Introduction to Atmospheric Science
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Lecture-06
The Earth system – Hydrological cycle

So, we continue with our discussion on the various components of the Earth System. If you recall this is chapter two. For the sake of continuity I just quickly run through some of the slides which we already saw in the previous class. So, the permafrost is one of the important components. Permafrost is permanent. It is permanent frost, frost embedded in soils for more than two years this happens in places like Siberia.

It affects the ecology and human activities in Siberia, Alaska and Northern Canada. So, we were talking about the climate change because of the climate change this thawing and melting of this permafrost in Siberia. So it is a good few meters 1500 meters depth in Siberia. So, if a global temperature rise of more than 1.5 degree centigrade takes place, which is not far off then, thawing of the Siberian permafrost takes place.

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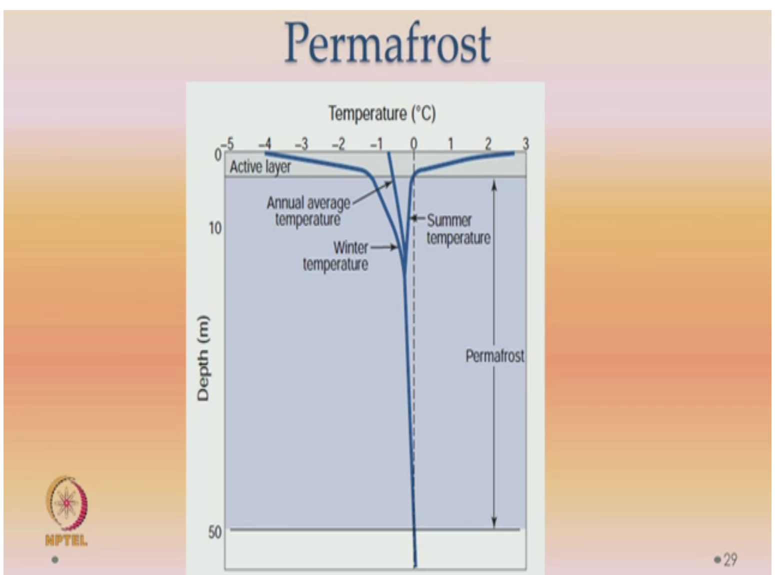

So, this is basically U graph which tells you the temperature versus depth, right. So, you can see that the summer temperature is on the right side. And the winter temperature is on the lower side and the average is something like this. So, the average has to be less than 0 degree centigrade for it to remain as frost. So, you can see that there is some the permafrost we have depicted it up to 50 meters right depth.

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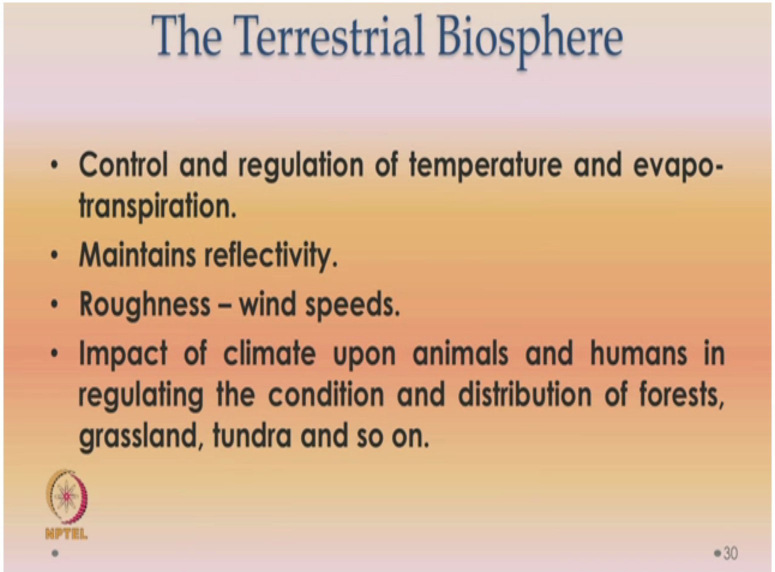

The terrestrial biosphere was the last component we saw in the last class. We, we went through these slides very fast. So, actually the most important thing it controls and regulates the temperature. Vegetation always controls both temperature and precipitation. We can see for example in Kerala, you get more rain okay basically because, the monsoon hits there first and so on and also if it is more green.

For example, IIT we have a temperature drop of 1 to 2 degree centigrade, when you enter the campus from outside that is because of the thick vegetation. There is also an important process which is basically the evapotranspiration which takes place in the plants. And also this vegetation maintains a particular kind of reflectivity, right. So, as you can very well imagine the reflectivity from tropical rainforest is quite different from a reflectivity from this barren desert in Saudi Arabia for example, right.

So, this has ramifications in basically outgoing long wave radiation incoming radiation um whatever has been captured, the reflectivity and all this radiation balance. And also this vegetation can alter the roughness of the surface. The roughness will alter the wind speeds, correct. And then, the impact of climate upon animals in humans and in regulating because of the terrestrial biosphere, we are also there animals are also there so, the impact of all these, animal life on regulating the condition and distribution of forest by afforestation, deforestation, all these things, ok.

Forest fires, natural, naturally induced forest fires, man induced forest fire as far as all these things have a big role to play in deciding the climate of the earth.

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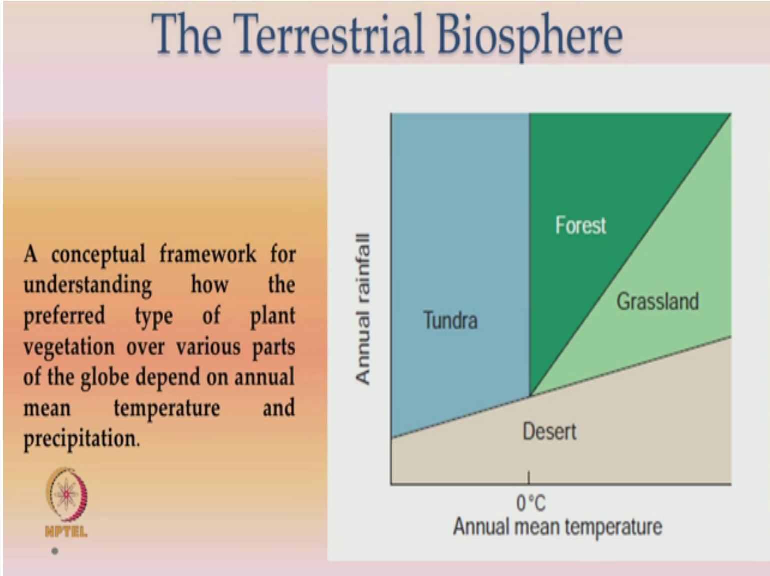

So, the terrestrial biosphere, this is a good conceptual framework for understanding how the a particular type of plant vegetation with various parts of the globe, how it depends or how they depend on annual mean temperature and precipitation. So, on the ordinate is rainfall and on the abscissa is the mean temperature so you can see that as the temperature increases, for regardless the type of vegetation.

As the temperature increases the amount of rainfall which is required increases, right. And obviously, the temperature is going to be very high in the desert region and tundra region the temperature is low and so on. So, you can move from left to right and understand how things vary. You can also move from bottom to top we have already discussed this in the previous class.

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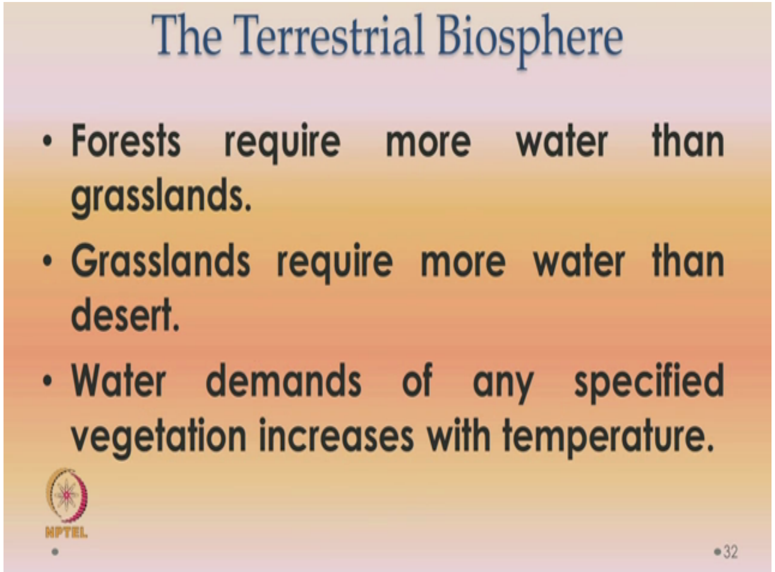

So, to summarize that View graph, forests require more water than grassland. Grasslands require more water than desert and for within a particular vegetation, the vegetation and the water demands of any space particular type of vegetation increases with temperature, ok.

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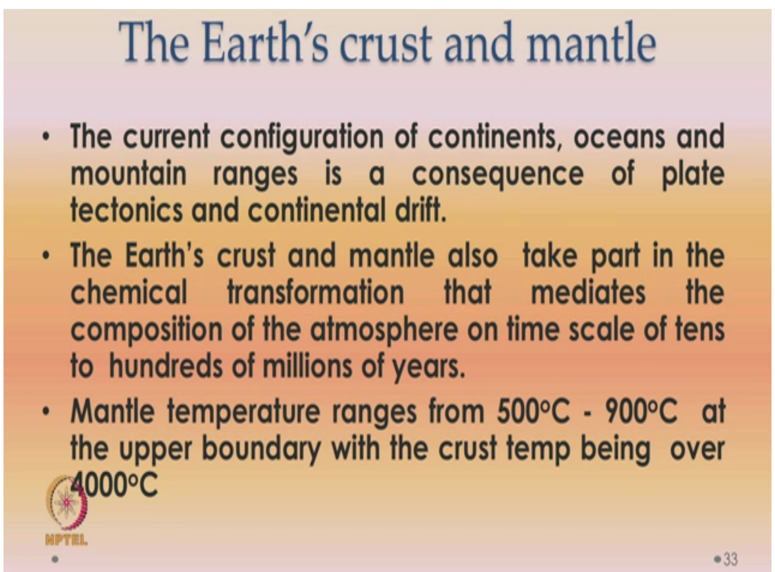

So, the last part basically which we are going to look at in today's class is basically the earth's crust and mantle, often not studied because it is considered as geology or geophysics and so on. But this also a major role to play one of the most important things I to break the suspense is the Earth's crust and mantle have a big role to play in the way the continents have been shaped.

The way the continents have been shaped also is also the is responsible for the way there are ocean currents, climatic regions which regions prospered first, where civilization started first, why did why was steam engine figured out in Europe and all that because the life started in Europe first and all. This it is not that some races particularly to over smart compared to others and so on near the Euphrates River actually Iraq, if you Guns Germs and Steel have you?

There is a book called Guns, Germs and Steel, okay. So, it was the earth's crust and mantles have a major role to play in deciding the shape of the continents, okay. Otherwise there is something called an aqua planet when you do simulations what we do is in atmospheric scientists when they do simulation we can do simulations on what is called an aqua planet. And aqua planet is a simulation where it is 100 % water, okay.

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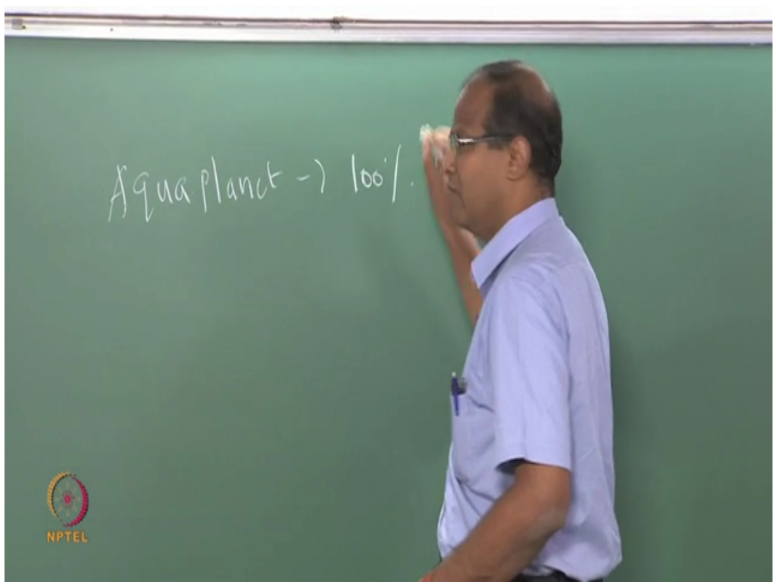

So, in order to get quick estimates we also look at this aqua planet simulation. Funda is, it is not an aqua planet only 72% of our planet 28 % is still okay land. Now let us get into this the current configuration of the various continents oceans and mountain ranges, is basically a consequence of what is called plate tectonics okay and the continental drift. The plate tectonics is actually theory, okay.

It is no belief that it is correct. But no theory is so sacred sank that it cannot be challenged. The goal of human creativity enterprise and knowledge is to basically challenge any theory, ok. The hydrodynamic through a challenge by Prandtl and Prandtl's boundary layer theory is now considered to be the theory. It, it is not the be all and end all of fluid mechanics that could be a new theory which could make explain things better.

As of now, as of now E is = H mu and as of now E is = MC squared okay; as of now Beaudelet Theory, Delta by X is much, much less than one. There is something called the sleeter of length of the boundary layer theory with which you can which you can simplify the governing Navier-Stokes equation and create and make them into boundary layer equations which will transform the elliptic equations into a parabolic differential equations which lend itself amenable to mathematical analysis through a similarity transformation which leads to the Blasier solution.

So, this is a two minute course on fluid mechanics, okay. You can also use the integral method now you the powerful finite volume, finite element and find a difference method to solve all this. Let us get back to this the Earth's crust and mantle. They also take part in the chemical transformation because there can be some something which is at the bottom of the ocean through some volcanic eruptions all these chemicals can be lifted all the way from the bottom to the atmosphere, ok.

So, there is a direct route from deep inside the mantle to the atmosphere. So, they also take part in the chemical transform, transformation. This can lead to changes in the carbon, carbon budgeting as well as the oxygen budgeting. Carbon budgeting which is automatically carbon dioxide in the atmosphere, so, that mediates a composition of the atmosphere on timescales off. But the time scale is not seconds or days or weeks it is of 10 to 100's of millions of years.

It is a very slow process, okay. So, the mantle temperature ranges from 500 to 900 degree centigrade inside the Earth's surface. At the upper boundary with the crust temperature, the crust temperature can be over 4,000 degrees centigrade. So, this is a special plan so this if you are interested in doing this you are going to study as you are interested in a subject called mantle convection, okay which comes under geophysics of geology okay.

Mantle convection is same equations fluid mechanics and heat transfer equations will come but scales will be very different. Temperatures also will be very different. So, your Boussinesq approximation and all that we do not know whether they will be valid or not, okay.

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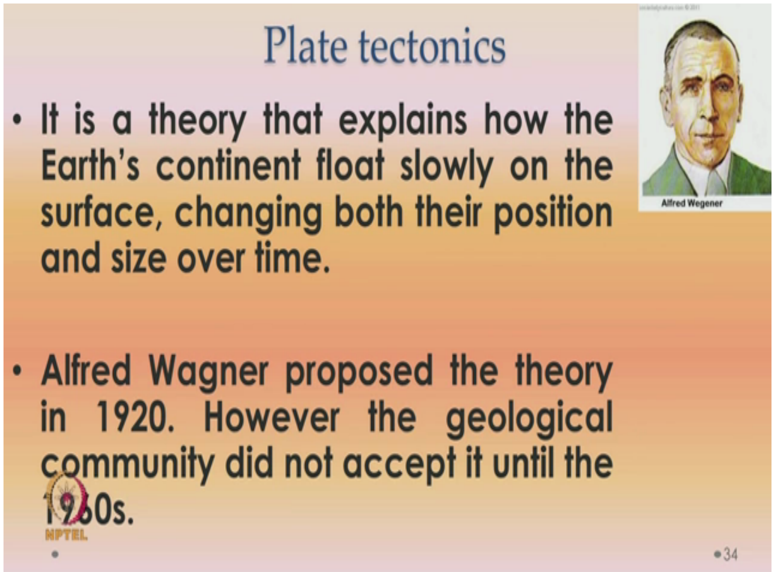

That is Alfred Wagner. So, 1880 to 1930 fluid for 50 years the German, okay so he figured out this theory. He proposed this theory of plate tectonics. What is plate tectonics? Plate tectonics is a theory that explains how the Earth's continents float slowly on the surface changing both their position. It should be Earth's continents changing both their position and size over time, okay the shape and size of continents.

So, they are saying that there everything is floating; that is what he is saying, okay. Everything is floating on the mantle, okay. He proposed a theory in 1920 as usual people did not accept this theory for a long time, okay. So, it took about thirty forty years so it was geological community which accepted this theory only in the 60's. So, this acceptance of this theory is less than 50, is around 50 years old.

What does this theory say? According to this theory, the Earth's crust also known as the lithosphere is broken up into approximately around 10 plates. There are some 10 plates, these plates are actually floating. It is scary to hear about this. But you will hear about this, but this is the truth. They are actually floating on the Earth's mantle, okay on the Earth's upper mantle the mantle is a partially molten layer consisting of various chemicals liquids and all that.

So these plates are floating on this. So, the major geological activity takes place at the interface of these various plates. At the interface of these various plates, plates can approach each other okay; then, plates can move away from each other. There could be some shear between this because of this lot of geological activities are taking place. What kind of geological activities?

The earthquakes, this thing and all that, we will see there will be some fault lines and all that, right, see small edges work on this. So, where in one plate tries to push into another, they pull further apart or move sideways with tremendous power, when these things are taking place, some action results.

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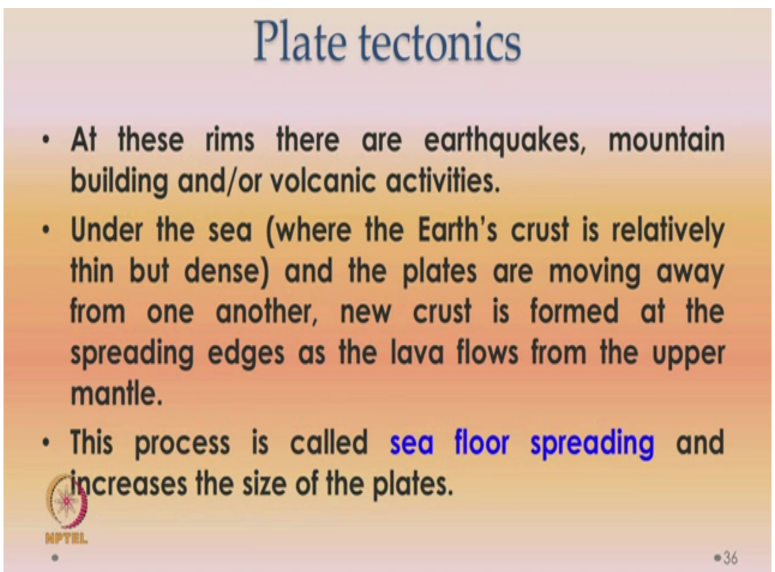

What is this action? At these rims, where these actions take place, there are earthquakes, mountain building and or volcanic activities, okay. This is a theory which he proposed. Under the sea, where the earth crust is relatively thin, okay under the sea, because already a lot of depth is covered by the water, the Earth's crust is relatively thin, but dense the plates are moving away from one another the new crust is formed at the spreading edges as the lava flows.

I will show you, to become more clear with the picture, as the lava flows from the upper mantle. So, this process is actually called the seafloor spreading and increases the size of the plates, okay.

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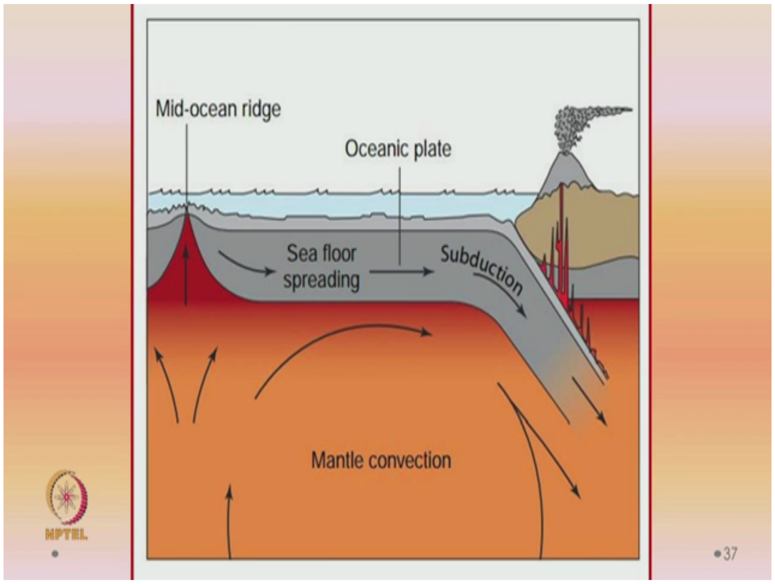

So I will give this presentation there is no need to copy this. So, there is a oceanic plate so I explained this concept. So, there is a mantle, so there is a mantle convection which is taking place. So, this is the ocean so here we have oceanic plate and there is a seafloor spreading and there is a subduction where this plate is just sucked. It goes into this, okay. When the rims of the thin undersea tectonic plates come towards one another, one edge goes under the another, other one edge goes under this is called subduction where the plate gets smaller.

Plates that lie above the region of up willing in the upwelling upwelling is the region where from the mantle that convection. Something is going up, they are spreading. So, somewhere it is spreading. Somewhere, it is some subducting and so on. So, where as plates that lay above the region of down welling are being pushed together. So, which means in slowly but surely the shape and size of the continents is changing. Some geological activity is taking place below, right.

So, earthquakes tend to be concentrated along the plate boundaries wherever there are there is an interface between the various plates you can actually see that the fault lines and the earthquakes are taking place along this you misses somebody must have taught you about this before, right.

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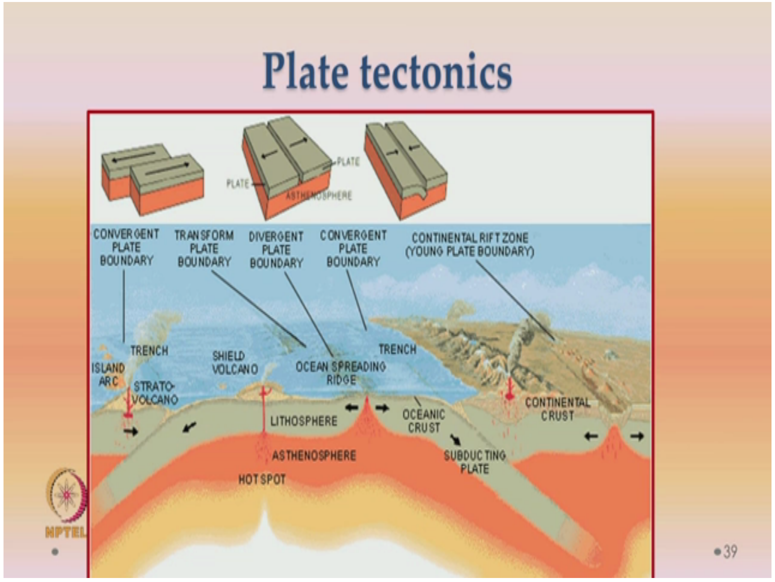

So, this is a picture where the left side it says there is a shear between the two plates. Here the two plates are moving apart. Here the two plates are moving towards each other. So, you can see hotspots, lithosphere, so, this is just a overview, right. So, there is something called convergent plate boundary, divergent plate boundary. Let us not get into all these details because our goal is to study atmosphere, okay. This is just to, just to give you overview, alright. I will give you this picture, okay.

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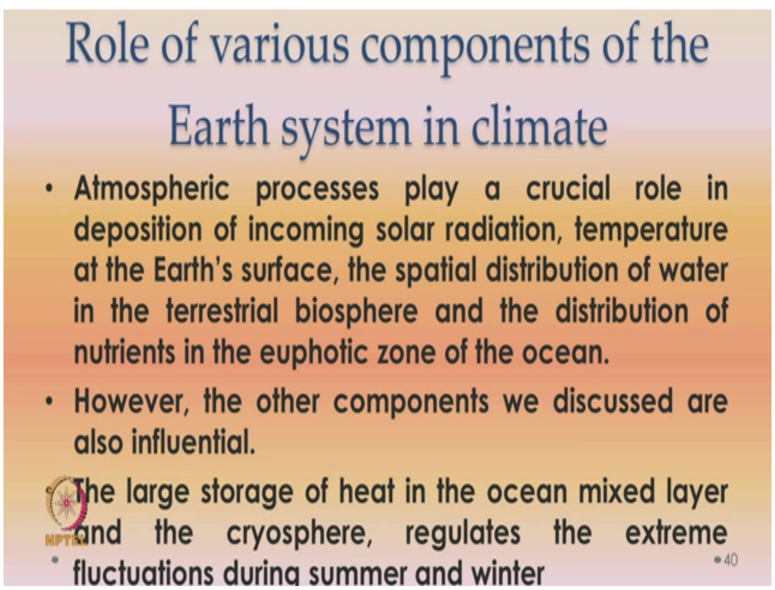

So, what is it now? Summing up, the role of various components of the Earth's system: What I want to say is the atmosphere is indeed, the most important, ok the atmosphere is very important in deciding the Earth's climate but the atmosphere is not the only thing in deciding the Earth's climate. That is what we understood by studying by studying this chapter 2 where we looked at all the other players, right.

So, let us summarize. Atmospheric processes play a crucial role in the deposition in the disposition of incoming solar radiation, the disposition of the temp, temperature of the Earth's surface, the spatial distribution of water in the atmosphere terrestrial biosphere and the distribution of nutrients in the euphotic zone. So, no doubt, all these things are controlled by the atmosphere but apart from that there are other things. What are these other things?

The role of other component is also influential for example the large storage of heat in the ocean mix layer and the cryosphere regulates the extremes in the weather, okay. It extremes the fluctuations during winter and summer because there is so much of a MCP delta t there is a thermal inertia associated with this boundary, ok.

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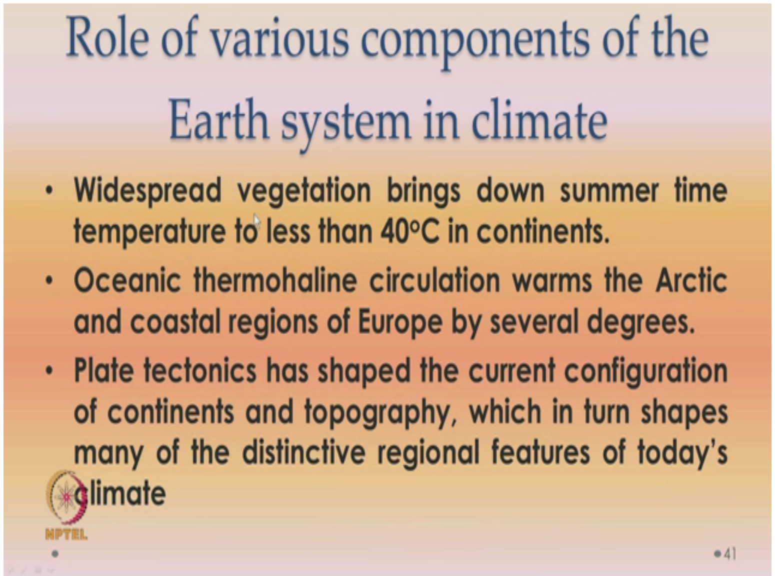

Widespread widget vegetation brings down the summer temperatures to less than 40 degrees in the continents. Otherwise, the summer temperature would have been much higher, all right. Point number 3: The oceanic thermohaline circulation which is occurring because of differences in temperature and salinity. That is why it is called thermohaline convection, if you recall. So, the oceanic thermohaline circulation, it warms actually the arc arctic region and the coastal zone of Europe by several degrees.

That is why Europe is very, very has a very, very habitable climate. Otherwise for 50 degrees London, Hamburg, all these places should have been -40, -50 highly unliveable. So, the ocean currents are making, a are making are having a big role in making Europe so habitable, right. That is why a lot of population is concentrated in Europe. Europe is a, the continent developed first months before there, okay.

Now plate tectonics which we discuss in today's class has shaped the current configuration of continents and topography and somehow most of the continents are in the northern hemisphere. We do not know why? Most of the continents are in the northern. And northern hemisphere appears to be more developed. You can see that more that northern hemisphere is I mean I showed in one of the pictures of the right, northern hemisphere is more developed. If you look at the GDP of northern hermisphere and southern hemisphere, there will be vast disparity.

The only decent countries in southern hemisphere is Australia, New Zealand, probably Brazil now. South Africa, okay. Most of them, okay. So, if you see now southern hemisphere in Singapore and all is still 0 degrees, right. Singapore is still equator; so, south we do not have any countries which are economically advanced, okay. So, plate tectonics has shaped the current configuration of continents and their topography which internships many of the distinctive regional features of today's climate, ok.

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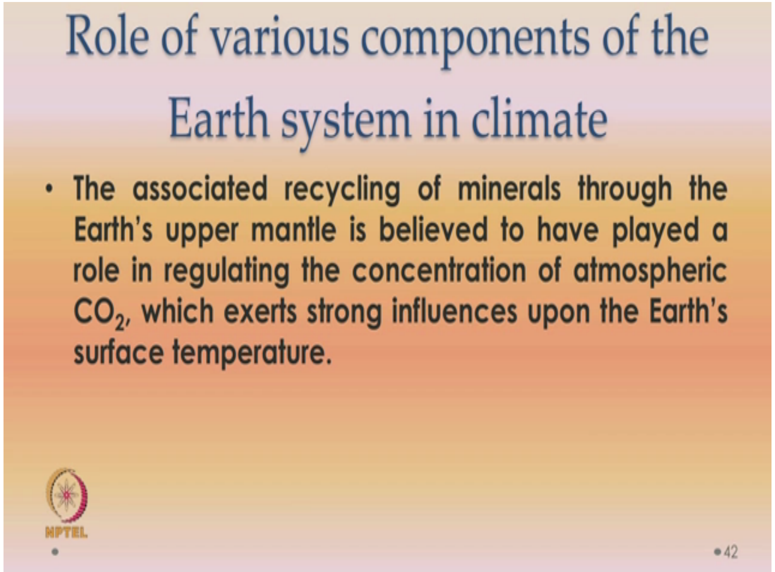

Finally, through the Earth's crust and mantle because of this continent, because of this plate tectonics and all these plates coming together, moving apart and all that and this mantle convection and all that there is a recycling of minerals through the upper Earth's upper mantle. And this is, this is, this is believed to have played a major role in the concentration of atmospheric carbon dioxide which exert strong influences upon the earth surface temperature.

In fact the original Big Bang Theory, originally when the earth was formed there is no oxygen. We will see that now. We will have to find out what is the source of oxygen in the earth. If you do in one of the subsequent classes we will try to do an analysis and try to see what does what has resulted in the production of oxygen in earth, ok. But the oxygen has built up for a period of time, all right.

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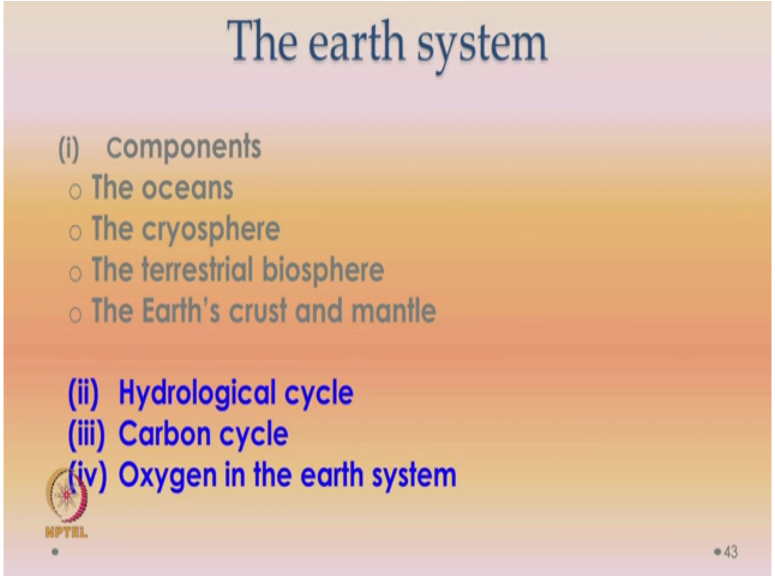

Now if you look at the earth system, E must be capital anyway it does not matter. So, the various components the oceans, the cryosphere, the terrestrial biosphere, the Earth's crust and mantle which have indicated in grey color we have already considered so far. And now if you recall this was the first slide in the second chapter, part 1 was the components. Part 2 is hydrological cycle. Part 3 is carbon cycle and part 4 is oxygen in the Earth's system.

We need to study each of this after we complete all the 4 parts. I promise that we will get into atmospheric thermodynamics. So, part 1 is now over now. We will have to go to part 2 where we look at the hydrological cycle any doubts so far, ok.

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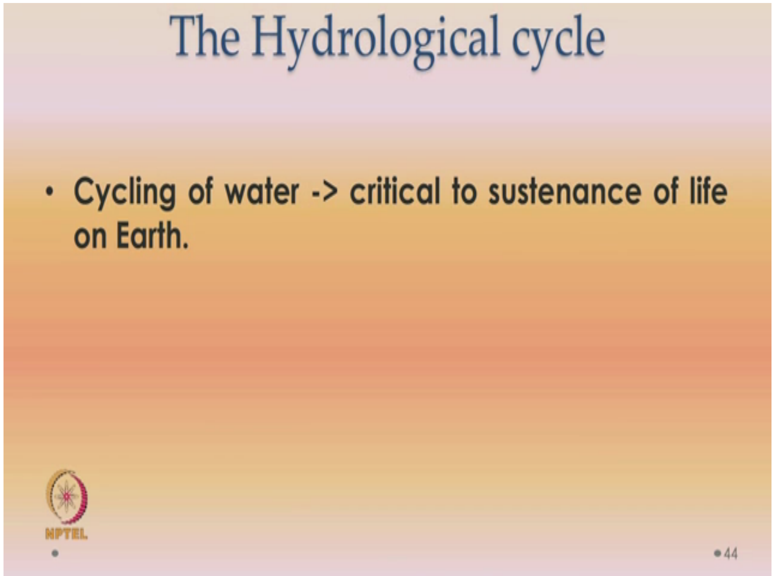

The cycling of water, hydrological cycle refers to the cycling of water, okay. I draw logical cycle cycling of water. It is critical to the sustenance of life on earth because water can exist in water vapor or water can exist as ice water, can exist as liquid water, itself. So, it is critical to the sustenance of life on Earth. There is no doubt about it, okay.

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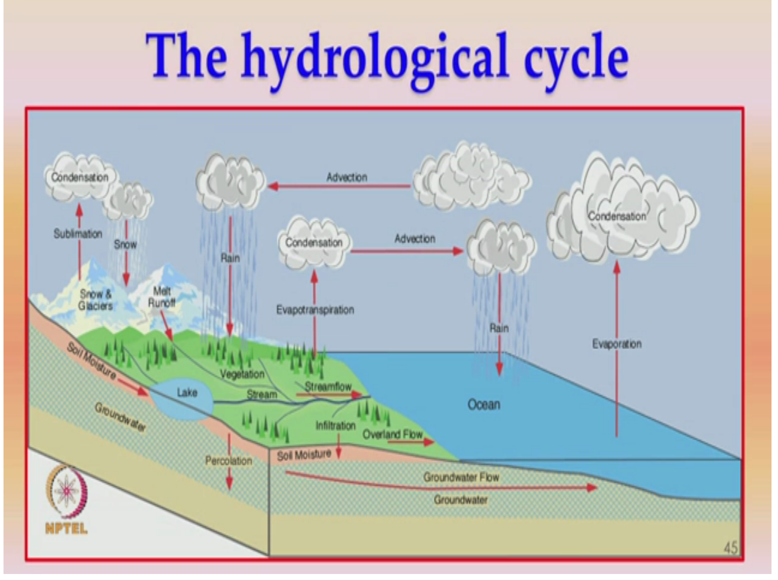

This is this picture is coming from your geography school days, right. Now, let us look at it a little more carefully. So, this is a hydrological cycle so where do we start, okay? From the ocean from the ocean, there is evaporation; then clouds, condensation and it may not condense at the same place by winds. It may be transported so this is called advection, right. So, there can be horizontal transport it may rain elsewhere and we are very happy if it rains on the land, okay.

If it keeps on raining on the ocean it is of no use to us. So, it rained and who brings these clouds to the, who brings these clouds to the land? Winds, okay which are the most important winds? Which are bringing the clouds to the land as far as India is concerned. North West monsoon no, southwest monsoon it is also it is Mausam actually it is a modification of the word Mausem. The southwest monsoon are also called as the Indian monsoon or the Indian summer monsoon which caused heavy rain in JJAS.

June July August September okay, so, we call JJAS name. Now, we are in J next is J will come S will come and after that it will stop; then the winds will reverse that is called the retreating monsoon then, the direction will reverse and you will get winds from northeast from the cold Himalayas it will and then because of the Coriolis component the Earth's rotation it will basically take a turn. Let us say all the Cyclones heading towards Madras will then go to Andhra Pradesh.

Or it will go to Orissa and finally it made Bangladesh also. Have you seen that? There that is called recurving, can also take place, okay. So, winds are very, very important, okay. Wayu, right wayu bagavan, that is what they say. They are very, the clouds have to come from the ocean so that it lands it rains on land. Then vegetation, evaporation and transpiration okay then this evapotranspiration again cause clouds condensation advection.

So, this is there then, this rain can come down. It can cause a stream flow on that rain can directly go again into the ocean, okay. Or it can do infiltration and become groundwater. It can be stored as groundwater. Then, you can also have snow and glacier. There is melting and then big rivers are formed like Himalaya and Ganga and Jamuna and then you can have this and then, they go through the plains and finally they join the sea.

So, this is basically the hydrological cycle. So, each of this can be characterized you can have mathematical equations for each of this and then model this for a limited region or you can model it or a regional scale or you can model it over the whole herd scale. So, this comes into the subject of hydrology which is a big, which is a big subject in civil engineering, okay. Now please take down this figure.

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Reservoir of water	Mass x 10^{-3} kg/m^2	Residence time
Atmosphere	0.01	Days
Fresh water(lakes and rivers)	0.6	Days to years
Fresh water (underground)	15	Up to hundreds of years
Alpine glaciers	0.2	Up to hundreds of years
Greenland ice sheets	5	10,000 years
Antarctic ice sheet	53	100,000 years
Ocean	2,700	
Crust and mantle	20,000	10^{11} years

Please take down this table. So, this gives, this gives it this is a table which lists the major reservoirs of water in the earth and the mass into 10 to the power of -3 kilogram per meter cube. That means the mass is the value given in the table into 10 to the power of 3 kilogram per meter cube. So, this is basically mass density per meter square of surface area whenever you want to find the actual mass what you do? Multiply by 4 Pi Re square where Re is 6370 kilo meter or 6.37 in 10 to the power of 6 meters.

This is a value which would you should not forget in this course, okay. Atmosphere: 0.01 into 10 to the power of -3 kilogram per meter cube. The residence time is only days. That is if you trace a particle its life is only a day, few days. Then, fresh water lakes and rivers mass is 10 to the power of -3 is 0.6. The residence time is days 2 years, fresh water is 15, alpine glaciers is 0.2, Greenland ice sheets, okay ice sheets on Greenland is 5.

Antarctic Ice Sheet is 53, the ocean is 2700 and the crust and mantle is 20,000 okay. But you see, what is the logic behind this table? How has this table been arranged in the order of increasing, very good. It is arranged in the order of increasing residence time. Mantle, look at the mantle, the residence time is how much, okay? So, what is residence time?

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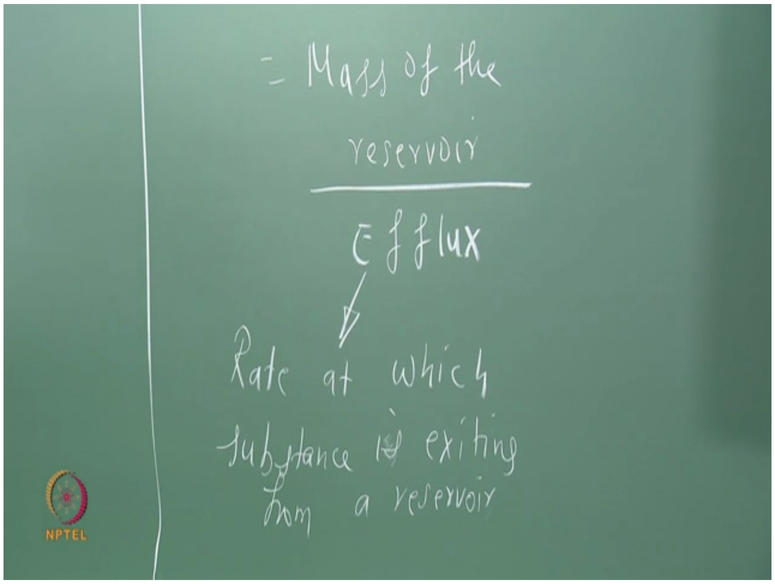

The residence time is the mass of the reservoir divided by efflux. Efflux you are copying there, okay. Then, we solve the problem now. Say that again. No, no. That is okay. Ocean is basically sometimes it can drop immediately and or OD everything comes back to the ocean. No, that is way it is left in the blanketing, okay. Now, what is the residence time in the table? The residence time is basically the mass of the reservoir divided by the efflux. Efflux is the rate at which substance is exiting from the reservoir, okay.

Okay,all right, say that again. Now, these can be there are various estimates for that, right. So, you can have some proxies based on some analysis, some correct; there will be an whether man. But, agreed upon by many people these. You can use some dating and this thing how much time it is taken and some approximate calculations. Just how do people say that the Big Bang Theory and all that it is something like that?

Some little bit of opera approximation will be there but that as you said is correct it can be 10 to the power of 11or 2 into 10 to the power of 11 or 4 into 10 to the power of 11 or 5 into 10 to the power of 10. It is of that order. It is very huge, okay. So, what we can do is, I do not know. For example, as far as climate is concerned, the satellites are available only for 40, 50 years. So, if you look at the change in pattern we can extrapolate by a few 100 years.

But 10 to the power of 11 years so what data they have used we do not know. For ice, what we can do is, we can go into Siberia, go deep down and get the ice sample at various heights, various depths then, you can correlate with the carbon dioxide and for a particular depth so, the ice is continuously forming on it, you can actually get the time. That is what they do. So, they read, it is a mixture of science plus some so, we can say it is a guesstimate, okay.

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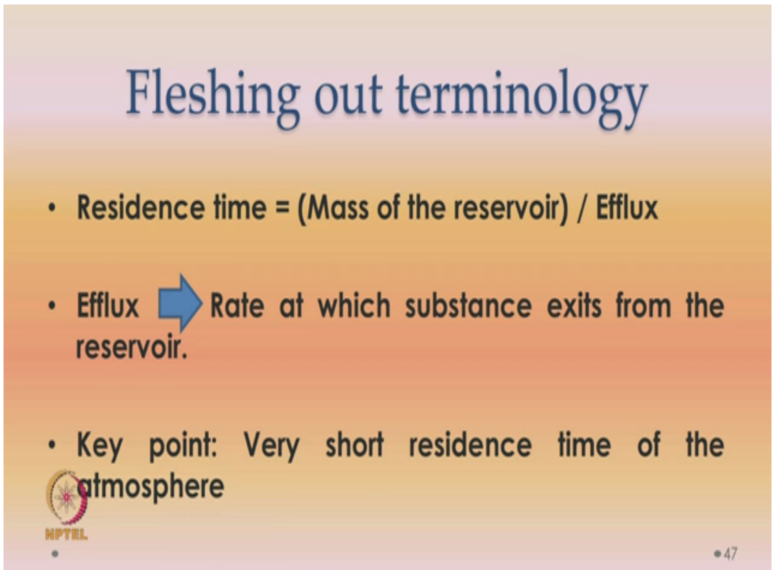

Let us flesh out some terminology. The residence time is the mass of the reservoir divided their efflux. Efflux is the rate at which substance exits from the reservoir. The key point what you have to understand from this previous table is extremely short residence time of the atmosphere of the order of few days, okay. Shall we move on to the next one, okay?

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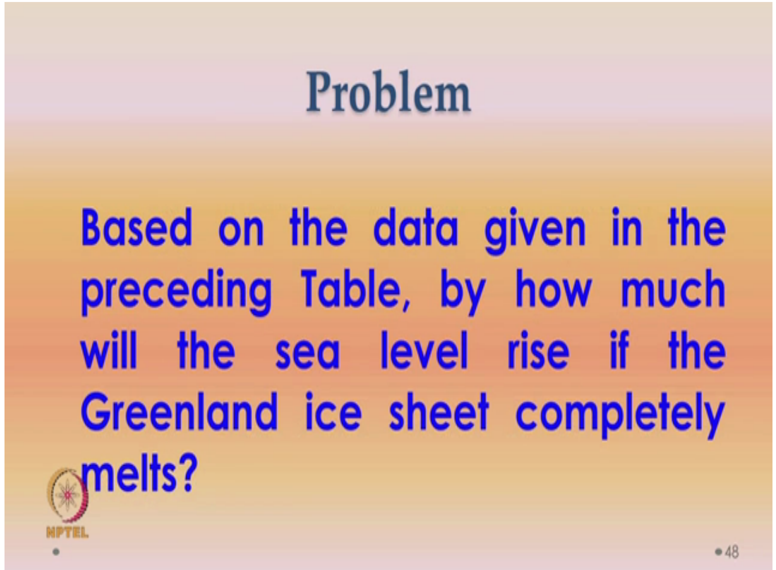

Based on the data given, please take down this problem. Problem number 7 is it okay. Then, be 7, so I will just pack it I want to use the number, okay. What happened, okay? Please take down.

Problem number 7, based on the data given in the preceding table by how much will the sea level rise, based on the data given in the preceding table by how much will the sea level rise if the Greenland ice sheet completely melts, okay. So, take a few minutes and.

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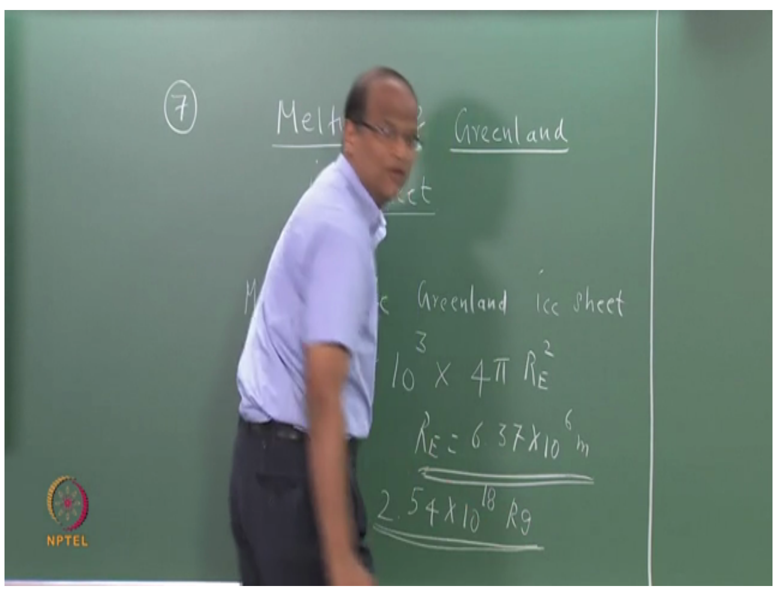

Please start solving, so, first you will have to calculate the mass of the Greenland ice sheet, correct. What is the first step? It is always based on per meter square of the surface area. So, you have to multiply it by 4 PI RE square, okay. It is kilogram per meter square of the Earth's of total surface. Area of the earth that is the way it is, these are the units using atmospheric science. I told you in the first class itself. Then you are tying yourself up in knots, is it not. There should be a baseline for this thing then you will never be able to calculate the trolley.

Then, next you will ask me said what is this a square a surface area of the entire Antarctica. So, it is it go on so. Somewhere, you do understand where is your house? My house is next to him? So, where is his house? His house is next to my house I mean, need that problem cannot be solved, okay. Let us work it out slowly, so mass of the Greenland ice sheet is, what is the value of giving the table, 5 into 10 to the power of +3 because mass into 10 to the power of -3 kilogram per meter square is 5, so, ever mass is 5 into 10 to the power of 3 into.

So, this is the radius of the earth please do not forget this in this course okay yeah substitute 6.3 into 10 to the power of 6. Tell me some huge number, Kg, is it okay. Now, we have to find out how much the level will rise. For that you have to make an assumption. Density, okay 1000 kilogram per meter cube assumption number one densities 1000 kilogram per meter you forget the 1025 that is okay.

Then not 2 3rds what is it? We have to make couple of assumptions 72 % of the Earth's surface is only covered with oceans. Density of water is 1000 kilogram per meters meter cube and when it melts, it will be uniformly distributed over this 72 %, correct. Now, calculate the keep the height by which it rises as X, pull out the X, okay.

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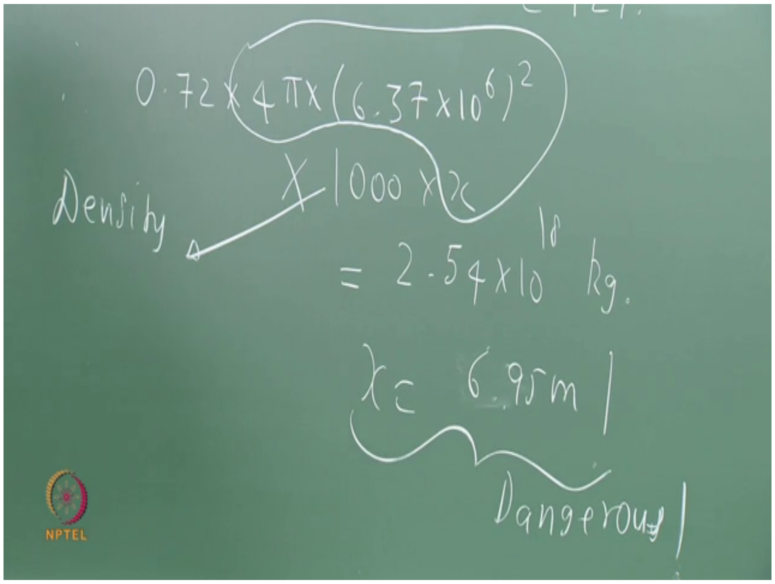

Now, what is it, okay? Okay, I have multiplied by 0.7 - also okay it does not matter too high know point something so what will happen is the whole Greenland ice sheet melts 6.95 meter is like 22 feet 23 feet. Very bad, scary, is it not? So, you can find out if any of the other things, whatever you can do the calculations for other things also, right.

X is = 6., it is dangerous. Simple analysis we are able to say but it won't melt day after tomorrow or tomorrow. You do not worry about that. But if it melts like that any of those were any of those things which are remaining as ice if they melt. That means, we are going to have trouble for a long period of time. The trouble is not next week or next month but to receive the global warming takes place slowly.

But surely the temperature is increasing and the temperature anomalies correct as reported with Charles Keeling carbon dioxide and Mauna Loa, Hawaii, if that were to be true. Then you can say that we are in trouble. Man will come out with some solution. That is a different matter, okay. But right now, this it is a cause for concern, all right.

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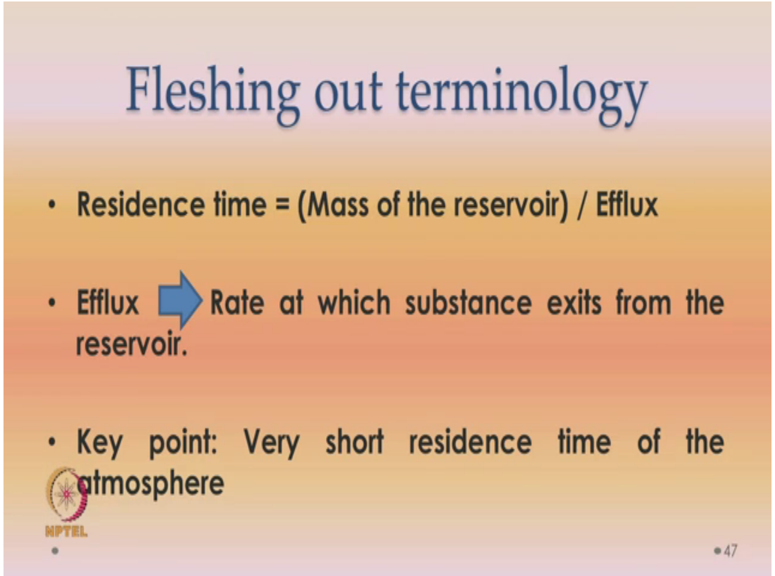

Now, let us go back to the why is the residence, is everybody through with this problem? 6.9 from last bench, is it fine 6.95, okay. Why do you think we have a very short residence time on the atmosphere, this one right? Can you tell me some reason? Anybody, solar, no what is the core atmosphere, what is it? What could be the reason residence time is mass of the reservoir divided by efflux. What is a mass of the reservoir? So, if you want to have low residence time, you are, you either have, low efflux or you have high efflux or low mass of the reservoir.

There is a while the mass of the reservoir is reasonably low. We will remove that. The efflux seems to be very high for the atmosphere, why? Continuous interaction, large exchange rates, because of winds and other things so process atmospheric processes are very fast, compared to the processes in the mantle, okay and that there is a large latent heat of vaporization of water. Because of this, generally the atmospheric time scales are very less, okay.

So, therefore the atmosphere is a very efficient component of the Earth's surface in transferring the energy and water from the Earth's surface to the atmosphere. Are you getting the point? So, the atmospheric sorry the atmospheric branch of the hydrological cycle is very efficient because it can do things very quickly. So, in your hydrological cycle, this complex interplay of various things in the hydrological cycle, the atmosphere plays a very important role because processes are very quick here, in the atmosphere.

Is it okay, next we will have to go to next two classes? Let us do some little bit of math in hydrology, okay.

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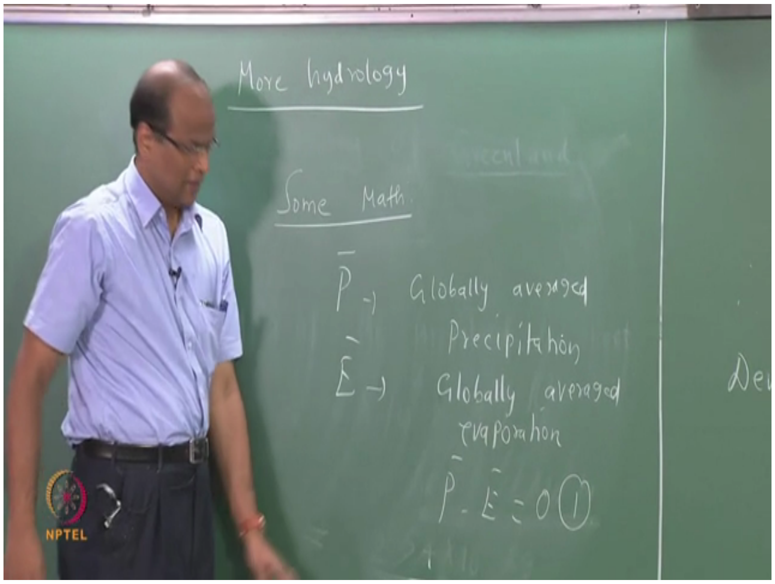

Let us say that the globally averaged precipitation centimeter per year or millimeter per month or something. It is globally average and E bar is a globally averaged evaporation. What can you say about the 2, on an average if you are sufficiently average P = E, very good. That is our first equation. At a global scale precipitation is = evaporation. If this were not to be the same, some lot of changes would have taken place which would have been noticed by several scientists, which would have caused some other changes.

So, there we have proved that it is clear that those seniors are not taking place. Therefore, there is no appreciable imbalance. There is no appreciable imbalance between the globally average precipitation and the global average evaporation. However, when you analyze the hydrological balance for limited region P is not = E. Now, we are able to understand what I am, the subtle difference.

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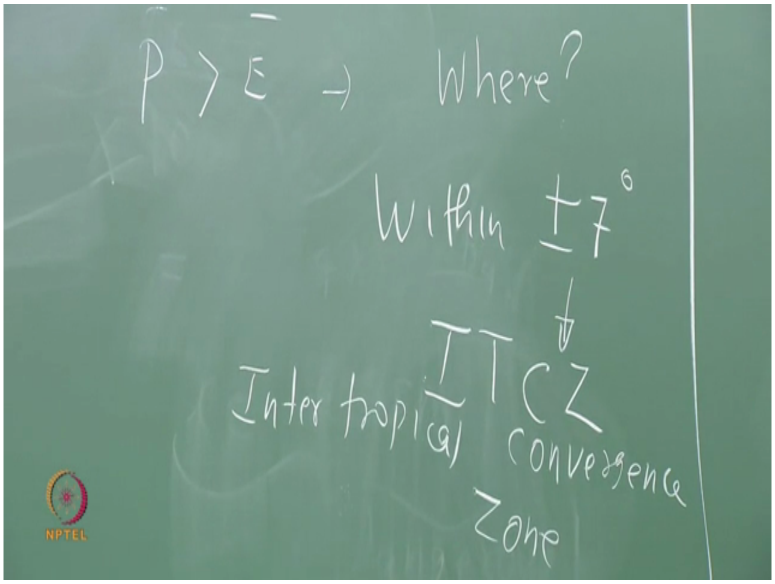

If P is not = E, two possibilities are there. Possibility one, P is greater than E where that is precipitation is more than evaporation or significantly more you can always put it as P is much, much greater than E whatever. Rain forest, so, give some mathematical condition. So, within + or – 7 degrees latitude it has been seen, it has been experimentally measured and confirmed that precipitation is much, much greater than this thing. This is your Amazon forest, Singapore, all those places in that region, okay. So, this up to + or - 7 degrees is called Inter Tropical Convergence Zone, okay.

Now P is, where deserts if P is much, much smaller than E or the desert, evaporation is very less, sorry precipitation is very less, evaporation is very high. This so whatever where is it going? The question is clear? Where is water it now you are able to understand? That is called RG, okay. Lot of evaporation is taking place, these deserts are pretty basically 10, 15, 20, 25 degrees so whatever, Dubai or Dubai must be 20 degrees to 15 to 20 degrees not Chennai is 10 degrees Delhi is 30 R 29 degrees. Dubai must be 25 I do not know more, around that only, okay.

So, as this water evaporates and becomes water vapour this water vapour is carried either to the Intertropical Convergence Zone or it is taken to the mid latitudes where it causes lot of rain in Europe and other places. So, it will go either to the mid latitudes or to the equator. So, there is heavy incoming solar radiation, lot of clear skies, heavy evaporation, but no rain, okay.

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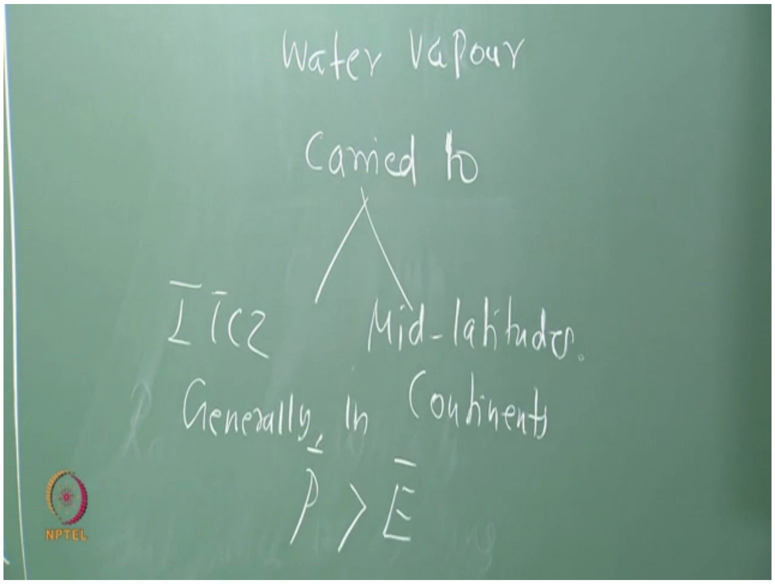

So, the water vapor carried to. But generally in continents, it is seen that P is greater than E which is very good for us. This is responsible so this P is greater than E you know the primary reasons why the sustenance of plant animal and human life continents. So, all right, over the continents, it is seen that the precipitation is more than the evaporation.

Now, in the next class, in the next class, we will just take a column, we will just take an atmospheric column, apart from P - E there is also a transport of water vapor which is coming by the winds. So, PE and transport by wind must also come and if PE and transport by wind are not in balance, there is a net change of water vapor in the reservoir. So, you will get an unsteady equation that will be the; so that is an atmospheric unsteady equation, okay.

Now if we apply the same to a reservoir of water like a reservoir in a lake or something, you will get the basic hydrology equation. This unsteady head instead of transport by instead of transport by winds you will get transposed transport by percolation, okay. Stream flows from tributaries, rivers. So, if you account for all this then, you will have incoming, outgoing then, there is evaporation then, you will do a that is a basic hydrology model.

So, in tomorrow's class, we will do a simple with two, three steps will delay the basic hydrology model applied to a lake and see if there is a rainfall on the lake, how the height or the height of the lake will respond to changes in a simple model. So, if you want to know more about it totally take some advance ideology because how many of you are civil engineers.

You must have done all this it may be elementary to you but for other peoples it will be new. We will just but I am some simple constant area lake. Sometimes the lake can be shaped like this, sometimes it can be like this, depending on this when there is a forcing, what is the forcing, forcing in the form of rain, if it happens, then the lake will respond differently.

That is a funda, how to design a reservoir, okay our goal is only atmospheric science. But we will do little bit of hydrology also will dabble in hydrology one or two classes then we look at carbon cycle, oxygen cycle and get back to thermodynamics. Thank you.