Remote Sensing and GIS

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Lecture - 02
Basics of remote sensing

In continuation of my first lecture, today I will cover the basics of remote sensing. So before I start let us briefly go through what I have covered in the last lecture. So what do you mean by image that we have already covered in the last lecture.

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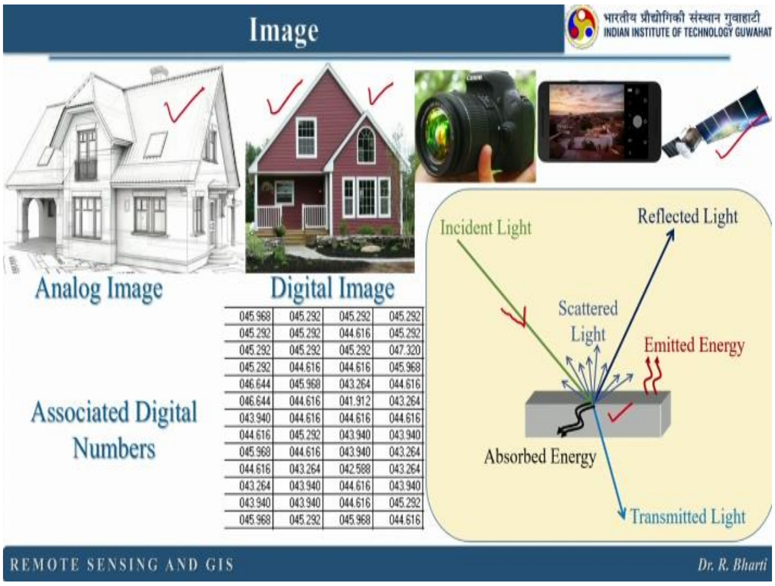

So here there are 2 images, the left hand side image which is this one, this is analog image and whereas the right hand side which is digital image, so analog images can be produced using a paper pen or color pencil, whereas the digital images can be captured using cameras. So now-a-days, this is very popular, anybody is holding a DSLR or normal camera or even a mobile phone through which you can easily captured an object and now in remote sensing, we always referred to sensors.

So here this is one example of spaceborne satellite where it has various sensors and those sensors are sensitive in different wavelength region and then they generate images and those images are basically a number. So if you zoom any image, even this image, if you zoom you will find small pixels, small square boxes, check box. So if you zoom you will find those pixels are growing bigger.

So those pixels which is referred in remote sensing are nothing but a digital number. So just for the visualization purpose, we have assigned some color to those numbers based on their intensity and we could able to see the images and here this is the fundamental of interaction of light with the matter. So here you can see this particular, incident light is falling on this surface. And then which is getting reflected emitted, absorbed, transmitted or scattered. So this is the fundamental of remote sensing how we capture these images.

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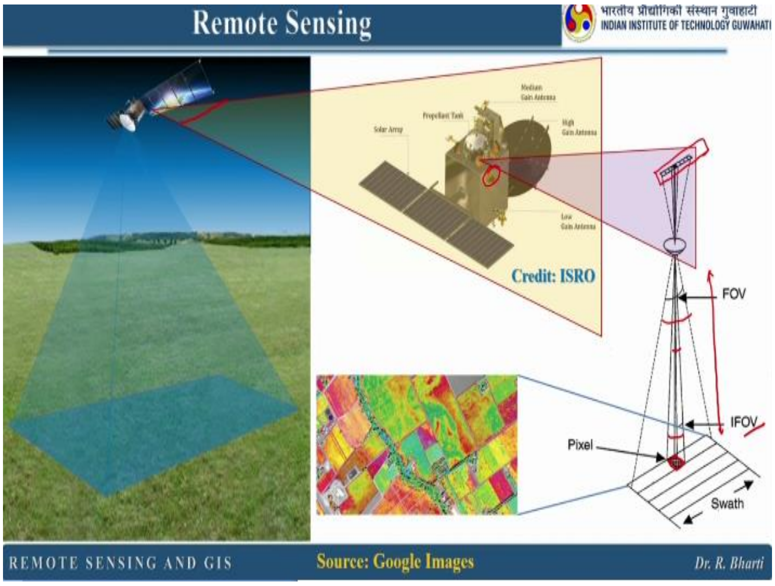

Now, if you consider a flight or a sensor which is basically involved in remote sensing, so here you can see this particular spaceborne satellite or here you can also imagine a spacecraft or an aeroplane which is having several cameras. So it is not necessary that one satellite is carrying only 1 or 2 sensors. It can have many sensors acting in different wavelength region. So here, you can see this is the enhanced view of the satellite.

So here, you can find many sensors are attached. So these sensors are basically a group of detectors which can image the area. So if you see the next enhanced version or zoomed version, so here you can see there is the array of detectors which are sensitive in a particular wavelength region and 1 detector is looking at only 1 pixel. So remember in the image, I told you 1 pixel is basically a square box, so that is basically generated or acquired by a single detector.

So now this is known as this angle, which is actually capable of generating an image. This is called IFOV and FOV is for the whole image. So here you can see based on this height or the altitude of this sensor and the field of view or in this case, IFOV can be used to calculate, what is the size of pixel on the ground? So this is basically how much area 1 detector is looking at the ground and that is getting converted you know in a number.

So whatever energy is coming from different portion of this pixel will get averaged and you will get a single value and subsequently these pixels are arranged in a particular manner and then we could able to see the images.

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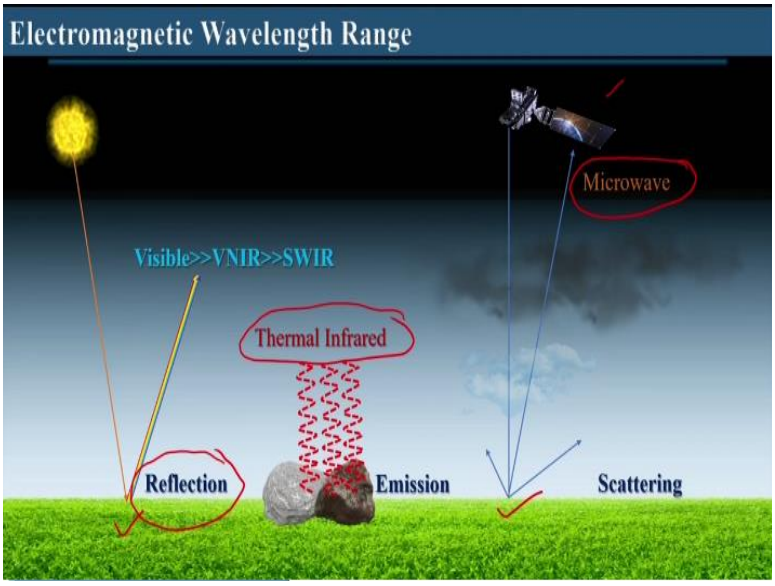

And again, this is already we have covered in the last lecture here, sun is our source of energy and which is illuminating our surface, and then which is getting reflected and here, you have 3 different phenomena, which is happening. So if we talk about this reflective domain, so in reflective domain basically we consider 0.4 to 2.5 micrometer. So this is the wavelength range where we can measure the reflected energy from the surface.

In the next one, which is known as thermal domain, so in thermal domain the wavelength starts from 3 to 16 micrometer and we measure the emitted energy from the target and here in this one, this is microwave domain. So here we illuminate the surface or sun is already there, so in case if you are doing passive remote sensing, then sun is our source and that will illuminate our surface and the microwave energies which are falling on this surface that will get back scattered and those back scattered energy will be received by this satellite.

So this is the fundamental of this energy and target interaction.

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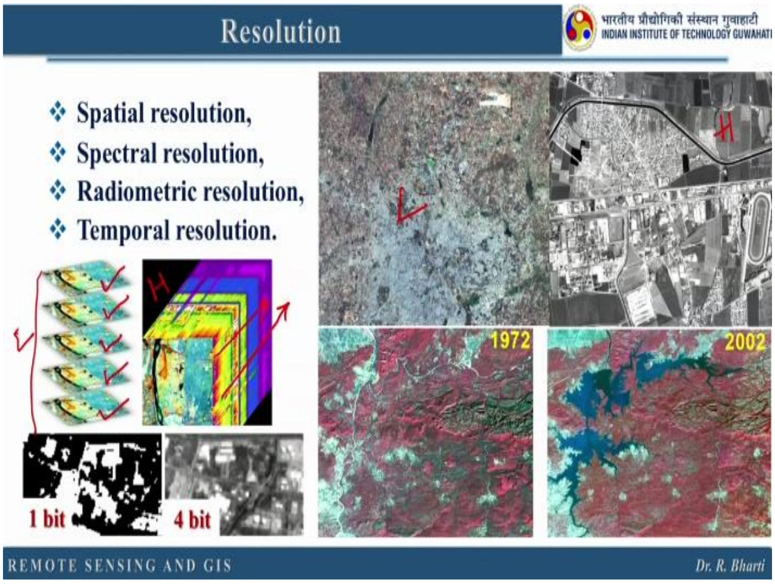

Now, we have also covered this resolution. So briefly let's go through it. So spatial resolution, basically it defines the size of the pixel in your image. So if the pixel of your image covers larger area on the ground that means that is low spatial resolution data, if a pixel on ground covers a smaller area that means that is a high spatial resolution image. So in this case, this is high spatial resolution, this is low spatial resolution.

The next one is spectral resolution, so here you can see there are 5 bands and here you have n number of bands. So, how do we define spectral resolution? First of all, we have to see how much bands or how much images have been captured in a particular wavelength range. So let us start from 0.4 to 2.5 micrometer and considering it has only 5 bands which is here.

So the number of bands and what is the bandwidth of each image? So that means the first image has been generated using 0.4 to 0.5 micrometer wavelength energy. So this is the first image, the second image has been generated using 0.5 to 0.6 micrometer, third one is 0.6 to 0.7, then 0.7 to may be 1 micrometer then the last one maybe 1 to 1.5. So we have only few bands in 0. 4 to 2.5 micrometer wavelength range.

Whereas in this one which is hyperspectral image here you have more number of bands and bandwidth will be may be let us say 10 nanometer or 15 nanometer. So in this case, this is high spectral resolution example, and this is low spatial resolution example, then radiometric resolution. So in radiometric resolution, we always define the capability of the sensor to resolve the incoming radiation in how many levels.

So suppose if the light is falling on my eyes and I can see only 2 sets of color then that means my eyes are having very less resolution, less radiometric resolution, but in case if I have high radiometric resolution for my camera, then I will be able to resolve many grey levels in between black and white. So here this is one example when you have 1 bit data, so this will be like Boolean image either 0 or 1, so either bright or dark.

Whereas in the next for the same area, when you have 4 bit data, you can say, you can see many more details. And the last one is temporal resolution where we see whether my satellite is having capability of revisiting this area in 1 day, 2 day, 4 day or 10 days or may be after a year, so the repeatability of the satellite to acquired these images of the same area in this same time.

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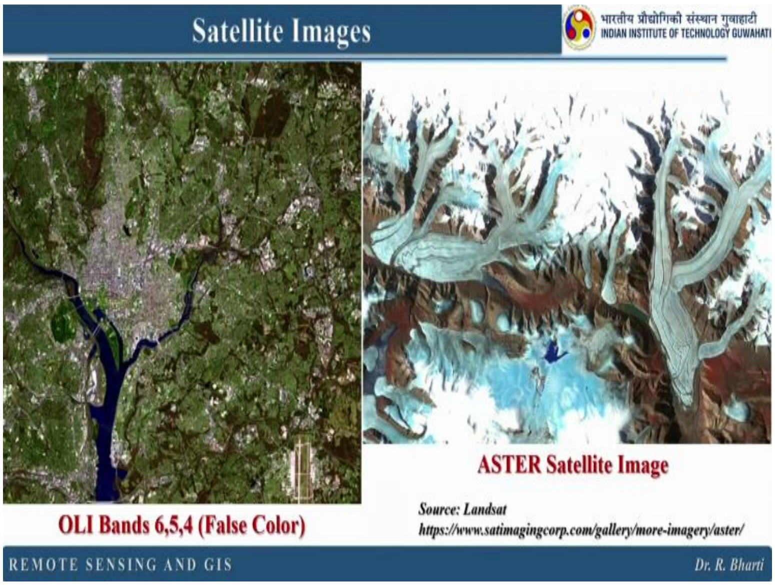

Now these are few examples of satellite images. So this you can find easily in the google, you just simply write the sensor name and sample data and you can always access to all the sample images. So here first one is OLI band, right hand side is ASTER image where you can see some glaciers and this is the example from IKONOS data.

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Then this is the example from microwave. So in microwave remote sensing information is coming to us through the back scattered energy, so information will be completely different from our visible infrared or thermal data. That you will understand slowly once you cover this whole course.

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This is another example from IKONOS and SENTINEL.

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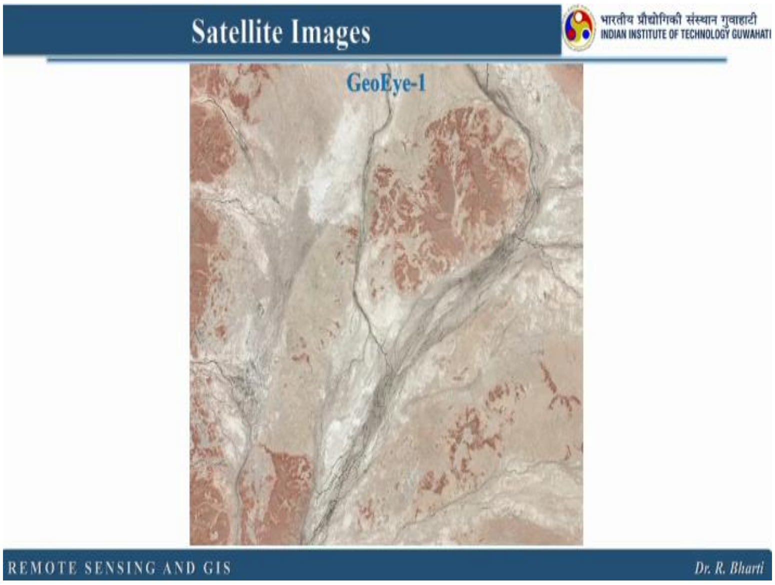

This is from GeoEye, so first one is JPEG.

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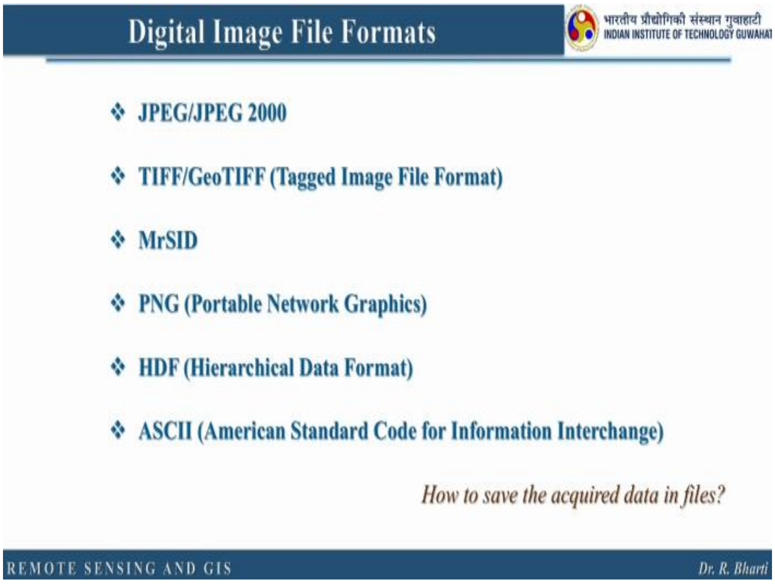
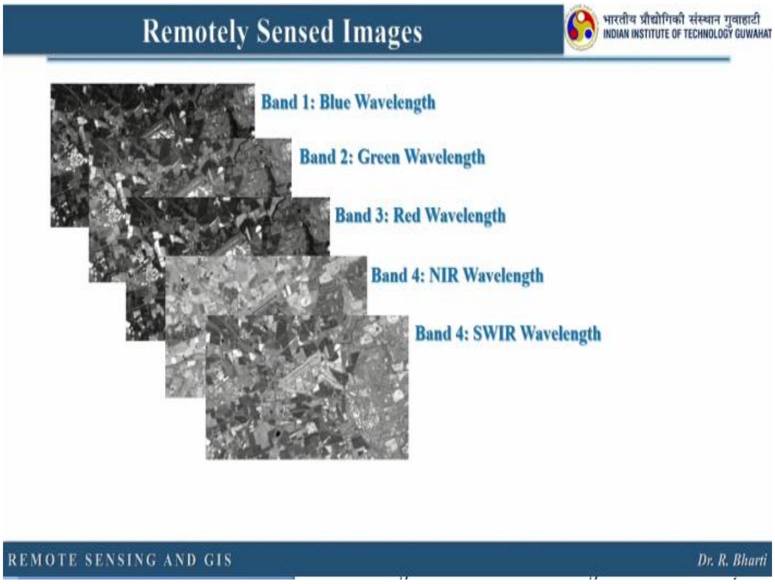


Then next is TIFF or GeoTIFF, then MrSID, then PNG, HDF, ASCII. So remember ASCII is also a file format in which you can save your image, but here the visualization will be only in the number form. So you can save all your digital numbers, DN values acquired by your sensor and then subsequently you can import this in MATLAB or C or maybe other remote sensing software and you can always see your images.

But how to save this acquired numbers in files? Because normally when we capture our image through our normal camera or may be mobile phone you get only 1 file and that is let us say 0.4 to may be 2.5 micrometer or 1.5 micrometer, but here in remote sensing, we acquired within this range we acquired multiples of bands, remember bands means different wavelengths are used to generate separate images.

So here, for 0.4 to 2.5 micrometer you may have 10 bands or 10 images, so how to save them together in a single file? But before that let us understand what are these bands? Right? **(Refer Slide Time: 13:35)**



So the first band acquired by a sensor which is sensitive in blue wavelength that means 0.4 to 0.5 micrometer and this image has been generated, for the same area from the same sensor, the green wavelength has been used to generate the next set of image and so on. So red, then NIR, then SWIR and you can see the information which is there in blue wavelength is different from green wavelength, different from red wavelength, different from NIR, different from SWIR.

Why it is so? Because all the materials which are available on the surface does not matter whether it is earth or any other planet, they have different sensitivity or different interaction process with the light and that depends on their chemical composition. So it is important to study these objects in different wavelengths and identify their composition. So this is how you will slowly understand, what are the capabilities of remote sensing? It is not only for the visualizing the area, this is also for the understanding the area and the objects.

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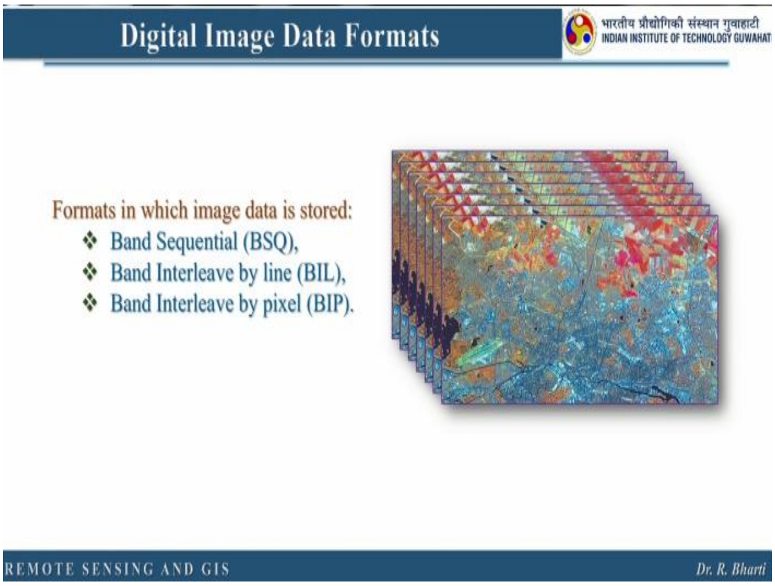

So these are the different types of data formats, which we use to store our digital numbers. So when you have 4, 5 or 6 bands, so here I will use 3 band example, and I will show you how these images are stored together in band sequential data format, band interleave by line, band interleave by pixel.

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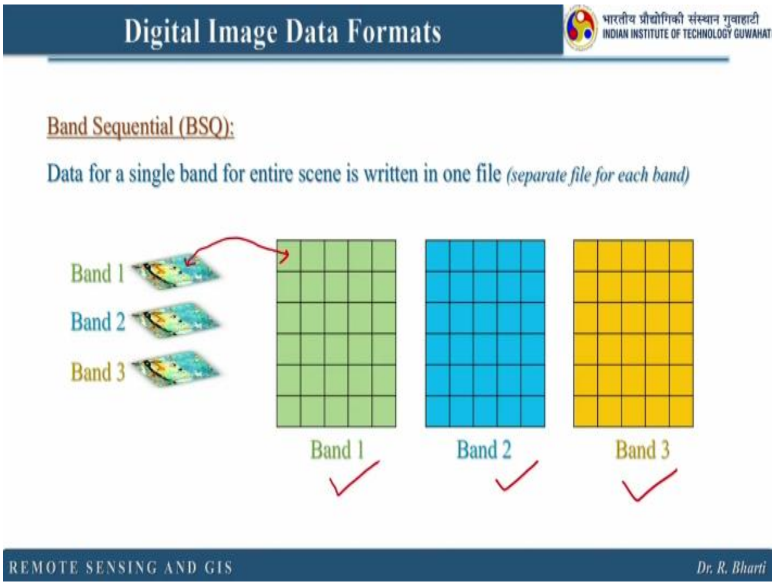

So let us start with the first 1 which is band sequential. So here when you have band 1 that means you have a matrix and each value correspond to one digital number and in image it is called pixels. So 1 pixel of this image is basically 1 DN value in your matrix, right? So likewise for band 2 also you have one matrix and for band 3 also you have 1 matrix. So in band sequential data for a single band for entire scene is written in 1 file, separate files for each band.

So this is the most easiest, so you can generate one ASCII file for this, one ASCII file for this, one ASCII file for this and then it is known as band sequential data format in which our data is saved.

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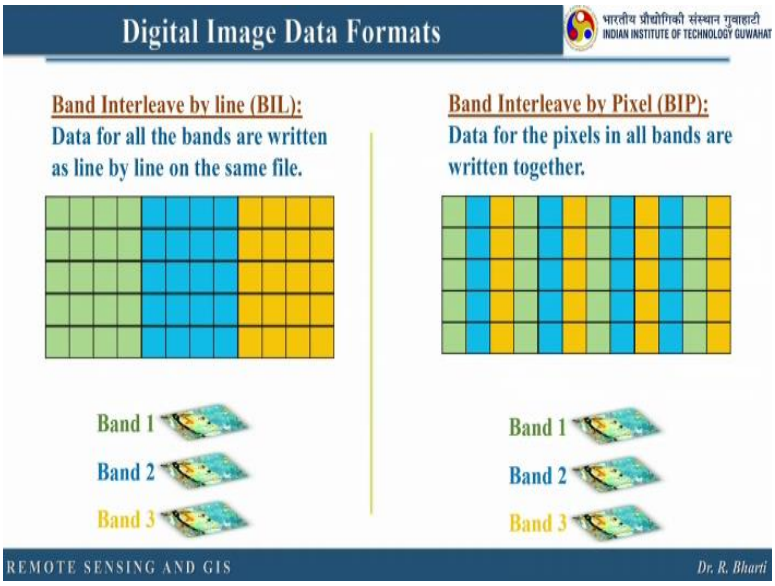

Now, the next one is band interleave by line, where data for all the bands are written as line by line on the same file. So here again for the 3 bands will see this is the first line of first image, then first line of second image, then first line of third image. So likewise, so here we have only 3 bands, so let us end here. Then second line of first band, second line of second band, second line of third band.

Then third line of first band, third line of second band, third line of third band, then fourth line of first band, fourth line of second band, fourth line of third band. So band means image. So likewise we save our data in single file using band interleave by line format. So now we have another, the next one which is band interleave by pixel. So data for the pixel in all bands are written together.

So here pixel wise so first pixel of first band, first pixel of second band, first pixel of third band, then second pixel of first band, second pixel of second band, second pixel of third band, likewise, we will complete this data. So here now we have understood, like what is 3 different types of file format or data format in which we can save our remotely sensed images.

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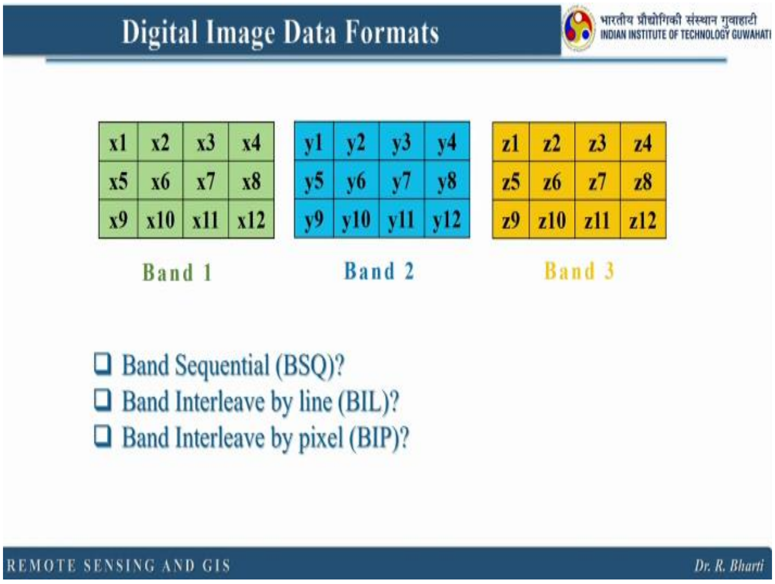

Now this is for your exercise. So it is not like assignment, but you can try, so you can try writing all these band 1, band 2, band 3 values in 3 different file formats.

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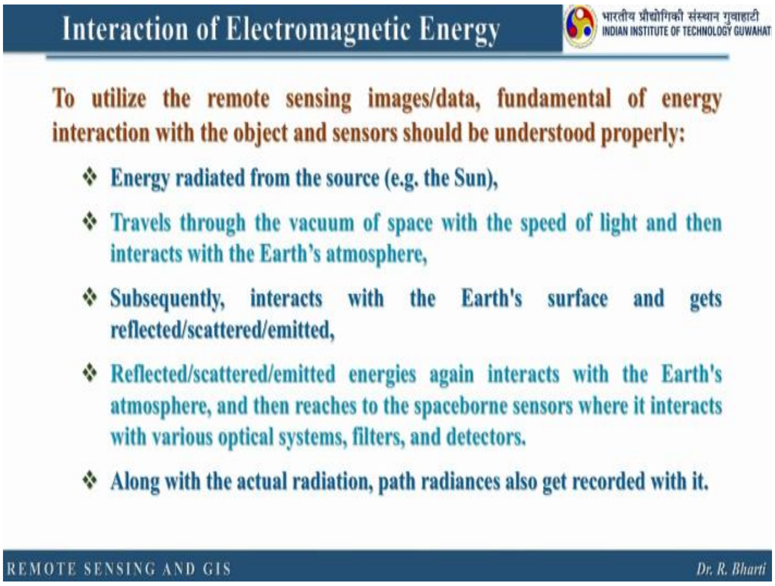

Now, interaction of electromagnetic energy with the matter, so to utilize the remotely sensed image, fundamental of energy interaction with object and sensors should be understood properly. So for that let us start from the beginning, energy radiated from the source; in this case we are always referring passive remote sensing, so sun is our source which travels through the vacuum of space with the speed of light and then interacts with the earth atmosphere.

Subsequently interacts with the earth surface and get reflected, scattered or emitted in different wavelength region. Now next is reflected, scattered or emitted energy again interacts with the earth atmosphere and then reaches to the spaceborne sensor where it interacts with various optical system filter and detector and subsequently it get recorded from our atmosphere. So this I will explain here.

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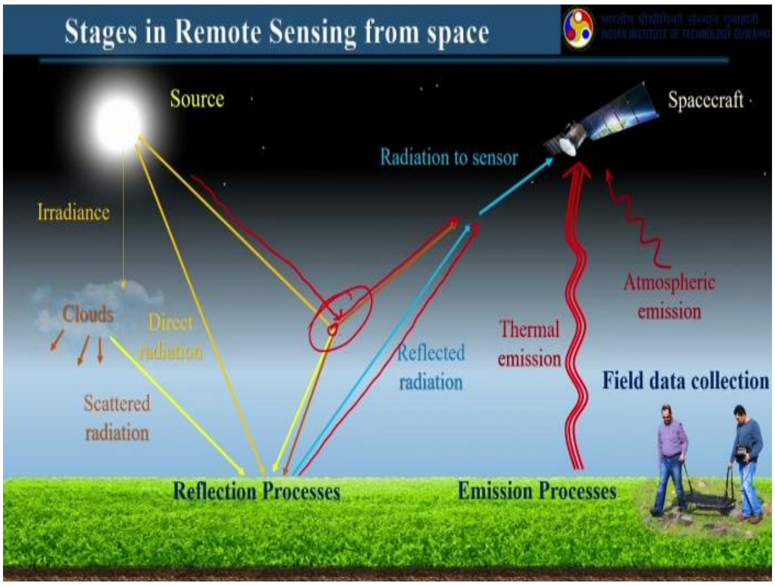

So this is our source and which irradiated our surface and in between clouds are there, atmosphere is there, so it always interacts with them and then some of the energy comes directly to our surface and then this is the overall phenomena. So here, you can see there are few energies which are interacting with the atmosphere and here is your may be gaseous molecule or may be water vapor and from there, it get directly reflected or emitted and which is captured by your sensor with the real data.

So along with this information is also getting recorded. This is known as path radiance. So these are the error in your remotely sensed data because this is important to remove in order to accurately identify your material from space, because these are the extra energies which have been introduced by our atmosphere.

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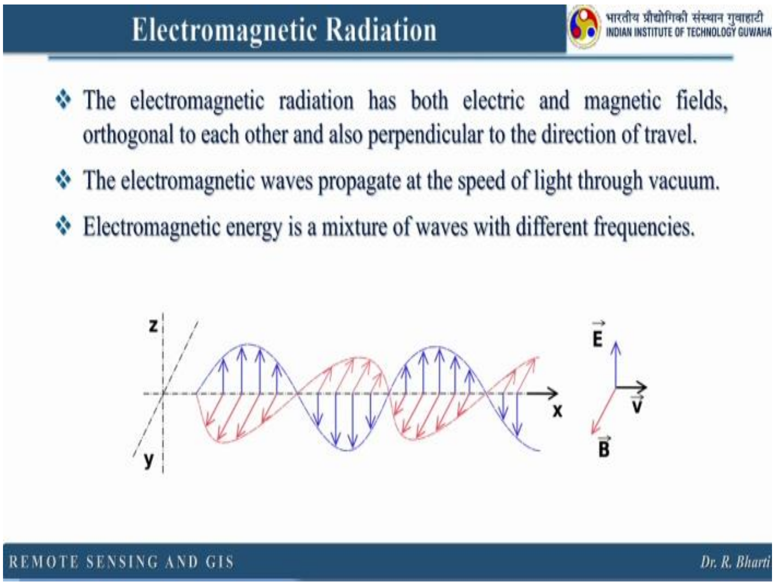

So before we proceed we have to understand what we mean by electromagnetic radiation, so the electromagnetic radiation has both electric and magnetic fields, orthogonal to each other and also perpendicular to the direction of travel and here you can visualize this, so it has 2 different direction and which are perpendicular to each other and then electromagnetic waves propagate at speed of light through vacuum.

Because this is important, if there is a change in the velocity then again that our everything will change, all the calculation will change. Electromagnetic energy is a mixture of waves with different frequency that we have already seen that starting from visible, then infrared, then microwave. So there are different wavelengths, different frequency, different energy associated with them.

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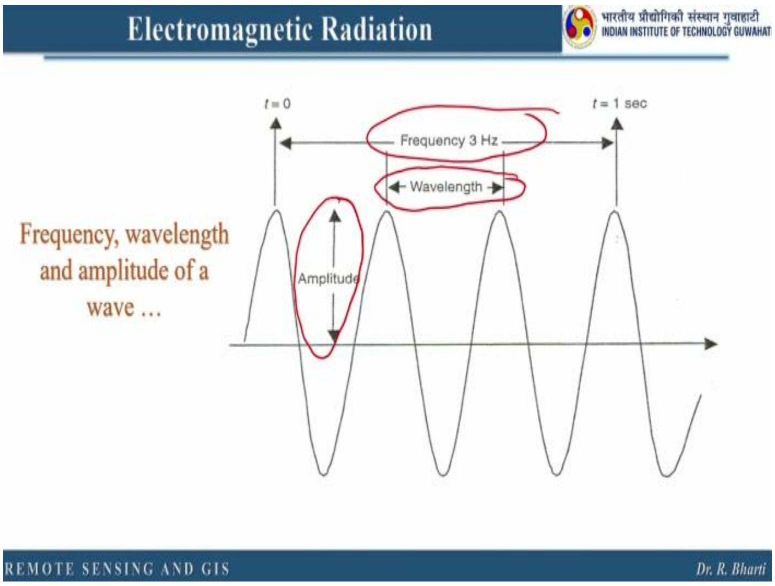

Here just these are fundamentals, but you have to understand it thoroughly, so frequency wavelength and amplitude of a wave. So here you can just see this is the wavelength how we define our wavelength and this is the amplitude of our wave and this is the frequency. So this is very important you have to understand it then only you will be able to use remote sensing and GIS in your problem.

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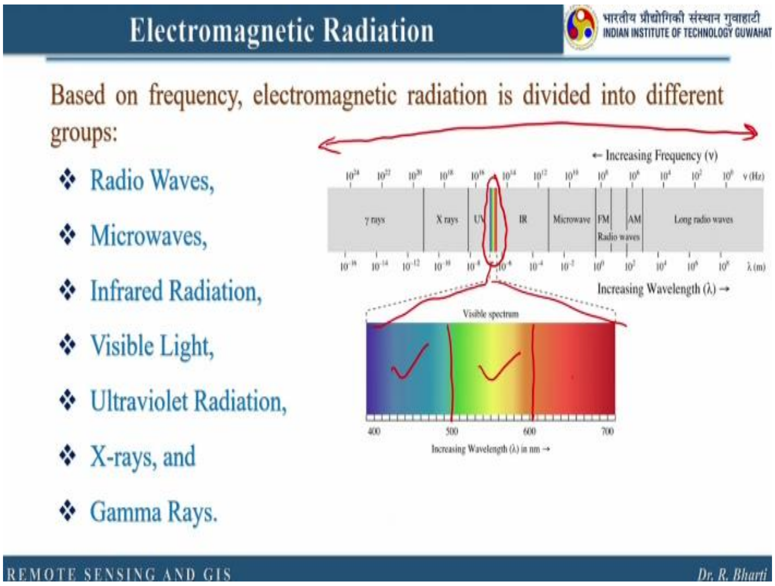

So based on frequency, electromagnetic radiation is divided into different groups. So which are like Radio Waves, Microwaves, Infrared, Visible, Ultraviolet, then X-rays and Gamma rays.

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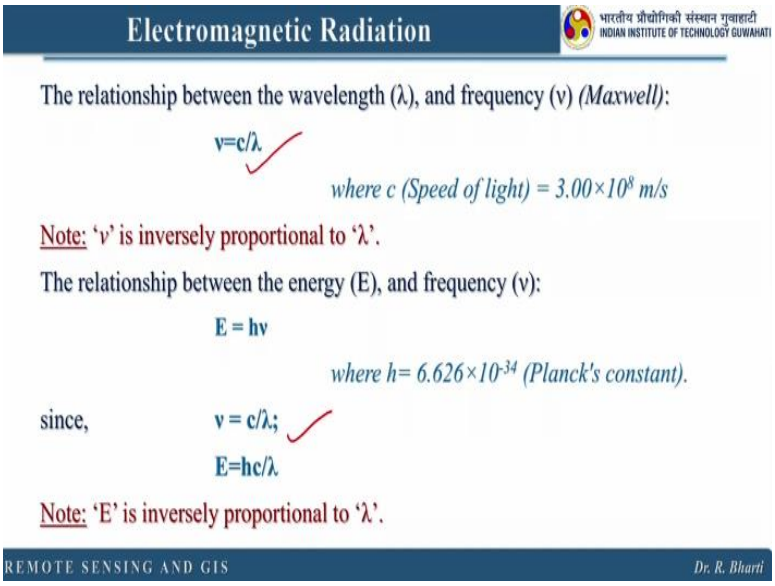

So the relationship between wavelength and frequency, this is very fundamental, but you have to understand it thoroughly. So here you can see nu is equal to c by lambda and where c is the speed of light and here it is very clear that nu is inversely proportional to lambda, lambda is our wavelength and nu is our frequency. The relationship between energy and frequency that is E = h nu and h is the Planck's constant.

So if we replace this nu from the previous equation, so it will become this, nu = hc by lambda. So here again E is inversely proportional to lambda. So that means in the shorter wavelength region we have high energy, but in the longer wavelength region, we have less energy. So this is very important because slowly you will understand, what is the application of all these fundamentals in remote sensing?

The next one is Stephen Boltzmann Law. So total emitted radiation from a blackbody is proportional to the fourth power of it is absolute temperature where total emitted radiation is sigma T to the power 4.

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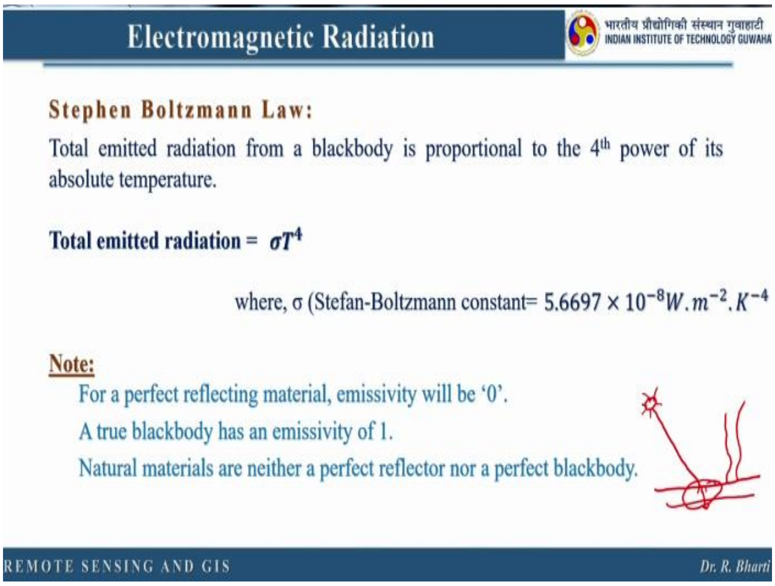

So here this sigma is known as Stefan Boltzmann constant and here this is very important to understand for a perfect reflecting material emissivity will be 0, why? Because if you see suppose, this is your source, which is our sun, then this is illuminating our surface and here we assume that whatever energy which has been received by this surface, it is getting reflected. So this will happen only when a material is perfect reflecting material.

So here what will happen the all the energy whatever is received that will get reflected and when it is getting reflected, there is no energy absorbed here. So there will be no emission. So that means emissivity will be 0. So a true blackbody has an emissivity of 1. This is another case where we consider our surface is perfect blackbody. So in that case what will happen whatever energy is coming here that will get absorbed and there will be no reflection.

So after certain time, what will happen to maintain the equilibrium with the surrounding these energies will be emitted. Then the next point is natural materials are neither a perfect reflector nor a perfect blackbody because in nature, this perfect reflecting material and blackbody, true blackbody it is theoretical concept. So we do not have anything on our surface or in any other planets so far known that all our grey bodies so they can reflect some amount of light and they can also absorb some amount of energy.

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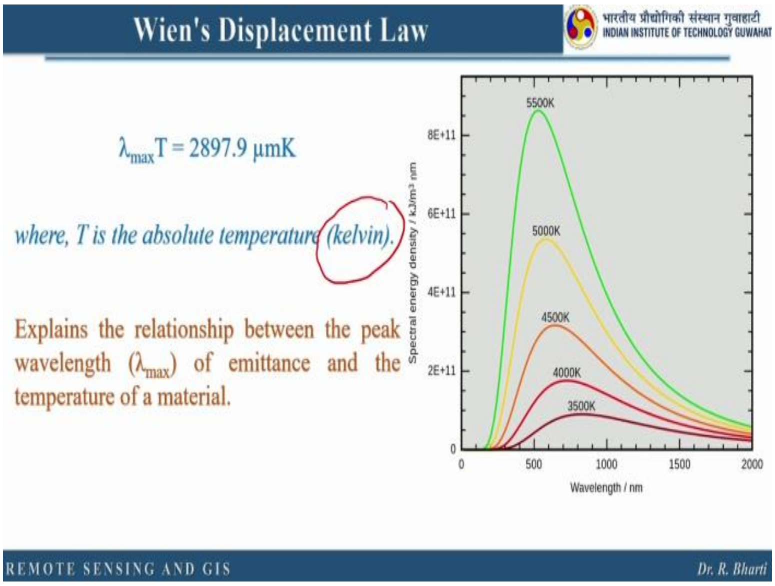

The next concept is Wien's Displacement Law, where lambda max T is equal to this number. So where T is the absolute temperature which is always considered in kelvin and it explains the relationship between the peak wavelength of emittance and the temperature of material. So if you know, what is the temperature of the material, you can always find what is the lambda max so where at which wavelength this material will give you maximum emissivity.

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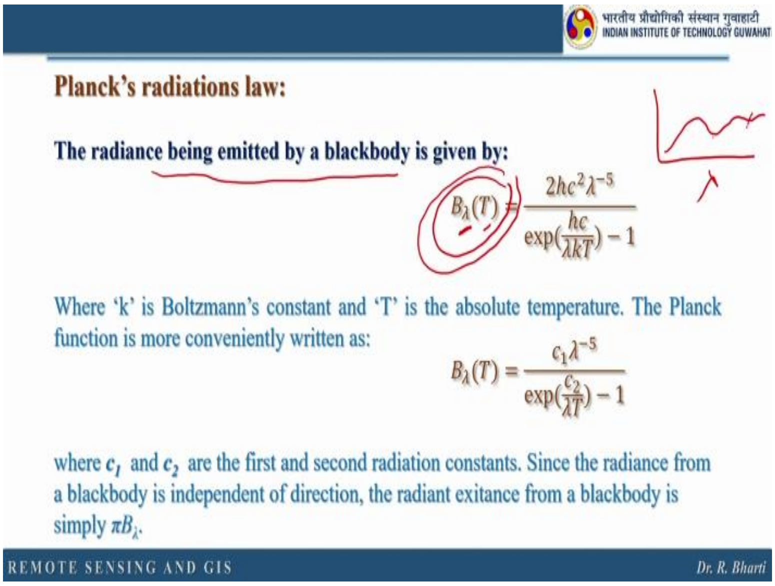

Then Planck's radiations law, the radiance being emitted by a blackbody is given by this formula where k is the Boltzmann’s constant and T is the absolute temperature. The Planck function is more conveniently written as this and where c1 and c2 are the first and second radiation constant, since the radiance from a blackbody is independent of direction, the radiance exitance from a blackbody is simply pi B lambda.

So here this is important to understand the radiance being emitted by a blackbody, you can read this and here we have written this B lambda and T. So whatever radiance we are getting that is a function of lambda and temperature. So if you change the wavelength or if you change the temperature any of these if you are changing your radiance will be different. So this is very important to understand.

So this is why? We are having this spectral response different in different wavelengths. So if wavelength is changing, material response is changing and if the temperature we change there may be change in the Spectra.

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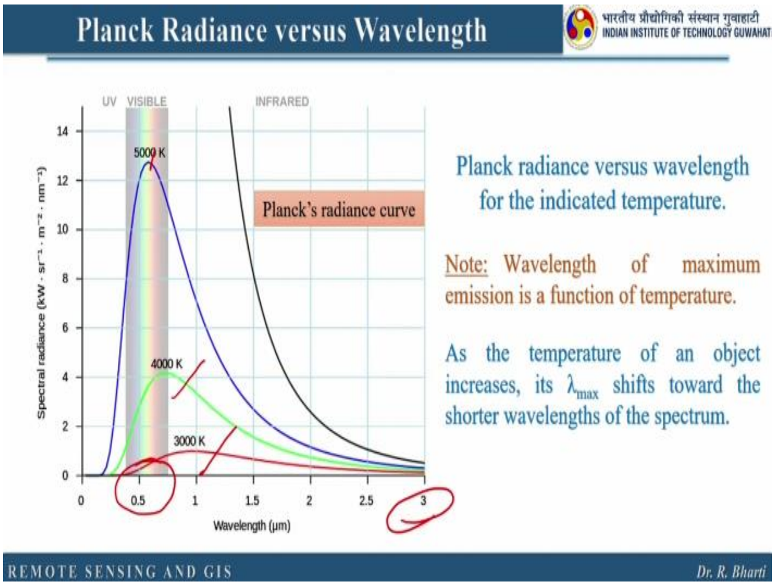

Planck Radiance versus wavelength, here Planck radiance versus wavelength for the indicated temperature. You can see here that for different temperatures their responses are different. And here one thing is to note wavelength of maximum emission is a function of temperature that already we have covered in the previous slide, as the temperature of an object increases it is lambda max shift towards the shorter wavelength of the spectrum.

Now here you have to correlate with the fundamentals. So when you have shorter wavelength, then you have maximum energy. So here you can see in this particular wavelength 0.5 micrometer, you have more energy whereas if you see in the longer wavelength, you have less energy. So this is important to understand, what is the radiance behavior with respect to temperature as well as the lambda?

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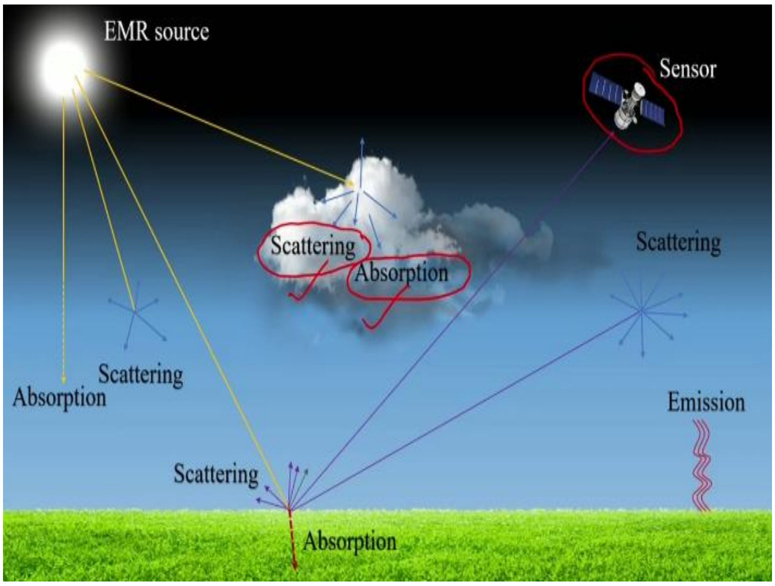

Now here you can see when sun is illuminating our surface, there are different things happening in our atmosphere. So here what is happening? This is very important scattering and absorption. So when light interacts with our atmosphere in the previous slide, I have covered till it is interacting with the surface and in between, it is passing through our atmosphere. But what exactly is happening in the atmosphere?

So these 2 are happening, scattering and absorption, so these 2 plays very significant role in order to modify your radiance, so whatever is coming or reaching to your satellite or your sensor. So they are modifying your signals and that will be recorded by your satellite.

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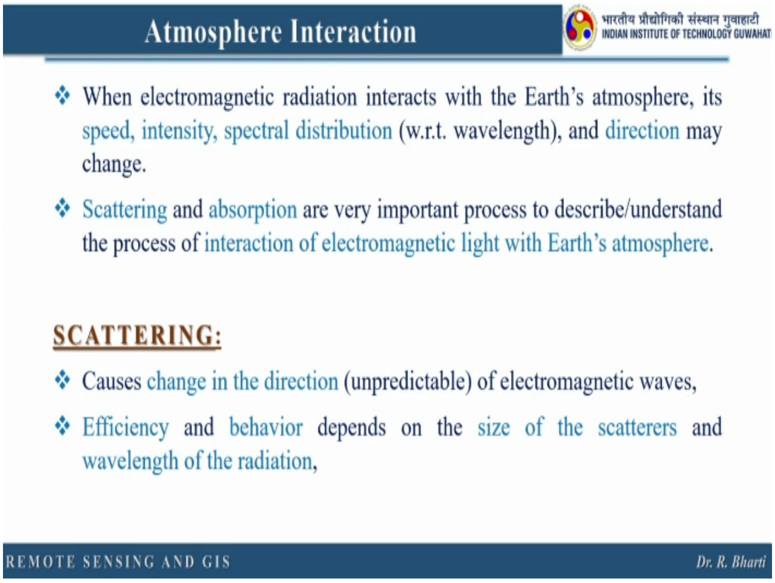

So let us start with atmosphere as whole, when electromagnetic radiation interacts with the earth atmosphere, its speed intensity, spectral distribution and direction may change, because here your media is different. Now scattering and absorption are very important process to describe or understand the process of interaction of electromagnetic light with the atmosphere, earth atmosphere.

So let us start with scattering. So it causes to change the direction of electromagnetic waves and these directions are unpredictable. So you cannot predict that if water vapor is present in the atmosphere, what will happen? How much direction it will change for the incoming radiation? Efficiency and behavior depends on the size of the scatter and wavelength of the radiation, so the efficiency and behavior of this scattering is defined by the interacting material.

So here if you are having dust in your atmosphere, if you are having more water vapors or if you have more gases then interaction will be different and what is their size of the molecule and then what is the wavelength you are looking in? So in case if you look in blue wavelength your scattering process will be different, for green it is different, for red it is different, for infrared it is different, for microwave it is different.

So the behavior of a scattering changes with the size of the molecule and the size of the wavelength. So size of the wavelength means what is the wavelength? Shorter wavelength or longer wavelength.

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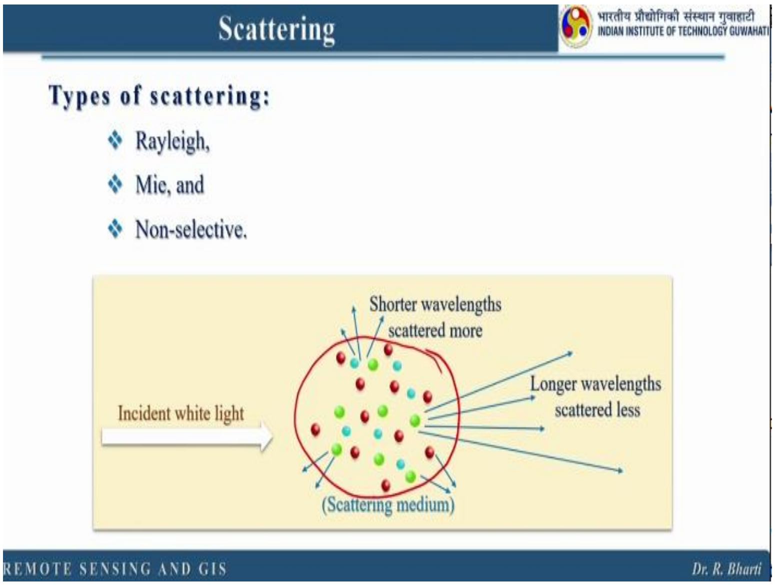

So there are 3 types of scattering, first one is Rayleigh, the next is Mie and then you have Non-selective. So this is the one image with where you can understand what is happening in the atmosphere. So you have the scattering medium, it can be because of your gases, it can be because of your dust, it can be because of your water vapors present in the atmosphere.

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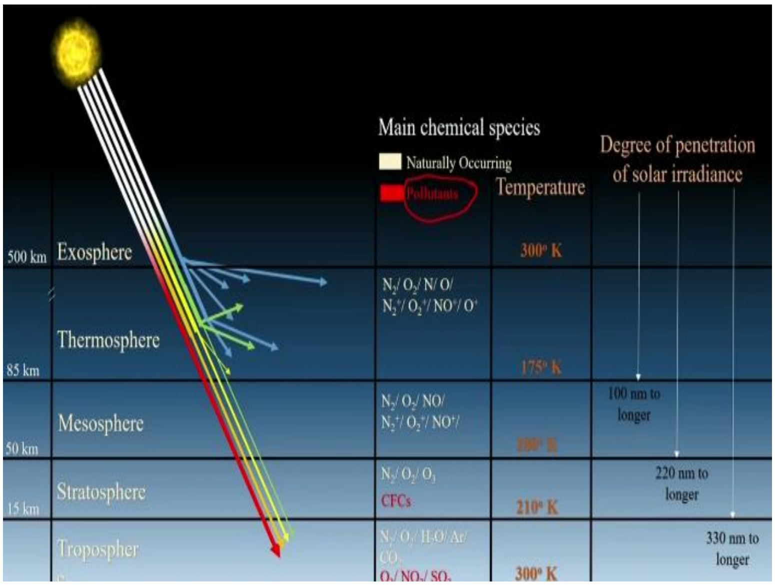

Now here you can see different layers of our atmosphere and where you have different types of gases present and there are some polytents also so which are actually interacting with our incoming radiation and they are getting modified.

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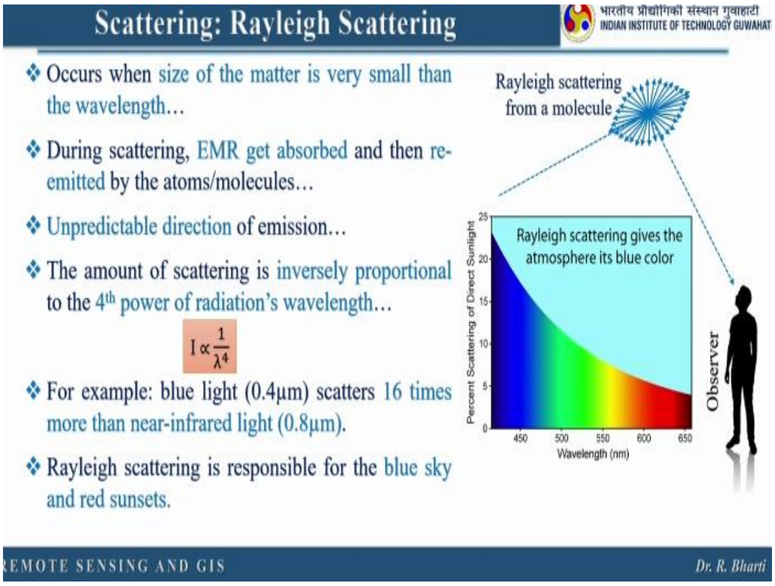

So in Rayleigh scattering, so it occurs when size of the matter is very small than the wavelength during a scattering EMR get absorbed and then re-emitted by the atoms or molecules. So here you can see that Rayleigh scattering and it is unpredictable in direction. So you cannot predict the direction of emission and the amount of scattering is inversely proportional to the fourth power of radiations wavelength.

So which is this, and here for example blue light, which is basically 0.4 to 0.5 micrometer scatters 16 times more than near infrared light, which is 0.8 micrometer in this case and

Rayleigh scattering is responsible for the blue sky and red sunsets.

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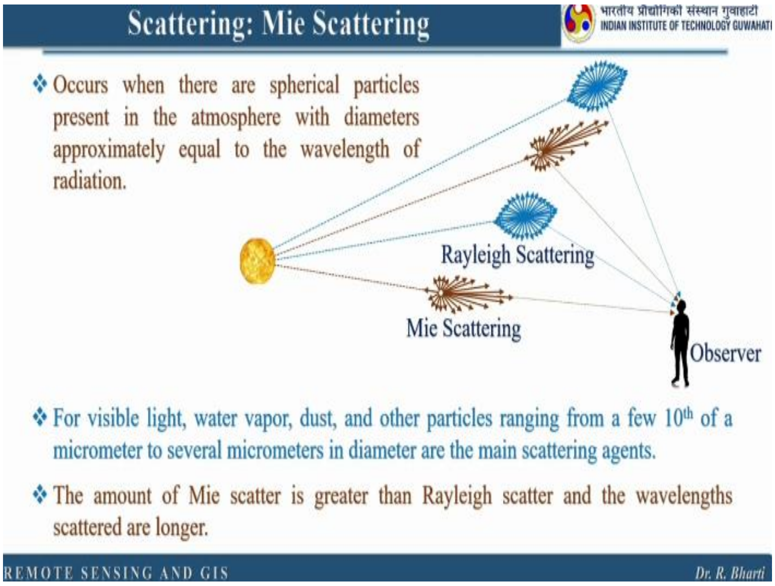

In Mie scattering, it occurs when there are spherical particles present in the atmosphere with diameters approximately equal to the wavelength of radiation and the amount of my scatter is greater than relay scatter and the wavelength scattered are longer. So now we are shifting towards longer wavelength.

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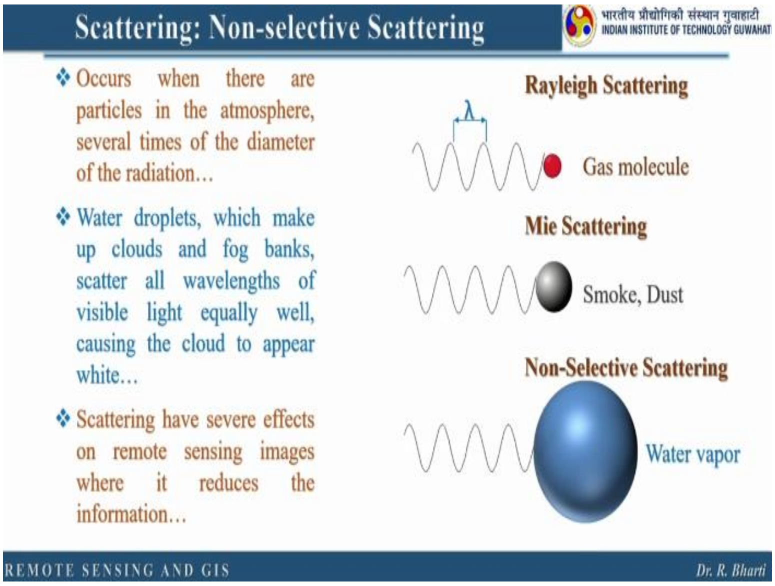

In Non-selective scattering, it occurs when there are particles in the atmosphere several times of the diameter of the radiation, water droplets, which makes up clouds and fog banks, scatter all wavelengths of visible light equally well, causing the clouds to appear white. Scattering have severe effects on remote sensing image where it reduces the information. Here you can see the example of Rayleigh scattering and Mie scattering and the Non-selective. So this is to understand what is happening in this scattering and different types of this scattering.

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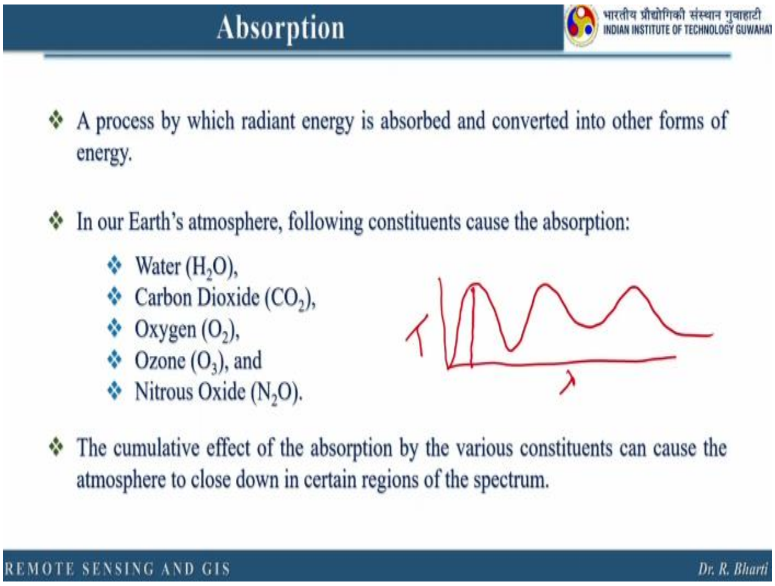

Now the next one, if you remember scattering and absorption are modifying our radiation in the atmosphere. So the absorption is also an important parameter to simulate or to remove the effects of atmosphere from our remotely sensed images. So a process by which radiant energy is absorbed and converted into other forms of energy in our earth's atmosphere following constituents can cause the absorption like water, carbon dioxide, oxygen, ozone and nitrous oxides.

The cumulative effect of the absorption by the various constituents can cause the atmosphere to close down in certain regions of the spectrum. So now here let us assume. This is our wavelength and this is the transmission of our atmosphere. So here you have transmission. So that means the more the value that means the atmosphere is transparent in those wavelengths.

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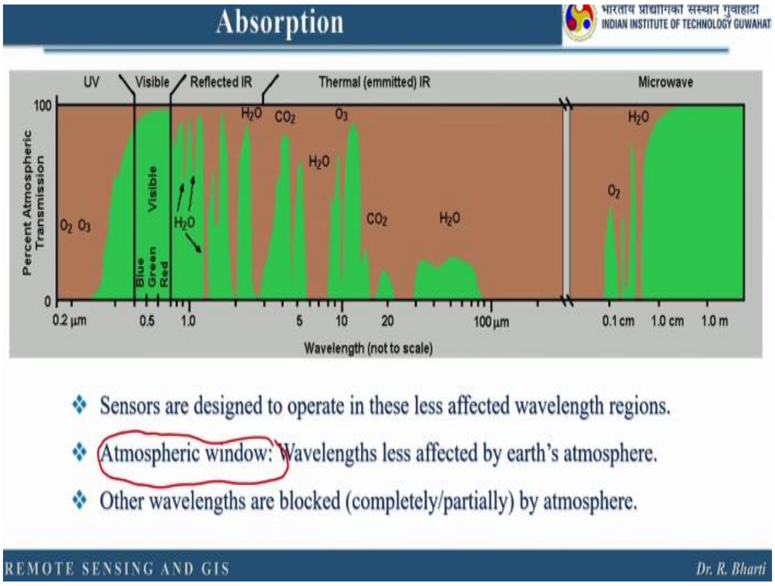

So this you can understand here. So here the green color represents, you have transparency in your atmosphere. So these wavelengths can be used to capture image from space in different wavelengths and other wavelengths are basically blocked by gases or may be the other atmospheric constituents. So our sensors are designed to operate in these less affected wavelength regions.

Atmospheric window, so the wavelength or the range of wavelength which are actually allowing which are allowed by our atmosphere to reach the surface and again travel back to the space to our sensor. So those are known as atmospheric window. Now the next one is other wavelengths are blocked may be completely or partially by our atmosphere.

So now here there is a very interesting information like there are few wavelengths which were blocked earlier also and now also, but in the beginning of remote sensing, they wear known as noise. So if you have more interaction with the atmospheric constituent, you will have modified signals and that you cannot use to really know what is lying on this surface in that particular wavelength region, so we used to call them noise.

But nowadays those noise are basically one type of data which can be used to identify, what is the atmospheric constituent? So if the constituent is more you will have more interaction and you will have more noise, so that now we are resolving in terms of information. So slowly we are evolving and we are moving ahead in different direction. So now, you need to understand the basic concept of DN number then radiance and reflectance, emittance, transmittance, absorption.

So these fundamentals are used and now onwards I will always call radiance, reflectance, emittance and you have to refer all these fundamentals.

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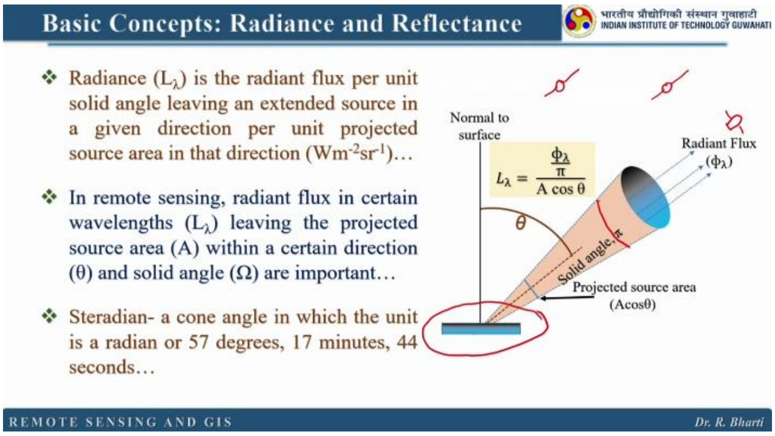

So radiance is the radiant flux per unit solid angle leaving an extended source in a given direction per unit projected source in that direction and the unit of radiance is watt per meter square per steradian. In remote sensing radiant flux in certain wavelength leaving the projected source area A within this certain direction that is our theta and solid angle are important. So here you need to understand, this is the area which we want to sense.

So from where we are capturing this data. So if your sensor is located here or if it is here the information which you will get that will be different, because that is also defined by the angle what is your view angle. So steradian, you know, it is a measure of your angle and which also can be represented in degrees minutes and seconds, so these are fundamentals.

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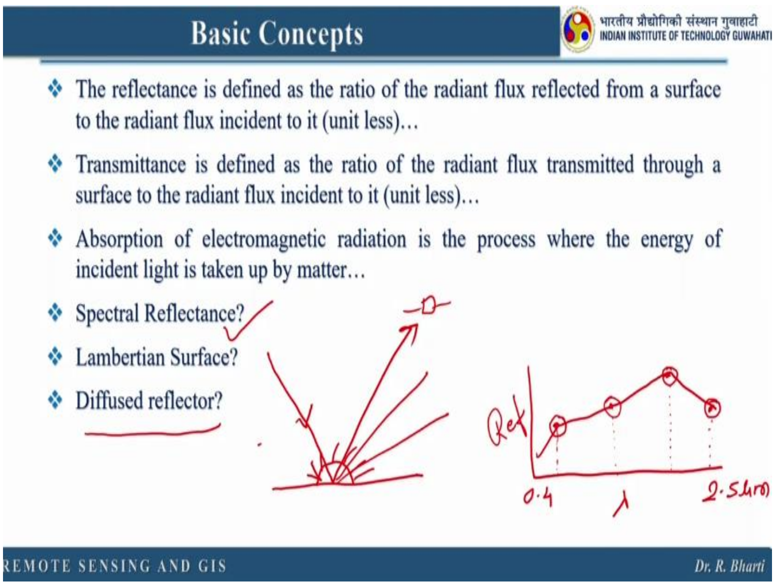

Now next is the reflectance is defined as the ratio of the radiant flux reflected from a surface to the radiant flux incident on it and it is unit less now, I will draw some figure to understand, this is your surface, this is your source. Now your sun is illuminating this surface, sorry illuminating this surface and which is getting reflected and your sensor is here. In this case we are assuming there is no atmosphere.

So whatever energy is coming from our source to the target, target is this, target is here. So this is called irradiance and the reflected energy from our surface, which is reaching to our sensor that is called radiance. So what do you mean by radiance and reflectance? So when you measure this? This is called radiance where all these angles are involved. So that is why you have unit watt per meter square per steradian.

And when you have irradiance that is also, there also angle is involved. So unit is watt per meter square per steradian. So when you calculate reflectance, it is basically radiance by irradiance. So then what will happen to your units that will get cancelled and then you will have unit less quantity. So for a given target this reflectance is very important. So this reflectance is very important why because reflectance is free from all your illumination condition and the angles.

So here for one material reflectance value in a particular wavelength is fixed. So that is something like your fingerprint it cannot be changed. So either you have to refer a particular X wavelength to identify a material or a set of wavelengths like X1, X2 and X3 wavelengths are used to identify this A material right? Then next one is transmittance, which is defined as the ratio of the radiant flux transmitted through a surface to the radiant flux incident on it.

Then absorption of electromagnetic radiation is the process where the energy of incident light is taken up by the matter and then there are few concepts you need to understand spectral reflectance, lambertian surface, diffused reflector. So first, let us start with spectral reflectance. So spectral reflectance is you have a surface illuminated by your source and it is getting reflected and which is measured by your sensors and sensor is capable of resolving this 0.4 to 2.5 micrometer wavelength in 5 bands.

So you will have one value here value can be more or less, this is for example, so in this wavelength you have 4 values captured by your sensor and if you draw it will be like this. So here, what I am saying, this is lambda and this is reflectance, so reflectors versus lambda. Now here you can see, for this particular wavelength your value of reflected energy is different, for this particular wavelength reflected value is different, for this particular wavelength, you have different value.

So that means this is the behavior of material which is regulating all these values. So if we change the material the response will be different. So if you are measuring this reflected energy across the wavelength in different segments, then it is known as spectral reflectance. If you have only single value then you say it is reflectance, but if you measure across the wavelength and in, maybe 5 points or maybe in 10 points, so that depends on your satellite data.

The next one is lambertian surface. So when you have a perfect reflector, what will happen? This will act as a mirror and it will reflect equal amount of energy in all the direction which is very rare in the natural condition, so natural materials are not lambertian in nature, so they will have different response in different direction, so lambertian surface is a perfect reflecting material which can reflect equal amount of energy in all the direction.

So does not matter you measure here, your information will be same. Then diffused reflector, this is again, you are not including the angle here. So what will happen in diffused reflector? Your cone of the measurement will be large that will not be focused.

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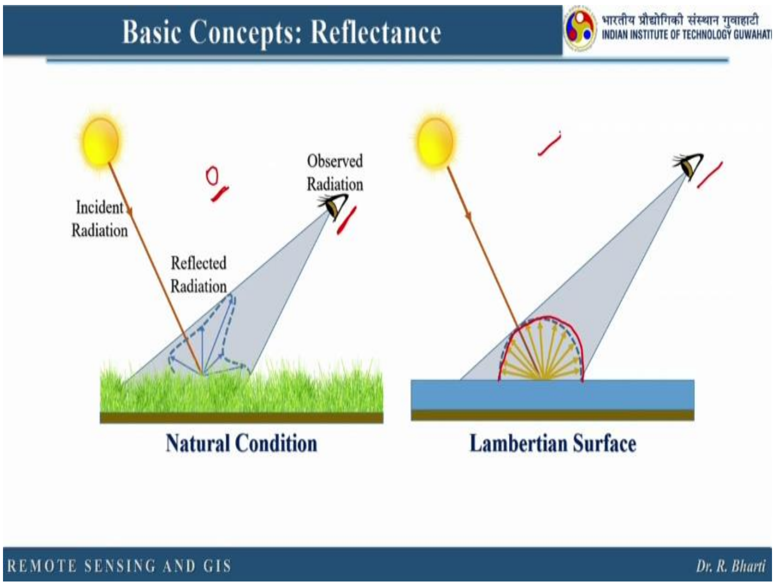

So here, there are 2 photographs and here you can understand the sun is illuminating this particular surface and here based on this material characteristics and the roughness of the surface, your reflected energy will be different. So if you are seeing from here, your information will be different. If you see from here, your information will be different. So seeing means, you have a sensor or you have a camera which is located here or here.

In the next one, when you have a lambertian surface, what will happen, you will have equal amount of energy reflecting in all the direction. So doesn't matter whether you look from here or you look from here, your information will remain same. So in the next lecture, I will cover bi-directional reflectance and how it is affecting our measurement where different parameters also like source sensor geometry, they are also involve in modifying these signals. Okay, so this is all for today. Thank you.