Introduction to Atmospheric Science
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Lecture-04
Vertical structure of atmosphere contd ... and The Earth system – Oceans

Good morning. Welcome back. So, in today's class we are looking at the, we are discussing the standard atmosphere. The standard atmosphere is one which is temporarily and horizontally averaged; so it is averaged over the whole globe. I mean, it is averaged X and Y. It is also averaged over time. So, it represents a mean in a particular, it represents mean in some sense. So, we can consider this standard atmosphere to be a function of Z only okay the height coordinate is Z in atmospheric science.

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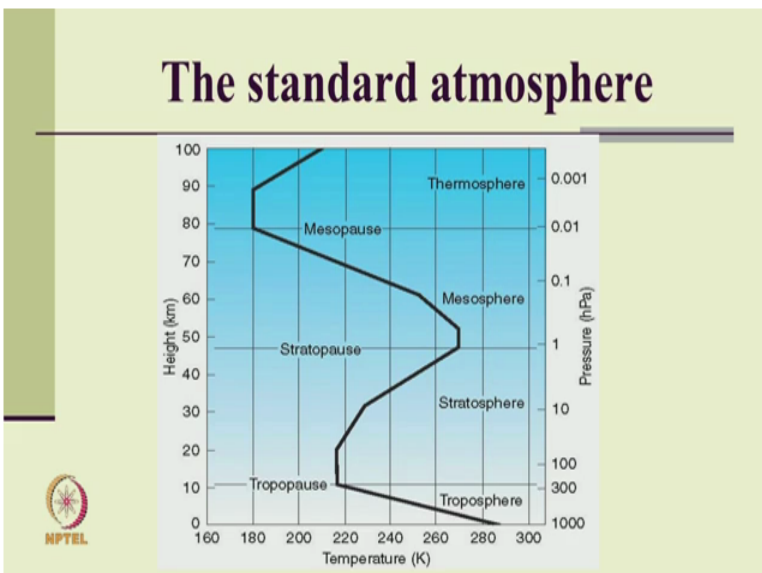

So, we saw that the lowest 10 kilometers is the troposphere and the line of demarcation between troposphere and stratosphere is the tropopause. It is a tropopause because in the tropopause it, the temperature becomes is invariant with respect to height then it increases and this gradient is slightly changing because of the concentration of various gases. Then, we hit the mesosphere where again there it meso, we hit the mesosphere where again there is a stratopause.

And then, you have got a decreasing temperature. We saw the reason for all this. And then, finally you have got a mesopause where the temperature is invariant to the respect to height and then because of higher radiation and photo ionization and photo-disassociation the temperature increases. Why does the graphs stop with 100 kilometers. Look at the pressure at 100 kilometers already. The pressure is 0.001 bar is it not?

I mean basically it is so rarified that there is not much activity as far as which is of interest to the atmospheric scientist. All that is okay the physics people and people who are doing cross ecology and all that may be interested in a air atmosphere, something they want to find out something whether there is an interplanetary motion of some particles. For us first 100 kilometers is still is too much. We are satisfied with that.

Yesterday we quickly ran through a problem where there was a difficulty, right. We wanted to give keeping this standard atmosphere in mind. We wanted to figure out what is the %age what is the mass of the air, for the fraction of the mass of the atmosphere which is contained within the first 10 kilometers. For example, that is the troposphere. So, this is problem number 5. So, we will just clean up this problem before we.

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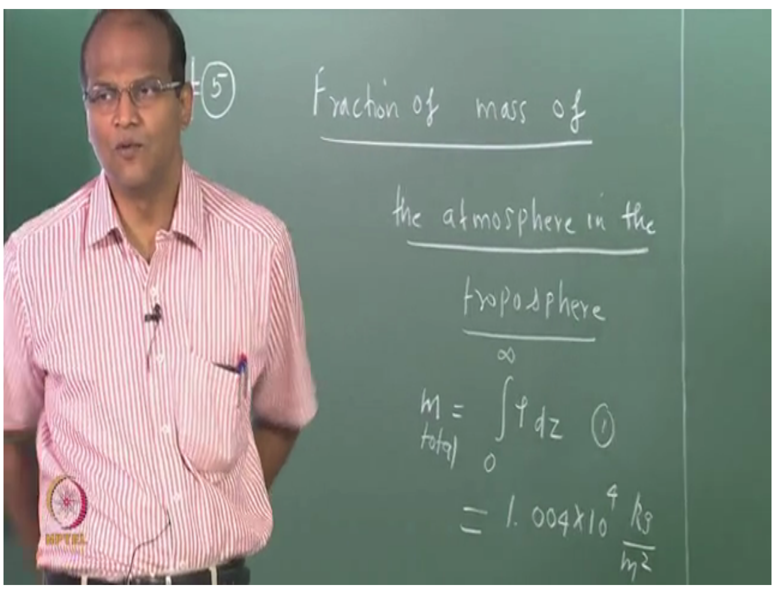

So one, this is the one, correct? total mass of the atmosphere this has got a value equal to, so this has got a value =1.004 into 10 to the power kg per meter square which when we multiplied by four Pi re square where re was 6.37 into 10 to the power of 6 meters, we got some 5.110 to the power of 18 kg. That is the mass of the atmosphere, all right.

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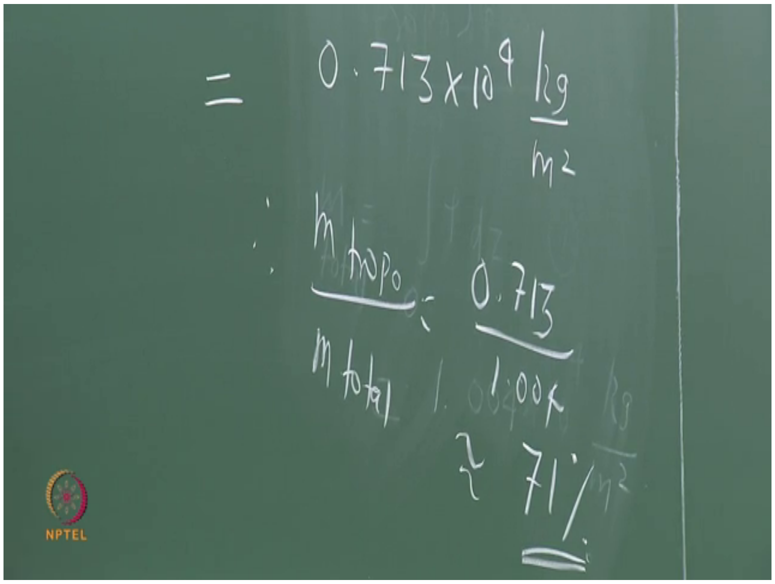

Now, we want to find out mass 0 to 10, alright. So, we in one of the early class I told you that the variation of density and pressure are similar okay therefore everything falls in place you will assign some equation numbers. Agreed, now, please substitute the limits 1.25 is what we agreed upon 1.2 feet kilogram per meter cube, right.

So, so what do you get? But - taken care of it, so, please do not forget to put it as 8000 here; here 10 by 8 is already this dimensionless this H scale 8 is 8,000 meters. How much is this now? 71 So, if the troposphere height slightly varies its latitude and all that and if you consider some 12 kilometers it will come to that 80%, so nearly 75 to 80% of the atmosphere is contained within the first 10 kilometers that is very, very surprising, is it not it?

The atmosphere is very dense at the lower levels. Is this fine? So, this is the problem we tried to solve yesterday and by some strange method we got the same 71 %. But now it is all fine. It is consistent with our understanding and we go from basics and the only extra thing we applied was Rho =Rho naught but this is okay we figured out we already discussed that the variation of density with height and the variation of pressure with the height are similar.

This is okay, right. So, we, we are still continuing with the introduction now the next important participant or player is basically winds, okay. After the vertical structure, you look at the winds in the atmosphere.

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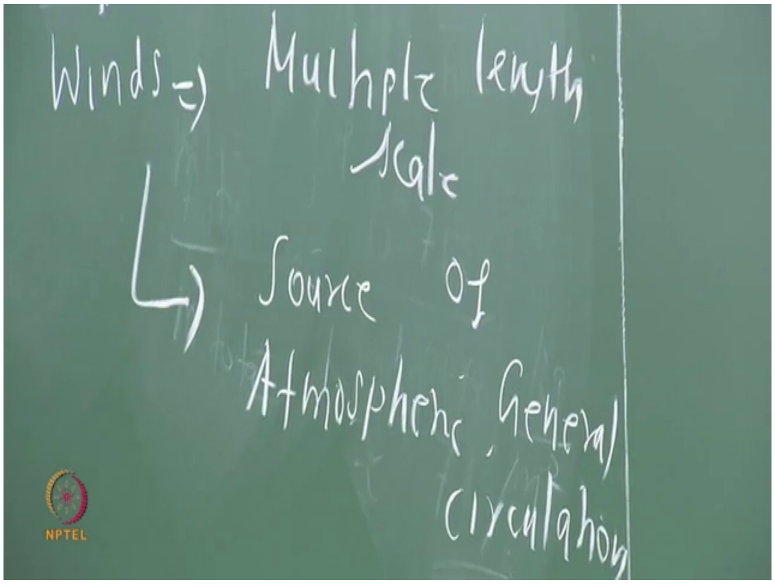

What are, what is the basic cause, what causes winds? Differential heating of the Earth's crust, right the differential heating of the Earth's crust is important reason for the generation of wind. And winds are generated in multiple scales. You can have a local bloom it is raising which is only a few kilometers thick, okay. You can have your planetary winds which are occupying some particular latitude to some other latitude.

You can also Baro Clinic waves which are all occupying, which are flowing between two particular latitudes, that is the baro clinic winds are flowing from north to south and they restrict the knot. So, temperature difference it is possible to have a cyclone which is or a typhoon which is few 100 kilometers, okay it is possible to have a extra tropical cyclone or Anti it is possible to have an anticyclone, okay. It is possible to have your twister.

So, all these are wind. So, the winds can be the scales can be so it is difficult to model winds if you are trying to solve the fluid mechanics part of the problem. If you are trying to solve it as a fluid mechanics problem there can be small scales there can be large scales. There can be atmospheric turbulence there is also a boundary layer within the atmosphere and everything can be cleaning. Everything can be everything is absolutely fine.

But in the airplane goes the sudden turbulence which is called cat clean air turbulence which we do not know okay clean air turbulence so clean air turbulence can be for a few 10's of kilometers or the aircraft will go through this for 5 minutes 900 kilometers per hour 5 minutes means you can figure out it is of the order of 100 kilometers. Cyclones so all these are a part of what these winds are source of what is called atmospheric general circulation okay.

So, the atmospheric general circulation is basically cost is basically the consequence of all these winds. And now let us see the various kinds of winds quickly.

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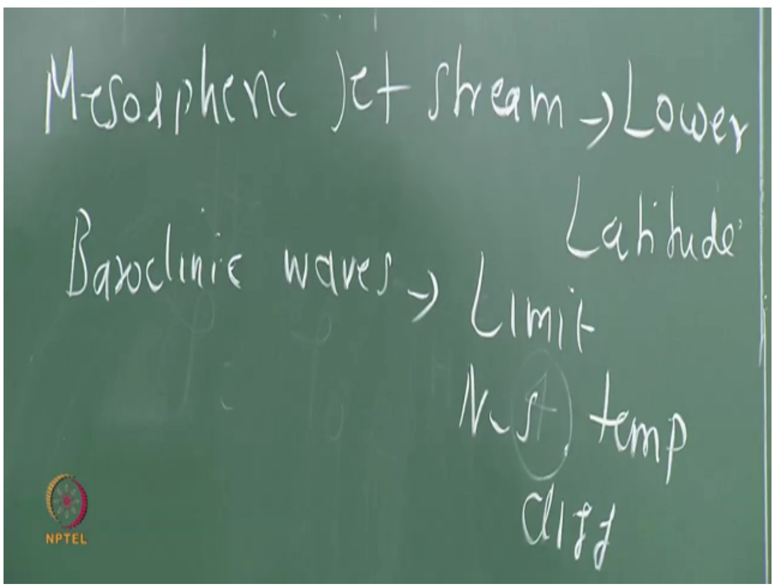

So, planetary winds, so, these are basically westerlies. A Westerlies is by definition of wind which is flowing from west to east, okay. We also have so the Tropos the Tropospheric Jetstream which is shown in the slide. The Tropospheric Jetstream which is shown here you can see, okay.

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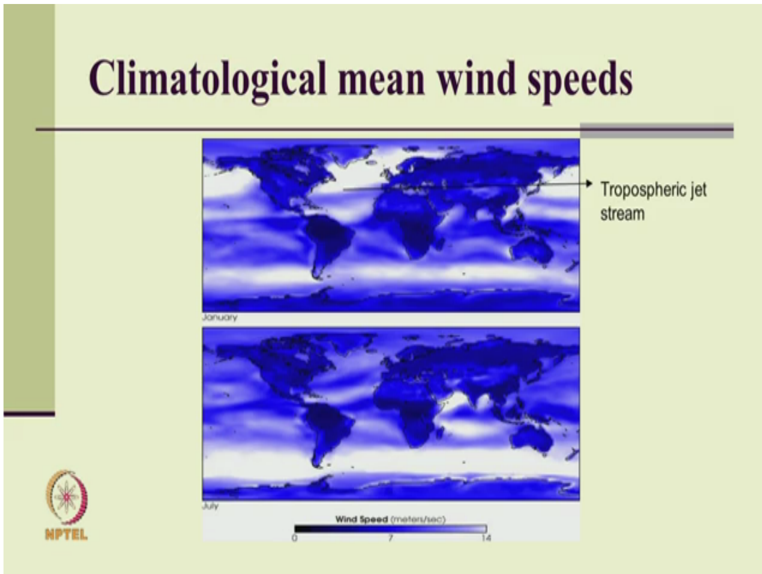

So, you can see the color code if it is dark blue, it is a few meters per second. If it is light blue, it is 7 meters per second. If it is almost whitish blue, then, it is very high. So, you can see that the tropospheric jetstream, okay. You know that the trope prophet is Tropospheric Jetstream is responsible for maintaining decent temperatures one of the reasons for maintaining decent temperatures of the East Coast of U.S. and all that, right.

So, we can keep on discussing with this. We are basically, it is only an introduction chapter, we will quickly go through this. So, the planetary winds are westerlies. There is also we have meso tropospheric mesospheric jet stream which is at lower latitudes. So, this is basically at mid-latitude. Then, we also have what are called Baro clinic waves which are flowing from equator to the pole which limit the north-south temperature difference, ok. The baro clinic waves limit the north south temperature difference.

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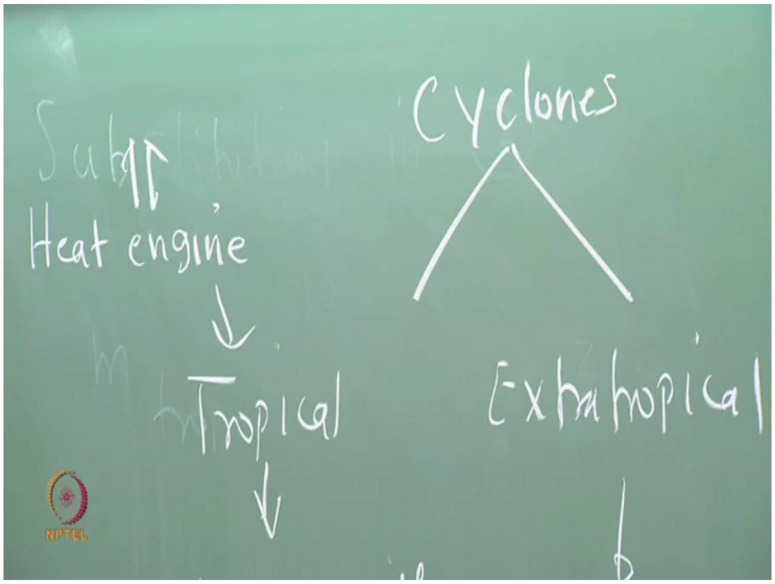

Then, we have tropical cyclones. So, you can have tropical and extra-tropical. Extra-tropical is a cyclone which occurs which occurs outside the tropics. A tropical cyclone occurs within the tropics is + or - 23 degrees, okay, okay. So, the tropical cyclone is a big is a meso scale, okay. Meso scale means is the order of few 100s of kilometer to thousands of kilometers. That is a a meso scale.

So, the tropical cyclone you can have something like this okay. There will be a portion where the pressure is lowest. This is known as the eye of the cyclone and generally it will move. Generally it will move northwards and then because of the Coriolis component the Earth's rotation it generally moves towards the west, sometimes it will go to the land, it will resurface and all that. So, accurate prediction on this tropic tropical cyclones, 48 hours before 72 hours before is very important.

To prevent loss of life and property, to give adequate warning, to take mitigation measures, to move cattle and so on, okay. So, this comes under what is called NWP numerical weather prediction, okay. So, the cyclone by definition is what is a big heat engine, how does it get energy? We do not burn a fuel what is the source of energy? It is the release of latent heat of condensation.

The release of latent heat of condensation, what are becoming water, what will become water vapor. And this latent heat of condensation is the source of energy. So, whenever the cyclone is in the ocean because of this latent heat and all this. This transfer processes it will become lot of energy it will become more and more virulent and violent.

As it hits the as it hits the land there will be a lot of buildings trees and it has its source of energies reduced because the water the condensation is not available for it. Therefore it slowly reduces its power and after some few 100 kilometers it completely dissipates. When it brings, when it hits the land, it also brings with lot of clouds, many of which many of these clouds are rain bearing clouds. Therefore, the tropical cyclone is associated with lot of rain and because there is a huge pressure difference.

You can calculate that because of this pressure difference you can actually calculate the velocity maximum wind speed, which we will do in the later part of the course. Then it will come with terrific winds so it can also destroy electrical cables, transformers, okay buildings and these things and so on. So, it is basically, there is lot of, it is not just rain, it is the violent the tropical cyclone can be very violent.

They call it as typhoon in other places for example right now there is a typhoon Halong for example it is possible in SriLanka or in Andaman and Nicobar from east of Andaman you can have a cyclone just crosses the Andaman, just crosses heavy crust and goes and rain and then it goes to the left, it is possible. But the landmass is sufficient because the landmass basically results in the dissipation, okay because of the friction, all right.

So, we can keep on talking about the cyclone prediction is my area of research, one of the areas of research. So, I should exercise restraint and go to the next one, alright. So, you can look at our papers Chandrasekaran, Balaji and all that if you have written some papers and prediction of tropical cyclone, all right. Now, winds, winds and pressure. I also told you about smaller scales like plumes, right.

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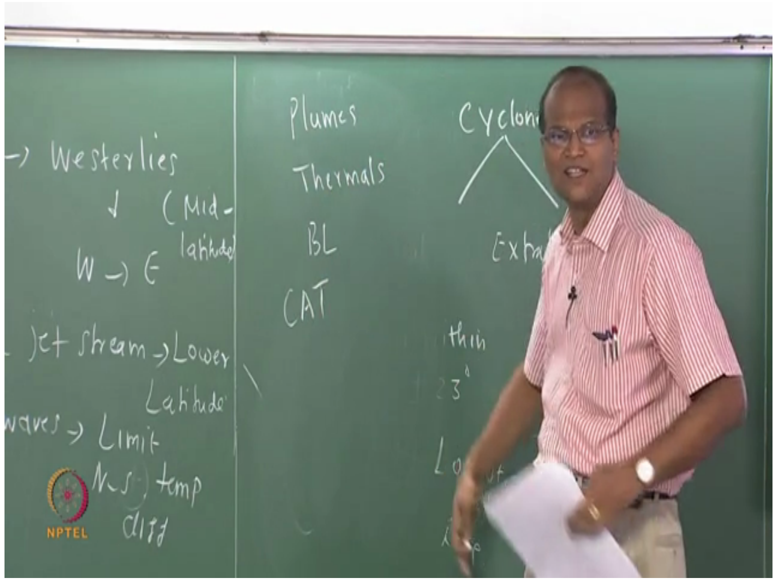

Plumes, thermals, boundary layer, clear air turbulence, these are all the other things associated with winds, okay. So, these plumes thermals atmospheric boundary layer then carry turbulence right. So, these are all the smaller scale, okay.

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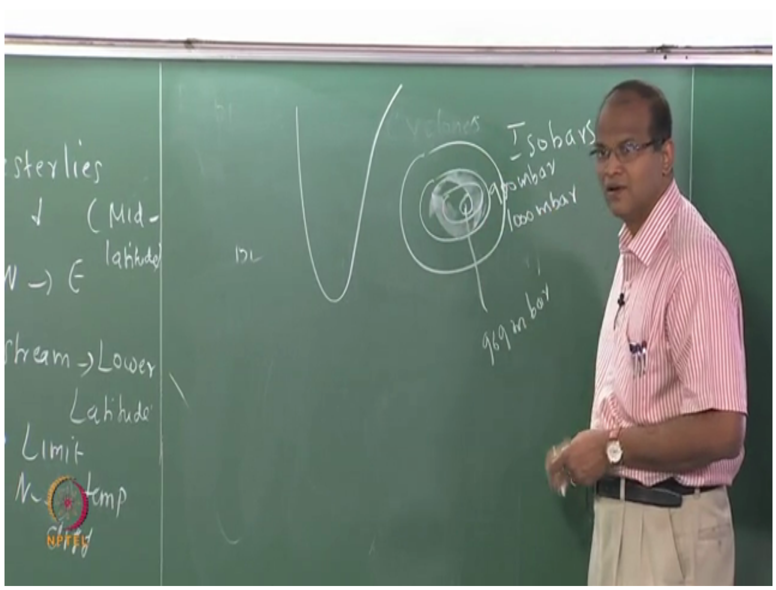

Now, it is possible for you fits like this. So, these are basically called isobars, line joining points having equal pressure, okay. So, you can say 1000 millibar, 980 millibar, so the centre could be some 960 millibar. So, the pressure gradient if you know from the Bernoulli's equation all that the pressure, more the difference in pressure, the winds will be very strong. So, if these isobars are all very crowded and the center pressure will be 949, 950 and so on, you can actually calculate the wind speed by using by simplifying the governing loss.

This is called the cyclist profit approximation which we will see later we can actually get a first order estimate or whether it will be 20 meter per second, 40 meter per second, 60 meter per second and so on, based on which you can classify as a low pressure, weak depression, strong depression, category 1 storm, category 2 storm, category 3 storm and the worst will be the category 5 storm. Katrina they are called super some super cyclone, okay.

We have got so that means they are all very highly concentrated. But the eye will be very calm so the rain will occur mostly around this region, okay. At the center there would not be rain basically because of this dynamics of the cyclone. We can study later, all right. Now, this picture shows you the distribution, in the distribution of this climatological mean wind speed climatological mean wind speed means it is averaged or very rainy season. You can see that this planet remains white color. They are very dominant in the mid latitudes and so on, okay.

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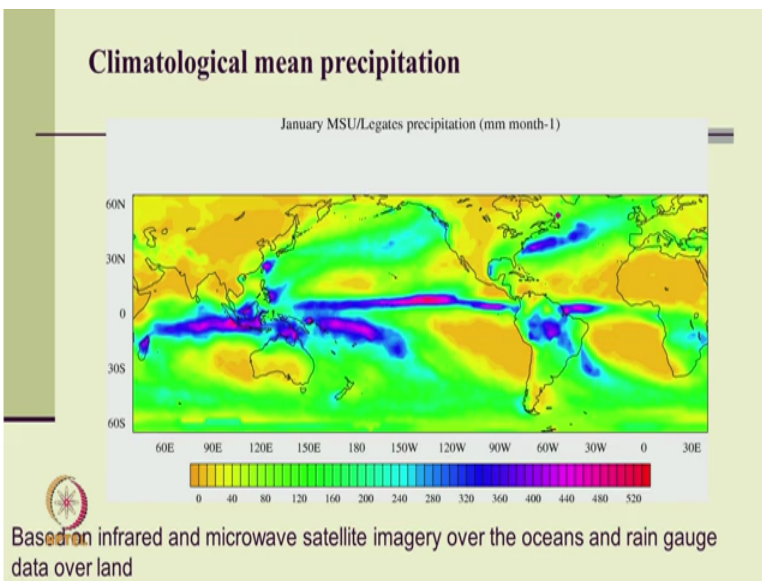

The last thing we have to consider in our introduction chapter is the climatological mean precipitation. So, this is basically I will post you these slides okay in a couple of days. So, the climatological mean proceed this is basically for the month of January. You can see that the scale is millimeters per month you can see that lot of rain is concentrated in + or - 7 degrees north and south which is called the ITCZ. So, the last one we are considering is, okay.

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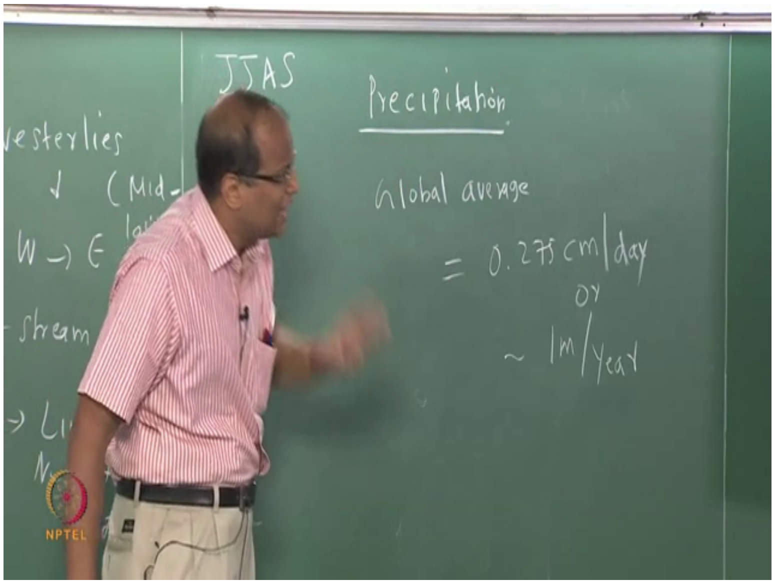

So, the last one is the, I am sorry I think this is precipitation so the global average. Any idea, what will be the global average per day? Rainfall averaged over the globe, 0.275 centimeter per day or approximately 1 meter per year, so which will be like this from the surface so this is the average one meter per year. There are places like Gulf, Saudi Arabia, all this, where there is no rain. There are places like Sarah, Punji, Kerala and all these places, Mumbai for example, where there is heavy rain.

So, this is the average generally the rain is very heavy in the equatorial regions as it can be seen, right, the millimeters, per millimeter per month. This is, this is the unit so you can see that near the equator you got high rainfall, okay. So, you can see here. This is what is this? Japan is this, Taiwan, okay. So, Taiwan and so you can see Singapore and all the good heavy rain so, this is the January rain, okay.

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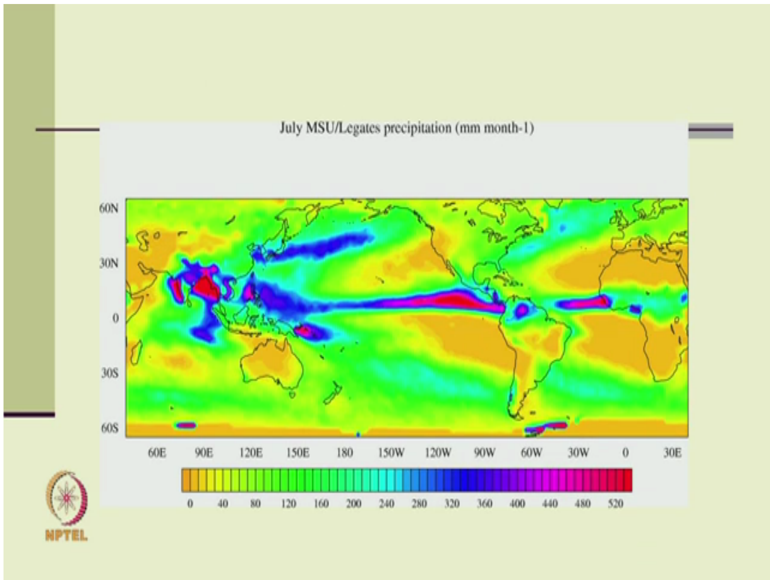

Very interesting, is basically the July rain. Now you are all students of atmospheric science. Please tell me what are the salient features of the July rain? Very good, monsoon. Where is a monsoon in this light where can you see sure India where, where in India except for a Northwest, west coast, okay. Bombay to Trivandrum you can see that heavy rain in July. This is a July average.

So, you can see the monsoon in India. The monsoon is also there in Calcutta, Bangladesh and all this, okay. So, people from the East will confirm that you got, you get good rain in July. So, we call it as we call to the JJAS rain.

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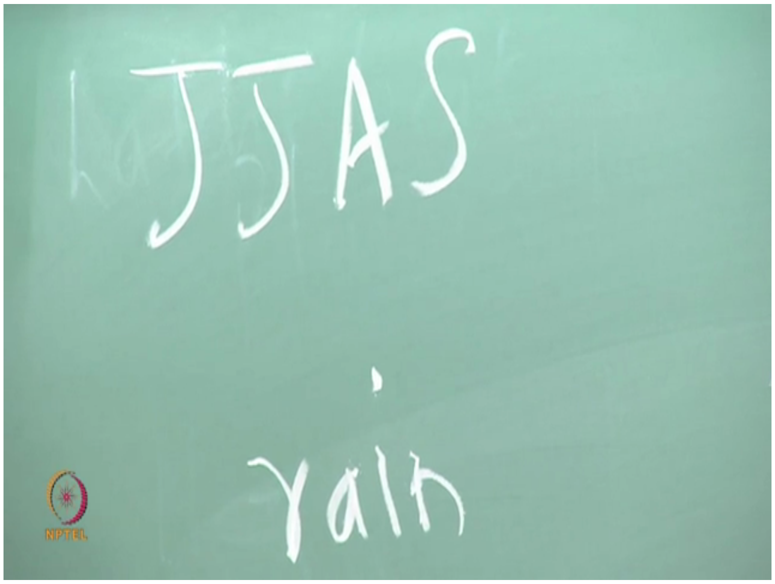

June, July, August, September. This is the terminology using JJAS. That is the Indian monsoon okay. June, July, August, September, July, right now July crossed. People are arguing about El Nino effect reduced, monsoon or July is picked up June was very bad in India. You can see that very interesting this thing near the equator again there is heavy rain but you can see in now near Japan also it is monsoon, cyclone time in Japan so you can see that this confirms.

Then, you can see that near Papua New Guinea it is rain and so, right. So, you can see that as you go down the rain decreases and you can see that parts of the Gulf okay absolutely dry throughout, okay throughout. It it is dry but you can see that during January it is not raining anywhere in India, during January it is not raining anywhere India. But it changes in so what is this funda about this monsoon, okay.

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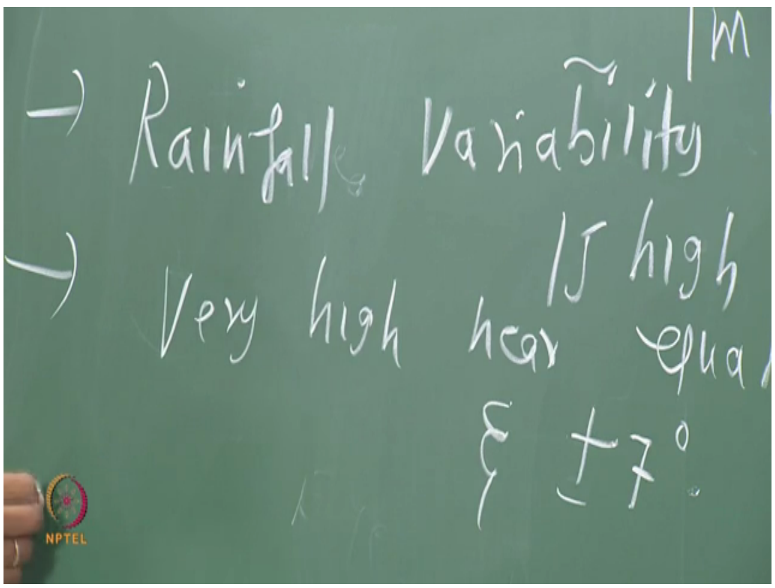

So, if you look at precipitation so you can see that near equator it is high. So, the first thing is what can you see? The scale is from 0 to 520 and from orange color to red color and all the colors of there all over the place. So, what is the first point you figure out? Rainfall is highly variable. There is high variability of rainfall, okay. Rainfall variability is high very high in the tropics, correct. Very high near equator, okay. Some are monsoon in the northern hemisphere monsoon word comes from the Persian or Arabic word mausome.

Mausome is weather. So, people could not pronounce mausome I think they made it monsoon. Just like Thiruchirappalli was made thiru chira palli and then trichy, right. Thiruchirapalli, okay very sophisticatedly we call it Trichy. Like this mausome we came to monsoon, okay. So, what is this funda about the monsoon? The winds, the winds along with the clouds are actually coming from the south, they cross the equator and they move here, okay.

They from the west they are trying to come to the cross the Indian landmass. There is a heavy there is a high Western Ghats, okay so these are carrying as they cross the equator because of this high tropical convection. What is that the + or - sign on degrees is called ITCZ which is called the Intertropical Convergence zone. Intertropical Convergence zone the equator is here so the winds are blowing from both sides.

And they are blowing like this, there is a rising of the airmass and because of this lot of heat which is generated because of the, because it is closed it is the equatorial region so you get towering high clouds cumulonimbus clouds, okay. So, when these winds are crossing from south to north, they will carry these clouds into the they bring this rain bearing clouds into India, the west coast of India and as for Chennai is the problem because we were to cross the Western ghats.

Chennai is in the rain shadow region so Chennai you can see there is no rain. Where is Chennai here? There is no rain but you may ask Sir, how come there is rain here? What happens is some are some winds are brought here and by the Coriolis component of the Earth's this thing they take a turn here and then simultaneously there is a low pressure which is created in the indo-gangetic plain, okay.

Because the low pressure is created in indo-gangetic plain there are heavy clouds at the head. We had the head bay that is south of Bangladesh there is a lot of cloud mass and there is a difference in pressure and general direction then because of the Coriolis component the winds flow west that so your Bihar, Chhattisgarh, Jharkhand, Uttar Pradesh, all these places, Delhi, Haryana, all these places also get rain.

But the beauty is Tamil Nadu is left out. Tamil Nadu is left out in fact there is a strong correlation between Chennai rain and, and the monsoon average. If JJAS, June July August September rainfall is very high in Chennai, monsoon will be failure in India. They are inversely correlated. We got a lot of rain in June but now it has become hot again. So, if Chennai gets lot of rain that means somewhere it is not raining because our rain is the Northeast Monsoon.

The northeast monsoon basically is let us see the previous figure. Here it is January so if you have talked about November then, there will be rain in this region and not this monsoon. The winds are coming from here okay when the winds are coming from here what happens is, it is not a sustained wind like the southwest monsoon. So, rainfall is invariably produced by tropical cyclones because the sea surface temperature is high.

Then, there is a latent heat of condensation the winds bring. So, the even though a lot of rain bearing clouds may be there in the ocean, it is the wind which bring the rain. Monsoon is not just the clouds. The winds have to bring the clouds to the land. Otherwise in the ocean it will keep on raining. What is the use? It is most of the times it is raining over the ocean. But because we are not living in the ocean we are living. So, we want the winds to come and hit the land okay.

So, precipitation is a big area of research. Globally precipitation is =evaporation that is a hydrological balance. But locally precipitation is not =evaporation. In Saudi Arabia, there is much more evaporation and precipitation. In Kerala, there is much more precipitation than evaporation. So, these regional imbalances, the problem is because of climate change they are saying that these imbalances are growing. Wherever it is not raining it is raining even less; wherever it is raining it is raining even more, okay.

And instead of raining continuously 5, 5 centimeters every day it just range 50 centimeters one day and 25 days it is not raining. So extremes are also increasing, okay. This what, if you have to do this, you have to do a very sophisticated analysis remove the effect of all the variables and you have to study the correlation coefficient and you have to do extensive statistical analysis, okay. So, this brings us to the end of this chapter. Any doubts so far, okay.

The January or July currently, say that again, I do not understand. Beyond means like this well that is a yes mm generally it is happening the north also is it not it I would say there. The this brown color it is happening, but also the landmass is not uniformly distributed. There are winds the land mass is also not uniformly distributed so, right. So, if you see this it is more or less symmetric because there is nothing in between.

But here the South America or North America there is a peculiar shape. So, because of this peculiar shape, the winds may change this thing and there is a tropospheric Jetstream, it is a combination of various factors, okay. So, the shape of the landmass also plays a part. So, that is why it would not have a perfect knots of the symmetry, right. And there is more land in the northern hemisphere than the southern hemisphere correct, know. Is it clear?

So, it requires some higher order analysis. Atmospheric science is a new subject many questions are still open. People have not answered. It is less than 100 years old. It is not like thermodynamics to civil engineering is 300 years old, ok. So the next chapter, so we have completed the first chapter. So, we are going to the second chapter now. Basically this is the earth system, ok.

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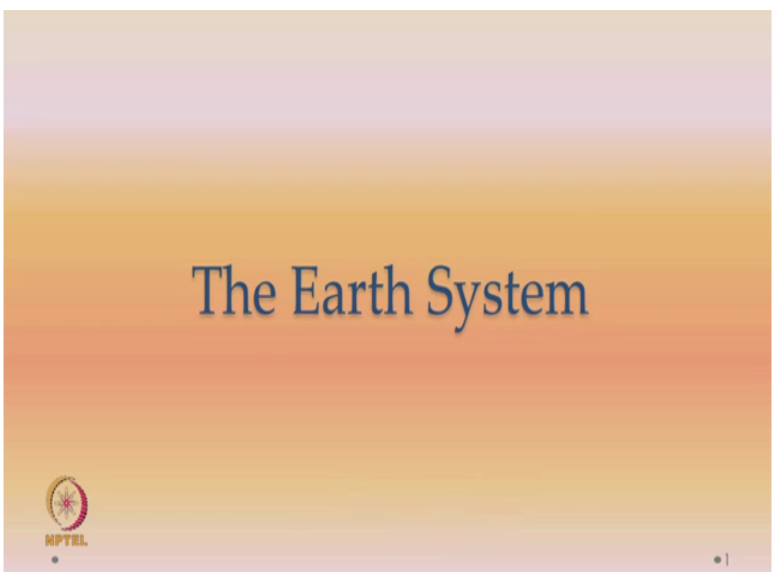

So, we will spend about a couple of hours in this chapter. And then, after this we have we move on to atmospheric thermodynamics. You can take down this a very important statement.

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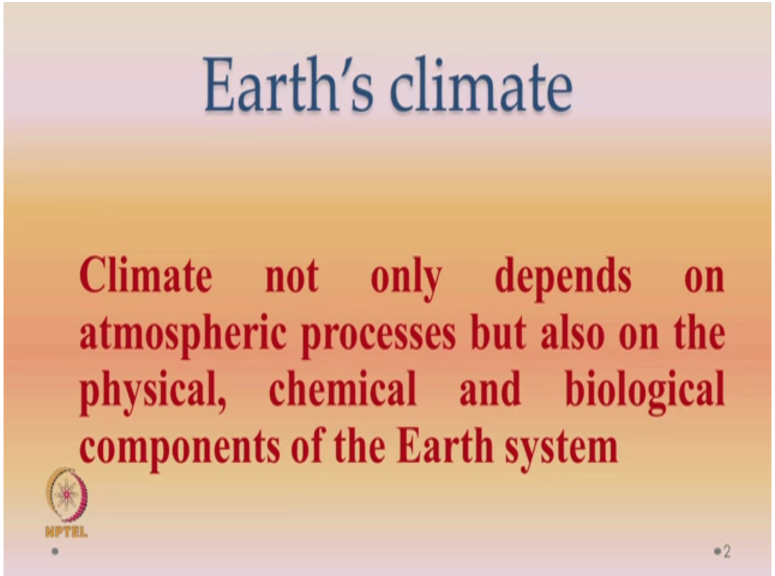

The climate of the earth not only depends on the atmospheric processes but also on the physical, chemical and biological components of the earth system. I come again. The climate of the earth not only depends on the atmospheric processes but also on the physical, chemical and biological components of the earth system, ok. Now, this definition has to be fleshed out this statement has to be fleshed out. We will have to see what are these physical, chemical and biological components, okay? Now, shall I move to the next slide?

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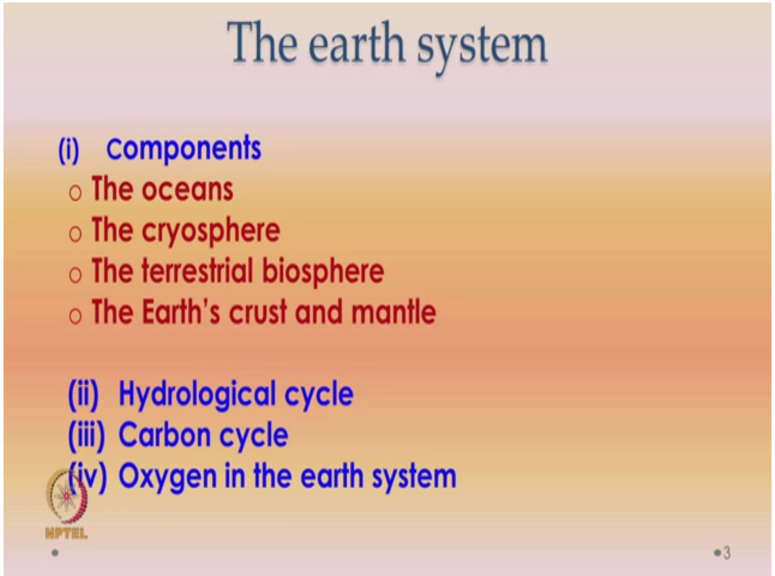

Please take this down. The earth system, the components are: First, the oceans next, the cryosphere, next, the terrestrial biosphere and fourth, the Earth's crust and mantle. The components of the earth system are first, the oceans then, the cryosphere then, the terrestrial biosphere then, the earth’s crust and mantle. Oceans cover 72 % right of the Earth's surface, right. Oceans are very important they have a large thermal inertia M into CP, okay.

They are responsible for making the earth highly habitable because they reduce the temperature anomalies and temperature differences. In the oceans also there is a biosphere because there are Phytoplankton, animals, plants, all these things so, there is a photosynthesis. There is this activity in the oceans also, right. The cryosphere is that part so, oceans is clear. The cryosphere is that part where everything is in the form of ice, glacier, Antarctics, Arctics, Permafrost in Siberia.

It is Siberia where everything is permanently frosted, okay. It is frost everywhere. So, these things are when they melt, when the radiation falls, they melt and then, when they melt, what happens is the reflectivity changes and reflectivity changes more illuminating will take place then more melting means more reflectivity. So, they all have feedback effects. So, we have to look at the cryosphere. When they melt, they also release water into the oceans, okay. When they freeze some water is reduced so, it is also involved in the water balance.

Next, the terrestrial biosphere is basically all the plants, trees in all these land masses, okay. Photosynthesis, afforestation, deforestation, right forest fires and this is very important in the oxygen and carbon dioxide cycle balance, right. And then, finally the Earth's crust and mantle plate tectonics which leads to earthquakes and so on. So, sometimes volcanic eruptions from the inside of the Earth's crust, some sulphur dioxide, and aerosols are all thrown out, okay.

And from the Earth's crust some things are transferred to the ocean from the ocean it is transferred to the atmosphere. So, this is if so, there is lot of convective heat transfer taking place in the Earth's crust and mantle. If you want to study this you are you are specializing in a topic called mantle convection. So, you have to study the magnetic field this thing, all these things are taken into account and you do not take a 10 centimeter by 10 centimeter cavity and solve it using fluent.

It so it will be 100's of kilometers, so your grid size, number of nodes, you may require supercomputer to solve, or other possibilities to take the general equations, simplify take only the most powerful terms and try to analytically solve. We use a transformation so all these things are possible, ok. That is also fluid mechanics. So, the earth system is determined not only by the 4 components, by the hydrological cycle precipitation, ok.

Precipitation, evaporation, transpiration, all this runoff ok surface runoff all these things are part of the hydrological cycle. In the insuent classes we will see all these one by one then, the carbon cycle, ok. Carbon cycle is not only involved in photosynthesis carbon, carbon calcium, so, carbon and calcium carbonate and all this in the rocks and all this activity which is taking place. So, the carbon cycle is very, very important, ok in this earth system.

And then, oxygen in the Earth's system; oxygen is required for the sustenance of life who the original when the earth was first formed, there was no, the it is completely devoid of oxygen you might have heard this. Then, oxygen slowly evolved and what are the mechanisms which are responsible for the generation and sustenance of oxygen these things we will see. So, so, the next few lectures will be on this.

After we complete this will go to the third chapter which will be atmospheric thermodynamics, ok. So, we still have some time we will just start with this.

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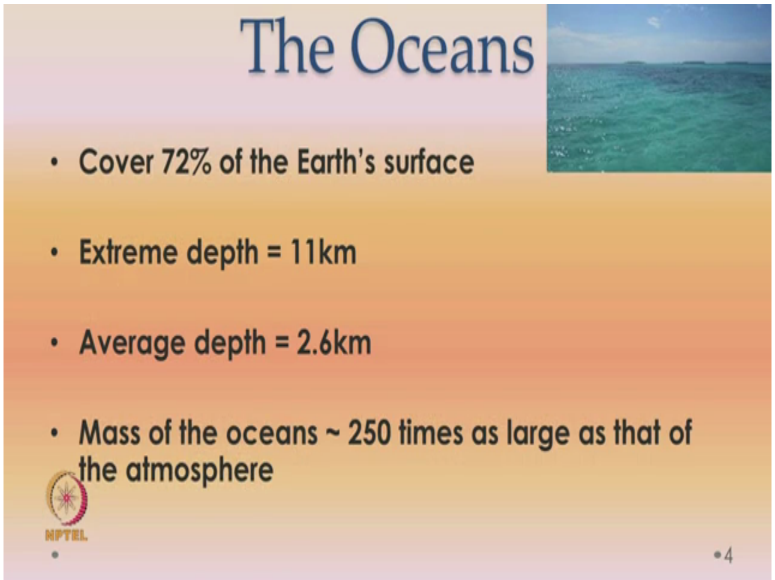

The oceans I will make this slide make these slides available to you but important points you can just note down so that you do not fall asleep, ok. So, the oceans cover 72% of the Earth's surface. The extreme depth Mariana Trench of what is it somewhere it is about 11 kilometres, alright. Oceans cover 72% of Earth's surface, extreme depth is 11 kilometers, the average depth is about 2.6 kilometers.

Quite high it is about 2.6 kilometers, right the mass of the oceans is 250 times as large of that of the atmosphere. So, 5.11 into 10 to the power of 18 kg into 250 and that will be water. That is why we have abused power plant. We take cold water from the ocean and heat it and put it back put it and put it back. We, we reject all the power plant all the power plant exhausts is basically going either to the ocean or to the atmosphere, okay.

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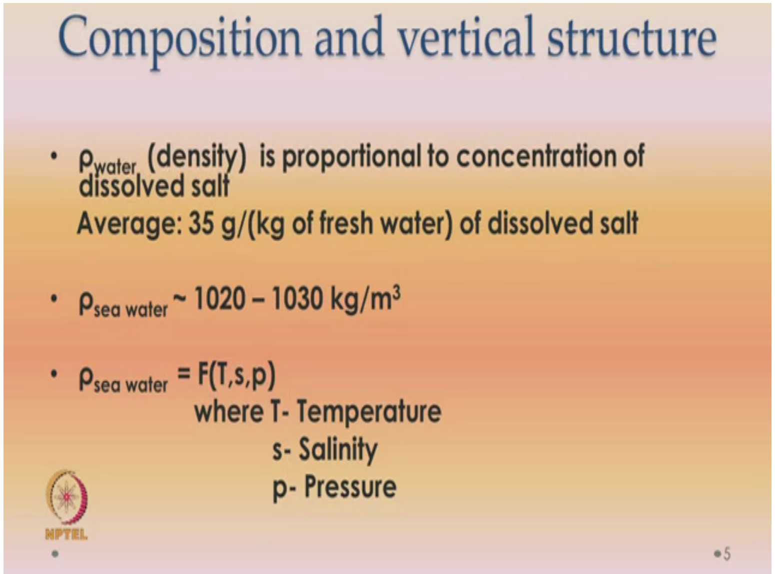

The density of water is proportional to the concentration of dissolved salt. This is pretty obvious to you. Average is about 35 grams per kg of fresh water, okay. So, that means about 3and a half %; the salt content is okay in the ocean. So, the density of seawater is not 1000 kilogram per meter cube it varies between 1020 and 1030 kilo gram per meter cube. So, this density of seawater is a function of the temperature salinity and the pressure, okay.

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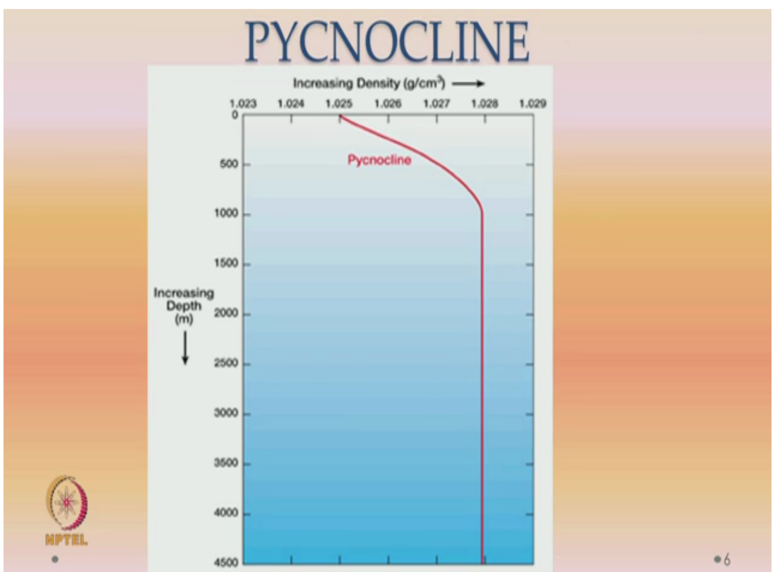

Please take down this figure. So, this is basically the density of water. The density of water with depth, okay. So, the region where the density sharply changes with depth is called the pycnocline after that it is well mixed. That means the density is more or less constant, okay. So, this is the typical but the increase is not too much it is increasing from 1.025 to 1.028 or something, okay.

So, the plot is, it is also peculiar you can see. Density should have been in the y-axis and the depth should have in the x-axis. But we always draw like this in atmospheric science; height will be always the vertical coordinate; height or depth okay, all right.

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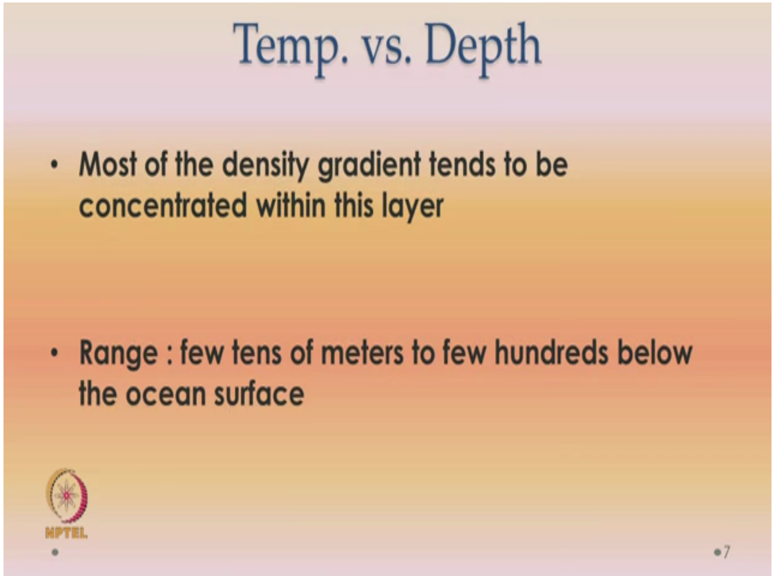

Most of the density gradient tends to be concentrated within this layer, which layer this pycnocline range. So, this that depth, this depth which one, this one, where it changes, it varies from few tens of meters to few 100s of meters, okay.

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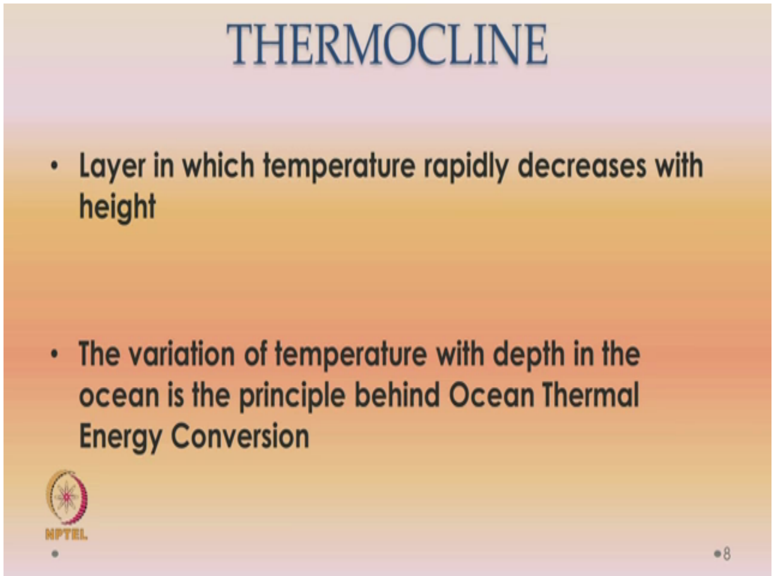

Thermocline the pycnocline is that with respect to salinity. The thermocline is, is with respect to temperature. So, the layer in which temperature rapidly decreases with height, okay. So, I will show you this.

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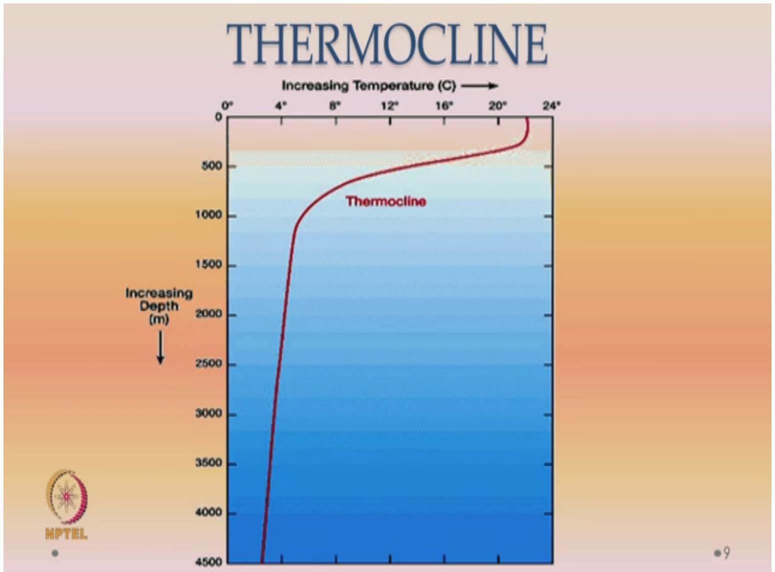

You can take down this. This is a very important plot. Temperature was at depth of the ocean, okay. So, the temperature of the surface here is, what is the temperature at the surface? 20 to 22 or 22 degree centigrade, correct. The temperature the surface is 22 degree centigrade. What is the temperature at 1,000 meters depth, okay?

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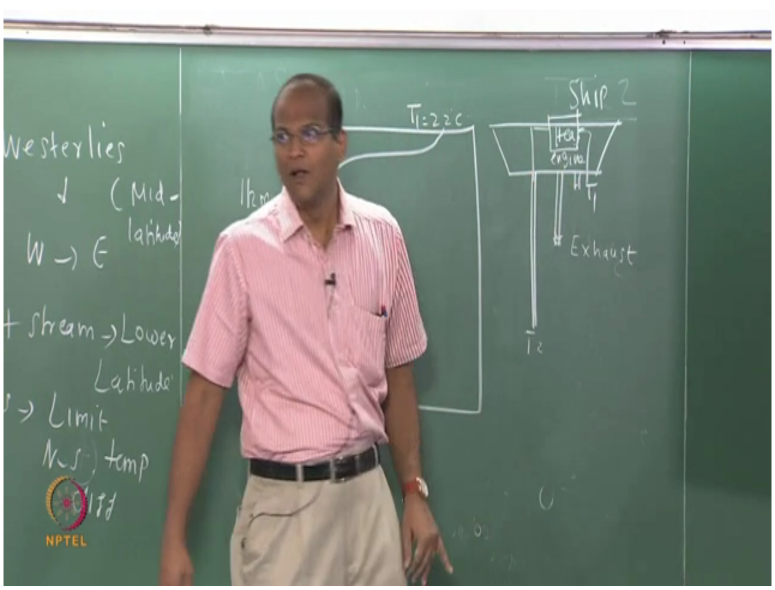

So, let us say this is T1, ok; so, T1 how it is possible to run a heat engine between these two temperatures and generate power. This is the principle of ocean thermal energy conversion, okay. What take ocean thermal energy conversion? So, what you do is, you take hot water at 22 degree centigrade and use this water to convert the fluid, to convert some working medium from liquid to vapor. This vapor will run a low temperature turbine.

Work will be produced. Then, the exhaust from this turbine, okay that will be condensed by the cold water from below, okay so, you can have, you can have a ship. So, here it is T1 here is T2 then you run a heat engine then, after this is done you will dump the water somewhere here, okay. So, you will find out how much the temperature is increased then you will find out the depth at which it matches with the depth of the outside and then you will exhaust it. But basically this is easier said than done, because from a ship how do you transfer power to the shore?

Conceptually, it is very appealing that the ocean temperature difference can be used with the harness power. It is intellectually appealing but there are a lot of practical difficulties. For example, of the Chennai Coast, okay

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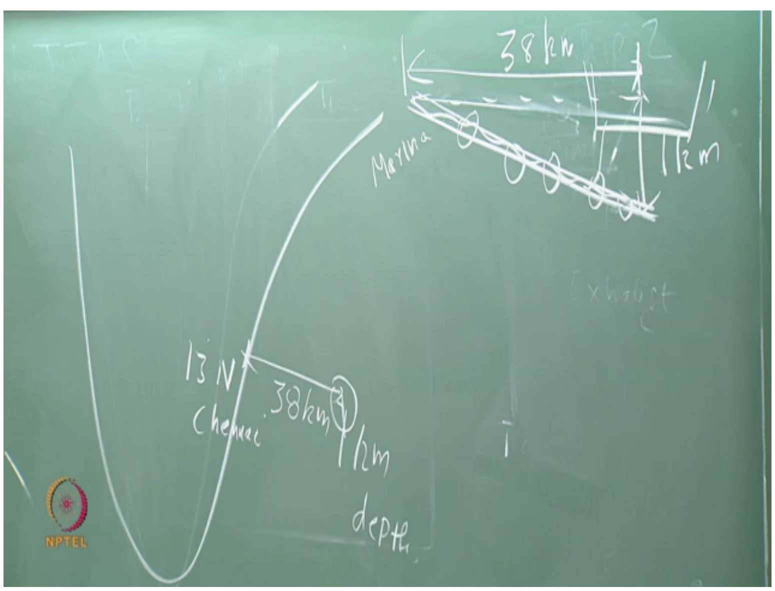

To reach 1 kilometer depth you have to go 38 kilometers. So, which means if this is your marina, it is very gentle. This 1 kilometer takes about 38 kilometers. So, if you want to have a power plant based on Vortech you should be able to lay your pipe here right and then you should be able to anchor all this and so you have to have very specialist underwater diving underwater divers will do this or you will just have it on a ship.

If you have it on a ship then, how do you transfer to the power? The power also has to come through underground cables. What happens in ship if there's a cyclone? These are some of the practical difficulties. However, in places like Andaman and Lakshadweep, the gradient is 1is to 1. You get 1 kilometer depth within 1 kilometer into the ocean. So, you can have your pipes along the ocean floor itself.

And then, it is possible for you to because they are all volcanic islands and all this. So, therefore as a concept it is very good; as a technology it is very good; to make it into an engineering this thing have a power line, takes a lot more effort, okay. So we will continue with the oceans in tomorrow's class. Thank you.