Surface Water Hydrology
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Lecture 02
Hydrologic Cycle and Its Different Components

Hello students, welcome to the second lecture of Surface Water Hydrology.

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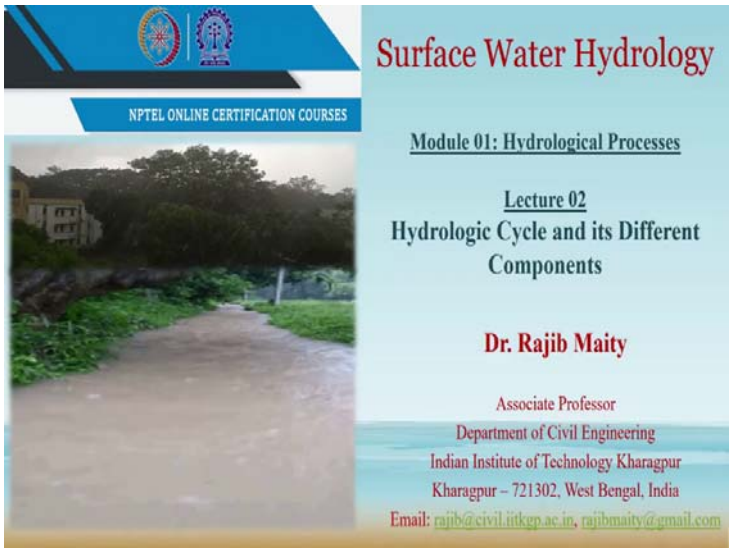

In this lecture, we will cover the hydrological cycle and its different components. As you can see, we are still in module 1 that deals with hydrological processes, and in this particular lecture, we will cover hydrologic cycle and its different components.

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So in this lecture, there will be two concepts will be covered; spatio-temporal distribution of water on earth and hydrological cycle and its different components.

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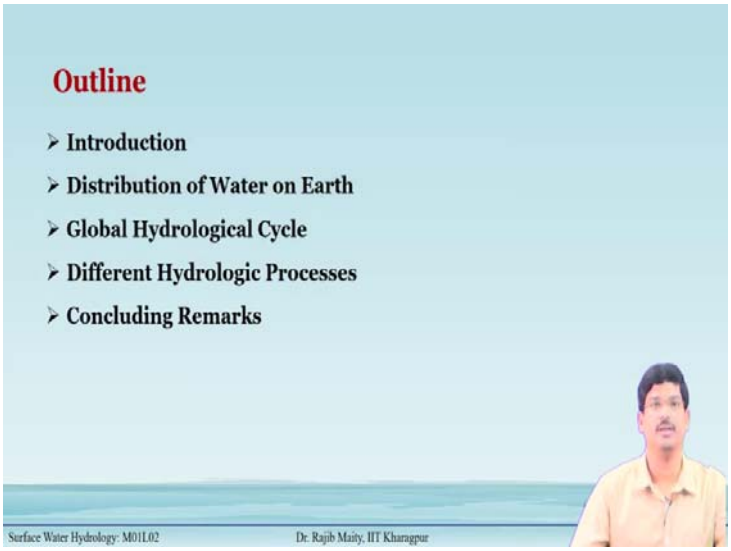

In the outline, first we will give some general introduction and then the distribution of water on the earth, global hydrological cycle, different hydrological processes and then some concluding remarks.

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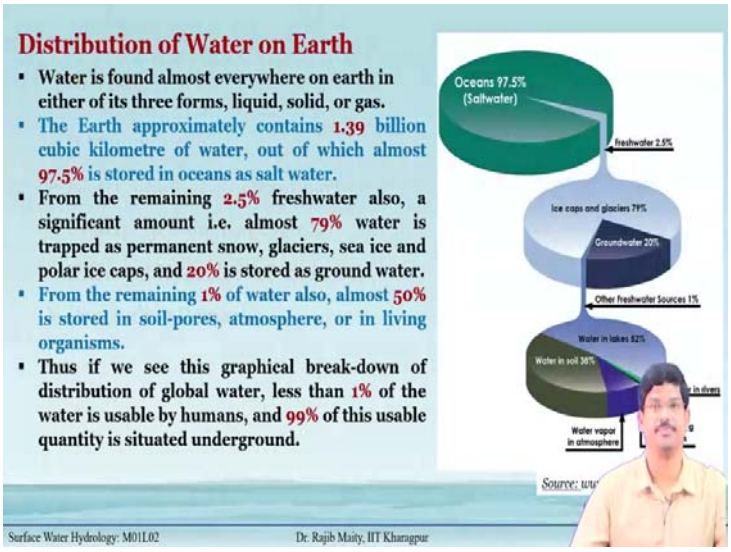

As you can see, the distribution of water on the earth is almost everywhere. We can see either of its three different forms – liquid, solid or gas. It can stay in any one of the forms in the hydrosphere that we discussed in the first class.

Now approximately, it contains about 1.39 billion cubic kilometer of water, out of which almost 97.5 percent is stored in the ocean as salt water. Why this information is important is that salt water is almost of no use for the living organisms for different purposes. Remaining 2.5 percent is the freshwater, which is useful to us, and again, if we see here this diagram this 2.5 percent freshwater also, there is a significant amount that is almost 79 percent of the water is trapped as a permanent snow, glacier or ice sea and the polar ice caps.

So, though useful but these are not accessible to the human community. Rest approximately 20 percent is stored as in the groundwater, which is also available to us, no doubt. But again, there should be some caution, there should be some responsible use of it. So, what is available, the remaining amount, it is 1 percent of the water. This 1 percent of the water is readily available to us from different sources like rivers, lakes, even in the form of soil moisture.

So, out of this 1%, almost 50 percent is stored in the soil pores, atmosphere or in the living organism. So, you can also see that if something is in the atmosphere, something is in the soil pores or in the living organism, they are also not usable, i.e., we cannot directly use them. Of course, whatever it is available in the soil pores, the plants can utilize it but for the animals and human community, it should be available in the lakes or rivers or small depressions.

Thus, if we see this breakdown of the distribution of global water, it is almost less than 1 percent is usable by humans. 99 percent of this usable quantity is in the underground. So, this graphical presentation you can see the total amount out of which the 97.5 percent is the salt water and remaining 2.5 percent is freshwater.

Now, within this 2.5 percent of the freshwater, as you can see that 79 percent is in ice caps and glaciers, whereas in the groundwater, it is 20 percent, approximately. Remaining 1 percent, if I see its distribution, then it is also in the 5 different groups. The 52 percent of water is in the lakes, then 38 percent water is in the soil, which the plants can utilize.

In the atmosphere, it is in the form of water vapor. Then remaining water in the living organism, this green part is the water in the rivers. So, in this part also the maximum storage is in the lakes and in the soil and there are very less percentage in the river and as water vapor in the atmosphere that you can see from this graphical presentation.

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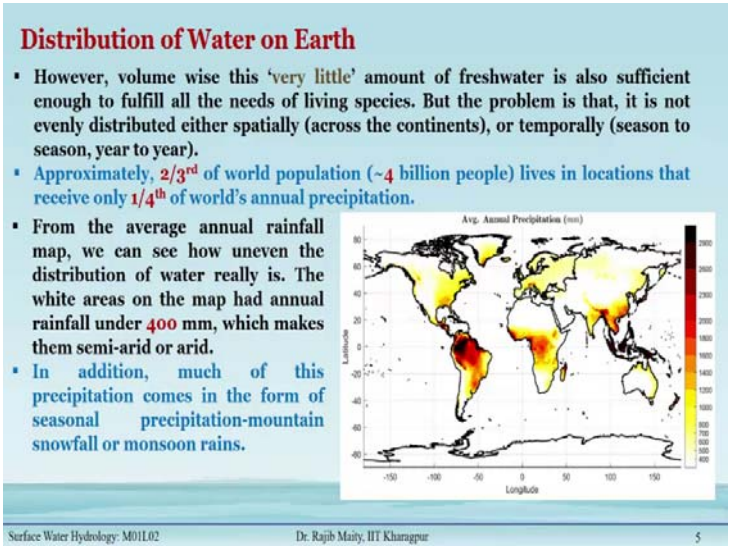

Now, if we see that distribution of the water on the earth, then we see the volume wise, this "very little", very little in quote-unquote, respect to the saline water, is also sufficient enough to fulfil all our needs for this entire living species.

But the problem is that, it is not evenly distributed either spatially or temporally. Spatially what I mean from all across the earth from one continent to another continent, and temporally what I mean that day to day, so from one season to another season or year to year, this is also not uniformly distributed.

Now, how these things are distributed that we will discuss now. Approximately, two-third of the world population, that is 4 billion people live in the location that receives only one-fourth of the world's annual precipitation. So, you can image that the population is high and the available water resource is less for that part, and, from the average annual rainfall map, as you can see here, in this part, this is average annual rainfall, shown in mm. We can see that how uneven this distribution is. The white patches that you can see here, these are the areas receiving less than 400 mm of annual rainfall, and this red patches and the dark red patches are of course higher. But you can see that this spatial distribution, this color tone is showing this distribution, the water availability from the annual precipitation is highly uneven considering the entire world.

In addition, much of this precipitation comes in the form of a seasonal precipitation, the mountain snowfall and monsoon rains. That means, it is the annual total that you can see in this plot. But again in a year, if I see, how is it distributed across the 12 months or across the year, then also we will see it is highly concentrated during some months. these are generally

controlled by seasonal precipitation or the mountain driven or orographic or snowfall or during some monsoonal circulation.

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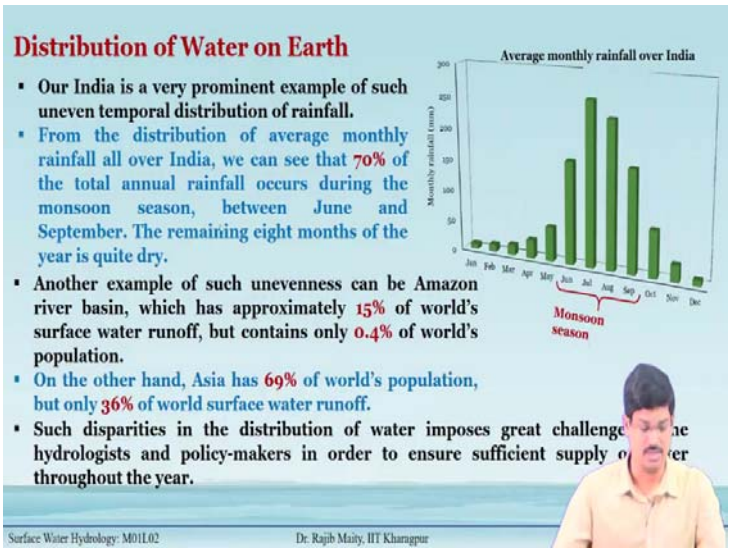

Here is one example, that is shown here, particularly in case of our Indian context, that in India, there is a very prominent example of such uneven temporal distribution of rainfall. As you might be knowing that from the distribution of the average monthly rainfall over India, we can see that about 70 percent of total annual rainfall occurs during the monsoon season only.

By this monsoon season, what I mean is that, June, July, August and September. These four months are called the monsoon season, and you have experienced that we receive most of the rainfall during these four months only. And, we sometime abbreviate it as *JJAS*. So this is the monsoon period, and you can see that monthly rainfall magnitudes in the Y axis. So, these 4 months receive the most of the precipitation.

If I go back to the global distribution, this unevenness can be also seen in the Amazon river basin, which has approximately 15 percent of the world's surface water runoff but it contains only 0.4 percent of the world population. So, not to surprise, the maximum amount runoff we get at a region where the population is least.

On the other hand, if we see, Asia, another continent, has a 69 percent of the world's population but only 36 percent of the world surface runoff is there in this continent. So, this kind of disparities in the distribution of the water imposes some challenges to us, I mean

hydrologists as well as the policy-makers, field practitioners, in order to ensure the sufficient supply of the water throughout the year.

That means, if I get sufficient amount of rainfall or sometimes even more that what is required, say during these 4 monsoon months, and now this storage, whatever we receive during these 4 months, with that, we need to run the entire year. So, as you can see, we have to understand the nature of a particular locality, how it receives rain, how the available water resources are there, and then, what we have to do, is that, we have to develop some sort of management strategies, so that we can manage that water for the entire year.

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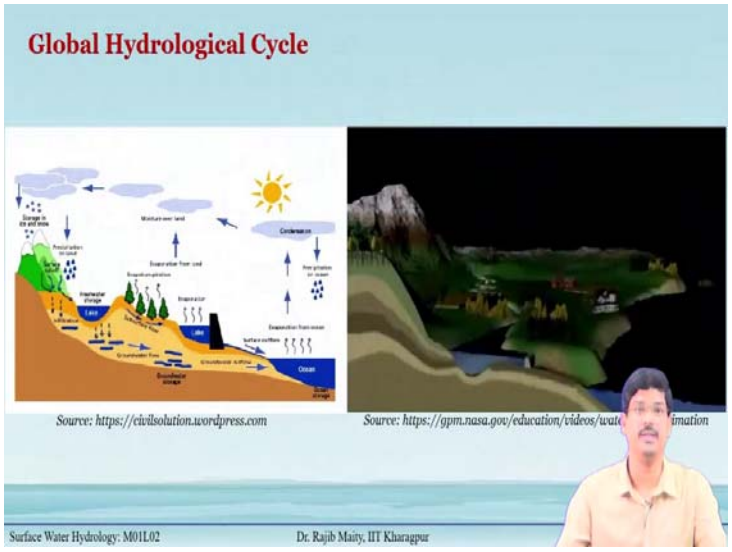

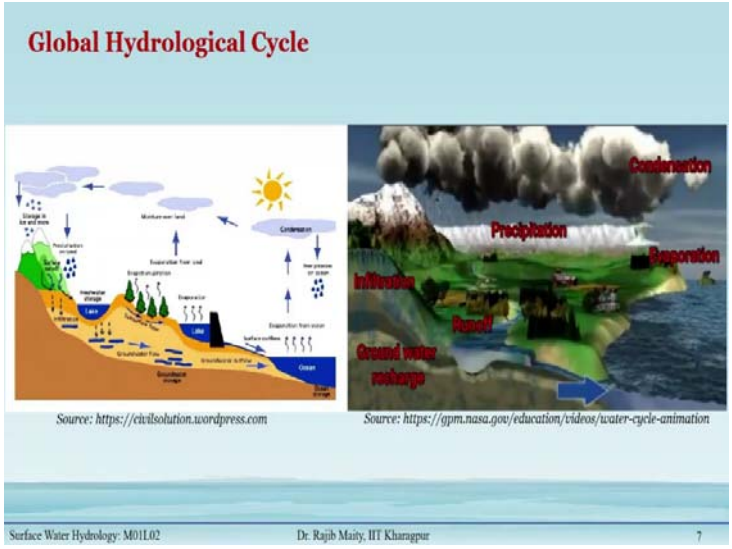

Here, you can see the global hydrological cycle. The major processes are shown here. As you can see that there, I can just run this animation here, you can see it here. So, the major driver,

as you know, for this entire hydrologic cycle, that is the movement of the water on the globe, is the solar energy.

So, it creates some evaporation on the ocean and the water bodies, it rises up, creates some condensation, through this atmospheric circulation, it is carried to different parts of the earth, then, it precipitates. Then runoff occurs, and then, there are other processes. It basically circulates through the different processes.

So, when it comes and falls on the land, local depressions are filled up, runoff generated, that runoff joins to the local water bodies. Some part of the water also infiltrates, and it joins to the groundwater, and groundwater also flows and discharged in the nearby water storage or even to the ocean. So, it is basically endless, and as you can understand, the major driving force is the solar energy.

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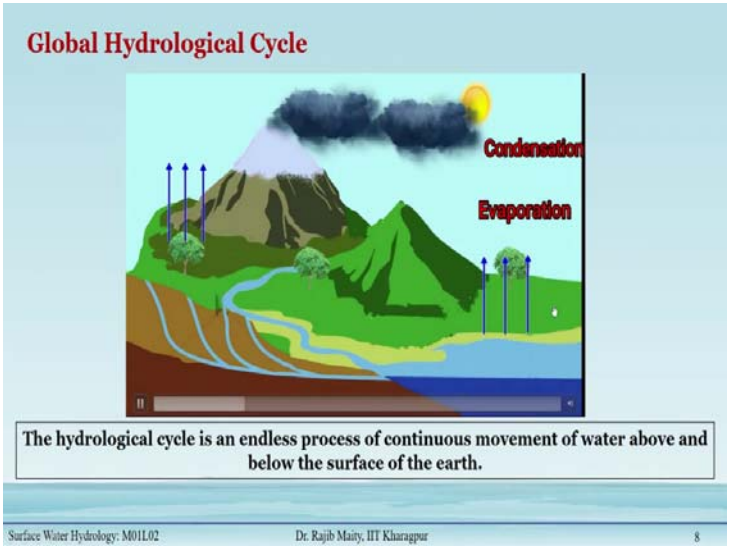

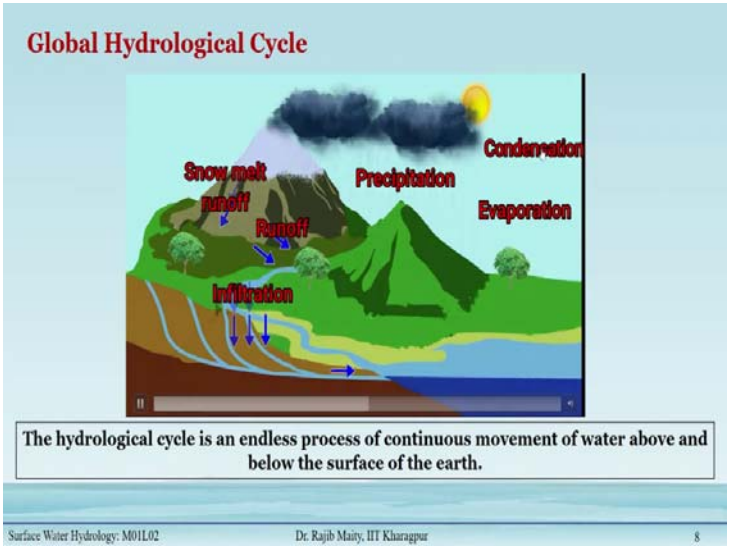

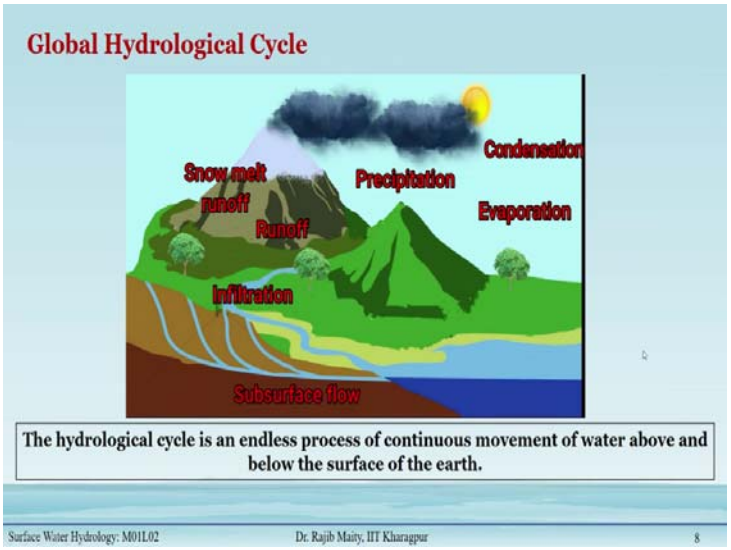

Another animation, small animation you can see here, it is showing the specific name of some of the processes that we are going to discuss in the subsequent slides. So, as I told you that due to the solar energy from the land surface, from the ocean surface, from water bodies, it evaporates, it goes up. There is a process, process named as a condensation. The clouds are formed, and from the cloud there is a precipitation down either in the form – the precipitation is basically both the rainfall and snowfall. There are different forms of precipitation. Once it falls, it creates some runoff, its infiltration occur and then it goes as a subsurface flow.

So, this hydrologic cycle is an endless process of continuous movement of the water, above and below the surface of the earth. So, it is above means I mean the atmosphere and below means it is the subsurface water, and of course, the surface water we can see there the storage and movement.

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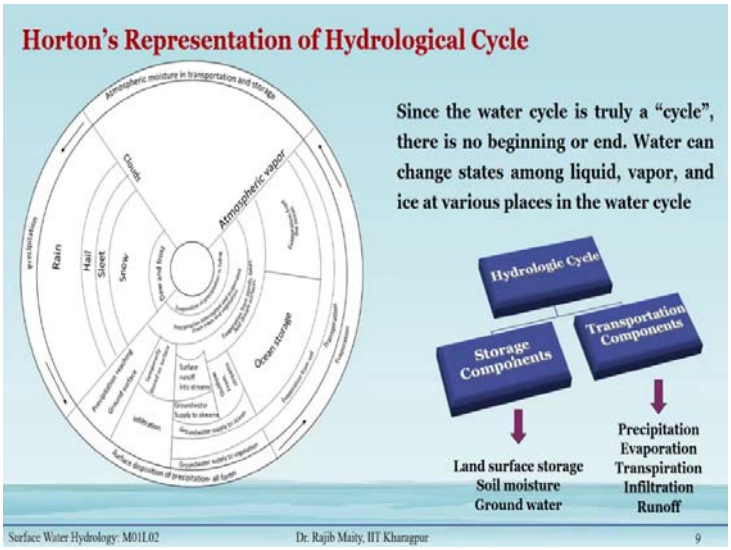

There is another beautiful representation by Horton. It is called the Horton's representation of hydrologic cycle. That you can see here. This, most of the part is in the atmospheric moisture, and transportation starts from here, it forms the clouds, and when it comes as a precipitation, it is in different forms like the rain, hail, sleet, snow, dew and frost. Thus, it is received in different forms, precipitation reaching the ground surface. Some parts of precipitation is intercepted and evaporated from the trees and vegetation. Evaporation also takes place from the precipitation directly that is falling, and then this part is basically going and directly joining to the atmospheric vapor. And the other processes like the precipitation that is reaching to the ground surface may be either temporarily stored on the surface or it can infiltrate.

After this infiltration or after this temporary storage, it can go as a surface runoff into the streams or groundwater supply to the streams, groundwater supply to the ocean or even evaporation can take place from the soil directly, then it goes to join the atmospheric vapor. Other part the groundwater supplied to the vegetation and from the vegetation, it comes via transpiration, then it goes to the atmospheric vapor again. And from the surface deposition of the precipitation in all forms, it goes, via evaporation, to the atmospheric moisture again.

After the ocean storage from the groundwater to the ocean and from the outflow from the streams, it goes to the ocean storage, and from the ocean storage also, the evaporation takes place, and it joins to the atmospheric vapor. And then in the atmosphere it again condenses and forms the cloud. So, you can see that it is truly a cycle, and there are different parts are there where the atmospheric water, surface water, ground water follow different processes.

The main thing here is that, since the water cycle is a truly a cycle, it has no beginning or no end. Water can change its state of course during this path among the liquid, vapor and ice at various place in the water cycle.

In this, I want to show you two different major groups, groups in the sense of two different components, basically one is the storage component and other one is the transportation component. Under this storage component, we can see that there is a land surface storage, there is a soil moisture storage, there is a groundwater storage. So, different this kind of storages are possible.

And the transportation component means it transports from the one place to another place, one form to the another form or one subsystem to the another subsystem. These are the precipitation, evaporation, transpiration, infiltration, runoff. These are some of the examples here.

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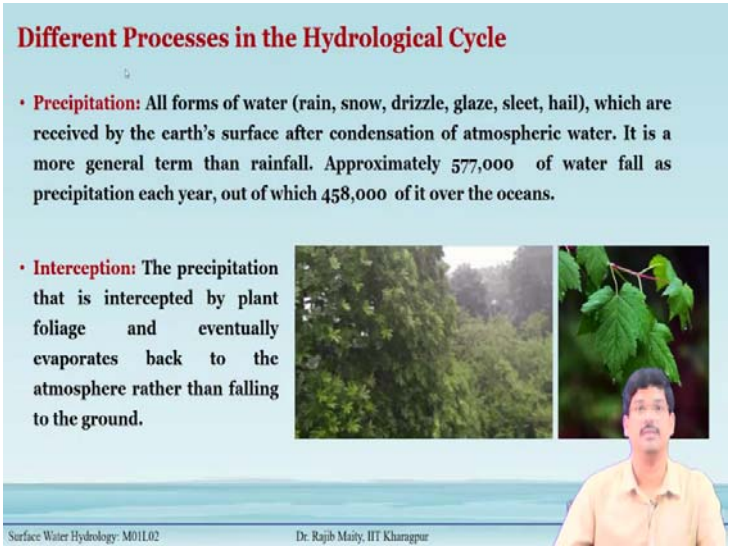

So, we will take up these processes one after the another. The first one is the precipitation. The precipitation can be in the all forms of water, as I mentioned some of the names, like snow, rain, drizzle, glaze, sleet, hail. These are different forms of precipitation, which are received by the earth surface after the condensation of atmospheric water. It is a more general term than rainfall. The rainfall is basically in the form of liquid, and when we refer to the precipitation, it basically covers all forms that the earth surface receive water after condensation.

So, you can see another figure here, that approximately 5,77,000 km cube of the water falls as precipitation each year. It is in the km cube. Approximately, this much km cube of water falls as precipitation each year. Out of which 4,58,000 km cube falls over the ocean itself. So, a significant percentage of the precipitation falls on the ocean itself, so directly converted to saline water. As we have already discussed, the saline water is almost of no use to the living organism.

Secondly, it comes *interception*. The interception means, when the precipitation that is intercepted by the plant foliage and eventually evaporates back from there itself to the atmosphere, rather than falling on the ground. You can see some pictorial representations here, when the precipitation comes and falls on the canopy like this, and there is some water is hold on the leaves itself, and from there, instead of falling down, falling on the ground, it evaporates from there itself. So, this process is known as the interception.

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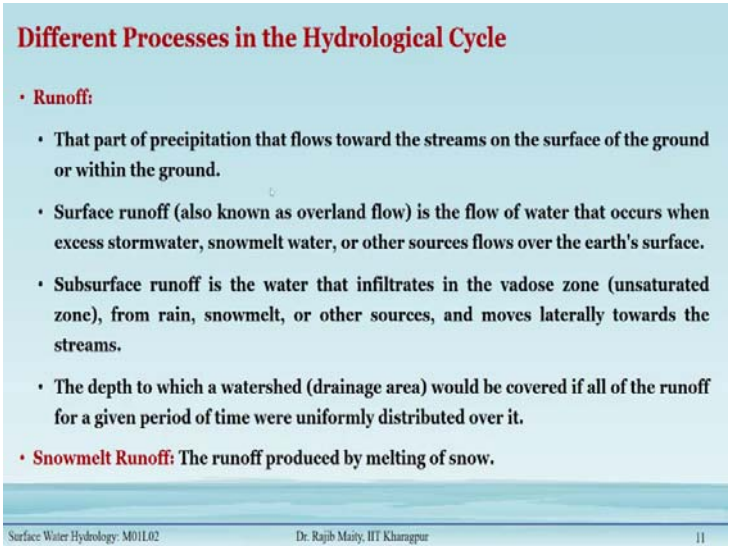

Next, comes the *runoff*. There is some part of the precipitation that flows towards the streams on the surface of the ground or within the ground. The surface runoff it is also known as the overland flow, is the flow of the water that occurs when the excess storm water or snowmelt water or other sources of the flow over the earth surface. So, if it is above the earth surface then it is the surface runoff.

Whereas on the other hand, the subsurface runoff is a water that infiltrates. Of course, we have to know what is infiltration (later). After the infiltration, it joins to the vadose zone. The vadose zone means, just immediately below the ground, the unsaturated zone of the soil strata. In that zone, there are some part of the water that infiltrates from the rain, snowmelt and other sources and then it starts, moves almost parallel to the ground surface towards the streams.

So, if the runoff takes place above the surface, we call it as a *surface runoff* and if it is just below the ground, then we call it as a *subsurface runoff*. The depth to which a watershed, that also means the drainage area, would cover if all the runoff for a given period of the time is uniformly distributed. That is the how we measure the runoff.

So, total volume divided by the total area that will give you a length unit and this is how we measure the runoff. Just to make it a similar to the rainfall measurement also. So, how much is the depth of the rainfall, when we say, it is the standing depth of water that is received. Similarly, in case of runoff also, total volume of the runoff, if we distribute all over the drainage area, then the standing height of the water is the measurement of the runoff. Another term is called the snowmelt runoff. This runoff produced by melting of the snow.

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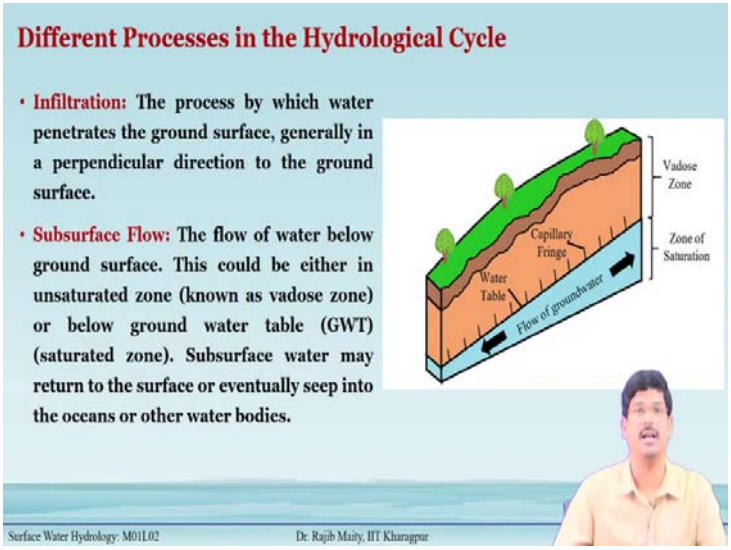

Then comes the *infiltration* that I mentioned in the last slide. It is the process by which water penetrates the ground surface, generally in the perpendicular direction to the ground surface. So, remember that this infiltration is just the process of the penetrating the ground surface, no other thing. Neither before, when it is above the ground surface or after penetrating the ground surface where it goes. It is just the process of the penetration of the ground surface. There are, of course, different ways to measure this. But, so far as the definition is concerned, it is the process through which the water penetrates the ground surface.

And then what is subsurface flow? The subsurface flow is the flow of the water below the ground surface. It could be either in the unsaturated zone, as I told, it is vadose zone, or it can be below the groundwater table also. Below the groundwater table means that it becomes a saturated zone. The subsurface water may return back to the surface or may eventually seep into ocean or other water bodies.

This last one, that I told, it depends on the topography. As a demonstration, you can see here. So, sometime depending on the topography, whatever penetrates at some highlands, at a later stage, towards the downstream, it may come up on the surface and join to the surface runoff also. So, this surface runoff and subsurface runoff are sometimes interchangeable. They join each other depending on the topography and the soil characteristics, and of course, the how the land cover is.

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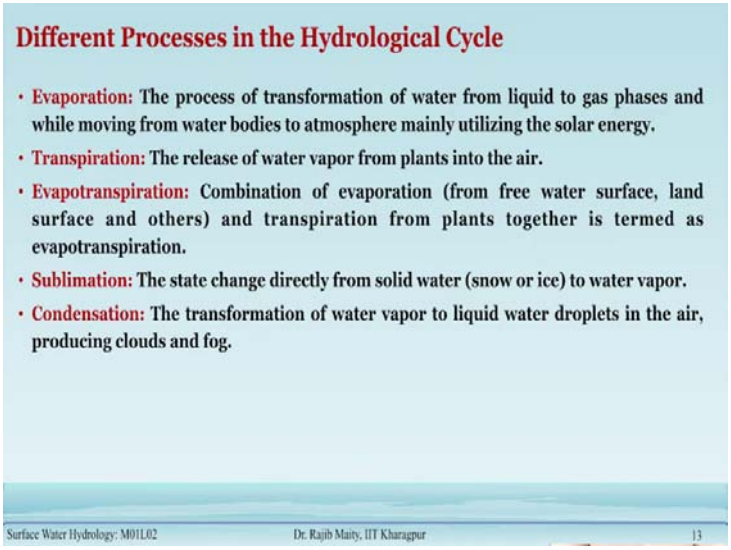

Next comes some of the terms that we have seen in the hydrological cycle. The first one is *evaporation*. It is the process of transformation of the water from the liquid to the gaseous phase. And while moving from the water bodies to the atmosphere, it mainly utilize the solar energy. So, due to the solar energy, the water bodies or even from the soil surface, the water can transform from the liquid phase to the gaseous phase, and this transformation process is known as *evaporation*.

There is another term called *transpiration*. It is related to the plants. It releases the water vapor during the process of photosynthesis and during their biological processes. Through these processes also, the liquid water is transformed to the gaseous phase. Thus, if it is through the plants, it is called the *transpiration*.

Now there is another term, which is a combination of these two, i.e., evaporation and transpiration, it is called *evapotranspiration*. So, the *evapotranspiration* is the combination of evaporation from the free water surface, land surface or others sources, and the transpiration from the plants.

Next come *sublimation*, the processes of changing the state of water directly from the solid to the gaseous form. It is called the sublimation. That means, the evaporation and transpiration or the evapotranspiration, they transform the water from the liquid phase to the gaseous phase whereas, the sublimation is basically directly from the solid state to the gaseous state.

And the opposite of this process, i.e., from the gaseous phase to the liquid phase is called the *condensation*. This transforms of the water vapor to the liquid, producing the cloud and the fog. This process called the *condensation*.

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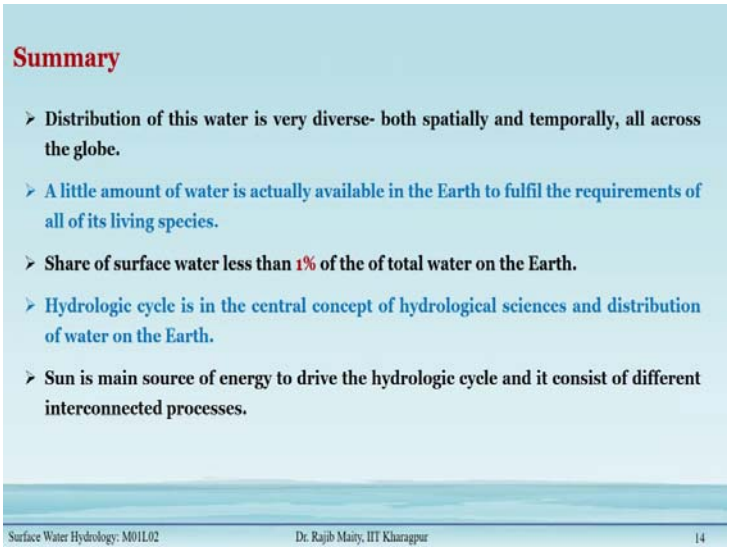

So, coming to the summary of this lecture, the distribution of the water is very much diverse all across the world and it is both spatially and temporally. Spatially means over the space if we see from one continent to another continent or even within a continent one country to another country, one region to another region, and temporally means over the time, from one year to another year or within a year from one month to another month. So, this varies a lot. In technical term, it is called spatio-temporal distribution. So, this distribution is wide, all across the globe.

Secondly, a very little amount of water is actually available in the earth to fulfil the requirements of all of its living species. The share of the water less than 1 percent of the total water on the earth. The share of the surface water, as we are talking about it and you saw it from the very initial pictorial diagram, is very less, It is less than 1 percent of the total volume of the water on the earth.

Hydrologic cycle is in the central concept of this hydrological sciences, and we have seen different processes related to it, and it is also responsible for the distribution of the water on the earth. And also, as you have seen, that sun is the main source of the energy to drive this hydrologic cycle, and this hydrologic cycle consists of different interconnected processes that we have discussed in this lecture. Thank you.