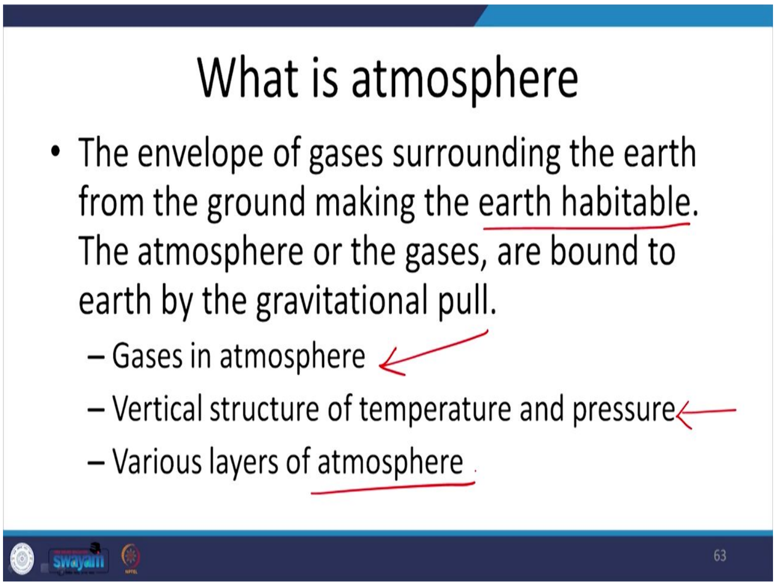
Introduction to Atmosphere and Space Science
Prof. M. V. Sunil Krishna
Department of Physics
Indian Institute of Technology, Roorkee

Lecture – 06
Structure of Earth's Atmosphere

Hello, dear students. Today, we will talk about the structure of atmosphere of the Earth. It means; we will discuss few important aspects about various characteristics about the atmosphere of the earth; what is the chemical composition of the atmosphere, how does the pressure, temperature vary with respect to height in the atmosphere things like that ok. So, what is atmosphere? To begin with I mean how do you define atmosphere?

(Refer Slide Time 00:55)

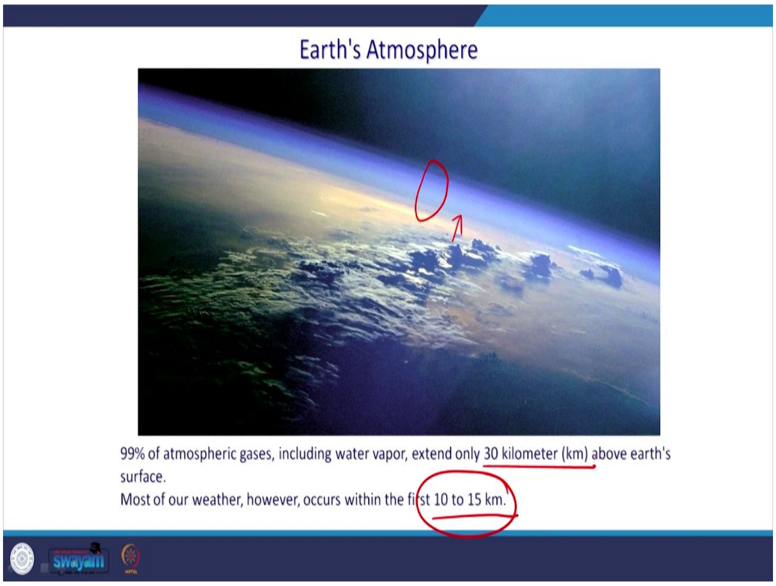


So, atmosphere is the envelope of gases that surrounds the planet; the surrounds the earth itself and it starts from the ground and it extends to several hundreds of kilometers into the space and atmosphere is the entity or the system which makes the earth habitable.

So, it supports life, life exists on this planet just because, there is atmosphere on this planet. And eventually, atmosphere or all these gases, the gas envelope is surrounded surrounding the earth or is held by the earth's gravitational pull. So, earth's gravity is what keeps the atmosphere bound to the earth ok. So, there are different gases in atmosphere; we will talk about, what are the different gases in the representing atmosphere since the gas envelop right.

Then, we will look at the vertical profile of temperature and pressure in the atmosphere; that means, we will look at how the variation how the pressure or temperature vary with respect to height ok. And we will define, what are the different layers of atmosphere and how is each layer different from the from the remaining and what are the basic characteristics of each layer stuff like that then.

(Refer Slide Time 02:10)



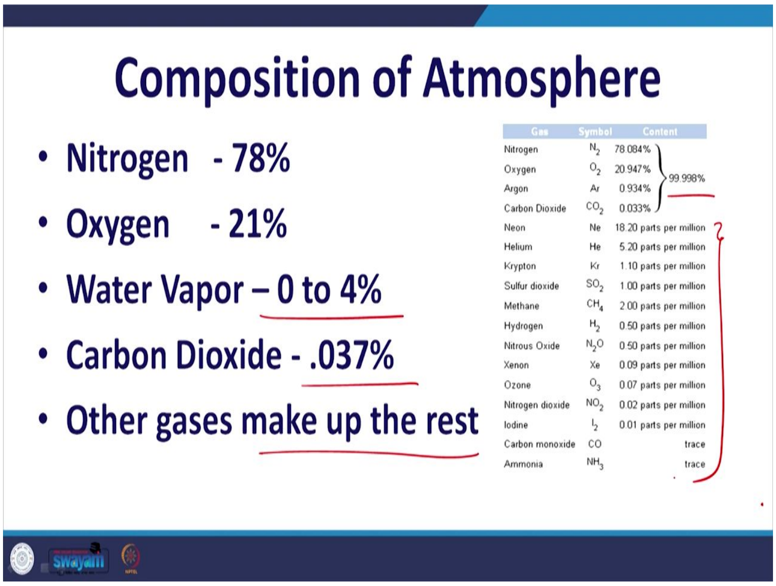
So, what is the atmosphere? We have defined what is the atmosphere. So, atmospheric gases, so in this picture; what you see, the blue layer that you see surrounding the planet or above the ground is the atmosphere. This is generally called as atmospheric limb ok. So, we know that 99 percent of all the gases including water vapour all this, the entire mass of atmosphere extends only up to 30 kilo meters above the earth's surface. So, about the above 30 kilo meters also, there is a lot of gas which generally constitute not more than 1 percent of the entire mass of atmosphere.

So, to be very easy to remember or a very well established fact, we can always say that 99 percent of the atmospheric gases exist within the first 30 kilometers of the atmosphere that is it. So, the remaining atmosphere is scattered or diffused over the entire let us say 700 kilometers ok. And it is also very important to note that; all the weather patterns all the weather system that you see around yourself or anywhere in the planet on the planet, result only in the first 10 kilometres, 10 to 15 kilometres to be precise. So, all the weather happens in the first 10 to 15 kilometers and the entire 99 percent of the atmosphere is below 30 kilometers limit.

So, this is these two are the very important characteristics of the atmosphere. So, we can always say how much atmosphere exists. I mean there is a lot of atmospheric envelope of course, the gaseous envelope is enormously large, huge it is, but the weight of 99 percent of the atmosphere is only up to 30 kilometers from the ground. Then, the second thing is; atmosphere is home to all the gases. Nitrogen, oxygen, argon every other gas that we can imagine right.

Now, atmosphere is the place where all the weather happens. You see rain, you see thunderstorms, you see you see lightning, you see so many things, you see clouds right. All these things happen in the first 10 kilometres, nothing happens after let us say 15 kilometers no weather system will develop beyond 15 kilometers generally ok.

(Refer Slide Time 04:27)



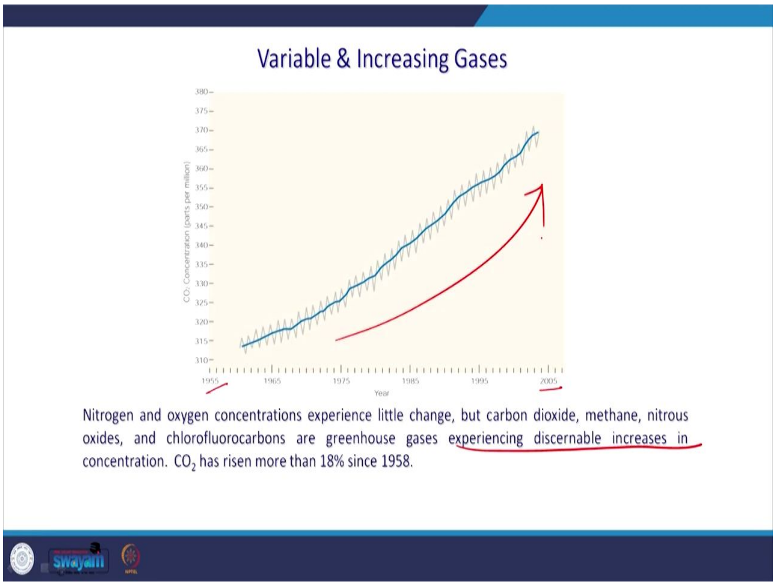
Now, if you look at the composition of the atmosphere, I mean what are the different gases that you can find in atmosphere of the earth. So, it is nitrogen which is 78 percent, oxygen which is 21 percent, water vapour is 0 to 4 percent by volume and is 0 to 4 percent because water vapor the content of water vapour, the variability of water molecules H2O molecules, as water vapor is dependent on many factors.

So, 0 to 4 percent is not at a particular place. So, at the tropics, due to the excessive heating; there is more water vapour, so maybe probably it will be up to 2 to 3 percent and the poles where it is dry that the water vapor will be nearly 0. So, it depends I mean. So, this is not something very important for us to for us to think about. But generally the other gases let us say carbon dioxide is 0.037 percent and the remaining gases all of all of which will constitute the rest of the percentage make up the rest.

So, if you look into the detailed chemical composition of the atmosphere of the earth, what do you realize is that nitrogen, oxygen, argon and carbon dioxide itself may make up to 99.998 percent of the atmosphere. The minor species, the trace species are always measured or always quantified in parts per million concentrations.

So, they are very very small numbers of course, but still there is it is or the entire volume of the atmosphere they are not to be neglected anyway right. But one thing that you should always remember is 78 percent of the atmosphere is nitrogen and 21 percent of the atmosphere is oxygen. And that the major species apart from nitrogen and oxygen are argon and carbon dioxide ok.

(Refer Slide Time 06:17)

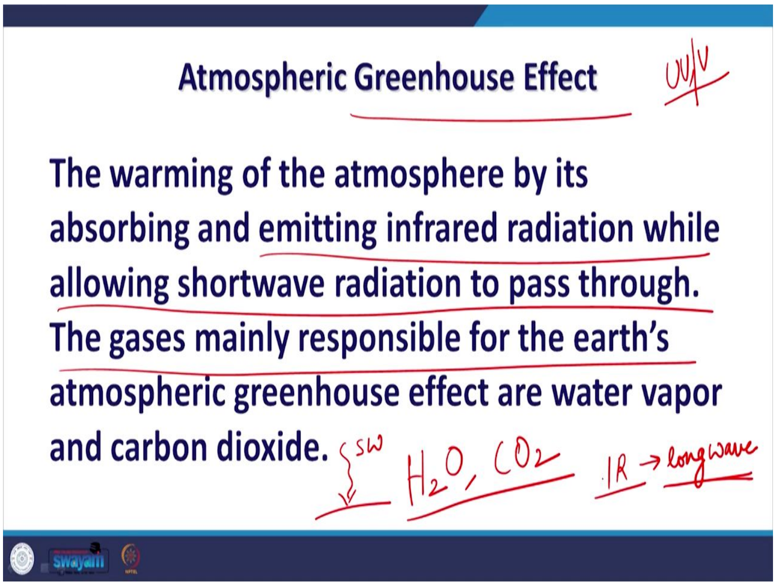


Then what happens is there is a lot of change in the atmosphere, the chemical species. But, generally nitrogen and oxygen concentrations generally do not experience a lot of change over the period of a lot of time. That means, oxygen and nitrogen concentrations experience little change, but carbon dioxide, methane, nitrous oxides, chlorofluorocarbons, greenhouse gasses experience I mean huge change over period of time. I mean that is we talk about CO2 levels increasing the lot. I mean so; that means, that there is a lot of variability in the CO2 levels, there is a lot of variability; that means, over a period of time the CO2 levels can go from a small number to a very large number.

So, this figure indicates the CO2 concentrations over the past, let us say to and starting from 1955 up to the year 2005. So, what you see is the concentrate the concentration of CO2 is steadily increasing. So, it is a steady increase. So, we always we have always seen that CO2 levels are always accompanied by increase in the temperatures. So, this is the CO2 levels are the main reason for the increase of heat or average temperature of the planet; that means, we are talking about the global warming right.

So, it is basically; so, now we see that atmosphere of the earth is composed of nitrogen and oxygen be a majority and to by CO2 a very small number. But CO2 stability or CO2's is variation or the anthropogenic effects; that means, the humans intervention in increasing or humans contribution in increasing the CO2 levels makes it a potential candidate to rise the temperature or the average temperature of the earth ok.

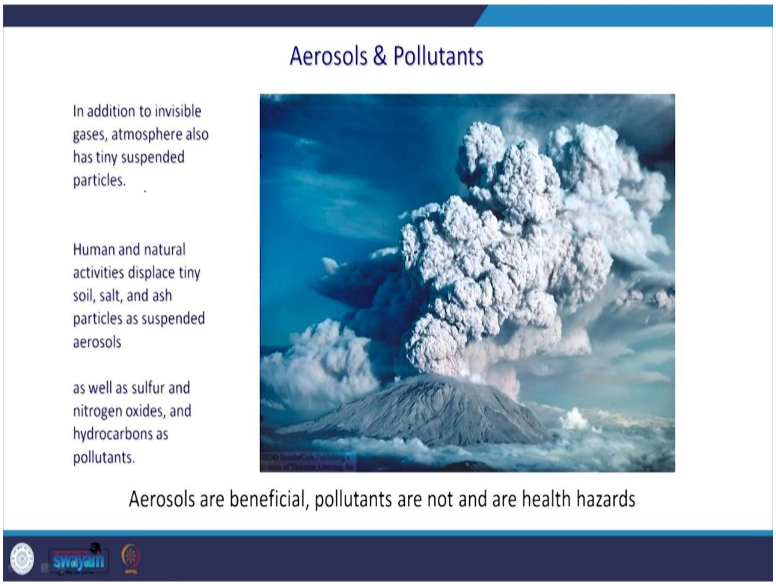
(Refer Slide Time 07:58)



Now so, this effect is generally called as the Greenhouse Effect Atmospheric Greenhouse Effect. So, the warming of the atmosphere by its absorption and emitting infrared radiation while allowing shortwave radiation to pass through; this is called as the greenhouse effect. So, the gas is mainly responsible for the atmospheric greenhouse effect are water vapor and carbon dioxide. So, H_2O and CO_2 have vibrational or IR higher active bands ok. Then, what the point is, the point is this; they will trap the outgoing infrared radiation; that means, which is also called as the long wave radiation.

So, they will not allow the long wave radiation to go out and they will allow this shortwave radiation; the shortwave radiation to enter the atmosphere. The shortwave radiation is the radiation with a small value of lambda; that means, the ultraviolet visible will fall I mean not really visible, but the ultraviolet radiation is a candidate for shortwave radiation and long wave radiation is generally the infrared radiation. So, these two molecules would not interact with ultraviolet, they interact when only with the infrared radiation because they are molecules; so it is naturally understandable right.

(Refer Slide Time 09:26)



Now, apart from gaseous, atmosphere is also home to several particles or let us say suspended particles. So, in addition to invisible gases like nitrogen oxygen and argon, atmosphere also has tiny suspended particles. It has very small tiny suspended particles. Human and natural activities displaced tiny salts, soil particles and ash particles to be displaced into the atmosphere as aerosol particles ok and apart from this sulphur, nitrogen, oxides and hydrocarbons as pollutants.

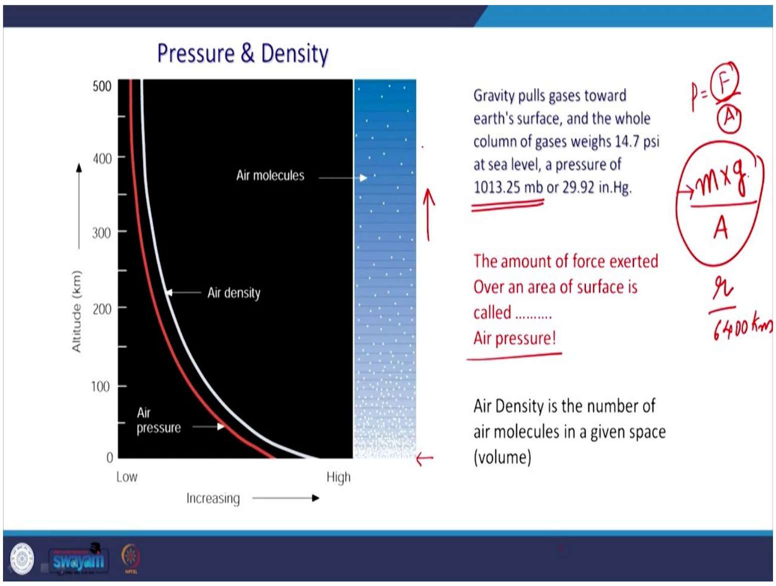
So, human activities are the ones which will; so, human activities will throw a lot of pollutants into the atmosphere of the earth. They remain there for a lot of time for a very very longer amount of time, they remained it and natural activities such as volcanic eruptions will deposit or will pump a lot of particles such as ash particles into the atmosphere. So, these particles are called as can be called as aerosol particles.

So, atmosphere also has a tremendous the population of these aerosol particles in it. Aerosol particles are generally helpful or they are beneficial for many many things, but the pollutants are not beneficial rather they are hazardous for the humankind. So, aerosols are beneficial in the sense that aerosols act as condensation nuclei for the clouds to form right. So, without their results, you can expect you cannot expect the clouds to form; that is a discussion we will get there sometime ok.

So, when we discuss about the cloud physics probably, we I will explain more about this. So, the point is the atmosphere is home to gases, the gaseous envelope is atmosphere. Apart from these invisible gases, there are lot of particles which are suspended in the atmosphere. And the height at which these particles are suspended will decide the amount of time these particles will spend at in the atmosphere.

So, it is naturally expected if the particle is heavier, it will be pulled by the gravity and it will reach the surface. But what has been seen is that; the height to which these particles go will decide the amount of time that it spends there.

(Refer Slide Time 11:54)



Now, one very important parameter when you talk about atmosphere is called as pressure. So, pressure by definition is force per unit area. So, the pressure by definition is the amount of force per unit area right. Now, so if you want to calculate the atmospheric pressure, you calculate the surface area of earth, the entire surface area of the earth. The force is nothing, but the entire mass of the atmosphere multiplied with the gravity.

So, this is the force that the atmosphere exerts on the planet on the surface and what is the total area this are the these atmosphere exerting, this pressure is the total surface area of the planet itself right. Now, if you calculate this, if you put numbers into this yeah so, area can be calculated by knowing the radius of the planet. So, radius of the planet is nothing, but 6400 kilometers right. So, you know all these numbers it is not a big thing.

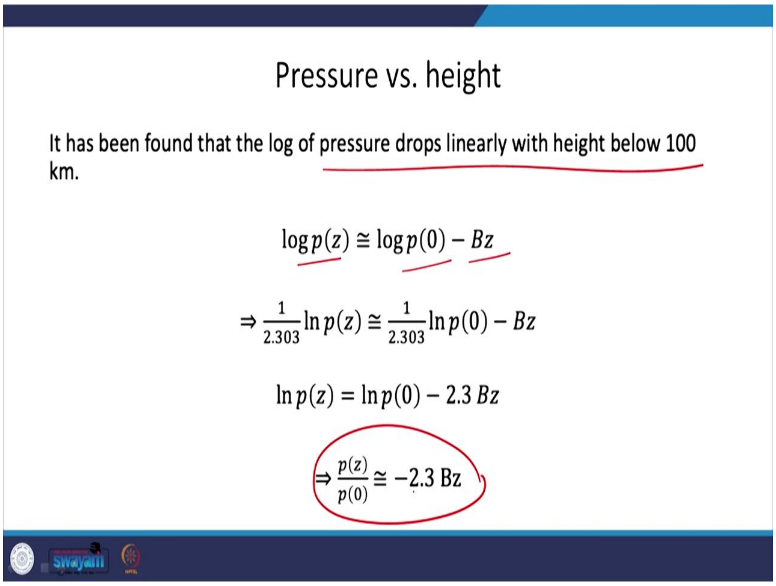
So, the force is the weight that atmosphere exerts on the planet surface. So, you can calculate the pressure. So, gravity pulls the gases towards the earth surface and the whole column of gases weighs nearly 14.7 psi at the sea level; so, which is equivalent to a pressure of 1013.25 millibar. So, this is the number that you want to remember for as long as for the rest of your lives. This is a very important number what is the pressure, what is the surface pressure is 1013.25 millibar.

So, basically the idea is the amount of force exerted over in a surface area is called as air pressure. And the air density, I am talking about the density. Air density is the number of molecules in a given surf given space. Let us say density is the number of atoms sorry molecules atoms or molecules per units are per unit volume; let us say ok. Now, if you see how does the pressure or density vary with respect to height, what you see is let us say, on the y axis you have the altitude. That means, you have the height in kilometers and on the x axis, you have the value of pressure or density. Pressure is given in the red curve and density is given by the blue curve.

So, what you see is; so, this is the ground, 0 is a ground. So, what you see is; there are more molecules up; obviously, more number of molecules are held by the gravity near the surface. So, more number of molecules more is the amount of force that they exert on the surface; more is the force, more is the pressure right. But when you see when you go up; what you see is the number of molecules. When you go up, the number of molecules are decreasing. That means, the density is large here and density is very small here. Equivalent to a density and the pressure is very high near the surface and pressure decreases as you go up.

So, that is what is being shown in this figure where you see that the density and the pressure vary in a similar fashion. They vary very much similarly that they decrease, that the pressure and density decrease as we go up. Let us talk more about this variation ok.

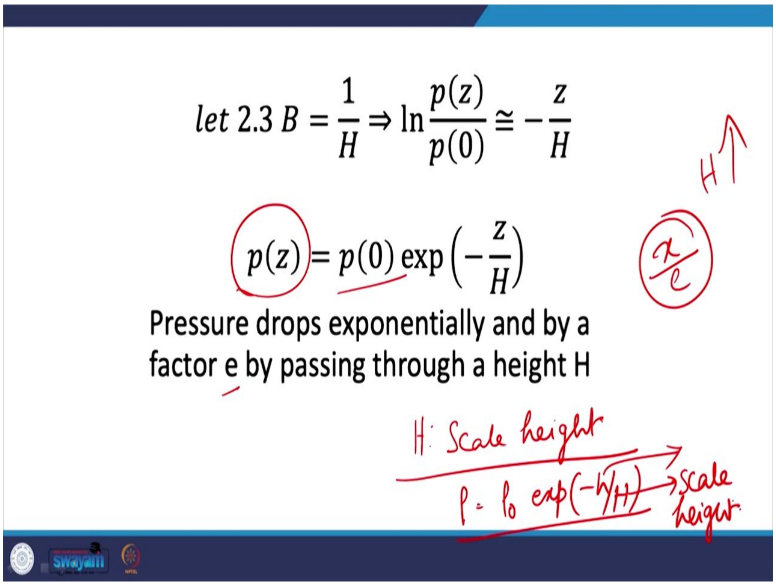
(Refer Slide Time 15:06)



Now, if you draw this variation; what you will realize is that the log of pressure drops linearly with height below 100 kilometers. So, that was an exponential curve if you take a log, then you will get a linear curve of course.

So, what has been written is that log of pressure at any height drops linearly because this is a linear variation with respect to pressure at the ground with a slope right. So, you must you multiplied by 1 by 2.303 and that what you will realize is that; pressure at any height z with respect to pressure at the ground level is equals to minus 2.3 times Bz.

(Refer Slide Time 15:54)

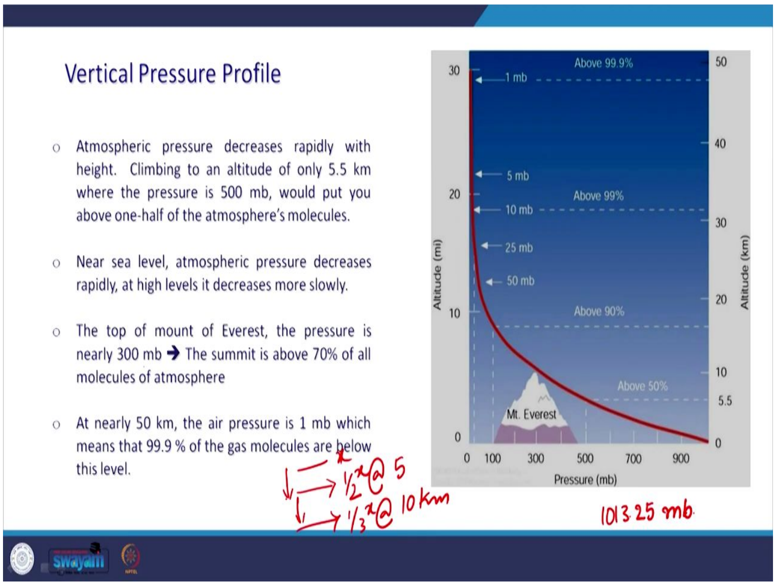


So, what you will see is that log of lawn of pz by p0 is minus 2.3 Bz; that means, that pressure at any height z depends exponentially with respect to pressure at the ground level. That means so it is an exponential growth from the top.

So, pressure drops exponentially and by a factor of e by passing through a distance of H. So, here you define capital H as the scale height. Scale height is the length dimension by travelling which distance pressure will decay to 1/ eth of its original value. So, at the ground if it is something let us say x after travelling a distance of H into the atmosphere, the pressures value will be x/ e, that is it.

So, we can also say that the density also varies in a similar way so, that the density is rho naught times exponential minus h by capital H. So, h is the height at which you are trying to find out find out the pressure, capital H is a scale height. We will derive a relation for the scale height as it is ok.

(Refer Slide Time 17:05)



So, few important aspects about the pressure profile let us say. So, if you see this figure what you see is; on the x axis, you have the pressure and on the y axis, you have the altitude. So, atmospheric pressure decreases rapidly with height, it decreases very fast. I mean exponential growth or exponential decay is very fast we know that. Climbing to our altitude of nearly 5.5 kilometers itself, the pressure will be almost half like 1013.25 is the pressure at the ground right, 1013.25 millibar is the pressure on the ground.

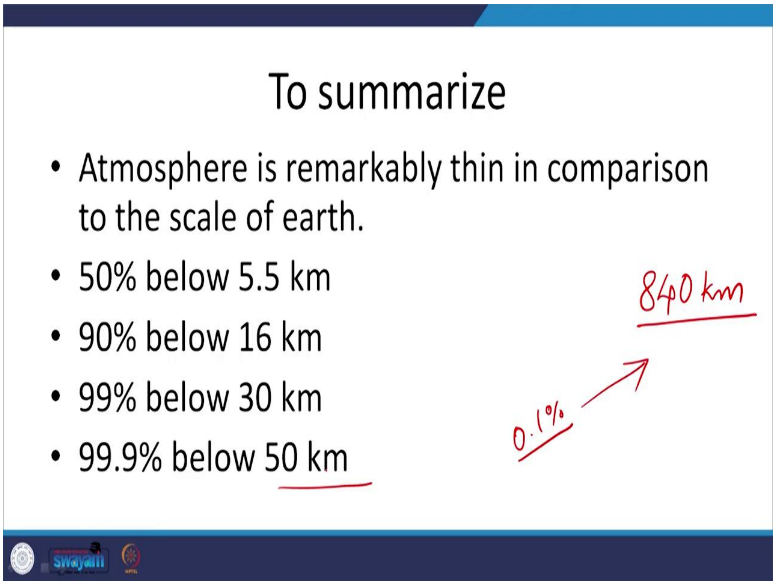
So, this is the amount of force that exerts that atmosphere exerts on the surface ok. Now, with this reference, what you will realize is that at an altitude of 5.5 kilometers itself; this pressure nearly drops to 500 mb I mean half of the pressure at the surface. So, that means that it; that if it is half; that means, half of the entire molecules of the atmosphere exist below 5.5 kilometers right.

So, straightforward and near this sea surface, the atmospheric pressure decreases rapidly and at high levels decreases more slowly; that means, the decay that is the nature of exponential variation. So, it will be very fast in the beginning and it will not be so fast, it will be slow afterwards ok.

The top of Mount Everest let us say for a for reference the pressure is nearly 300 millibar so; that means, one-third of pressure itself. It is nearly at her 10 kilometers, it is nearly one-third. That means, so the pressure has dropped to half at 5 kilometers and it has dropped to one-third at 10 kilometers. That means, so you see here; so, this is 1 here, it has dropped to 1, half of let us say this is x and one third of x; that means, this decay is fast and this decay is not as fast as this right as simple.

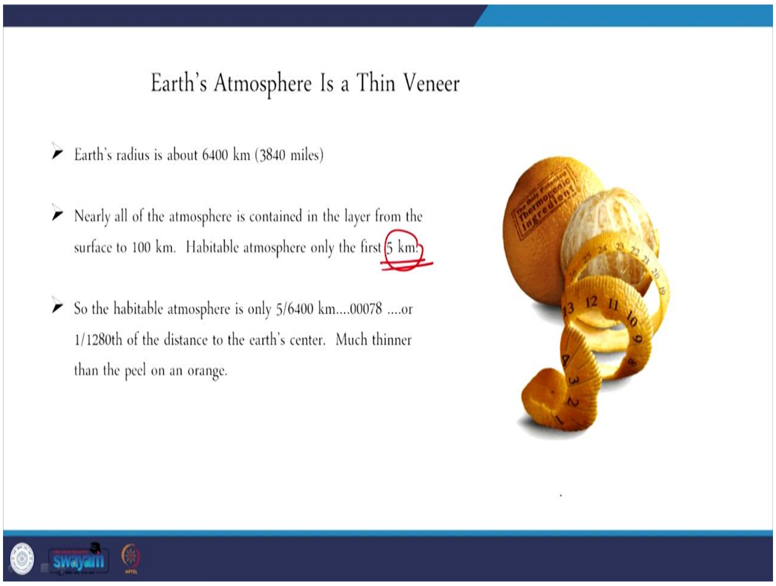
And nearly 50 kilometers; the air pressure is 1 mb. That means, the entire then the total number of molecules of the atmosphere are existing below 50 kilometers right ok. So, one thing that you have to understand from this is that pressure decays exponentially as you go up and the decay of pressure is very fast in the beginning and it will be slow afterwards ok.

(Refer Slide Time 19:34)



So, to summarize this discussion about the about this what you can say is I mark the atmosphere is remarkably thin in comparison to the scale of the earth. Of course, it is the 50 percent of the atmosphere is nearly is below 5.5 kilometers, 90 percent is below 16 kilometers and 99 percent is below 30 kilometers. And 99.9 percent of the atmosphere is below 50 kilometers. And we generally, take an example take the atmosphere to exist up to at least a 840 kilometers, it is not a standard number anyway ok. That means, that everything the 0.1 percent of the atmosphere is what exists after 50 kilometers, that is it. So, the entire atmosphere; the entire atmosphere is existing below 100 below 50 kilometers ok.

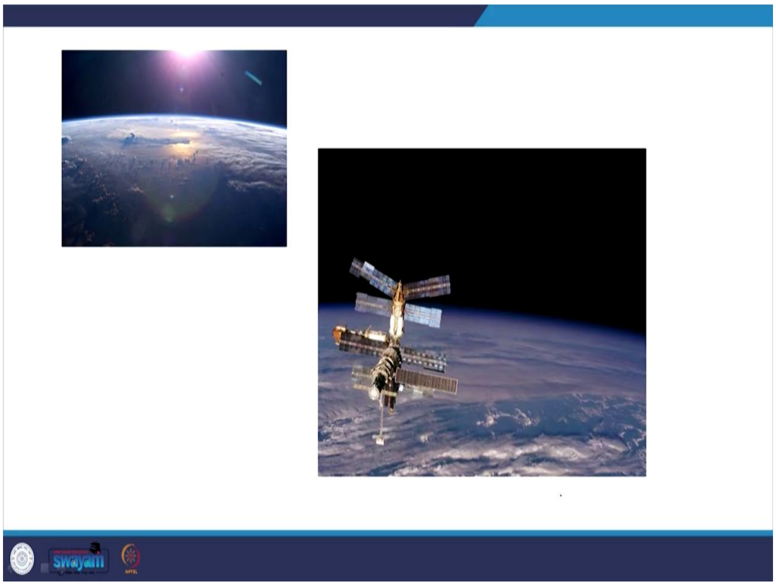
(Refer Slide Time 20:23)



Now, the atmosphere is actually a thin wiener, I mean the earth's so, to put to reference the at most the radius of the earth is nearly 6400 kilometers which is let us say 3840 miles. So, nearly all the atmosphere, so with this numbers let us see; if you put this in comparison with the radius of the earth, nearly all of the atmosphere is contained in the layer from the surface to 100 kilometers ok.

And most importantly, the habitable atmosphere is only within the first 5 kilometers, we should remember this. So, that means that; if you put habitable atmosphere for reference with respect to 6400 kilometers, you will realize that it is only 1 by 1280th of the distance of to the earth's center. So, you cannot even say that it is like a peel on the orange; the atmosphere is like a peel on the orange where the orange is the earth. No, it is not like that I mean it is much thinner than that.

(Refer Slide Time 21:19)



So, tomorrow we will discuss about the layers of atmosphere. So, today we have seen just the basic structure of the atmosphere of the earth; what are the different chemical species that exist in the atmosphere of the earth. So, tomorrow we will see how does the atmospherics temperature vary with respect to height. And based on this variation, we will try to identify different layers of the atmosphere and what are the salient features of these different layers of the atmosphere of the earth.

Thank you.