

# **ENVIRONMENTAL GEOSCIENCES**

**Prof. Prasoon Kumar Singh**

**Department of Environmental Science and Engineering**

**Indian Institute of Technology (Indian School of Mines), Dhanbad**

## **Lecture-3**

### **Concept of Atmosphere and their Constituents**

Welcome to the SWAYAM NPTEL course on environmental geosciences. In the model 1, we have already discussed, we have learnt about the origin of the earth and the internal structure of the earth. So, regarding different hypothesis about the origin of the earth has been dealt already in the lecture 1 and in the lecture 2, we have seen about the different layers of the earth's interior. Now in this third lecture, we will go through the concepts of atmosphere and their constituents. So in this second lecture, the important concepts will be covered in terms of atmosphere, what are the constituents of atmosphere, then what is troposphere, stratosphere, mesosphere, thermosphere and exosphere.

So these are few of the different layers of the atmosphere. In the first and second lecture, we have seen about the Earth's origin, and different hypothesis about the Earth's origin and the different layers of the Earth's interior. Now, just on the surface of the Earth, we are getting atmosphere and this atmosphere has different layers. So, in the subject environmental geosciences, it is very much needed to have the knowledge about the different characteristics of the different layers of the Earth's atmosphere also. So, this will be covered in this lecture.

Now, the atmosphere, the earth's surface is generally covered by a layer of atmosphere consisting of mixture of gases. So, this atmosphere is having the mixture of gases and other solid and liquid particles as well. So, the gaseous material extends to several hundred kilometers in altitude. The first 80 km of the atmosphere contains more than 99% of the total mass of the Earth's atmosphere. So, atmosphere is the layer of air that surrounds the Earth and stretches up to a significant height from its surface.

It is made up of a mix of different types of gases and is kept close to the Earth by gravity. The air is thickest at sea level and becomes thinner as we go higher. So compared to the

total mass of the earth, the atmosphere makes up only a small portion. It is making very very small portion. If you will compare it with the total mass of the earth.

So whatever material remaining present on the earth's surface is generally coming in the atmosphere and this atmosphere is divided into some different layers. So one by one we will learn about the different layers of the atmosphere. Now before that just we see the composition of the atmosphere. What is the composition of the atmosphere remains? See the composition of the atmosphere is having two major and minor constituents also apart from the water vapor.

So here you can see the nitrogen remains about 78.09% by volume and oxygen remains near about 20.97% by volume. So this Nitrogen and Oxygen is the major constituent of the atmosphere. Then minor constituent remains the carbon dioxide, 0.03% volume, inert gases, Argon, Helium, Neon, Krypton, etc., making up the remaining portion. And I have told you apart from these major and minor constituents is the water vapor present in varying amounts across different regions of the Earth's surface and concentrated mainly in the lower atmosphere. And the lower atmosphere is generally termed as the troposphere.

So this you can see here also that nitrogen and oxygen these two portion nitrogen and oxygen is having the major constituents in the picture also apart from the carbon dioxide and other gases. So structure wise just you can see here the structure of the atmosphere is divided into five basic layers the bottom most that is from the surface of the earth starts the troposphere and this is the troposphere. This portion is the troposphere. This is the surface of the Earth. So on the surface of the Earth, you can see here, this is the troposphere.

Then comes the stratosphere. Then comes the mesosphere. Then the thermosphere. And then the exosphere. Each of these layers plays a critical role in regulating climate, supporting the life and protecting the planet from solar radiation.

So this layer is having different characteristics also at different height the characteristics of the layers also changes so this we will discuss one by one about the different layers of the atmosphere. So the first layer which is just remaining above the earth surface is the troposphere. So here the important point is that altitude that the troposphere extends up to an average height of 12 kilometer from the earth's surface so it is from the if this is the earth's surface earth's surface. So from here to up to 12 kilometer height 12 kilometer,

generally, it remains the troposphere. It is thickest at the equator compared to the other regions. So this troposphere remains thickest at the equator.

And density wise, if you will see, the troposphere is the densest of all atmospheric layers. Whatever layers are coming up, this is the densest layer on the Earth's atmosphere containing about half of the total mass of the atmosphere. This is containing half of the total mass of the atmosphere. Now, regarding atmospheric process, this troposphere, the troposphere is layer, is the site of all essential atmospheric processes. Whatever processes are required for atmospheric activity, all are remaining in the troposphere only because that it generates the Earth's weather and climatic patterns such as wind, clouds and precipitation.

So we are seeing that even wind, clouds and precipitation are all because of the presence of the tropospheric layer. About half the mass of air comprising the entire atmosphere is generated in this zone. So this is about the atmospheric process and temperature wise if you will see the air temperature in the troposphere decreases at a rate of  $1^{\circ}\text{C}$  for every 165 meter of elevation. This is the earth's surface. So from the earth's surface,  $1^{\circ}\text{C}$  centigrade, It will decrease by 165 meters elevations. So this is very very important point because as we move up the temperature also decreases.

So this layer is vital to life on earth due to its role in weather formation and its concentration of atmospheric masses. So this is about the troposphere. Now in between the troposphere and stratosphere because the stratosphere is just above the troposphere, one layer is called named as tropopause. This is a boundary between the troposphere and stratosphere and it is an undefined region where temperature remains constant. We have seen that temperature was gradually decreasing, but here the temperature remains constant.

Whatever temperature was there at the height of this tropopause, there the temperature remains constant, marking the transition between the two layers, that is the troposphere as well as the stratosphere. So, what's the characteristics? The characteristics of the tropopause, that the altitude of tropopause is around 16 to 18 km, the around 16 to 18 km height we are getting one undefined region named as tropopause. And this tropopause, the temperature levels off and reaches a minimum typically around minus  $55^{\circ}\text{C}$ . So this much temperature generally remains near to the tropopause.

Just after troposphere and tropopause is the second layer known as stratosphere. The key features of the stratosphere is regarding its altitude, it is extending up to the height of 50

km. The stratosphere extends up to the height of 50 km from the Earth's surface. Movement of air, the air in this layer is relatively calm and stable with minimum temperature turbulence or weather disturbances generally we have seen such type of disturbances in the stratosphere but here the air in this layer is relatively remaining in calm and stable position minimum temper turbulence and weather disturbances. This is an isothermal region because the lower part of the stratosphere is nearly isothermal meaning temperature remains nearly relatively constant with altitude.

In the upper part, temperature again increases with height due to the presence of the ozone layer. So at the lower part, it remains nearly isothermal region. But as the altitude extends further, the upper part of the stratosphere, the temperature is increasing. Why? Because of the presence of the ozone layer at the height of near about 33 to 35 kilometer height.

So, in this way the temperature difference we got from lower to upper part of the stratosphere. Absence of clouds and water vapor remains there because this layer is free from cloud dust water vapor relating in clear sky we have seen these all were remaining present in the troposphere cloud dust and water vapor. Ozone layer the upper part of the stratosphere contains a highly concentration of ozone the ozone absorbs most of the harmful ultraviolet radiation from the sun allowing only a small non-harmful amount to pass through protecting living organisms from ultraviolet damage. So this is very very important layer which is near about at the height of 35 kilometers. So this stratospheric ozone layer actually protecting the life of the organisms from ultraviolet radiations damage.

So this layer plays a crucial role in shielding the earth from harmful solar radiation. This ozone layer, stratospheric ozone layer plays a very very important role in just protecting the life at the earth's surface from the harmful ultraviolet radiations. Now next again one undefined region we are getting in between the stratosphere and mesosphere that is named as stratopause. The stratopause is the boundary between stratosphere and mesosphere. The altitude of the stratopause varies 50 to 55 kilometers above the earth's surface.

Temperature increases with height because of the absorption of ultraviolet radiation by ozone molecules. This warming causes a temperature inversion, meaning that the stratosphere is warmer than the layer below it, that is the toposphere. It is an undefined region where temperature remains again constant. In the case of topopause, we have seen

the temperature remains constant. Here also again we are seeing that the stratosphere is an undefined region where temperature is remaining constant, marking the transition between these two layers.

It is the point where the temperature in the atmosphere begins to decrease again and after having risen steadily in the stratosphere due to the absorption of ultraviolet radiation by ozone. So the stratopause is a distinct atmospheric boundary that plays a key role in the regulating the temperature gradients and the atmospheric dynamics at high altitudes. So this stratopause is a very very important layer just in the atmosphere because it is just distinct in the atmospheric boundary which are playing a key role, important role in regulating the temperature gradients and atmospheric dynamics at higher altitudes. So, after the stratopause is again coming the next layer that is the mesosphere but the stratopause represents the peak of this temperature increase. At this point temperature is typically around 0°C to -10°C.

Atmospheric pressure continues to decrease with altitude and at the stratopause it is extremely low about one thousandth of the sea level pressure. The composition of the atmosphere at the stratopause is still primarily nitrogen and oxygen but the concentration of ozone starts to decrease as ozone is more concentrated in the lower atmosphere not in the upper atmosphere. So then comes the next layer that is the mesosphere. The key characteristics of the mesosphere can be outlined as that its altitude extends up to a height of 80 km. Temperature, one of the coldest regions in the atmosphere with the temperature decreasing as altitude increases.

Radio-wave absorbing layer we got in the mesosphere because at around 60 km above the earth's surface, there is an intermediate layer which absorbs the radio waves, aiding in communication and signal transmission. Again, just like the tropopause and the stratopause, we are getting the mesopause in the mesosphere. The mesopause is the boundary between the mesosphere and thermosphere. It is an undefined region where temperature remains constant, marking the transition between the two layers. The mesosphere is also the layer where meteors typically burn up as they enter the Earth's atmosphere.

So in this way, this mesosphere, this is just lying above the troposphere and stratosphere and it is extending up to the height of 80 km from Earth's surface and it is one of the coldest regions in the atmosphere. Again, just like tropopause, stratopause, we are getting here mesopause. Mesopause is the boundary between the mesosphere and

thermosphere. It is again an undefined region where temperature remains constant, marking the transition between the two layers. The mesosphere is also the layer where meteors typically burn up as they enter the Earth's atmosphere.

Characteristics of the mesopause. The altitude of the mesopause varies around 80 to 85 kilometers. Temperatures generally decrease with increasing altitude with temperatures typically ranging from minus 60°C to -90°C at the mesopause. The mesopause represents the point where the temperature reaches its minimum. It is the coldest region of the earth's atmosphere.

Next, the air pressure at the mesopause is extremely low, just like throughout the mesosphere, where atmospheric pressure is about  $\frac{1}{1000}$  of the sea level pressure. At this height, the atmosphere is very thin with only a few molecules of air per cubic centimeter. The composition of the earth atmosphere at the mesopause is similar to that of the rest of the mesosphere, dominated by nitrogen and oxygen with small amounts of other gases like carbon dioxide and ozone. So while we have seen the composition of the atmosphere in this layer is generally dominated by nitrogen and oxygen and very, very small amounts of other gases like CO<sub>2</sub> and ozone. While ozone is concentrated in the lower atmosphere but there is still some ozone present in the mesopause but this concentration is much much lower compared to the lower layers.

So in this way we are getting the ozone layer but the concentration remains very very low. Then comes the next layer that is the Ionosphere. The important concepts about the ionosphere, it is just lying above the mesosphere and overlaps with the thermosphere which is starting around 85 km and this ionosphere is extending up to the height of 150 km. So, this layer contains ionized or electrically charged particles which are created by the sun's radiation. This layer also protects from the meteorites because it just layer is protecting the earth by burning up small meteorites before they reach to the surface.

And this layer also tells us about the reflection and modification regarding the radio waves because making long distance radio communication possible by bouncing signals back to earth. The ionosphere plays a crucial role in both protecting the planet and enabling radio communication system. Then comes the next layer that is the thermosphere. The location is between 85 km to 690 km above the Earth's surface, above the mesosphere and below the exosphere. The temperature is, this is the hottest layer of the atmosphere with ranging from 500°C to 1500°C due to the absorption of solar ultraviolet and X-ray radiation.

Composition wise, if you will see, it is primarily oxygen and nitrogen, but with lighter gases also like helium and hydrogen at higher altitudes, highly ionized with free electrons and ions, especially at the upper layers. Regarding ionization and ionosphere, we can see that thermosphere is a part of the ionosphere, a region with high levels of ionization that influences the radio communication and the GPS. The ionosphere contains the F layer where ionization peaks. So role-wise, if you see the role in space weather, the thermosphere is very, very important for auroras and geomagnetic storms caused by solar interactions. It is also key to space weather phenomena that affect satellite operation and communication.

In satellites, in fact, if you will see the satellites in low earth orbit experience drag in the thermosphere, which can gradually lower their altitude. The density of the thermosphere influences this drag, especially during the periods of solar maximum. Energy absorption, as you will see, the solar radiation causes rapid heating, but the atmosphere is thin, so despite the high temperatures, it doesn't feel hot to humans due to the low air density. Solar cycle influence wise if you will see the thermosphere temperature and ionization level vary with the 11 year solar cycle impacting atmospheric drags, space weather and satellite orbits. So these are some of the important characteristics of this layer.

Then comes the next layer that is the exosphere. The main characteristics of the exosphere are that this exosphere is the outermost layer of the Earth atmosphere lying beyond the ionosphere. Here also we are getting undefined boundary. Its upper limit is not clearly defined as it gradually transitions into the vacuum of space. Composition-wise, this layer contains sparse particles, primarily hydrogen and helium atoms, which are so widely spaced that they can escape into the space.

Interaction the exosphere marks the fringe of the Earth's atmosphere merging with outer space. So the exosphere represents the final boundary between the earth atmosphere and the vastness of the space. So if summary is the that this earth atmosphere is having the bottom most layer is the troposphere then comes the stratosphere. Then after that is the mesosphere, then thermosphere, and then the ionosphere. So this is the different layers and different characteristics of the Earth's atmosphere. Thank you very much.