Introduction to Remote Sensing
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Lecture 05
Interaction of EM radiation with atmosphere including atmospheric scattering, absorption and emission

Hello everyone. Welcome to 5th lecture in the series of introduction to remote sensing. And in this particular lecture we are going to discuss interaction of Electromagnetic radiation especially with atmosphere including scattering, absorption and emission phenomenon which really affects our remote sensing satellite based images.

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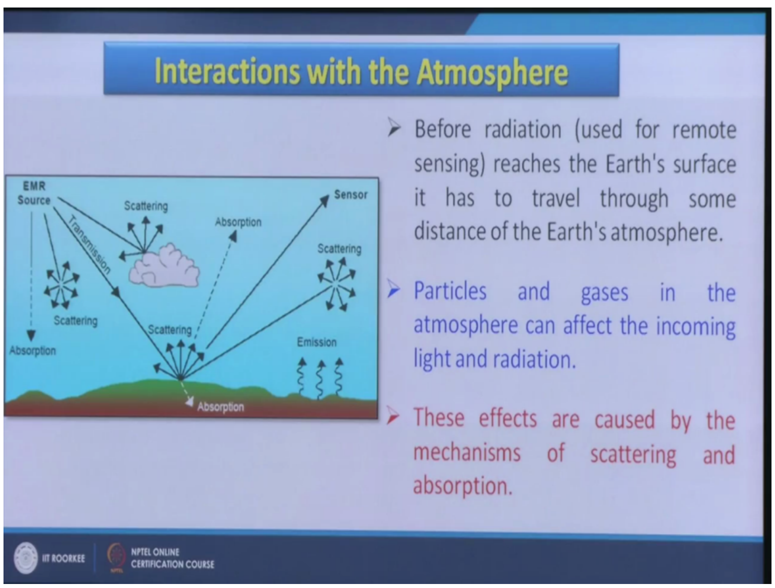

If you see here what we find that there are lot of scattering, absorption and other emission phenomenon occurs, that you can see here that EMR sources are there. And then it might be directly absorbed, there might some scattering depending on the size of particles available which we will see little later, different types of scattering as well.

Then transmission which is coming from say solar radiation and it interacts with the objects which are present on the surface of the earth. Again there might be some absorptions and there might be again scattering. And then the return signatures which goes to the sensor are also in between absorbed or some scattering may occur because of presence of atmosphere.

So all these things keep happening and they really affects our images which are being acquired by the satellites. So before this radiation which is used in remote sensing reaches the earth's surface as indicated here, it has to travel through some distances from the earth's atmosphere. And this total distance it travels back is around 840 km. when it is recorded by the satellite.

But before that it coming from the sun which is very far so particularly particles and gases which are present in the atmosphere can affect both the incoming and the outgoing radiation. And these effects are basically caused by the mechanism of scattering and absorptions phenomenon.

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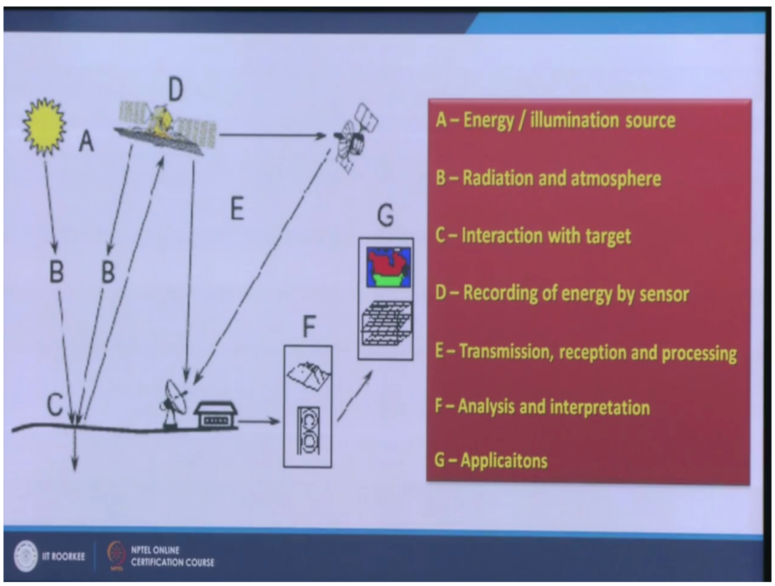

So as we know that this energy source a is A which is the sun and B is the radiation and atmosphere which is happening and then C is the interaction with target. And this figure we have seen so I am not spending much time on it. Then D is the satellite system which records the energy turned by the earth's surface and objects and then finally transmission reception, analysis, interpretation and then finally the applications.

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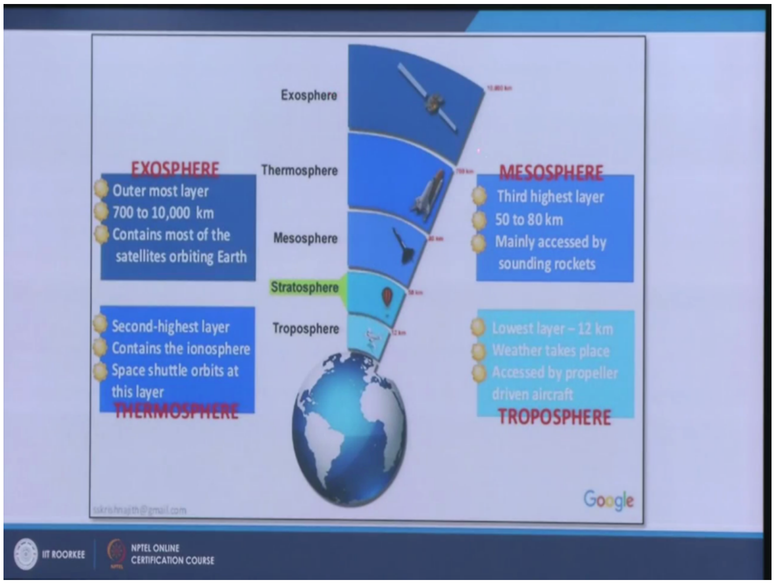

So we come to now different parts of ah atmosphere. So the top layer here we are having exosphere where are having our satellites. Thermosphere where these space shuttles generally fly. Then we are having mesosphere, where rockets and other things and stratosphere and troposphere. So these all layers of atmosphere are present there. We will go one by one. Like exosphere is outermost layer, which is 700 to 10,000 km thick, contains most of the satellites orbiting.

As we know that these earth orbiting, solar polar orbiting satellites are around 840 plus/minus 10 km. So they are mostly in this part of the atmosphere, which is exosphere. Then next one is the comb the thermosphere which is the second highest layer, contains the ionosphere space shuttle orbits at this layer. So the data which is acquired by this shuttle missions like shuttle radar topographic missions which was used to using SAR interferometry to create digital elevation model of the globe. So there also this shuttles fly in that part. Then we are having mesosphere which is the third highest layer 50 to 80 km mainly accessed by sounding rockets.

So in a typical satellite based remote sensing, though the signals have to pass through this layer but our we don't have any sensors in this range. Then is stratosphere and then troposphere, the lowest layer and these layers here in especially in the troposphere there is maximum, because the weather is here present, so the clouds dust and fog and all these phenomena are basically present, which are very close to the earth's surface. So if we start the looking the especially the scattering and absorption phenomena.

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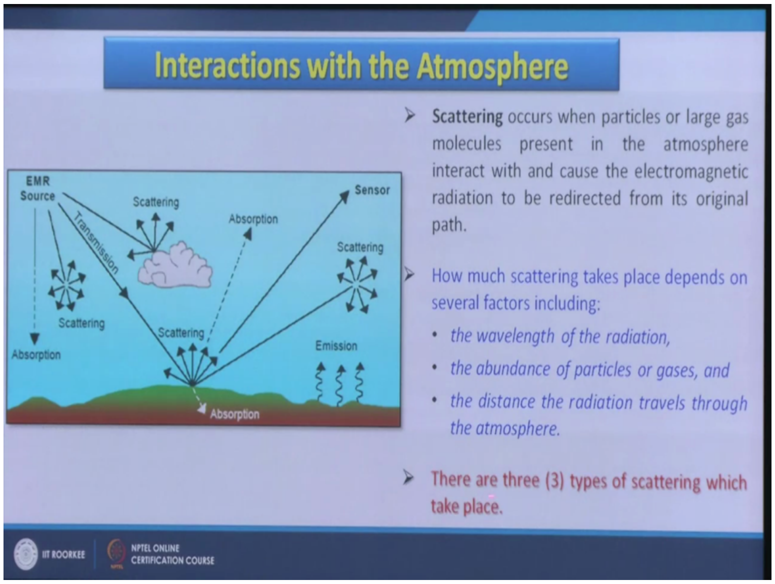

Scattering occurs when particles or large gases molecules present in the atmosphere interact with the and cause the electromagnetic radiation to be redirected from its original path. And so that see the the reflection or reflected energy has to go to the satellite, but before that it gets diverted or redirect redirected to from its original path and the sufficient energy don't reach to the satellite. And how much scattering takes place depends on the several factors especially the particle size and gases present also the wavelength of the radiation at what wavelength we are looking and then abundance of particles, gases and the distance from the radiation travel through the atmosphere.

So if we if it has to travel very long distance especially along the horizon then we might have a problem but along the zenith if it is the minimum then the distortions which may cause by the atmospheric scattering maybe little less. And there are basically three types of scatterings which affects the satellite images and which are which happens in the atmosphere before signal reaches to the satellites which we will see one by one.

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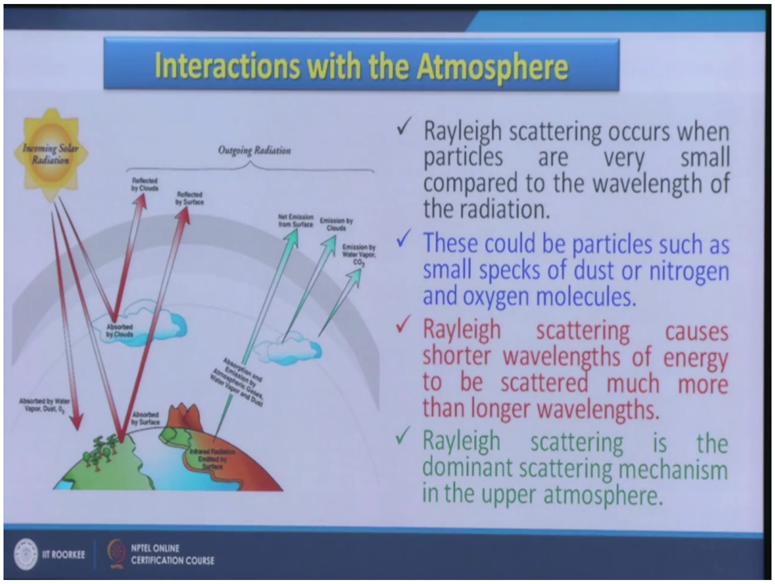

The first one is the Rayleigh scattering, which occurs when particles are very small compared to the wavelength of the radiation. So especially in the smaller wavelength bands this Rayleigh scattering phenomena can be observed. As you can see here, they say that the outgoing radiation which will be reaching ultimately to the satellite the Rayleigh scattering might occur here in this part. Especially to the wavelength which are very small.

This could be the particles such as small packs of dust, nitrogen and oxygen molecules so mainly the gases and very tiny particles of dust can a can create Rayleigh scattering. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than the longer wavelength. So it affects mainly in the shorter wavelength. Rayleigh scattering is a dominant scattering mechanism in the upper atmosphere part which is mainly shown here. Where the smaller particles can reach and the larger one cannot reach there.

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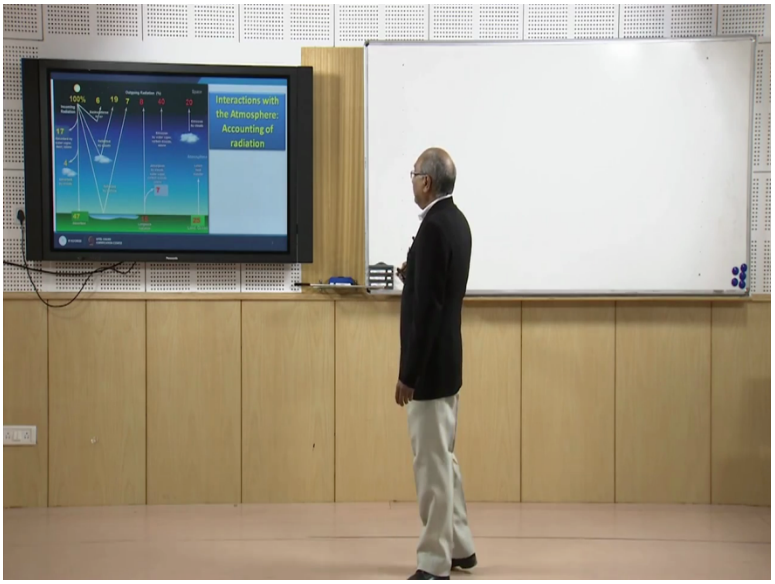

So this is if we start counting the total radiations, say 100 percent is the the sun which is giving to us. So if say that how the radiation get distributed that incoming radiation which was 100 percent, 17% absorbed by the water vapour dust and ozone before even it reaches to the surface of the earth. Again 4% might be observed absorbed by the clouds, then 47% is absorbed by the ground.

Then tiny part which is 7% is reflected by the surface maybe you might be having water body, and then it reach the satellite through passing through the atmosphere in between the clouds can again reflects and 19% of that energy is reflected back. May be the 6% of the energy may get scattered backscattered by the air far before it reaches to the surface of the earth.

There are some natural long wave radiations, which are also contributing. So if there is a 15% total, then only 8% reaches to the outer atmosphere, 7% is absorbed by the clouds or the gases present within in the atmosphere very close to the earth. And there might be emissions within the atmosphere about water vapour, carbon dioxide, ozone which may contribute 40% and then emissions by the clouds 20% and land and ocean they emit the latent heat transfer of about 25%.

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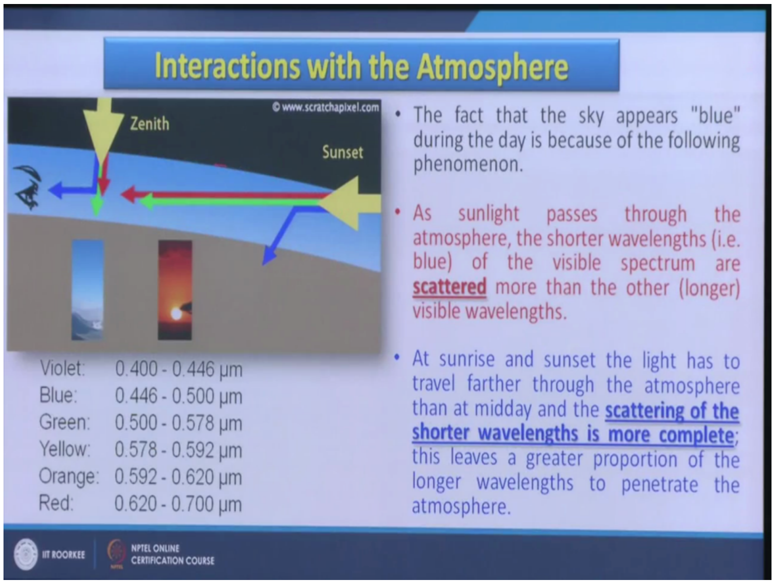

So this is how these things can affect as here shown that when that it has to light in sunset and sunrise conditions, the solar radiations has to pass through long distance within the atmosphere when it is along the horizon, then it is a different situation when it has to pass through the Zenith, then it is a different situation. Both are seen here. It is the you know in the normal conditions this is in the sunset or sunrise.

The fact that we know that why sky appears blue during day is because the following phenomena. As we have gone through during your school days, that the sunlight passes through the atmosphere the shorter wavelength that is the blue. The visible spectrum are scattered more than the other long wave long wave visible length. And as you can see the shorter wavelength part of visible spectrum is falling in the blue part. And therefore we see our sky generally blue in morning and evening.

Sunrise and sunset light has to travel as I have already mentioned through the atmosphere and the midday and it is the directly coming, scattering of shorter wavelength is more complete and this leaves a greater portion of longer wavelengths to penetrate the atmosphere.

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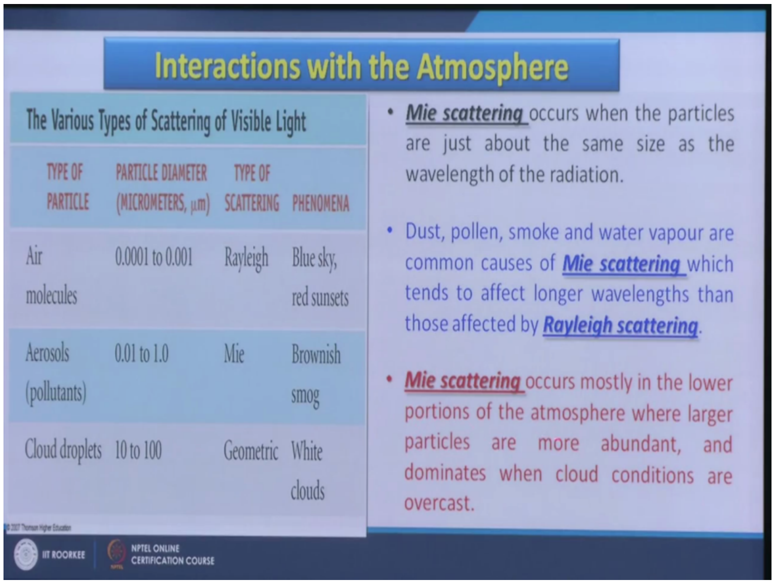

So therefore these distances through which the solar radiation has to pass and the wavelength in which we are looking will depend on these things. Now, the second type of scattering is the Mie scattering and when it occurs when the particles are just about the same size as the wavelength of the radiation. And the the dust, pollen, smoke, water vapour are common causes of Mie scattering. It tends to affect longer wavelengths, than those by affected by Rayleigh scattering. Rayleigh scattering always will affect the shorter wavelength bands.

So here is the various types of scattering of visible light like air molecules which are having of these dimensions mainly scattering will occur of Rayleigh type. The phenomena like blue sky, red sunset in the evening. Then aerosols which are present nowadays lot. And therefore their particle size is much larger and then there are chances of Mie scattering will occur in the longer wavelength. And this will create the brownish or smog phenomena, which is like being observed in the winter seasons every year.

And then there might be cloud droplets which are having very large size compared to air molecules or aerosols, 10 to 100 micrometer. And then this is type of scattering we call as geometric scattering. And basically the white clouds are observed. So when we observed the fog phenomena, so basically fog or nowadays what we see is not only the fog it is a smoke plus fog in short we say smog.

So both type of a scattering may occur Mie scattering and geometric scattering. And the major problem with this is because of the it creates the very poor visibility. Mie scattering also occurs mostly in lower portions of atmosphere where the larger particles are more abundant. Unlike Rayleigh scattering which occurs in the upper part of the atmosphere because of smaller particles are involved.

And this dominates when cloud conditions are overcast, when we are having more cloudy conditions. And especially as I have mentioned during fog season, winter season we observed this Mie scattering and the visibility near the surface of the earth reduces drastically.

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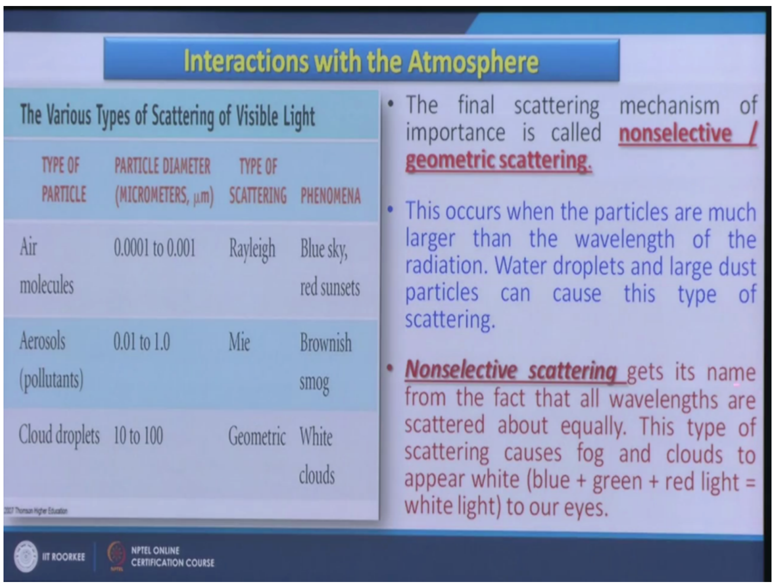

And the final scattering mechanism one more type of scattering I have mentioned here that is geometric or we also call as non-selective scattering. This occurs when particles are much larger than the wavelength of the radiation. And especially water droplets, larger dust particles can cause this type of scattering.

And non selective scattering, this name comes from the fact that all wavelengths are scattered about equally. And this type of scattering cases fog and clouds to appear white, blue, green, red and ultimately white to our eyes. And once this non selective scattering occurs the visibility reduces further.

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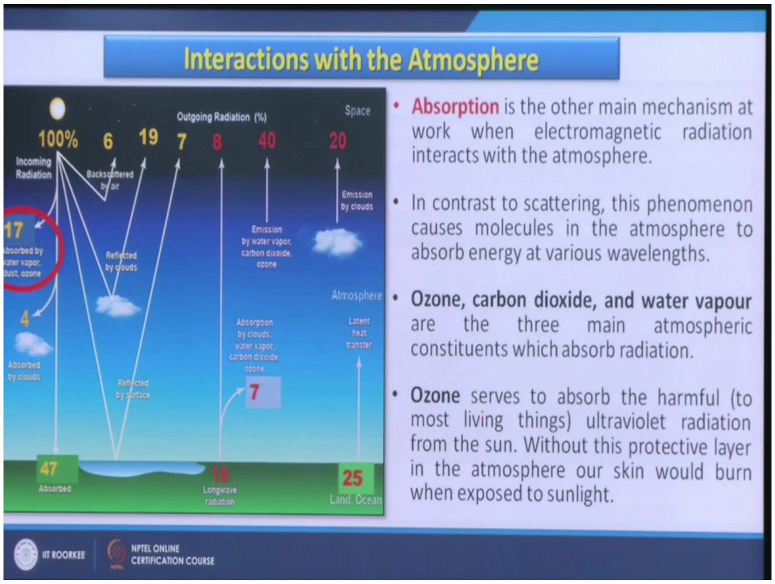

Now, another phenomena which is associated in satellite images especially the solar radiation, back solar radiations which is reached into the satellite is the absorption phenomena. And not only this absorption phenomena reduces the quality of our images but also it restrict where and which part of EM spectrum our bands or channels or sensors can be designed. So absorption is very very important phenomena from both point of view.

This mechanism that it works when electromagnetic radiation interacts with the atmosphere and the large amount of energy it contrast to scattering this phenomena causes molecules of atmosphere to absorb energy at various wavelengths. And gases which are present in the atmosphere like ozone, carbon dioxide water vapours are the three main atmospheric constituents which really observed absorb the large amount of solar radiation . As you can see that there about 17% incoming solar radiation is directly absorbed before it reaches to the ground.

But when it goes back again, then again it is absorbed and the ozone substrates of the harmful or most living things ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to the sunlight. So, this is very important about these phenomena. There are always blessing in disguise so ozone is absorbing lot of the solar radiation otherwise it can be very harmful.

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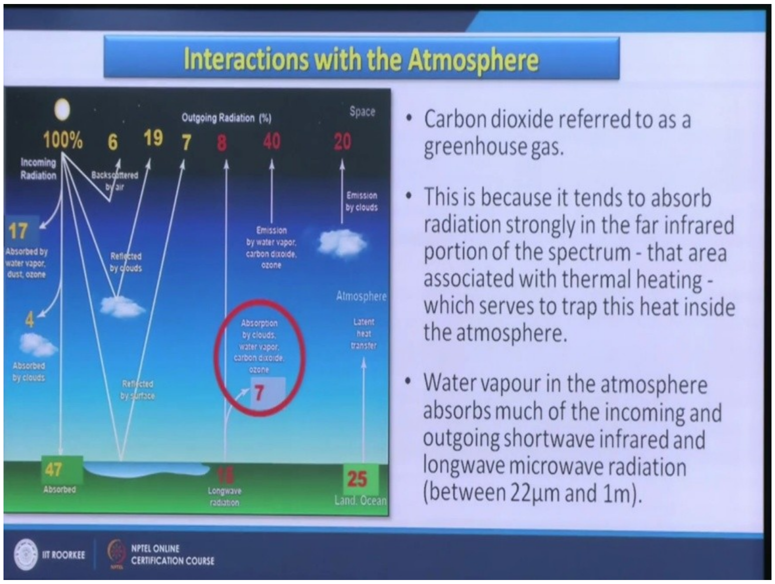

Carbon dioxide referred as a greenhouse gas in in our environmental sense and it because it tends to absorb radiation strongly in far infrared portions of the spectrum and that areas are associated with thermal heating preserves to trap this heat inside the atmosphere. So carbon dioxide absence of carbon dioxide will benefit but whereas absence of ozone will harm the humans. So the presence of these gases are important and their absorptions are also important. Water vapour in the atmosphere absorbs much of the incoming and the outgoing shortwave infrared and long wave microwave radiation. And that is between 22 micrometer to 1 meter.

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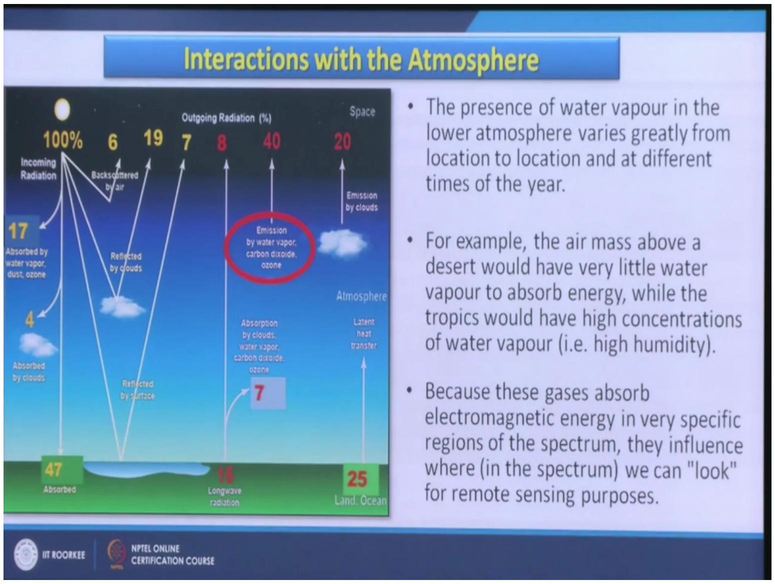

The presence of water vapour which which are in certain seasons is very high and especially in the lower atmosphere which varies from location to location at different times of the year because it has got the seasonal. So this the 40% absorption is here. This is outgoing shown in the red colour and this outgoing is 40% absorbed by the water vapour and other gases.

For example here mass above a dessert would have very little water vapour to absorb the energy while the tropics would have high concentration of water vapour because of very high humidity. And because of these gases absorbed electromagnetic energy in very specific regions of the spectrum they influence the spectrum where we can look for remote sensing purposes.

So here again I'm bringing this that absorptions from remote sensing sensors point of view, design point of view is very important. So different gases are absorbed and they provide us if it is energy is not absorbed than those part of EM spectrum are we call as atmospheric windows, which we will see just little later. And they provide the opportunity to put certain bands or channels in uh the sensor to acquire data of the surface of the earth.

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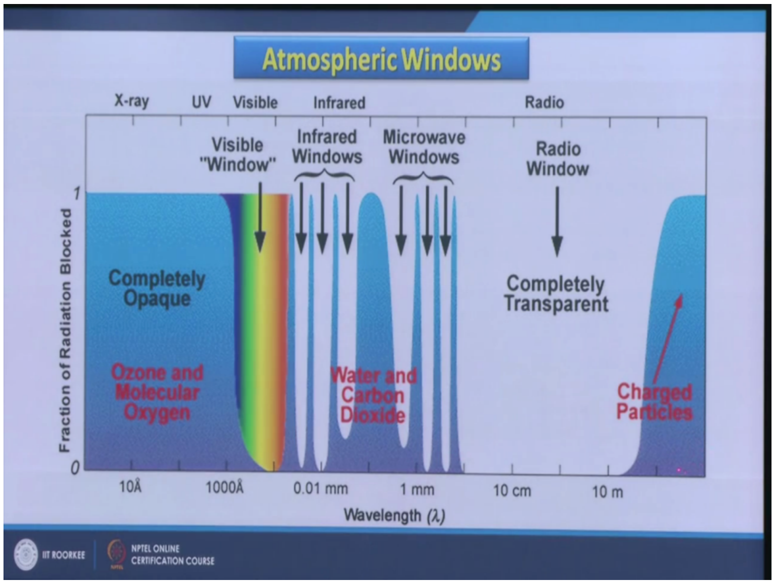

So these are the atmospheric window of a small part of EM spectrum is shown here. Like it is completely opaque of this part of EM spectrum where because of ozone and oxygen molecule molecular oxygen it is completely absorbed wherein in the visible part there is one window is available and we referred as a visible window. Then in infrared there are some some windows are there in between these are the blue lines are seen that these parts are opaque because of presence of different gases, water molecules and carbon dioxide.

In microwave windows are also there where different sensors have been designed and like in radio windows here because of larger wavelength the smaller particles may not affect and we are having a large window for radio transmissions. And then there are other places also might be the window. So we are mainly, in satellite remote sensing we are mainly concern in the visible windows, infrared windows and microwave windows.

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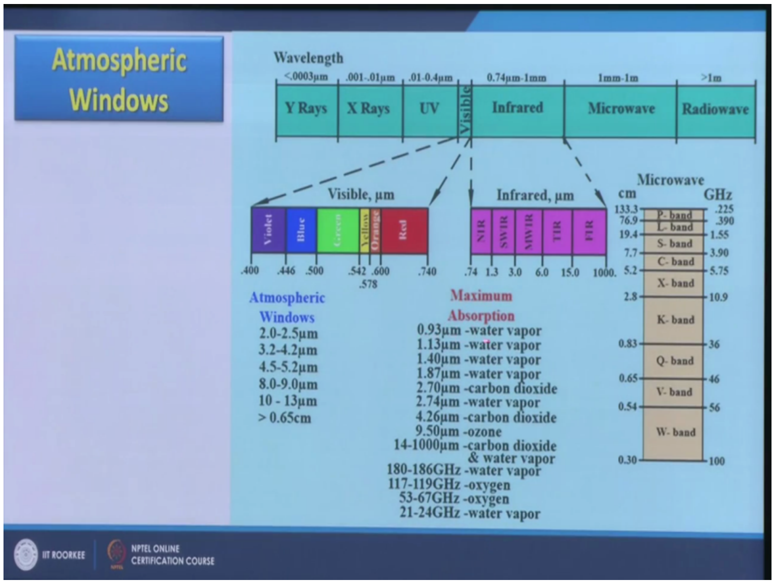

See, these are the atmospheric windows that 2 to 2.5 micrometer and so the maximum maximum absorptions are occurring there at these places, where the pics are shown here.

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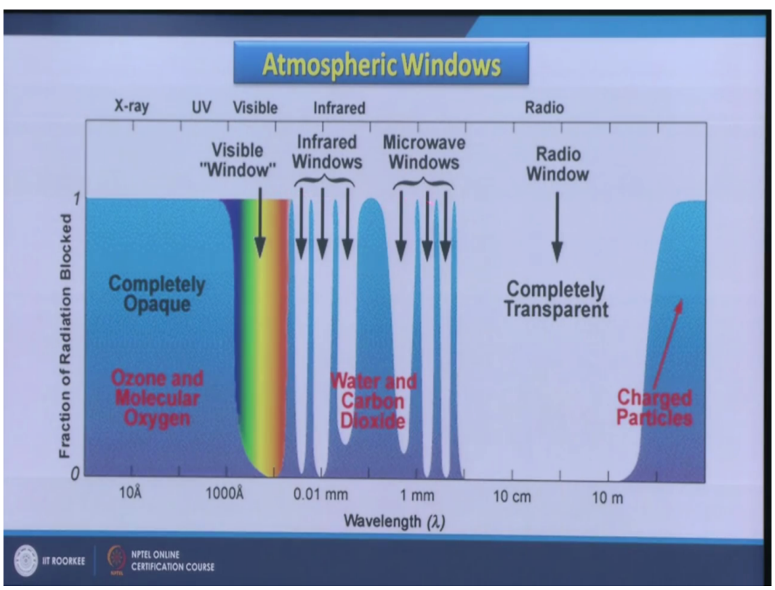

In these parts blue pics are shown here.

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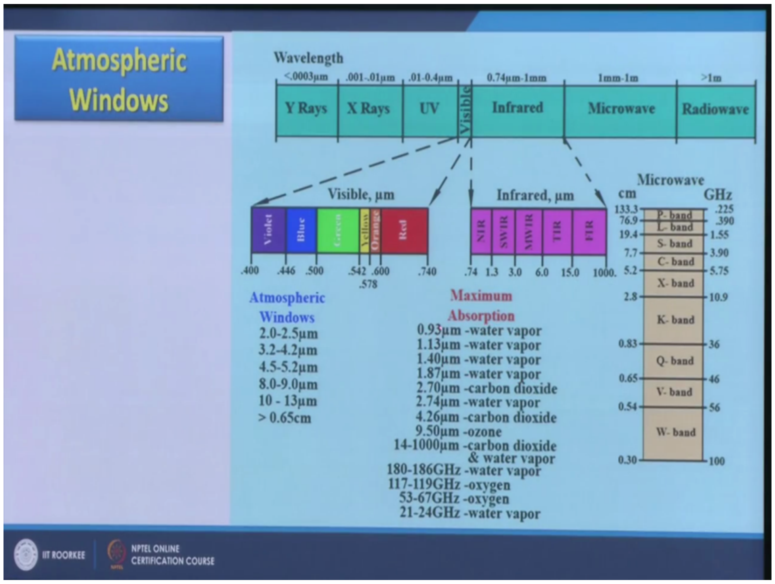

So here is the like these these first between 0.93 to 1.87 micrometer. These different maximum absorptions are available or are caused by the water vapour present in the atmosphere. Then at 2.7 the carbon dioxide , 2.74 again the water vapour and then again carbon dioxide and likewise the presence of water vapour Carbon dioxide ozone and other gases, oxygen may cause these absorption bends. However we are still having some atmospheric windows available to us, to put certain sensors on both the satellite. So, in visible part we are having some windows, in infrared part we having and definitely in the microwave region and radio.

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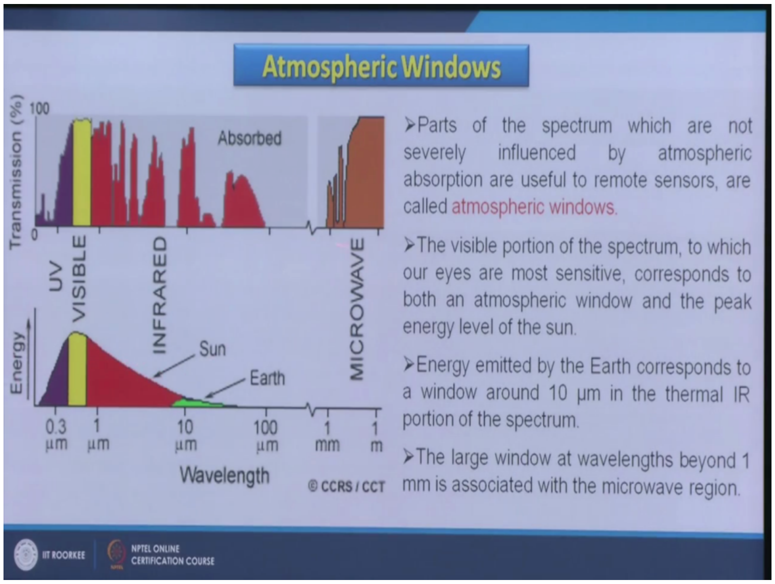

These the definition of atmospheric window is say, part of that atmospheric spectrum or EM spectrum which are not severely influenced by atmospheric absorption which are useful for remote sensing. Satellites or sensors and we call as atmospheric windows, where the your influence by the absorption is at minimum. In the visible portion of EM spectrum our eyes are more sensitive correspond to the both and atmospheric window and the peak level energy of the sun.

As we can see here, that this is the solar radiation which is reaching which is also coinciding with the visible part. And that is the maximum energy is available here whereas when we go towards the higher wavelength it reduces further. And this energy emitted by the earth correspond to a window around a 10 micrometer in the thermal infrared portion of spectrum where some sensors have been designed to take that data. And the large window at wavelength beyond 1 millimeter is associated with microwave region. So that is microwave region is also available for the window.

So this brings to the end of this particular topic which is the interaction of atmosphere interaction if solar electromagnetic radiation with the atmosphere and three types of scattering phenomena and absorption phenomena, how these affects our design of sensors or availability of atmospheric window to acquire satellite data. Thank you very much.