Introduction to Atmospheric and Space Sciences

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Lecture - 35
Cloud Seeding and Precipitation

Hello dear students. So, in continuation with our understanding of various Atmospheric thermodynamical Processes and the Formation of Clouds and Atmospheric Stability. We are discussing the Formation of Cloud Droplets or how droplets of ice will also exist inside the cloud ok. So, we have seen what kind of stability permits the air to be uplifted resulting in the condensation.

So, we will try to understand how the condensation will grow a particular droplets to the sizes of cloud droplets or to the size of rain droplets. So, in the last class we have seen that once ice crystal is formed in its direction or in its movement towards the ground it will collide with several other tiny droplets. And in some clouds ice crystals might collide with super cooled liquid droplets or water droplets upon the contact the liquid droplets freeze into the ice and stick to the ice crystal. So, this process is called as accretion or rhyming.

So, what you will understand is that tiny droplets of supercooled water will get stuck on the ice crystal and thereby the ice crystal will grow in size . So, the icy matter that foams in this process is called as graupel or snow pellets, this is mainly called as the snow pellets right.

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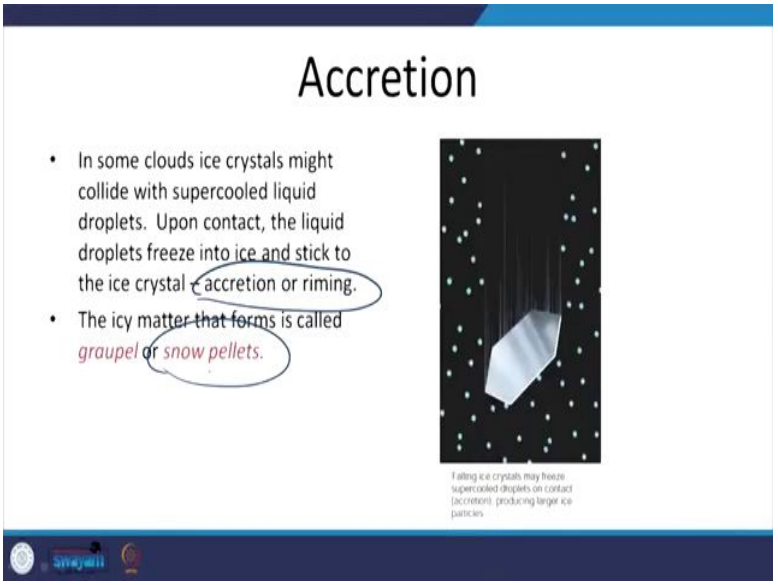

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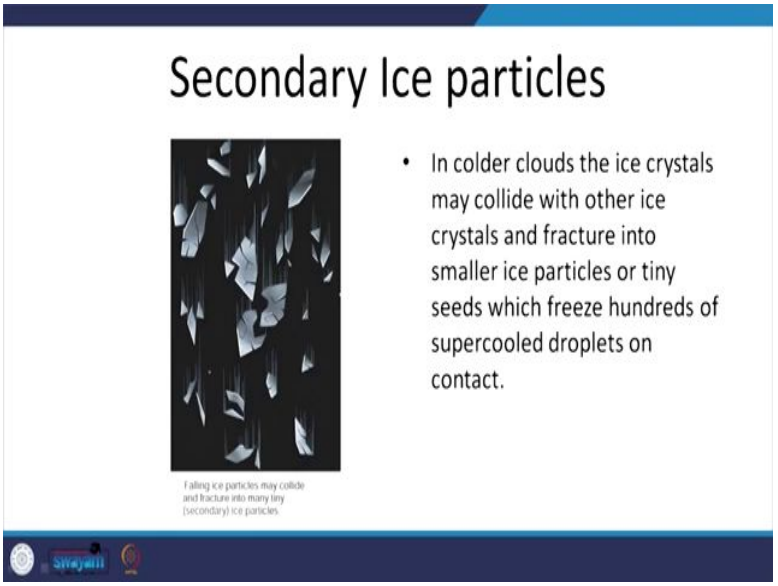

So, let us say in colder clouds the ice crystals may collide with other ice crystals and fracture into smaller ice particles or tiny seeds which freezes hundreds of supercooled droplets on contact.

So, when these ice crystals break small ice crystals will form and they will start collecting the droplets of tiny droplets of supercooled water. And in this process will allow the ice crystals to grow even more further right.

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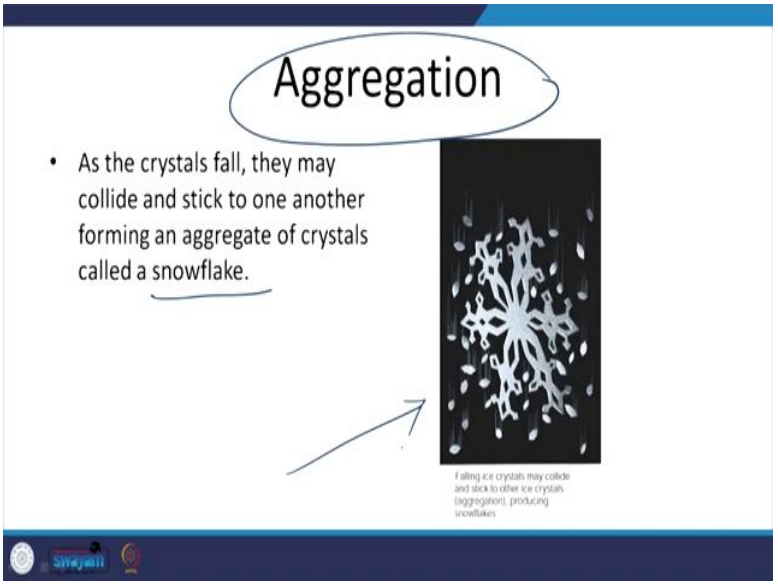

And that was something about the accretion and in addition to that, as the crystals fall as they continue to descend towards the lower altitudes they may collide and stick to one another forming an aggregate of crystals called as snowflakes

So, this is the journey from a simple ice crystal to what is called as the snowflake that you see when it snows right. So, this process is called as the aggregation; this process is called as the aggregation and this is the typical. Let us say this is how the snow flake will look like. So, this has a distinct shape actually alright.

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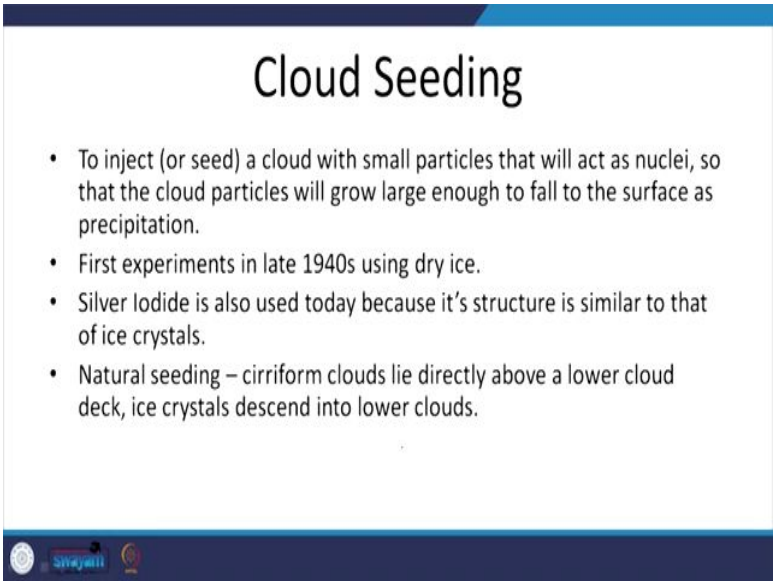

Now so, it is evident by now is that a cloud is a collection of highly small or tiny droplets of water. These droplets are typically of the order of few micrometers in size and as long as the cloud is stable they it will not lead towards the precipitation. Or so, the processes from a vapor, condensing onto the top of air cloud condensation nuclei which will result in a very small or very tiny droplets.

When these tiny droplets by any means or methods grow several hundreds of times then you will realize they are called as the rain droplets. These rain droplets are substantially larger and they are heavier in the sense they get attracted by the gravity and they will descend towards the surface right. So, the process of let us say making the precipitation artificially is called as the cloud seeding.

So, to inject let us say or to seed a cloud with small particles that will act as nuclei. So, that the cloud particles will grow large enough to fall to the surface of the earth and can also be called as the precipitation is generally called as the cloud seeding. So, the cloud seeding is the process in which you inject very small cloud condensation nuclei type of particles into the cloud so, that they will act as surfaces on which tiny droplets of water will condense and grow into the larger rain droplets right.

So, the first experiments of this sort were conducted in 19 in early 1940's using dry ice where the is itself used to act as surfaces for condensation right. Later it was realized silver iodide is also used today because it is structure is similar to that of an ice crystal basically it is a surface on which you want the vapor to condense right. Natural seeding is what the pseudo form plots light directly above or lower clouds like. So, ice crystal descends into the lower cloud. So, this is where the cloud seeding is mainly targeted right and it is the main outcome that is expected all of this process is the precipitation right.

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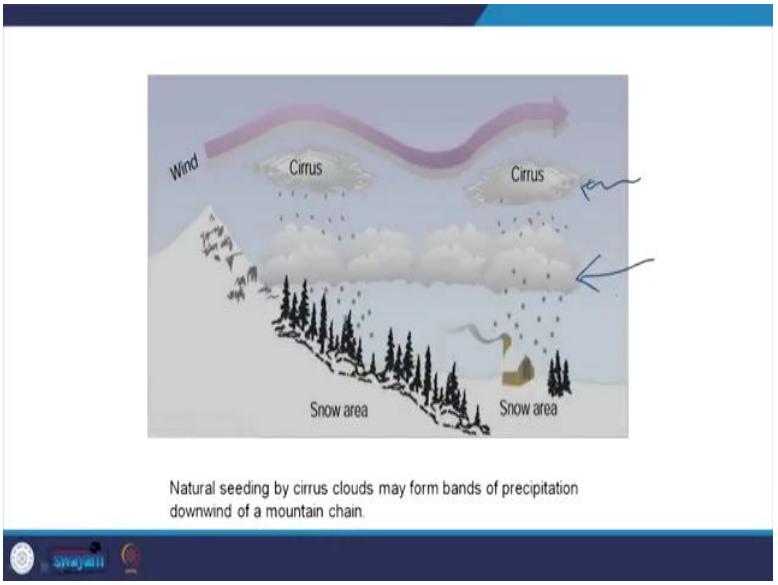

So, this is how you will seed the clouds let us say where natural seeding is occurring by the cirrus clouds which are related this is the cirrus clouds right. So, natural seeding by cirrus clouds may form bands of precipitation downward of a mountain chain. So, the cirrus clouds can themselves act as mechanism to provide tiny crystals of ice into the cumulus clouds, thereby they are naturally seeding this particular clouds which already have some vapour in it right.

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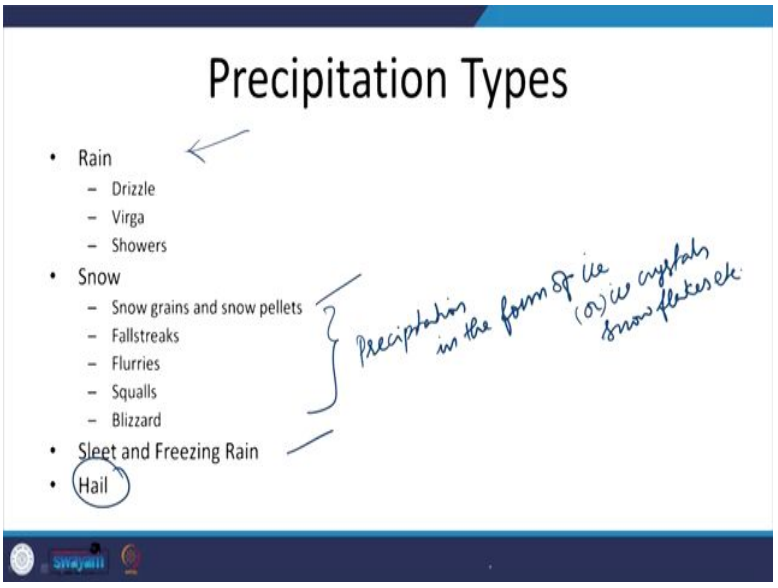

Now, when you talk about precipitation, what is precipitation? The basic idea of precipitation is when a small cloud droplet grows into a rain droplet at a sustainable size when it crosses a sustainable size, this rain droplet will start moving towards the ground bound by the gravity when this rain droplet reaches the surface you call it as precipitation right.

So, precipitation can be of many different types or many different forms let us say. So, the main or major form of precipitation is the rain, which can be a drizzle or which can be a Virga, which can also be showers. And the other form of precipitation which is of course, not in the liquid phase rather in the solid phase is the snow. Snow is not a single type of precipitation, within the snow category there are several other types of precipitation. Let's say snow grains or snow pellets, fall streaks, flurries, squalls, blizzard all these are precipitation in the form of let us say ice or ice crystals or snowflakes etcetera right.

And another form of precipitation which probably would not reach the earth is sleet or freezing rain or the most dangerous form of precipitation is hail or hail storms. So, we will try to understand how these different forms of precipitation are for the physical appearance or what are the various conditions during which this type of precipitation may actually occur right.

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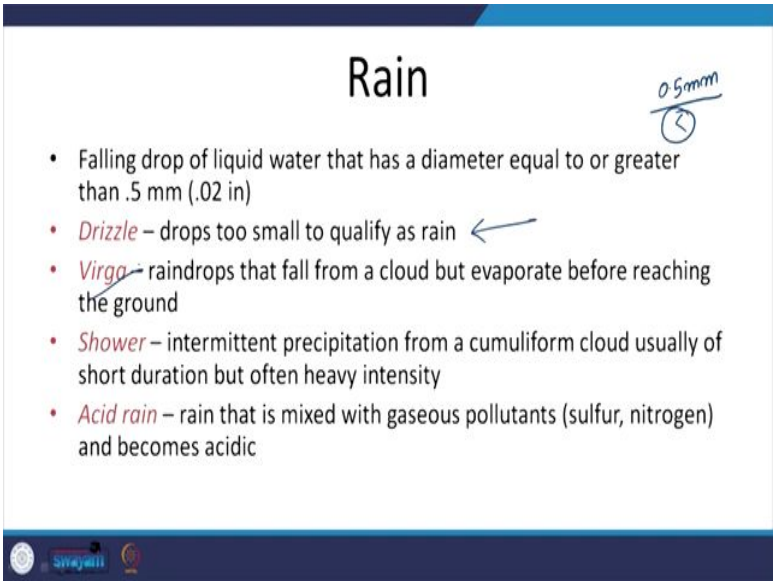

So, let us say rain. So, rain is the most known form of precipitation that we see very often right. So, let us say the falling drop of liquid water that has a diameter equal to or greater than 0.5 millimeters or 0.02 inch can be classified as rain. So, when the downward movement of

water in the sizes of more than 0.5 millimeter that is, then you call it as half a millimeter is generally called as rain.

So, what is drizzle then? So, drizzle is drops which are too small to qualify as rain. So, we use you put the scale as 0.5 millimeter. So, anything with any precipitation whose constituents or the whose droplets are more than 0.5 millimeters are classified into what is called as rain. So, something that is less than this limit, generally classifies to be what is called as a drizzle right.

And, what is Virga? Raindrops that fall from a cloud but evaporate before reaching the ground is called as Virga. So, if you imagine your cloud bottom to be at let us say for 8 kilometers or 9 kilometers, then whatever the precipitation that results in this cloud results out of this cloud must reach the surface only then you call it as rain right. If it is of a typical size, but if it condemned if it rains, but it never reaches the earth you call it as Virga.

Shower, shower is intermittent precipitation from a cumuliform cloud usually short duration, but often heavy intensity right, this is what is called as a shower. The acid rain are the ones in which rain that is intermixed with gaseous pollutants. So, gaseous pollutants exist in the atmosphere, but if H_2O precipitation is intermixed with this gaseous constituents or gaseous pollutants then you call this type of precipitation as acid rain right.

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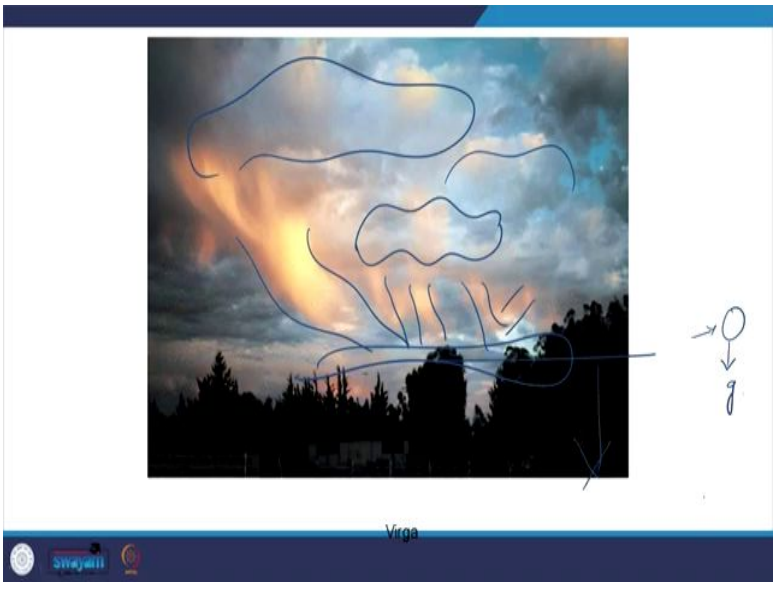

So, this is how it looks like. So, these clouds the are of course, they are precipitating; I mean the cloud is unstable. So, they tiny droplets are of course, growing to large droplets to be able to be pulled by the gravity.

But the thing is the precipitation is so less that this precipitation is released, but this precipitation that is being released like this is of course, not reaching the surface. So, this type of precipitation is not going to make to the surface. So, this is called as Virga right.

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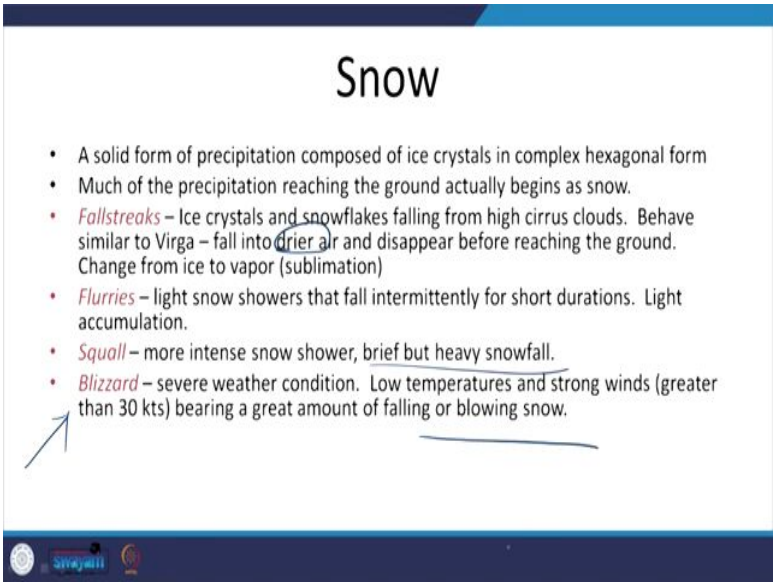

So, that was something about the precipitation in the form of liquid water, when you talk about precipitation in the form of solid H 2 O the different phase. A solid form of precipitation is composed of ice crystals which are in a complex hexagonal form, the ice crystals are in a complex hexagonal form. So, basically the precipitation in the form of solid is generally referred to as snow.

So, much of the precipitation reaching the ground actually begins as snow ok. So, within this particular class of precipitation there are several other let us say forms. So, fall streaks, ice crystals and snow flakes falling from high cirrus clouds. So, in our cloud classification we have seen that clouds which are very high in altitude are generally known as cirrus clouds.

So, ice crystals fall streaks are the ones which represents the ice crystals and snowflakes falling from very high cirrus clouds. So, they behaves similar to Virga fall into drier air and disappear before reaching the ground. So, they fall into the drier air so, where there is a lack

of moisture. So, these ice crystals will be evaporated and they will evaporated in the sense they will be melted. So, now, the point is the amount of water is lost into vapor again so, they will never reach the earth. So, this is similar to Virga, in the sense that there is precipitation in the solid form, but the precipitation hardly reaches the surface.

Flurries are the ones with let us say light snow showers that fall intermittently for shorter duration, light accumulation. So, these are very light kind of a snow events right. Squall is more intense snow shower brief, but heavy snowfall. And, blizzard is the most rare occurrence or is the most severe one in the form of precipitation in solid form, blizzard is severe weather condition.

So, the temperatures will be very low for to be able to cause this kind of an event. So, low temperatures and strong winds greater than let us say 30 knots per second bearing a great amount of falling or blowing snow. So, this kind of severe events of a snow are generally called as the blizzards right.

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So, this is just an example where ice crystals are kind of trying to precipitate, but they will never reach the surface. So, this is the type of cloud here is cirrus cloud. So, this is what is happening. So, this is the precipitation that is trying to reach the air, but it is not making to the earth anyway. So, what do you call this, as this you call as the fall streaks. So, these are the fall streaks right. So, these are what are called as fall streaks right.

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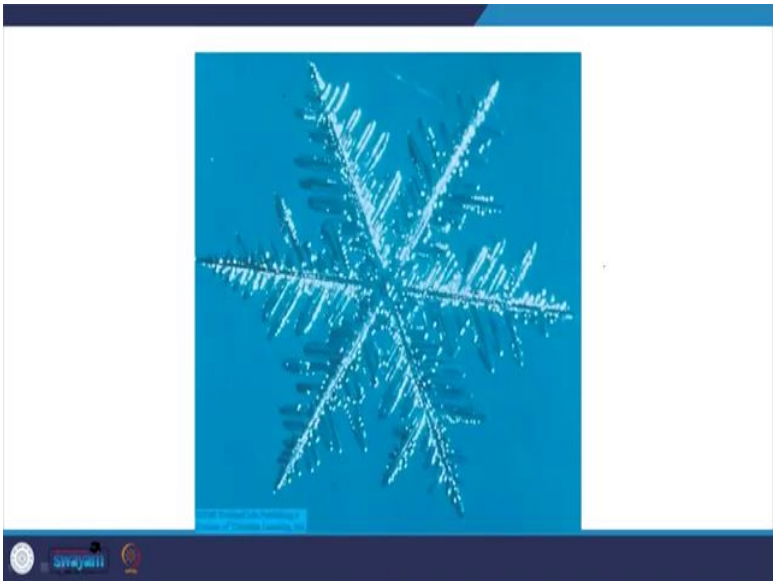

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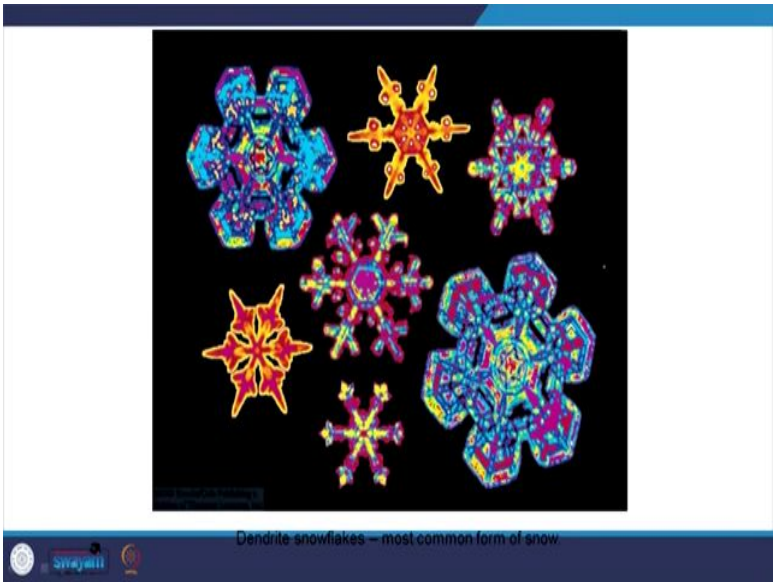

So, this is how it is typical snowflake will look like. So, most common forms of snow. So, this is this form sort of agglomeration right.

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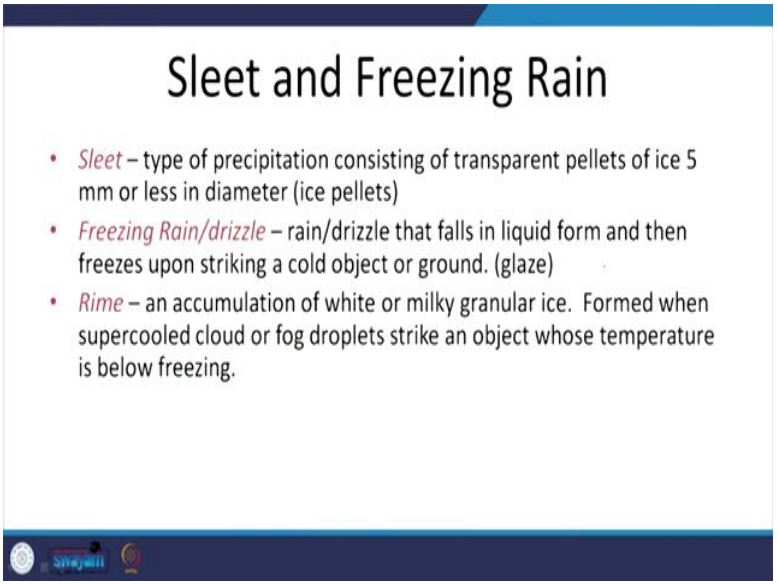

And the other form of a precipitation is sleet and freezing rain, sleet is a type of precipitation consisting of transparent pellet of ice 5 millimeter or less in diameter right. So, you call something else when it is in the size is more than that, but below that particular size you call it that the ice crystals, which are typically of the order of let us say diameter of 5 millimeter or less are called as this is the sleet.

It is a freezing rain or drizzle, let us say rain or drizzle that falls in liquid form and then freezes upon striking cold object or the ground is called as a freezing rain. So, it formed it of course, arrives in the liquid form, but it freezes upon hitting an even cooler or colder object right.

Rime is an accumulation of white or milky granular ice, formed when supercooled cloud or fog droplets strike an object whose temperature is below freezing. So, you have liquid water, but when it touches even colder surface you get to see what is called as the rime right.

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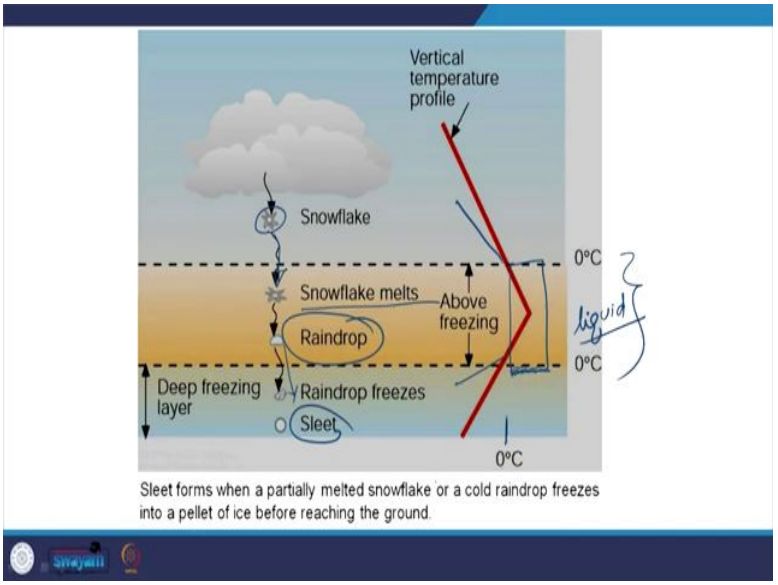

So, let us say if you look at the vertical temperature profile so, you have to understand. wherever the temperature is more than 0 degree Celsius they are freezing point of water is just that the water will be existing in the liquid phase in that particular point and when the temperature is becoming less than 0 degree Celsius automatically you will expect freezing and you will expect a lot of snow to be existing at that perfect temperature right.

So, let us say so, this is the temperature how it is varying. So, the temperature is increasing with respect to height up to a particular altitude then it is decreasing. So, whatever it is if you put the 0 degree centigrade mark here so, this region is the region which is kind of conducive for the water to exist in the liquid form as the temperature is more than 0 degree Celsius. So, water cannot freeze here, but anything which will be below this let us say this region, this region and this region are the ones where the water will exist in the ice form.

So, even if a snowflake which is falling from a particular type of cloud is in the solid phase when it falls due to the virtue of it is weight or the mass when it reaches this area where water is more likely to be in the liquid phase you will see that the snowflake will melt and it will form a rain droplet. Once it crosses this region and enters the region where the temperatures are sub 0 it automatically freezes again and then you will see the sleet. The sleet forms when a partially melted snowflake or a cold rain droplet freezes into a pellet of ice before reaching the ground. This is the basic understanding of the formation of sleet right.

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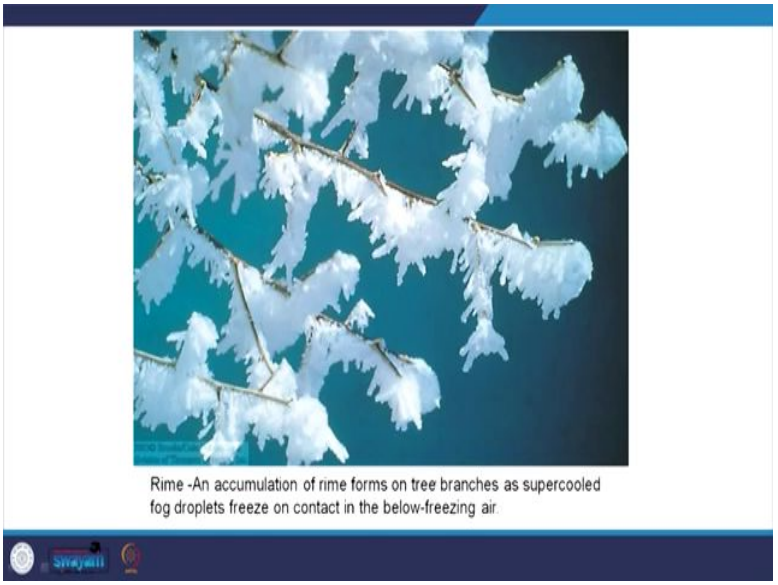

So, rime is accumulation of forms of rain on tree branches as supercooled fog droplets freeze on contact with the below freezing air. So, the atmosphere and the ground is itself is very cold or below freezing temperatures right.

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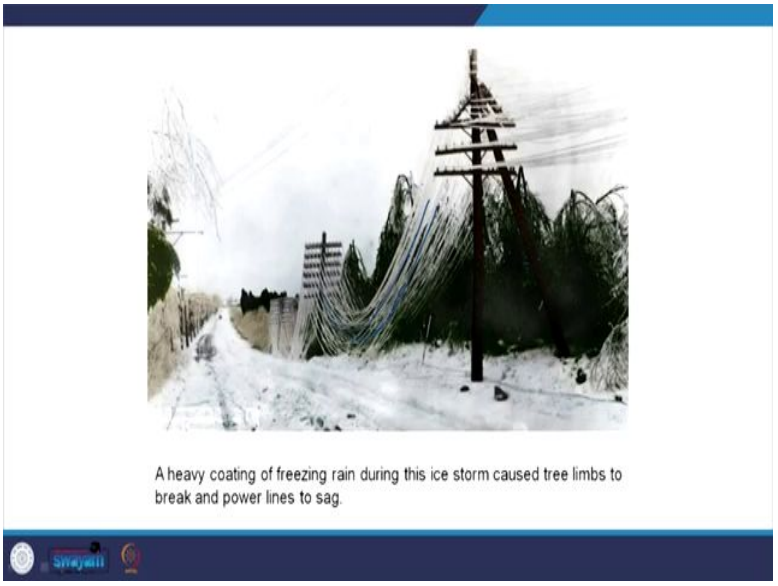

So, this is where you see, a heavy coating of freezing the rain during this ice storm caused trees limbs to break and power lines to sag. So, all the water has accumulated on the these power cables and it has crystallized or it has formed into ice. So, due to the weight you see the voids are heavily sat right.

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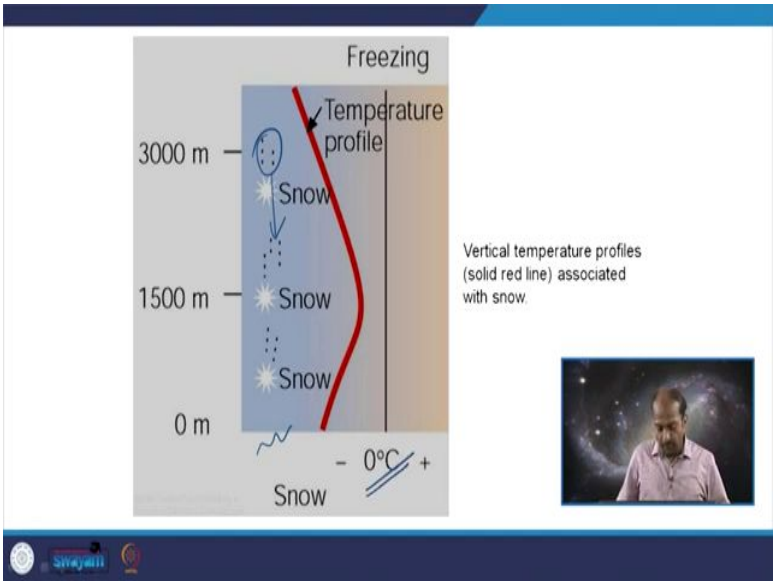

So, now we will list few important temperature profiles that are required for the formation of snow.

So, what you see here, the vertical line that you see is 0 degree Celsius mark; that means, this is the freezing point of ice let us see if you take a location in the polar region. What you will see is, the temperatures are sub 0 everywhere, at the ground or at the 10 kilometers or at 15 kilometers of whatever it is so, the temperature isalways I mean all of the heights the temperature is sub 0.

So, if in such a condition if you develop snow or ice crystals at a particular altitude and these ice crystals build up to a sufficiently larger amount of mass. So, that they travel towards the ground, then automatically as it travels there is nothing which can cause these ice crystals to get warm warmed or to melt. So, as a result finally, when it reaches the surface you will see only snow, but not rain. That is because the temperatures are always have always been less than the freezing point temperatures right.

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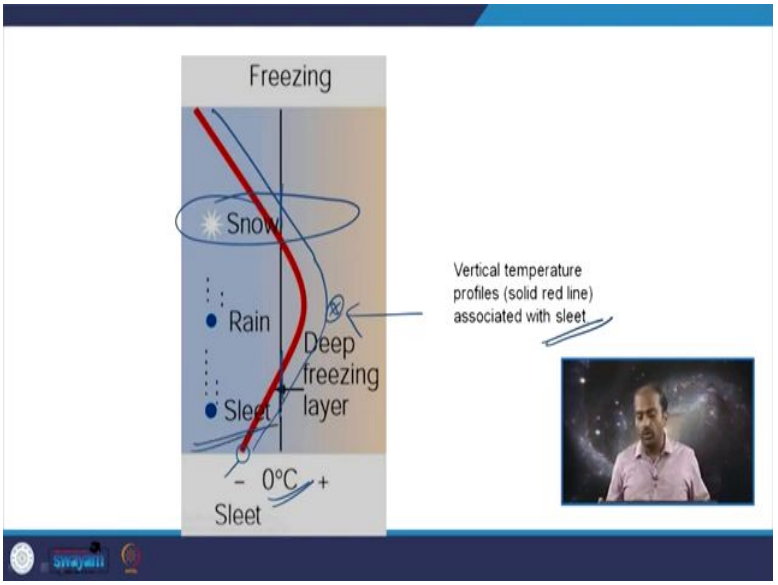

Now, so, vertical temperatures profiles associated with sleet. So, let us say you have 0 degree Celsius vertical line and now if the temperature of the atmosphere is varying like this. So, at the ground the temperatures are very less and as you go up the temperatures are increasing and they will increased to a particular height let us say and then they will decrease again, but they are crossing the 0 degree Celsius mark at two points.

Now if you imagine the cloud bottoms to be existing at these heights and if snow develops to a sufficiently large mass and it starts traveling towards the ground. Here at this point it encounters a region or a temperature which is more in the sense the temperature will melt the snow right. Now the snow will again cross that point and will again start freezing. So, partially froze water will eventually make it to the surface then you can call it as the sleet right.

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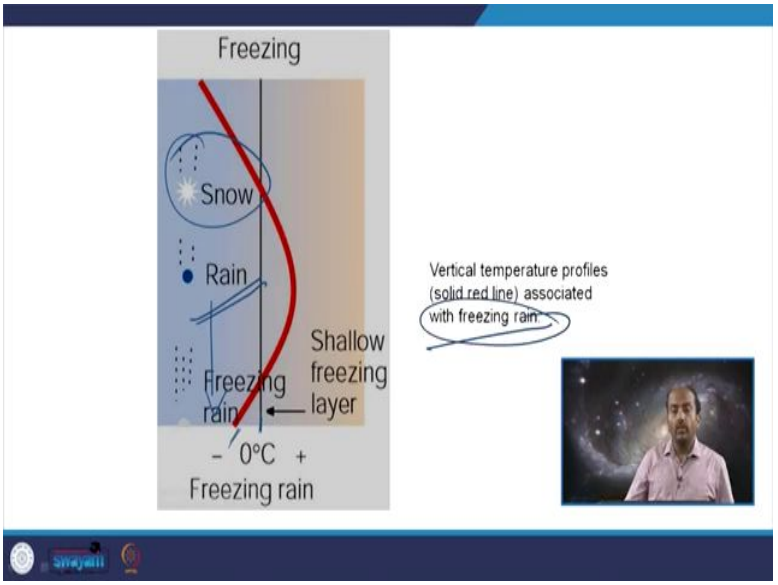

Now, vertical temperature profile associated with the freezing rain . So, what you see here is that, the temperature 0 degree Celsius temperature is the vertical line and the temperatures at the ground are not very low in comparison to the earlier case that we have seen.

If the temperatures are slightly less than the freezing temperature, but the point of origin of precipitation is allowing only ice to be precipitated, it gets heated to this particular point when it is when the temperatures are very high, but when it when it is again traveling towards the ground the difference in the temperatures would not allow all this liquid again to be solidified and again to be frozen into ice. So, as a result you will see a rain which is which we called as the freezing rain right.

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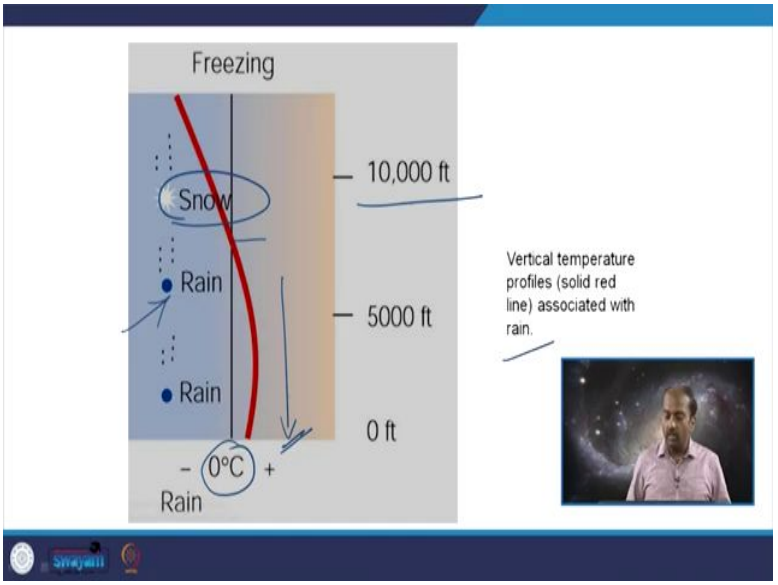

And similarly another profile of a temperature vertical temperature profile associated with right. So, this is where you see the temperature is never below 0 degree Celsius, only at this point it is below the 0 degree Celsius. So, you see that if the precipitation at a particular height 10,000 feet has resulted in the formation of snow which is traveling downwards, once it crosses the 0 degree Celsius limit then all the ice melts and it will create the rain.

Now, this rain has never been given the opportunity to again freeze throughout it is vertical descent right so; that means, that at the at the final outcome you will get see only rain right.

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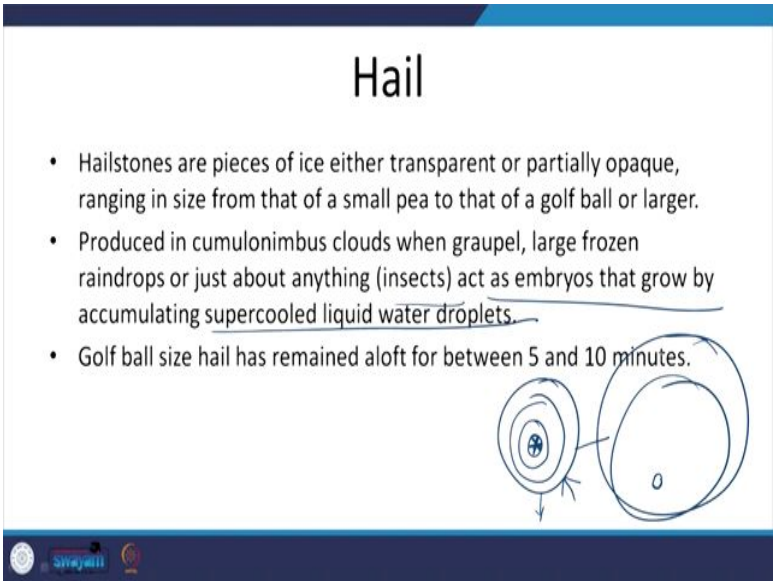

Now, hail is a is a totally different process in the sense hail is one occurrence where you see large ice crystals which are very large in comparison to a typical rain droplet or a typical ice crystal. So, hailstones they are generally referred to as hailstones in the sense that you see them to be very large and very impactful or very harmful for the life or for any property.

Let us say, hail stones are the pieces of ice either transparent or partially opaque, ranging in size from that of a small pea to that of a gold ball or even to the size of a baseball right. So, they are produced in cumulonimbus clouds when graupel, a large frozen raindrops or just about anything insects act as embryos that grow by accumulating supercooled liquid droplets.

So, anything any smallest entity if it starts accumulating water or if it starts accumulating the water vapor subsequently as it becomes larger. It comes in contact with even more amount of tiny droplets which will just get stucked onto the surface and because the temperatures are already freezing so, they will just again become ice. So, as a result this all insect or the small graupel will act as embryo for the creation of this particular object.

So, what do you see at the end of it, you will see a huge ice crystal can be as small as this and this can be as large as this or even larger than this right. So, this is the typical size that many reports have confirmed the hailstone can grow up to right. So, what has been seen is that, golf ball size hail has remained aloft for between let us say 5 to 10 or 15 minutes. So, they exist within the cloud.

So, there is a strong vertical updraft in the cloud which prevents this crystals falling to the ground. They will hold it as long as they could, but when the weight of the hail stone gets too high or overcomes the updraft, it has to come down and it has to fall on the ground and then it can cause a lot of damage depending on what it falls on to right.

So, hailstones begin as embryos, what is embryo? Embryo is the smallest entity which gives birth to the hailstone right. Hail stone begin as embryos usually the ice particles itself they are not anything else, it can be an insect, i it can be a pollutant, pollutant particle, soot anything that remains suspended in the cloud by boiled updraft.

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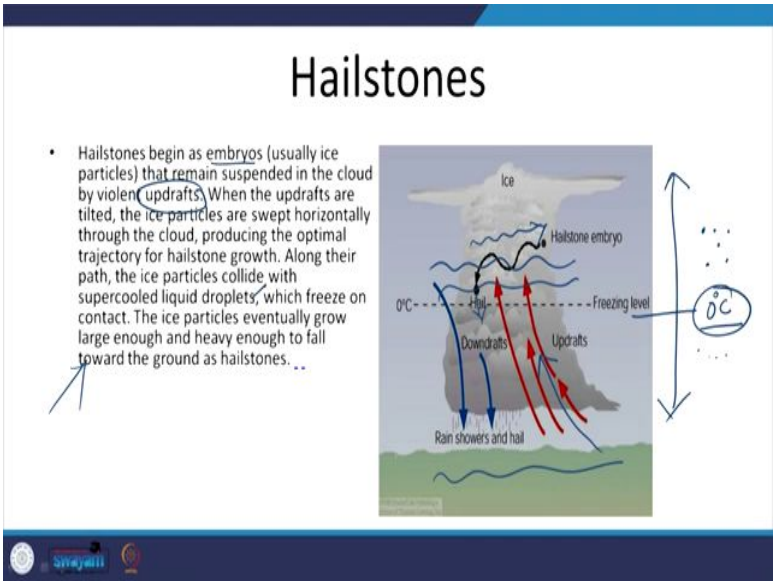

So, this vertical updraft is what makes these type of embryos available in the cumulonimbus cloud. So, you see this hugely vertically developed cloud is generally known as the cumulonimbus cloud and this cloud is the one which can bring every natural calamity to a particular point. It can bring rain, it can bring hail, it can bring thunderstorms, it can bring heavy amounts of lightning, everything right.

So, what you see in this figure is the updraft. So, this is the vertical movement of air which of course, creates the cloud in the first place with a strong moment of vertical air allows the hail or the allows the embryo to be present at a particular altitude. When the updrafts are tilted, the ice particles affect horizontally throughout the cloud. So, they are soaked like this throughout the cloud right. Along their path, the ice particles collide with supercooled liquid droplets.

So, this is the freezing level; that means, the temperature here is 0 degree Celsius anything above; water has naturally a tendency that it will exist in the ice form I mean these are ice crystals, but here what you see they are the water droplets. So, above this 0 degree Celsius the temperature is of course, decreasing with respect to height in this particular altitude.

So, the as a hailstone is traveling horizontally not just in a horizontal line as such, but the overall movement is the is the drift is in the horizontal direction. So, in that process it comes across many different ice small ice crystals. So, they it will start accumulating all those ice crystals on it is surface and it starts growing. So, this triggers the growth, along their path ice

particles collide with supercooled liquid droplets, which freeze on contact. The ice particles eventually grow large enough and heavy enough to fall towards the ground as the hail stones.

So, the most important thing that you should remember is that vertical updrafts will still prevent the hail from falling downwards, but when the weight becomes too much or when it overcomes the force of vertical updrafts then it has to naturally fall right. So, then you will see hailstone in this area where the cloud is existing right.

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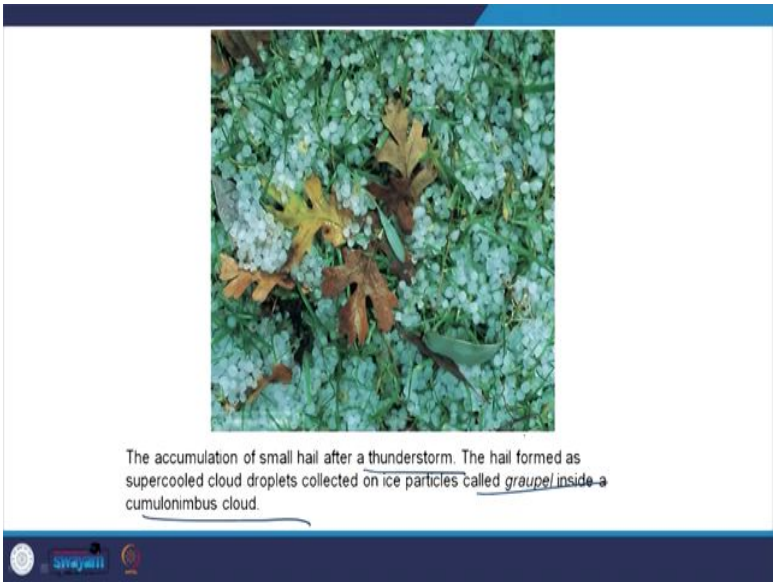

So, this is just an example of small hail where the hail is even very small in size the accumulation of small hail after thunderstorms. The hail formed as supercooled cloud droplets collected on ice particles called graupel inside a cumulonimbus cloud. So, if this crystal are kept in a vertical conducive updraft they will grow into large sized hail crystals right let us say. So, this is the giant Coffeyville hailstone which was which was almost like 1.67 pounds in the year 1970.

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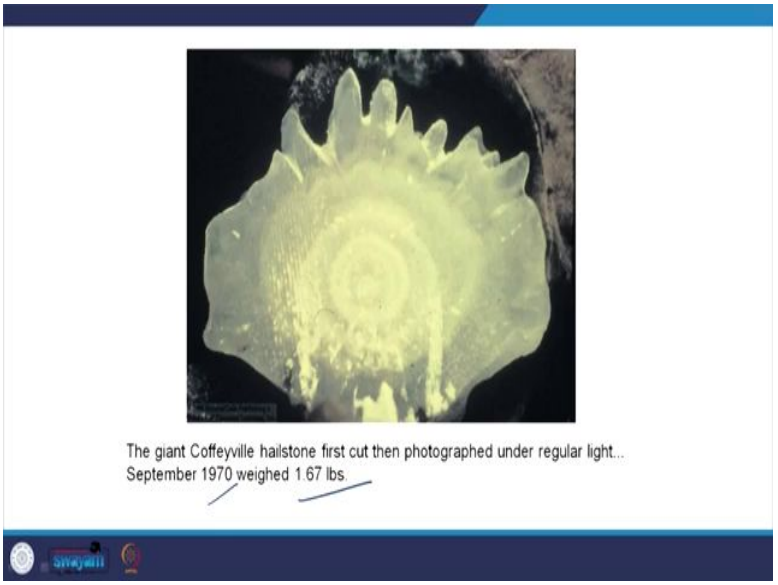

So, this can be very dangerous, I mean this the size if only one crystal or if the hail contains hundreds and thousands of crystals which are which are at least of the size of let us say baseball or even if it is a golf ball then you just imagine an object falling from the sky at an immense velocity of let us say 80 or 90 kilometers per hour if it falls on something it could be hazardous right.

So, hail storms are very dangerous for various different forms of life that exists on the on the surface right.

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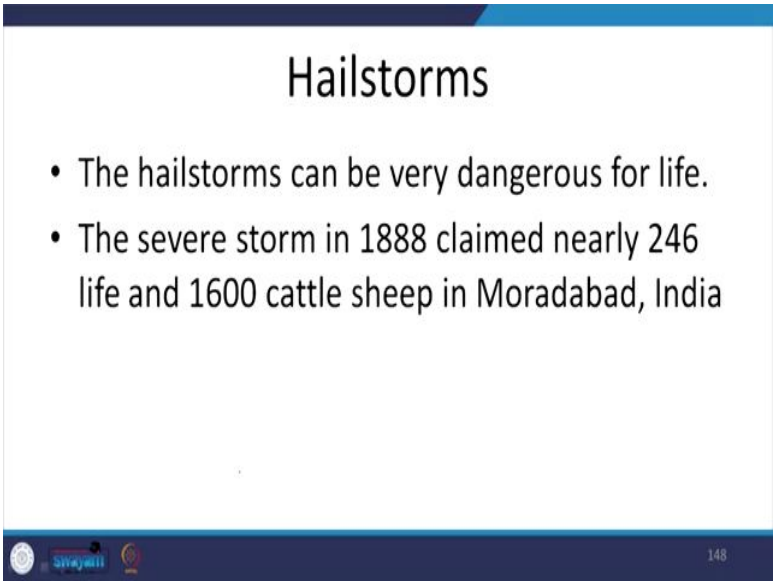

The severe storms in 1888 was the most infamous hail storm event which nearly claimed 246 lives of humans, and 1600 cattle sheep in India right. So, hailstorm is a very dangerous phenomena right.

So, this was something about various forms of precipitation. So, we have already seen what is the condition for the formation of cloud and what happens when you say that cloud has formed and what exactly is cloud and when the cloud will be unstable and when it will rain all this process. Then, when it rains we have seen how many different types of precipitation that this particular cloud can give us right.

So, we have seen precipitation in the forms of water, liquid water and precipitation in the form of a ice, various different forms of ice right. So, we will stop here. So, we will continue this discussion and understand once there is rain how do you measure it? I mean what kind of unit or what kind of measuring equipment you will use to understand how much it has rained, right.