Introduction to Atmosphere and Space Science
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Lecture – 08
Characterizing the Atmosphere Based on electrical Properties

Hello. So, in today's class we will try to understand the characterization of atmosphere based on the electrical properties. So, in the previous class we have seen the thermal structure of atmosphere wherein we have been able to identify its various layers of atmosphere depending on how the temperature varies with respect to the height. So, at each turning point we have defined one particular layer then we have four different layers which are the troposphere, stratosphere, mesosphere and thermosphere.

Now, in today's class we will try to see how we can discuss the electrical properties in the picture.

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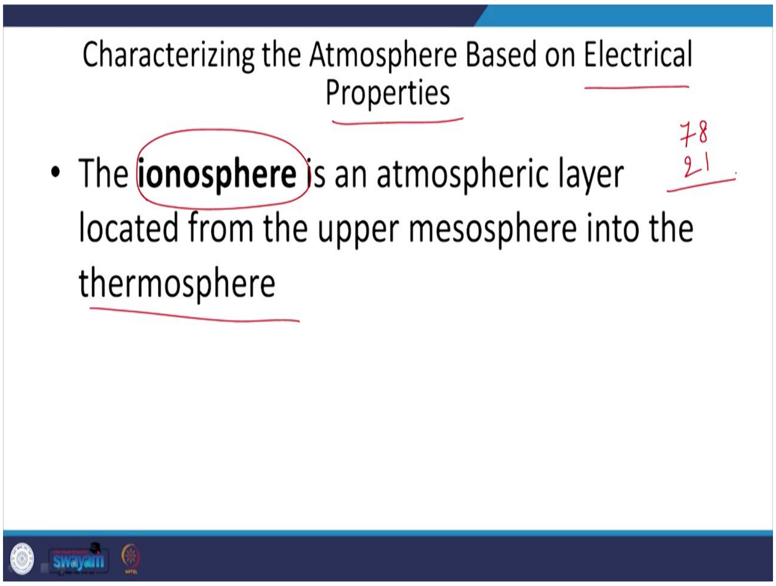

Now, based on the electrical properties, we define what is called as the ionosphere. Ionosphere is an important layer is also an atmospheric layer located from the upper mesosphere all the way into thermosphere. So, ionosphere is by definition is the region of the atmosphere where we have electrons and ions present in a large numbers so that they can influence the radio wave communication.

Now, the most important aspect is that in discussions so far we have always seen that it is the nitrogen and oxygen in the molecular form that means, in the neutral form are the major chemical species in the atmosphere. We are not talked about electrons we are not talk about ions anything like that we are not talking about anything electrical in nature that means, any charged quantities in nature.

Atmosphere in addition to all the neutral species such as all the gases is also home to various ions and electrons. So, this the region where these electrons and ions are present in large numbers is called as the ionosphere ok.

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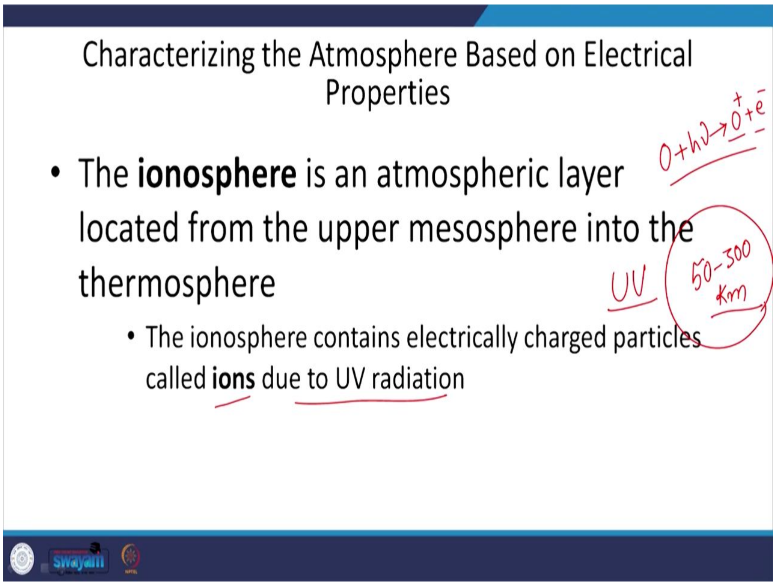

So, ionosphere contains electrically charged particles called ions due to ultraviolet radiation; that means, how these ions are generated that mean you have ultraviolet radiation which is extremely energetic in nature. In the beginning itself we have learned that ultraviolet radiation has the ability to ionize all the species that are presented atmosphere in gaseous form. It also has the ability or the energy to dissociate all the molecules. So, ultraviolet radiation can dissociate molecules and ionize atoms.

So, when you ionize an atom let us say a neutral oxygen atom; so, you will get an electron and ion. So, due to the action of this you will have the ionosphere present at nearly let us say 50 kilometres or 50 kilometres to almost 300 kilometres. So, this height limit sets the beginning and the ending of the ionosphere. So, ionosphere is the region where electrons and ions are present sufficiently in large numbers to be able to influence or affect the radio wave communication ok.

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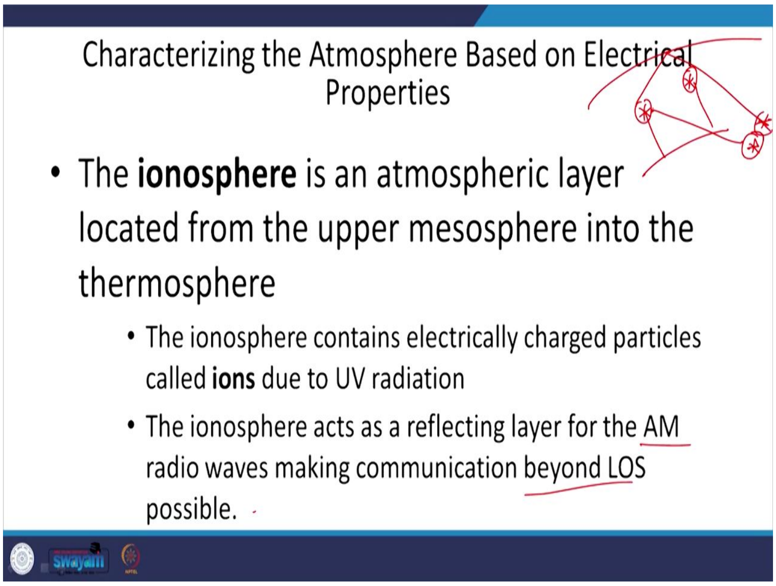

So, ionosphere acts as a reflecting layer for the amplitude modulated radio waves making communication beyond the line of sight possible; that means, generally the communication is possible between line of sights, line of sight reception points right.

So, if you want to achieve communication beyond the line of sight then you have to resort to some radiation which can whose wavelength is sufficiently larger to be so that it travels all the way from here to here. So, it is the ionosphere which acts as a reflecting layer on the top and makes the communication possible beyond the line of sight.

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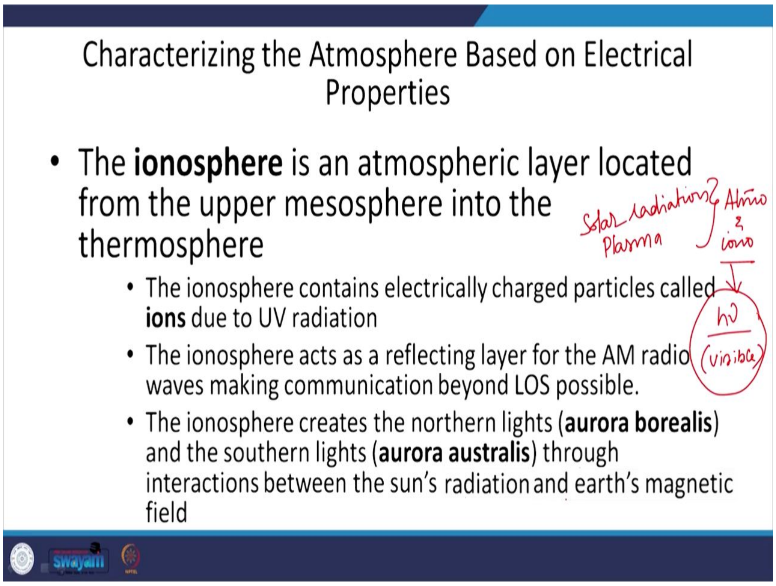

And, in addition at ionosphere creates the northern lights such as aurora borealis which you see in the northern hemisphere or northern pole and the southern lights which are aurora australis which you see in the southern pole through interaction between Sun's solar rays, solar radiation and the earth's magnetic field.

So, you have many processes in which Sun's solar radiation or plasma emitted by Sun when these things interact with the atmosphere or let us say in ion with the ionosphere releases photons, let us say which are in the visible spectrum due to the interaction of solar radiation and solar plasma with the atmosphere. Solar complex reactions can lead to the formation of visible photons which you always see as airglow or aurora.

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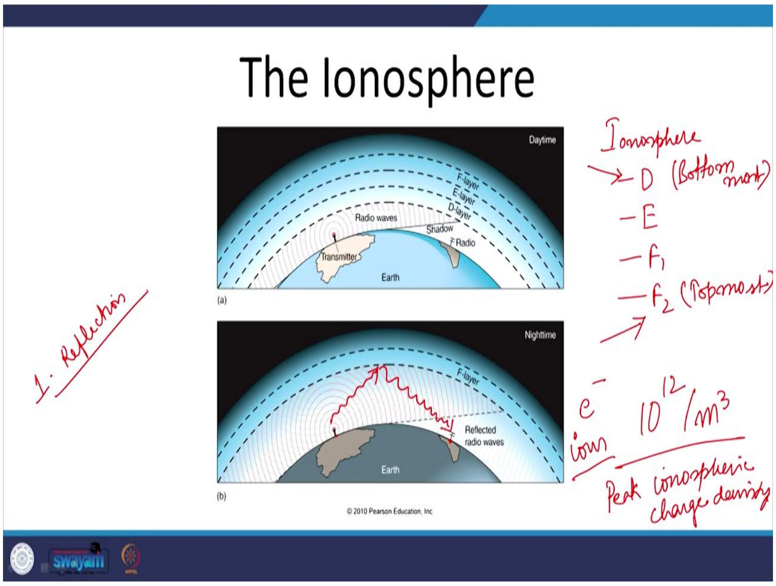

So, this is a pictorial representation; ionosphere is again divided into three different four different layers let us say. The ionosphere is let us say is defined let say into D layer, E layer, F1 and F2. Now, D layer is the bottommost, F2 layer if it is existing is the topmost. So, F2 layer is the one which experiences or which gets the complete energy from the sun and D layer is the one which gets the least energy from the sun.

Now, ionosphere itself is a compute complete module which we will take up at some point in this course, but I would like to make one particular point is that each of these layers have different set of physical and chemical processes which are responsible to create electron and ion densities in abundance. So, typically where the densities that we are talking about is 10 to the power of 12 per meter cube; 10 to power of 12 electrons or 10 to the power of 12 ions per meter cube in the in ions in the in the peak ionospheric concentration.

So, this is the peak ionospheric charge density; that means, you have this many number of electrons or ions per unit volume. In this picture what you see is this region is the shadow with respect to this transmitter, but if you have an ionosphere this the waves which are going towards the sky will get reflected and they will travel in this all in all directions making it possible to communicate between this point and this point right.

Now, most importantly, why does the F layer reflect electromagnetic radiation right. This is a very important physics question I mean this is a very important question wherein why reflection how does the reflection happen. It is very simple again how does the reflection why does the diffraction happen. So, electromagnetics we have seen that electromagnetic ray will get reflected when the refractive index condition between two media matches a particular limit right that is what happens here as well.

Now, the point is the ionosphere acts as a conducting layer or acts as a mirror in the sky which reflects the incoming radio wave signals from the ground on to the shadow regions ok.

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Now, this is the picture of the aurora. So, what you see is you see brilliant green colour patches in the sky. So, if you are able to see I mean the green colour that you are able to see. So, this must be visible photons in the green colour right. So, these photons or these emissions are the result of complex processes between solar plasma and Earth's magnetosphere or and Earths ionosphere ok. So, this is something about characterization of atmosphere based on the electrical properties, not based on the thermal properties right.

Now, several other aspects let us say pertaining to atmosphere and pertaining to pertaining to the radiation let us say that is emitted or absorbed by the observe absorbed by the planet's surface and atmosphere. So, what you see is the components of Earth's atmosphere or the Earth's system itself absorb and reflect suns radiation by differing amounts; that means, that not all the parts in the Earth's system absorb equally some parts will absorb more radiation in some parts will absorb less radiation.

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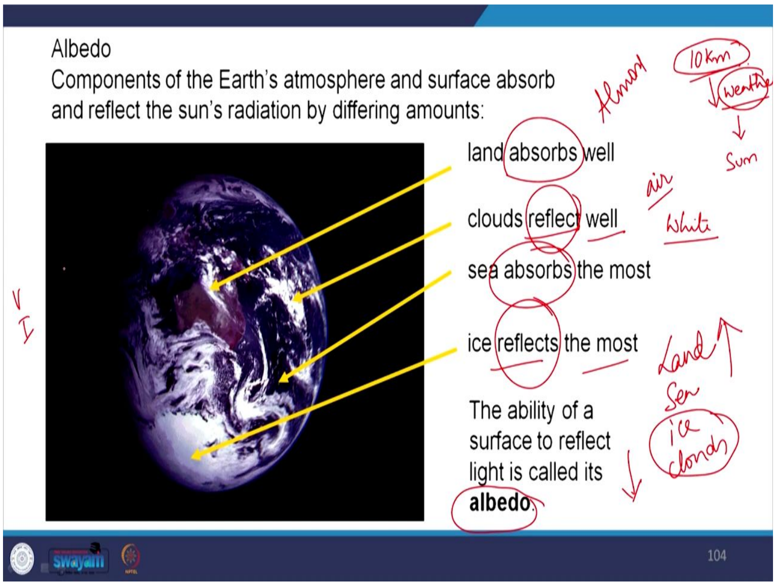

Let us say if you look at this picture what is what we will be able to see is that land absorbs very well; that means, the incoming solar radiation is well absorbed by the land good. Clouds reflect well; that means, clouds has the ability to reflect radiation away. I mean so; the clouds are stopping this solar radiation from entering into the Earth's atmosphere. So, typically that the cloud tops you always remember this number the cloud tops exist at 10 kilometres and all the weather happens below 10 kilometres.

So, all the weather happens below 10 kilometres and fundamentally we know very well that all the weather is driven by sun again. So, that means, that the cloud tops influence the weather very much ok. So, if there is a cloud then there is no heat be beneath the cloud and so many other things. But, the point is radiation is stopped very well by the clouds ok. Now, sea, the water bodies absorbs the most; I mean sea also absorbs very well and what is remaining – the ice. The ice reflects the most.

So, the point is objects or systems with white colour reflect very well. Now, this discussion again brings us one more very important aspect some points we have seen that in the evolution of Earth's atmosphere we have seen that there was a point when the CO_2 levels were kind of decreasing because of the photosynthesis reaction, right CO_2 levels were decreasing because a lot of CO_2 was converted into organic monomer and at the same time it was also releasing a lot of oxygen; that means, CO_2 is getting lost from the atmosphere.

So, when CO_2 was lost the global temperatures were decreasing because there is nothing to trap the outgoing infrared radiation. So, the global temperatures were decreasing. So, as the temperatures were decreasing there was a definite possibility that the Earth could have frozen and it was it has actually happened that over 5 million or 50 million years ago the entire Earth glaciated right.

Now, what happens? Then I mentioned something called as a negative feedback system wherein once the Earth glaciates you have you have this snow cover the only entire planet. Now, for it to come out of the this glacial I mean glaciation process it needs to get as much as energy from the sun because there is no other source beneath the glaciers right. So, there is no internal source for the Earth system we know that very well right.

So, for this Earth to come out of the ice age we need to have more radiation and if there is a lot of ice on the surface the ice has a tendency to reflect most of the radiation away. So, Earths will not get heated up and so, this is a loop in which this is a loop in the more glaciers you have and there is the radiation that you get is less and as a result you will never get out of the glaciations, I mean you will never get out of the ice age. So, there was it was a definite possibility in which Earth could have forever fell into the ice age and it could have never got back from there.

But what happened CO_2 levels were of course, increased, but of course, decreasing as a result of photosynthesis reaction, but then was still a lot of volcanic eruptions which were which were active and which were continuously pumping enough moles of carbon dioxide into the Earth's system. So, this curve this increase in carbon dioxide because of his source which are called as volcanoes was only the helping mechanism which could have which has actually thrown us or thrown the Earth out of the ice age otherwise the entire planet could have been a pile of ice, that is it ok.

Now, so, in this context so, what we see is we have four we do not have anything else I mean we have land, we have the ocean, we have the clouds and where we have the ice. So, these four systems have out of these four systems two systems have the ability to absorb very well and two systems have the ability to reflect very well right. So, land and sea are there to absorb the radiation and ice and clouds are there to reflect radiation. So, these two systems will try to decrease the average temperature than what it is today and these two systems will try to increase the temperature by some extent right.

Now, here you define what is a very important parameter, which is called as albedo. Albedo is the ability of a surface of a surface let us say land surface or any kind of surface to reflect radiation to reflect light that is it right. Now, in addition to these land clouds sea and ice we also have atmosphere or more familiarly called as air right. So, you have air, now what does it do? It does not do anything as in the entire the column of atmosphere is transparent to visible and infrared radiation we know that very well.

So, all the visible radiation and all the infrared radiation travels right through that atmosphere and it reaches the surface. Once it reaches the surface this these four things will come into picture and we will decide how much amount of radiation is to be taken by the Earth and how much amount of radiation is to be given away into the space ok.

So, here so, we can simply say that the ability of a surface to reflect light is called as albedo and albedo is very high for cloud and it is very high for ice, and the albedo is very low for land and clouds land and sea. So, as a result what you can say is that we can calculate albedo by incident in some radiation and again measuring what is the reflectance out of the surface right.

Now, since we have Earth which is a combination which is a very complex combination of these four different types of surfaces so, the entire Earth surface, that the Earth marble is made up of unequal proportions or time changing proportions of land, mass, clouds, sea and ice. We have a we have an albedo of the Earth itself; I mean Earth as a whole how much of radiation let us say if I throw 100 photons at Earth how many number of photons will be refracted and how many number of photons will be will be absorbed. So, this is called as the albedo of Earth itself, the planetary albedo.

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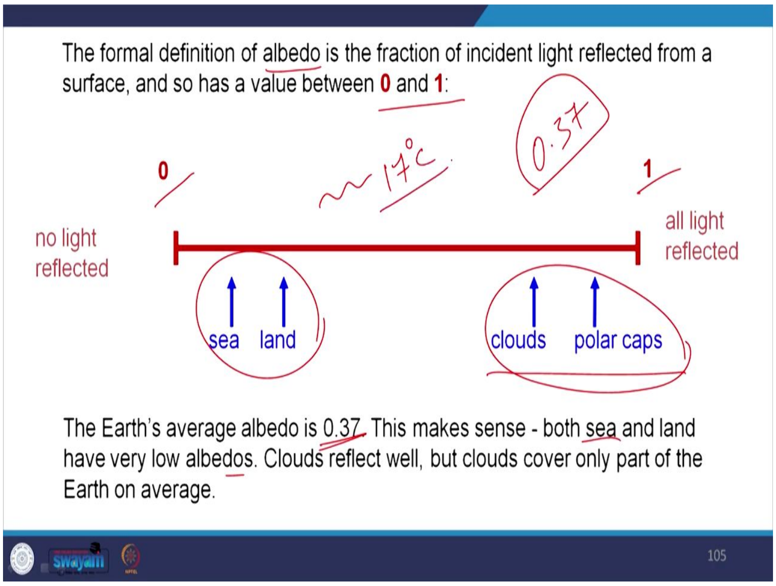

So, the formal definition of albedo is the fraction of incident radiation that is reflected from a surface. You throw something what is the what is the fraction that you get back or what is the fraction that the surface throws back or reflects back is generally called as the albedo. And, this value, since it is a ratio it can be only between 0 and 1 that is it. It cannot be greater than 1.

So, for a practical let us say understanding what you have is you have a you have a limit 0 and you have 1. So, when the albedo is 0; that means, no light is reflected that is it. So, when the albedo is 0 no light is reflected all of it is absorbed. So, we know that sea and land have a very good absorption capacity so, they lie in the lower portion of this albedo graph right and the clouds and polar caps they have the ability to reflect most I mean whatever happens whatever falls on them it has the ability to reflect most of it; that means, clouds and polar caps have higher values of albedo.

And, on the whole let us say the Earths average albedo is 0.37. So, I mean this. So, we can say that it does not it does not reflect much actually right. So, this makes sense, both sea and land have very low albedos right and the. So, it is mainly the sea cover that you see from the outside. You see you see the Earth to be a blue planet that is the sea that you see mostly. So, it has more ability to absorb than reflect ok.

Clouds of course, cloud cover varies with respect to time, it does not stay the same forever right. So, what you the take home from here is that the planetary albedo for Earth is 0.37, you remember this number always. So, you throw 100 photons into the onto the Earth you will get 37 photons reflected away that is it. The remaining are absorbed and this the remaining that is absorbed is only the energy that is that rises the Earth to 70 degrees Celsius average temperature ok.

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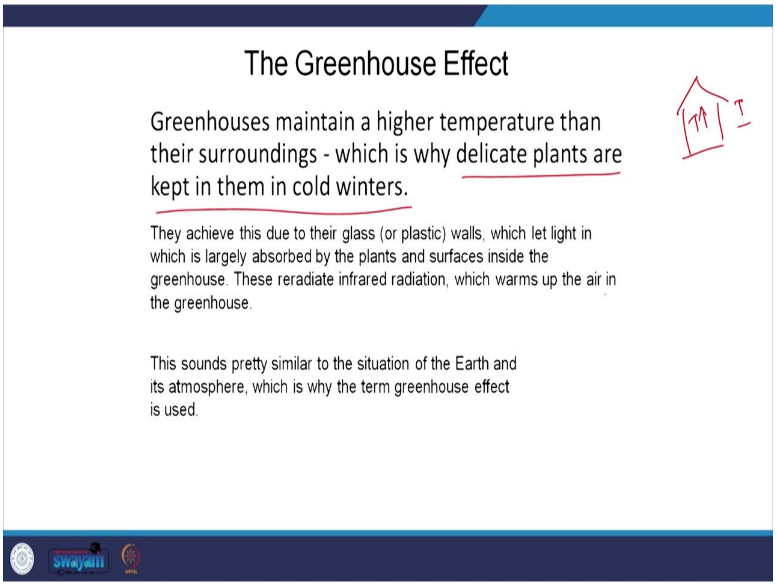

Now, in continuation this is very important that we understand, the greenhouse effect. So, what exactly is greenhouse effect? We have seen water vapour and water vapour, methane and carbon dioxide or we have named these chemical species as greenhouse gases. And, we know a very general understanding that these greenhouse gases are the ones which are increasing the average or average temperature of the Earth. And, these are the ones which are responsible for the very well known or very well understand concept which is called as the global warming whatever it is now.

Greenhouses; let us say what is greenhouse. Greenhouses maintain a higher temperature than their surroundings. So, you have a greenhouse then this temperature inside is relatively larger to temperature outside. Why should you have a green house? So, that you can put delicate plants in the inside this house in the cold winter so that they can sustain the winter right. So, they achieve this due to their glass or plastic walls which get which let light in which is largely absorbed by the plants and the surface inside the greenhouse. So, these radiate infrared radiations, which warms up the air in the greenhouse so, as a result right.

So, this sounds pretty similar to the situation that we have on the Earth and in it is atmosphere so, which is why the term greenhouse effect is used. So, that means, that you have maintained, that you have made a mechanism in which more amount of radiation could come into the system and as a result this radiation is kept inside the system and because you have this radiation the average temperature inside the system is larger. So, if you remove this radiation from this picture the average temperature is significantly small lower I mean smaller.

So, that means that, this mechanism of holding this radiation is what is being replicated in a greenhouse that is why you call it as a greenhouse effect right.

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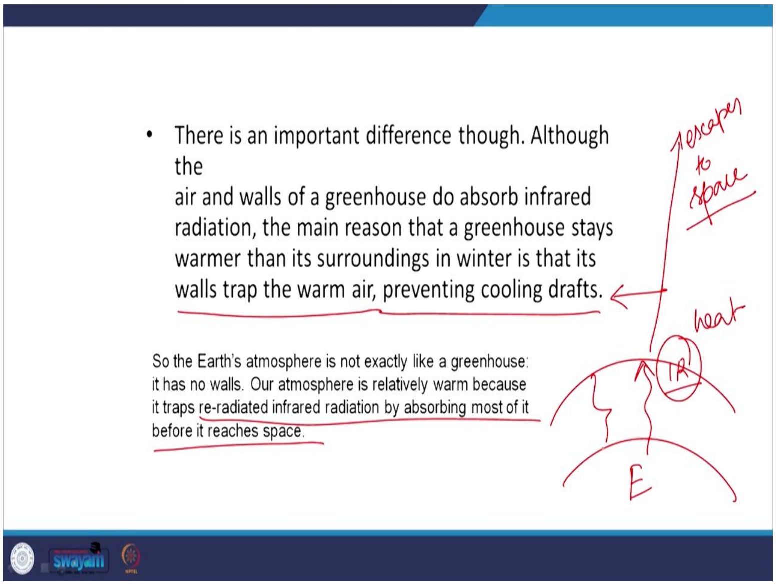

So, there is an important difference I mean there is an important difference of course, there is. So, although the air and the walls of the green house do not absorb infrared radiation that is that is how would they are made the main reason that the green house stays warmer than it is surroundings is that in the winter is that its walls trap warm air preventing cooling drafts and this is not there in the Earth system.

This is Earth system is the open system, you do not you do not put walls. So, that the warm it does not go beyond a particular point beyond the wall. There are no physical barriers wherein you allow something and you do not allow something. So, this is the major difference in comparison to the greenhouse and the greenhouse effect that we see on the planet Earth.

Now, so, the Earth's atmosphere is not exactly like a greenhouse; it is not completely like a greenhouse. It is of course, it represents the effect is of course, to some extent is true in the case of Earth. But, the mode and mechanism in which this effect is achieved is not completely the same between the greenhouse and the Earth ok.

So, the our atmosphere is relatively warm because it traps the re-radiated infrared radiation by absorbing most of it, before it reaches this space. So, it is basically you have this planetary surface and you have ultra infrared radiation which is emitted from this surface and this radiation is actually escaping into the scale space; escapes to space. That is that is what is happening.

Now, if you put a trapping mechanism and do not allow it to escape to the space what does it do? Infrared radiation is nothing, but heat this remains inside right. So, this is achieved in a different way. So, here the warm air is trapped by physical barriers and here the warmness is trapped by the greenhouse gases. So, that is the basic difference.

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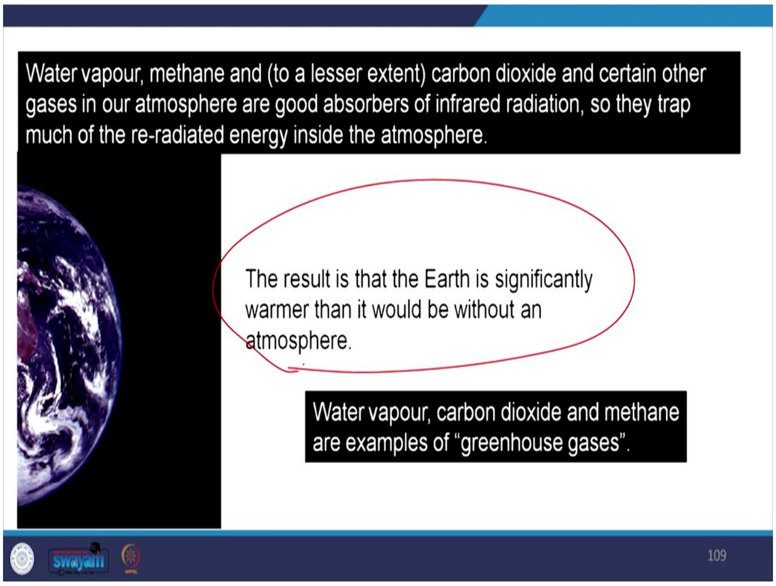

Now, among the other gases water vapor, methane and to some extent carbon dioxide, and certain other gases in our atmosphere are very good absorbers of infrared radiation, so, they trap much of the reradiated energy inside the atmosphere. So, that is what they do.

So, the result is that they are at this significantly warmer than it would be without an atmosphere. So, I mean greenhouse effect is after all not a bad thing, otherwise the temperatures will be very less in the night time and temperatures will be very high in the daytime. Water vapour, carbon dioxide and methane are examples of greenhouse gases.

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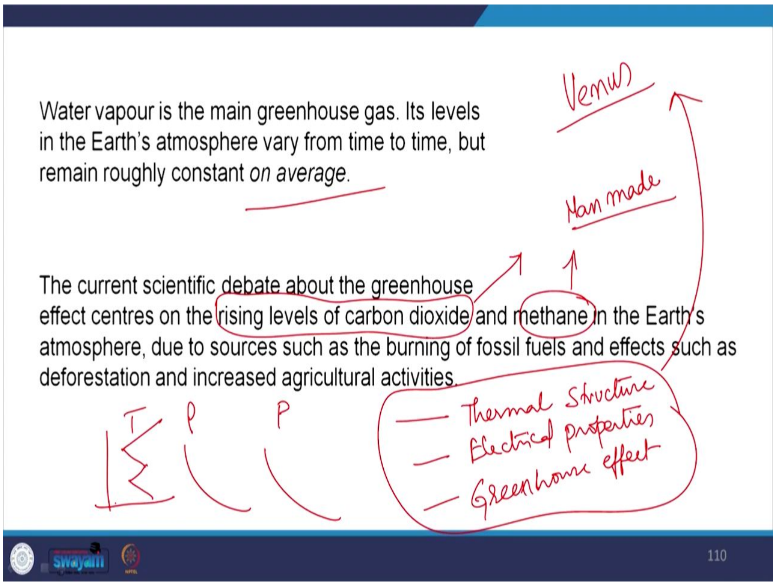

In tropics what happens you have more radiation, you have more evaporation then you have more water vapor in the sky right so, percentage of water vapor is very large. So, water vapor is the most important greenhouse gas. It levels in the Earth's atmosphere vary from time to time location to location, but more or less remain a constant on average over a large period of time ok.

So, the current scientific debate about the green house effect centres on the rising levels of carbon dioxide. So, this is rising level of carbon dioxide is manmade, the rest of the things are not manmade. Water vapor content will remain a constant. I mean there is no way that you can increase the water vapor levels by human efforts by very large extent so that greenhouse gas effect green house effect enhances. It is not possible that we do not do any process which will increase the water vapor in this in the in the atmosphere.

We are doing processes by which carbon dioxide is increasing in the atmosphere of course, and methane these two levels are increasing by manmade effects. So, these are anthropogenic in nature. So, these are manmade effects which have in the Earth's atmosphere. So, due to sources such as burning of fossil fuels and so many other things and such as deforestation and increasing agriculture activities. So, these things have contributed to increased amounts of carbon dioxide and methane. Now, we have seen that once you increase CO2 more amount of radiation is to be trapped naturally and then; that means, the average temperature is raised over a long period of time.

Now, this is something about so, this was something about the classification of atmosphere let us say that thermal structure of atmosphere. We have seen the thermal structure and characterization based on the electrical properties right; we have seen the electrical properties such as ionosphere and etcetera then we have seen the most important greenhouse effect night right.

Now, at this point I will make a small curiosity question for you. So, please try to look upon what is the what is the form or what was greenhouse effect on Venus? So, try to look into some books where you can find something about the greenhouse effect on Venus ok.

Now, so, this was something about the classification of atmosphere based on various types of physical parameters based on pressure, based on temperature things like that. So, now, one important thing is so, temperature varies in a non-uniform fashion; density varies exponentially; pressure also varies exponentially; temperature varies in a zigzag right ok. Now, so, this is this is some discussion about the thermal and electrical structure of the atmosphere ok.

So, we will stop here and we will continue this discussion based on about the circulation processes in the atmosphere of the Earth.