will not be getting rain as we are getting rain on this side that is on the rain shadow region as we are getting on the windward side, that is lighter precipitation will be there on the rain shadow region. Because the air masses are becoming dry, warm as it travels down the peak. This type of precipitation is usually of low intensity but for long duration.

It will not be having high intensity, but it will be lasting for so much duration. This is what is known as the orographic precipitation. Orographic precipitation is the precipitation which we are

experiencing on the locations where we are having hill, mountain ranges or some other obstruction of that kind. How it is producing we have seen in this slide. Now the third one is the convective precipitation.

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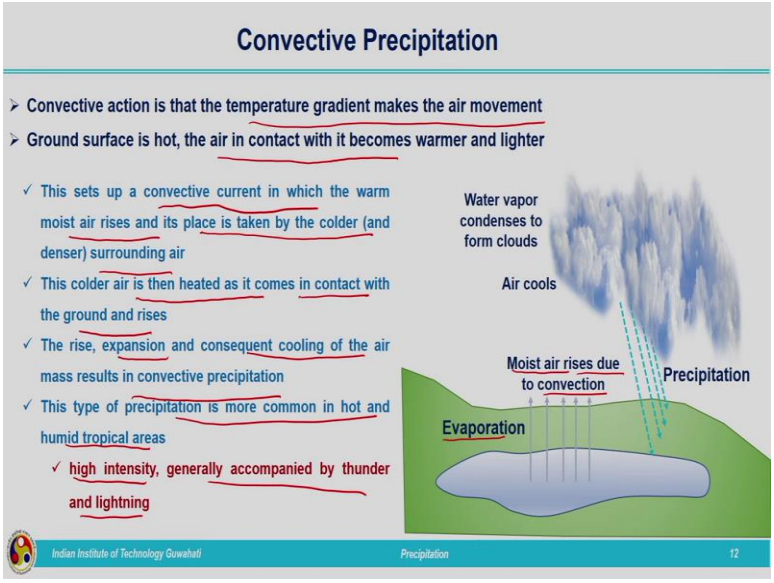

Here the lifting of air mass taking place due to the convective action. So, how it is taking place we can see. This is our land surface, we are having a water body present on the land surface and from the water body we will be experiencing the evaporation, water will be getting evaporated to the atmosphere in the form of water vapor.

So, the moist air which is present above these land surface or the water body will be taken away from that due to the wind action. So, here we are having the moist air and it rises due to convection. Convective action is that the temperature gradient makes the air movement. If you are having a road, one end is very hot and the other end is warm, high temperature and low temperature. So, how the heat transfer will be taking place, from the hot end to the cold end. In the similar way, if there is a temperature gradient, from the high temperature to low temperature, the flow of vapor or air mass will be taking place. So, here is a mixing of this warm moist air and the cold air will be taking place due to convective action.

So, as it moves up, air cools and water vapor condense to form clouds and we will be experiencing the precipitation. So, here in this case, there is no frontal action, there is no

orographic lifting, it is a plain area we are having the water body, water is getting evaporated into the atmosphere and this is warm air which is containing the moisture. This warm air will be moving up due to the temperature gradient present. As it moves up, the warm air becoming cool and water vapor will be condensing to liquid form, thus forming the clouds and we will be experiencing the precipitation. The ground surfaces are hot, the air in contact with the ground surface is warmer and lighter. This set up a convective current in which the warm moist air rises and when the warm moist air rises that places is taken up by the colder. So, that warm air will be replaced by the cold air.

So, this colder air is then heated as it comes in contact with the ground surface and again it rises. This process is continuing. As it rises, expansion of this air mass will be taking place and cooling of the air mass which results in the convective precipitation. This type of precipitation is more common in hot and humid tropical areas. This is of high intensity, generally accompanied by thunder and lightning. Plain areas will be experiencing majority of the time this convective precipitation.

Other type of precipitation is the frontal precipitation, because when the air mass, cold air mass is meeting the warm air mass we will be having the frontal precipitation. Here there is no definite front is not formed because here, because of the difference in the temperature the lifting off the air masses taking place. So, this type of precipitation is termed as convective precipitation. So, lifting process we have seen, three types of lifting, Orographic lifting, Frontal lifting and also Convective lifting, that is the first mechanism which is causing the rainfall.

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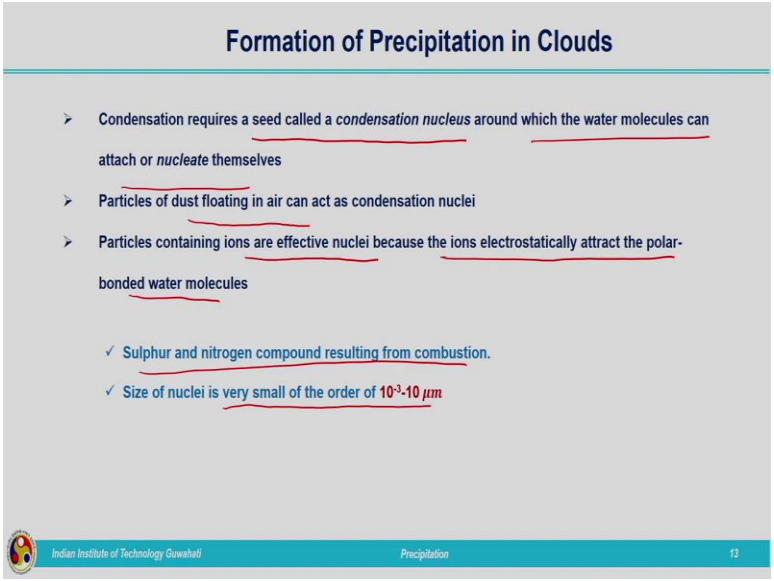

Second mechanism is the nucleation of the water vapor, that is condensation requires a seed called condensation nucleus, around which water molecules can attach or nucleate themselves. So, these particles may be dust particles floating in air or as I have told you aerosols or particles containing ions having effective nucleus because the ions electrostatically attract the polar bonded water molecules.

Sulphur and nitrogen compound resulting from combustion also will be causing the nucleation. Size of nuclear is very, very small of the order of 10^{-3} to 10 micrometers. You should understand it is of small size that is around 10^{-3} to 10 micrometers. So, we have seen two different mechanism behind the formation of precipitation. Now, let us see the dynamics of a cloud. What is happening within the cloud?

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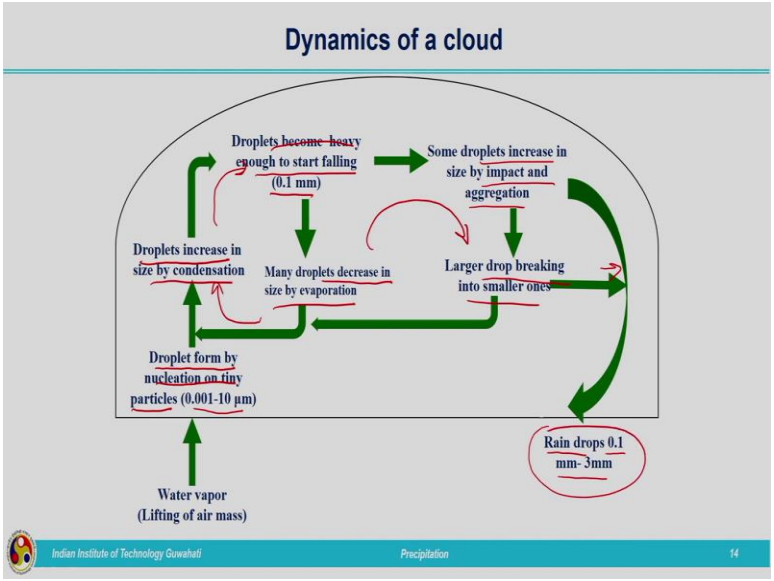

First process is starting from the water body, due to evaporation water vapor is formed and that water vapor or the air mass needs to be lifted up. So, first we will start with the lifting of air mass, whatever be the process behind that, let it be orographic lifting, let it be convective or frontal lifting, but the process is lifting off air mass.

So, the water vapor is getting lifted up and then what will happen we will be having the droplet formation by nucleation, nucleation on tiny particles. These tiny particles will be having around size around 0.001 to 10 micrometers. These droplets will be rising up, this will be increasing in size by condensation, then again it will be rising because these are very, very small it will not be falling down since the size is very small.

So, again it will be lifted up and more and more droplets combined together and they become heavy enough to start falling. At that time the size will be around 0.1 millimeters. When these droplets combined together and when the size becomes sufficient enough to fall down, then it will start falling. At that falling time also what will happen? many droplets decrease in size by evaporation. During the process of falling at that time also evaporation will be taking place. Because of evaporation what will happen? these tiny droplets will be converted back to water vapor. So, this process is continuously taking place and it will be joining together, form the droplets, increase in size. This process will be continuously taking place. This is one part.

So, here again from these droplets which are heavy broken into smaller one, this process continuing and on the other hand, some amount of droplets increase in size by impact and aggregation. So, when the size is increasing beyond a certain value, what will happen? it will be falling under gravity. We will be experiencing rain and rain drops will be formed which will be having approximate size varying between 0.1 millimeter to 3 millimeters.

So, when it is falling down, larger drops may break into smaller ones. So, these smaller ones may again mix up with the larger ones, and it will be falling as a raindrop or it may go in such a way that it will be meeting more and more droplets, increasing the size, it will rise up and the same process will be continuing in this way.

So, these are different activities taking place within the cloud. We are simply telling condensation of vapor taking place, cloud formation has taken place and from there we will be getting precipitation. What are the processes which are taking place within the cloud, mechanism behind the dynamics of a cloud, that is what we have seen here. Air lifting taking place, nucleation taking place, after that these tiny droplets will be mixing up together, some mixed up big droplets may be broken into smaller ones again. This process is continuously taking place within the clouds and finally we are getting the rain when it attains a size of 0.1 to 3 millimeters.

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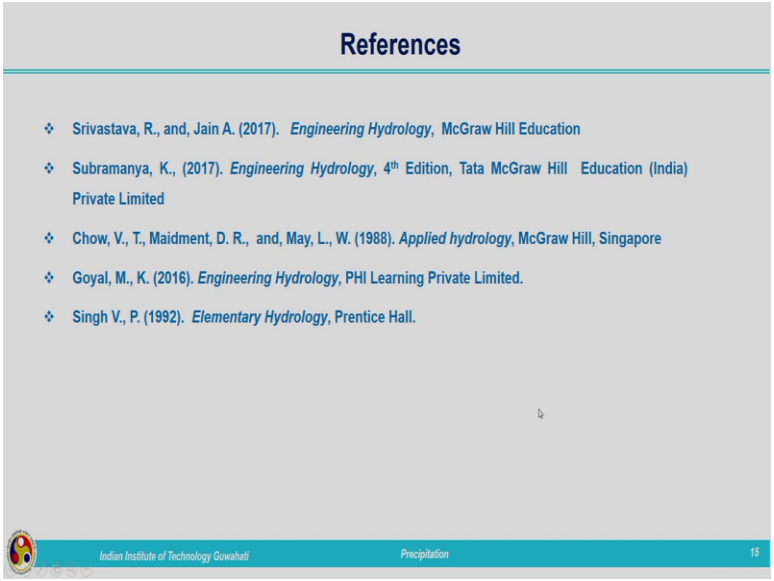

So, regarding this particular topic, you can have a reading through any of these textbooks. So, as of now, we have covered the mechanism behind the formation of rainfall, two mechanisms were there, lifting of air mass and nucleation. What is meant by this? What are the different lifting processes we have seen?

And after that we have seen the dynamics of a cloud, that is what are the activities taking place within the cloud. Now in the next lecture, we will see the different types of precipitation and the types of precipitation which we are experiencing. So, today I am winding up this lecture. Thank you.