Remote Sensing Essentials
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Lecture-04
Interaction of EM Radiation with Atmosphere Including Atmospheric Scattering, Absorption and Emission

Hello everyone, good morning , we will be in this discussion we are going to have on how EM that is electromagnetic spectrum or electromagnetic radiation interact with atmosphere and which includes the atmospheric scattering absorptions and emission. So, we are going to discuss on this interaction of EM radiation.

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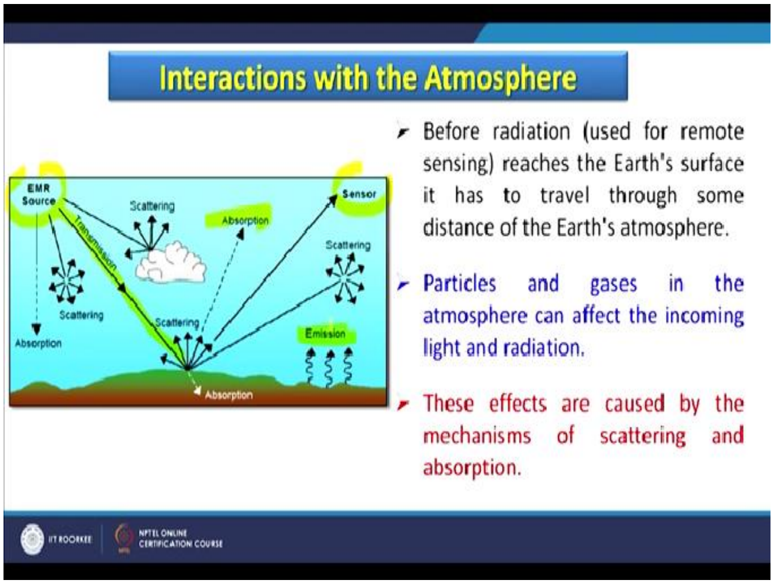

Basically as you can see here in this diagram and that the EMRs source here is the sun is shown here, the sensor is here, but before the radiation reaches to the sensor there are various processes which goes on this transmission directly may reach, but it has to pass through the atmosphere and there might be some scattering also. When they say and also when it interacts with the surface features or objects, then again there might be scattering.

So, radiation keep decreasing further when it goes towards the sensor, there might be some absorptions also and this all will deteriorate the quality of the data or signals or ultimately the satellite images. So, this we have to keep in mind that whatever in the images is being recorded, the signals which are being accorded, they have passed through these 2, 3, processes, scattering absorptions and some other you know associated phenomena.

So, before it reaches to the sensor or remote sensor which is around 840 kilometer away from the surface of the earth, it has to travel a lot and indeed been it has to interact with the atmosphere and in atmosphere there are particles and gases, which can affect not only incoming radiation, but all outgoing reflected radiation as well. If we talk about the emission, then also this emitted in case of thermal infrared when the source is not sun.

The natural emission which is being released by the objects present on the surface of the earth, then these 2 had to also pass through these scattering and absorptions. So, they also get affected by these phenomena. And these effects can cause 2 things which just mentioned that the scattering and absorptions.

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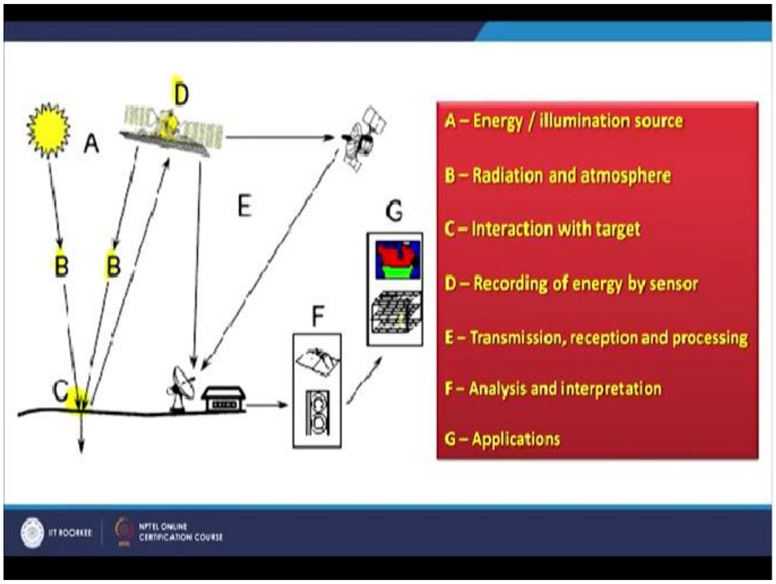

As we have been going through this diagram, and that we know that the this solar the sun is there and then the energy source which we have discussed, we have also discussed the radiation and atmosphere that is the big component mention here and also we have an interaction with the target that is the C component and then recording of this by the D and then transmission. So, when data is also transmitted towards the earth station, again it has to pass through and atmosphere.

But then they use them microwave signals and a lot of affects of scattering and absorptions may not occur as compared to for visible infrared or thermal infrared channel, but nonetheless it too has to pass through the atmosphere. And finally, you get the analysis and interpretation and applications are there.

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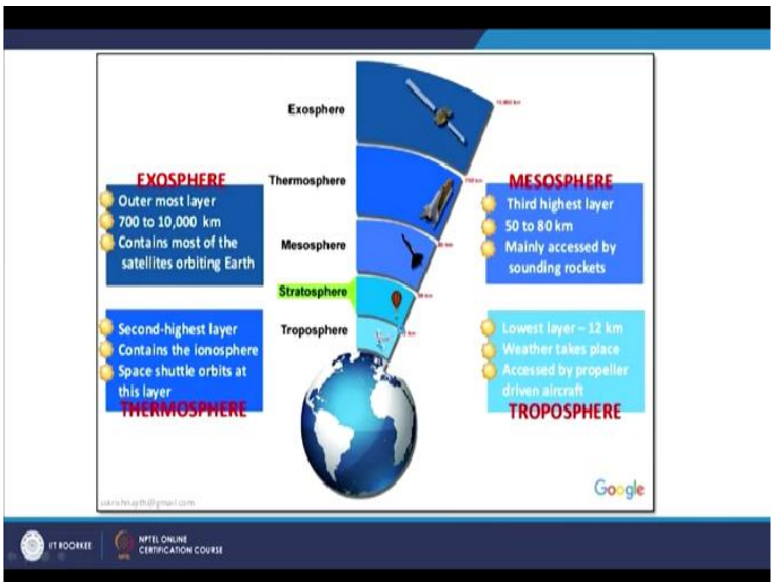

Now, if we very quickly if we go through different layers which surrounds us and different platforms which are used. So, if a aircraft are being used then they have to face only the troposphere, if values are used sometimes balloons are also using some special applications then it has to pass through the signal, have to pass through stratosphere if you know the rockets or other way of acquiring data mainly high altitude aircrafts or missions, then it has to pass through the mesosphere.

If there is a shuttle mission, like it has happened in case of shuttle radar, topographic mission and sometimes the data is also acquired through these missions shuttles, then it has to thermosphere and if it is satellite, then above 700 kilometer, generally these are at 850 + - 10, then exosphere So, all these layers of atmosphere are there. The outermost the exosphere, which is the outermost layer, just discuss from 700 to 10,000 kilometer contains most of the satellite orbiting earth.

Those satellites like polar or sun synchronous satellites or other types of also satellites sometimes they are located within this exosphere. The second highest layer, that is the thermosphere, which contains the ionospheres space shuttle orbits at this layer. So, as I already mentioned that shuttles are generally sent up to that height, then there is a mesosphere that is the third highest layer and which range from between 50 to 80 kilometer, mainly access by sounding rockets.

And the lower most layer that is troposphere and that is up to 12 kilometer and the weather takes place access by propeller driven aircraft, the most of the you know the clouds and dust and all types of gases maximum they are present in this lower most layer and they affect the maximum to the our signals.

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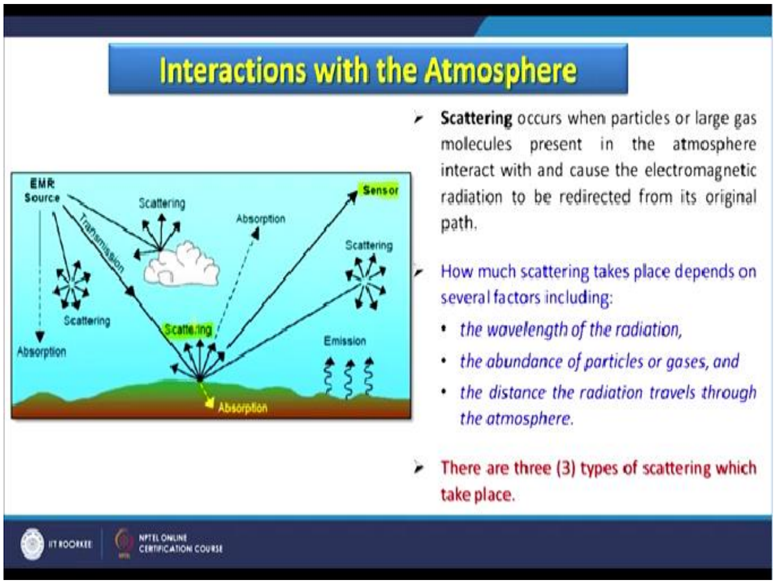

Now, if we continue with this figure, that scattering that is the which occurs when particles are large gas molecules present in the atmosphere and which interacts with this radiation and can cause this EM radiation to be redirected from its original path. So is scattering as one can also see that when this radiation is reaching part of this radiation is being absorbed by earth surface material, but rest is getting scattered in all types of directions.

And how much scattering will take place that will depend on several factors, which includes the wavelength of the radiation and when we are using multispectral scanners at that time in different wave bands or different channels, we get a scattering effects differently. So, that is the meaning here that the wavelength of the radiation which this scattering affects. Abundance of particles or gases that is the density of particles which are present in the atmosphere through which the signals have to pass.

And the third one is the distance the radiation travels through the atmosphere. And if it is you just vertically aboard generally sensors, these polar orbiting satellites or sun synchronous satellite they take data from using another view and then the signal has to travel a little less distance and therefore these atmospheric effects may not be as great as compared to oblique sensors. So, we that what kind of a scattering affects are there, which affects our signals in the field of remote sensing. So, there are 3 types.

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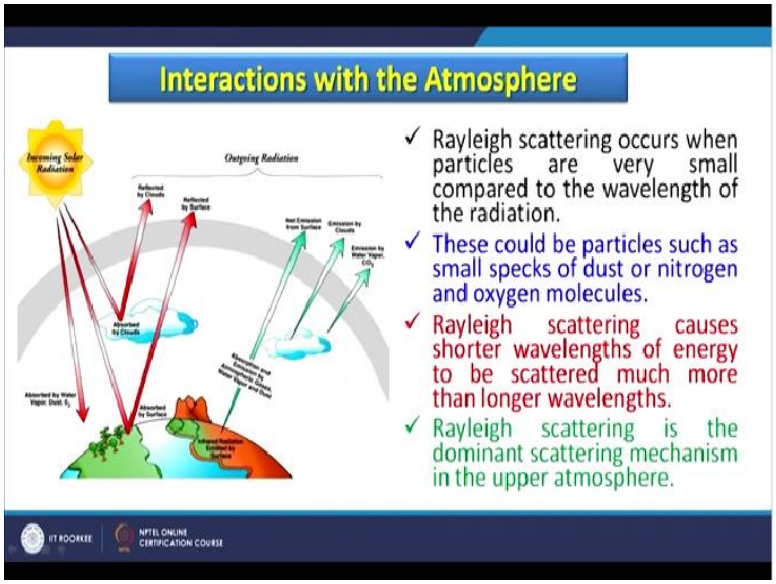

And the first one is Rayleigh scattering and it occurs when particles are very small compared to the wavelength of the radiation. So, this is what is important here that it will only occur when particles are very small compared to the wavelength. So, if wavelength itself is very small and then of course the effect of Rayleigh scattering is going to be different, what when particles are very large, then the effect of release catering will not take place at all.

Then these particles could be such as small what are those small particles that a small specks of dust or nitrogen oxygen molecules present in that atmosphere and Rayleigh scattering causes shorted wavelength of energy to be scattered much more than the longer one, because the shorter wavelength and small parties they are affected most if you are having the smart particles, particles like dust, nitrogen or oxygen molecules.

And Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere and that is what is because these gases and also is fine particles of dust and erosions are there.

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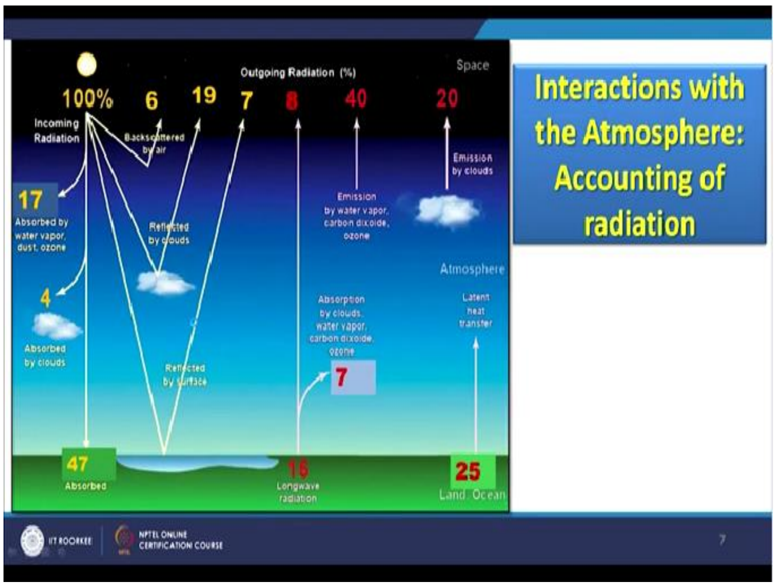

Now if we see that you know the total radiation and if we take as 100% which is coming from sun, then where it get distributed. So, 17% of this one is absorbed by the water vapor, dust in ozone within the atmosphere. Then 4% roughly is absorbed by clouds and then 47% is absorbed by the ground itself on land surface. If it interacts with the water body may get reflected and that goes to 7%, that may be also rather than absorption, it may be reflected by the clouds then it is a quite good amount that is 19%.

And within air as soon as we start journey towards that before that it interacts with the air within atmosphere and back scattering may also happen, but that is a minor component that is about 6%. No longer radiation which is soon here in percent in red, that long wave radiation which is coming from the surface of the earth is absorbed by clouds and water vapor carbon dioxide ozone, that is 7% and then 8% reaches out of atmosphere which can be recorded by the satellites.

Nowadays a lot of applications have outgoing long wave radiation are there people are utilizing this information in case of climate change studies. Also, we have utilized these important bands in the outgoing long wave radiation induced by an earthquake. And several examples we have studied and we have found that there are changes in because of an earthquake event in any area. So lot of applications are there of outgoing long wave radiation though it is just 8%.

Now, 40% of this is emission by water vapor carbon dioxide within this. So, that is also added and 20% is emission by the clouds also. But it is possible employing remote sensing sensors to just isolate this one and record outgoing long wave radiation, as I have mention that lot of research is now depending on inputs coming from outgoing long wave radiation for climate change and other studies including earthquake studies.

There are some other transports also that is like latent heat transfer from the land or maybe from the ocean. So, these are the components of energy which are going away from here.

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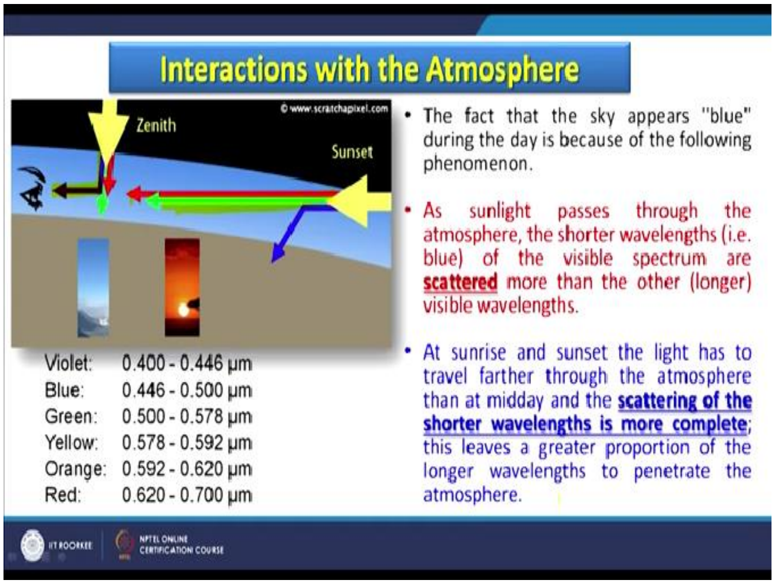

Now, when is this is very basic physics, which we have studied during school time, that if the signal are coming from Zenith that you downward or Northway view then these have to travel very less, and therefore, you would have a more blue component, then red and green. But when sun is near horizon or sun rises there then the light source or radiation from the sun has to travel a long distance through the atmosphere.

And therefore, in that case it a red component becomes larger and that is why we see during sunset or sun rise, we see skies red, as have been told in the school time and when the sun is the light is coming from top, it does not have to travel a lot through the atmosphere then we get the blue, we just remember that these fundamentals which we have studied in our school time, maybe 10 or 10 + 2 classes, these are all are being used here.

Whether it is this concept which just I have told you or other concepts which are all those physics, which have been studied during those time are basis of remote sensing here. So, you know fundamentally nothing has changed, except that the applications have improved lot. So that this is the emission which just I have said that the fact that the sky appears blue during the day is because the following phenomena as sunlight passes through the atmosphere, the shorter wavelength that is blue of the visible spectrum are scattered more than the other longer visible wavelength.

And that is why we see sky is blue. At sunrise and sunset, as I have already mentioned, that light has to travel through a long distance in the atmosphere at midday, and the scattering of shorter wavelength is more complete. And this leaves a greater portion of longer wavelengths to penetrate atmosphere and that is why it is red.

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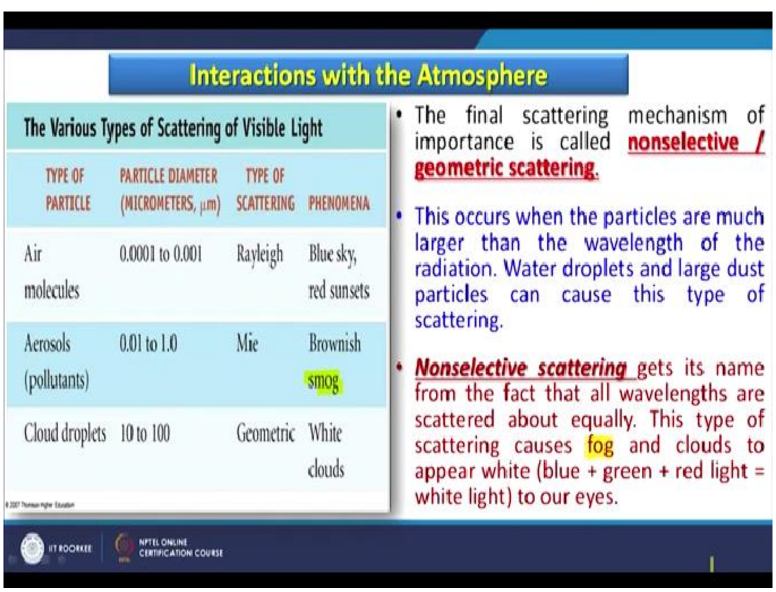

Now, when different sizes of particles interact because all particles are they are not of the same size within the atmosphere or in different layers of atmosphere, they are having different sizes of particles. And therefore, they will interact with the radiation differently depending of course on the wavelength is also discuss earlier and then they might create different type of scattering, 3 types of scattering which are discussed in remote sensing are important here.

The first one which we have already discussed the Rayleigh scattering and this is as you as mention also that it is the very small particle size, when this size of particles are there, then we see Rayleigh scattering and the phenomena which is like blue sky or red sunset or sunrise which we see generally. Now, when the particles are becoming larger, maybe pollutants rather than guess molecules, then you are the sizes comparatively larger than the above example for Rayleigh scattering.

Then Mie scattering occurs. Of course, again it will depend on the wavelength, but the particle size are larger than then wavelength then this is what is happened and the result is brownness sky or maybe smoke or fog the we call that. So, during fog seasons because the particles are larger than the wavelength and therefore the visibility reduces and the waves energy cannot penetrate through and visibility reduces we call as a fog and it happens when particle size are much larger.

And when you are having cloud droplets and the size is much, much bigger. Then what we witness in case of Rayleigh or Mie scattering, then a different type of scattering which is called geometric will occur and the white clouds which we see is because of the geometric scattering. So, 3 types of scattering Mie scattering occurs when the particles are just about the same size as wavelength of the radiation.

Dust, pollen and smoke and water vapor are common causes of Mie scattering, which tend to affect longer wavelength, then those affected by Rayleigh scattering, because of particle size and Mie scattering occurs mostly in lower portion of the atmosphere, where larger particles are more abundant and dominate when cloud conditions are overcast. So, we also see during this time. Now, the finally scattering mechanism of importance is called non selective or geometric scattering with just I have mentioned that this occurs when particles are much larger than the wavelength.

So, one is smaller than wavelength that is Rayleigh scattering about equal to or little larger than wavelength then Mie scattering and when the particles are much, much larger than the wavelength, then geometric or non selectively scattering occurs and examples are water droplets and large dust particles can cause this type of scattering that is non selective scattering. So, non-selective scattering gets its name from the fact that all wavelengths are scattered about equally.

And this type of scattering causes fog during fog season this is what either Mie scattering or geometric scattering because during fog season the particle size sometimes are much, much larger especially I am talking about the fog which is witnessed in northern India in the indo gangetic plain almost every winter and there because of smoke and instead of calling fog people started calling as smoke. And this non selective scattering causes also cloud to appear white and because of the combination of various lights.

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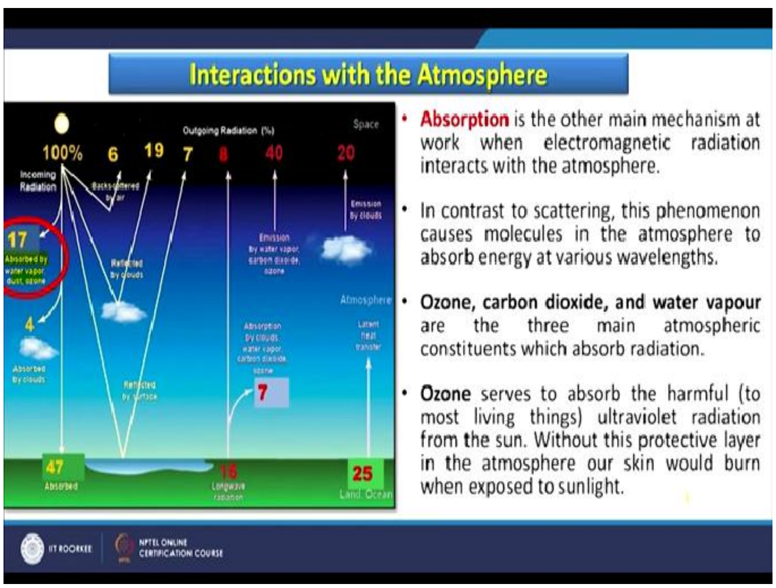

Now, so far we have discussed the scattering, there is another phenomena which is absorption, absorption is like my way by the water droplets, absorption my way the clouds and absorption by the land features or land objects are there, absorptions might be also by water body, but any particular wavelength. So, like infrared radiation is absorbed by pure water and almost completely.

So, you do not get any reflection out of that. And that is one of the reason why in the infrared channels or infrared bands of satellite images, generally water body appears completely black because of a high absorption. So, absorption is the other main mechanism. And that works when electromagnetic radiation interacts with the atmosphere. And in contrast to scattering, this phenomena causes molecules in the atmosphere to absorb energy at various wavelengths.

Ozone carbon dioxide and water vapour, these are the constituents in that atmosphere or that which absorb radiation in a large way. Ozone serves to absorbs the harmful or to most living things, ultraviolet radiation from the sun. So, it is very important ozone in depletion of ozone layer is causing a lot of problems on the surface of the earth. So, without this protective layer in the atmosphere, our skin would burn when exposed to the sunlight. So, we need a protection from ultraviolet light.

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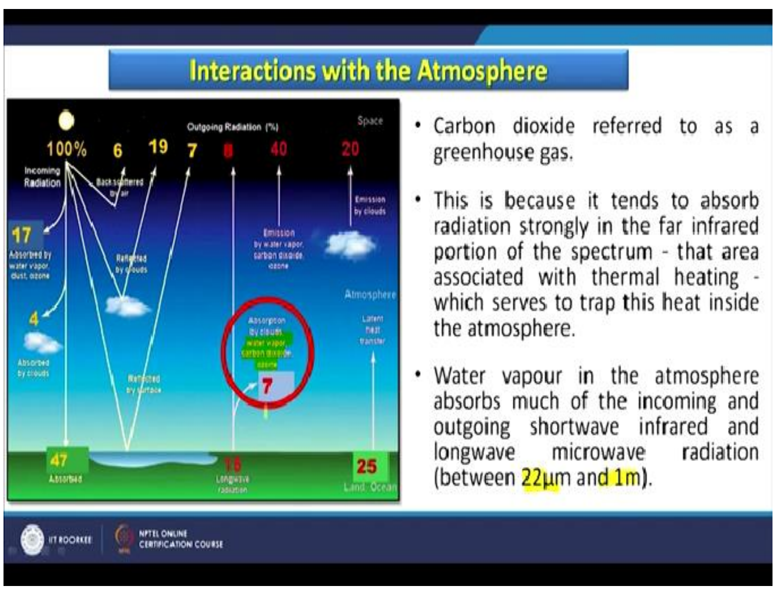

And that is why we need also ozone. Now carbon dioxide referred as a greenhouse gas, and which way here like I mentioned here that the carbon dioxide and ozone these are all absorbing constituents and this is because it tend to absorb radiation strongly in far infrared portion of the spectrum. And that area associated with thermal heating or we detect these things in thermal infrared channels also.

And water vapor, which was also mentioned here. Water vapor in the atmosphere absorbs much of the incoming and outgoing. So, both incoming and outgoing shortwave radiation, infrared and longer microwave radiation which is between 22 micrometer to 1 meter that is also absorbed components not entirely sometimes, but the component is shown also here.

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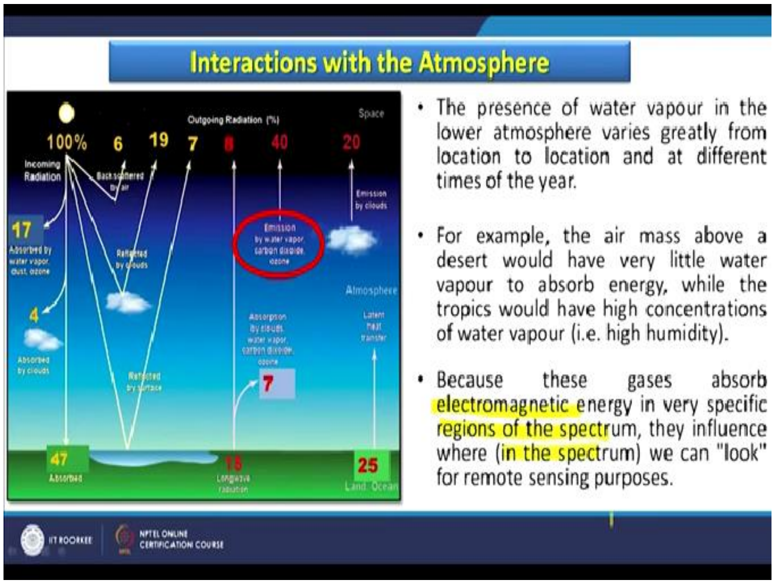

And the presence of water vapour in the lower atmosphere varies greatly from location to location like in desert areas, you may have very little water vapor in the lower atmosphere and therefore, this absorptions may not occur and sometimes we get a very good satellite images of desert areas, but where the unity is much more that means the presence of water vapor in the lower atmosphere is much higher than the quality of image may get affected because of absorption of radiation.

And for example, air mass above the desert would have very little water vapour to absorb just I have mentioned and while tropic would have high concentration of water vapor due to high humidity and because of these gases absorb electromagnetic energy in very specific regions of the spectrum depending all these absorption and scattering as mention also earlier that depend on which part of the spectrum we are talking.

And that means, in which channel it will affect most and which channel it will affect less**.** So, it definitely depends on the that EM part of that EM spectrum region of the EM spectrum, the influence and we look from remote sensing purposes.

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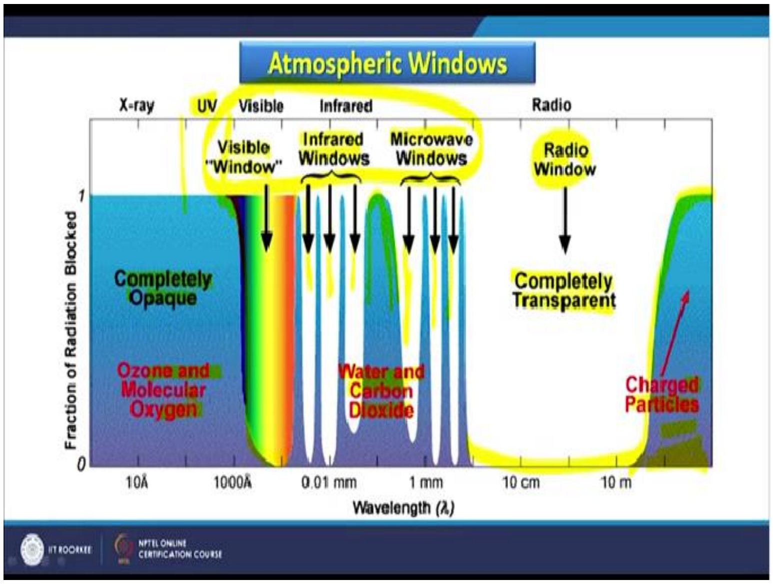

So, now we come because what we see we tried to find those areas of EM spectrum are those reasons or those part of EM spectrum where absorption is minimum. And if there are various such sections of EM spectrum, where absorption because of these water vapours, carbon dioxide, ozone are less and we try to exploit those regions to design sensors and these regions where you are having less absorptions. These are called atmospheric windows.

So, these are the windows allowed why the atmosphere where minimum absorptions takes place. So, like here it is shown that like X-ray completely opaque, it does not allow, there is no basically atmospheric window which will allow these X-rays to reach to a sensor because the entire energy will be completely absorbed by the atmosphere. So, therefore, it is mentioned here is completely opaque. Also ozone and molecular oxygen also observe.

So, you do not have any window there in this part, almost same with the ultraviolet, ultraviolet part of EM spectrum, you do not have any atmospheric window. However, when you reach to the visible part, there you can see that we are having a window at which is this one and which is our visible window. Then there are parts not continuous in case of visible there is a continuous window.

But in case of infrared there are only few windows in between, like you can see infrared. So, there is one window is here, another window is here, the third window. So, in earlier time, when these knowledge such information was not available or not fully available at that time the sensors like Landsat, MSS and the bandwidth we are designed in a continuous fashion like 0.4 to 0.5 micrometer 0.5 micro meter to 0.6 micrometer 0.6 to 0.7 micrometer.

Without considering these fine atmospheric windows especially in infrared region. Similarly, then there is a part of infrared where water and carbon dioxide completely absorbs and there is no atmospheric window available in this part. However, when we move towards longer wavelengths that is in microwave window microwave region there we get few windows here, one window here, one window here and one window here.

So, we get we are having sensors and which works in the microwave region. When we move further, then there is a large window available and which is called the radio window and this is completely transparent, it gets less affected little affected I would say not completely, but little affected by atmosphere and radio signals can travel very easily. This is that part which is also used for the satellite transmissions.

So, whether it is a your expect in case of very dense cloudy conditions or very low cloudy conditions with full of water, then our like the satellite TV may get affected because of that. Otherwise, this is a quite wide fully available atmospheric window is there. Most of the satellites like these polar orbiting satellites or remote sensing satellites also use this part of EM spectrum to transmit data from satellite towards the satellite earth stations are there.

Then of course, the opaque part is coming which is charged particles are there beyond this radio are beyond 10 meter, there are no sensors. So, remote sensing sensors are mainly focusing in the visible part infrared part and microwave region, these are the regions are where atmospheric windows are available and where lot of sensors have been designed which are onboard of various satellite. So, these windows are atmospheric windows are very important for our understanding in remote sensing.

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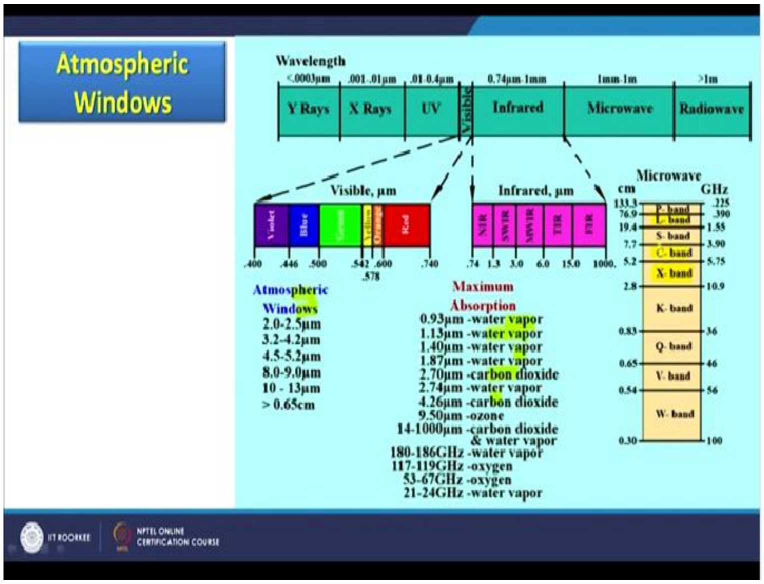

Now, we continue on this atmospheric windows I was mentioning about the visible. So, these are the atmospheric windows in finer details for the visible same with the infrared, but these are affected different wavelength they are affected by different either oxygen or water vapour or carbon dioxide and of course, then in microwave region these bands are also available. So, a lot of satellites like C band you are there expand have been used by various satellites L band and microwave satellites they are using.

And these like earlier then we said or sentinel they are using the C band for data acquisition or imaging acquisition in microwave region.

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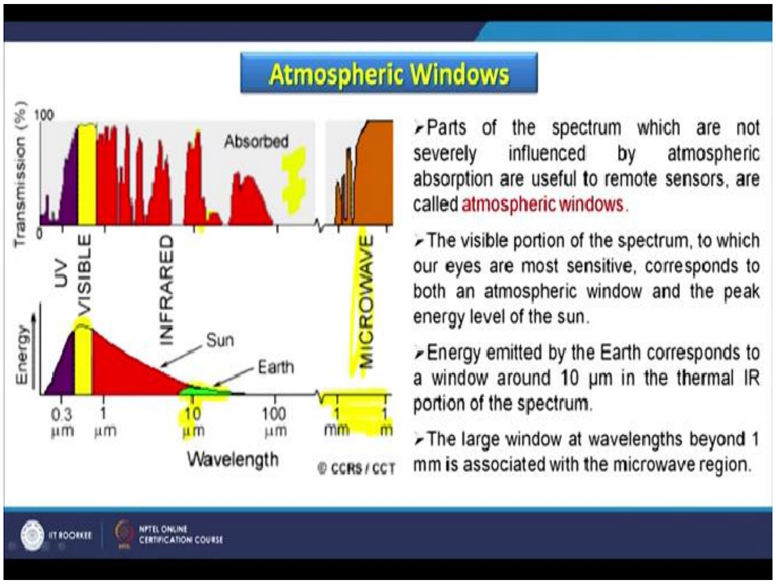

These atmospheric windows so if we want to define then atmospheric windows are part of a spectrum, which are not severely influenced by atmospheric absorptions are useful to remote sensors are called atmospheric windows. The portion of EM spectrum which is available for sensors to get the EM energy, radiometric or electromagnetic radiation which can reach up to the atmosphere are called atmospheric window.

Visible portion of the spectrum to which our eyes are most sensitive correspond to the both an atmospheric window and its peak and peak energy level of the sun, that as you can also see. So, this is the peak energy level of the sun and that falls in that coincides with the visible window also. And then the energy emitted by the earth corresponds to a window which is around a 10 micrometer in the thermal infrared portion.

So, this is the emitted energy which is shown here and there is atmospheric window is available where the sensors have been designed here. So, these red parts, yellow part or and this violet part they are all but rest are absorption. These are not atmospheric windows here. And then large windows at wavelength beyond 1 millimeter beyond the millimeter is associated with the microwave region, which we have this is 1 millimeter microwave region and a large window is available.

So lot of satellites have been or the sensors have been designed for this one. So, this brings to the end of the discussion and as we have discussed about the interaction of the atmosphere with electromagnetic radiation, we have also discussed scattering, we have discussed absorption and also in last we have discussed atmospheric window. All these things are very, very important. One more point I would like to mention here, in that sometimes they during live sessions, and those who are going through these courses have asked questions related with the source of information or for further readings, what this would refer.

So, nowadays as you might have realized that the slides or PowerPoint presentations which I am having most of these figures and lot of material either coming through the net or some books are there and a lot of online books or online information is available. So, one has to make sure that you are referring to some authentic information or authentic online source there are various and it is very difficult to provide a list.

But there are various just make sure that information is authentic and use that information very judiciously. So, a lot of resources are available. So, we need not to discuss very specifically about particular book, the information or the discussion which I am having I am not representing any book or any specific literature or any specific site an information been collected in past from various sources and also my own experience in this field of about 30 years. Thank you very much.