**Conservation Geography**
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**Module - 5**
**Hydrosphere**
**Lecture - 15**
**Hydrological cycle**

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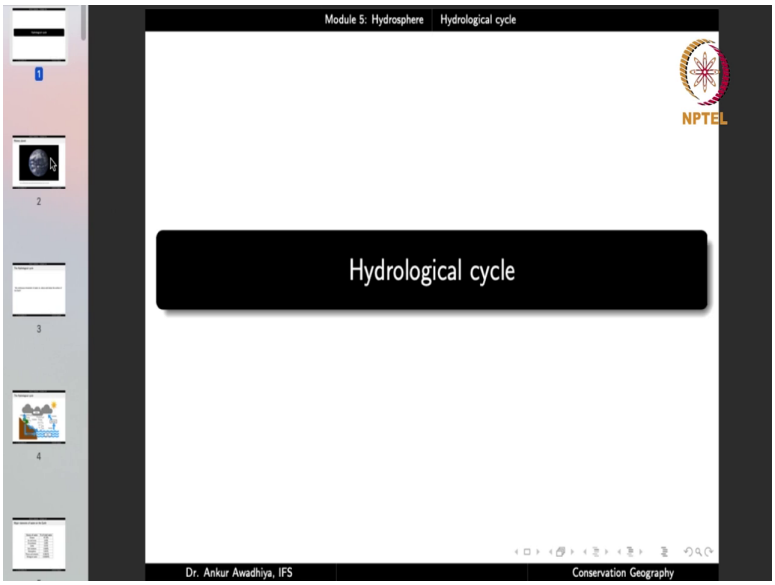


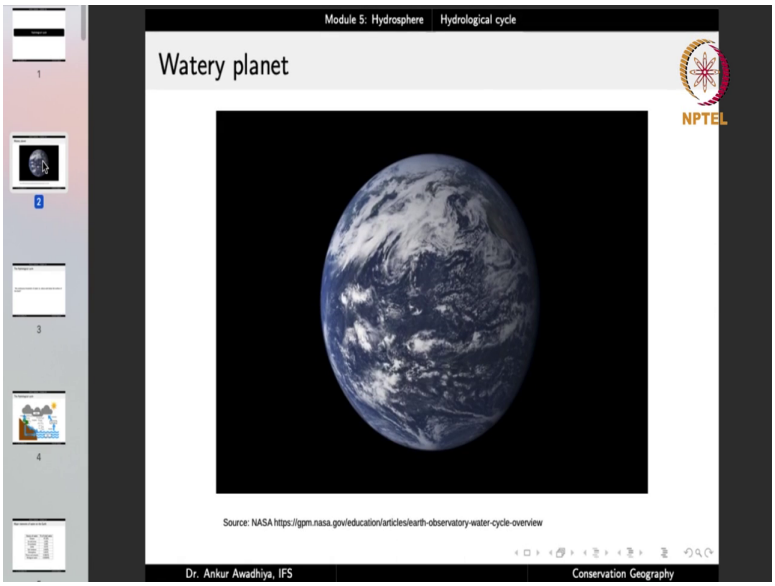


Namaste! We carry forward our discussion on the hydrosphere and in this lecture we shall have a look at the hydrological cycle or the water cycle, now we have seen before that the Earth is a watery planet, a large portion of the Earth as much as around 70 percent of it is covered with water bodies including seas and oceans, now we also have water on the surface, above the surface and below the surface of the Earth.

So we are talking about things such as the water fraction that is there in the atmosphere and the water fraction that is there in the form of groundwater as well, plus we also have a lot of water that is there in the living organisms, that is water in the biosphere, now all of this water keeps on moving from one portion to another portion and this movement occurs through a cycle that is known as the water cycle or the hydrological cycle.

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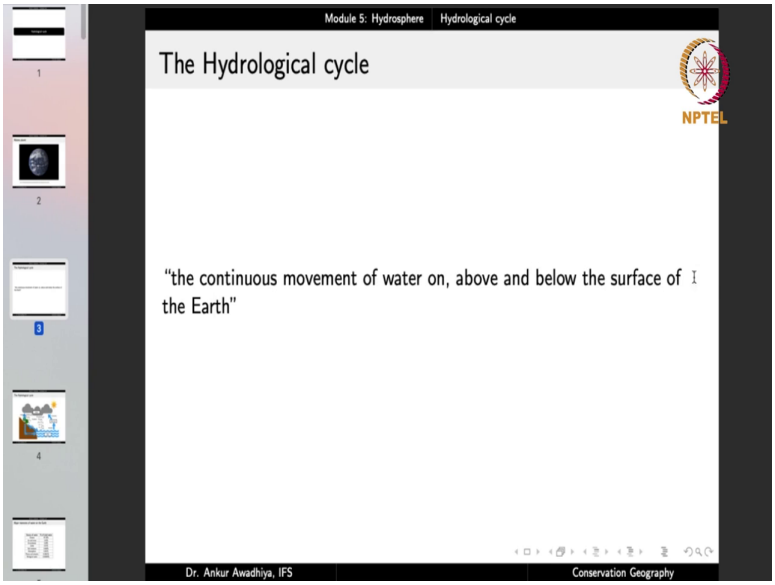


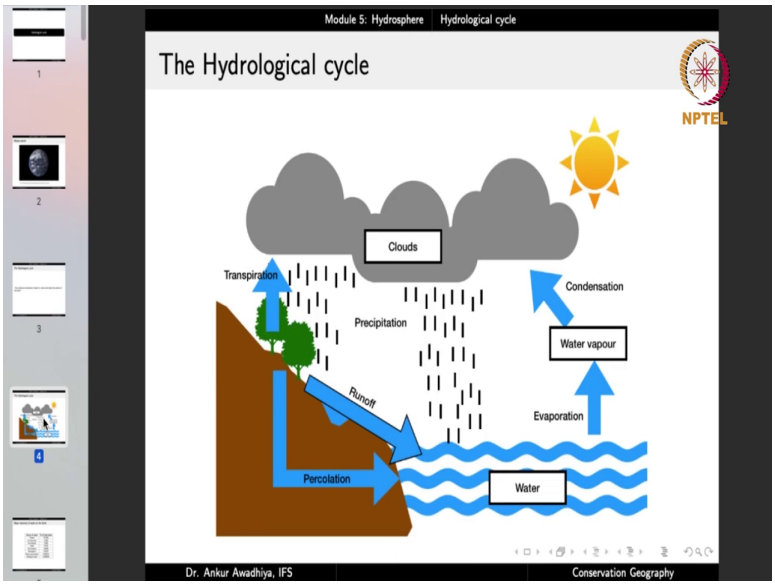


So we can define the hydrological cycle as the continuous movement of water on, above and below the surface of the Earth. So the water cycle is a continuous moment of water, the water cycle does not pause, the water cycle does not stop, the water cycle goes on and on, so it is a continuous process, it is a continuous movement of water. Where? On, above and below the surface of the Earth.

So in short this is the hydrological cycle we have water in different water bodies on the surface of the planet say seas, oceans, ponds, lakes and so on, now this water on getting heated with the heat of the Sun it gets evaporated, so evaporation is the process in which this liquid water converts into water vapor, now once it has converted into water vapor it has reached into the atmosphere, so it is now a part of the atmosphere.

Now in the atmosphere it can move from one place to another place with the winds so it moves up using convectional currents and then it moves also through advection and when it cools down it condenses, when it condenses it forms structures such as the clouds but there are also a number of other structures such as fog, mist, haze and so on.

Now in these clouds, these clouds can also move with the winds and later on when the water droplets in the clouds they coalesce together, they increase in size they become too heavy too heavy to remain suspended and in that case they come down as precipitation that is rain.

So we can have precipitation in the form of rainfall, in the form of snowfall, in the form of hailstones and so on and because the clouds can also move together with the winds we can have this precipitation over the water bodies or we can have this precipitation over land, now when the water is there on the land it starts to move according to the gradient of the land, according to the slope of the land because of gravity.

Now this water movement is known as runoff, so some portion of water will run off to these bodies which are the oceans and the seas, some portion may stand accumulated in the Earth and these accumulated bodies are in the form of lakes and ponds, a fraction of water that has fallen on the ground also is seeped into the Earth so it becomes a part of the ground water.

The water in the ground can be taken up by plants and these plants will then release this water into the atmosphere through a process that is known as transpiration. Or this water that has entered into the ground it can come out it can join the surface runoff or it can directly drain itself into the seas and the oceans.

So essentially if you take water at any point, if you take water in the clouds or if you take the water in the oceans we can look at a complete cycle so water starts here, it completes a cycle and it comes back here, so this is the hydrological cycle.

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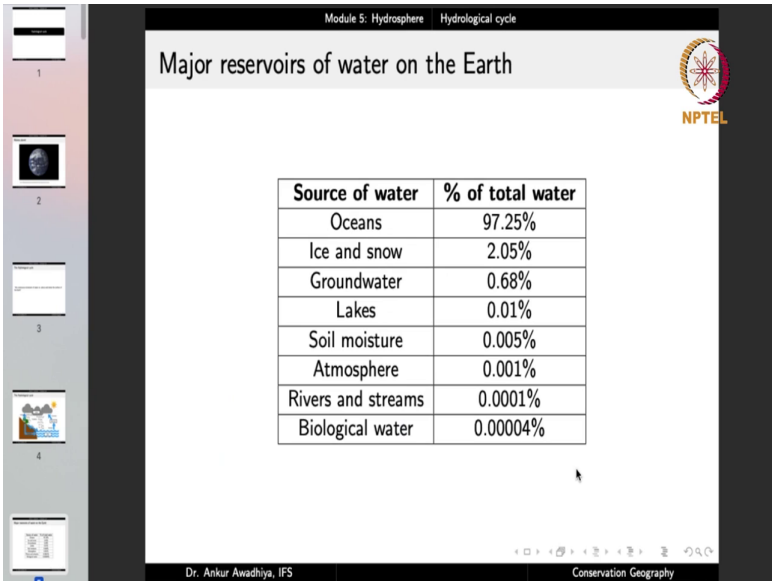


And the hydrological cycle moves water through all the different reservoirs of water on the planet, so we saw that the oceans are the largest reservoir around 97.25 percent of water is there in the oceans then we have ice and snow, groundwater, lakes, soil moisture, atmosphere, rivers and stream and biological water.

So the water cycle is moving water through all of these reservoirs, now because some reservoirs hold water in the form of solid, some other reservoirs hold water in the form of liquid and some other reservoirs have water in the form of gases, so we have different processes that take place to move this water from one reservoir to another reservoir. So we can have the process of evaporation, condensation, precipitation, sublimation and so on.

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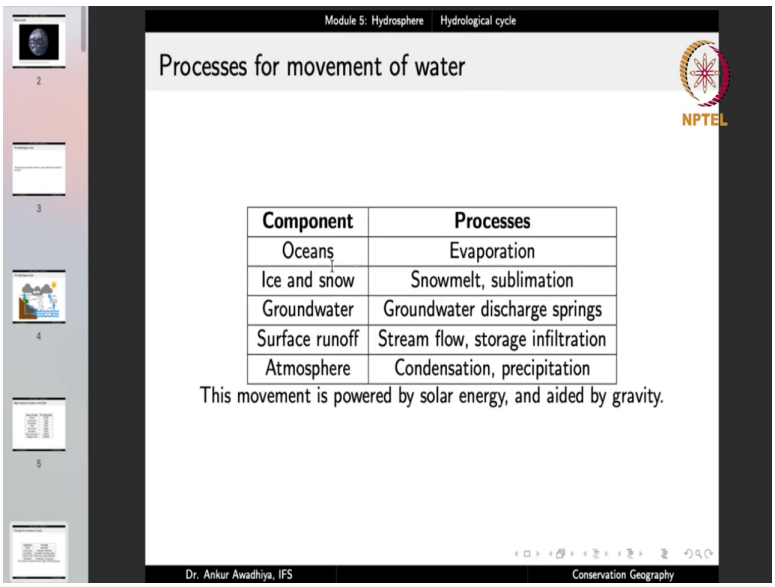

So in the oceans the major movement or the major process is evaporation, so water leaves the oceans in a majority in the form of evaporation, in the ice and snow components we have snow melt and sublimation, so snow melt is the conversion of solid ice into liquid water and sublimation is the conversion of solid ice directly into water vapor or the gaseous form.

So the water leaves this component through snow melt and sublimation, water leaves the groundwater in the form of groundwater discharge springs or it may directly be released into the oceans.

Water leaves the surface runoff component in the form of stream flow in which case it moves into the oceans or it moves in the form of storage infiltration in which case it moves into groundwater and water leaves the atmospheric component through condensation and precipitation and all of this movement is being powered by solar energy aided by gravity.

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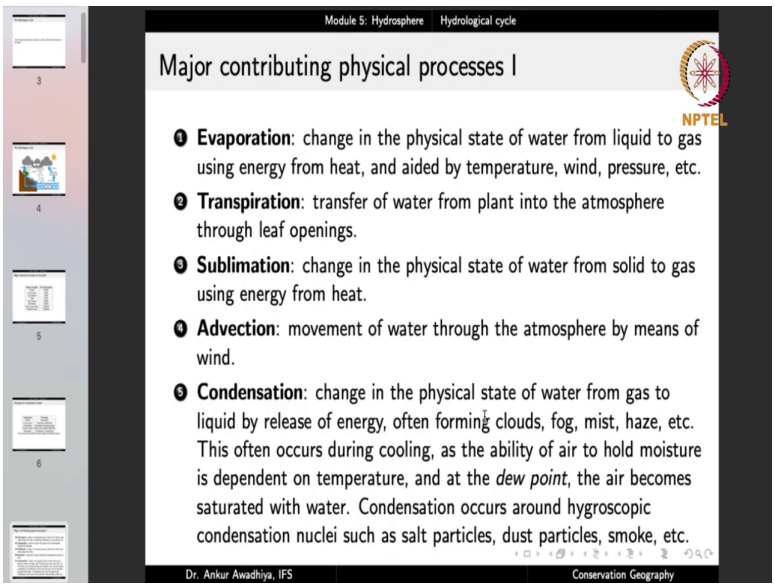

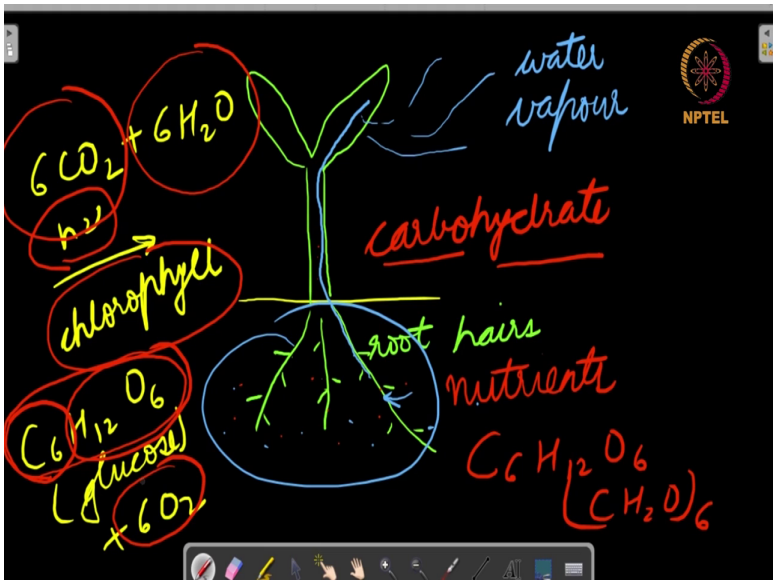


So let us now have a look at the major contributing physical processes, we have evaporation which is change in the physical state of water from liquid to gas using energy from heat aided by temperature, wind, pressure differences and so on, so evaporation is the conversion of water from liquid to gas. Now when water has to convert from liquid to gas it requires energy which is the latent heat of evaporation or the latent heat of boiling, so in this case this heat is taken from the surroundings.

The major source of this heat is the Sun but we also have sources such as the geothermal energy or the heat from the Earth that can also play a role in evaporating the water and evaporation is aided by things such as wind movement. So if we have winds then the amount of evaporation increases, it is aided by temperatures, so when temperature increases the air can hold a larger quantity of water vapor and so more amount of evaporation takes place, it is aided by pressure differences so if the pressure in an area lowers then water will convert into water vapor to take the space; so these are the various aiding mechanisms for evaporation.

Then we have transpiration, transpiration is the transfer of water from plants into the atmosphere through the leaf openings, now these leaf openings are known as stomata they are there in the leaves mostly in the lower surface of the leaf and through the process of transpiration water is converted into water vapor and released into the atmosphere and why do plants need to perform transpiration it is there to create a pressure gradient so that the plants are able to suck up water from the ground.

Now the water that is coming from the ground into the plants will also be carrying a number of minerals which are used as nutrients so basically what it means is that if you have a plant and here you have the root system so the water that is there in the ground is taken up by these

roots primarily through very small structures that are known as root hairs now root hairs are there to increase the surface that is available to gather water, so these are the root hairs.

Now when water moves into these roots then it also carries with it the minerals or different salts that are present in the soil, so these salts act as nutrients so through this process the nutrients are moving into the plants and to ensure that water keeps moving into the plants this water after it is taken up through the roots it is moving through the stem, it goes into the leaves and from here it is lost into the atmosphere in the form of water vapor.

Now this loss of water, if this loss of water did not happen then where would all of this water go, the plants have a limited capacity to hold water and if that capacity is exceeded then this process would stop and in that case the plants will not be able to get their nutrients. At the same time plants also require water to perform photosynthesis, so if we write the equation of photosynthesis it goes like this 6 $CO_2$ plus 6 $H_2O$ in the presence of light and in the presence of chlorophyll, it gives $C_6H_{12}O_6$ which is glucose plus 6 oxygen.

So essentially plants are using up carbon dioxide and they are using up water, so water is also one of the reagents to perform photosynthesis, they require light and they require chlorophyll and when all of these are together then in the plants glucose will get generated, glucose is a carbohydrate, so carbo refers to the carbon portion so it has carbon and hydrate means that it has water so basically you can write $C_6H_{12}O_6$ also as $(CH_2O)$ X 6.

So in this case it has carbon and it has water so it is a carbohydrate and it will also release oxygen and we have observed before that this release of oxygen is what led to the great oxygenation event that changed the composition of the atmosphere, so this is where the oxygen in the atmosphere comes from so plants need to perform transpiration to get water and the nutrients from the soil.

So this is a process in which water in liquid form which was present in the ground is converted into water vapor and released into the atmosphere through leaf openings that are known as stomata.

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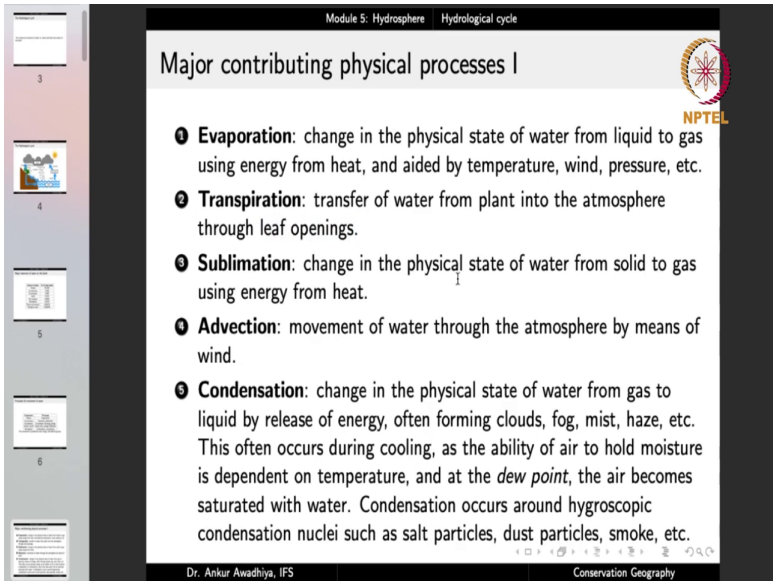


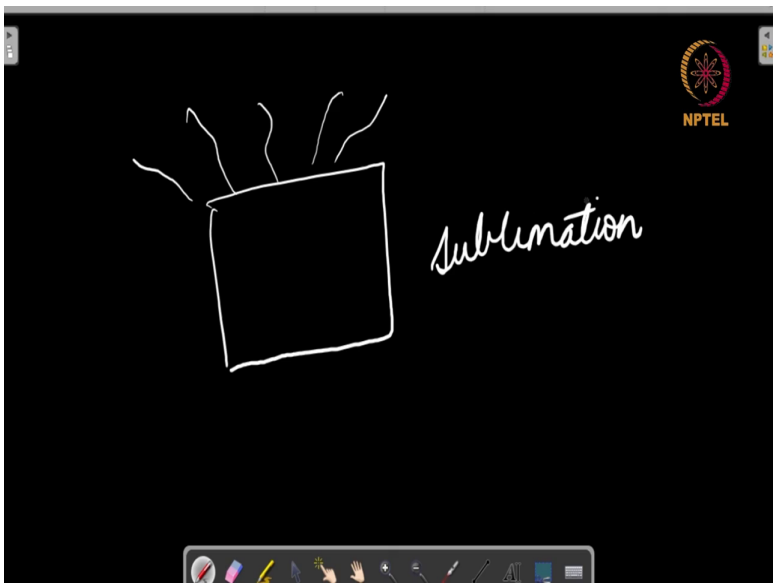


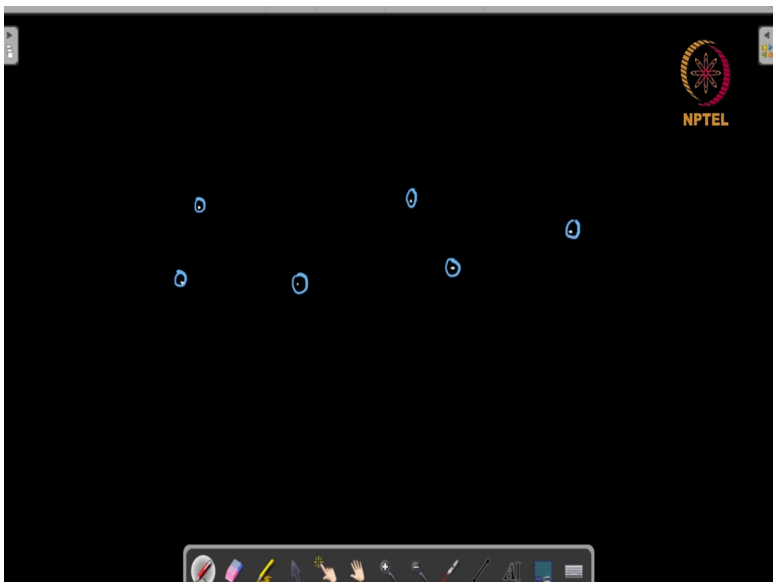

Then we have sublimation, sublimation is change in the physical state of water from solid to gas using energy from heat so in the process of sublimation water does not convert from solid to liquid and then move into gas, water directly moves from a solid state into a gaseous state. So essentially when we talk about sublimation if you have a block of ice then the water that is there in this ice will directly get converted into water vapor and this process is known as sublimation.

Another process is advection, advection is forced movement of water together with the winds so it is movement of water through the atmosphere by means of wind, so when you have wind movement the water that is there in the air in the form of water vapor that also moves, so this is the process of advection.

Then we have condensation, condensation is the opposite of evaporation so in condensation it is a change in the physical state of water from gas to liquid by release of energy, so in the case of evaporation it required energy, in the case of condensation it releases energy often forming things such as clouds, fog, mist, haze, etc. This often occurs during cooling because you have to release energy in the form of heat, so this release of energy will happen in a cool surrounding.

So this often occurs during cooling as the ability of air to hold moisture is dependent on the temperature and at the dew point the air becomes saturated with water, what does that mean the air has a limited capacity to hold moisture now this capacity to hold moisture it is dependent on the temperature if you heat up the air then it will be able to hold a larger quantity of water vapor if air cools down then it will be able to hold a smaller quantity of water vapor.

Now dew point is the point at which the air is 100 percent saturated with water so you take air at a higher temperature, add moisture to it and then you reduce the temperature of the air so at some point you will have air that is 100 percent saturated that is the amount of moisture that is present is equal to the capacity of air to hold moisture and beyond this point the moisture has to be lost from the air because it does not have any further capacity to hold this moisture.

So this loss of moisture will happen through the process of condensation so in condensation this moisture in the form of water vapor will be converted into liquid water and it will be shed out of the air and this happens when the temperature is at the dew point or below the dew point.

Condensation occurs around hygroscopic condensation nuclei such as salt particles, dust particles, smoke etc. So when condensation is happening it has to leave water somewhere and typically the water is left around the hygroscopic particles such as dust or salt so these are known as condensation nuclei because when condensation occurs it is around these particles that the water will condense in the form of a liquid.

So these act as nuclei to start the condensation process, if you do not have these nuclei then perhaps the air would not find a mechanism to release the water so it will become super saturated that is holding water above its capacity and as soon as it gets any impurity or it gets any surface or which it can shed the water immediately it will shed the water so these particles are known as condensation nuclei.

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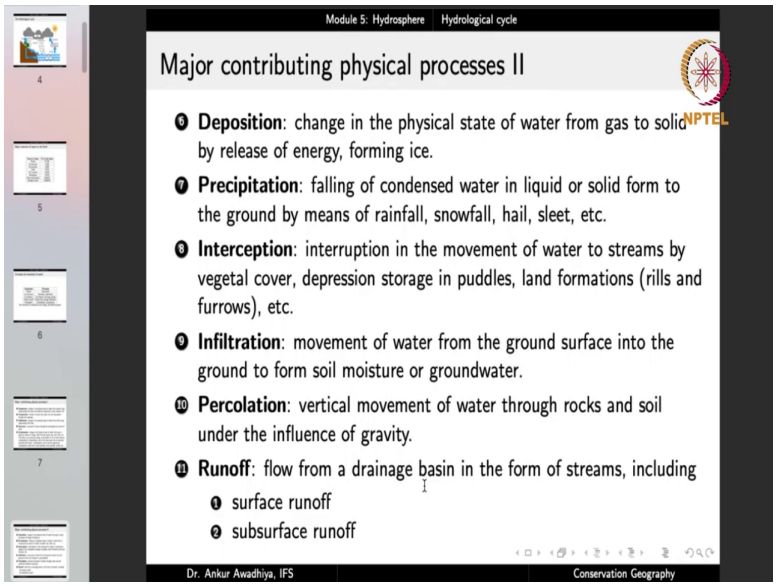


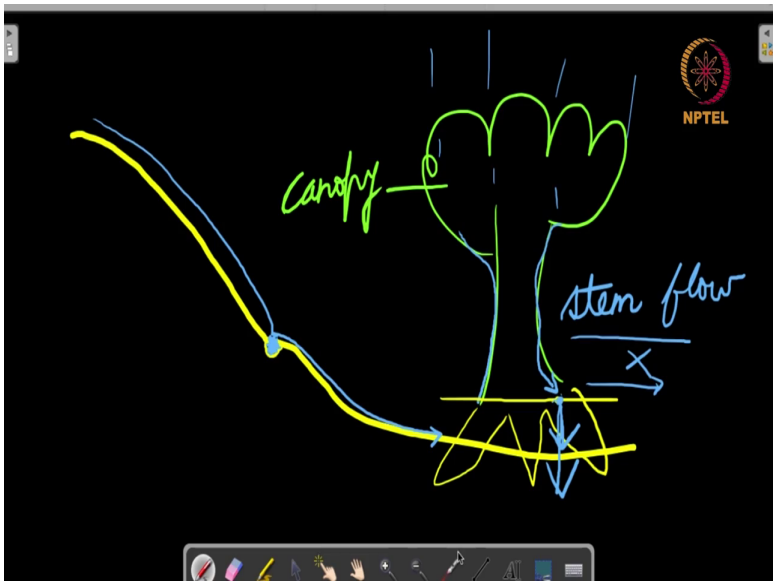

Another process is deposition, now deposition is the opposite of sublimation, in sublimation water converted from solid to gas without going through a liquid phase, similarly in the process of deposition water moves from gas to solid without going through the liquid phase, so deposition is the change in the physical state of water from gas to solid by release of energy and forming ice.

Then we have precipitation which is falling off condensed water in liquid or solid form to the ground by means of rainfall, snowfall, hail, sleet, etc. So the falling of the condensed water either in liquid form such as rainfall or in a solid form such as snowfall or hailstones or a mixture such as sleet, now sleet is a mixture of water and snow so this condensed water in the form of solid or liquid or a mixture it falls to the ground by means of this process that is known as precipitation, so precipitation means rainfall, snowfall, falling of hailstones, falling off sleet and so on.

Next we have interception which is interruption in the movement of water to streams by vegetal cover, depression storage in puddles, land formation, rails and furrows, etc. Now interception is the interruption in the movement of water to the streams, so essentially what happens is that when you have rainfall the water that falls down to the Earth it tends to move towards the streams and with the streams it will tend to move towards the oceans. Now interception is the interruption of this process, that is in the process of interception the water is interrupted from moving into the streams and into the oceans.

Now how can we have these interruptions, suppose water is moving, so suppose this is a land formation and you have water that is flowing like this, now in this case at this spot suppose there is a small depression here so in this case the water will get accumulated here, some amount of water gets accumulated and so this water is now not directly moving into the streams, this is an interruption in the flow of this water so this is interception.

Another way is in the form of trees so when you have a tree the water that was falling down in the form of rain water, it now does not directly reach into the ground, so the trees stop this movement of water and this water gets collected in these canopies, so this is the tree canopy which is the leaves and the branches, so these leaves and the branches they hold the water and after sometime this water will start to move through the bark and through the stem of this tree in a process that is known as stem flow. And then it will reach the ground.

Now if the water had directly fallen on the ground it would have fallen at a very high speed, so in that case the rain water would have done a lot of erosion and then it would have swiftly

moved into the nearby streams. But what do these trees do, these trees stop that movement of water they interrupt the water from directly hitting the ground, slowing it down and so the amount of erosion becomes less and the soil gets protected.

And at the same time when this water moves down, it moves through the stems of these trees so if you stand under a tree during a rain you will find that you are not getting hit directly by the rainwater but if you touch the stem of the tree you will find that it is damp it is wet because water is moving through the surface of the stem into the ground.

And typically the roots in these locations they are able to dig into the soil so when this water comes here now this water will not move in the form of a surface flow this will not happen but it will slowly get absorbed into the soil, so it will become a part of the ground water and so in this way the water is not moving into the streams in the form of surface runoff but it is getting into the ground so this is the importance of interception.

Now after in interception we also have infiltration, infiltration is the movement of water from the ground surface into the ground to form soil moisture or ground water, so after this interception when the water is moving into the ground, this is infiltration, once the water has entered into the ground there will be percolation, percolation is the vertical movement of water through rocks and soil under the influence of gravity. So once this water has entered into the soil here, in the form of infiltration, now it is moving down under the influence of gravity and this is percolation.

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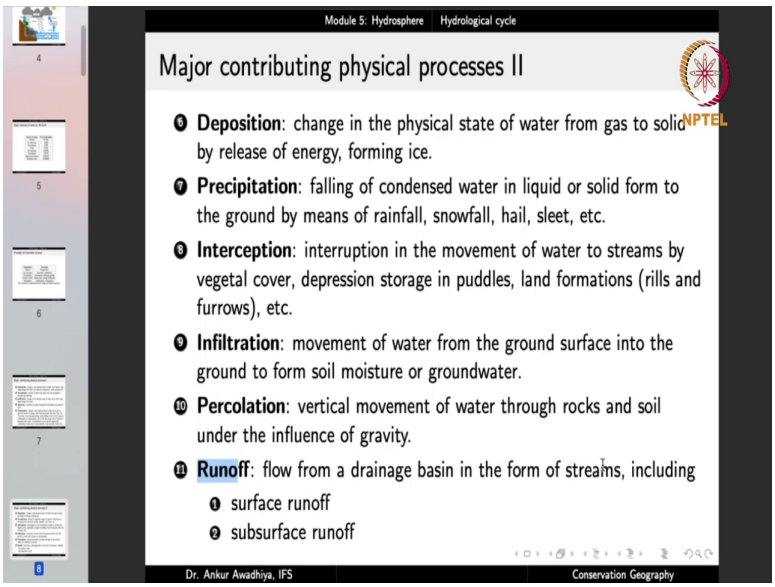

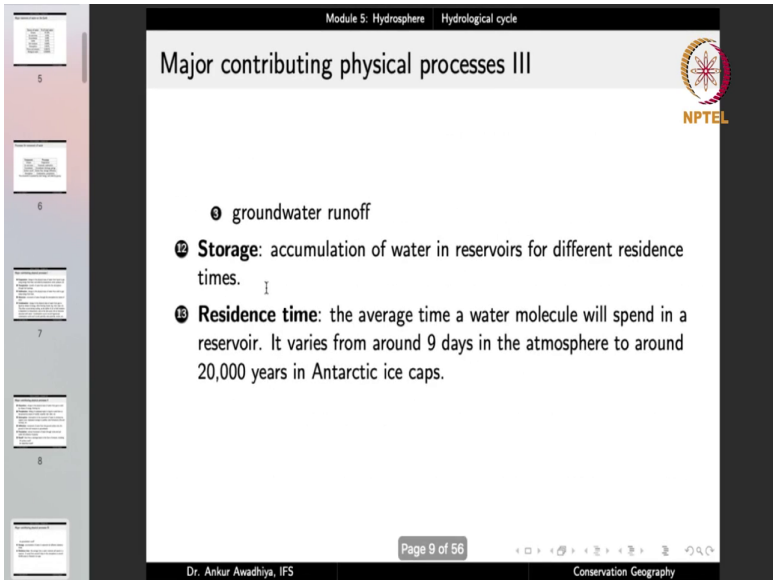


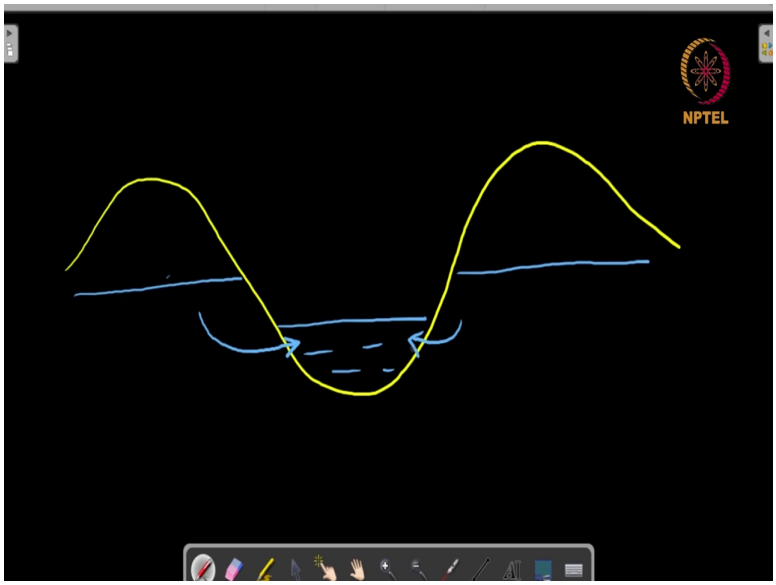


Next we have runoff which is flow from a drainage basin in the form of streams including surface runoff, subsurface runoff and groundwater runoff, so essentially when we talk about the movement of water in the streams then we are talking about a runoff, now this runoff can occur on the surface so when rain falls on the ground it moves through various channels it enters into a stream and then it begins to move out towards the oceans or towards an inland lake.

Now these movements are known as surface runoffs, we can also have subsurface runoffs and we can also have a ground water runoff, now groundwater runoff refers to a situation where the groundwater is moving into the streams so essentially what is happening is that it is an opposite process to that of infiltration.

So you have this, so suppose this is the land and here you have a stream say a river but suppose the groundwater is at this level so in that case some amount of water will begin to flow from the groundwater into the streams and then it will begin to move away from this drainage basin, so this is known as a ground water runoff.

Then we also have storage which is accumulation of water in different reservoirs for different residence times where residence time is the average time a water molecule will spend in a reservoir which varies from around 9 days in the atmosphere to around 20000 years in the Antarctic ice caps. So this is the average time a water molecule will spend in a reservoir.

Now we have talked about different reservoirs such as oceans or atmosphere or ice caps or groundwater and when we talk about the residence time what is the average time that a water molecule will spend in the reservoir once it have, it has entered into this reservoir, so the residence time can be as low as 9 days in the atmosphere.

So on an average a water molecule stays in the atmosphere for only 9 days after which it gets condensed or it gets precipitated or deposited somewhere to around 20000 years in the Antarctic ice caps. So if a water molecule has entered into the Antarctic ice caps it can expect to stay there for around 20000 years.

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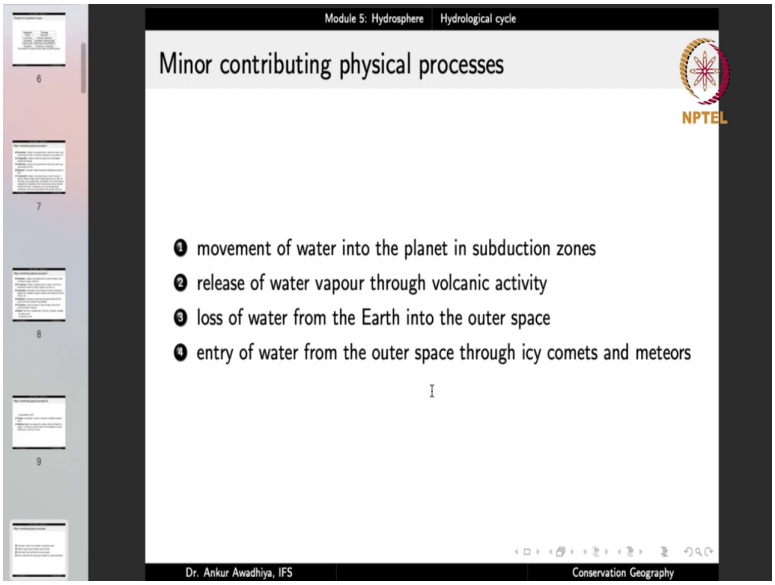

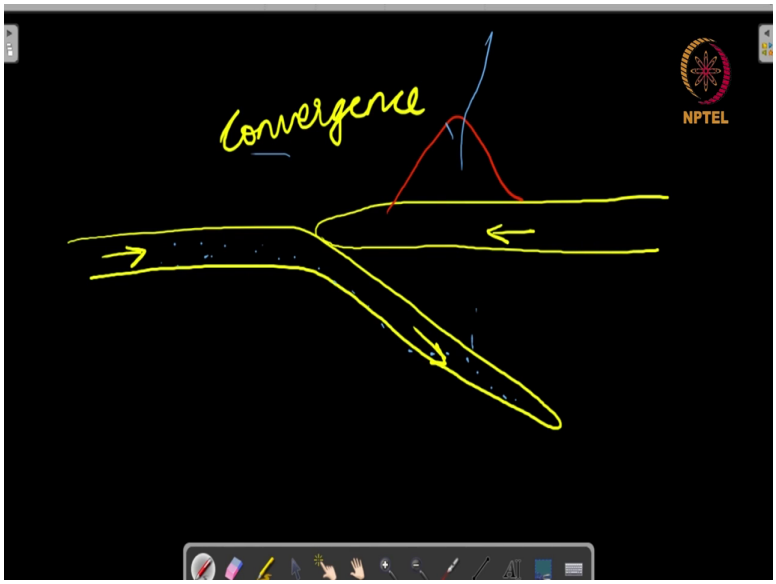


Now apart from the major processes we also have certain minor contributing physical processes such as movement of water into the planet in the subduction zones, now you will remember that a subduction zone is an area where two plates are colliding and one of the plates is moving below another plate, so this is a region of convergence, now in this convergence typically if you have a convergence of say an oceanic plate with a continental plate then the oceanic plate will move down and when it moves down the water that was here in this plate it is also moving down.

So this is a process through which water from the crust is moving into or towards the mantle so this is a minor contributing physical process or another process is the release of water vapor through volcanic activity and we had observed here that in most of the cases we find volcanoes in this region which spew out this water in the form of water vapor, so this is another activity that is happening.

Then we have loss of water from the Earth into the outer space so when water is moving up in the atmosphere a part of it can also get lost into the space or some water may enter into the atmosphere through things like icy comets and meteors so these processes also happen but by and large when we talk about the hydrological cycle these are very minor processes, so very small amount of water is moving through these mechanisms but it is important to note that these mechanisms also do exist.

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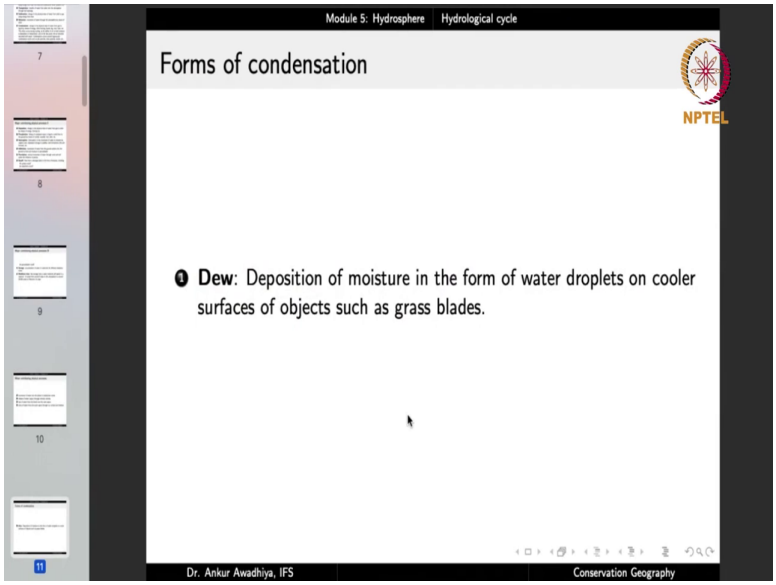


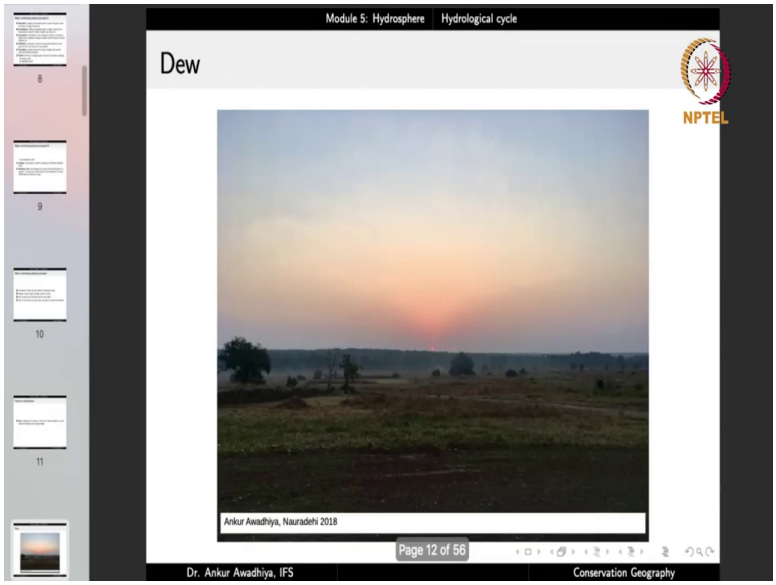


Now when we talk about condensation, condensation can happen in a number of forms so we can have condensation in the form of clouds, in the form of dew, in the form of haze, in the form of mist and a number of ways, so let us now explore some forms of condensation, the first one is dew. Dew is the deposition of moisture in the form of water droplets on cooler surfaces of objects such as grass blades and you will typically observe dew formation in the winter months.

So if you go out early morning in a winter month you will find that on the cooler surfaces such as grass or such as say the bodies of vehicles you will find very small droplets of water, now in this case because these surfaces are cold the air that is near these surfaces it crosses the dew point at which point it becomes super saturated and it begins to shed out the moisture

in the form of liquid water so that is dew. So typically you will observe dew in the case of early mornings especially in the winter months on things such as grass blades.

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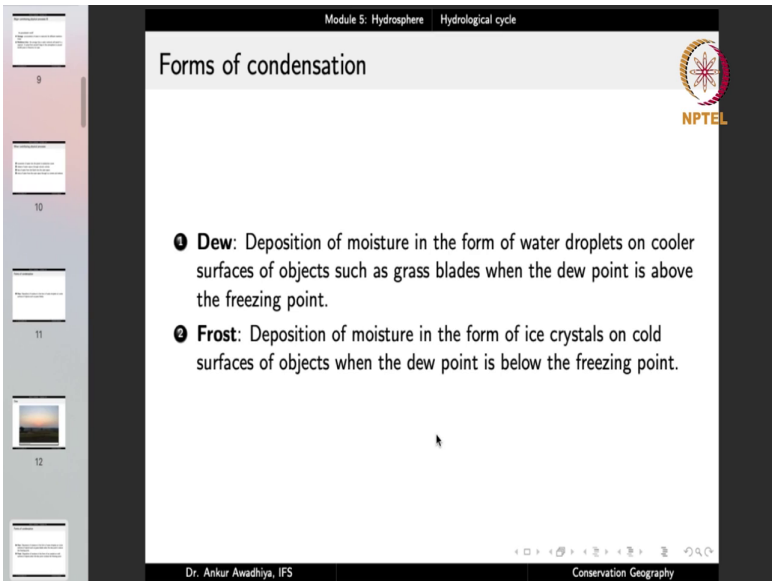


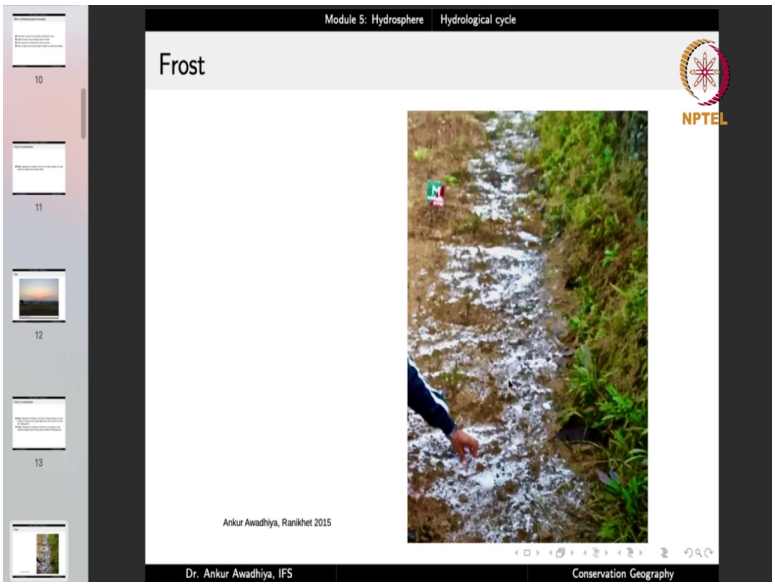


Another is frost, frost is the deposition of moisture in the form of ice crystals on cold surfaces of objects when the dew point is below the freezing point, now in this case the water directly gets deposited in the form of ice crystals so this is how a frost looks like. So you will find that you have ice deposits on the soil and this typically happens when the dew point is so less or is at a so little temperature that it is less than the freezing point of water so the air is able to hold the moisture till its temperature goes below the freezing point of water and so the water is deposited in the form of ice crystals.

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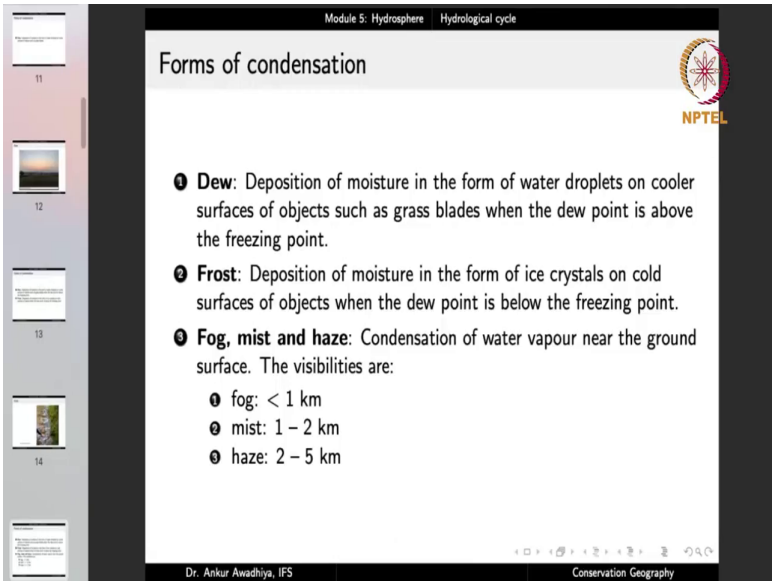



Next we have fog, mist and haze which is condensation of water vapor near the ground surface and this typically happens very similar to the formation of clouds so in this case the water condenses in the dust particles or say pollen grains or smoke particles very near to the ground surface so you have a cloud that gets formed near the ground and depending on the visibility, if the visibility is less than 1 kilometer we call it a fog, if visibility is between 1 to 2 kilometers we call it a mist, if visibility is between 2 to 5 kilometers we call it a haze.

So this is condensation of water vapor near the ground surface but not on the ground surface so this is what a fog looks like, so as you can observe these trees that are at a far off distance they are not very visible.

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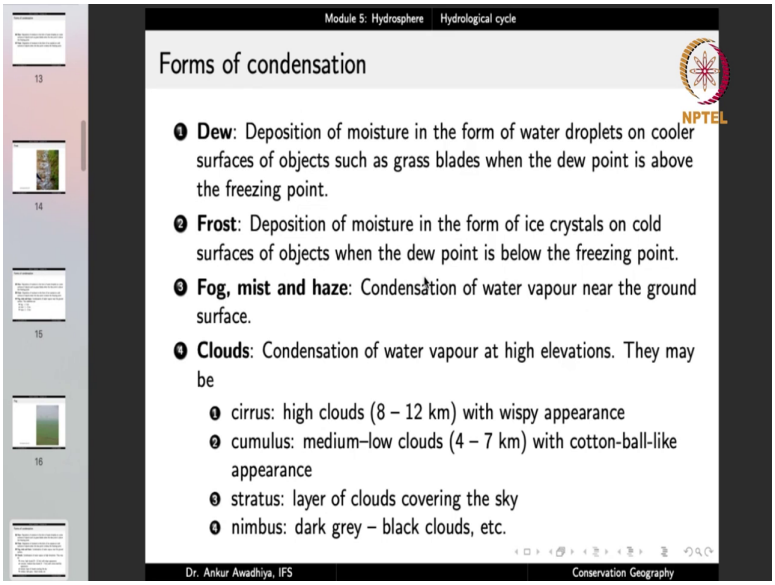


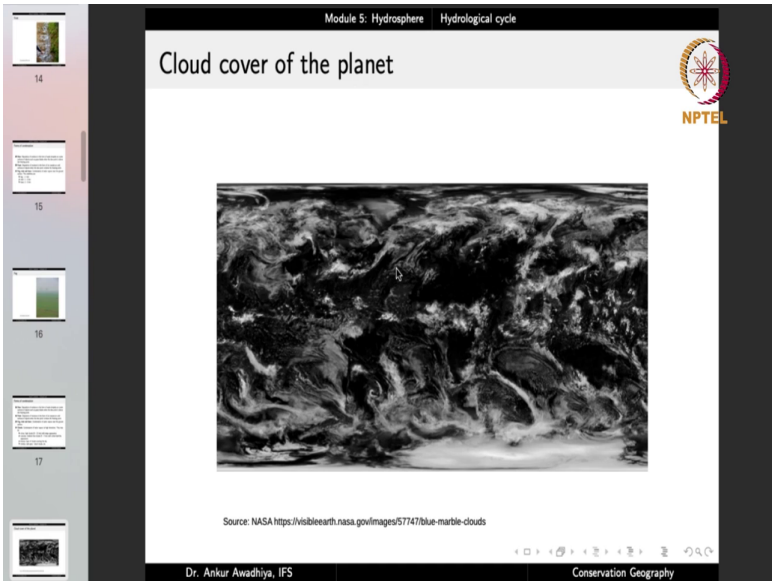


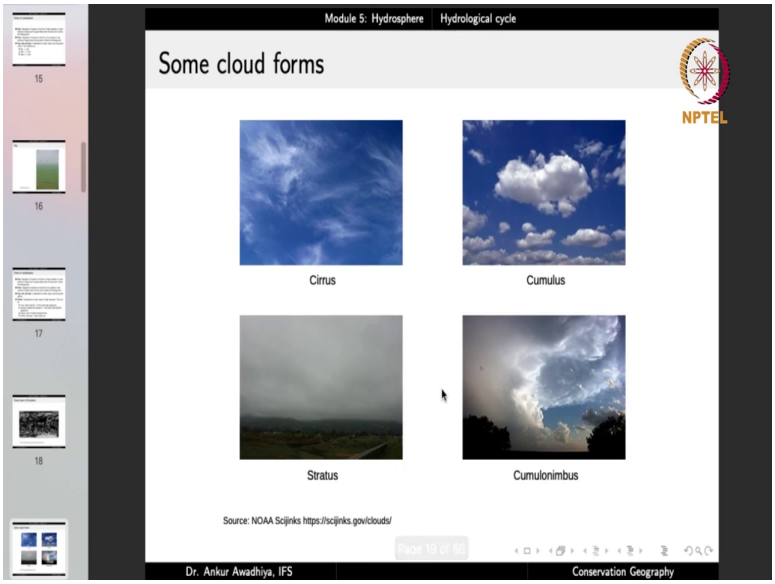

Next we have clouds which is condensation of water vapor at high elevations in the atmosphere and you can have different kinds of clouds. So we have cirrus clouds which are high clouds at a height of 8 to 12 kilometers with a wispy appearance; cumulus is medium low clouds 4 to 7 kilometers with a cotton ball like appearance; stratus, stratus means a layer so it is a layer of clouds that covers the whole of the sky or a large portion of the sky and you also have nimbus which is dark gray to black colored clouds typically the clouds that bring rain.

So this is if we look at the cloud cover of the planet this is what it looks like so you can observe that we have a lot of clouds in the atmosphere and these are the different kinds of clouds so you have cirrus clouds so these are very high clouds and they look like a horse's tail so they have a wispy appearance. Then you have cumulus clouds they look like cotton balls, they are at a middle altitude, you have stratus clouds which cover the whole of the sky and you have nimbus clouds which have these black spots and which typically bring rains.

Now nimbus can be in the form of cumulonimbus so this has a cottony appearance but it is black or it can be stratonimbus which is covering the whole of the sky but it is dark gray or black in color and bringing rains and so on.

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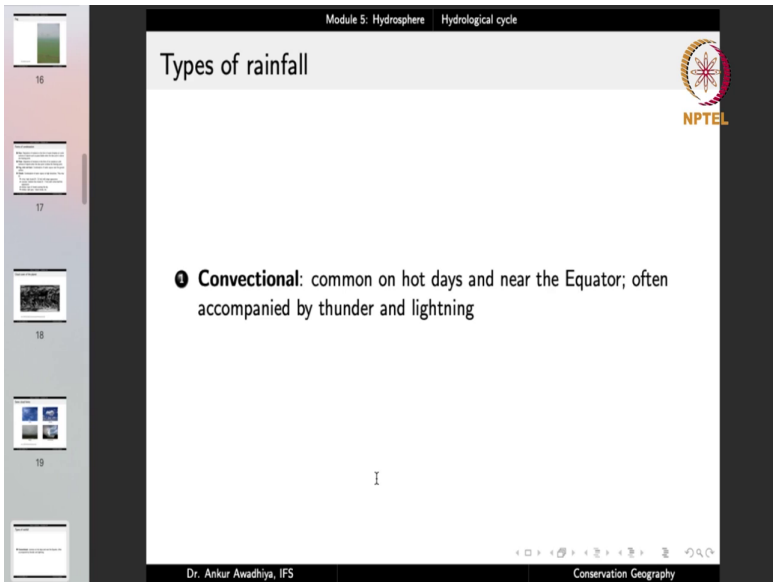

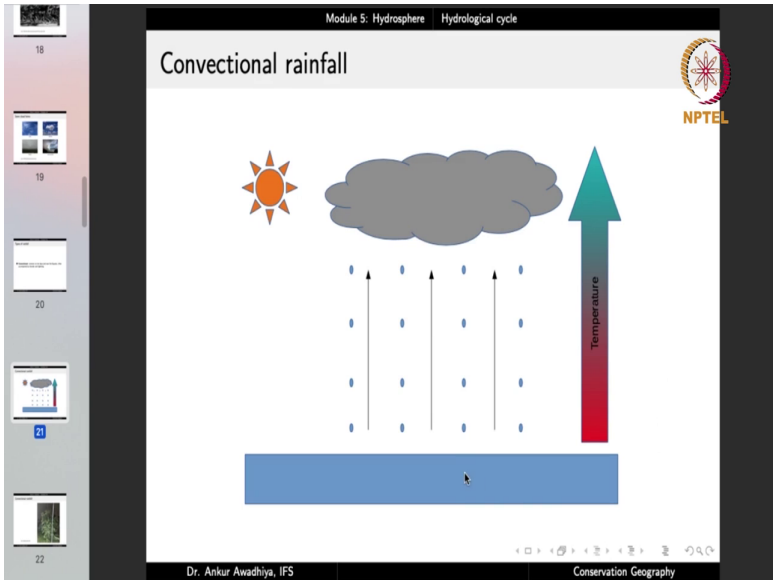
Module 5: Hydrosphere
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Convectional rainfall
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Low temp
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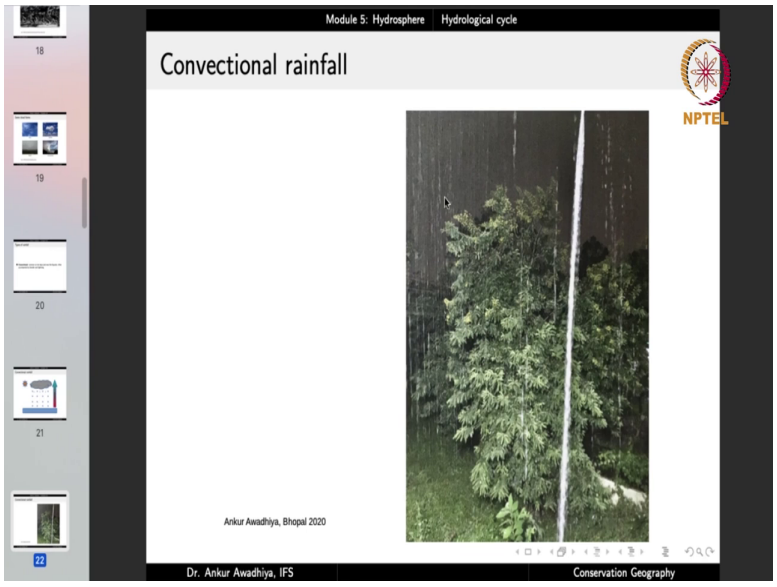
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And when we talk about rain there are different kinds of rains, we have conventional rainfall which is common on hot days or and near the equator often accompanied by thunder and lightning, in the case of convectional rainfall what happens is that the water that gets heated up gets converted into water vapor, it moves up through the convectional currents that gets set up, now what we are talking about is that once you have a surface probably the surface also has some amount of water or some amount of moisture.

Now when you have the Sun and the land is getting heated up now in that case convectional currents are set up which means that the air here is warmer and so it becomes less dense and it rises, so you have a moment of air upwards and along with this air the water vapor also moves up.

Now we know that as we move up the temperature reduces so here you have a low temperature and in this low temperature this water vapor condenses when it condenses it forms clouds in this area and when the clouds get formed and when you have a lot of moisture that is moving into the clouds the air becomes super saturated and then it starts to condense here.

So essentially in the morning times and in the afternoons the air is getting heated up it is moving upwards it is taking the moisture upwards but then towards the evenings when it is becoming a bit cooler when the Sun is setting in at that time the clouds will begin to give out rain and so you will have a very intense amount of rainfall often accompanied by thunder and lightning so that is convectional rainfall it is powered by the convection currents powered by the Sun and you have moisture that is moving up then when it moves up the temperature reduces it forms clouds and then you have a precipitation. And often this convectional rainfall is a very intense rainfall so here in this picture you can see that there is a very intense amount of rainfall that is occurring.

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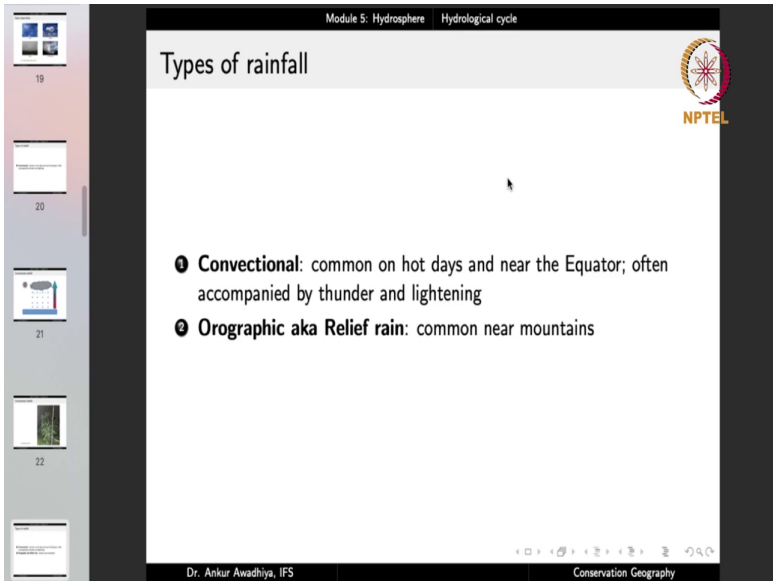


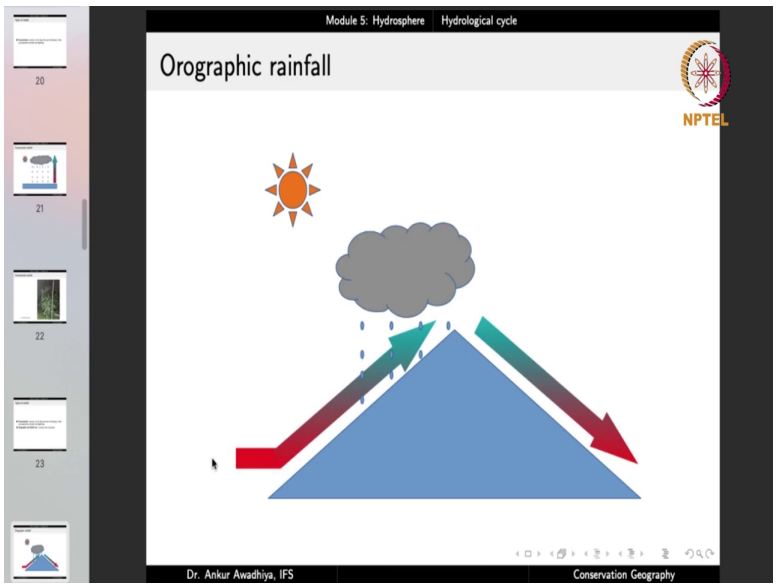


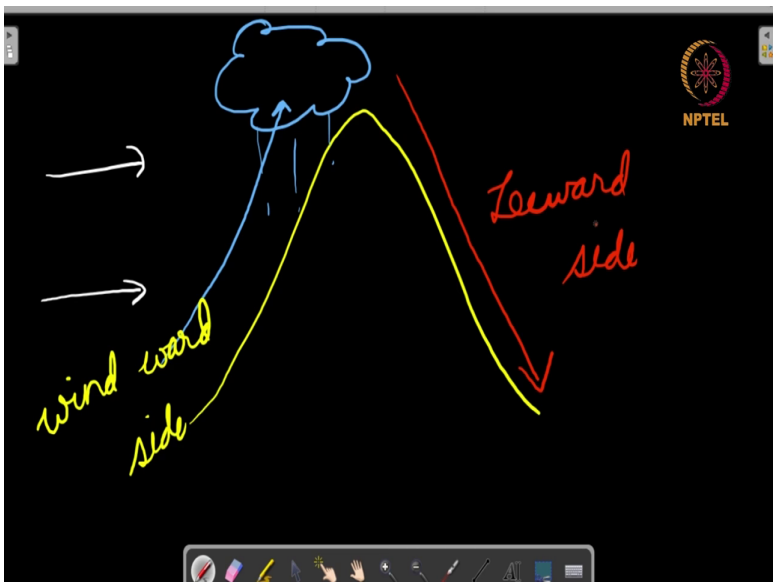

Another rainfall is the orographic rainfall or the relief rainfall, now we had observed this term orogenesis which means mountain building, oros is mountain so orographic rainfall is that rainfall that has got to do something with the mountains or something with the relief, now in this case the rainfall is common near the mountains and what happens is when you have a wind that is blowing towards the mountains when it reaches the mountains it starts to move upwards following the slope of this mountain.

And when the air moves upwards again you have a cooling because of this cooling there is a cloud formation and there is rainfall, when the air moves on the other side it typically gets warmed and so you will have a heavy rainfall on this portion but not any rainfall in this portion so if this is the wind direction, if you have a mountain like this and if the wind moves in this direction you will have an upward movement of the moisture here you will find tremendous amounts of clouds and you will have heavy rain in this side but when the air is moving down on the other side of the mountain it gets warmed.

And when it gets warm there is no further rainfall on this side, now the left side that is facing the winds is known as the windward side and the opposite side is known as the leeward side so the orographic rainfall is characterized by heavy rainfall on one side that is the windward side which faces the winds and very little rainfall on the other side which is the leeward side, so this is the orographic rainfall.

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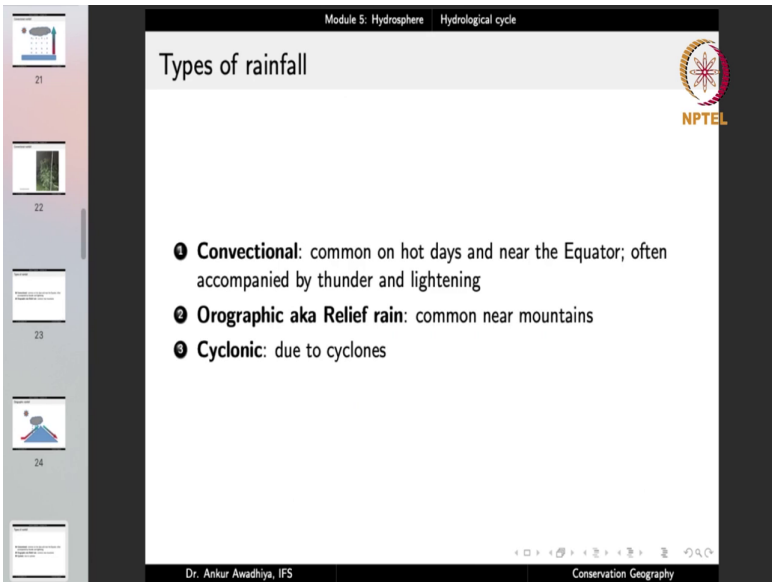

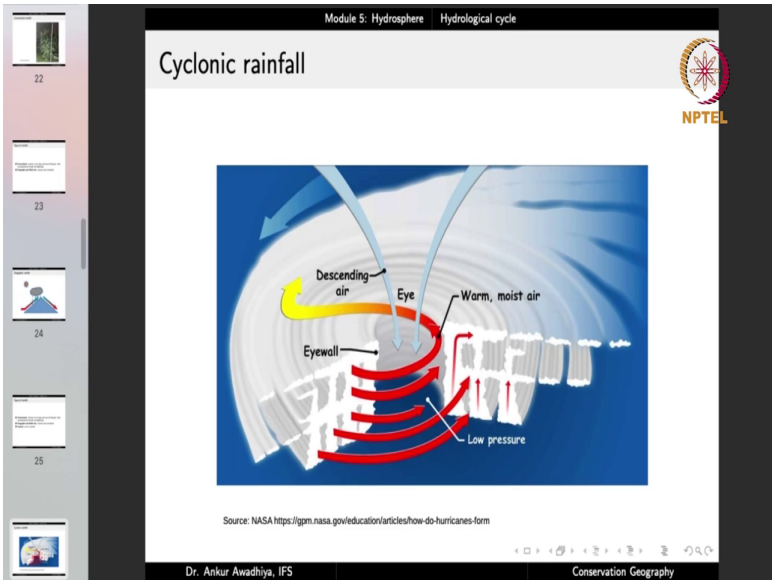


Third we also have cyclonic rainfall that occurs with the cyclones and we had observed that in the case of cyclones you have a very rapid movement of air towards a low pressure center and then the air moves up the air also rotates because of the Coriolis force and when the air is moving up you get a tremendous amount of rainfall, now this rainfall is only associated with the cyclones and so this is known as the cyclonic rainfall, so these are the three major rain types you have convectional rainfall, orographic rainfall and cyclonic rainfall.

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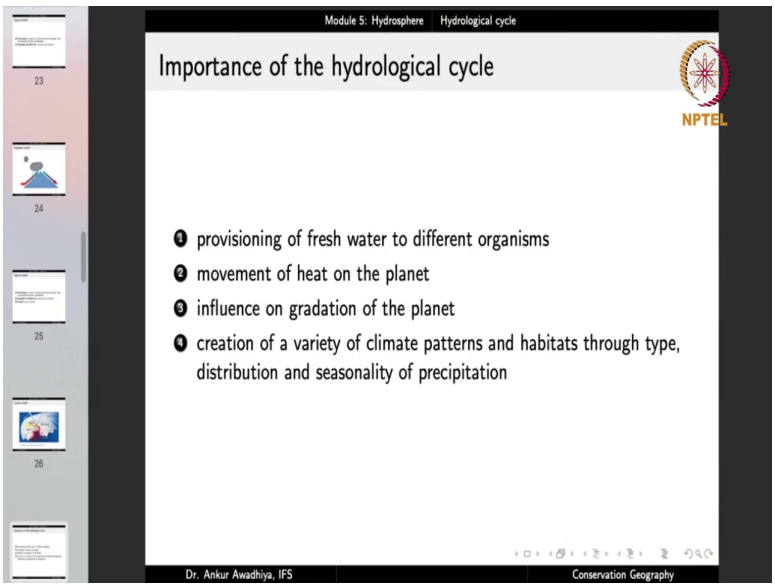


So what is the importance of the hydrological cycle, well it provides fresh water to different organisms and fresh water is needed for the survival of different organisms. Now all the organisms are not living close to the larger size water bodies, if we did not have the water cycle then where would they get the water from? Because of the hydrological cycle the water

from the oceans is being moved into the land areas and so the hydrological cycle in a way sustains all the life on this planet or most of the life in this planet.

There is a moment of heat on this planet because of the hydrological cycle, why, because in the warmer areas when there is evaporation the water gets converted into water vapor taking up the heat and then when it moves with the wind to other areas and when it cools down and it condenses then there is a release of heat so in a way the heat from the very hot areas is being taken to other areas primarily through the latent heat of vaporization.

Now latent heat of vaporization of water is very large and so the hydrological cycle moves a large amount of heat from hot areas to cooler areas, so this plays a role in the heat budget as well. It plays a role on the gradation of the planet because when you have water that is moved to the land areas this water when it begins to flow in the form of say rivers or rivulets or streams it will perform erosion, it will also perform certain amount of deposition on the sides of the rivers and also near the deltas.

So in a way it is playing a role in the gradation of the planet, it is a very important geomorphological agent, so this is another importance of the hydrological cycle, it plays a role in the in influencing the gradation of the planet by creating geomorphological agents in the form of water movement.

Another importance is that it creates a variety of climate patterns and habitats through type, distribution and seasonality of precipitation. Type meaning that whether it is in the form of rains or it is in the form of snow so if you have snowfall there will be a very different habitat that gets created full of ice and snow if there is rainfall it is a very different kind of habitat.

Distribution that is which places get this rainfall and in what amount, so certain areas that have a very heavy amount of rainfall they will have a very different climate, say tropical forest or equatorial rainforest, they get a heavy amount of rainfall and those areas that do not get a large amount of rainfall those areas that get a very scanty amount of rainfall they become deserts and so the distribution of rainfall means that certain areas become equatorial rainforest and certain other areas become deserts which are very different habitats.

And seasonality of precipitation, so in certain areas you have lots of rainfall in a very short period of time which results in a flood-like situation, in other areas the rainfall is distributed over a very large number of months so the seasonality is different and in those areas you do not get that much amount of floods.

Now areas that are flooded are a very different habitat, areas like marshes and the areas that do not receive floods are a very different habitat and so the type, distribution and seasonality of precipitation creates various forms of habitats, more the number of habitats, more will be the biodiversity, so the hydrological cycle plays a very big role in terms of creating different habitats and sustaining different kinds of biodiversity, so that is another importance.

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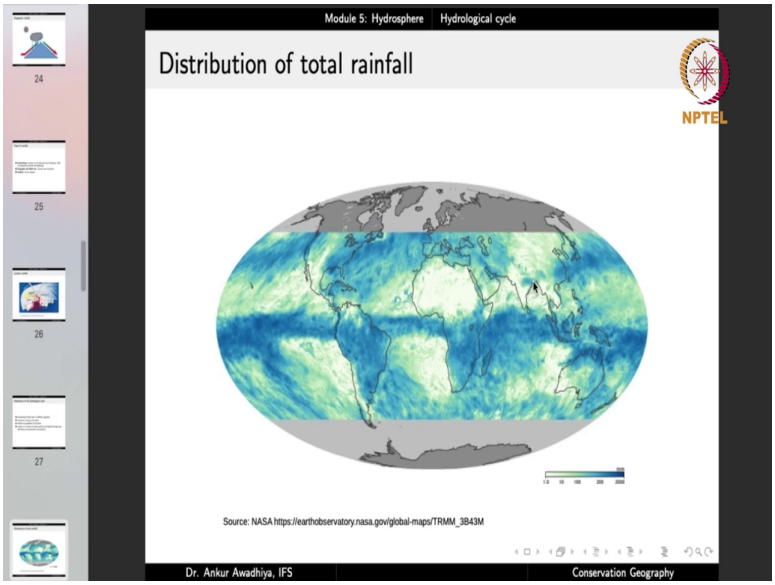


If you look at the distribution of total rainfall we will find that areas that are near the equator they get a very heavy amount of rainfall mostly convectional rainfall and otherwise you have certain areas that get more amount of rainfall in certain areas that get less amount of rainfall so this is the distribution of total rainfall on this planet, these areas that get a heavy amount of rainfall we have the equatorial rainforests here.

So in South America, in Africa, in Southeast Asia we have a very heavy amount of rainfall and in those areas where we get less amount of rainfall we have the deserts, so this is the Sahara desert, this is the Arabian desert, this is the Thar desert, so the distribution of rainfall creates different habitats.

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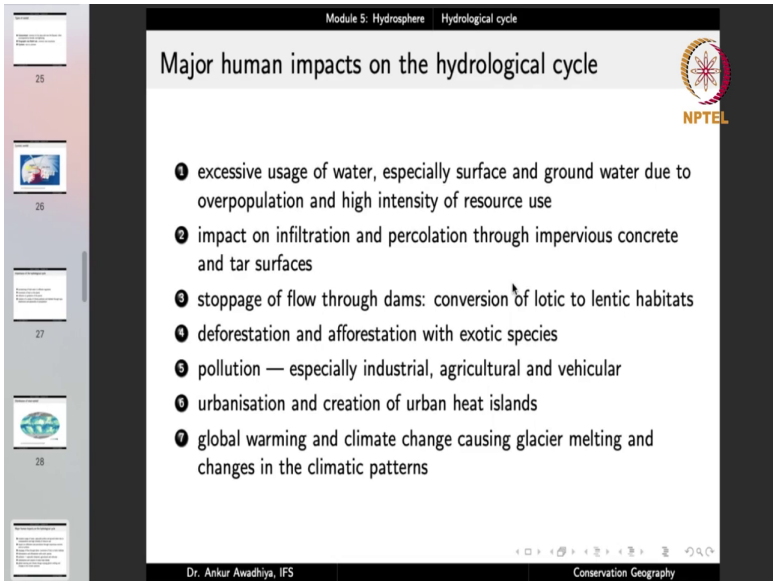


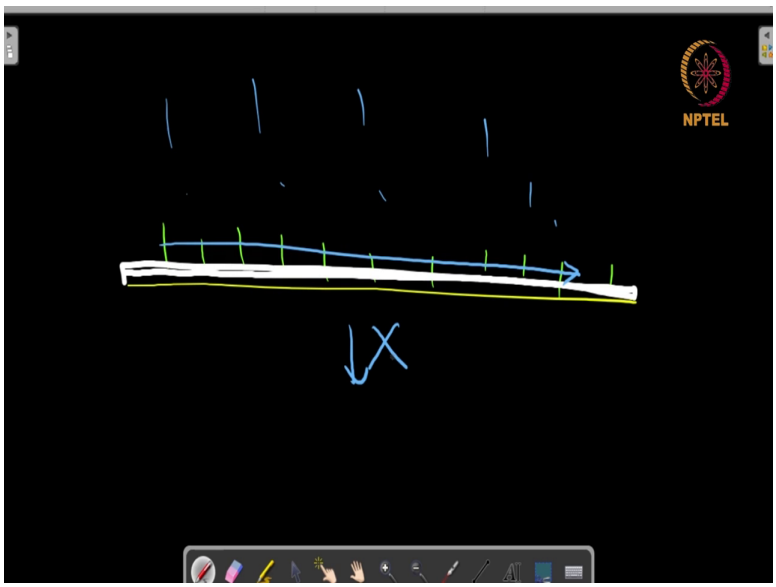


But then these days the humans are also playing a big role in influencing, impacting and disrupting the hydrological cycle, now the hydrological cycle naturally is dependent on processes like evaporation and transpiration, infiltration, percolation but now we humans are changing these, so what are we doing, there is an excessive usage of water especially surface and groundwater because we are overpopulated and there is a high intensity of resource use.

Now because of that a number of our water bodies are now drying up, the areas that were known for the lakes now no longer have those lakes because all that water has been used up. In certain cases, all that water has been drained out to make way for things like buildings so you will often find wetlands and ponds that are drained out, filled up with Earth and then a high rise building gets created, constructed there.

So this is one impact that we are having on the hydrological cycle, if we do not have the wetlands then the amount of groundwater will go down because wetlands act as locations where a large amount of infiltration of rainfall, infiltration of surface water happens. Then we also have an impact on infiltration and percolation through construction of impervious surfaces such as concrete and tar.

Now in a natural condition most of the ground would be just covered with grasses and grasses aid the infiltration of water by creating hindrances to the water movement so essentially the water that falls in the form of rain water it is not able to move that fast because all these grasses will be stopping that water and essentially when we say groundwater recharge it implies only three things; if the water is running you have to make it to walk, if the water is walking then you have to make it to stand and once the water is standing it will have nowhere else to go it will go down.

Now the plants, the trees, the grasses what do they do? They aid in all these processes, they reduce the speed of water and they have a surface that permits this water to move into the groundwater reservoir but what are we doing, we are removing all of these grasses and we are covering this whole area with a concrete surface, now if you have a concrete surface or say a tar surface then this water has nowhere else to go it will only flow down, there will be absolutely no infiltration.

Now with the development of civilization now we have routes that are practically everywhere, a large portion of the Earth is now covered with our buildings and all of that is hindering the flow of water into the groundwater reservoir so that is another impact that we humans are having on the hydrological cycle, we are stopping the flow of water through dams, converting the lotic habitats into lentic habitats.

Now lotic habitats are those habitats where the water is moving, lentic habitats are those habitats where the water is standing, so we are stopping the flow of water now when we talk about the hydrological cycle the water that was falling on the ground it was moving towards the oceans through the streams, through the rivers, now when we stop that water what happens is we create an artificial wetland, now this artificial wetland may be in a location that is having impervious rocks.

So in that case this wetland will not be aiding in the groundwater recharge but on the other hand what it will do is that the sediments that were being moved by the rivers, the salts that were being moved by the rivers, they are now stopping, they are now getting accumulated

and that will lead to environmental consequences, so we are not just over utilizing water, we are not just hindering the movement of water into the groundwater reservoir but even the water that is moving into the oceans we are stopping that as well.

A large number of deltas are now shrinking because these sediments that were being brought by the rivers they are now getting clogged up in the dams so we are now facing a situation where a large number of our deltas are shrinking, they are disappearing. Then we are doing deforestation and at times afforestation but being done with exotic species, those species that are not suited for that area now when we do deforestation when we cut away the trees, then we are impacting the hydrological cycle not only because the trees perform a vital role of transpiration but also because the trees hold up the water and aid in the groundwater recharge.

So in a number of cases we are cutting up the trees making way for say agricultural fields or habitations, so we cut up these trees we make a road or we set up buildings or in certain cases we change the species composition, so we remove those species that are natively suited to that habitat and we plant trees brought from outside.

Now these trees that are being brought from outside they might not be that well suited to the habitat, so essentially it is possible that they take out a large amount of groundwater and release it into the air which will lead to drying up of lands because they are not native species, they have not evolved to suit themselves to this particular habitat, so this is another impact that we are having.

Pollution, especially industrial pollution, agricultural pollution, vehicular pollution; so all of these pollutants that we are generating a large portion of it is getting into our water bodies if you look at the plastic bags that people throw out a large portion of it makes its way into the water bodies it makes its way into the rivers and ultimately into the oceans, not only does it disrupt the animal life there because a large number of animals can get trapped in these plastics, they eat up these plastics that choke their elementary canals but at the same time it is also polluting by releasing a large number of chemicals into these water bodies, so this is another impact.

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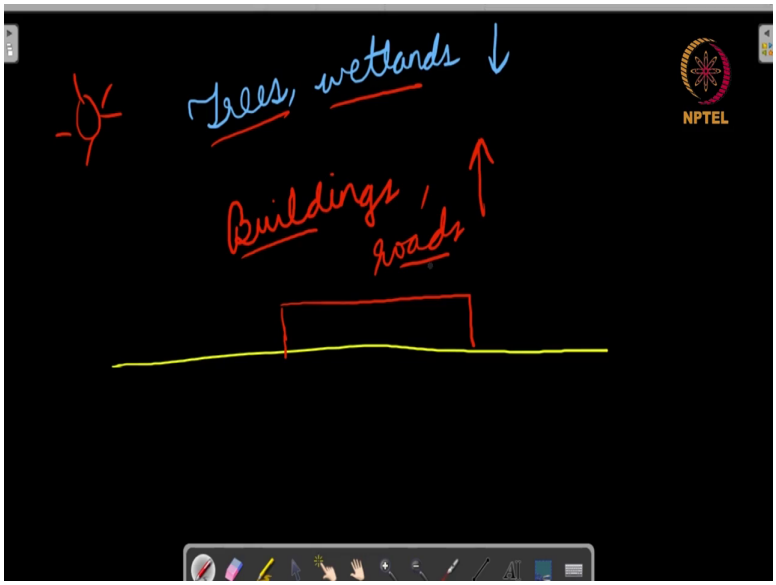



Urbanization and creation of urban heat islands, so what is an urban heat island if you consider a location where in a certain area you have a concentration of buildings and roads, so these are large in numbers, but things such as trees or things like wetlands they are less in number. If you look at our cities you will find this situation, so in the cities we have a large number of buildings, we have a large number of roads and there is very little amount of trees and wetlands because they have essentially been removed to make way for buildings and roads.

Now when we talk about the energy from the Sun if you have trees there will be shade, if you have wetlands they will moderate the climate, but when we talk about buildings with lots of concrete and roads made out of either concrete or tar then these structures, the buildings and

the roads they absorb the heat, they retain the heat and in that case what happens is that these areas become warmer than their surroundings.

So essentially if you look at these areas if we say make a temperature profile, the temperature profile will look like this, so here we are plotting the temperature and the temperature in the surroundings will be average but then the temperature here will be, will rise then it will fall again here, so this now looks like an island on a temperature chart, so this is an urban heat island, urban because it is being created through urbanization, heat because the temperatures are high and island because this is an anomaly of high temperature that is surrounded by areas that are having a lesser temperature.

Now when we create these urban heat islands we also disrupt the hydrological cycle, why, because in these areas we are creating a situation where a lot of convection will happen because these areas are getting heated up but because these areas have less amount of water we are putting dry air upwards, at the same time when we talk about precipitation, when we talk about condensation, condensation can only happen when the temperatures in the upper atmosphere are low.

Now in this case we are adding up heat into the upper atmosphere as well, so this disrupts the hydrological cycle, we will not have that much amount of rains as we were having before, so this is another impact on the hydrological cycle, creation of the urban heat islands.

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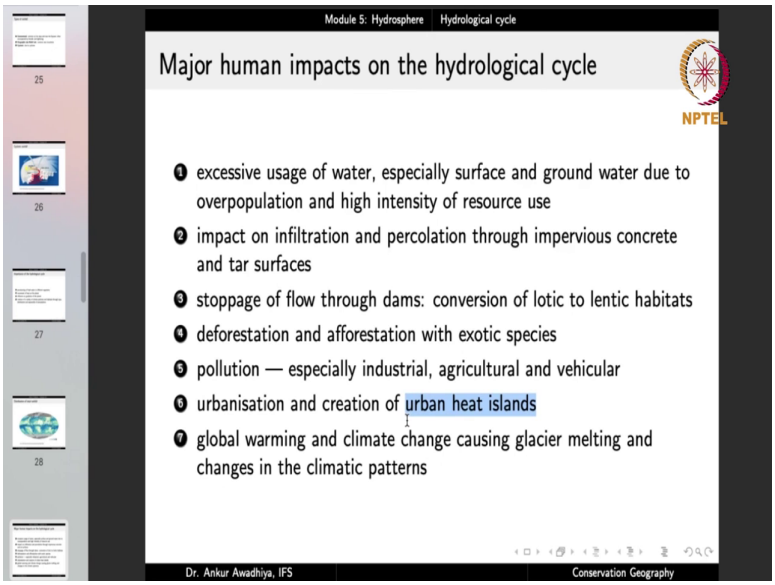

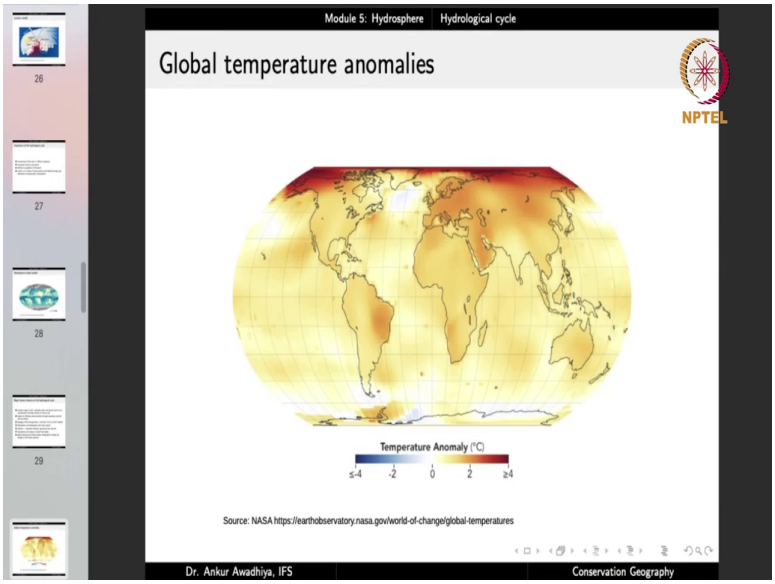


Another impact is global warming and climate change that is causing the melting of glaciers and changes in the climatic patterns, so through global warming what we are doing is that we are changing the temperatures of the planet, the planet is going is becoming more and more warmer, we are changing the wind patterns, we are changing the places where rainfall used to happen, we are changing the type of rain, the type of precipitation, we are changing the seasonality of precipitation, we are changing the distribution of precipitation.

So in effect what is happening is that we are getting more number of extreme climatic events, we are pushing certain areas towards droughts, we are pushing certain areas towards floods which is another disruption to the natural hydrological cycle, so if we look at the global temperature anomalies we find that here the yellows and the reds represent an increase in temperature and blues represent a decrease in temperature and if you look at the world map will find that roughly every place is now yellow or red, except say a few batches here or a few patches here, roughly all of the world is now heating up.

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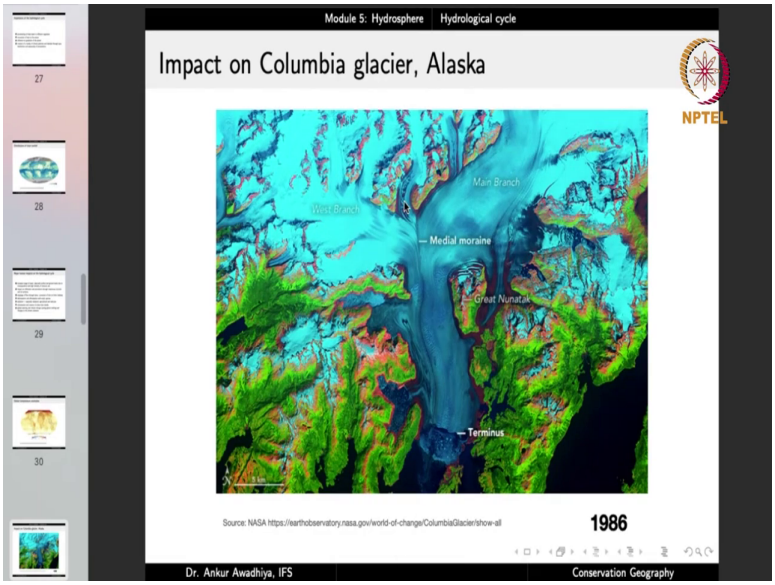


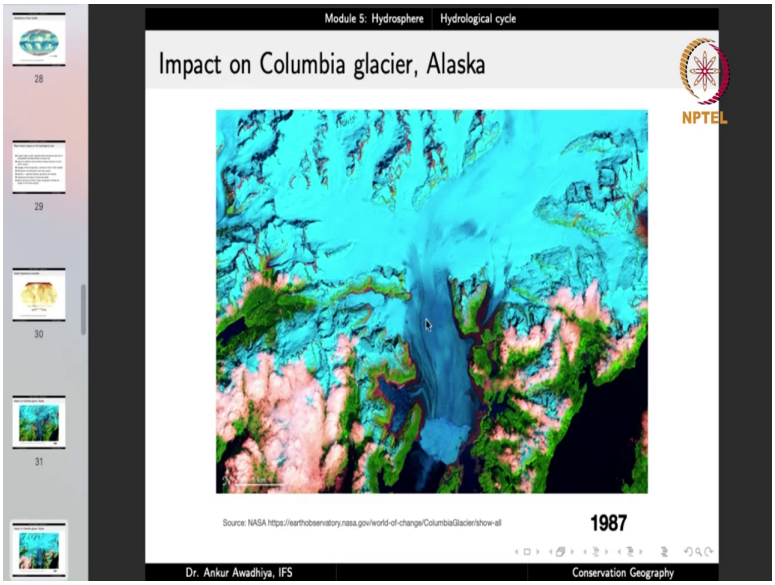


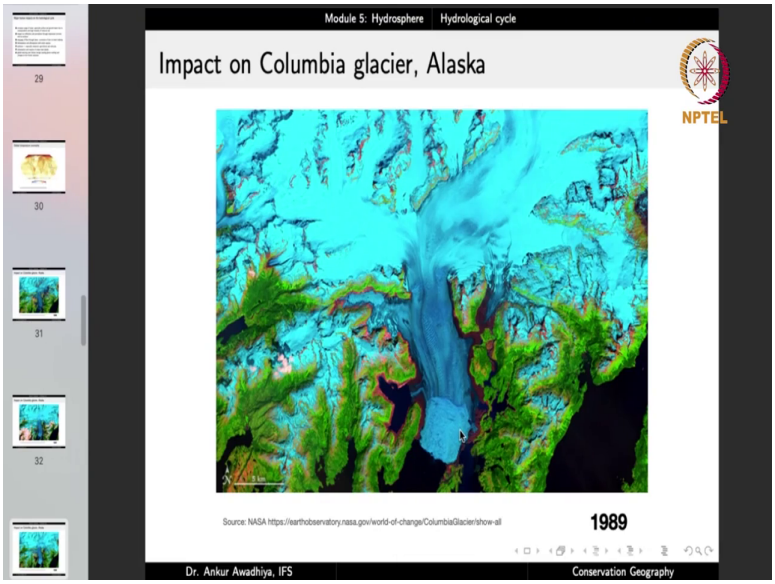

Now what kinds of impacts is it having, so this is an image of the Columbia glacier in Alaska and this is a false color composite so this is not exactly the color that we are accustomed to seeing, the true color composite would have shown a glacier in white color but this is a false color composite which means that we are playing with the bands of the satellite imagery so as to enable us to look at the phenomena more clearly.

So in this band combination it is easy to see things like the moraines. Now in this case this is an image from 1986 and we find that this Columbia glacier it has a west branch, it has a main branch, there is a medial moraine in between and this is the end of this glacier so this is a pretty large size glacier, this scale is 5 kilometers so the width of the glacier is somewhere around 3 kilometers in this area and it is getting ice and snow from all of these different areas.

Now let us look at what we have done to it, so this is the image from 1986, this is the image from 1987, so the major difference what we are observing here is in this location, so earlier this was the terminus and we find very small number of ice chunks that are moving into the ocean now the ice chunks are much more in number, by 1989 now the tip has shifted back, so earlier we had started from a terminus at this point, so let us put the cursor here, now the terminus is here so this is the image from 1989.

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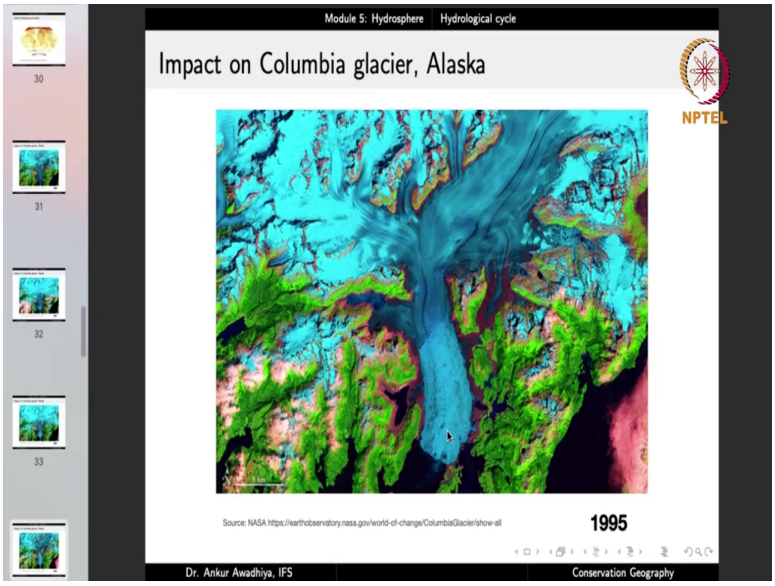

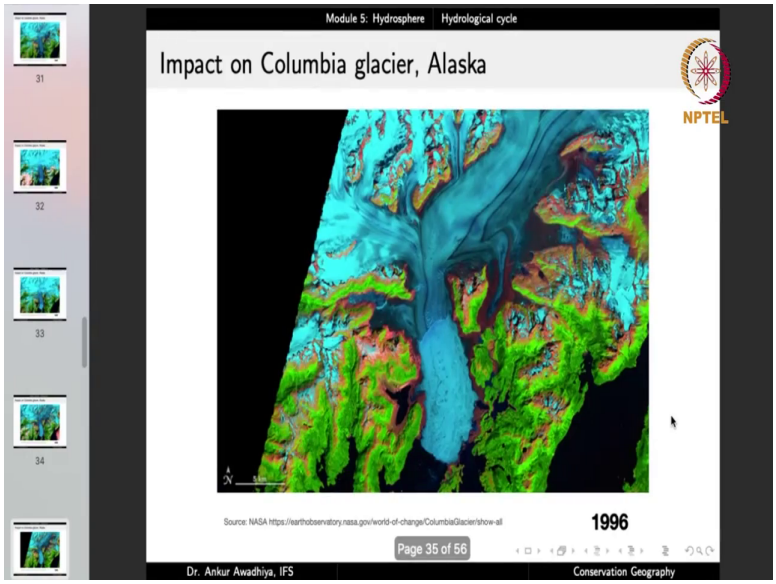


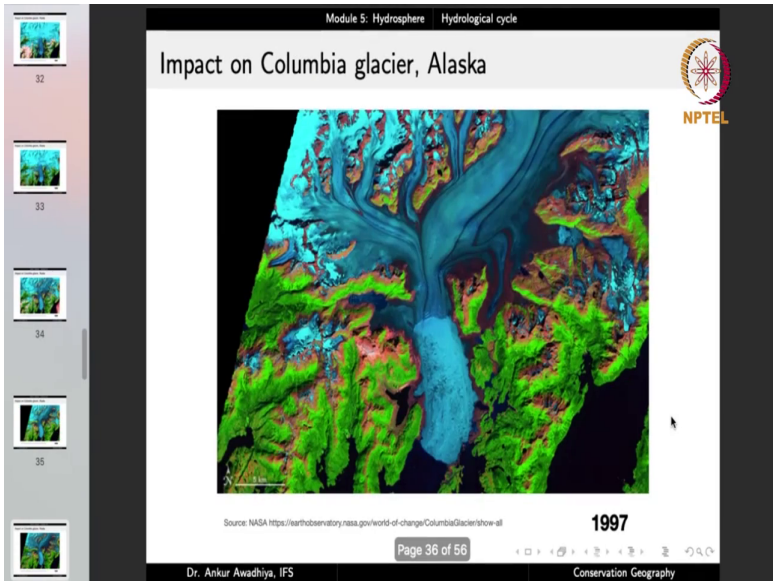


This is 1995 and you can observe that now the glacier has shifted to this location, the glacier is melting, the glacier is disappearing. Now remember that when we talked about the ice caps in the case of Antarctic ice caps the water had a residence time of roughly 20000 years, even in the case of the Alaskan glaciers the water has a residence time of several thousands of years.

But now the water that was stored up that would have remained in that place for very long period of time that is now melting up at a very fast pace, so this is another change that we are bringing, so this is the image from 1995, 96, 97 and now you are observing that the ice is changing its color because there is now a rapid amount of melting everywhere. Now the melted water it creates pools, it creates small streams and so they look very different.

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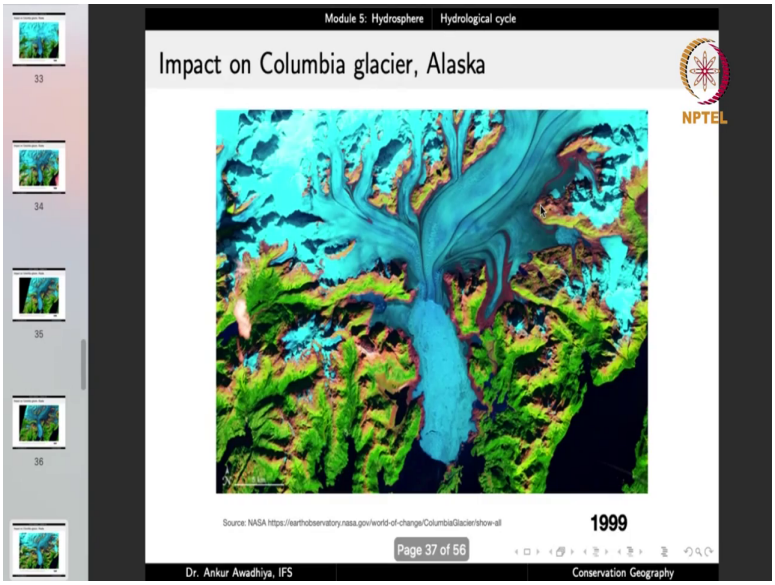
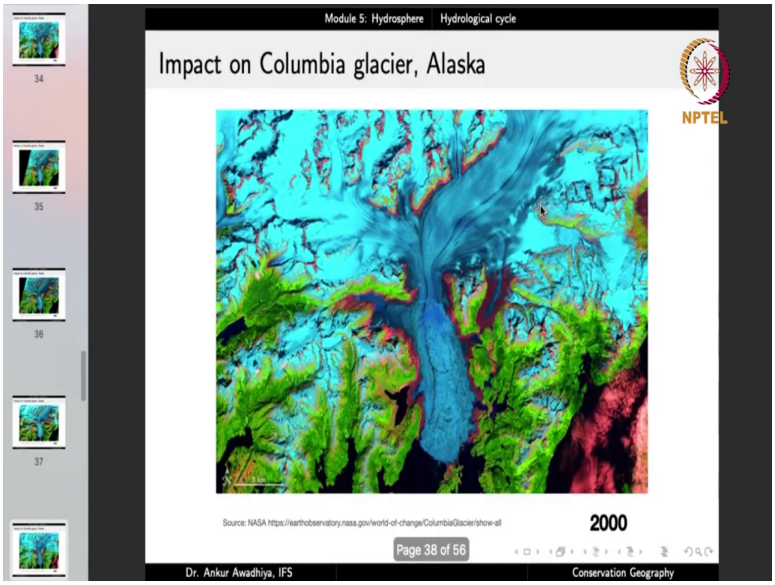
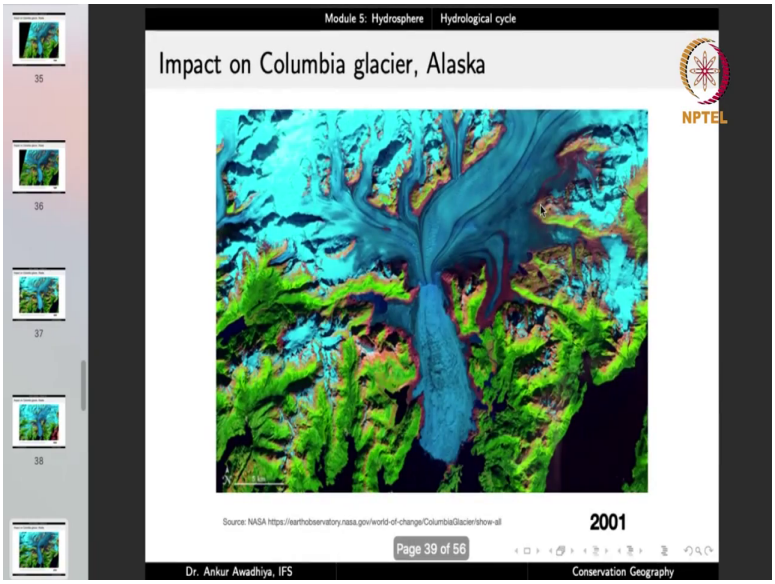
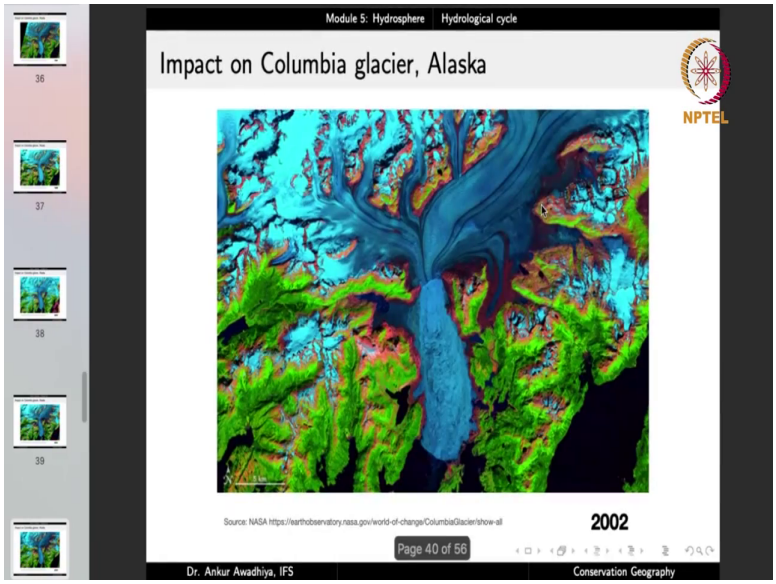
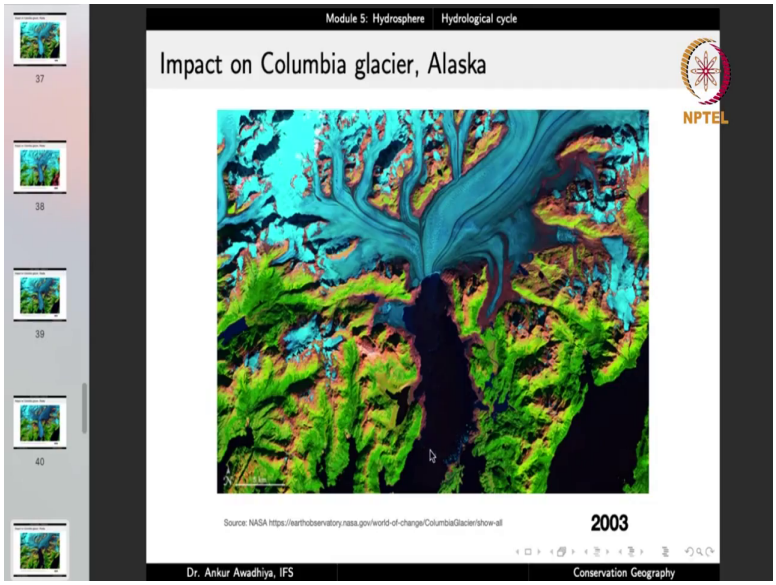


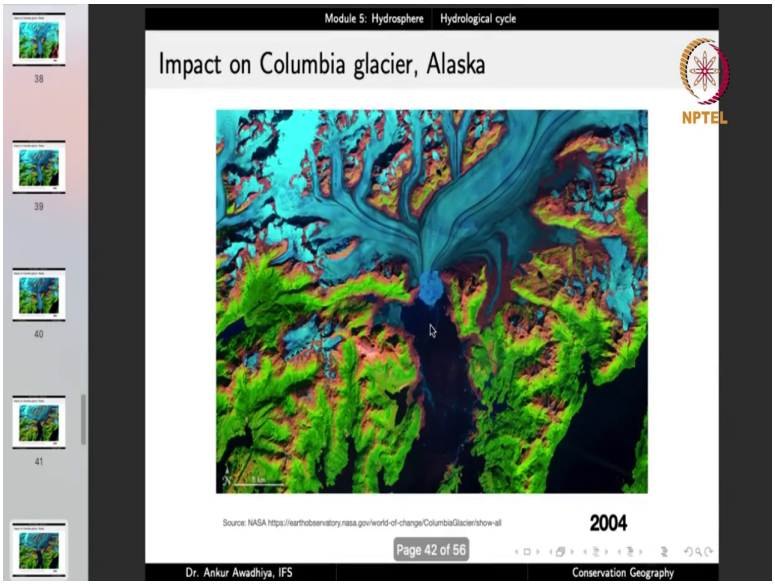





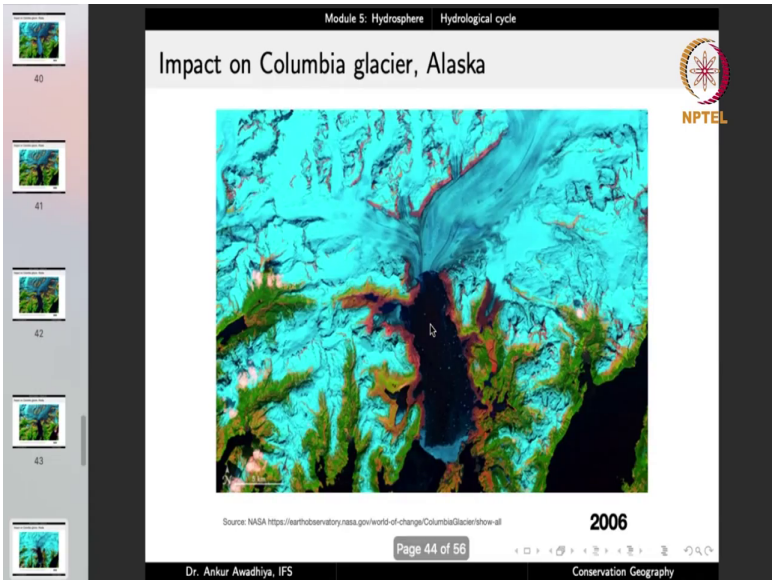




This is 1999, 2000, 2001, 2002, 2003. So we had when we began we had the terminus here, now you have the terminus here so all of this portion is now gone.

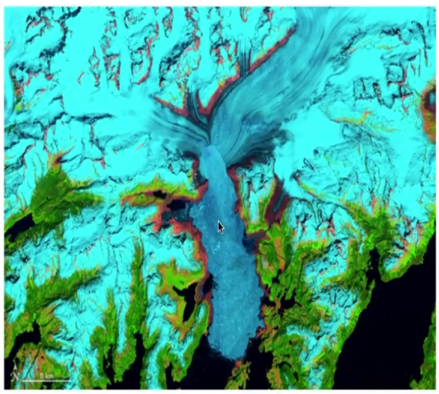
(Refer Slide Time: 55:42)







## Impact on Columbia glacier, Alaska



Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

2008





## Impact on Columbia glacier, Alaska

Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

2009



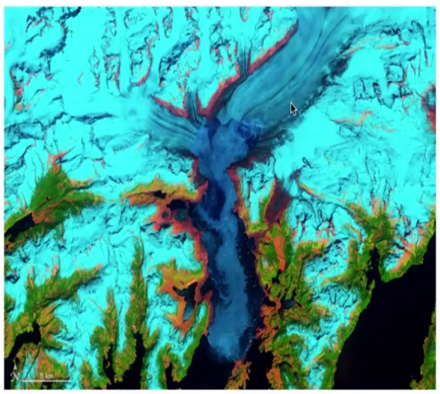


## Impact on Columbia glacier, Alaska

Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

2010

## Impact on Columbia glacier, Alaska



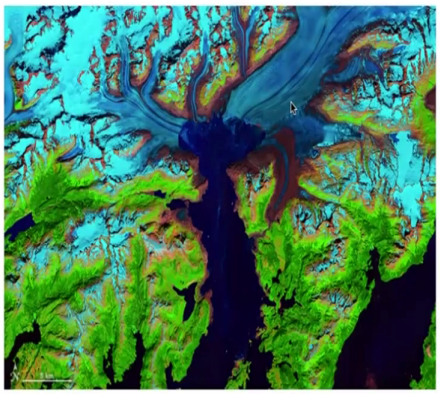
Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

2011





## Impact on Columbia glacier, Alaska



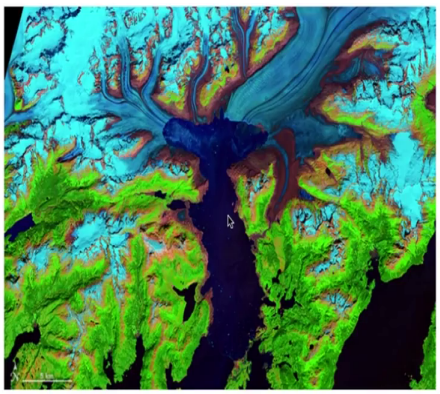
Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

2013





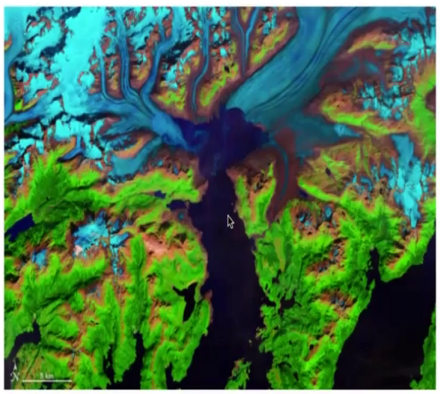
## Impact on Columbia glacier, Alaska



Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

2014

## Impact on Columbia glacier, Alaska



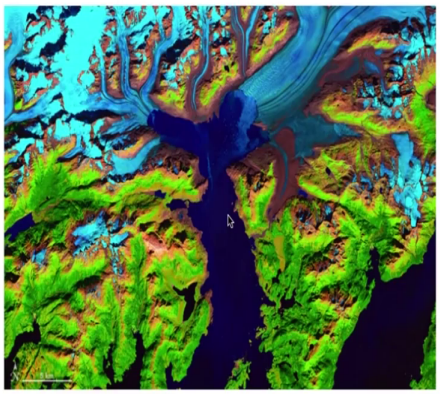
Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

**2015**





## Impact on Columbia glacier, Alaska



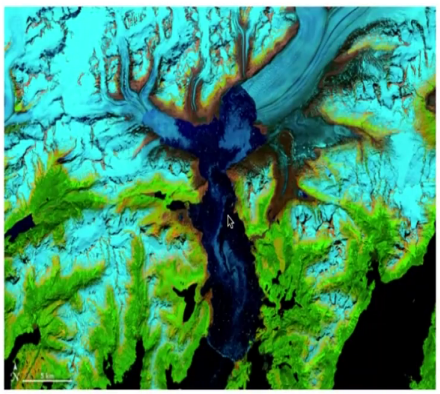
Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

**2016**



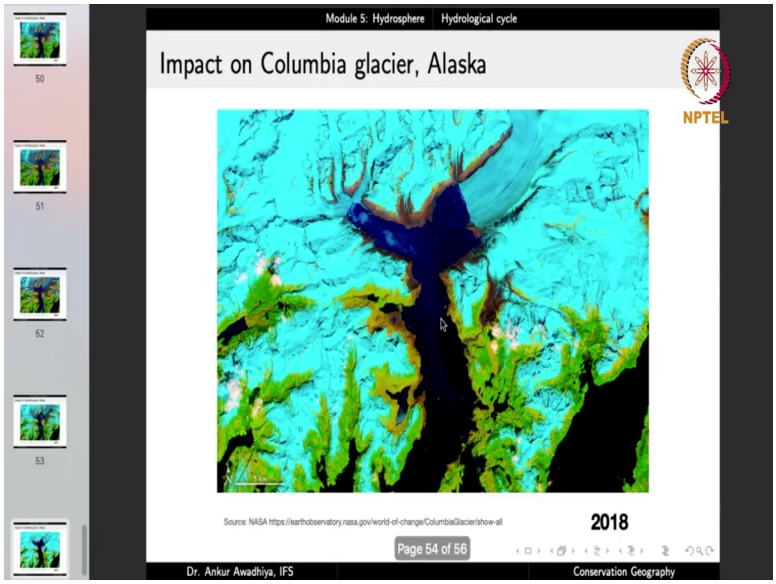


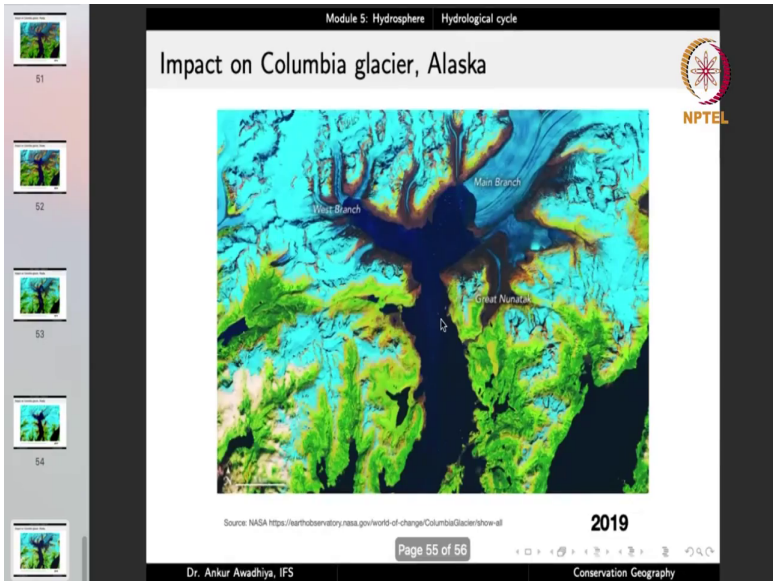
## Impact on Columbia glacier, Alaska



Source: NASA https://earthobservatory.nasa.gov/world-of-change/ColumbiaGlacier/show-all

**2017**




2004, 5, 6, 8, 9, now both of these branches are now getting eaten up, 2010, 11, 13, now in 13 you find that now both of these branches are no longer connected they have melted away, 14, 15 and 16. This is the kind of impact that we are having on the system 2018, 2019. So this is the rate at which we are losing the glaciers, this is the rate at which we are impacting the hydrological cycle.

Now not only is this hydrological cycle being impacted just by the melting of the glaciers, but what is happening with this melt water? This melt water is moving into the oceans, when it moves into the oceans what does it do, you now have more amount of water in the oceans, so the oceans are now overflowing, so essentially the areas that are close to the sea, to the sea or the oceans essentially the coastal areas they are now getting inundated, there is a flooding.

Now if you have a flooding in a town where will people go? We are essentially reducing the amount of land that we have on this planet. At the same time when you look at ice, the ice has a large amount of albedo, it reflects most of the heat back but water has a low albedo, so global warming essentially increases global warming and if you do not do something urgently probably it will be too late. So that is all for today, thank you for your attention. Jai Hind!