**Conservation Geography**
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**Module - 5**
**Hydrosphere**
**Lecture - 14**
**Oceans and Water Movement**

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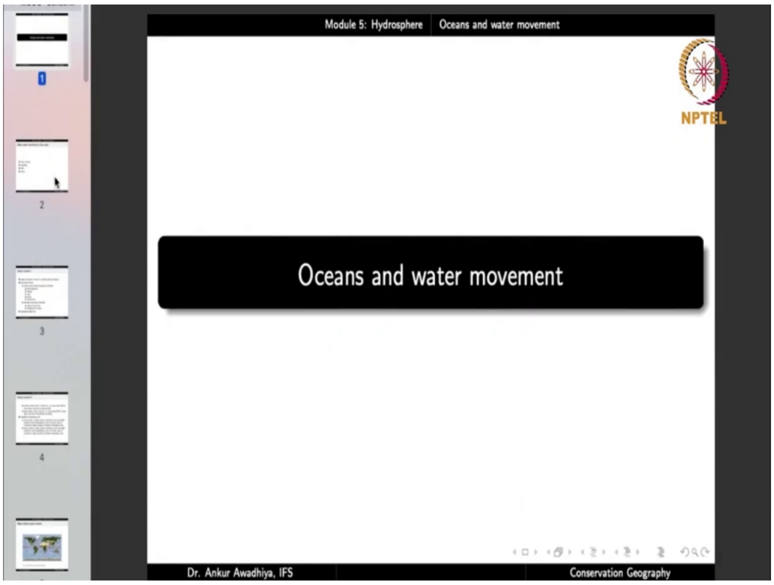


Namaste! We move forward with our discussion on the hydrosphere and in this lecture, we shall explore oceans and water movement.

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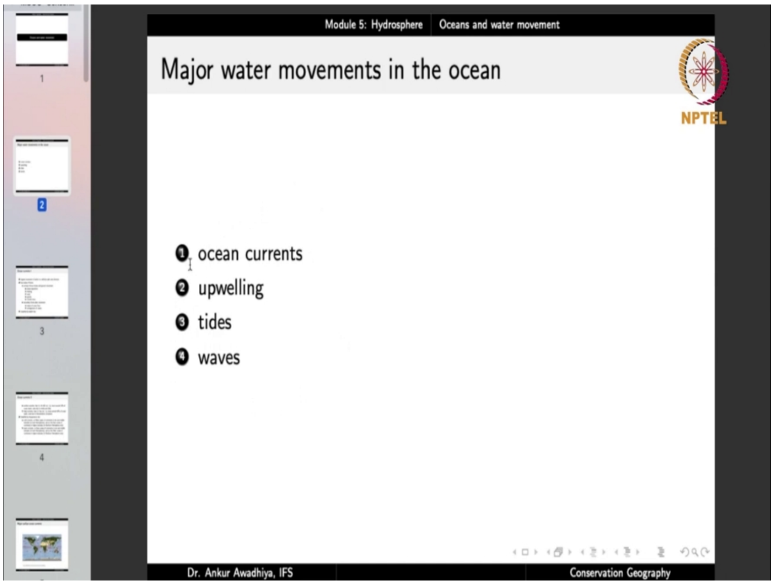

Now, oceans formed the largest portion of the hydrosphere. And so, the major water movements in the ocean become very important. The major water movements that happen in the ocean are the ocean currents, upwelling, tides and waves. And we should have a look at all these four types of movements in this lecture.

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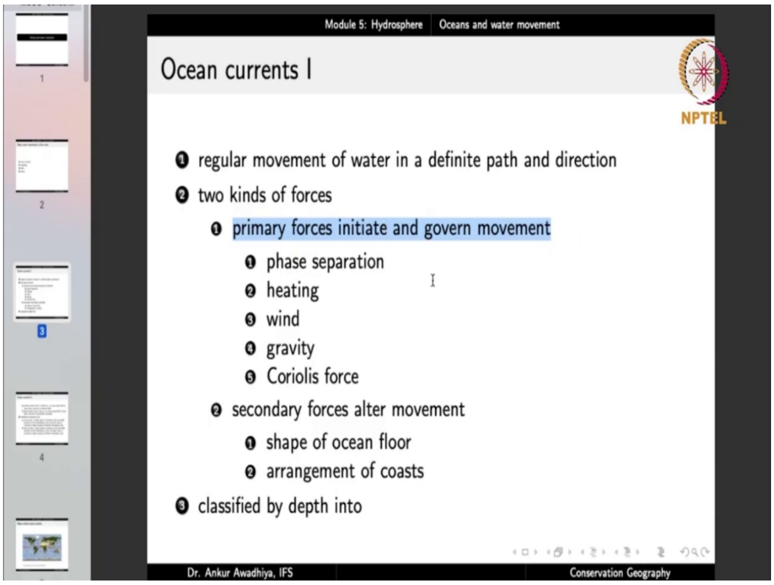


So, let us begin with the ocean currents. Ocean currents are defined as regular movement of water in a definite path and direction. So, it is a regular movement of water, it is not that the water moves at some times and the water does not move at other times, it is a regular continuous movement of water in a definite path and direction. So, when we talk about ocean currents, we can tell the exact path and exact direction that water takes when it moves in the form of a current.

So, this is a regular movement of water in a definite path and direction. And there are two kinds of forces that play a role in the ocean currents. The first is the primary forces that initiate and govern the movement. So, they are the main forces that start the currents and that govern the movement and most of the properties of the currents. These include phase separation. Now, phase separation is a process in which when a liquid with a solute is frozen, then the frozen portion contains only the molecules of the liquid, whereas all the solutes are left out.

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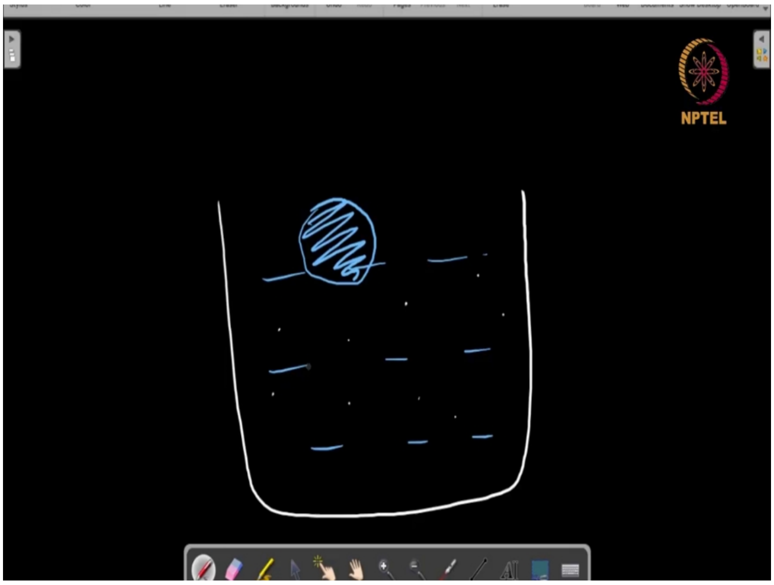


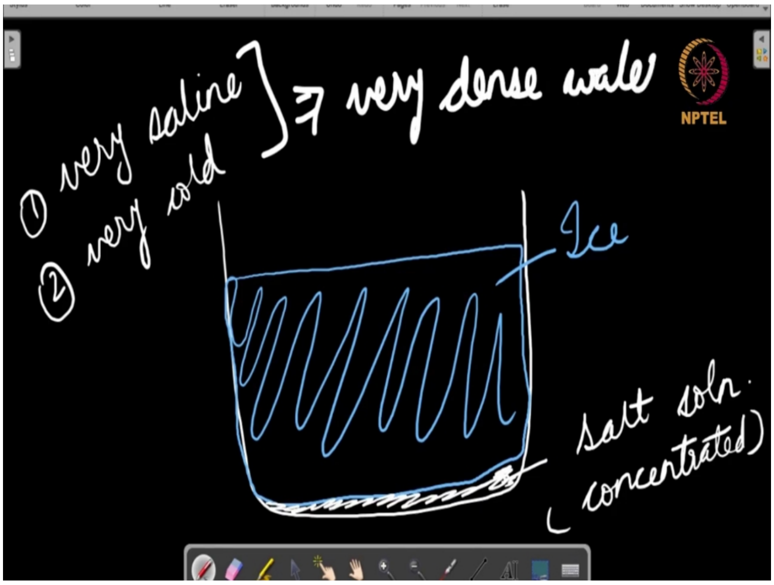


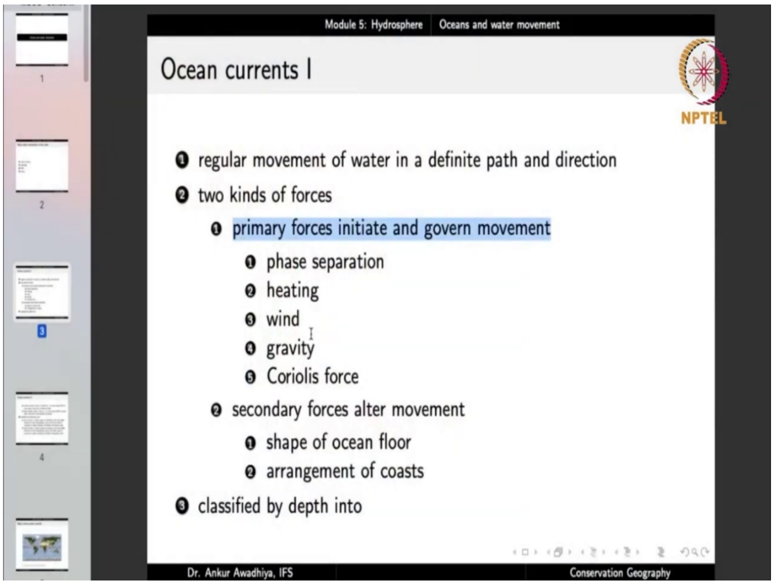

So, essentially, if we take a tumbler of brine, which is salty water, so, here you have water. And this water has a lot of salt in it. And if you take this tumbler and if you put it into a freezer, you will find that ice grows. And so we get a block of ice that has developed. And when this ice gets formed, then this ice come contains only of the water molecules, it does not contain any salt.

So, it is not a salty ice. It is an ice that is made out of freshwater. And so, what happens to the salts, the salts are left out and they become more and more concentrated. Now, with time you will have a situation in which the majority of this tumbler will be filled with ice. In this case, all of this is ice and we will be left with this portion which is a highly concentrated salt solution.

So, this is a salt solution, which is highly concentrated. So, when we talk about phase separation, it is the separation of both the phases the solute and the solvent. And it occurs when the solution is put up for freezing. It also happens in a number of other circumstances say when crystals are being formed, but for the context of hydrology, we are more or less interested in the phase separation that happens in the case of salty water when it is being frozen.

Now it becomes very important in the case of thermohaline circulation, because what is happening here is that when you are reducing the temperature, you are getting a ice that is made out of pure water and you are getting a very highly concentrated salt solution. Now this salt solution that remains it has a number of properties, 1, it is very saline, 2, it is also very cold because it is resulting when the water is being frozen and so, the temperatures are also very less.

Now, if you have a water that is cold and that is full of salts in that case that water will be very dense because of 2 reasons; one water has the highest density at around 4 degrees Celsius. So, if you reduce the temperature, the water becomes more and more dense and the water also has a high load of salt, which also increases the weight per unit volume. So, with both of these, it becomes very dense water.

Now, if we consider the polar areas, where this process is going on where the water is very cold and it is freezing, and it is giving out the salts, so, that the resultant water is very high in salt concentration and is very cold. Where will this water go? Well, this water is the densest water that we have. And so, this water will move down it will move from the surface of the ocean down towards the ocean bottom. And so this jumpstarts a process that is known as the thermohaline circulation or the global conveyor belt. And we will look at it in more detail in a short while.

So, this is one primary force that initiates and governs the movement of water under the primary forces heating. So, if the water is being heated, you will get things like convection currents or you will have forces like winds that get developed. So, the third primary force is wind.

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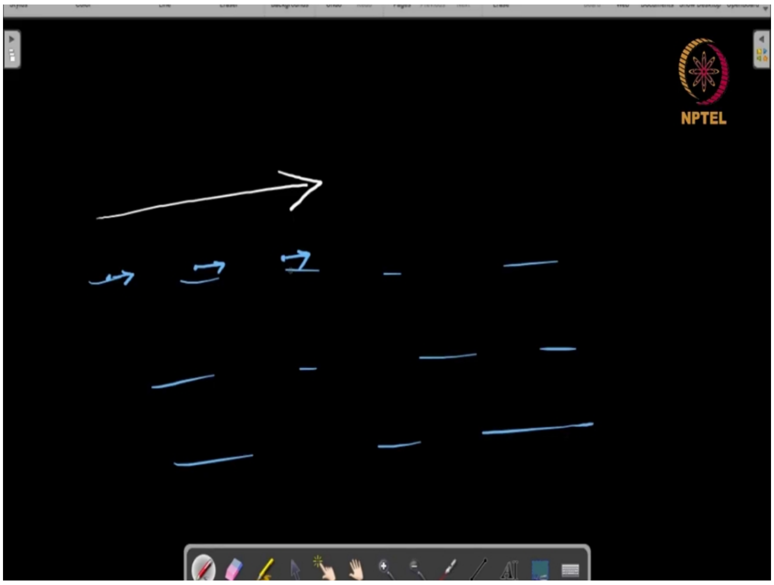


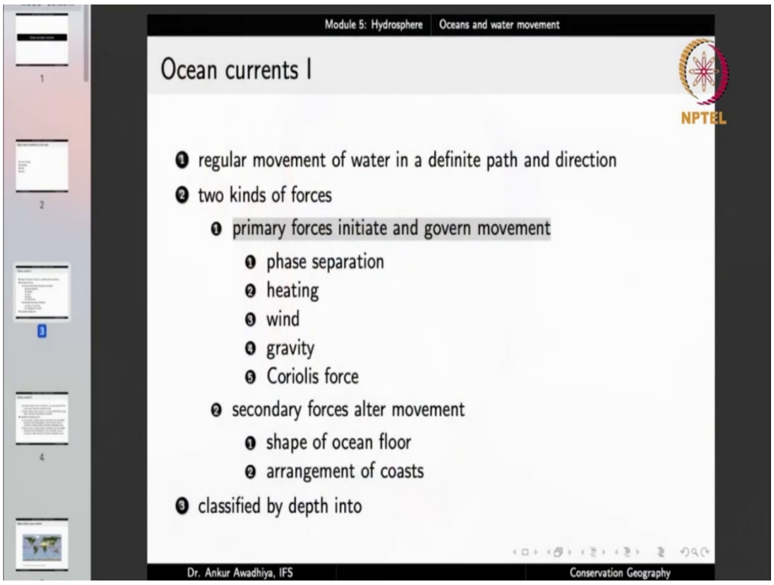


In this case, if you have the body of water and there is continuously a wind that is flowing in a particular defined direction. Now, the water molecules that are there on the surface, they will also interact this with this wind and they will also start to move in this particular direction. And this will result in the generation of a surface current. So, winds are also primary forces that initiate and govern the movement.

Another force is gravity. So, when we are talking about phase separation, the water that is very dense is very cool is moving down because of gravity. So, gravity plays a role in the movement of water. Once this dense and cold water reaches to the bottom of the oceans, where will it go from there? Well, it will take the path that takes it even further down.

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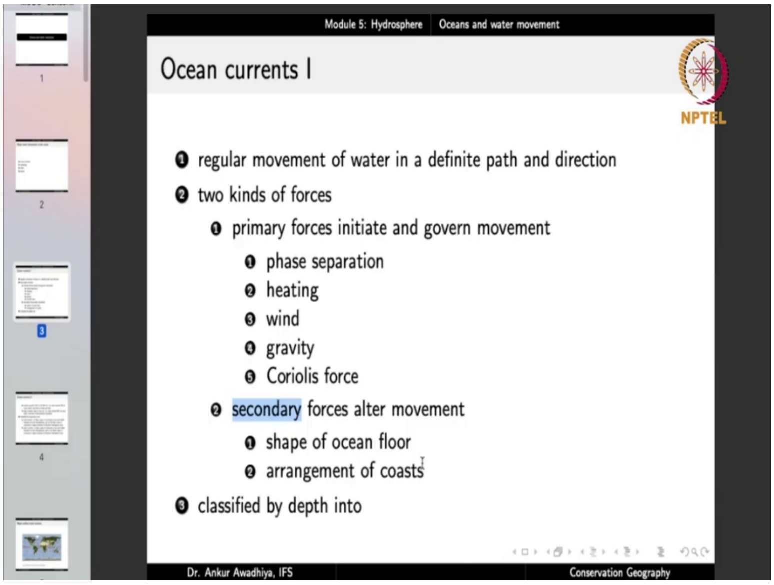


So, for instance, if this is the continental shelf, then we have the slope and then we have the abyssal plain and we are getting ice formation in this place which will result in a very dense water. So, this dense water it was formed here it moved down because of gravity and once it is reached to the floor, it will now move along the surface. So, it will be very similar to the flow of water overland.

Now, this water is behaving like a very different water from all the remaining water that is here. This denser water it is flowing like a river and this is flowing like a river because of gravity. So, this movement of water is being done because of gravity. Another primary force is the Coriolis force, because it governs the movement.

And as we have observed before, Coriolis force is a fictitious force that happens when you have movement on a body that is rotating with respect to an inertial frame of reference. Now because the Earth is rotating, so any movement in the Northern Hemisphere will be turned towards right.

Any movement in the southern hemisphere will be turned towards left with the Coriolis force being maximum at the poles and 0 at the equator. So, Coriolis force, because it defines the direction of movement of water. So, it is also a primary force then we have secondary forces that alter the movement. So, these secondary forces include shape of the ocean floor.

So, when we say that this water is moving along the ocean floor, then it is following the contours of the ocean floor, meaning that if the ocean floor has a different configuration, this water will perhaps move differently. So, this becomes a secondary force it becomes a secondary factor that is altering the movement, it is not initiating the movement, it is not governing the movement, but it is bringing about smaller alterations. Similarly, the arrangement of coast.

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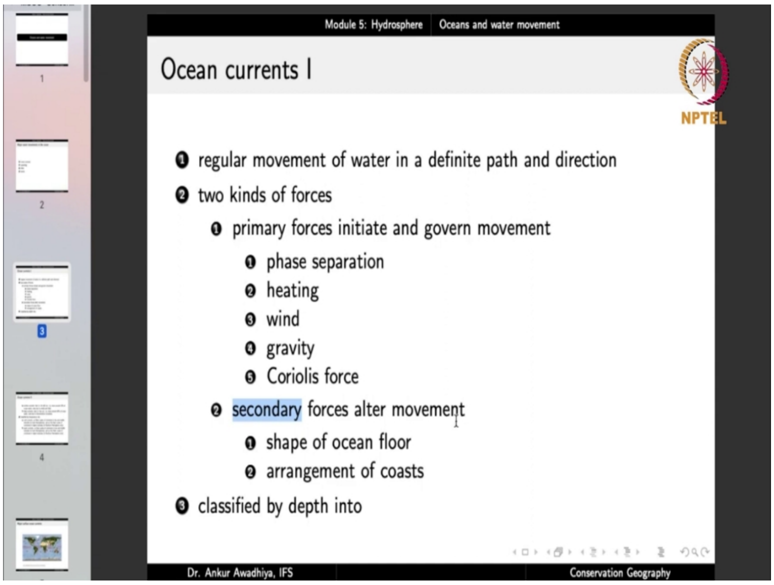


So, when we have a surface water. So, in this body, when we have a current that is moving on the surface, when it reaches to this coast, then it cannot move on the land, because this is a water current. So, depending on the shape of the coast, this water will have to change its direction.

So, in this case, the shape of the coast also becomes a secondary force or a secondary factor which is altering the movement of water it is not initiating it is not governing the movement, it is just altering the movement of water. So, these are the two kinds of forces that play a role.

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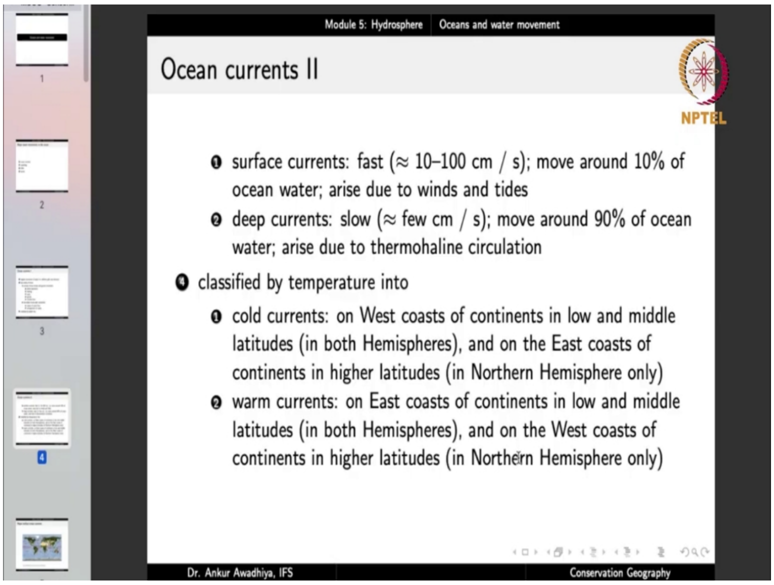


Now, ocean currents are divided by depth into surface currents and deep currents. Now, surface currents are fast currents typically around 10 to 100 centimeters per second. But they move away a very small amount of water just 10 percent of ocean water moves because of surface currents. And they arise due to winds and tides. So, there they are on the surface.

On the other hand, we also have deep currents, which are very slow, typically a few centimeters per second, but they move a large quantity of water as much as 90 percent of movement of ocean waters is due to the deep currents. And these deep currents are mostly the thermohaline circulation that we just talked about. So deep currents are slow, but they move a large quantity of ocean waters, and they arise due to thermohaline circulation.

Now, depending on temperature, we can have cold currents and we can have warm currents. Now cold currents are typically on the west coast of continents, in low and middle latitudes in both the hemispheres and on the east coast of continents in the higher latitudes in the Northern Hemisphere. Now, when we talk about these west coast and east coast, this is occurring because of the Coriolis forces that change the direction of these currents.

Similarly, we have warm currents on the east coast of continents in low and middle latitudes in both the hemispheres and on the west coast of continents in the higher latitudes in the Northern Hemisphere.

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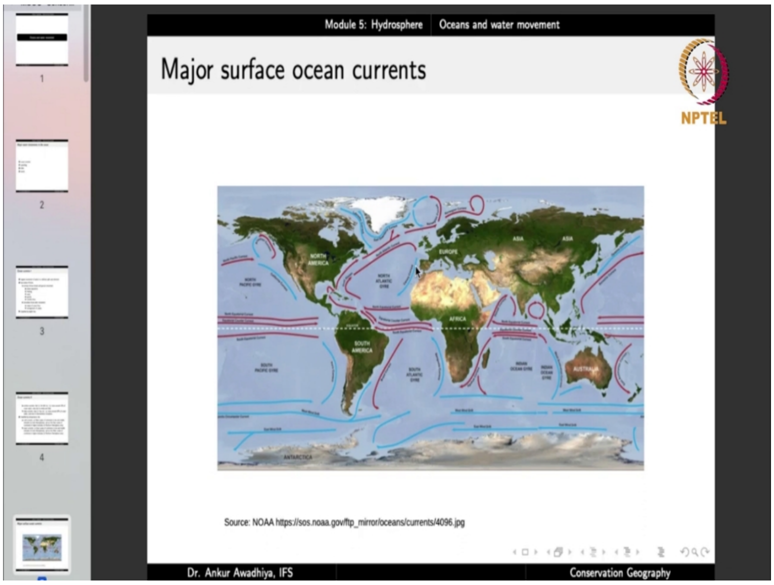

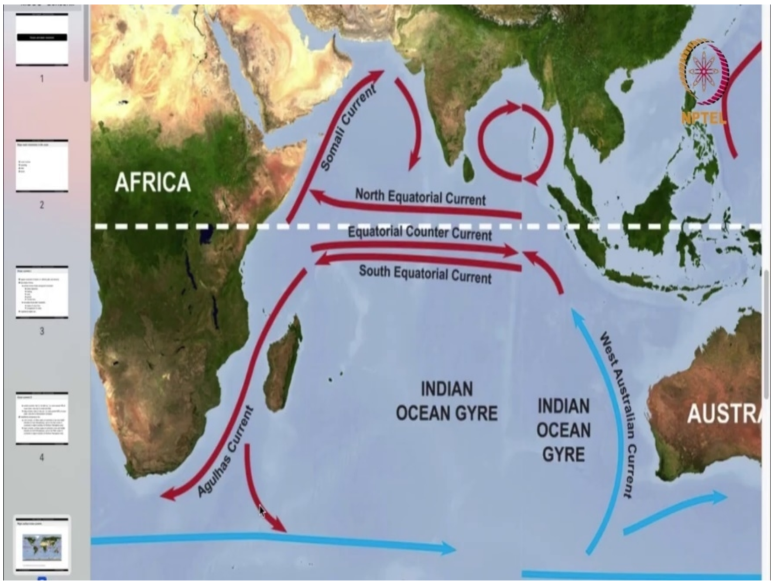


So, this is how it looks like in this chart, that red colour is indicating the warm currents and the blue colour is indicating the cold currents. So now, let us zoom up this chart and have a look. Now near India, we have this warm current which is the Somali current which is originating here near Somalia, it moves like this and then on the west coast, it turns like this and then it joins the equatorial current, the North equatorial current.

In the Bay of Bengal also we have this movement. Now you will notice here that India being in the Northern Hemisphere, these currents are turning towards their right in the southern hemisphere, the currents are turning towards their left. And here we have in the Indian Ocean, we have the West Australian current which is a cold current it moves then it warms up and it becomes a part of the South equatorial current.

Now because the North equatorial current is moving westward and the South equatorial current is moving westwards, typically here we get an excess amount of water and this flows towards the east in the form of an equatorial counter current. And all of these are warm currents. Then this South equatorial current, it moves along the coast of Africa, in the form of Agulhas current which then splits and becomes a part of the wind drift in the southern hemisphere.

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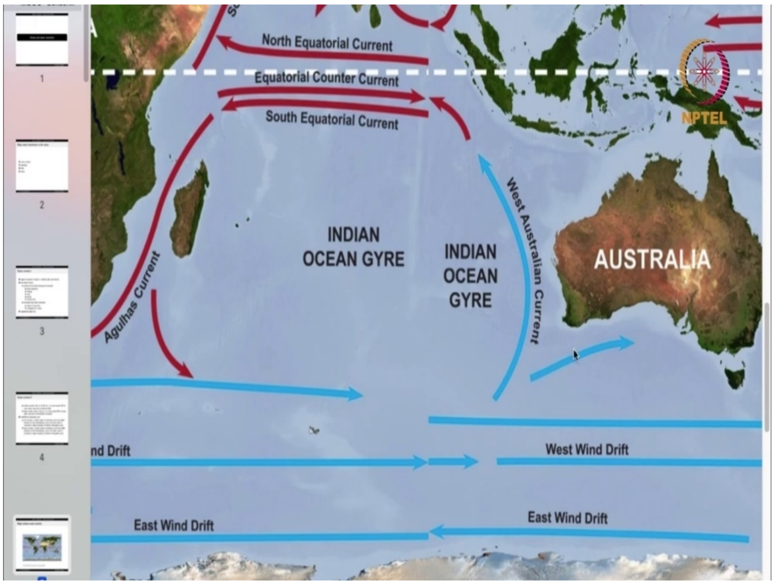


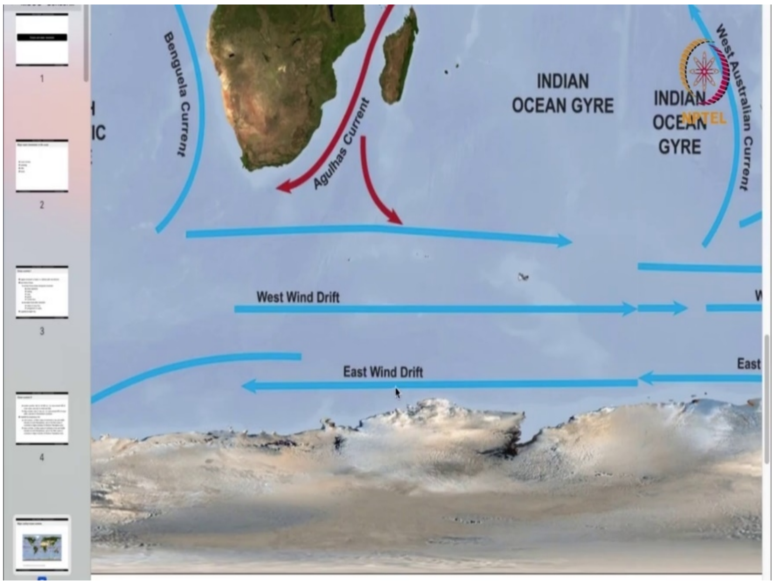


This wind drift also splits here to reach the southern coast of Australia. So, this is a cold current. Now near the Antarctica, we have the west wind drift and the east wind drift. And all of these are cold currents.

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Now, in the Atlantic Ocean in the South Atlantic, here we have the Benguela current. Again, here you can note that the currents are turning to their left, this being the southern hemisphere. So, you have the Benguela current, which is a cold current, and it touches the western coast of Africa.

Now being a cold current, it reduces the temperature and at the same time, it makes the air very dry. And so, this area will typically have deserts. So, we have the Namib Desert here. Then it meets with the South equatorial current. And here is well we have the equatorial counter current and the North equatorial current.

Now, the South equatorial current moves southwards in the form of Brazil current and this is a warm current, now being a warm current, it will increase the temperatures and it will create more amount of rainfall because it will make the air more humid and then this will ultimately join the west wind drift.

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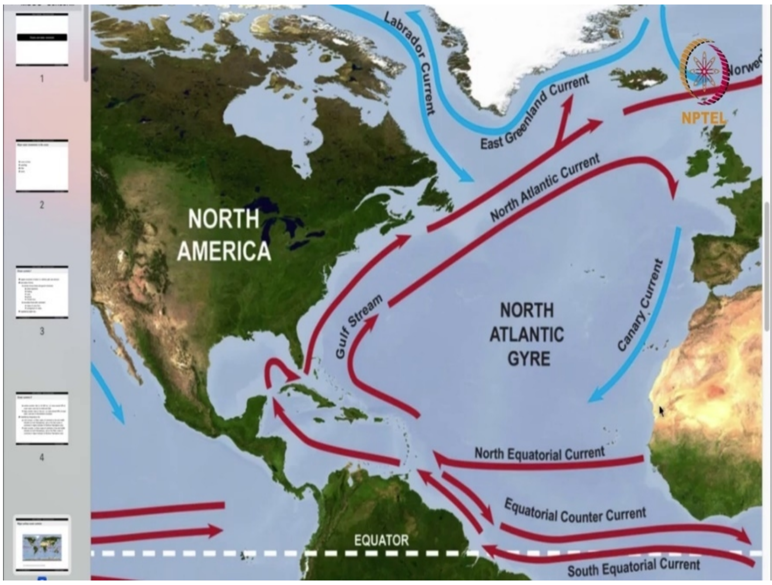


In the northern Atlantic, we have this north equatorial current, which then moves in the form of Gulf Stream. So, the Gulf Stream is a warm current to in the Northern Hemisphere, what we are observing is that the eastern coasts are having the warm currents and the western courts are having the cold currents.

Now, this Gulf Stream continues in the form of North Atlantic current then it turns and becomes the Canary current. Now Canary current is a cold current. So, here as well you will find less amount of rainfall. So, these areas will be typically drier.

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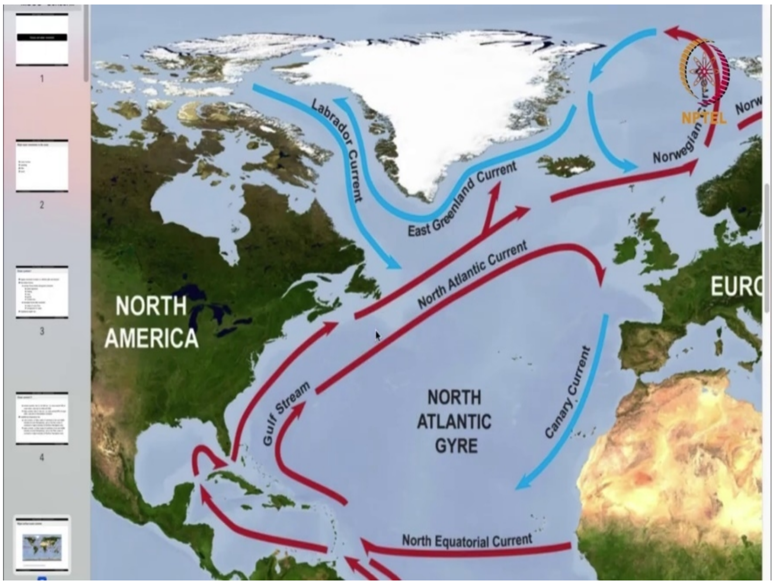


Then this North Atlantic current it moves further becomes the Norwegian current. So, this is a warm current it moves towards the polar regions becomes cold and then it becomes a cold current. This cold current then moves in the form of East Greenland current and here you can observe that it is following the coast. So, when we said that the shape of the coast plays a role, here you are observing that the shape of the coast is actually playing a role.

Otherwise probably this current would have moved like this. So, because the Greenland is like this, so we have this current that is following the coast. And then in this area, it becomes the Labrador current which is a cold current, it moves south and then it joins the North Atlantic current.

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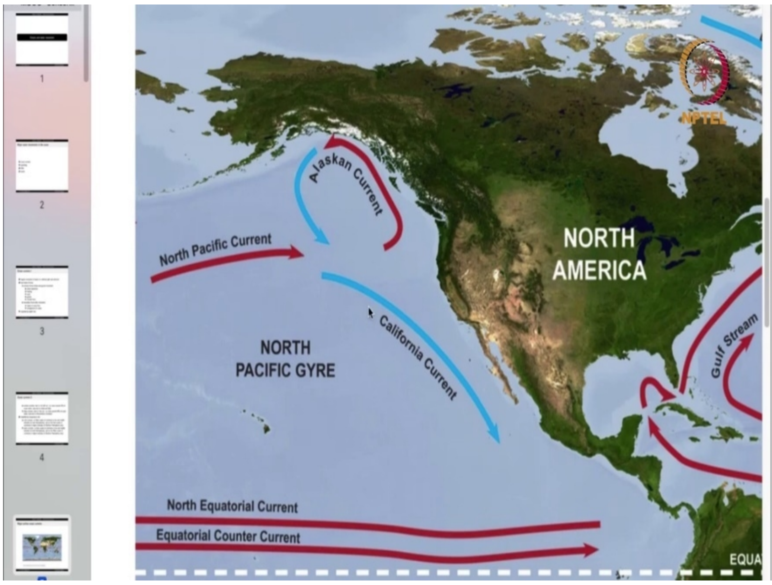


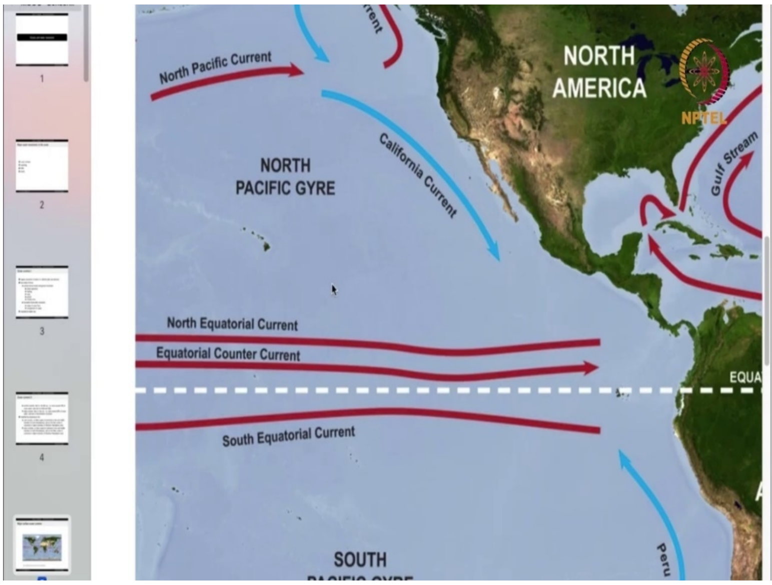


In the Pacific Ocean, we have the Alaskan current which is a warm current. So, again here this here we have a warm current and then it continues in the form of Californian current which is a cold current. Here we have the North Pacific current which also joins it. So, Californian and current being a cold current, it will reduce the temperatures and it will reduce the rainfall. So, the western portion will be typically drier.

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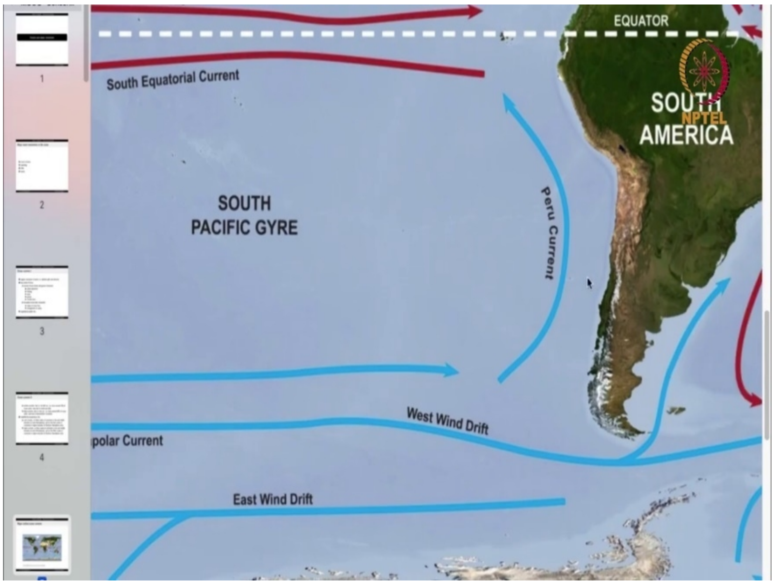


Then we have the North equatorial current, South equatorial current and the equatorial counter current. Now in the South Pacific, we have the Peru current. Now this Peru current again is a cold current. And so these areas will be cold and dry. And so we again have deserts in this area.

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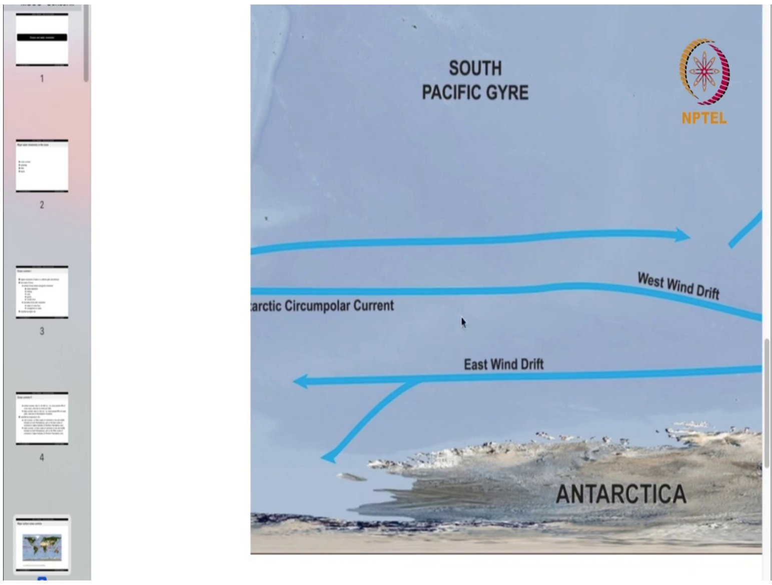

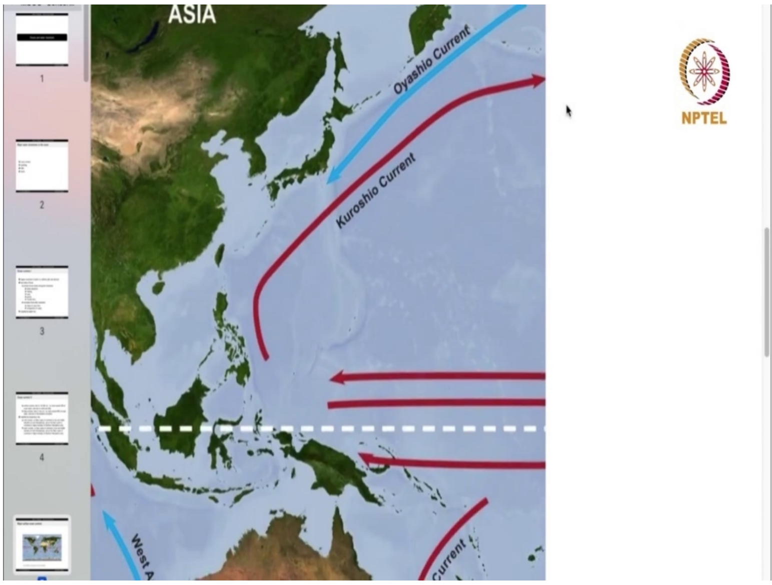


Now, moving to the south, we have the Antarctic Circumpolar Current which continues as the west wind drift and here the cold portion continues in the form of in the North Pacific it continues in the form of cold current which is known as Oyashio current and here we have the warm Kuroshio current. So, these are moving in opposite directions.

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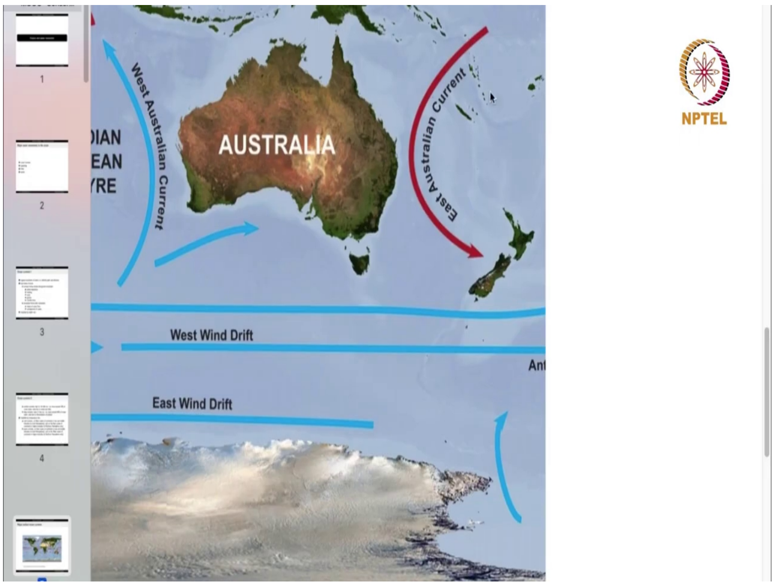

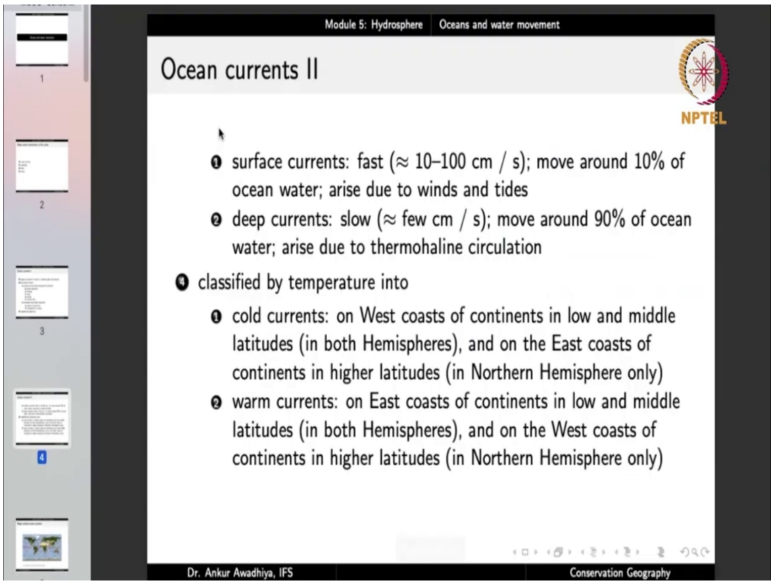


And in the South Pacific, we have the East Australian current which is a warm current. Now here again because this is a warm current, so, these areas will get more amount of rainfall, this Western Australia, West Australian current being a cold current, these areas will have less rainfall. So, typically you can observe that the east coast of Australia is better because of which we are getting more amount of forests the west coast of Australia is more drier and so, this portion it is appearing to be dry. So, on the basis of temperature we have cold currents and we have the warm currents.

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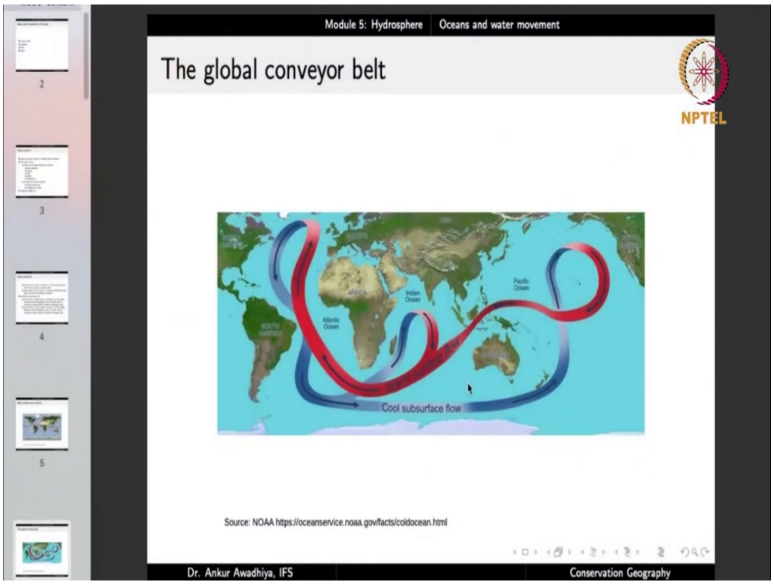


Now, let us talk about the global conveyor belt or the thermohaline circulation. Now, this is one of the most important movements of water. It is moving as much as 90 percent of the water that is being moved in the oceans is being moved because of this conveyor belt.

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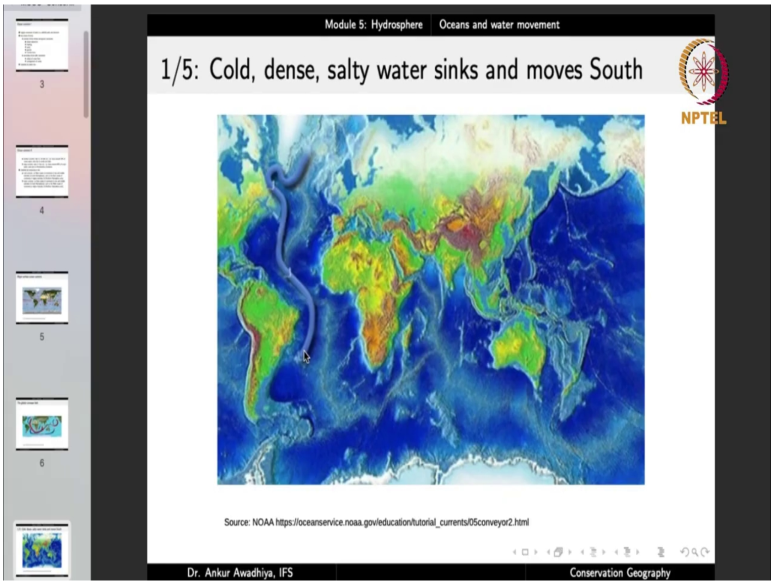


Now, this conveyor belt starts from North Atlantic and in this area, this area being very cold, we are getting a phase separation. So, the water that remains is very cold, it is very salty, it is very dense, and so, it sinks down. Once it has sunk down it moves along the ocean floor towards the south.

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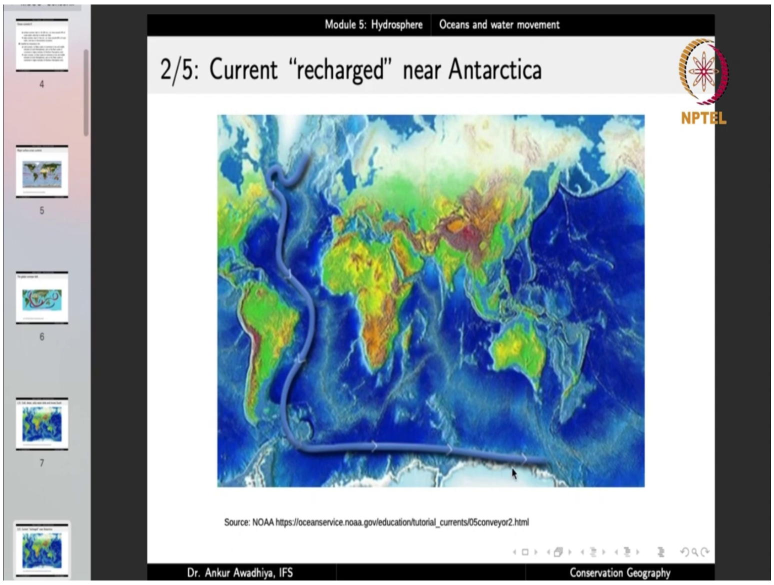


Then it is recharged near Antarctica, what do we mean by that, we had a phase separation here and similarly, we have a phase separation here. And so, here again this current gets even more amount of cold, salty, dense water and so, it continues like this.

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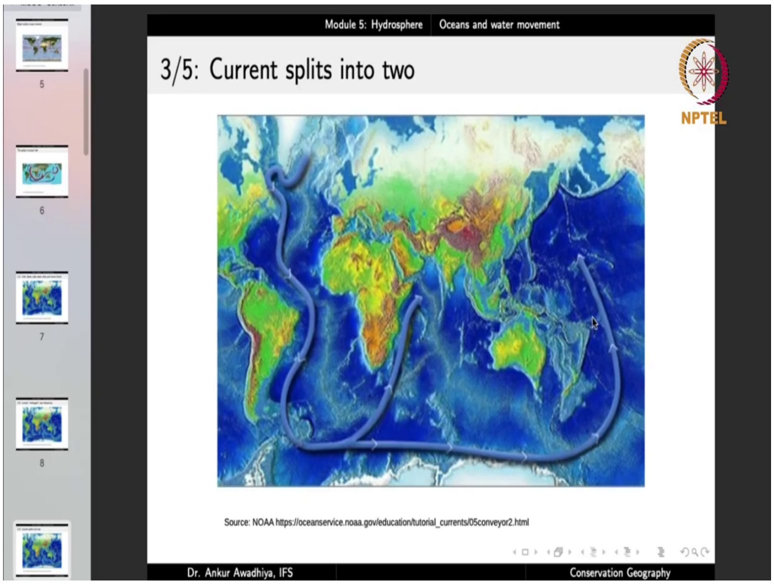


Next, this current splits into two portions, one portion enters the Indian Ocean the another portion enters into the Pacific Ocean.

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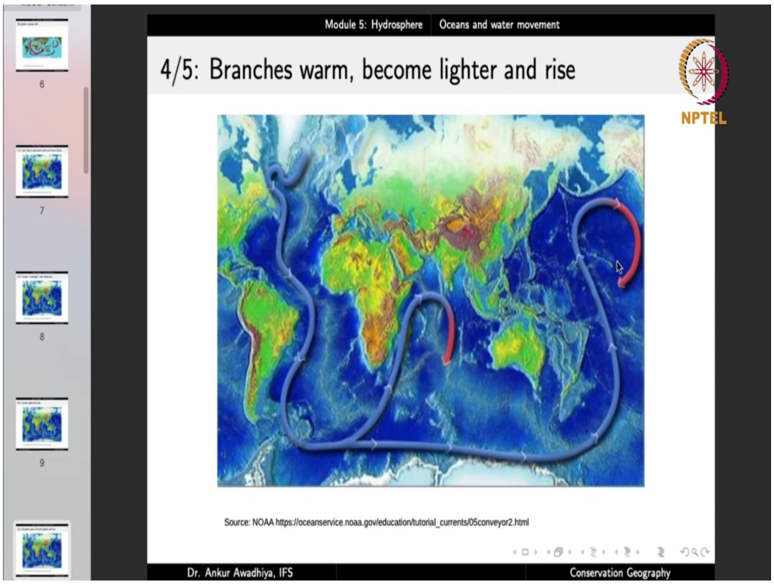


And these branches then warm up once they warm, they become lighter and they rise. So, here we are observing that this current is now rising, and it has now become a warm current. Similarly, here, this current has now risen and it is now a warm current. Now, we are talking about the surface movement of water.

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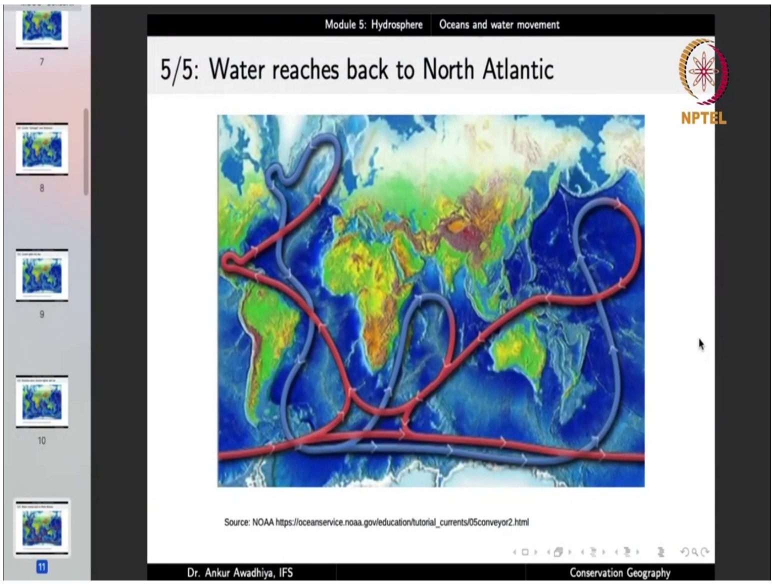


And this water then moves in these routes to reach back into the Atlantic, the North Atlantic and so, all this water is now moving like this, you have a surface movement like this, you have this surface movement and all of this moves back into the North Atlantic and so this current continues. So, this is the global conveyor belt or the thermohaline circulation. Now, what is this current actually doing?

So, as you can observe that in the colder areas, this current is carrying cold, salty, dense water towards the equatorial regions. So, it is taking cold water from cold areas moving them towards the equator and near the tropics it is getting warmed to this current warms it rises and then it moves the warm water towards the poles. So, essentially, this current is getting its energy from the difference in temperatures in the equatorial regions and in the polar regions.

And it is moving heat that is thermal energy from the equator towards the poles. So, this is very important. Now, when it moves thermal energy from away from the equator, it means that the equatorial areas or the tropical areas are not that warm as they would have been if this current was not functioning. And because it is carrying thermal energy towards the poles, the poles are not that cold as they would have been if we did not have the circulation.

So, in essence this circulation is actually moderating the temperatures, it is making equatorial areas less hot and it is making the polar areas less cold which has very important ramifications not just for biodiversity but also for human beings. The equatorial areas typically are very hot and if this current stops, they will become even more hotter. In those situations, how will people live there?

Similarly, in the cold in the polar areas, they are already very cold. And if this current stops to move water, then they will become even further colder. Then how will humans live there? So, this current plays a very important role in moderating temperatures. And in this way it helps sustain life, even in those areas of Earth that would be having a very extreme temperature if these currents were not working. So, this is how the thermohaline circulation works.

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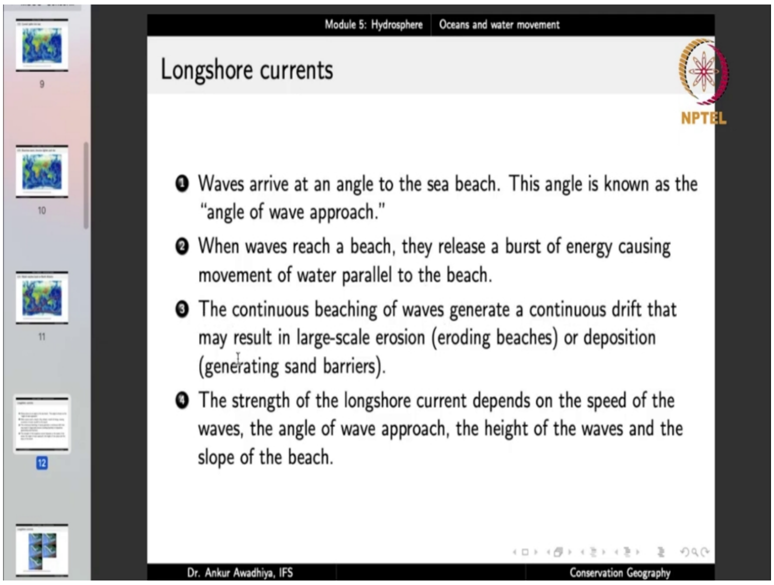


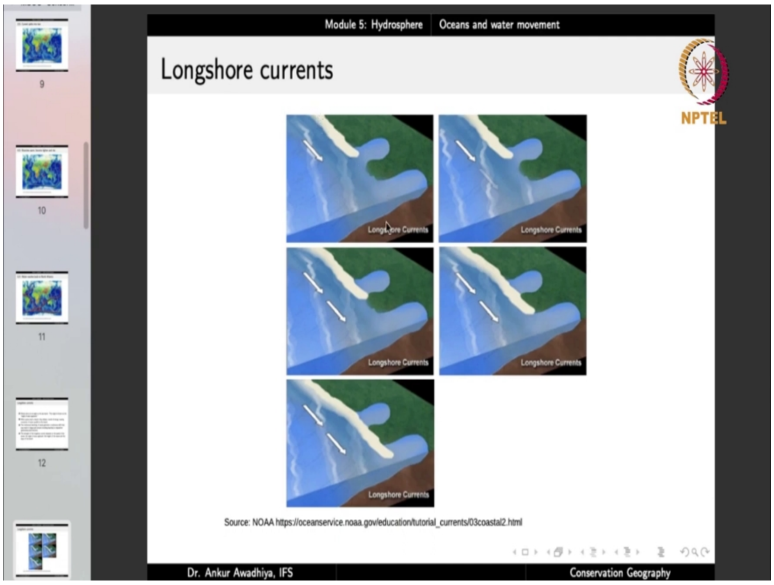


Another current that we have is the longshore current. Waves arrive at an angle to the sea beach; the angle is known as the angle of wave approach. So essentially, if this is the sea beach, the waves are arriving at an angle to the sea beach. When waves reach a beach, they release a burst of energy that causes movement of water parallel to the beach, what is happening is that when these waves, when they hit the beach, there is a transfer of energy, the waves are carrying energy.

And now this energy is made available at this point. Now, with this energy, the water starts to move and the movement of this water will be parallel to the shore or parallel to the beach. So, it causes a movement of water parallel to the beach. And the continuous beaching of waves generates a continuous drift that may result in large scale erosion or deposition. So what is happening is that you do not just have one wave, but you have a train of waves.

So, we get waves one after another. And so, once the first wave has touched the beach, it has started to release its energy and when this wave moves forward, another location will get the burst of energy, then another location will get the burst of energy and so on.

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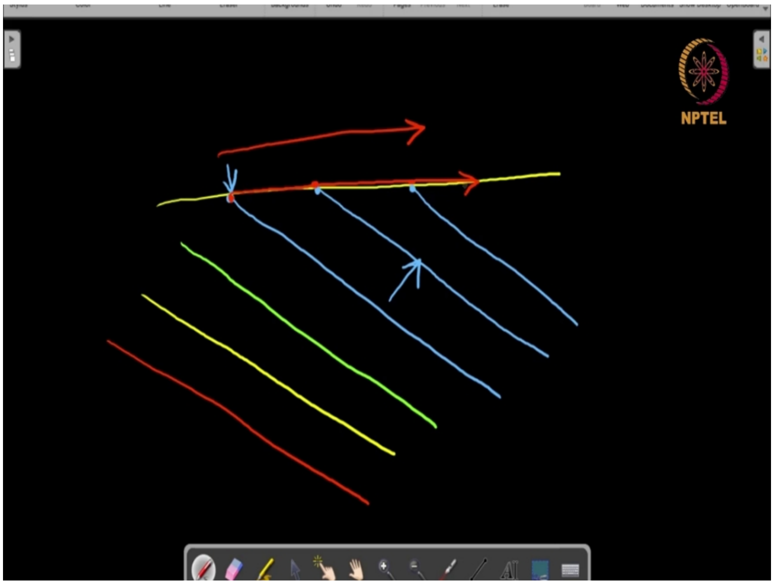


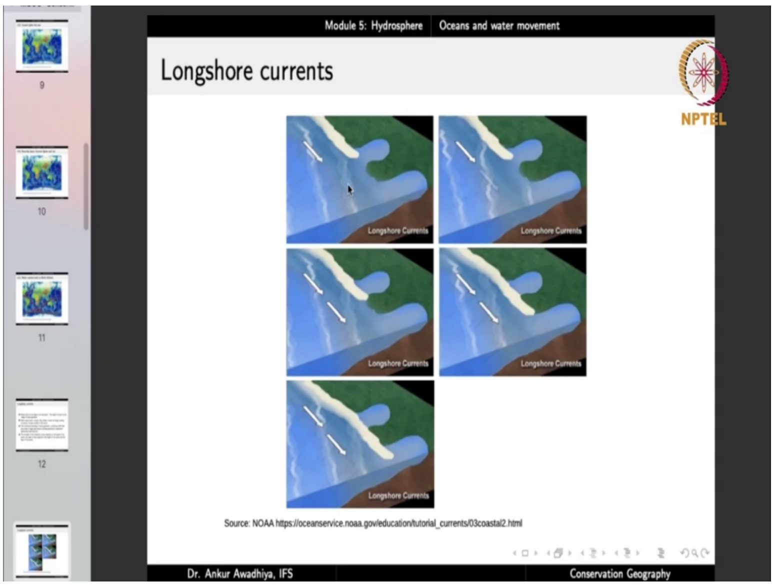

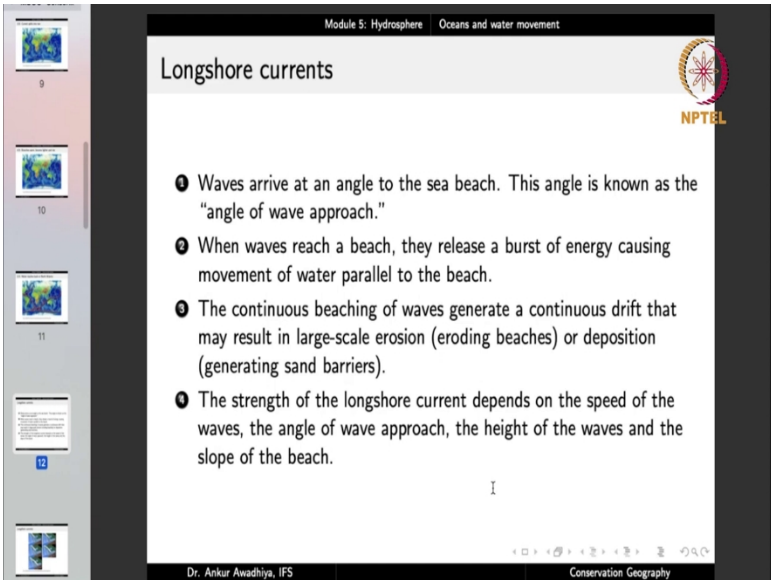


So, essentially what is happening is that if this is the sea beach, and we have the wave that is moving at this angle, now the wave is moving in this direction. So, in the first instance, we have a release of energy here, then later on, when the wave reaches like this, we have a release of energy here, then later on, we have a release of energy here, but then, the release of energy at any point is not a one-off incident, because this wave is being followed by another parallel wave which is being followed by another parallel wave and so on.

So, what happens is that this train of waves, it goes on releasing energy in this sequence. So, you will have energy release first here, then here, then here and so on. So, at all of these points, we are getting a release of energy in this direction. And when that happens, water starts to move and water will follow the shape of the beach.

The water will be moving parallel to the beach. So, in this case, when the waves are hitting at an angle, we get a movement of water that is like this. So, you get a continuous movement of water parallel to the beach, and this is the long shore current. Now, when the water is moving, then the water may result in erosion or it will result in deposition. So, what is the water going to erode?

The water is going to erode the sand that is there on the beach. So, this is a movement of water that is parallel to the beach and water being a very good geomorphological agent, it will do its regular job erosion and deposition. So, when it erodes away the sand, the beaches will reduce in size, when it deposits the sand somewhere later in those locations, the beaches may expand or it may even result in the formation of other structures such as the spits.

So, we had observed spit in one of the earlier lectures, and the spits are formed because of the longshore currents or it may result in the generation of a sand barrier. So, we get different landforms in the form of eroded beaches, sand barriers, spits and so on that are generated because of the longshore currents.

Now, the strength of the longshore current depends on a number of factors the speed of the waves, because both the speed more quickly is the energy getting released, and so the waves will be more powerful. The angle of the wave approach, the height of the waves and the slope of the beach.

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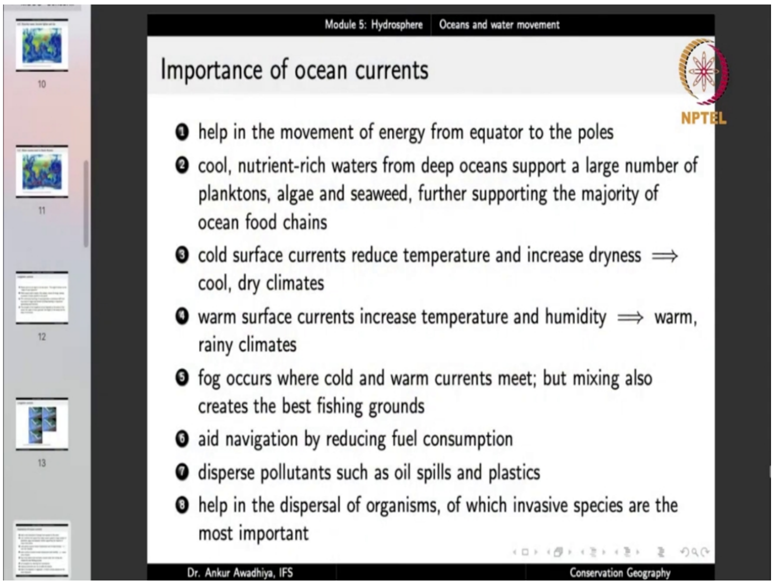


Ocean currents play a number of important roles, they help in the movement of energy from the equator to the poles, meaning that they are transferring energy that is thermal energy from the equator, which are getting more heated towards the poles, which are having a deficit of energy. Once that happens, the equatorial areas reduce their temperatures they are not as hot as they would have been in absence of these currents, and the polar areas become a bit more warmer than they would be if these currents did not exist.

From the ecological point of view, this helps a number of organisms because it moderates the conditions in both of these locations, both the equatorial locations and the polar locations. And from the economic point of view, it makes these areas habitable by human beings. And we do not have to spend as much amount of energy for climate control as we would have to spend if these currents were not there.

Similarly, cool, nutrient rich waters from deep oceans support a large number of planktons, algae and seaweed, further supporting a majority of ocean food chains. Now what is happening with these currents is that the cold water is brought upwards through various upwelling locations. And this nutrient rich water is being made available for different organisms. When it comes to the surface, we get a location where we have ample amount of nutrients plus ample amount of sunshine.

So, the organisms the phytoplankton and the plants will be able to use these nutrients to make food. Now, ecologically, this will support a large number of food chains in the ocean. And from an economic point of view, we will be able to harvest this biodiversity that is sustained by these currents. So, we can perform fishing in these locations to extract these fishes in an economical manner because we will be having a very large number of fishes.

Cool surface currents reduce the temperature and increase dryness. So, because they are cold, so they reduce the temperature. So they make it make the surrounding cool and being cold currents, they do not add moisture to the air. So, they make the air dryer. And so these result in cool and dry climates. whereas warm surface currents do the opposite thing. They increase temperature and humidity and result in warm and rainy climates.

Fog occurs where cold and warm currents meet but this also creates the best fishing grounds. Why? Because the cold currents are bringing in a lot of nutrients. And when they are meeting with the warm currents, then we have a situation where it is not as cold the temperatures are also moderated. So, in those circumstances we can have much more amount of biological productivity as compared to a location that would be having an equal amount of nutrients but is very cold.

Ocean currents aid navigation by reducing fuel consumption because the waters themselves are moving. And so any vessels that are floating on this water they will also be moving along with the currents. So, if you move a ship along the route of a current, then less amount of energy is required to move the ship. So, it helps to save fuel.

And when these currents move water, they also disperse pollutants, such as oil spills and plastics, which means that they protect the biodiversity of those areas that are having oil spills by rapidly moving the oil spill away from that area. But the negative consequence is that it exposes the biodiversity of other areas to the oil spills, because it is taking this oil to other locations.

So, this has both ecological and economic ramifications. Ecologically, certain communities, the biological communities get protected, certain other communities become more vulnerable. And economically, we will have to spend money to treat the oil spill in a larger area. Otherwise, it would have been much more localized. If the currents take the oil to a beach, then we will have to clean up the beaches.

If the currents were not there, then probably the oil spill would have been much more localized. And it also helps in the dispersal of organisms of which the invasive species are the most important. What happens is that the organisms that need to disperse, they can also hitch a ride. So, if there is a log that is floating on water, the ocean currents will take this log to very far off areas and the organisms that need to disperse. If they are sticking to this log, these organisms will also be taken too far off locations.

So, it aids in the dispersal of organisms. The negative consequence is that it also aids in the dispersal of invasive species, alien species. Now these invasive alien species if they reach into some other areas, they can wreak havoc to the local biodiversity. So that is a negative consequence.

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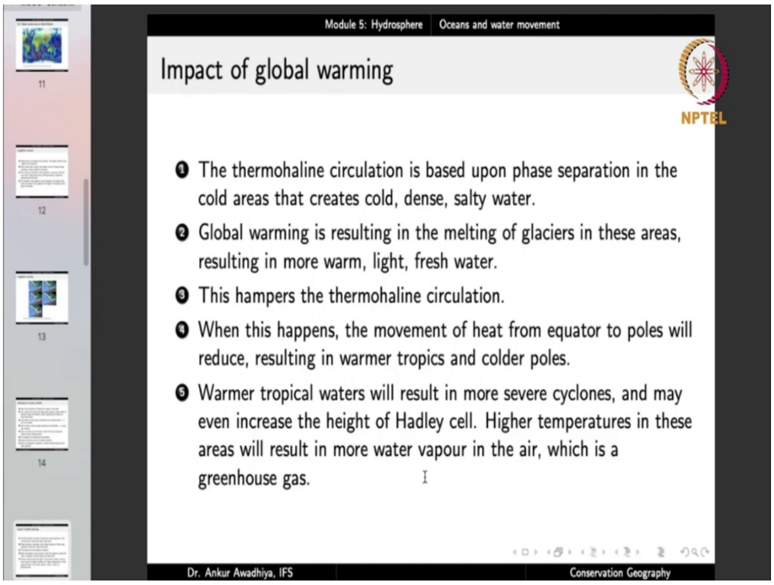


So, ocean currents play a lot of roles. And here it is important to note the impact of global warming. 90 percent of the oceanic circulation is happening because of the thermohaline circulation. And thermohaline circulation works because near the polar areas, the situations are so cold that ice is forming out of water. And when that happens, we have a phase separation, which generates cold, dense salty water which starts the thermohaline circulation process.

Now, with global warming it what is happening, the temperatures are going up. And so, in the polar areas, now we are not getting that much amount of generation of ice. In fact, a lot of glaciers are already melting. Now when the glaciers melt when these ice caps melt, what happens is we have fresh water that is pumped into the system in these cold areas. Now, the thermohaline circulation can only work when you have cold dense water that seeps down, moves down.

Now if you dilute that water with a lot of fresh water that is generated when you have global warming due to the melting of ice, you will have a situation where the thermohaline circulation becomes weaker. We can also reach a point where the thermohaline circulation stops completely.

Now if the thermohaline circulation stops, what will happen, we will have the equatorial areas getting warmer and the polar areas getting cooler, which will thankfully again start this thermohaline circulation because the polar areas will become colder. But then this will have an impact, a severe ecological and economic impact if the thermohaline circulation weakens for you in a bit because it will lead to large changes in the habitats.

So, the thermohaline circulation is based upon phase separation in the cold areas that creates cold, dense, salty water. Global warming is resulting in the melting of glaciers in these areas, resulting in more warm, light and fresh water which hampers the thermohaline circulation. And when this happens, the movement of heat from the equator to the poles will reduce resulting in warmer tropics and colder poles.

And warmer tropical waters will result in more severe cyclones. Why? Because the cyclones the tropical cyclones, they get their energy from the warm surface waters. So, if the thermohaline circulation stops, we will have more amount of warm water in the equatorial and tropical areas. So, more number of cyclones, more severe cyclones and it may even increase the height of the Hadley cell.

Why? If the areas are warmer, then we will have larger sized convection currents in the atmosphere, that would increase the size of the Hadley cell. So, we will have changes in the atmosphere as well. And higher temperatures in these areas will result in more water vapor in the air, which is a greenhouse gas.

So, what is happening, if the thermohaline circulation stops because of global warming, in that case, in the equatorial areas, we will have more amount of heat, more amount of heat will result in more amount of water vapor in the air, which would result in trapping of even more amount of energy. So that will be a positive feedback.

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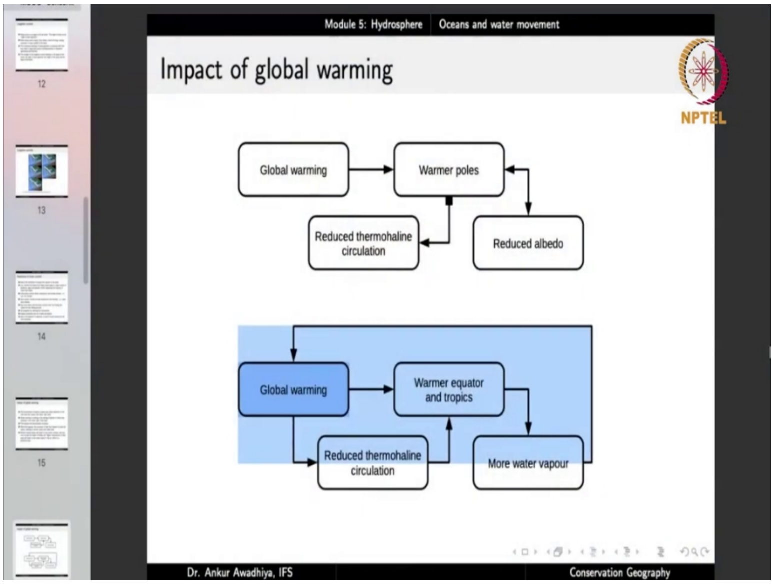


So essentially, what happens is that because of global warming, we will have warmer poles. Warmer poles will result in reduced thermohaline circulation that is weakening of the thermohaline circulation and warmer poles will also result in the melting of ice caps, which would reduce the albedo. Now albedo refers to the reflectance of a surface. When we look at white-coloured ice it reflects most of the heat.

Now when this ice melts, the areas will become covered with water and water has a much lesser albedo as compared to ice. So, this water will then absorb more amount of sunlight as compared to ice. And when more amount of sunlight is absorbed, in that case, the poles will become even warmer. So, with reduced albedo, we will have an even warmer pole, which will further lead to more amount of melting of ice, further reducing the albedo, which will further warm the poles.

So, this is a positive feedback. If there is global warming, the poles will become warmer and warmer with time. Another thing that will happen in the tropics is that global warming because of reduced thermohaline circulation will result in warmer equator and tropics.

Directly as well global warming will result in warmer equator and tropics, which would result in more amount of water vapor in the air, which would then further enhance the global warming. So, what we are observing here is that if you have global warming, then up to a certain level, you are protected by the global thermohaline circulation. But after a level what will happen is that it will become a positive feedback.

And once it becomes a positive feedback, it will be next to impossible for us to reverse the process. So when we talk about the global community, setting a threshold or setting a limit to the amount of warming that is tolerable, this is what we are talking about. If warming continues beyond a level, we will find a large destruction of biodiversity. And perhaps we will reach a stage where we will have no longer any control to bring the system back to normal because of the positive feedbacks.

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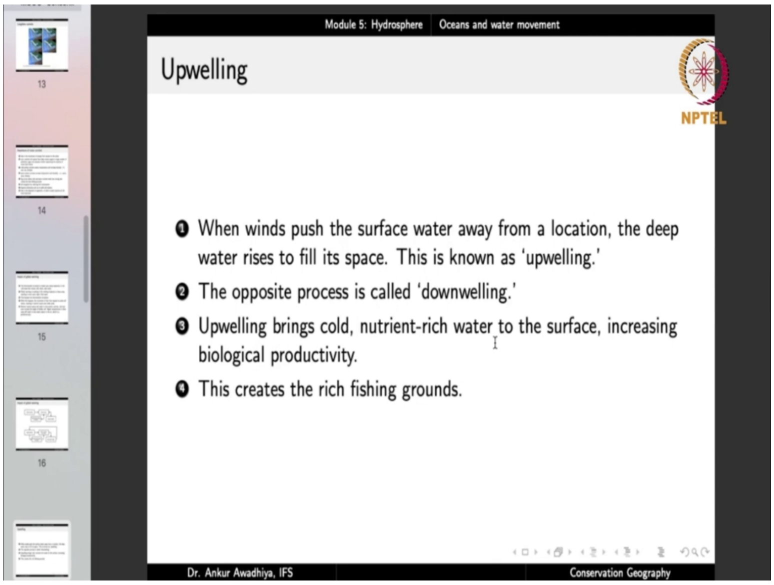


Another movement of the ocean water is upwelling. Now upwelling is the movement of waters from down below to upper areas. And this typically happens because of winds. So, when winds push the surface water away from a location, the deep water rises to fill its space, and this is known as upwelling. And opposite process called downwelling also happens if the winds are concentrating surface waters into an area.

So where will those waters go? They will move to the sides or they will go down and those locations will be known as downwelling locations. Now upwelling brings cold nutrient rich water to the surface, which increases biological productivity, creating rich fishing grounds.

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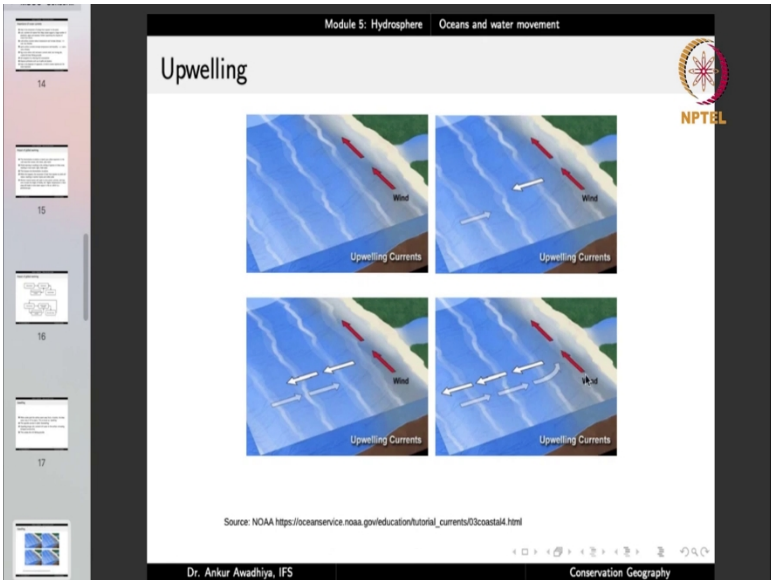


So, this is what happens in the case upwelling you have a vent that is pushing water away from this area. And when the water is being pushed away, you have a void that gets created here and this void is filled by water that rushing from the bottom to the top and this movement of water, it will be further, further and further enhanced if we have a continuous movement of when and this will become an upwelling location.

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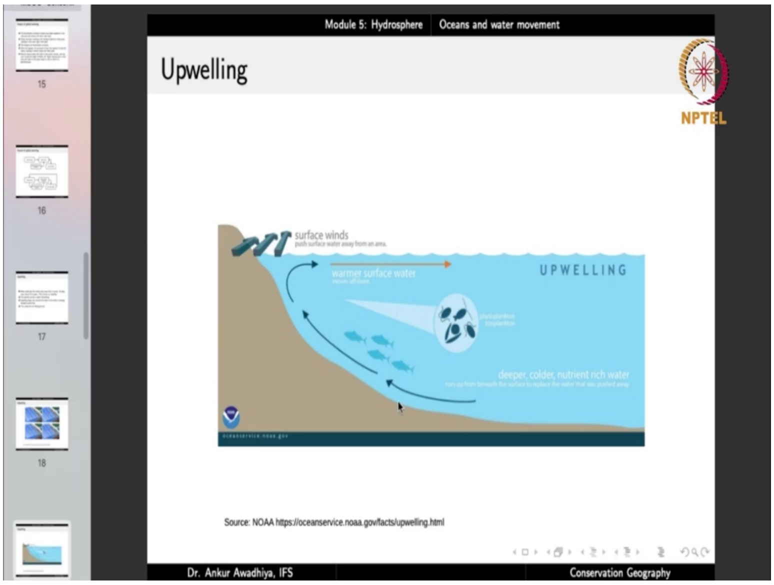


So, essentially when you have these surface winds that are pushing water away you have a movement of the cool nutrient rich water upwards and because it is nutrient rich, so, it will support a large number of planktons which will in turn support a large population of fishes.

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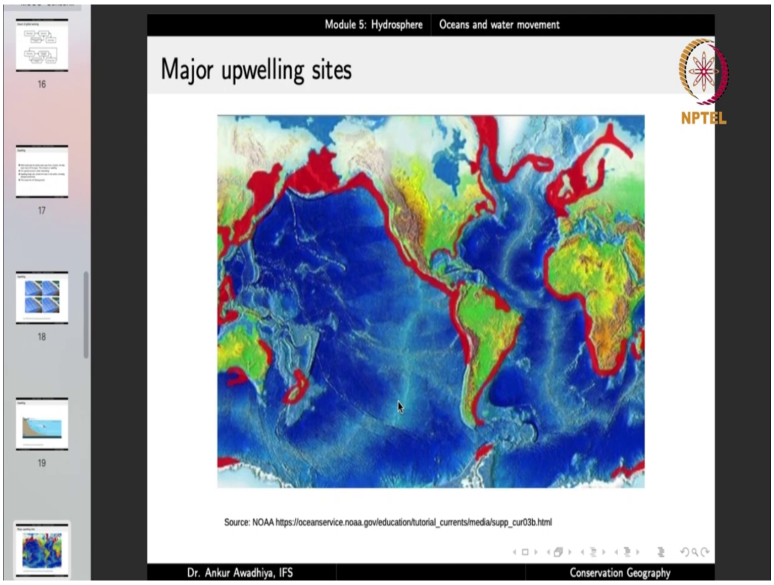


And so, we have these major upwelling sites which are also very rich fishing grounds. So, this is a very important place.

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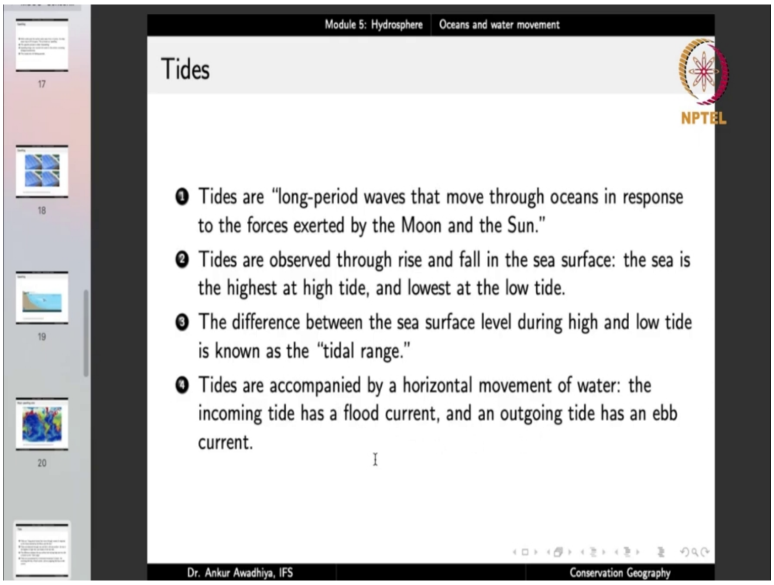


Yet another movement is tides. Tides are long period waves that move through the oceans in response to the forces exerted by the Moon and the Sun. So, just like waves, the tides are also waves, but they are long period waves, they are slow, they have very long time periods. They are observed through rise and fall in the sea surface, the sea is the highest at high tide and it is the lowest and the low tide.

The difference between the sea surface level during high tide and low tide is known as the tidal range and tides are accompanied by a horizontal movement of water, the incoming tide has a flood current and the outgoing tide has an ebb current.

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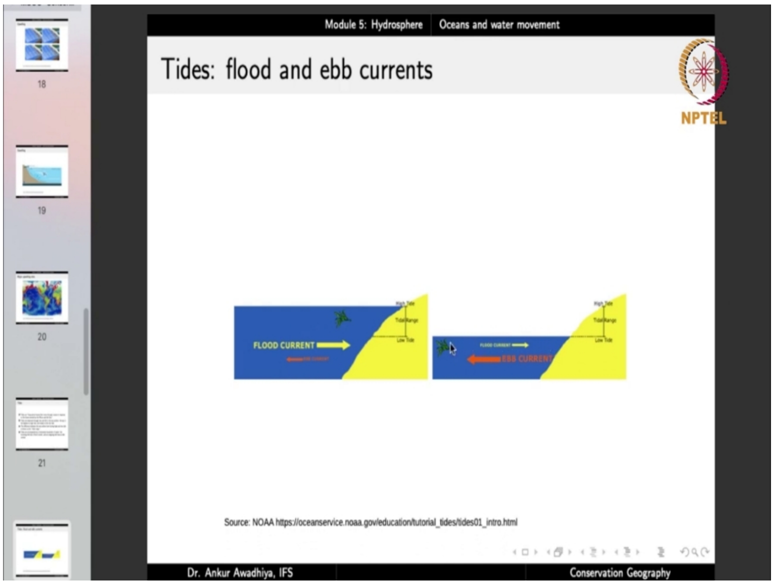


What does that mean? It means that when the sea surface level is rising during a high tide, we also have a horizontal movement of water in the form of flood current. So, this is being shown here in the form of the movement of this seaweed. So, during the high tide the seaweed will move from this area towards the shore. On the other hand, when we have a low tide the water levels are receding down and in this case there is an ebb current which pushes the seaweed away from the shore. So, these are the flood and the ebb currents.

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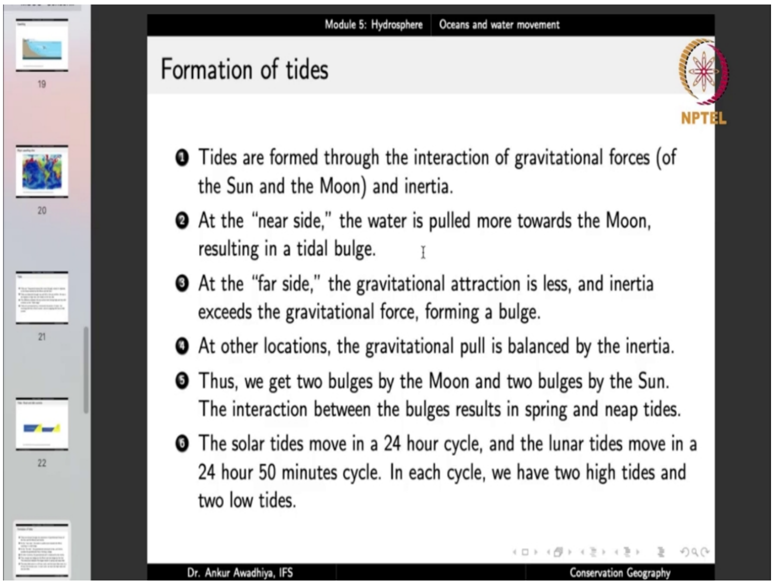

How are tides formed? Tides are formed through the interaction of gravitational forces of the Sun and the Moon together with the inertia of water. So, tides are occurring because the Sun and the Moon are attracting the water towards them. But water also has an inertia it does not want to move because it has a mass and so, it will resist this attraction and the interplay of both of these will result in the formation of a tide a long period wave that will move across the oceans.

At the near side, that is at the side where the water is close to the Moon or the Sun. So, at the near side, the water is pulled more towards the Moon or the Sun resulting in a tidal bulge.

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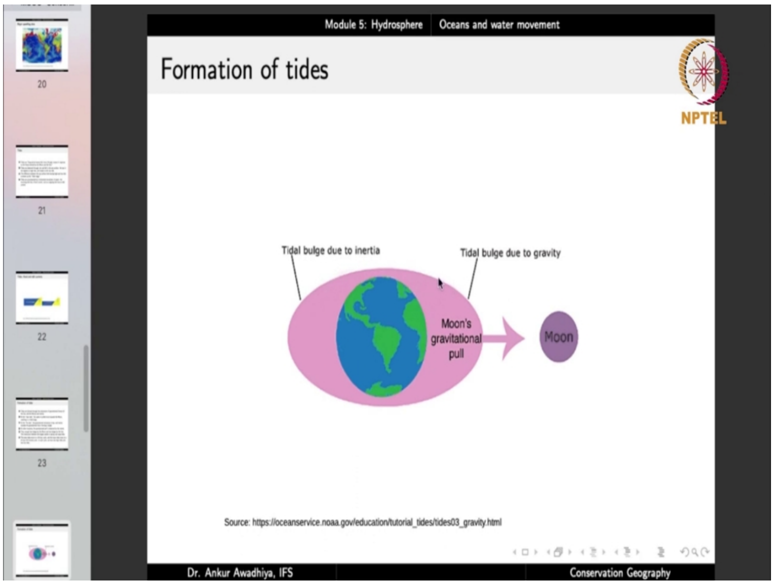


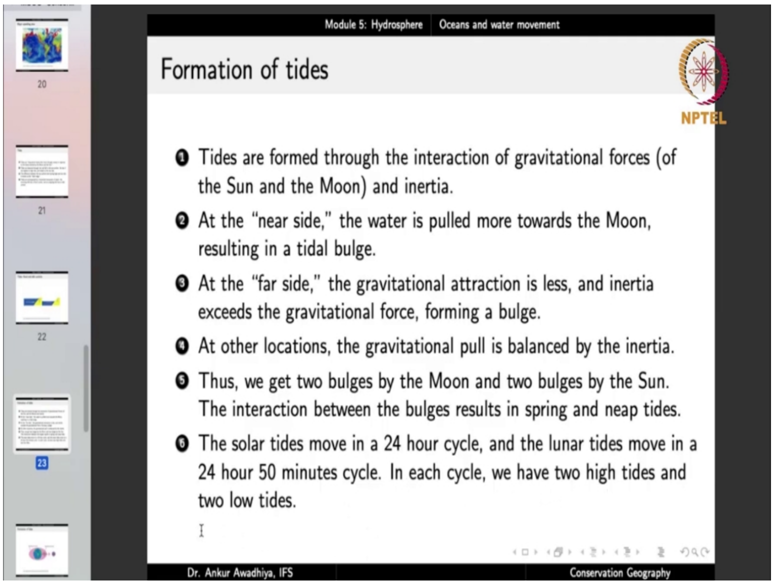

What we are saying here is that if this is the Earth, this is the Moon and here the sea level is greatly exaggerated to allow for understanding. So, in this portion in the near side, we get a tidal bulge due to gravity. So, the Moon is attracting the water and so, we get this bulge.

At the far side the gravitational attraction is less and the inertia exceeds the gravitational force which forms a bulge. So, here is well we get a bulge and this bulge is not because of gravity it is because of the inertia. So, essentially we can say that this water is not moving the amount of gravitational attraction here is less and it will it is even lesser than the amount of gravitational attraction on the Earth.

So essentially, the water remains here because of inertia the Earth moves and so we get a tidal bulge here as well. And at other locations, the gravitational pull is somewhat balanced by the inertia not completely. So, we do get a tide in other locations but it is not as high. Thus, we get two bulges by the Moon and two bulges by the Sun and the interaction between these bulges results in spring and neap tides meaning that if the Sun is resulting in a high tide, the Moon is also resulting in a high tide, so both of these impacts will add together to make an even higher tide.

Similarly, if both Sun and the Moon are making a low tide, then we will have an even lower tide. Whereas if one of them is making the high tide and the other is making a low tide in that case the effects will cancel out somewhat and so, we will not have that high or that low tide. So, both of, both these bulges interact and they result in spring and neap tides.

Now, the solar tide moves in a 24-hour cycle, because this is the period of rotation of the Earth whereas, the lunar tide moves in a 24 hour and 15 minutes cycle because the Moon when it is revolving around the Earth, this is the amount of time it takes when we also considered the rotation of the Earth. And in each cycle we have two high tides and two low tides.

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So, this is how it will look like. Now, in this case, the yellow colour shows the solar tides and the pink colour shows the lunar tides. Now, when the Moon and the Sun are on one side, so, the Earth the Moon and the Sun they form a straight line. So, in this case here we are getting a high tide and the height is very high because both of these impacts are adding together. Similarly, on the side as well both impacts are adding together.

So, when you have both the Sun and the Moon on one side or the Sun and the Moon on opposite sides, in both of these cases we get spring tides, in which case we get very high tides and very low tides. On the other hand, if the Sun and the Moon and the Earth they make a 90-degree angle, then we get a neap tide. So, these are not as high because the impacts are not adding together. So, this is a neap tide and this is a neap tide.

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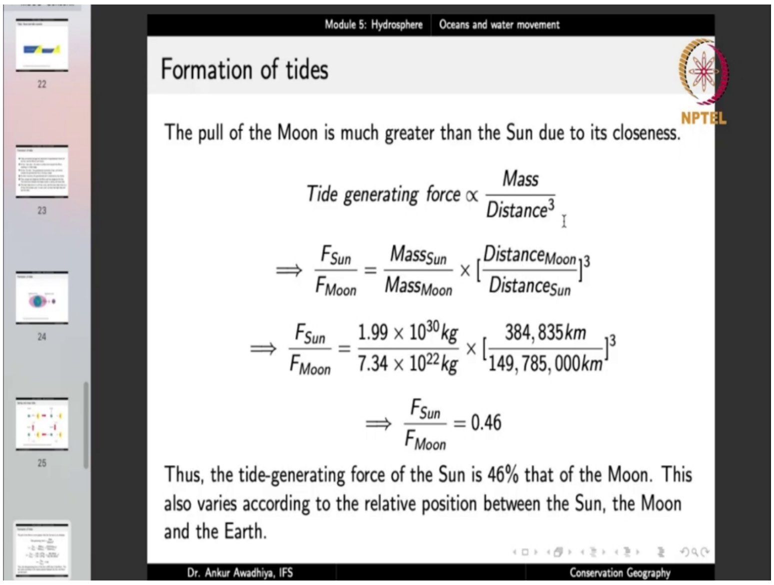


Now, if we consider the amount of, force that is being applied by the Sun and the Moon, the pull of the Moon is much greater than the Sun because the Moon is much more closer to the Earth. Now the tidal generating force is given as it is proportional to mass divided by distance to the power 3. So, the force of Sun divided by the force of Moon will be given by mass of Sun divided by distance of the Sun, from the Earth. to the power 3, whole divided by mass of Moon divided by distance from the Moon to the power of 3.

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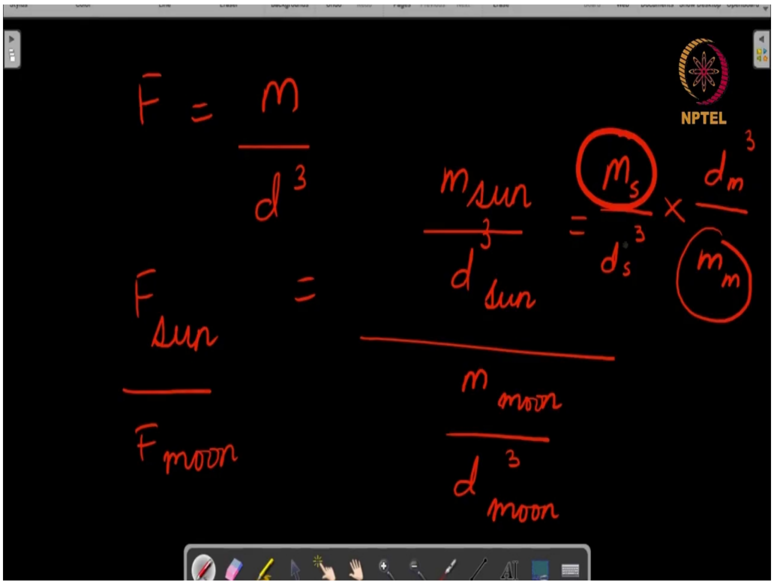

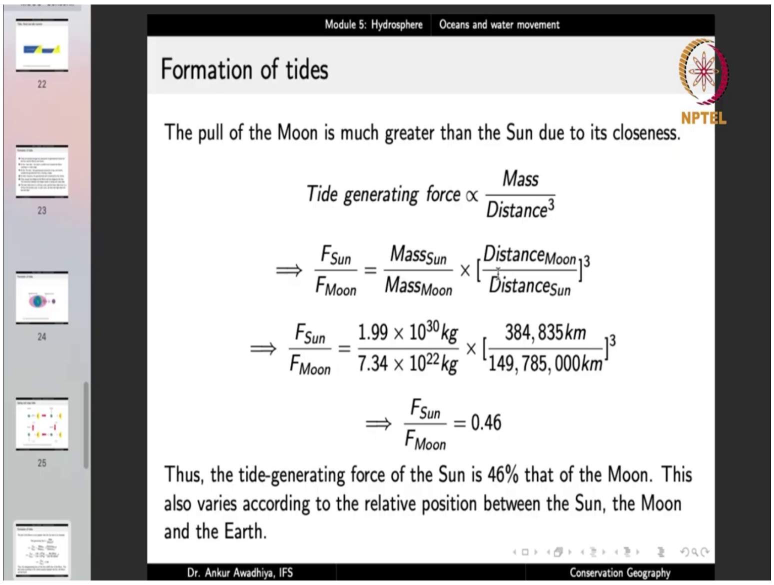


What we are seeing here, is that the force is equal to mass divided by, distance cube. So, the force of Sun, divided by the force of Moon will be given by, the mass of Sun divided by distance from Sun to the power 3, whole divided by, the mass of Moon divided by distance from Moon to the power 3. So, this can be written as, mass of Sun divided by distance from Sun to the power 3, multiplied by distance from Moon to the power 3 divided by the mass of the Moon.

So, this is what we are writing here, mass of Sun divided by mass of Moon, mass of Sun divided by mass of Moon, multiplied by distance from Moon divided by distance from Sun to the power 3, distance from Moon divided by distance from Sun to the power 3. And putting in the figures for the mass of Sun mass of Moon, distance of Earth from the Sun and distance of Earth from the Moon, we get that force of Sun divided by force of Moon is 0.46 which means that the tide generating force of the Sun is only 46 percent or roughly half of that of the Moon.

And this also varies according to the relative position between the Sun, the Moon and the Earth. Because here we are taking the average distance from the Moon and the Sun to the Earth, but the actual distances will be different depending on the orbit of the Earth and the Moon.

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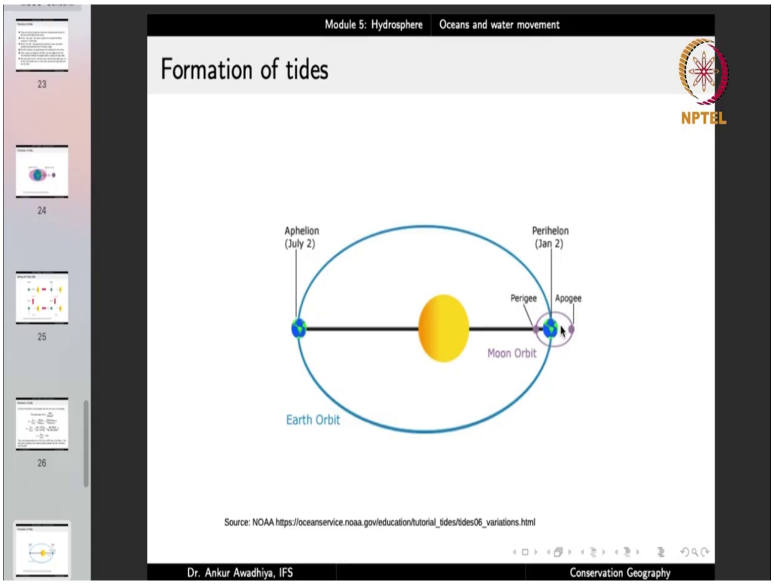


So, in this case, when we look at the orbits they are elliptical orbits. And if we consider the orbit of the Moon around the Earth, we have a point which is known as perigee where the Moon is closest to the Earth and we have a point known as apogee where the Moon is at the greatest distance from the Earth.

Similarly, if we consider the orbit of the Earth around the Sun, we have point that is known as perihelion, where the Earth is closest to the Sun and we also have a point called aphelion, where the Earth is the most distant from the Sun. Typically, these points occur around 2 to 4 July and 2 to 4 January.

Now, in this case, if we have this configuration where the Earth is at the perihelion to the Sun is having the high is exerting the largest amount of force, the Moon is at the perigee that means that the Moon is also exerting the largest amount of force that is possible, we will have exceptionally high tides. So, these will be exceptionally high spring tides.

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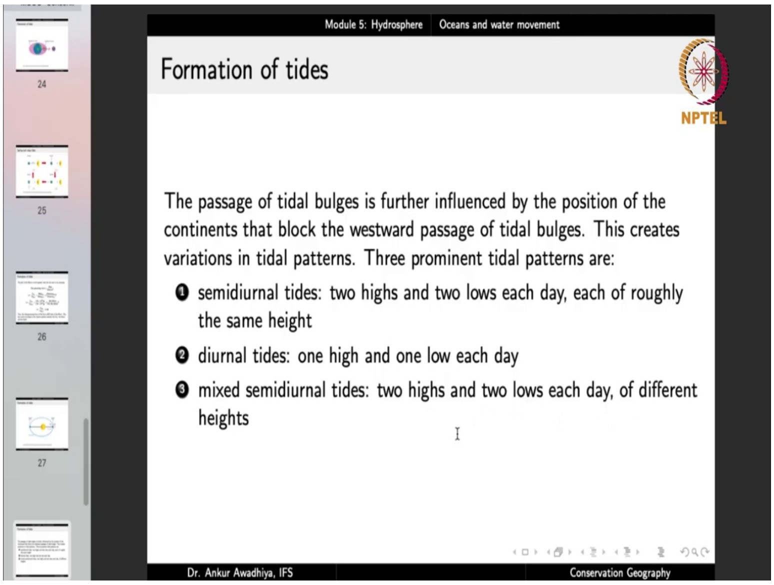


So, this is about tides. Now, the passage of tidal bulges is further influenced by the position of the continents that blocked the westward passage of the tidal bulges. So, when we have these tidal waves that are moving, if there is a continent that comes in the way then the tidal waves are not able to move, this creates a further level of variation.

So, this creates variations in the tidal patterns, there are 3 prominent tidal patterns, semidiurnal tides, which means two high and two low in each day, each have roughly the same height. Diurnal tides, which is one high and one low in each day, and mixed semidiurnal tides, which is too high and too low in each day, but have different heights.

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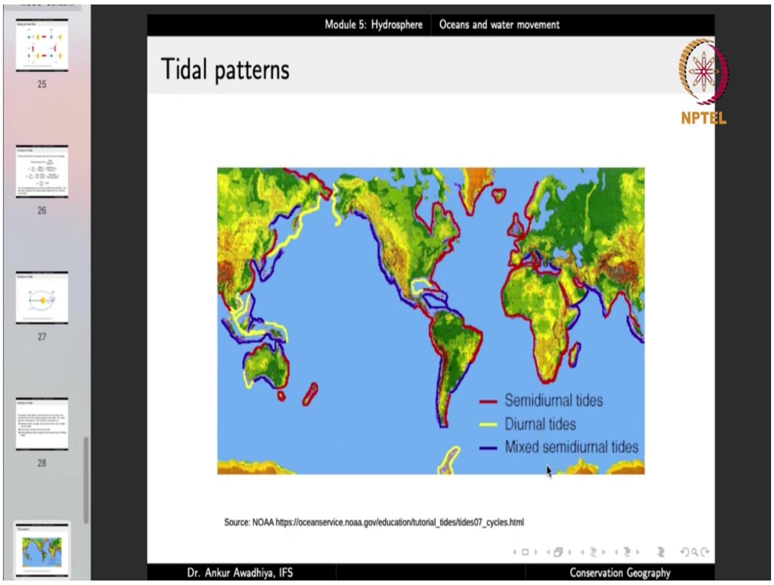


So, different locations on the Earth have different patterns, we have semidiurnal, diurnal and mixed semidiurnal tides.

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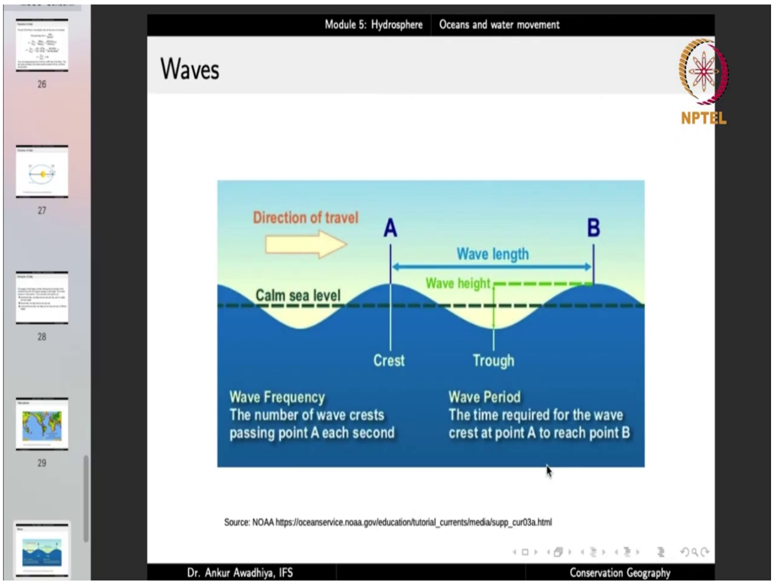


Another motion of the ocean water is in the form of waves. Now, when we have a wave that is traveling, the particles of water only move up and down, they do not move in the direction of the wave. Wave only transfers energy it does not transfer the mass.

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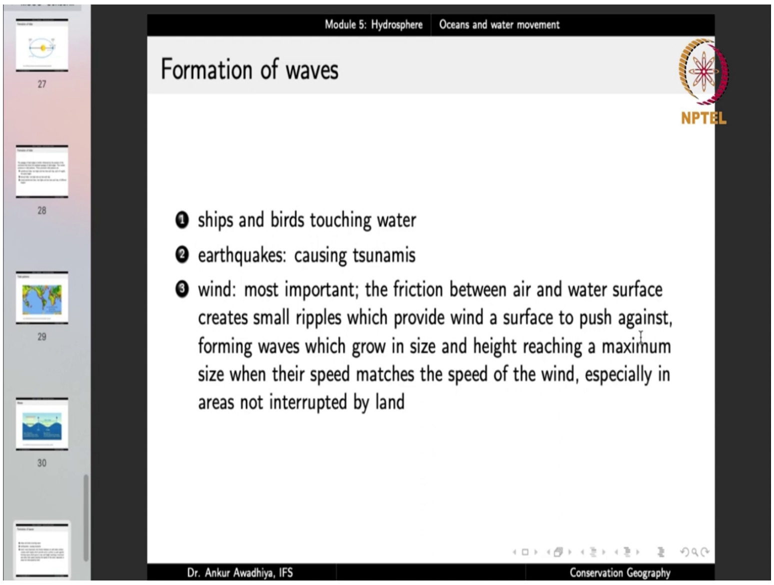


And waves originate when ships or birds touch water and create a ripple or if there is an Earthquake that creates a tsunami wave or when there is wind. Now, when you have wind the friction between air and the water surface creates small ripples, which provide wind a surface to push against which then form waves, which grow in size and height, reaching a maximum size when their speeds match the speed of the wind, and especially in areas that are not interrupted by land.

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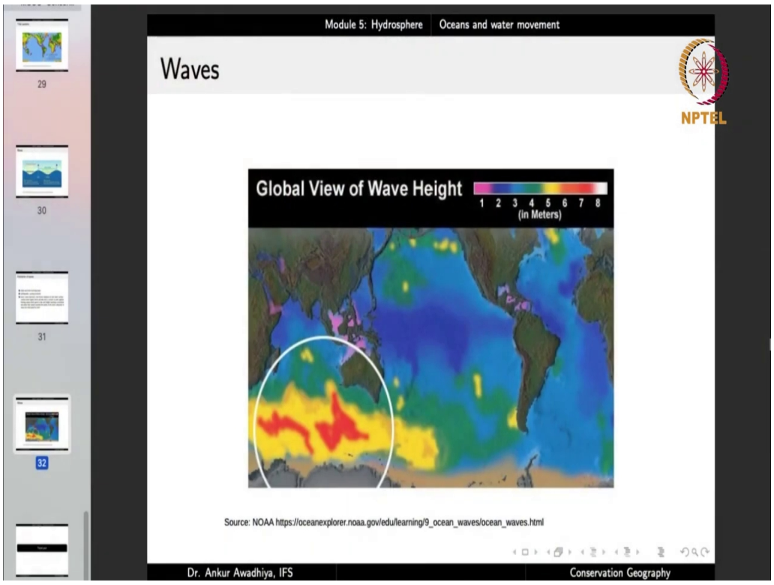


So, if we look at a global view of the wave height, we will find the largest or the highest waves in these areas, where you do not have any landmass for a very long distance. So that is about the movement of waters in the next lecture, we shall explore the hydrological cycle. That is all for today. Thank you for your attention. Jai Hind!