Conservation Geography
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Module - 4
Atmosphere
Lecture - 11
Atmospheric circulation and weather

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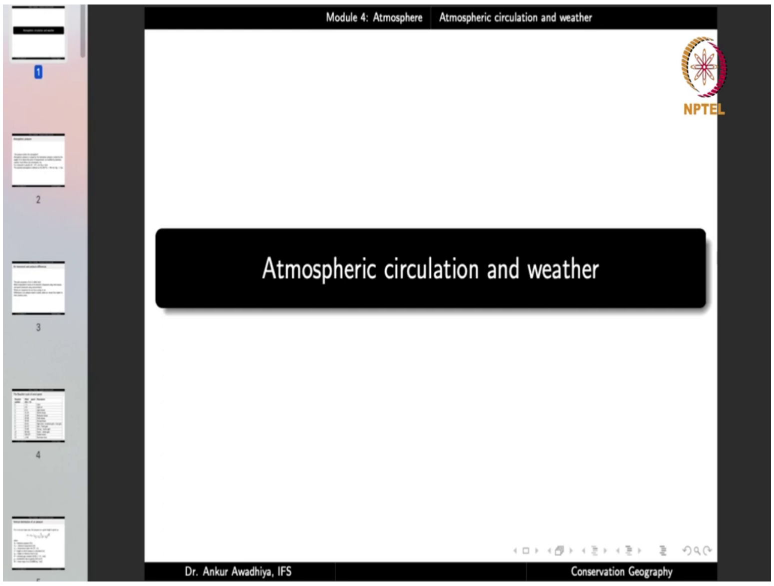

Namaste! We move forward with our discussion on the atmosphere. And in this lecture, we shall have a look at atmospheric circulation and weather. Now, we had ended the previous lecture by looking at the differences in temperature in different regions of the Earth, we looked at different factors that govern the amount of heat that comes into an area.

And we saw that near the equator we have a surplus of heat and near the poles we have a deficit of heat, a surplus of heat occurs when more amount of heat is given into an area then is taken out and a deficit occurs when less amount of heat is given to an area and more amount is lost from that area.

Now, it looks a bit paradoxical, how can you lose more amount of heat than you have in an area. Now, this paradox is solved through the circulation of heat on this planet. So, for instance, the polar regions get less amount of heat from the sun, but they are able to lose out more amount of heat because they are getting heat transferred from the equators towards the polls by means of things such as air circulation and water circulation.

So, in this lecture, we shall have a look at the atmospheric circulation, which is a mechanism to redistribute the heat on this planet. So, through atmospheric circulation, it is ensured that the equatorial areas do not get overheated. So, the excess heat is shifted away from the equatorial areas and at the same time the polar areas do not turn extremely cold, so that they are getting certain amount of heat from the equators.

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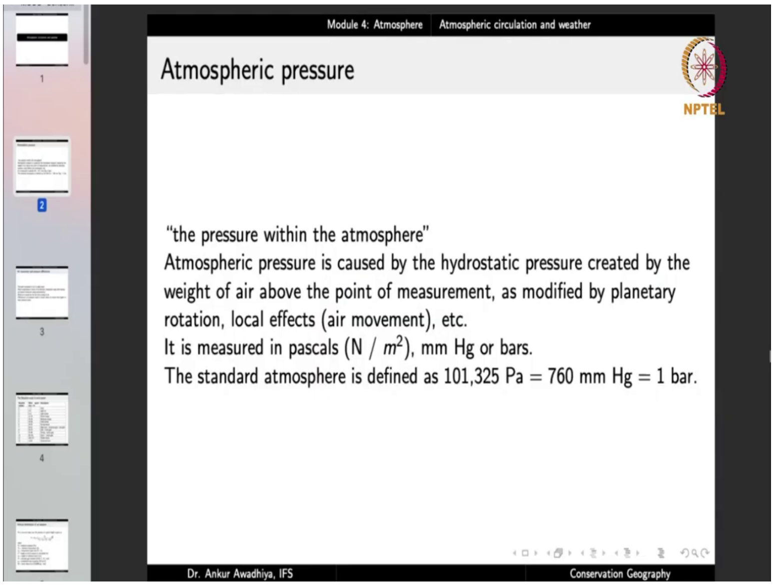

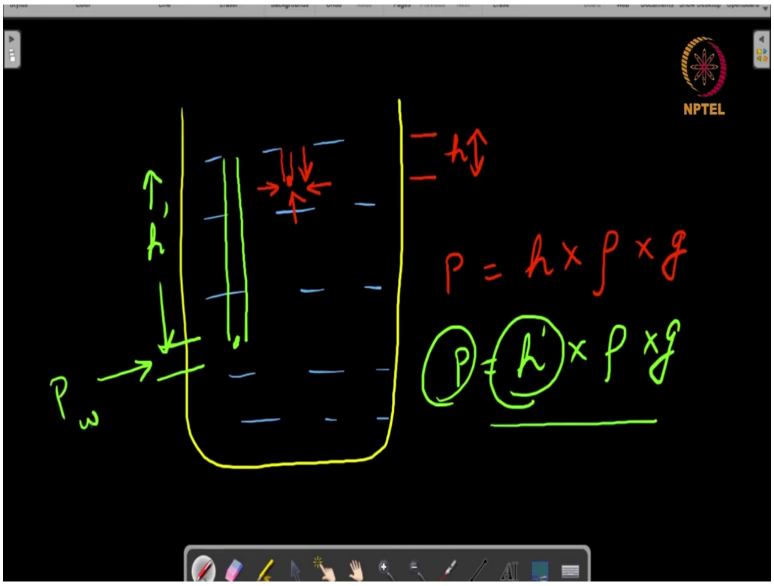

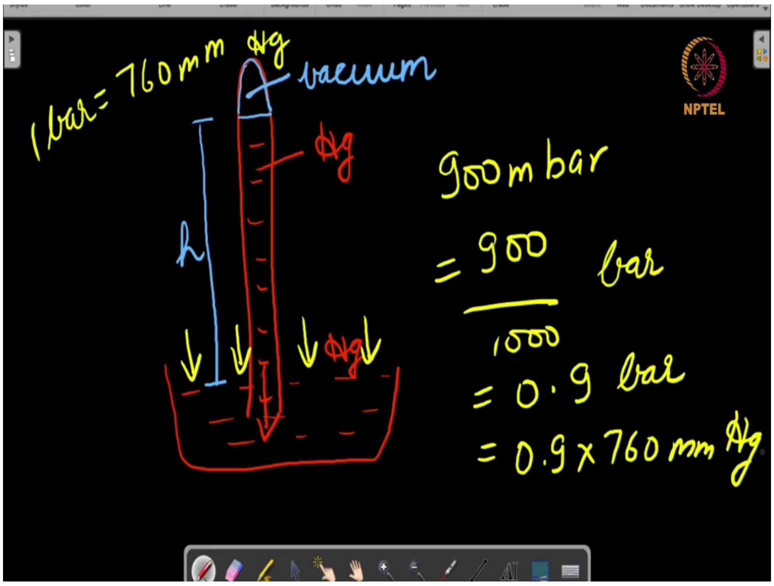

Now, when we talk about atmospheric circulation, the most important concept is that of the atmospheric pressure, which is the pressure within the atmosphere. Now, atmospheric pressure is important because it drives the movement of winds, it drives the movement of air that causes winds. So, we know that air always moves from a region of high pressure to an area of low pressure, because in the area of high pressure you have an excess of air, in the area of low pressure you have a deficit of air.

And so, air moves to fill in the void. Now, we can say that air moves from a high-pressure zone to a low-pressure zone. So, if you want to understand how air moves in the form of winds, we can begin by understanding what causes different amounts of atmospheric pressures on different areas of the Earth. Now, atmospheric pressure is caused by the hydrostatic pressure created by the weight of air above the point of measurement, as modified by planetary rotation, local effects such as air movement, etcetera.

So, when we say hydrostatic pressure, what do we mean? Now, consider a tumbler of water. Now, this tumbler is full of water. Now, if we consider a point here. Now, at this point all the water in this water column that is above this point are exerting a pressure downwards. And if there is a pressure downwards vessel this particle not move downwards, it is because this is balanced by an equal amount of pressure from the bottom.

And so, from all the points, or from all the directions, we can say that this point is having a pressure that is given by this value of h multiplied by the density of the fluid multiplied by the acceleration due to gravity. So, that is the pressure at this point. Now, if we consider another point here. Now, in this case the value of h is larger, let us call it h prime. Now, the pressure at this point is given by P is equal to h prime into rho into g:

$P = h' \times \rho \times g$

Now, more is the h prime more will be the pressure. And so, if we look at the atmosphere, the areas that are down below, areas that are near the surface of the Earth, they will be having a greater amount of pressure than locations that are higher above, because as you move up, there is a lesser column of air above you to exert the pressure. So, atmospheric pressure is caused by the hydrostatic pressure.

This kind of pressure is known as a hydrostatic pressure, created by the weight of air above the point of measurement as modified by planetary rotation, local effects such as wind move, air movement, etcetera. Now, it is not just the hydrostatic pressure, but we also have certain modifiers. So, for instance it is possible that at this location we are also having a thrust of water.

So, essentially, we have a pipe that is pushing in water. So, that would also result in a certain amount of pressure differences. So, the pressure will not be the same as that given by this formula, but this will be modified by the pressure of the water that is getting in at this location. Now, similarly, in the case of atmospheric pressure, the hydrostatic pressure is modified by planetary rotation, local effects such as air movement, etcetera.

The pressure is measured in terms of Pascal is which is Newton per square meter or millimetres of mercury or bar. Now, millimetres of mercury refers to the fact that traditionally we have been using Barometers. Now, a Barometer technically is a glass that is completely filled up with mercury. So, this glass tube is filled up with mercury and then this glass tube is inverted into a vessel that contains mercury.

Now, when this glass tube is inverted, then certain amount of mercury will flow into this vessel and so we will get a vacuum created here. So, this area will now get a vacuum because certain amount of mercury has flowed from this tube into the vessel. Now, the height of this column is an indication of the amount of atmospheric pressure why, because, when you consider this tube, then this much amount of mercury is not going down into the vessel because it is being balanced by the atmospheric pressure that is acting on this free surface of the vessel.

And so, the height of this mercury column can give us the atmospheric pressure, if the pressure increases, then this height would increase the amount of vacuum would reduce, if the pressure reduces, then the height will go down. Now, the standard atmosphere or the standard atmospheric pressure is defined as 101325 Pascal is which is equivalent to 76 centimetres of mercury or 760 millimetres of mercury and we also call 1 atmospheric pressure as equal to 1 bar.

So, you will also hear or you will also read that in certain charts we are saying that the pressure is 900 millibars. Now, 900 millibars would mean 900 millibar is 900 divided by 1000 bar is 0.9 bar and because 1 bar is equal to 760 millimetres of mercury, so 900 millibars will be equal to 0.9 into 760 millimetres of mercury. So, we can convert between these units by dividing them by the constant factors.

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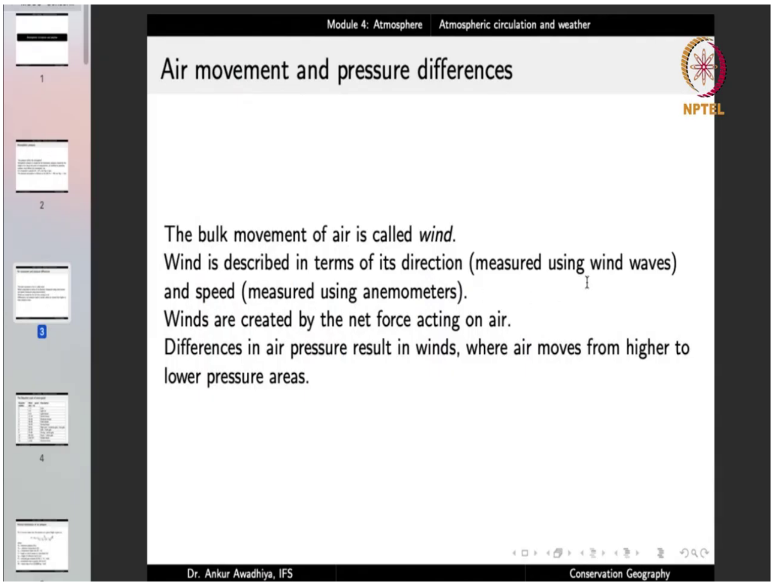

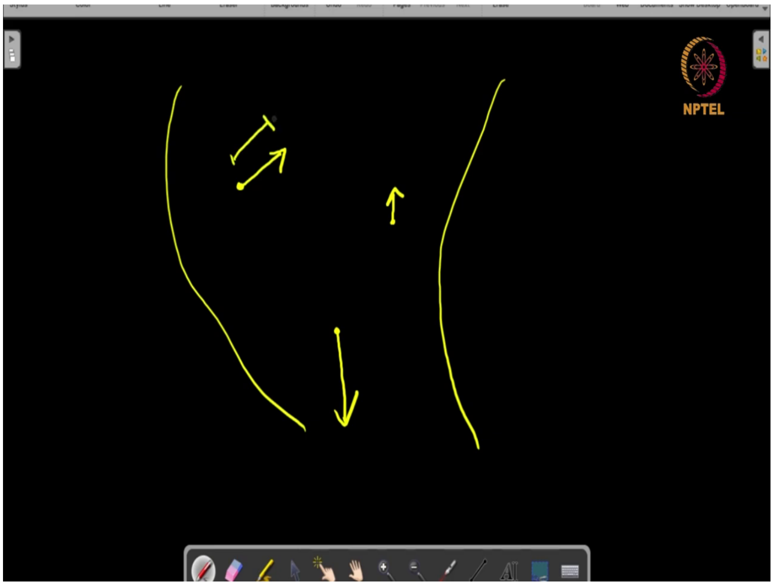

Now, the air movement is caused because of pressure differences, the bulk moment of air is called wind. And wind is described in terms of its direction and speed, which means that wind is typically taken as a vector quantity. It has a magnitude and a direction. So, when we draw a chart with wind patterns, we will typically draw it something like this. So, at this location, this is the wind at this location, the wind is like this, at this location the wind is like this.

So, these arrows are telling us the direction in which wind is moving and the length of the arrows is telling us the speed of the wind. Now, the direction of the wind is measured using wind waves, and the speed of the wind is measured using anemometers. Winds are created by a net force acting on the air. So, what causes the wind, the wind is caused because the air has been pushed, pushed by certain forces.

Now, if the forces balance each other out, then there will be no wind. But if there is an unbalanced force, then that force will be able to push the air in a certain direction with a certain speed, which will result in a wind. Differences in air pressure result in winds, where the air moves from higher to lower pressure areas.

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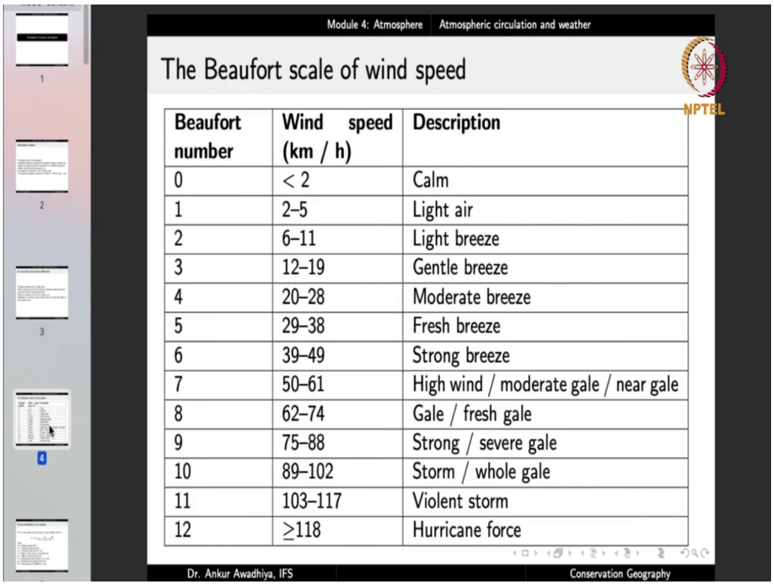

Beaufort number	Wind speed (km / h)	Description
0	< 2	Calm
1	2–5	Light air
2	6–11	Light breeze
3	12–19	Gentle breeze
4	20–28	Moderate breeze
5	29–38	Fresh breeze
6	39–49	Strong breeze
7	50–61	High wind / moderate gale / near gale
8	62–74	Gale / fresh gale
9	75–88	Strong / severe gale
10	89–102	Storm / whole gale
11	103–117	Violent storm
12	≥118	Hurricane force

Now, we can classify the winds on the basis of their speeds using the Beaufort scale of wind speed. Now, here we have the Beaufort numbers from 0 to 12. And if the wind speed is less than 2 kilometres an hour, we will say that it is a calm wind. If it is between 2 to 5 kilometres per hour, it is a light air, 6 to 11 is a light breeze, then we have gentle breeze, moderate breeze, fresh breeze, strong breeze, high wind, gale, strong gale, storm, violent storm, and a hurricane force. So, as the wind speed increases, we have an increase in the Beaufort number from calm to hurricane force. So, calm is the smallest wind speed and hurricane force is the largest wind speed.

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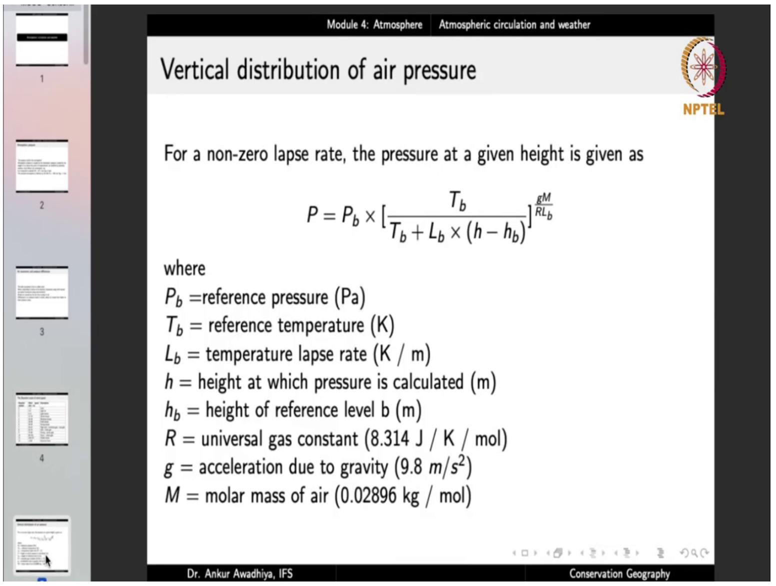

Now, the pressure that is there on different locations is given by this formula, which takes into account the non-zero lapse rate. Now, lapse rate is the rate at which temperature decreases as we move up. Now, when we were talking about a fluid such as Water or a fluid such as Mercury, then temperatures will not play a very large rule, because these fluids do not expand very much, but when we are talking about air, so air being a gas or a mixture of gases, it expands a lot when it is heated.

And so, the amount of pressure that you will have in an area will not only be governed by the altitude, but it will also be governed by the lapse rate, which is there on that particular planet or celestial body. And so, we write pressure is equal to Pb which is the reference pressure multiplied by Tb, which is the reference temperature divided by Tb plus Lb, which is the temperature lapse rate into h minus hb which is the height at which the pressure is calculated minus the height of the reference level.

Typically, we take the reference level as the sea level and this portion is raised to the power g M by R Lb, where g is the acceleration due to gravity 9.8 meter per second square, capital M is the molar mass of air divided by R which is the universal gas constant 8.314 joules per Kelvin per mole multiplied by Lb, which is the temperature lapse rate. Now, if you look at this formula, it tells you that as h increases about hb.

So, when h is greater than hb, it means that we are moving up. Now, when we move up, then this portion becomes a positive number. Once it becomes the positive number, then this fraction it is less than 1 and when it is less than 1 the pressure is reducing. So, when this portion Tb divided by Tb plus something, it becomes less than 1.

So, P is less than Pb, which tells us that as we move up the pressure reduces, which is what we had also intuitively understood by looking at the weight of air that was lying in the column above that particular point. So, this formula tells the same thing.

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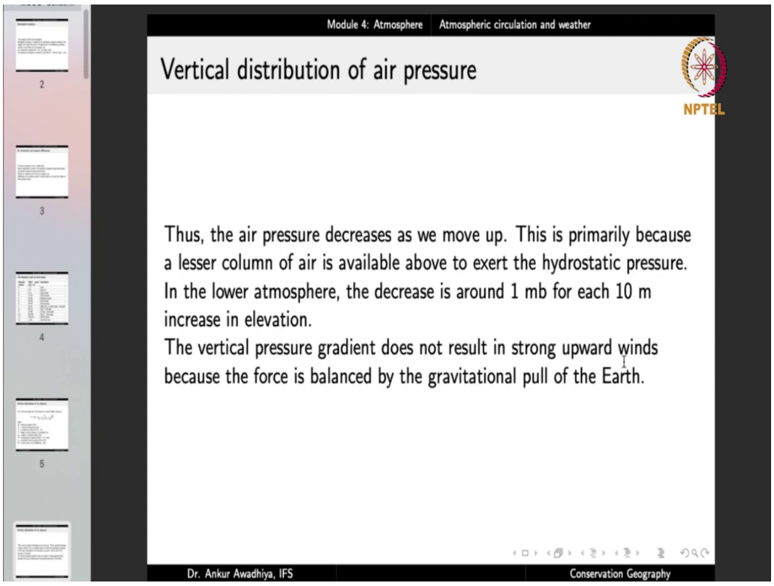

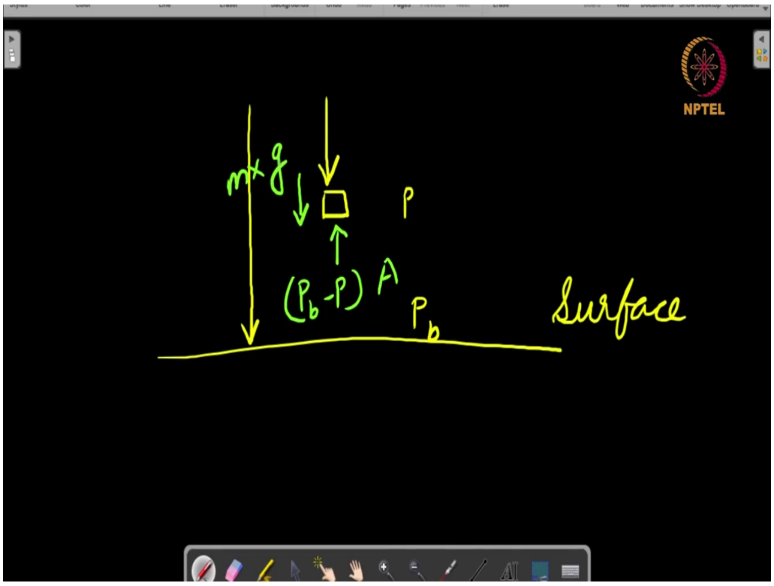

But the question is, if there is a change in this pressure, if the pressure reduces as we go up, why do not we always find a wind that is moving from the ground level to the above levels. So, the air pressure decreases as we move up, primarily because of a lesser column of air that is available about to exert the hydrostatic pressure. In the lower atmosphere this decreases around 1 millibar for each 10 meters increase in elevation.

So, there is a reduction in pressure. But this vertical pressure gradient does not result in a strong upward wind, because the force is balanced by the gravitational pull of the Earth. By which what we are saying is that if you consider this to be the Earth is surface, when we consider a parcel of air here, so there is a pressure that is acting from the weight of the column that is above, but at this ground level, the amount of pressure is much larger.

So, here you have Pb and here you have P. And so, the net force that is acting on this parcel is given by this value. Now, Pb is greater than P. So, you have Pb minus P multiplied by A, which is the area of the cross section of this parcel. Now, this is a pressure that is acting upwards, but this pressure is exactly counterbalanced by the gravitational force which is pushing it down, which is given by mass into acceleration due to gravity.

So, both of these balances each other out, because of which we do not find a strong upward wind movement even though at the ground level the pressure is high and as we move up the pressure reduces. So, intuitively if we disregarded gravity, we would have expected a strong wind moving from ground level to upwards but because of gravity, this thing does not happen.

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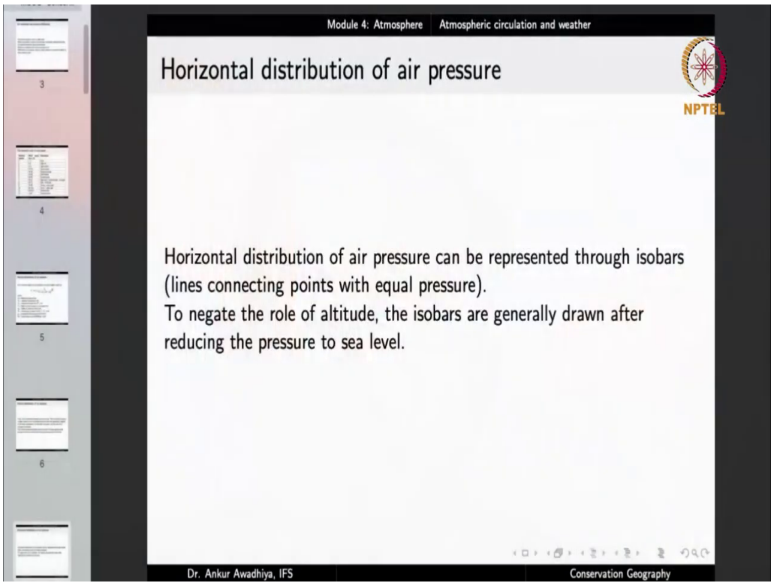

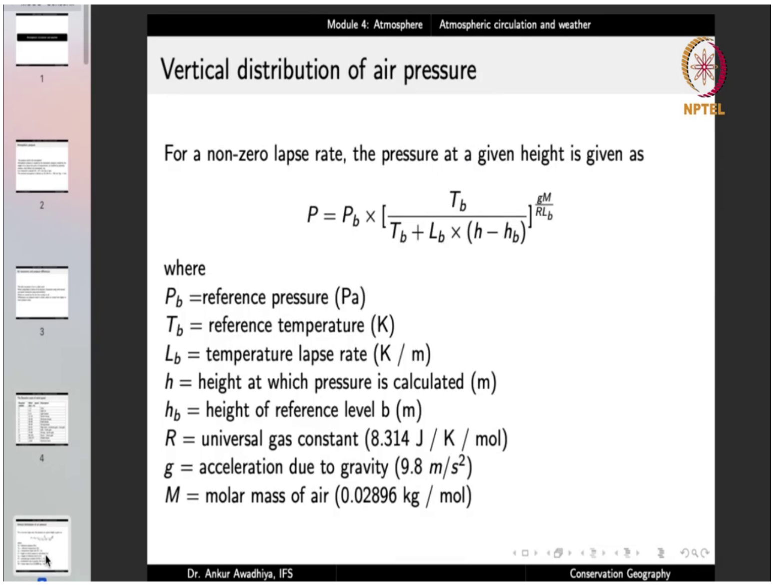

So, what happens is a horizontal distribution of air pressure resulting in winds. So, we do not find a lot of vertical winds, but we find a lot of horizontal winds. Horizontal distribution of air pressure is represented through isobars which is lines connecting points with equal pressure, iso means equal and bar refers to the pressure. So, isobar is a line that joins points having equal pressure.

Now, because, as we move up the pressure reduces, so we generally reduce the pressure to the sea level. So, we make use of this formula. And so, if the pressure is noted at a point which is at an altitude, then we convert this pressure into Pb by using this formula and this pressure is generally written at say the sea level or say something like 100 meters above sea level or 30 meters above sea level. But what is done is that throughout the chart, all the pressures will be modified, will be reduced to a standard pressure, at a standard height.

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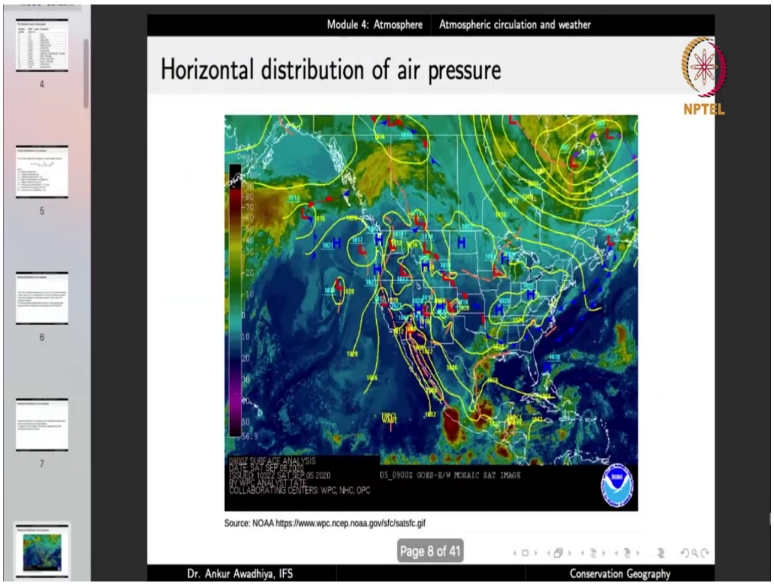

And this is how the isobars look like. So, here these yellow lines, these are the isobars. So, we have all these points that are having the same pressure, here we have all these points that are having the same pressure and what is the pressure the pressure is given by these values. So, at all these locations, the pressure is 1024 millibars. At all of these locations, the pressure is 1020 millibars and so on. So, that is how we represent air pressures on a chart.

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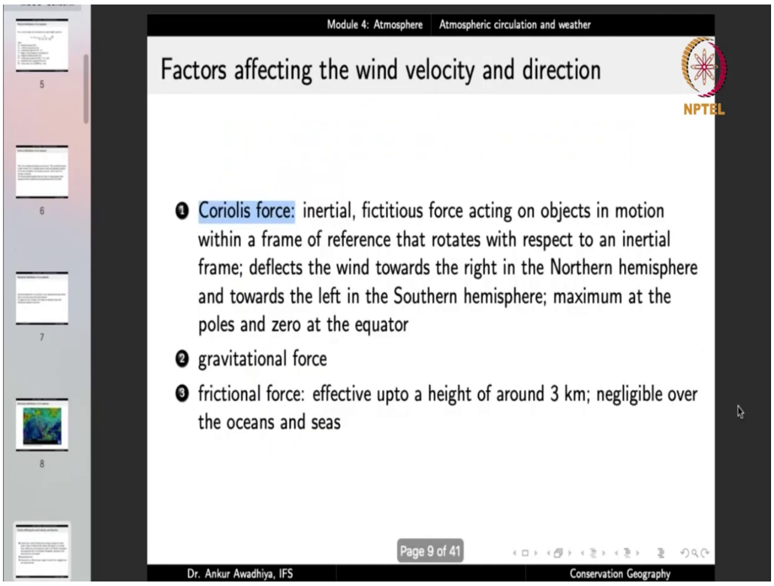

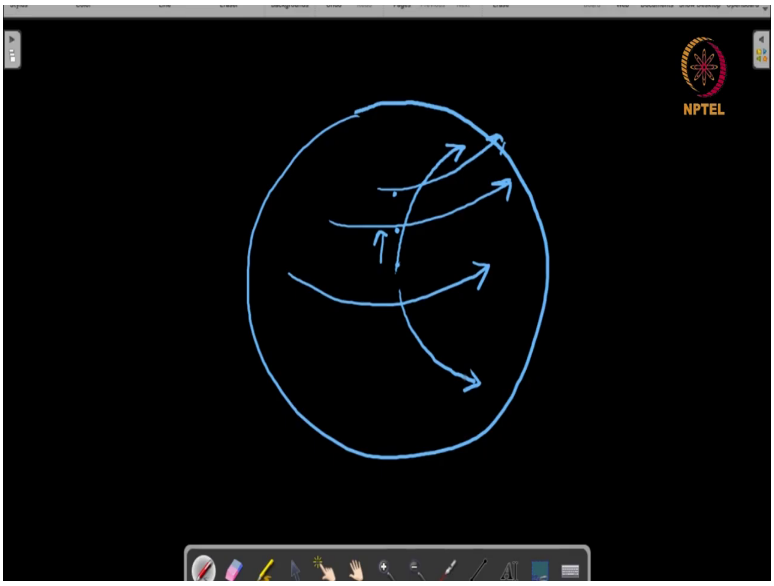

Now, when we talk about winds, velocity and direction, then winds are not just governed by these pressure differences, there are certain modifying factors that also play a role. And three of them are most important, the first is the Coriolis force, the gravitational force and the frictional force. Now, Coriolis force is an inertial fictitious force, that actual objects in motion within a frame of reference that rotates with respect to an inertial frame.

What we are saying is that if we consider the Earth, now, the Earth is rotating from west to east, so the Earth is rotating like this. Now, if we consider a point that has a parcel of air that is moving northwards. Now, by the time it reaches here, the frame of reference itself has shifted. So, now it is frame of references like this, when it reaches here, the frame of reference has shifted again.

So, because of this rotation of the Earth, we will find that the air parcels will appear to be moving towards the right in the Northern Hemisphere. And in the southern hemisphere, they will appear to be moving towards the left. So, this is the Coriolis force. It deflects the wind towards the right in the Northern Hemisphere and towards the left in the southern hemisphere.

It is maximum at the poles and 0 at the equator, because this Coriolis force has got to do with the rotation of the frame of reference. Now, this rotation is most observed in the poles and it is least observed on the equator. And so, the Coriolis forces maximum in the poles and it is zero at the equator. The second force that acts is the gravitational force. So, because of the force of gravity, it is possible that the air parcel will not just move in a straight line, but will tend to move towards the ground, because it is being attracted.

And the third force is the frictional force, it is effective to a height of around 3 kilometres negligible over the oceans and seas. What does that mean, because of the frictional force, the speed of the wind will go down. So, these are three forces that modulate the direction and speed of the winds.

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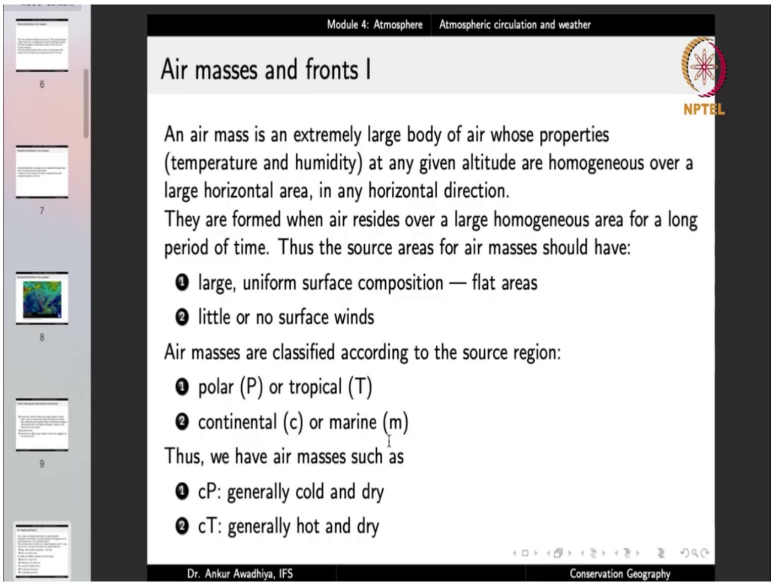

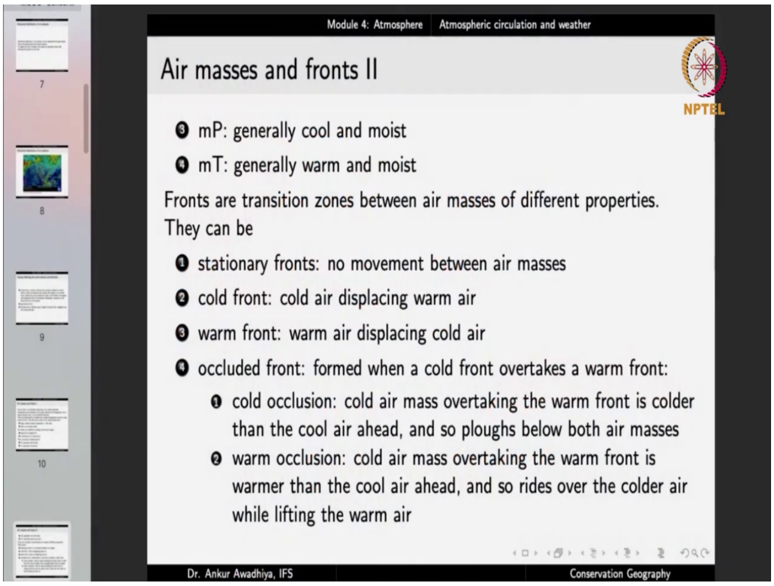

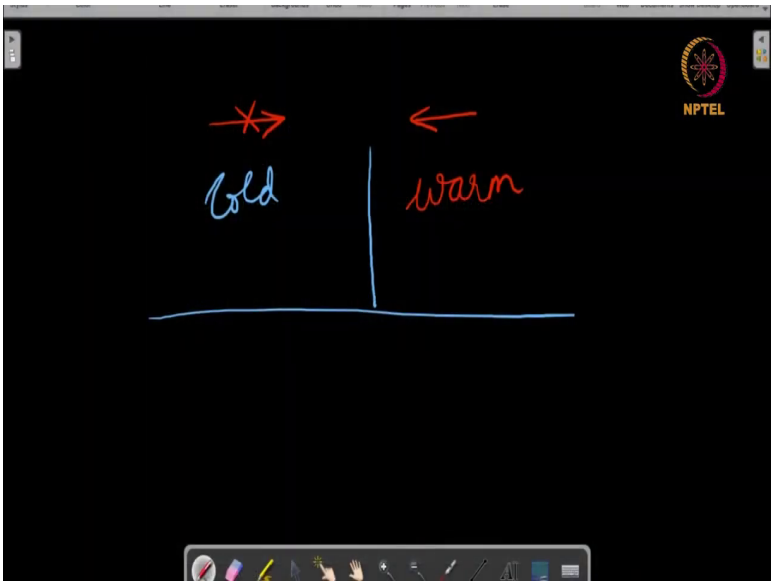

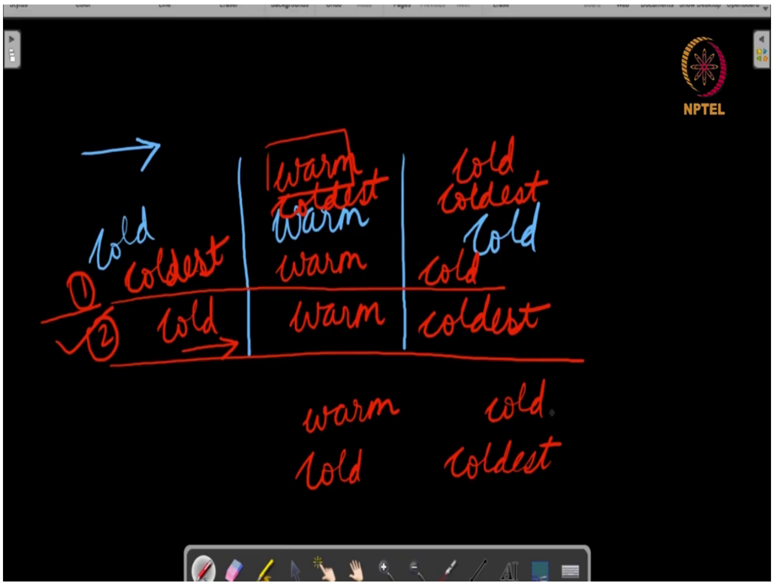

And when we talk about the movement of air, it is important to note this concept of air masses. An air mass is an extremely large body of air, whose properties temperature and humidity at any given altitude are homogeneous over a large horizontal area in any horizontal direction. Now, this concept becomes important when we are talking about planetary winds, because in the case of planetary winds, we are not talking about very small parcels of air, we are more concerned with those parcels that are very large in size.

And how can you have a very large parcel of air, consider an ocean the air above the ocean, everywhere it is getting the same conditions, it is getting a good amount of moisture because below it you have water and it is getting roughly the same temperature because the temperature of sea surface is roughly constant because it has a moderating effect.

And so, when the air stands on this ocean or sea surface for a long period of time, it will have the characteristics of this surface that is it will be moisture lade in and it will be having the temperature which is corresponding to the temperature of the sea. If you have a parcel of air, say over the ice caps, in that case also you will have an air mass that will be very cold.

So, the characteristics of the air are determined by the characteristics of the surface over which this air has been lying for a long period of time. And if the surface is homogeneous, then the air mass will also be having a homogeneous characteristic. Typically, in respect of temperature and humidity. Air masses are formed when air resides over a large homogeneous area for a long period of time.

So, the source areas for air masses should have large and uniform surface composition essentially flat areas. So, they are large areas, because air masses are large in size and they are uniform. So, that the whole of the air mass gets a uniform characteristic, especially in terms of temperature and humidity. The second characteristic is that there should be little or no surface winds, because if there were surface winds, then in that case, the properties of the air from one place to another will vary.

And in that case, we will not call it an air mass. So, when we are talking about air masses, we are talking about very large parcels of air that are roughly homogeneous everywhere. And so, now we can talk about their interaction's, interaction of a hot air mass with a cold air mass or interaction of a dry air mass with a wet air mass. Now, because these are large in size, so their impacts on a planetary scale are also much greater.

So, we are not talking about local winds we are talking about large scale air masses. Now, air masses are classified according to the source region they can be polar, if they are coming from the poles. They can be tropical if they are originating in tropical areas. They can be continental if they are originating over land, or they can be married if they are originating over waters.

And so, we can have four different combinations continental polar, continental tropical, marine polar, and marine tropical. Now, typically polar air masses will be colder, tropical air masses will be warmer, continental air masses will be drier because they are originating overland, marine air masses will be wetter because they are originating over water bodies.

So, cP will be continental it means it is a dry, P means polar, it is cold, cT continental is dry and tropical means it is hot, mP marine means moist and P polar means it is cool, mT, M marine means moist and T tropical means warm. So, you have these four major classes of air masses. And when air masses meet, we have front. So, fronts are the transition zones between air masses of different properties. So, now we are talking about what happens when two air masses meet.

So, when they meet, they generate a front. And we have four different types of fronts. First is stationary front when there is no movement between the air masses. So, the air masses are stationary, in that case, we will call it a stationary front, then we have a cold front when the cold air is displacing the warm air. So, what we are saying here is that you have a cold air mass, so this is cold, and you have a warm air mass.

Now, what happens when the air moves like this, the cold air is pushing over the warm air. In that case, the front that gets generated is a cold front. A warm front is when a warm air is displacing the cold air, meaning that we are not talking about this situation we are talking about this situation, the warm air is pushing the cold air, then you have a warm front. And we also have an occluded front, which is formed when a cold front overtakes a warm front.

Meaning that we began with this situation. So, you have a cold air, you have a warm air and you have another cold air. Now, in this case, the air is moving like this. So, you have a front between cold and warm, but then the cold air here is moving at such a high speed that it overtakes this front the warm front. In that case, we will call it an occluded front. And here we have two different categories you have cold occlusion, where the cold air mass overtaking the warm front is colder than the cool air ahead. And so, it ploughs below both the air masses.

Now, the important thing here is that the cold air masses generally stayed down because they are denser. So, the cold air will remain down the warm air will come on the top and so when you have a cold versus a warm air mass and when you have the cold air that is pushing it, so the cold air comes below this warm air mass and then it gets another air mass which was colder than the than the warmer air mass, but probably it was not as cold as the coming air.

So, when we say this situation, what we are talking about is what happens in case one, where this is colder, this is warm, and this is cold. And the second situation is this is cold, this is warm, and this is colder. So, let us say that this is the coldest air. So, what happens in these two situations. So, these are the two occlusions cold occlusion and warm occlusion. The cold occlusion happens when the cold air mass overtaking the warm front is colder than the cool air.

So, in this case, this is the cold occlusion. So, in this case the coldest air. So, when the coldest air interacts or pushes against the warm air, the warm air will go up and the coldest air will come below it. Now, you have the cold air and, in this case, what will happen is when it moves further you will have the coldest air down and this cold air on top.

And so essentially who will have this warm air mass will be lifted. In the case of the warm occlusion, the cold air mass overtaking the warm front is warmer than the cold air ahead and so it rides over the colder air while lifting the warm air. So, in the case of the warm occlusion, what happens is that when this cold air is pushing here, and it is the fastest air. So, you will have the situation where the cold air gets to the bottom, the warm air floats on the top, but this cold air now does not get below this coldest air, the coldest air remains at the bottom and the cold air rides on top of it. And both of these result in very different situations.

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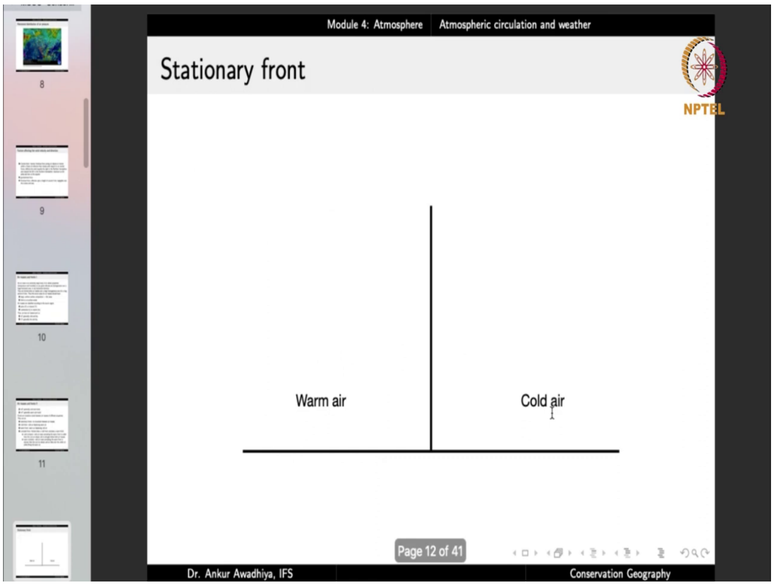

So, this is a stationary front you have warm air and cold air and there is no movement.

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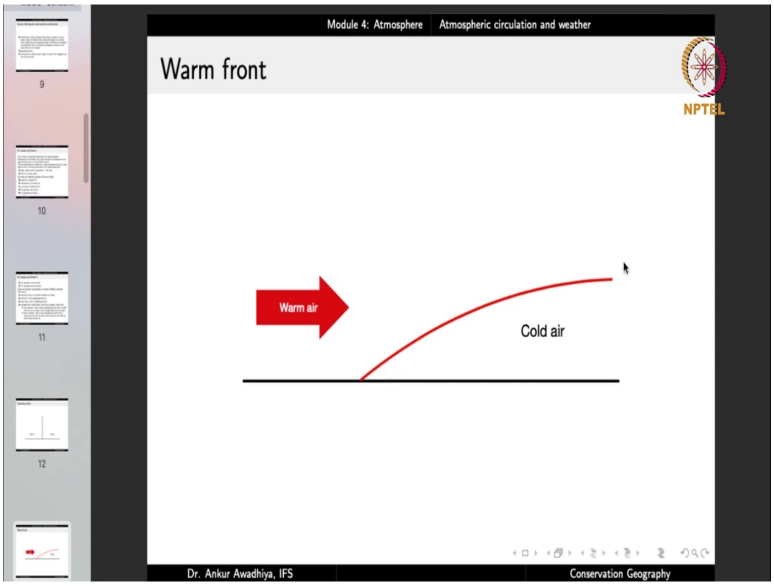

This is a warm front. So, the warm air is pushing against the cold air, the warm air being lighter, it gets on the top, and it creates a gently sloping front which is the warm front.

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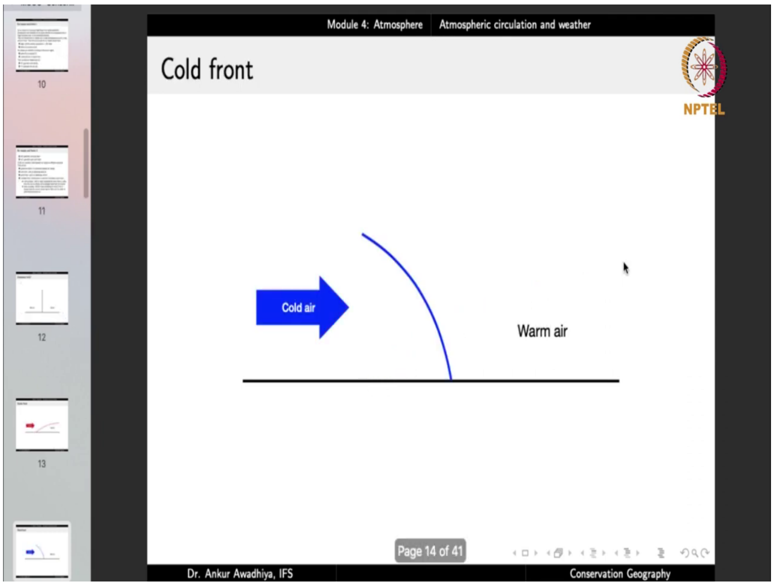

This is a cold front. So, in this case, the cold air is pushing against the warm air. The cold air being denser, it remains at the bottom and it creates a very steeply declining cold front.

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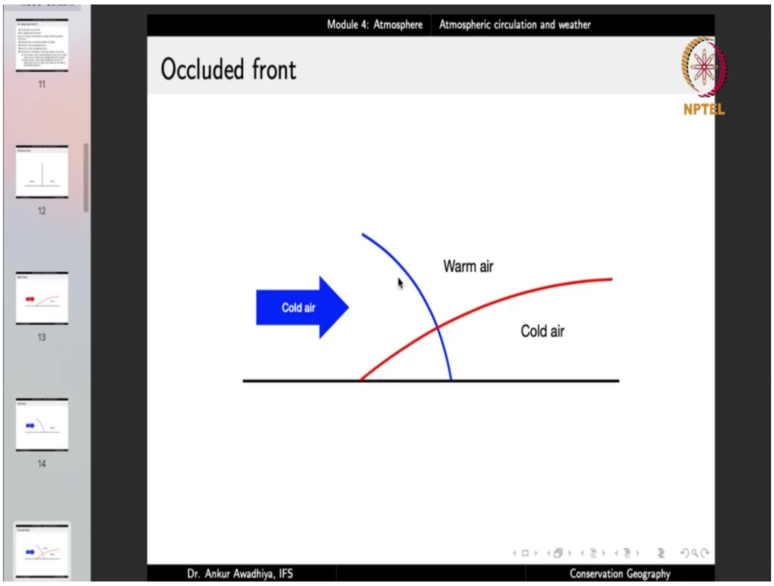

And an occluded front occurs when the cold air gets or it moves at such a fast speed that the cold front has now overtaken the warm front. Now, with these backgrounds, we can now talk about the general circulation of air in the atmosphere.

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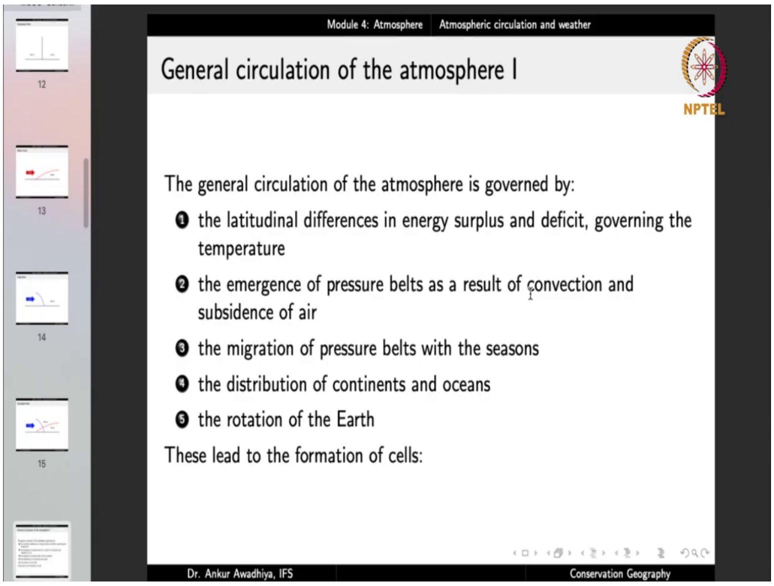

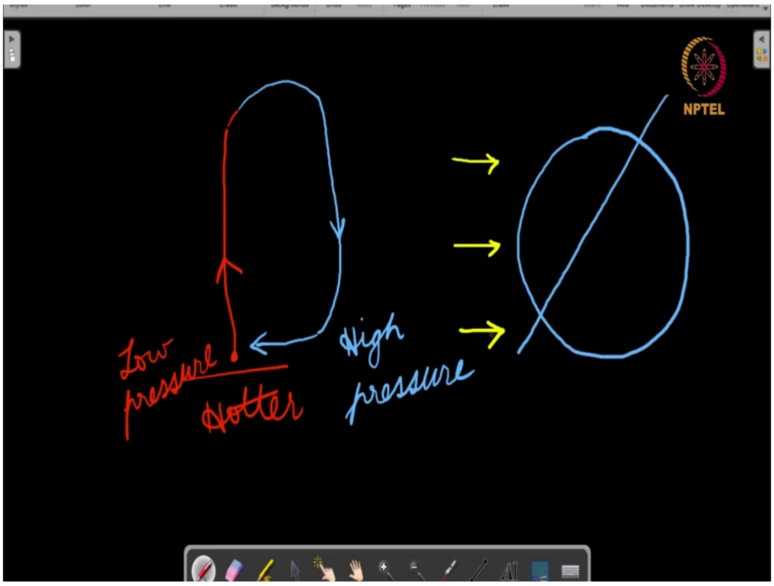

So, the general circulation is governed by the latitudinal differences in energy surplus and deficit which govern the temperature. So, essentially near the equator is you have higher temperatures near the poles you have colder temperatures. Now, this result in very different air masses.

And these air masses then, when they interact with each other, they result in different wind patterns on this planet. So, the general circulation is governed by the energy that arises out of the differences in energy surplus and deficit. Now, we have the emergence of pressure belts as a result of convection and subsidence of air.

Now, what we are talking about here is that if you have an area that is getting hotter, the air here will get warmer and it will rise, because the warm air is less dense, so it will rise and as it rises, it will lose its temperature, it will lose the heat because in the upper layers it is colder, once it becomes cold, it becomes denser and it goes down. And once it goes down here you have a deficit of air because the air is moving up.

So, there is a vacuum like situation that is getting created. Here you have an excess of air because so much amount of air is coming down. And so, this air will now move in this direction. So, this creates a loop like pattern, it creates a convection loop. So, we have the emergence of pressure belts as a result of convection and subsidence of air. In those areas where you have convection, where the air is moving up, you will have a situation of low pressure near the Earth is surface.

And in regions where you have a subsistence of air, so so much amount of air is coming down that you will have a high pressure in these areas where you have subsidence. Now these pressure builds that get created, they migrate with the seasons. Why? Because if you consider the Earth, the Earth is tilted. So, essentially what that means is that we have summer seasons when the sun is moving either towards the north pole or towards the south pole.

So, the sun is not always shining here at the equator. When the sun shifts to the north. You have the summers in the northern hemisphere, when the sun shifts to the south, you have entered in the Northern Hemisphere. And so, the sun is moving relatively to the equator. Now, with this apparent movement of the sun, we have changes in the pressure belts. Because now a different area is being heated. It is not just the equator that is being heated maximally. But at times, areas above or below the equator they are getting maximum amount of insulation.

And when that happens, those will be the areas with the lowest pressures. And so, the pressure belts move with seasons. It is also governed by the distribution of continents and oceans. Because as we have observed over the oceans, the frictional forces are lesser and at the same time, we have the generation of air masses when the air is there on a continent or on the ocean.

So, we have continental versus marine air masses. So, depending on the configuration of the oceans and continents in an area, the patterns will change. And it also is governed by the rotation of the Earth, which results in the Coriolis forces that get applied. So, that changes the direction of the winds. Now, because of these, we have the formation of cells.

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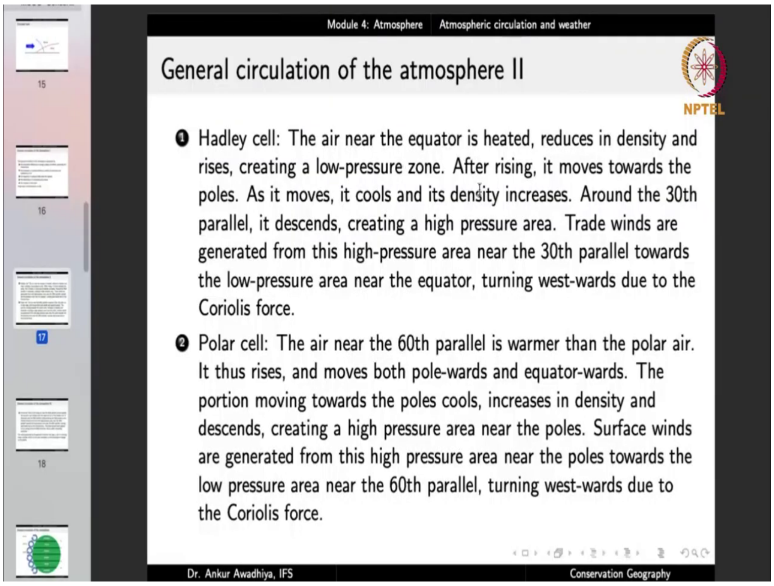

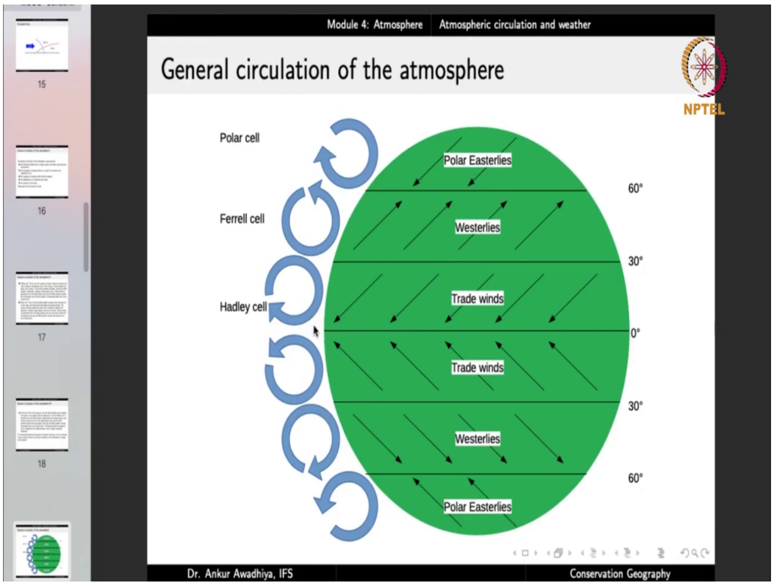

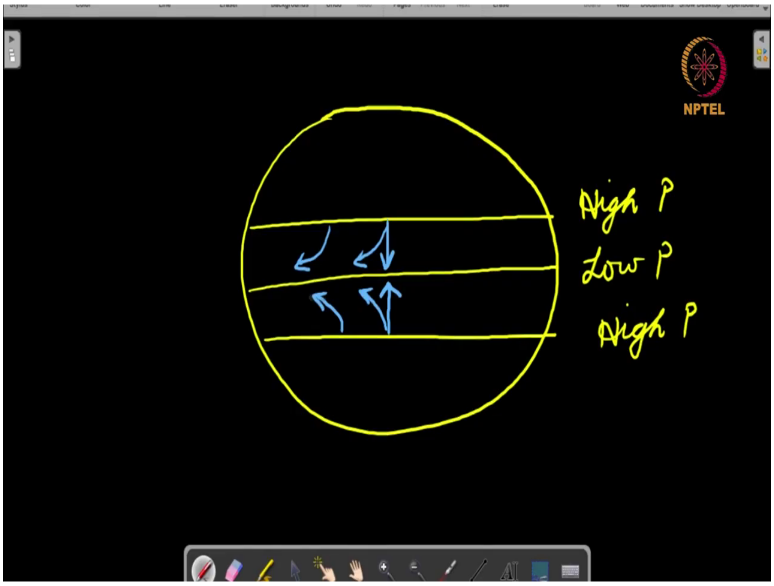

And there are three cells that are important. So, we have the Hadley cell. So, the air near the equator gets heated reduces in density and rises creating a low-pressure zone. So, what we are talking here is that near the equator, the air is getting heated, because this area is receiving typically the maximum amount of insulation. So, because of this heating, the air gets heated, it moves upwards.

So, we have this movement upwards and after rising, it moves towards the poles, so, this air near the equator it has to go somewhere. So, once it has raised to a higher elevation, it moves in both directions, it moves towards the poles. As it moves, it cools and its density increases, because now it is not getting that much amount of heat. So, it cools and the density increases. Around the 30th parallel it descends creating a high-pressure area.

So, this is what we are talking about it goes up it moves towards the poles and then it starts to descend. So, this is an area of subsidence. This is the area of convection. This is an area of subsidence. This again is an area of subsistence. And so, you have a high low pressure here, a high pressure here and a high pressure here. So, around the 30th parallel it descends creating a high-pressure area.

Trade winds are generated from this high-pressure area near the 30th parallel towards the lower pressure area near the equator, turning westwards due to the Coriolis force. So, once you have high pressure here, low pressure here, you have a situation, where, so this portion is having a low pressure, this portion is having a high pressure and this portion again is having a high pressure.

Now, because air moves from high pressure to low pressure areas, so in this case, the moment should be like this, but because of the Coriolis forces in the Northern Hemisphere, the winds turn towards their right. So, the winds will turn like this. In the southern hemisphere, the winds should have been going like this, but because of the Coriolis force, they turn leftwards. So, they become something like this. So, this is the kind of pattern that gets generated.

So, here you have the trade winds that are formed. So, these turn westwards due to the Coriolis force and in both the hemisphere they are turning westwards. Then you have the polar cell, the air near the 16th parallel is warmer than the polar air. So, here we are talking about the 16th parallel, 60 degrees north and 60 degrees south. Now, the air here is warmer than this air at the poles.

Now, because it is warmer here again the air will rise it will move towards the equator and towards the poles and near the poles it will come down. So, you will have an area of subsidence here or an area of high pressure, here you will be having an area of low pressure and you will have these winds that are turning towards their right or turning westwards in both the northern and the southern hemispheres and these are the polar easterlies.

Now, because they are turning towards the west, so they appear to be coming from the east, and so we call them easterlies. So, this is the polar cell. The air near the 60th parallel is warmer than the polar air, it rises moves both pole words and equator words. The ocean mover moving towards the poles cools, increases in density and descends, creating a high pressure area near the poles. Surface winds are generated from this high-pressure area near the poles towards the low-pressure area near the 60th parallel, turning westwards due to the Coriolis force. So, these are very similar.

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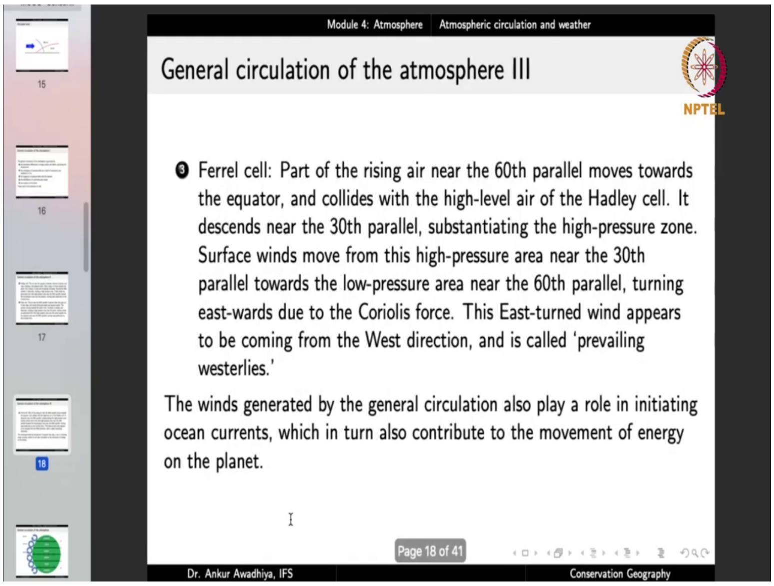

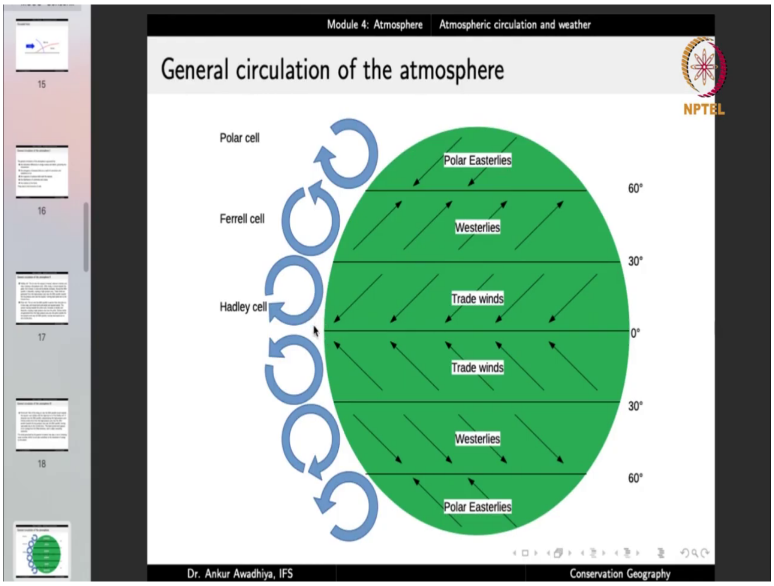

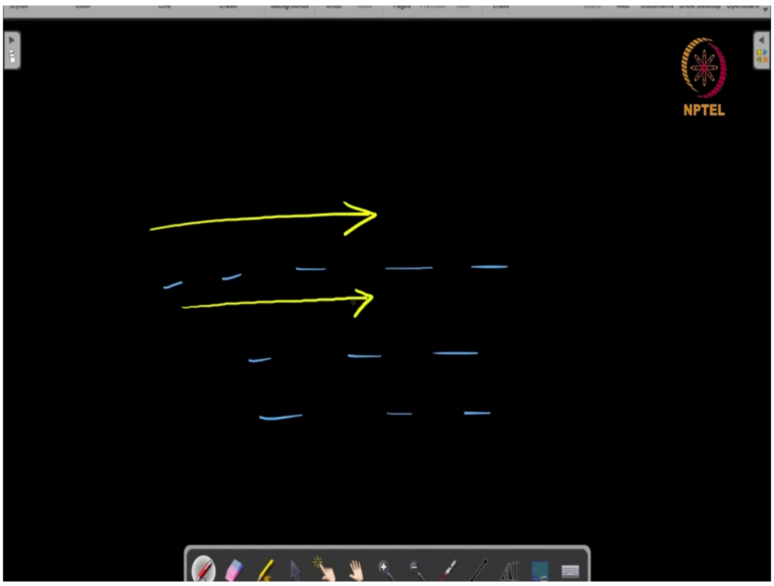

The third is the Ferrel cell. Part of the air rising near the 60th parallel moves towards the equator and collides with the high-level air of the Hadley cell. So, what is happening here, is that when we consider this portion, so the air was rising, it was moving towards the poles and towards the equator. So, now we are talking about this cell. So, the air rises, it moves towards the equator, and the air from the Hadley cell was also moving towards the pole.

So, both of these collide near this 38th parallel and they come down. So, in this case, this is a zone of conviction or a zone of low pressure, this is a zone of substance or a zone of high pressure. So, now the air will move from the high-pressure area towards the low-pressure area turning towards the right, so it becomes the westerlies. So, in the Northern Hemisphere it appears to be coming from the west.

And similarly, in the southern hemisphere it appears to be coming from the west. So, these are the westerlies. It descends near the 38th parallel substantiating the high-pressure zone. Surface winds move from this high-pressure area near the 30th parallel towards the low-pressure area near the 60th parallel, turning eastwards due to the Coriolis force. This Eastern wind appears to be coming from the west direction and is called the prevailing westerlies.

So, these are three most prominent planetary winds, we have the trade winds, we have the westerlies, and we have the polar easterlies. The winds generated by the general circulation also play a role in initiating ocean currents, which in turn also contribute to the movement of energy on the planet.

So, what is happening is that when you have a water body and you have a strong wind, that is blowing above it, and this wind is consistently moving in roughly all the seasons, because these winds are being generated due to the general circulation, which is arising because certain areas such as the equator are getting heated up more than the polar areas. Now, in this case, because the winds move in the same direction for a very long period of time or essentially perpetually.

So, in this case, the ocean waters also begin to move. And these results in ocean currents. And ocean currents also play a big role in shifting the heat from the equator towards the poles. So, in this case, what we saw was that here the heat from the equator was being pushed towards the poles. Here, the heat is again being pushed towards the poles. And when the waters are there, they are also pushing the heat towards the poles. So, this is the way in which heat moves from the equator towards the poles.

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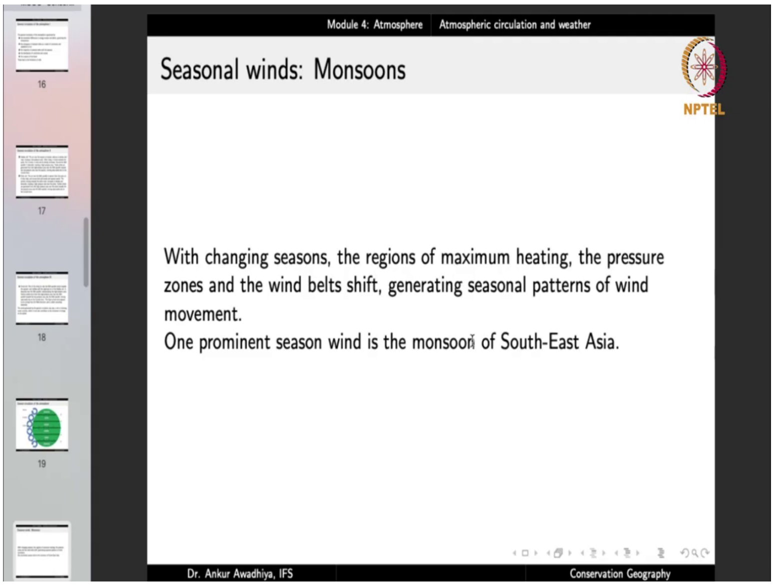

Now, apart from the planetary winds, we also have seasonal winds such as monsoons with changing seasons, the regions of maximum heating, the pressure zones and the wind builds shift, generating seasonal patterns of wind movement, which is the monsoon. And monsoons are very prominent in Southeast Asia.

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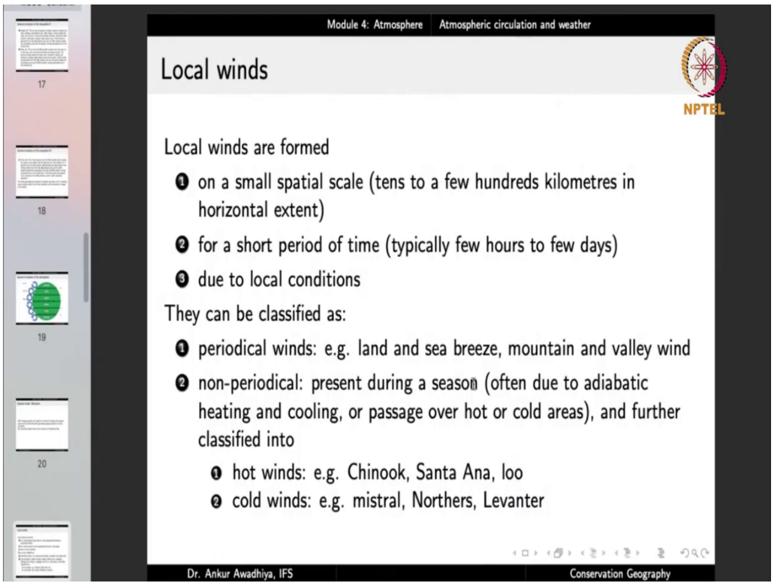

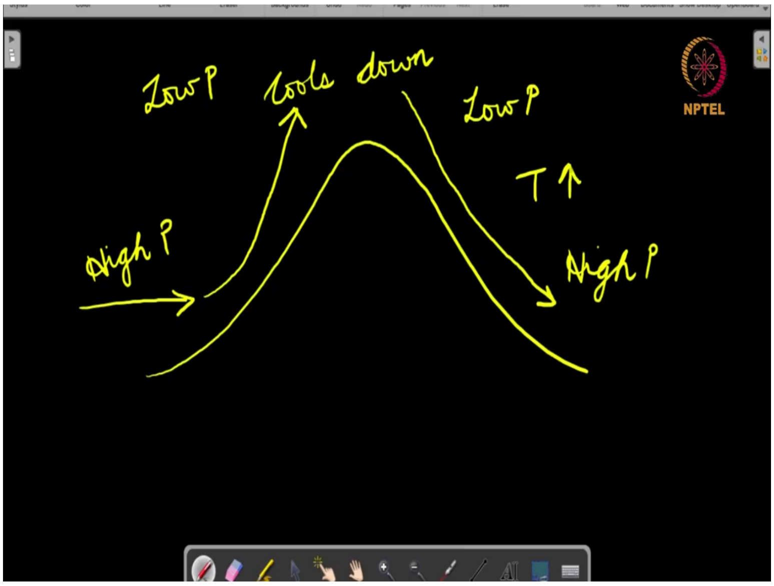

Now, apart from these winds, we also have local winds, local winds are formed on a small spatial extent that is tens to a few 100 kilometres in horizontal extent, for short period of time, say a few hours or a few days. And because of local conditions, they are classified as periodical winds that occur periodically such as land and sea breeze, mountain and valley breeze or non-periodical local winds, which are present during the season, often due to adiabatic heating and cooling or passage over hot or cold areas.

And are further classified into hot winds and cold winds. Now, what is adiabatic heating and cooling, adiabatic heating and cooling means heating and cooling off something without an addition or subtraction of heat or thermal energy. So, essentially what happens is if you take a parcel of air and if you compress it, then because of this compression, this parcel of air will get heated up.

Similarly, if you rarefied this parcel of air, the temperatures will go down. Now, in this case, you are having a change in the temperature without adding heat or subtracting heat from this air parcel. So, this is an adiabatic heating or cooling we typically get these adiabatic heating and cooling when for instance, the air is moving and it gets a mountain. So, in this case, you have a mountain and you have an air that is moving and then on encountering the mountain the air starts to rise.

Now, when the air starts to rise, here you have low pressure and here you have high pressure. Now, when it goes towards the low-pressure areas, the air starts to expand. And when the air starts to expand, the air cools down. Similarly, when the air moves from the top of the hill downwards, it is moving from a low-pressure area to a high-pressure area. And in this high-pressure area, the air is getting compressed.

When the air is getting compress the temperature increases. Now, in both of these situations, we are not talking about the addition or subtraction of heat, we are only talking about changes in pressure that are either compressing the air or that are releasing the air from the compression. So, this is adiabatic heating and cooling. So, you have local winds that are periodical winds that occur, say daily.

So, in the morning you will have the sea breeze in the evening you will have the land breeze, or you can have the mountain in the valley wind or you can have non-periodical winds that are present throughout the season, because the winds are moving either over a hot or cold area or because of adiabatic heating and cooling.

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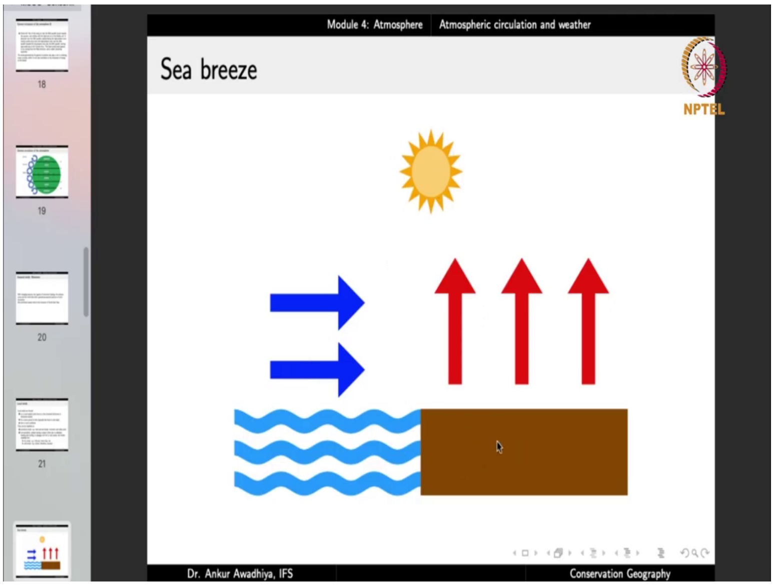

So, what is sea breeze, sea breeze occurs in the daytime. So, in the daytime, if you consider a piece of land and a piece of water, the land gets heated up much quickly and much more as compared to water. So, in that case, this portion becomes hot, if this portion is hot, the air above becomes hot. When this air is warm, it rises up and the cool air from the sea rushes to take its place. So, you have the movement of cool air towards this land piece in the daytime. So, this air is moving from the sea towards the land and so this is the sea breeze.

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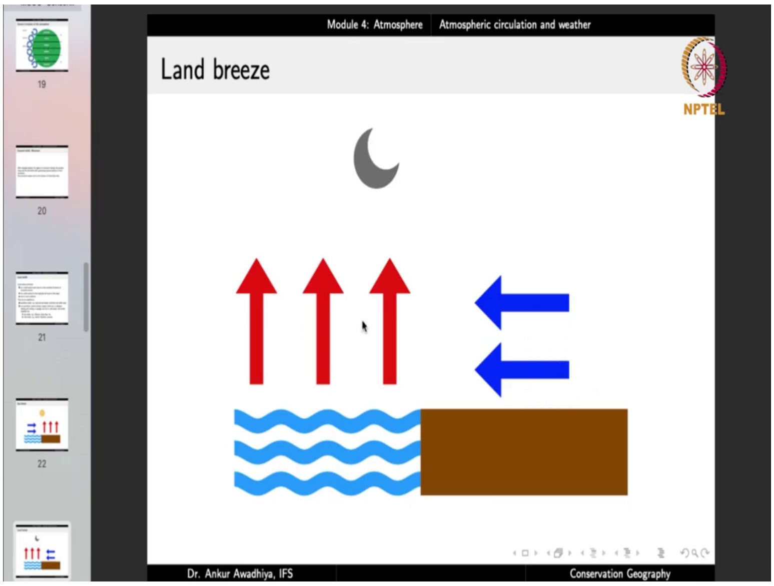

And opposite thing happens in the night time. So, in the night time the land cools down much faster than the sea. So, you have a situation where here you have a cold air, here you have a warmer air. So, the warmer air tends to rise and the cold air rushes to take its place. So here you in the right time you have a wind movement from the land towards the water, which is the land please.

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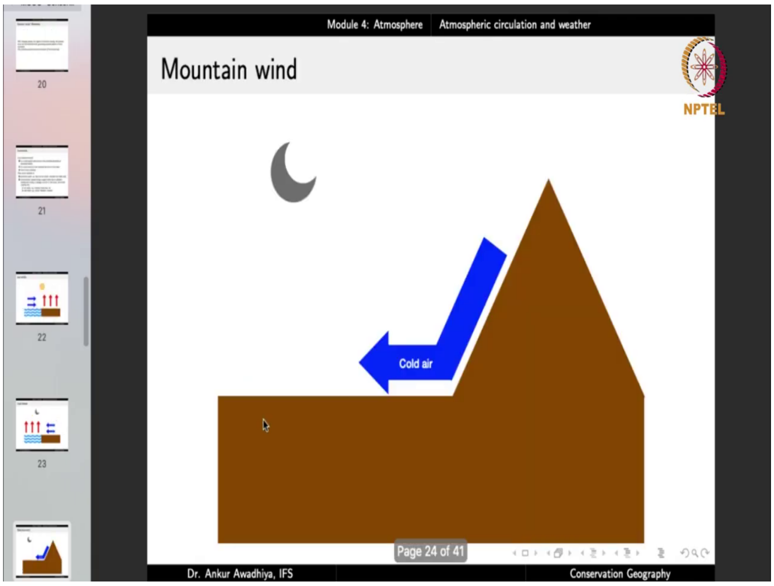

Similarly, in the case of mountains, in the night time, this portion cools down faster. And when this land cools down the air which becomes dense, it moves down. And so, you have a perpetual moment of cold air from the mountain slopes towards the valley. And coming from the mountain, this is known as a mountain wind.

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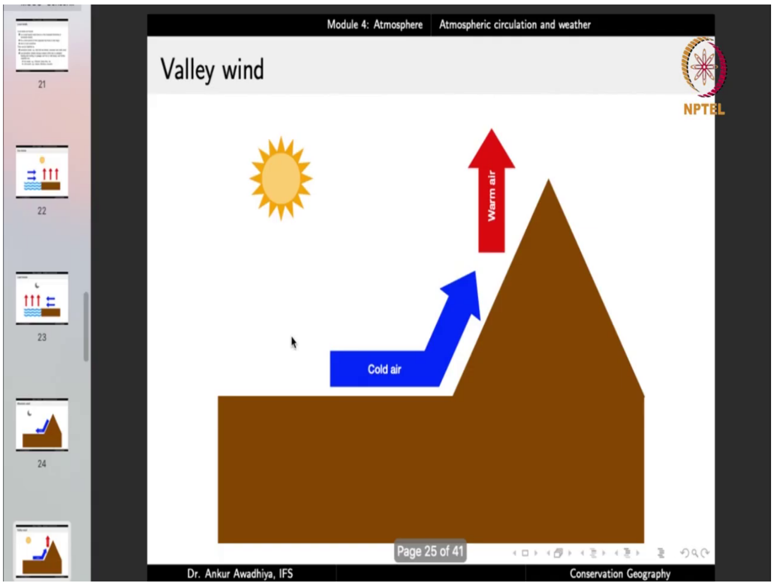

In the daytime, what happens is that this portion on this aspect which is facing the sun, it heats up more than the valley. And if this portion heats up, the air becomes warmer it rises and the cold air rushes to take its place and it is called the valley wind.

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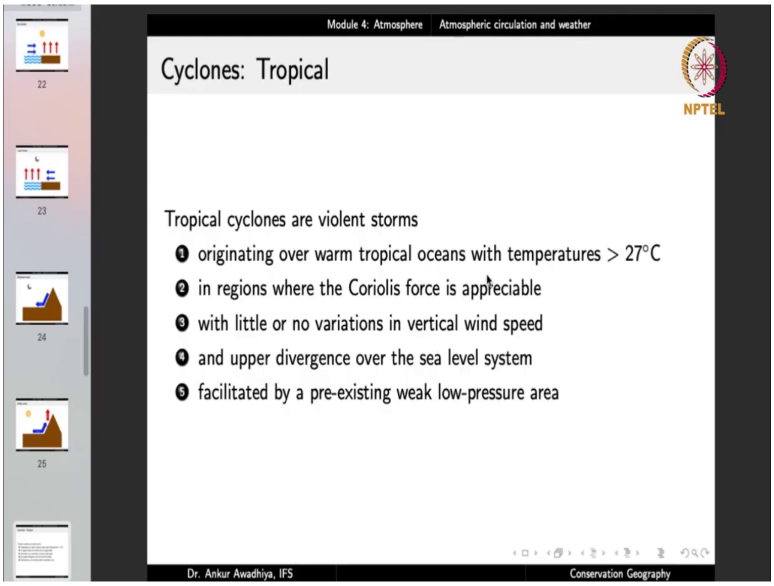

Another big atmospheric circulation is cyclones. And we have two different kinds of cyclones, we have tropical cyclones, and we have extra tropical cyclones. Tropical cyclones are violent storms originating over warm tropical oceans, where temperatures are greater than 27 degrees Celsius. So, over warm tropical oceans with high temperature it means that the air here is humid and the air is warm.

Now, if the air is warm, the air will move up. Now, when the air moves up, it cools when it cools, and because it is full of moisture, there will be rainfall. When there is rainfall, you have a conversion of water vapor into water with a release of heat. And this process moves heat from the lower layers from near the sea surface towards the higher layers of the atmosphere. So, this is the driving force.

So, tropical cyclones originated our warm tropical oceans in regions where the Coriolis forces appreciable because of which the winds go round and round. With little or no variations in vertical wind speed, otherwise, it would have led to a balancing off the air pressures. And upper divergence over the sea level system. So, the air the warm air that is rising up it has to go somewhere.

So, it diverges in the upper layers of the atmosphere. So, the air is moving up and near the sea surface the air is moving towards the cyclone, then it rises up and then it spreads out. And it is facilitated by a pre-existing weak low-pressure area. A low-pressure area ensures that wind is moving towards the low-pressure zone to jumpstart the cyclone.

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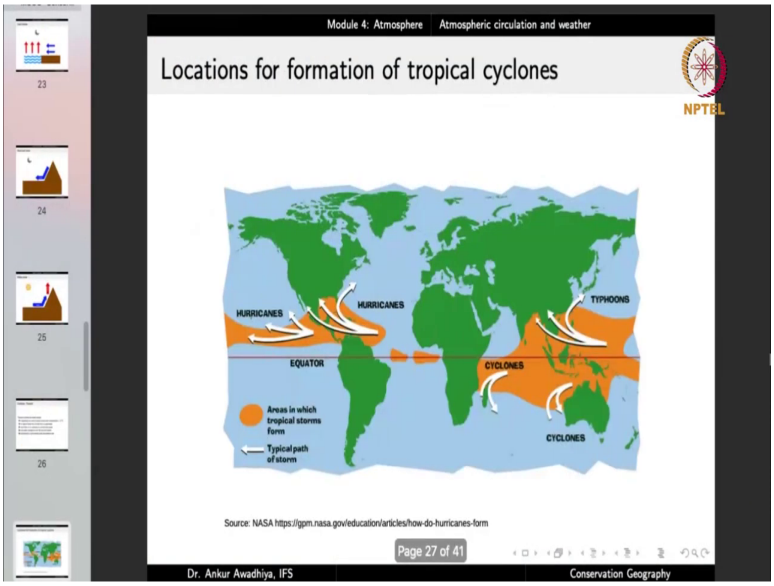

So, when we talk about warm tropical oceans, so these are the areas where we typically get the cyclones. They are known by different terms like typhoons, or cyclones, or hurricanes in different areas.

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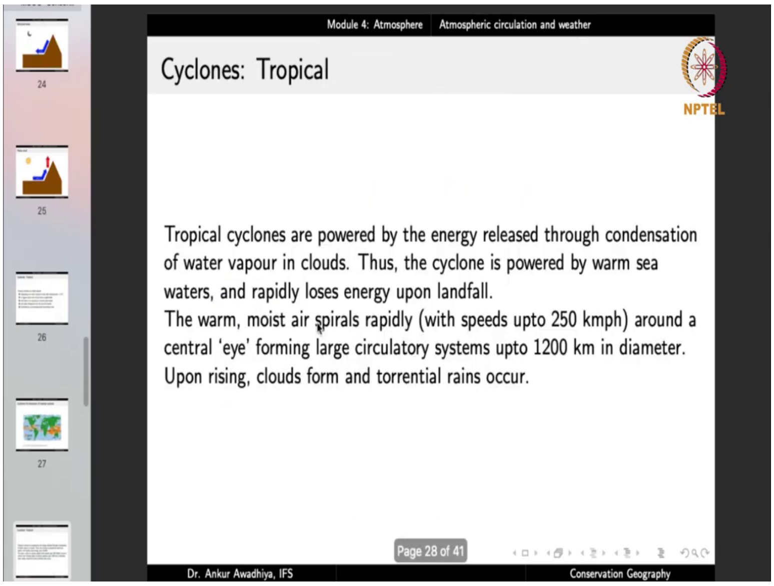

Now, tropical cyclones are powered by the energy released through condensation of water vapor in the clouds. Thus, the cyclone is powered by warm sea waters, and rapidly loses energy upon landfall. So, because it is dependent on the warm water of the seas or oceans, so as soon as a cyclone enters into a land area it makes landfall, this source of energy gets cut, and the cyclone rapidly dissipates.

The warm moist air spirals rapidly with speeds up to 250 kilometres per hour, which as you will remember is beautiful scale 12 around a central eye, forming large circulatory systems up to 1200 kilometres in diameter. So, these are large circulatory systems upon rising clouds form and torrential rains occur.

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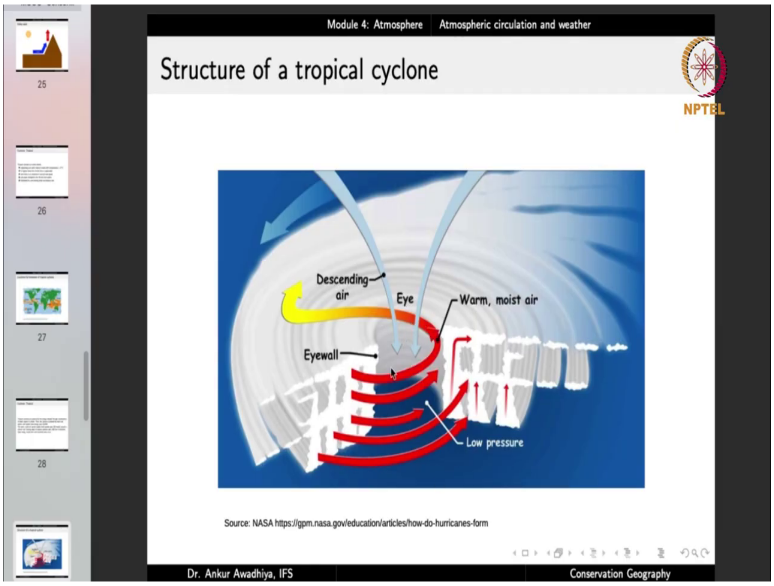

So, this is how it will look like the cyclone will have a central eye and it will have a moment of air that is going round and round in circles, the warm moist air rises it relieves to arrange rainfall and this is how the cyclone will propagate.

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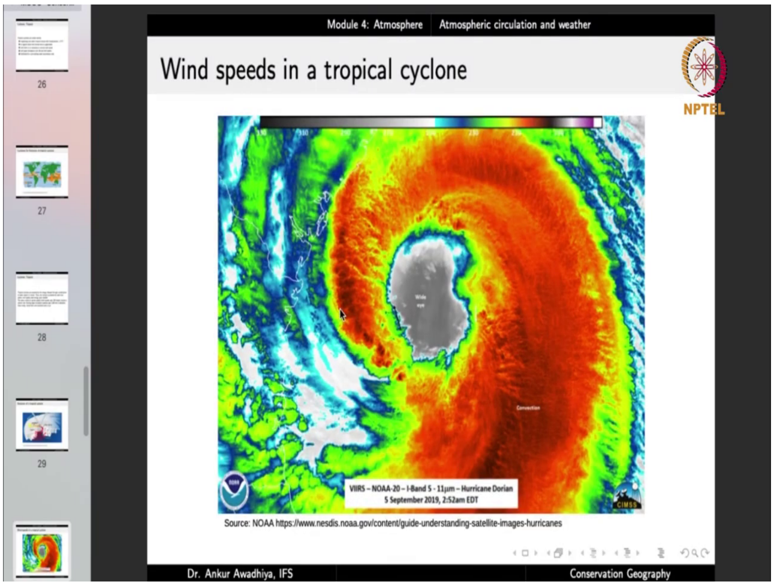

This is a figure that shows the wind speeds in a cyclone. And typically, you will find that in certain, in the eye area the wind speed is less, but around it the wind speeds are very high.

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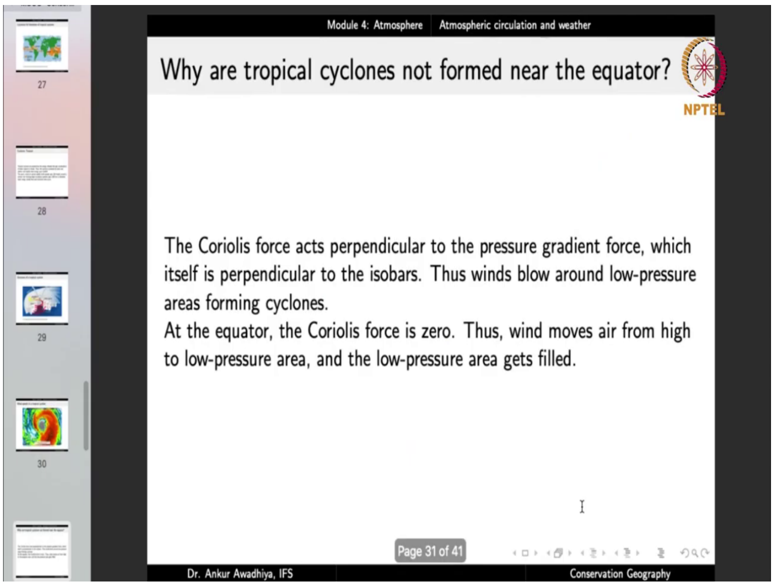

Now, cyclones do not form near the equator, because the action of Coriolis force is of paramount importance for the functioning of cyclones. Now, we have seen before that the Coriolis forces highest near the poles, and is lowest or nearly 0 near the equator. Now, near the equator when the Coriolis force is 0.

So, in that case, the air will rapidly fill up the low-pressure area. So, the Coriolis force acts perpendicular to the pressure gradient force, which itself is perpendicular to the isobars. So, what we are talking about is that if you talk about these two regions, this is high pressure, this is low pressure. Now, the wind moment is perpendicular to these isobars.

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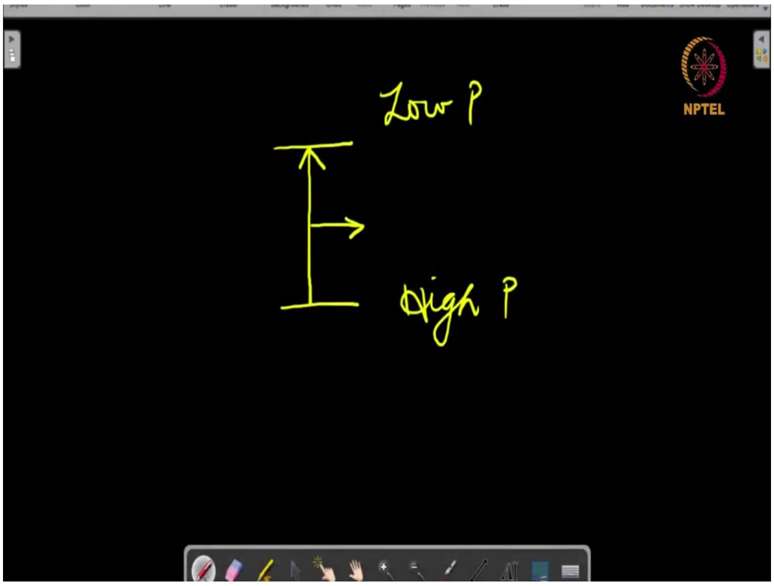

So, this is the wind moment and the Coriolis force is perpendicular to this wind moment. So, it is parallel to the isobars and when you have the Coriolis force acting, then winds blow around a low-pressure area to form the cyclones.

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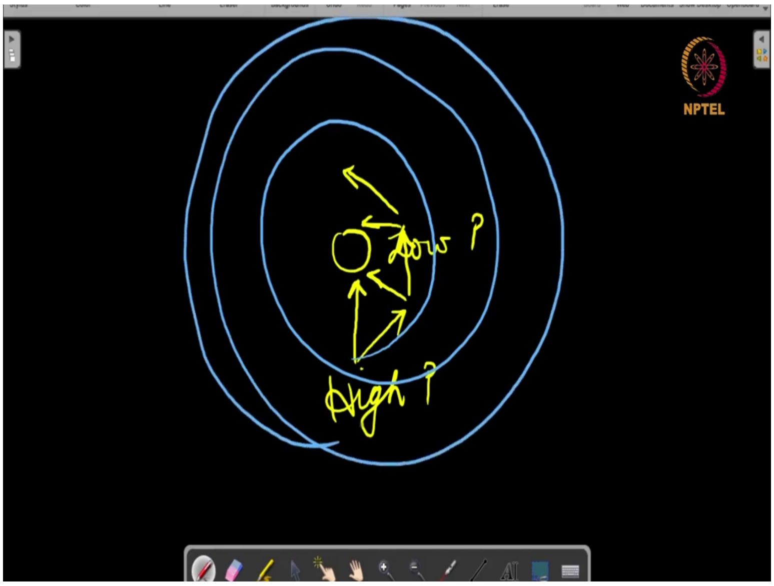

So, what is happening is that when you have low pressure area and you have a surrounding high-pressure area, the air which was trying to move towards this low-pressure area what is happening is it is turned towards the right. Then it again tries to move here but it again is turned towards the right, it again tries to move here, it is again deflected to the right. So, what happens is that now the air is moving like this. And so, the air is not able to fill up the void. But at the equator the Coriolis force is 0, so the air directly moves from the high-pressure area to the low-pressure area filling up the low-pressure area.

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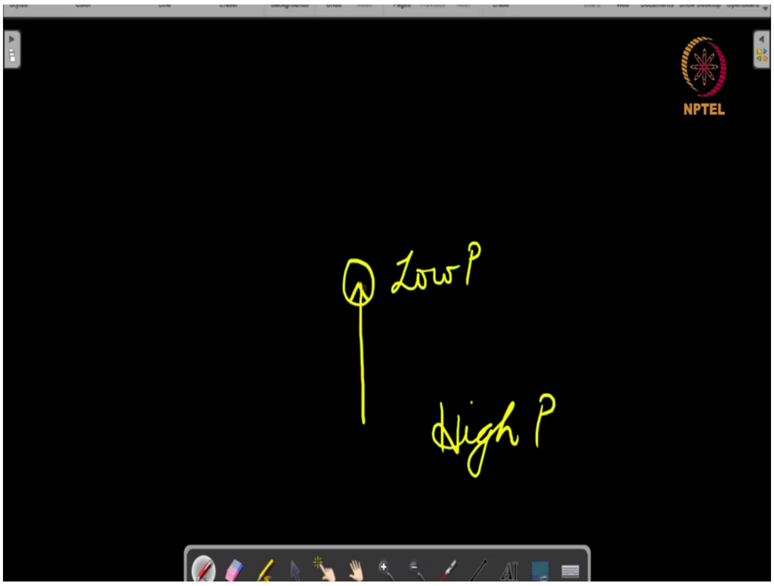

So, at the equator what will happen is that you have a low-pressure area and here you have a high-pressure area. Now, in the absence of Coriolis force, air will directly move from high pressure area to low pressure area filling up the low-pressure area. So, without a difference in pressures, there will be no further wind moment. And so, you will not find cyclones near the equator. Similarly, you will not find cyclones near the poles because they require the heat of warm surface waters to fuel them. So, near the poles because the temperatures are low, so you will not get cyclones. So, you get cyclones in between.

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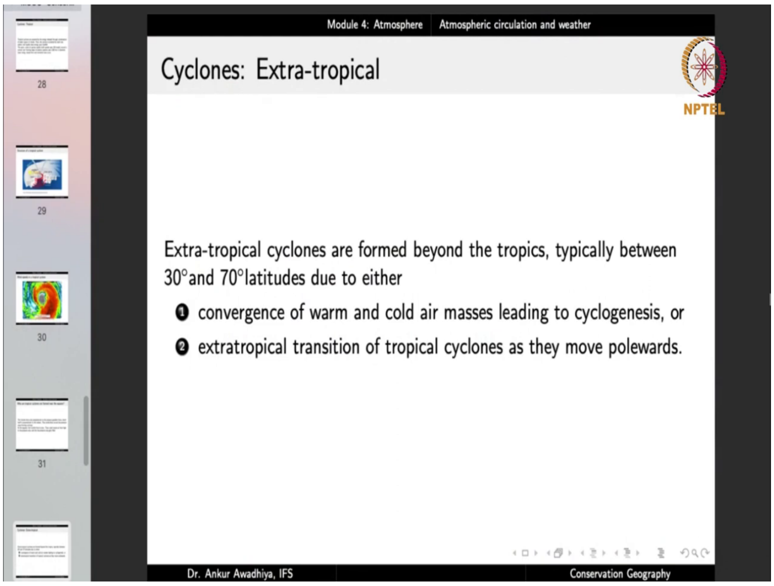

We also have extra tropical cyclones, which are found beyond the tropics, typically between 30 degrees and 70 degrees latitudes because of two things, one is convergence of warm and cold air masses. And second is extra tropical transition of tropical cyclones as they move pole wards. So, what does that mean?

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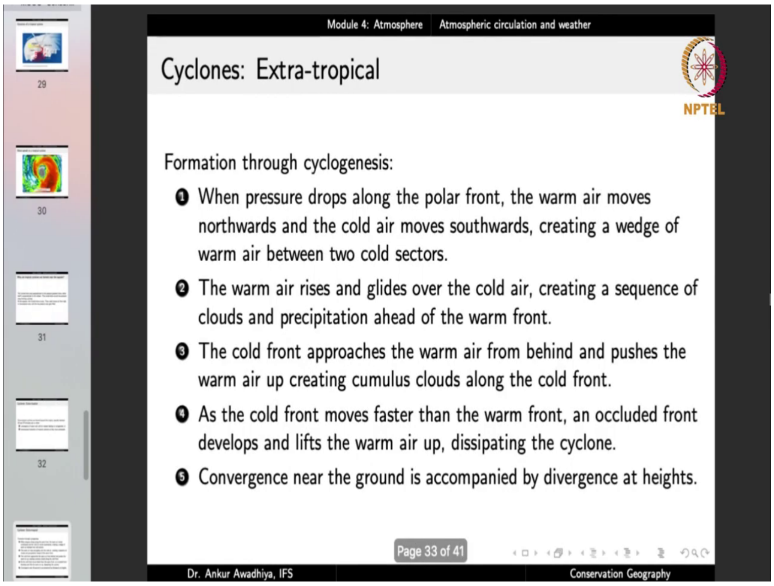

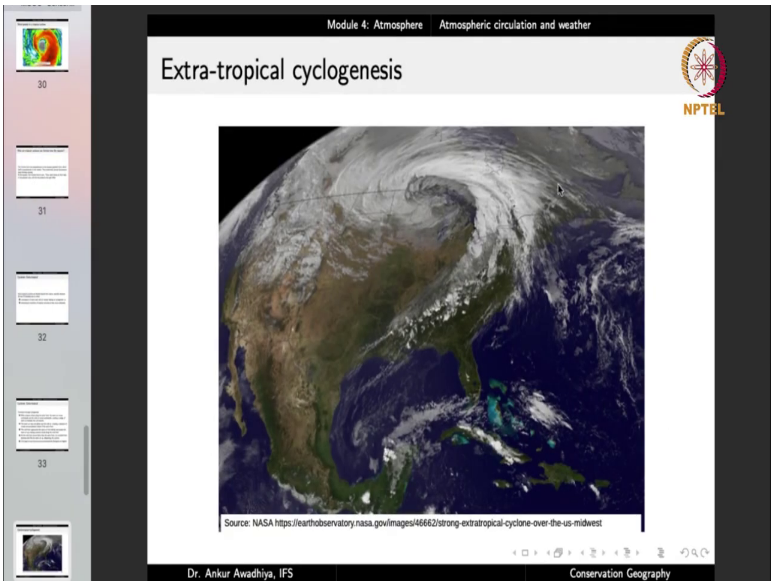

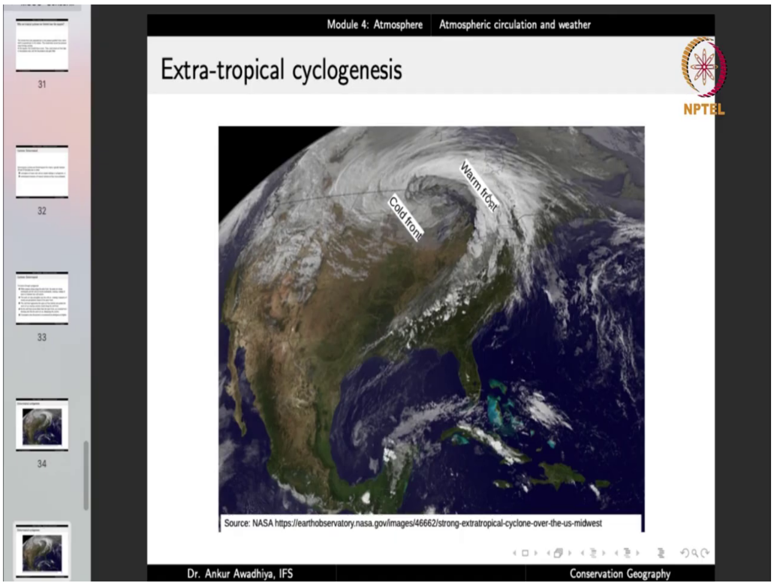

In the case of cyclogenesis, we have a pressure drop along of the polar front. The warm air moves northwards and the cold air moves southwards, creating a wedge of warm air between two cold sectors. So, what we are talking about is this. So, you have warm air that is moving towards the poles. You have the cold air that is moving towards the equator and in between you have this patch that remains.

Now, the warm air rises and glides over the cold air, creating a sequence of clouds and precipitation ahead of the warm front. So, what we are talking here is that this portion is the warm front. Because this air is warm, this air is cold, and the air is moving like this, so you have a warm air moving towards the cold air. Now, because the cold air is denser, it remains at the bottom, the warm air is steadily rises and rises, and when it rises, it cools.

And this warm air then leads to precipitation. When it is getting cooled, the cold front approaches the warm air from behind and pushes the warm air up creating cumulus clouds along the cold front. So, we find clouds even here in the cold front, because the cold front is pushing against the warm air and the cold air is getting to the bottom and it is steadily rising the warm air.

Now, if the cold front moves faster than the warm front, you will get an occluded front. The occluded front lifts the warm air up dissipating the cyclone. So, this is how the cyclone will end. And convergence near the ground will be accompanied by divergence at the heights. So, essentially in the case of extra tropical cyclones that are formed through cyclogenesis. The reason for their formation is the creation of warm and cold fronts and the cold front is typically faster, so it creates an occluded front which will ultimately end the extra tropical cyclone.

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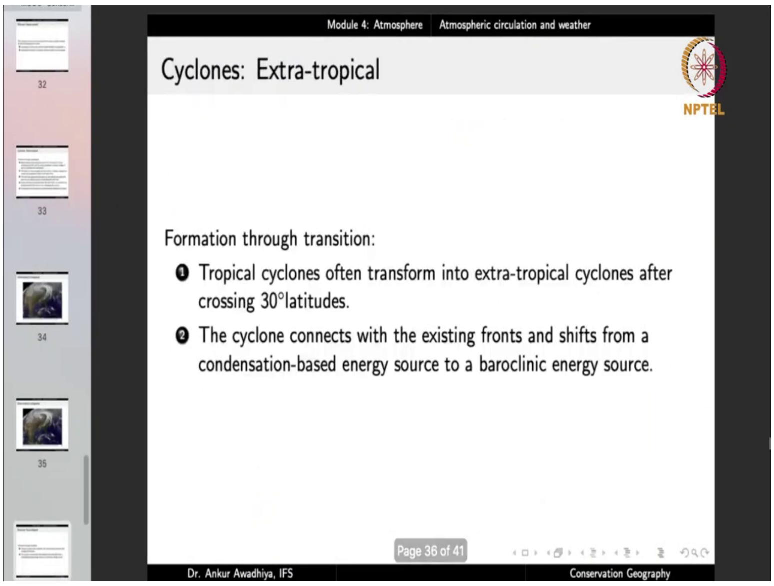

The other way of formation is through a transition. So, when the tropical cyclones are moving towards the poles, after they cross the 30-degree latitude, they become extra tropical cyclones. So, what will happen is either upon landfall, the tropical cyclone will finish because it is no longer getting warm sea waters or otherwise, it will merge itself with the fronts that are there towards the poles. And in that case, it will change its characteristics, it will shift from a condensation-based energy source to a baroclinic energy source. So, it is now not using the warm sea surface waters but it is using the pressure differences.

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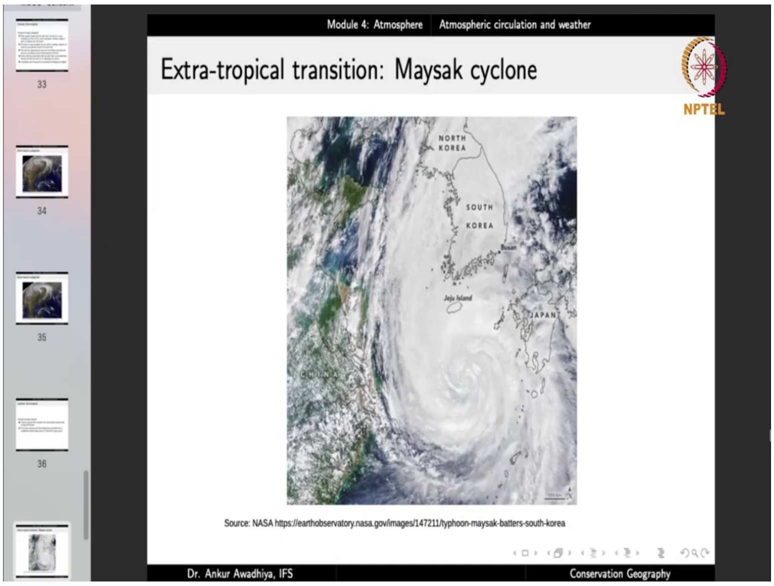

So, that is an extra tropical cyclone. So, here we are observing the Maysak Cyclone that is shifting from tropical to an extra tropical cyclone.

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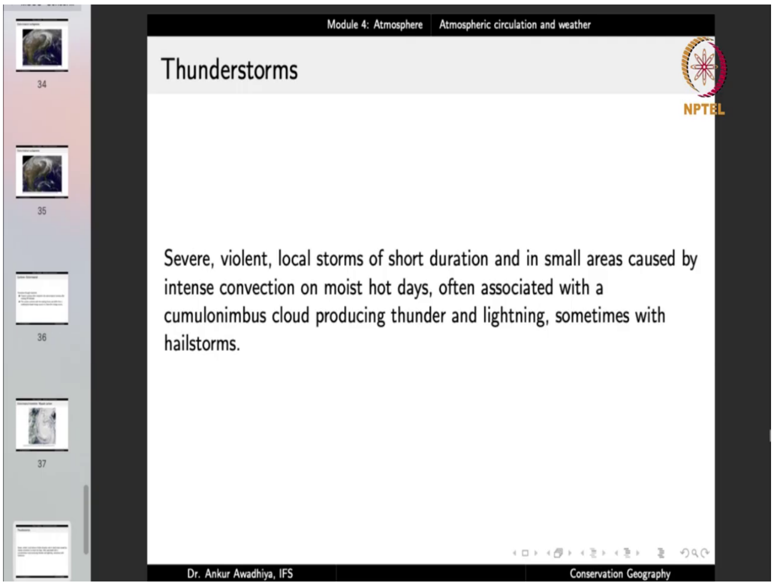

We also have thunderstorms which are severe violent local storms have short duration and in small areas caused by intense convection on moist hot days, often associated with cumulonimbus cloud producing thunder and lightning, sometimes with hail storms. So, in India, we typically find thunderstorms in the pre-monsoon seasons when it is very hot, but it is also a bit more moist.

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So, what happens in that case is that you have a local piece of land that is getting heated up during the daytime setting up convection currents. So, the convection current raises the hot and moist air upwards. When it raises it upwards, the air cools and that results in precipitation. So, you will have lots of rainfall, you may even get Hill formation.

So, in this lecture we began by looking at what causes the movement of air. We saw that pressure differences cause movement of air and these movements are also modulated by several other factors. We looked at air masses, we looked at planetary circulation, we looked at seasonal circulations, we also looked at local winds and thunderstorms. So, that is all for today. Thank you for your attention. Jai Hind!