Remote Sensing: Principles and Applications
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Lecture - 11
Interaction of EMR with Terrain Features – Part 1

Hello everyone, welcome to today's lecture in the course remote sensing principles and applications. Today we are going to get introduced to the concepts of how electromagnetic radiation interacts with terrain features. So, before going on to understanding the interaction of EMR with terrain features, we will quickly recap what we studied about the sources of EMR in our previous classes.

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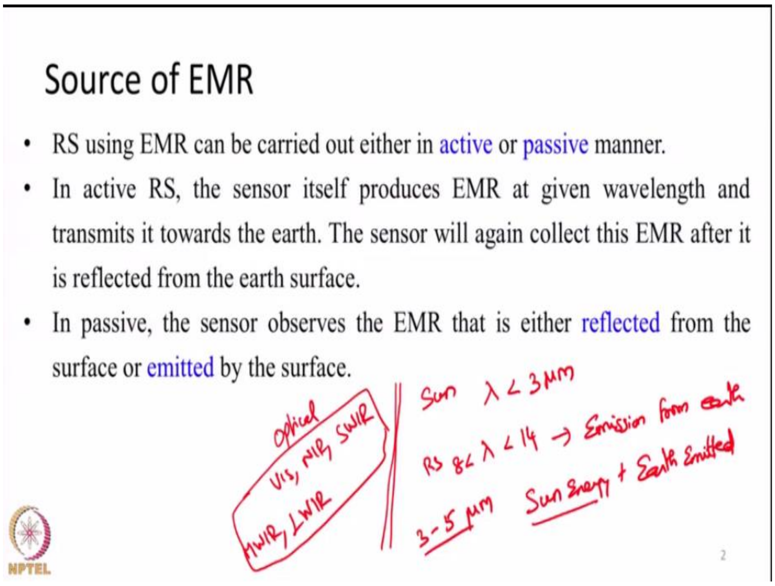

So, the basic source of electromagnetic radiation is primarily the sun, when we are doing remote sensing in wavelengths less than 3 micrometers. When we do remote sensing in wavelengths around 8 to 14 micrometers the primary source is the emission from earth this we saw already in previous classes. When we do remote sensing in between the MWIR region around 3 to 5 micrometer region we will get a mix of sun's energy plus earth emitted. So, we will get both of them especially during day time. During night time, sun's energy will not be there, we will be seeing only earth's emission. So, these are all the primary sources of energy especially in the optical bands that is visible, NIR, SWIR, MWIR and LWIR wavelengths. And in this particular lecture, we are going to see what are the basic principles of interaction between terrain features and electromagnetic radiation in such wavelengths.

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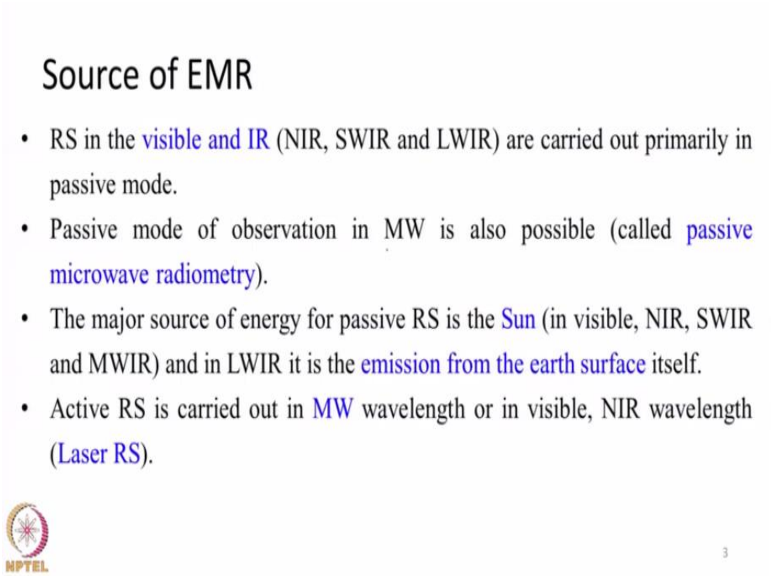

So, this is again just a recap of previous classes. In the visible and IR band, for especially passive mode of remote sensing the primary source of energy is from the sun. And we can also do passive mode of remote sensing in microwave wavelengths. We will see later in a separate class.

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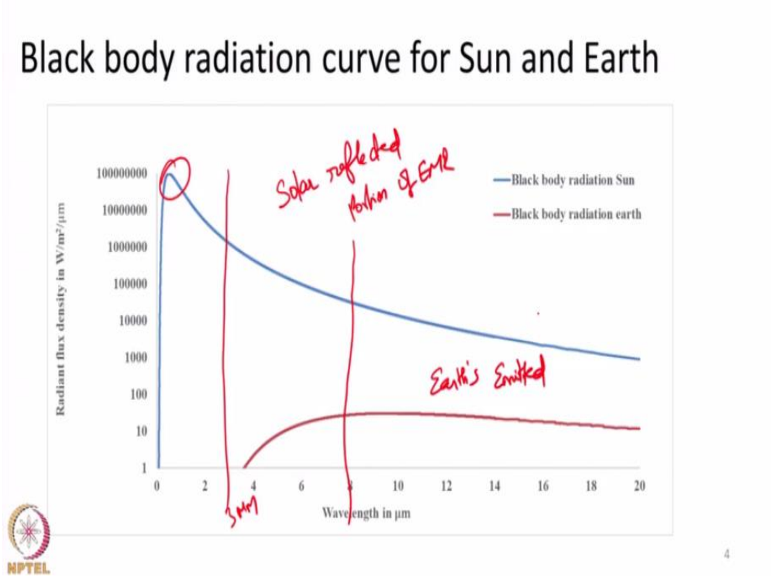

This is quickly again another recap of the energy from the sun so this is peaking around the visible wavelength. The maximum energy from the sun is coming around visible wavelength. So, up to this particular point around like 3 micrometers approximately solar radiation is much larger in comparison to earth’s emission. So, whatever we are sensing in this wavelength we call it as solar reflected portion of EMR. And wavelengths greater than 8 micrometers range we will see it as earth’s emitted portion of EMR. Actually in this figure you may notice sun’s energy is still much higher than earth’s emitted energy but still this will be rounded up. We will see later what happens to sun's energy when it reaches these particular bands. This is again still at longer wavelengths.

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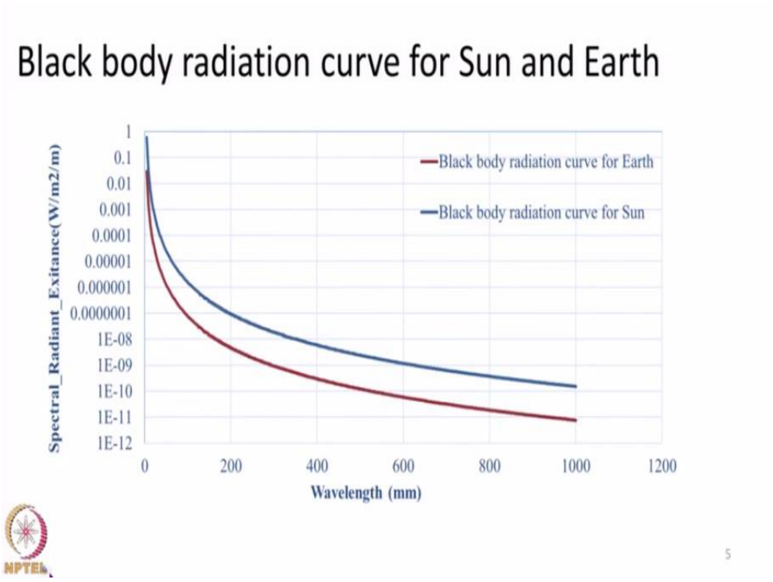

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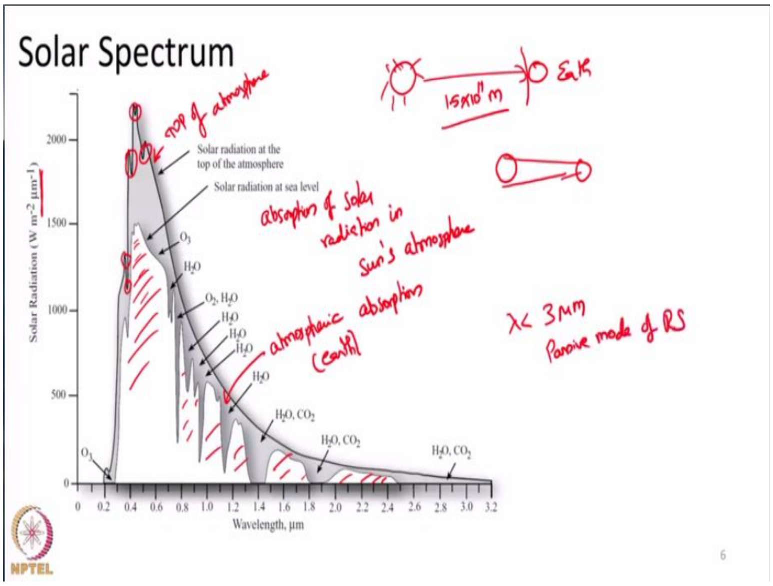

Now we go little bit deeper into the topic. This is what the solar spectrum that reaches the earth's surface that is top of earth's atmosphere and where does it reaches the earth surface actually the terrain. So, if you compare this particular graph with the previous graphs I shown you, here if you look at the y axis, here the values are much larger whereas if you look at the y axis in this particular curve the values are shorter. That is because of 2 reasons one is, there is a change in the units used. There, the units were expressed differently and one more thing is we also noted that the solar radiation has to travel quite a long distance to reach earth. This is roughly around 1.5×10^{11} meters roughly on an average. And also the irradiation from solar energy will reduce when it is traveling towards the earth that is Point 1. And, Point 2 is solar radiation actually subtends a very small solid angle. All the radiation reaching the earth subtends a very small solid angle. Actually only a fraction of what is emitted by sun is reaching the earth. That is why whatever we have noticed in the previous slides which was much larger has actually reduced to a great extent. But, still the shape is preserved.

One more thing you can notice is, these sharp absorption features like the previous slides I have shown you in this particular using the Planck's law the curve was extremely smooth without any sort of dips and all. Whereas here in this particular slide, there are lot of characteristic peaks and dips in this curve. These small absorption features wherever there is a dip there is energy being absorbed. It is due to absorption of solar radiation in sun's atmosphere itself. Sun also has atmosphere, we call it as photosphere which is made up of a lot of heavy elements, heavy metals which are in gaseous state. So, those elements present in sun's photosphere will absorb some characteristic wavelengths. Very similar to how earth's atmosphere behave, sun's photosphere also will behave like that. That is why we are actually seeing this sharp absorption features in the solar radiation reaching the top of earth's atmosphere. So, now it is clear that this is the energy that reaches the earth's atmosphere or top of earth's atmosphere. But this is modified again to a great extent by earth's own atmosphere and this white portion is what we get for remote sensing purposes. So, essentially whatever is being given here are due to atmospheric absorption. In wavelengths less than 3 micrometers, we are essentially going to use only the energy what is there in the white color portion within this curve for remote sensing of earth surface using passive mode of RS.

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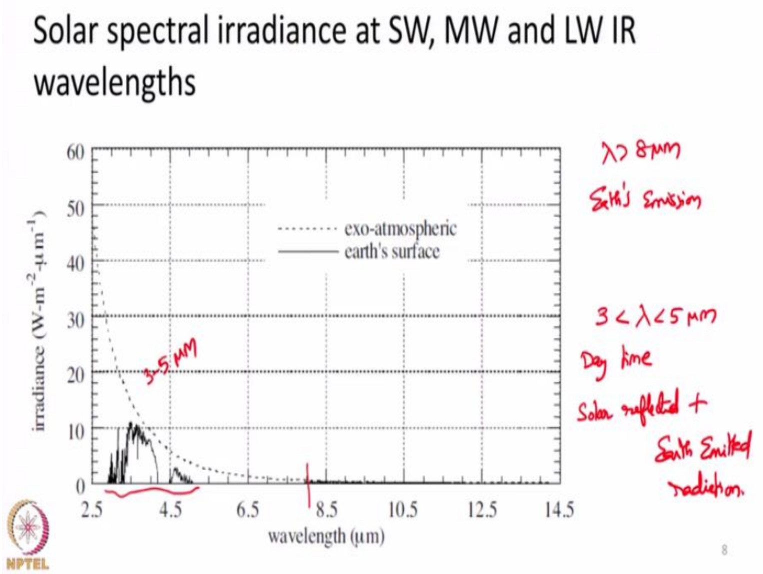

So, this I told you when we discussed in wavelengths greater than 8 micrometer, earth's emission actually peaks. We are actually sensing earth's own emission. But when I showed you the black body curves for earth and the sun, we noted that the black body radiation at sun's temperature was still much higher even at longer wavelengths.

In reality as solar radiation while travelling to reach the earth's surface, major part of its energy will be lost, only a fraction of it will reach the earth's surface. In that particular fraction, if you look at this particular slide, we will be able to see the energy coming from the sun, this dotted line actually goes very close to 0 after this 8 micrometer wavelength. Almost it is extremely close to 0. So, as the sun's energy travels in that particular small solid angle subtended by sun on earth surface most of the energy is lost and only a fraction reaches the earth surface. Within that fraction most of the energy comes only in the shorter wavelengths less than 3 micrometers. In wavelengths greater than 8 micrometers, solar radiation reaching the earth's surface is almost 0.

That is why I said earth's emission peaks in that particular wavelengths. Using theoretical laws, sun's radiation is much higher than earth's radiation. That is in true. But due to all these like inverse square law, travelling of sun's energy from its position to earth's surface, within short solid angle and due to earth's atmosphere, everything complicates things and removes major part of sun's energy coming in longer wavelengths. So, essentially the solar energy reaching the earth's surface in wavelength greater than 8 micrometer is 0. And further earth's atmosphere takes care that nothing reaches surface. Only between the wavelength of 3 to 5 micrometer, some small amount of solar radiation reaches the earth's surface actually. That is given by this particular curves. And that is why I said when we do remote sensing in wavelengths between 3 to 5 micrometer especially, during day time, we will get signal of both solar reflected plus earth emitted radiation.

So, in this lecture and in the next lecture, we are going to see the basic principles of how this solar energy interacts with earth surface. And also how this earth emitted portion gets emitted and how both of them reaches the sensor actually. So, what are the different things that happen in between the incoming solar radiation, how it interacts with surface and how it reaches the sensors. The basic principles we are going to see in this lecture and next lecture. When solar radiation reaches the earth surface it may undergo 3 different processes, one it may be absorbed by the feature on which it falls, it may be reflected back, it may be transmitted into the feature over which it falls.

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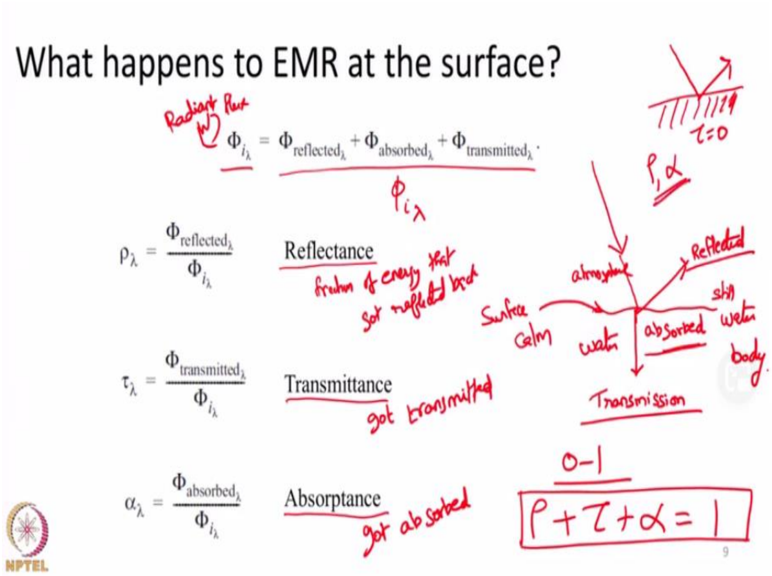

So, that is given in this particular slide. Let us say here is a still water body, like very calm water body, some sun's radiation is coming over it. When it comes, this is atmosphere, this is water and this is the surface. So, we have seen in initial classes when we dealt about the properties of EMR that when electromagnetic radiation traveling from one medium to another medium, when it comes across the surface of the second medium, a portion of EMR will be reflected back. So, that is what will happen as a first component. Solar radiation will come in and some portion will be reflected back and that amount will vary based on surface characteristics. We will see in later classes. So, this is like the reflected component. This is the first part.

Then since it is water we all know sunlight can pass through water to some depth. So, Refraction will happen. Then the sunlight will pass through water to some extent. That is transmission. And some portion of energy will be absorbed within water itself. So, any of these 3 parts or all the 3 can happen when solar radiation interacts with features. It can be reflected back. Reflection happens at the surface basically when solar radiation from atmosphere touches the surface, a part of it will be reflected. So, that is happening at the surface, we call it reflection. And reflection will send the energy to the same medium from where the energy came. That is reflection will send the energy back to the atmosphere. Direction may change but essentially it goes back to atmosphere. Then some portion of energy will go into the medium say here in this example it is water.

A part of that energy which went into the water will be transmitted continuously or a part of it can be absorbed. So, these 3 essentially takes care of the total incoming solar radiation. Say this is the total energy radiant flux in unit watt that reaches the earth surface, a part of it is reflected, a part of it is absorbed, a part of it is transmitted. If you divide everything by the total incident energy itself, we get what is known as reflectance, what is known as transmittance, and what is known as absorptance. So, reflectance is the fraction of energy that got reflected back and transmittance says what fraction of energy got transmitted or passed through within the second medium. This is what fraction of energy got absorbed within the second medium. So, this everything will vary between 0 to 1.

Reflectance, transmittance, absorptance, all will vary between 0 to 1. And reflectance plus transmittance plus absorptance will be equal to 1. Because the total energy is conserved and hence when solar radiation interacts with earth surface, the reflectance, transmittance and absorptance will be equal to 1. So, this is like one of the major rules that we have to remember. And one more thing, here we took an example of water. If it is like land surface, like hard rocks or something beneath it, then transmittance will be 0, because energy cannot transmit through rocks. So, what essentially will happen is the total incoming energy either has to be reflected or has to be absorbed. So, there will be some reflectance and some absorptance. Transmittance will be 0.

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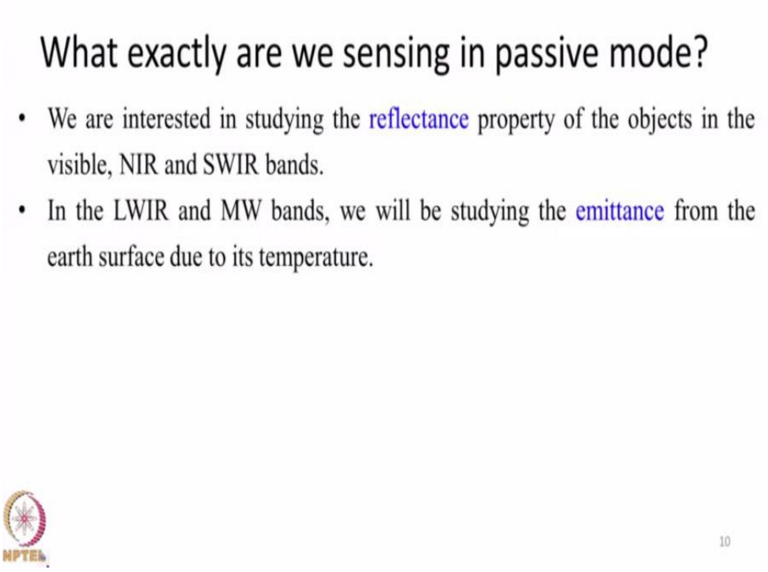

So, what exactly are we sensing in remote sensing especially in passive mode? When we do remote sensing in passive mode in wavelengths less than 3 micrometers, we are interested in studying the reflectance property of various earth surface features, how object reflects. That is what we are interested in studying or that is what we will get actually. Whereas if we do passive remote sensing in wavelengths between 8 to 14 micrometers, that is the long wave infrared portion, We will be studying how much earth's features are emitting by virtue of its temperature. So, in shorter wavelengths, we are interested in studying reflectance properties of objects. In longer wavelengths, means long wave infrared region 8 to 14 micrometers, we are interested in studying the emittance property or how much energy is being emitted by objects.

So, first we will see the reflectance property, what are the basic characteristics of reflectance? That emission property and those laws relating to it everything we will see later in thermal infrared remote sensing lectures. Now we will confine our lectures mostly to wavelengths less than 3 micrometers.

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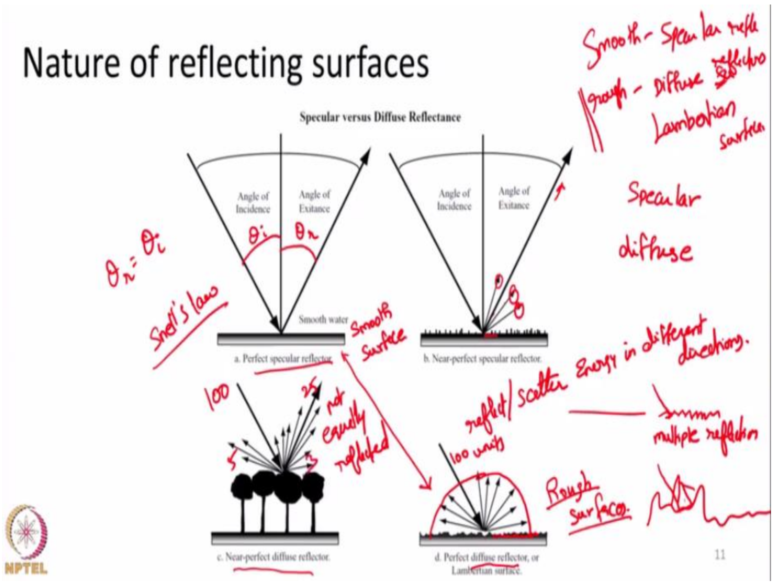

So, I said whenever solar radiation reaches the earth's surface a part of it will be reflected back. Based on the reflection, we can classify the earth's surface as specular or diffuse. What is specular surface? Or, what is a specular reflector? A specular reflector basically is a really smooth surface. That is it will obey Snell's law of reflection. This is we have seen in earlier classes.

What exactly Snell's law? When EMR interacts with the smooth surface, the angle of reflection will be equal to the angle of incidence, θ_r will be equal to θ_i. The fraction may be different but the angle will be preserved. That is what fraction of energy reflected(reflectance) may vary but the angle will always be preserved in smooth surfaces or specular reflectors.

Then the other extreme end of the portion is diffuse reflectors. Diffuse reflectors are essentially rough surfaces. What is rough surfaces? Rough surfaces are which contains lot of tiny variation or even larger variations in the surface features maybe like a sandy beach. If we look at it in bright sunlight, it will appear rough to our eyes. Sandy beach is actually kind of rough when we compare the wavelengths like visible wavelengths.

Similarly, some terrain will be really rugged and rough, lot of stones, lot of peaks falls, all those things. Such terrains are rough features. So, what will happen in rough features? In rough features, there will be lot of tiny surfaces. Let us say, instead of being this smooth, rough surfaces may be composed of lot of such tiny elements. What will happen when one particular ray comes and strikes it? It will be reflected back and it will undergo multiple reflections. Since the surface is rough, when a EMR comes and strikes here, it will be reflected back. Based on angle, it will be again reflected. If there is another surface element, it may be again reflected back. Everything will be somewhat specular in nature. But due to the multiple reflections happening, due to the surface roughness, the incoming energy will be instead of being sent in one particular direction, it will be scattered in different directions. So, a diffuse reflector will essentially reflect or we can also say scatter. Scattering is essentially redirecting in different directions. So, reflect or scatter energy in different directions.

So, this is what will happen for rough surfaces. And for rough surfaces, we have given a name, diffuse reflector or a Lambertian surface. And smooth surfaces, we call them as specular surfaces or specular reflectors. We call a surface as truly diffuse or truly Lambertian only when the incoming energy is equally split into different directions. Let us say incoming energy is some 100 units. This 100 units of energy is equally split into the entire hemisphere surrounding that particular object of interest. Here we call that particular surface as diffuse reflector or Lambertian surface. So, specular reflector and diffuse reflector are 2 ends of spectrum of reflecting surfaces. In reality, earth surface features most of them are neither truly specular nor truly diffuse. They lie somewhere in between, most of the surfaces. So, what will happen? A surface can be near specular that is what you are given in this particular figure. Near specular is there can be one primary direction in which energy will be sent. But still energy will be diverted into different directions. It is not like a really extremely smooth surface. There can be tiny variations in surface which causes major portion of reflected energy to go in one direction.

But there will be some small portion of energy reflected in other directions. Similarly, some surface can be near diffuses. Energy will be deviated into different directions. But they will not be equally reflected. They will be reflected in different directions in different amounts. Maybe as I said if hundred units of energy coming, say 25 units went in this direction, 5 units went in this direction, 3 units went in this direction and so on. So, specular surfaces are such ones in which whatever is being reflected will be reflected in only one direction and it will obey Snell's law. Diffuse is exactly opposite to this. Whatever is being reflected, will be reflected equally in all directions in the hemisphere covering the object. Most of the earth surface features are neither purely specular nor purely diffuse they are in between.

So, near specular means there will be a primary direction which most of the reflected energy will go but there will be some secondary directions. On the other hand, near perfect diffused reflectors energy will be split into different directions but they will not be split equally. Few directions will get somewhat higher percentage of reflectance. Few directions will get somewhat lower percentage of reflectance. So, based on the nature of reflecting surfaces we can characterize the surface into specular, diffuse, near specular or near diffuse.

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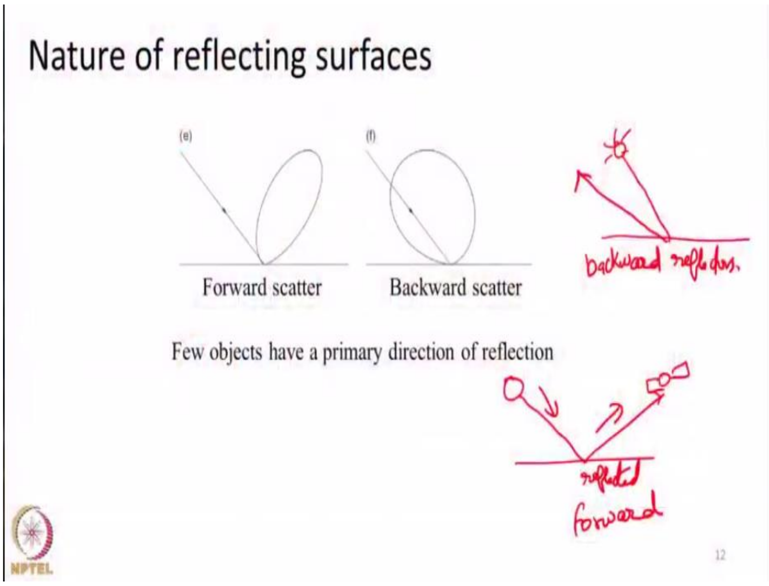

Like as I said even in near specular or near diffuse cases there can be one major direction in which energy is being sent. Based on that direction, we can classify objects as forward scatterer or backward scatterer. So, what is forward scatter or backward scatter? Let us take this example say there is sun, surface is here, sensor is located here exactly opposite to the direction of sun, sun's radiation is falling on it say this is going like this.

So, the energy is now coming in, after getting reflected the energy is going in direction opposite to the direction in which it came. We call such surfaces as forward reflectors. Some surfaces will reflect the incoming radiation back in the direction same as the incoming radiation. Such objects are called backward reflectors. These surfaces can be specular, diffuse, near specular, near diffuse whatever. But we are just telling which direction the primary reflected energy is going. If it is going in a direction opposite to that of the incoming direction, we call it forward reflector. If it is going almost the same direction as that of incoming, we call it as backward reflector.

What is the real implication of observing a forward reflector and a backward reflector? If the sensor position changes, it introduces a completely different view of the object we are looking on. Few examples are given in the next slides. So, these particular slides show you how vegetation looks when we take photographs in forward and backward directions.

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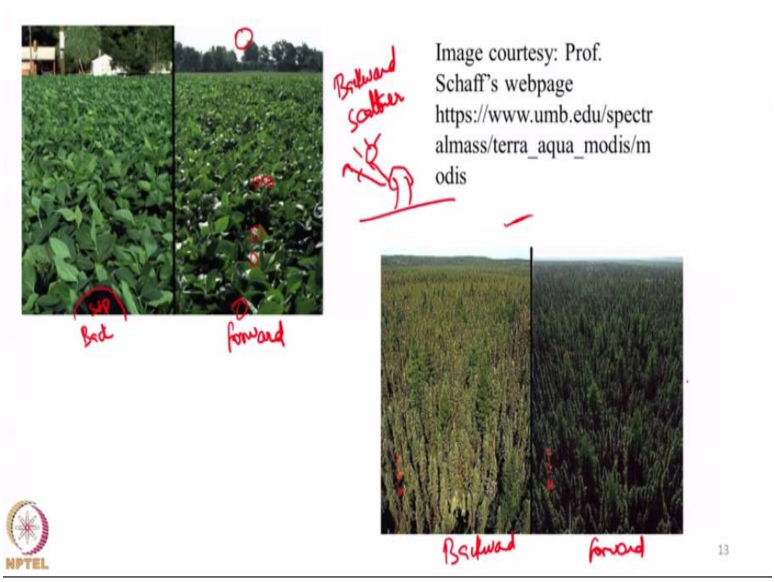

So, vegetation is primarily a backward scatterer. That is most of the energy that get reflected from the vegetation is in the same direction of incoming radiation. So, reflection will happen in the same direction. Vegetation is a backward scatterer. So, this photo is taken in backward direction like sun is here, you can see the shadow of the photographer, the sun and the photographer are in the same direction in this photo. This photograph was taken from a forward direction. That is sun is here, photographer is here. In this photo, both sun and photographer are here only in this direction. Similarly, in this particular photo here, this is backward photograph, backward direction photograph. This is forward direction photograph. These photographs are taken almost at the same time, same sensor and everything.

But just see how the looks differ just because of the variation in the difference. Backward photograph looks more diffuse whereas forward scatter we have like lot of reflectors. Here the backward scatter appears actually much brighter. In forward photograph, it appears much darker and so on.

So, based on terrain characteristics whether it is specular or diffuse, whether it is a forward reflector or backward reflector and by virtue of sun surface and viewing geometry same feature may appear totally different. So, this is the primary factors that controls how objects will appear when remote sensing images are being collected.

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This is another example not only vegetation but also soil. This is again backward photograph. This is forward photograph. How soil looks? Here the same soil, same fill. This looks much brighter. This looks extremely dark. So, this is because of just in change of view angle and because of the nature of reflecting surface.

So, in summary, in this particular lecture, what we have seen is the incoming solar radiation especially in wavelength less than 3 micrometers primarily undergoes process of reflection, transmission and absorption. We just started discussing about the reflectance nature of terrain features. The terrain features based on reflection property can be classified as specular or diffuse or near specular or near diffuse.

And also based on the primary direction of reflection, they can be classified as forward reflector or backward reflector. And because of this variation in terrain reflection features and due to sun and sensor viewing geometry we may get a totally different picture of the terrain features. Thank you very much.