Remote Sensing Essentials

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Lecture-05
Interaction Mechanism of EM radiation With Ground and Spectral Response Curves

Hello everyone, and we are in this discussion we are going to have on this interaction mechanism of EM radiation with ground and spectral responses curves which we are also going to discuss in this class. Earlier in just in the previous discussion we have discussed about the interaction of EM radiation within the atmosphere, we little bit tell about the radiation interaction with the ground but now be we will have a brief discussion on how this EM radiation interact with different objects which are present on the surface of the earth. And then how their spectral response curves are generated.

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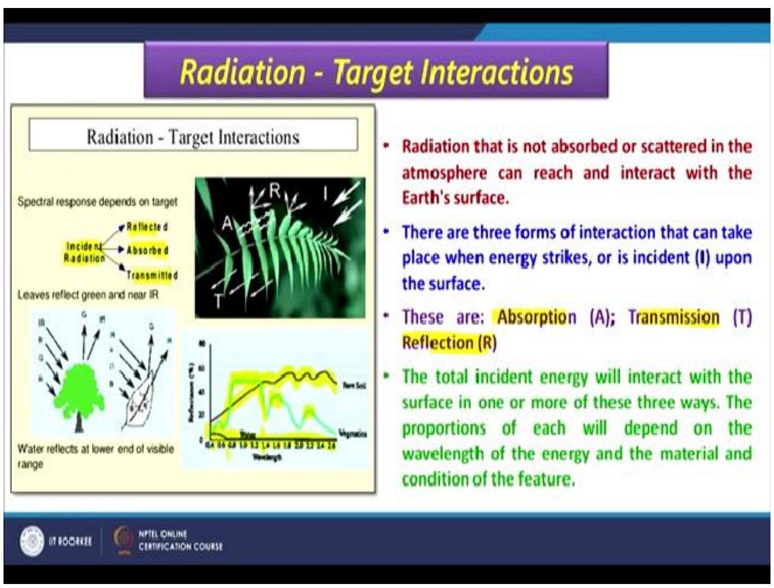

And if we take the example here is about they say example about the vegetation. And then the incident radiation which is might be the solar radiation here, which may get reflected, absorbed or transmitted. So, 3 things may happen. So, depends on the type of target, where this incident radiation is falling, different types of vegetation or different conditions of even same vegetation may reflect, may give different kinds of signals.

As soon that the vegetation having the maximum reflection in the infrared part of EM spectrum, but whereas in the visible part it does not have much reflection and other parts also a little bit there and then here peaks, but rest is not there. So, what we understand through this curve of vegetation not very any specific vegetation but any type of healthy vegetation that it is having the maximum reflection in infrared channels.

So, when we see the satellite images and they say color composite or false color composite, in case of false color composite we assign red color to infrared channel and vegetation is having high reflectance. So, in false color composite vegetation appear says red, but the near true color images like you see on Google Earth, then generally vegetation and this infrared channel same green color and you see the vegetation appearing in the green. So, vegetation what we understand from this that vegetation having the maximum reflection of incident radiation in the infrared part of EM spectrum.

If we compare with this water, so it is having just in the beginning of EM spectrum or visible part of EM spectrum, it is having little reflection, but rest is complete absorption is there . So, in the previous discussion, I have mentioned that an infrared channels, an infrared bands of remote sensing images, we find that when the infrared channel having maximum reflection for vegetation, but for water, it is complete absorption.

These are ideal conditions, if vegetation not healthy water is having turned TR pollutants then different kinds of curves. So, we are talking about pure things. Also, if you are having bare soil it behaves differently in different part of EM spectrum. So, in the beginning of a visible and near infrared, it does not have much reflection, but later on it is having quite good reflection. So, what we gather from this that each and every object, which is present on the surface of the earth may interact differently in different parts of EM spectrum.

Then this incident radiation hits that one. So, radiation is not completely absorbed or scattered in the atmosphere, part of which we have also discussed different components in percentage can reach and interact with the earth surface. So whatever the material or objects which are present it will interact with those and there are 3 forms of interactions which may takes place when this incident radiation occurs, that is upon it depends on the surface.

So, one is the absorption like water body in infrared absorbs the infrared radiation and the may transmit and also may get reflected like vegetation reflect maximum in infrared. So, the total incident energy will interact with the surface in one or more of these 3 ways and that is absorption, transmission and reflection and the portions of each will depend on the wavelength of the energy and material and conditions of the features.

It just discussed that if vegetation is not healthy then we will not get this standard curve for vegetation. And same way if water is not pure, then again we will not get the similar curve here. And in different as you can realize that in different wavelength bands or different channels or bands of different sensors on board of satellites, these objects or these features will interact differently. So, that is why when we make color composition of different bands, in order to make color images.

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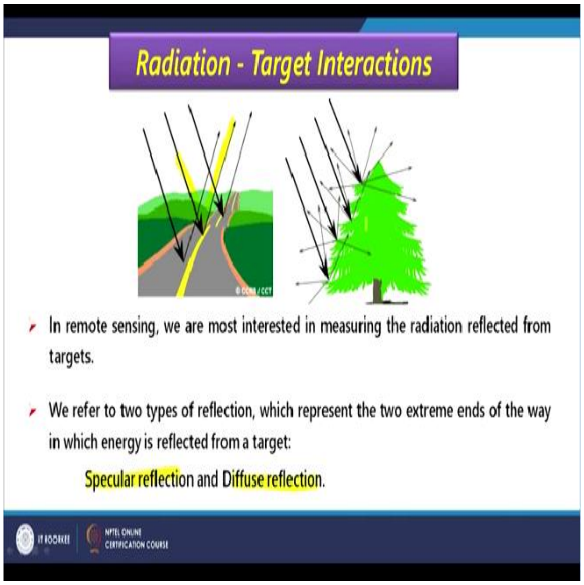

We try to get maximum reflection of different objects, at least in those 3 channels, which we are combining for RGB or red, green, blue color combination. So, in remote sensing, what we are interested is measuring the radiation which is reflected from the target. Because the solar radiation will hit say vegetation or road or a mountain and whatever it is reflected back which reaches to the satellite that is most important for us or to the sensor that is most important.

And we referred to 2 types of reflection which represents the 2 extreme ends of the way in which energy is reflected from the target, one is the specular reflection and another one is the diffuse reflection. So, 2 types of reflection may occur here. Specular reflection example here shown that maximum energy is reflected back towards the sensor and whereas diffuse reflection may occur on the soil surface maybe on a vegetation.

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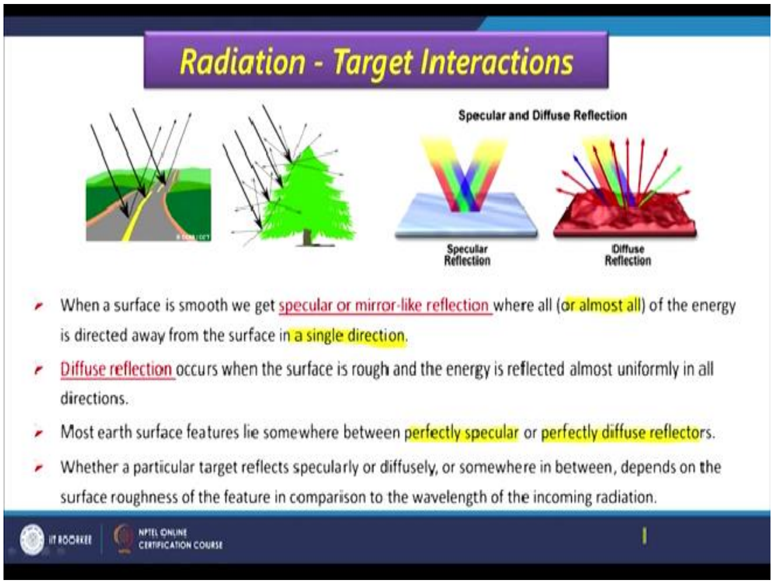

Now examples are also given here. As I just mentioned that when a surface is smooth, we get specular or mirror like reflection from water body also sometimes we get this mirror like reflection and one of the very famous example of specular reflection in satellite images which is seen from water bodies especially in the ocean parts and that is called sunglint, where almost of the energy is directed away from the surface in a single direction and that is recorded by the sensor.

So, you see a very wide patch in satellite images of a water body when the sunglint phenomena occurs, that is sunglint phenomena is nothing but a specular or mirror like reflection from the surface but that may occur when water body is very calm, if a sea is not very calm this you know having lot of waves and other things, then you may not get that is some glint kind of phenomena and diffuse reflection as you are maybe vegetation, maybe bare soil, maybe mountains, you may get diffuse reflection.

So, diffuse reflection occurs when the surface is rough and the energy is reflected almost uniformly in all directions. And that the disadvantage with diffuse reflection is that the energy which supposed to be reaching to the sensor and will not be there only very little energy will be reaching there, but in case of specular reflection and the almost all the energy get directed towards the sensor and you get a very good registration of the energy or signals.

So, most earth features lies somewhere between perfect specular and perfectly diffused reflector. That means none natural objects are perfect specular and nor perfect defuse, they find in between these 2 extremes. Whether a particular target reflect specularly or diffusely or somewhere in between basically it depends on the surface roughness of the feature in comparison to wavelength of incoming radiation.

So, depending also wavelength. So, this is wavelength defendant, but nonetheless also roughness or surfaces smoothness dependent reflection.

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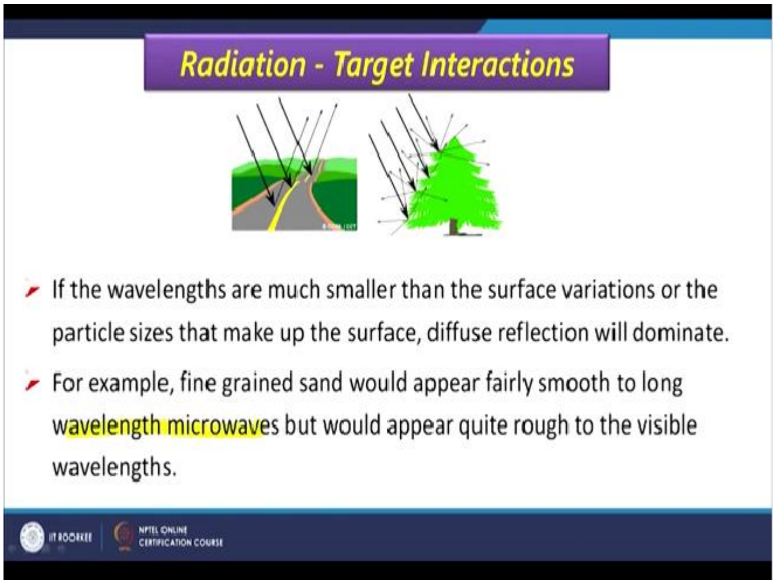

If the wavelengths are much more smaller, then the surface variation or particle sizes that makes up the surface diffuse reflection will dominate. So, wavelength that means in the shorter wavelength a diffuse reflection for example, you fine grain sand maybe in desert conditions would appear fairly smooth as long as wavelength and microwave but would appear quite rough in the visible wavelength.

Because wavelength in case of microwave are very large and therefore these small changes or the small differences in the sand particles may not be get registered with that, and therefore, it will appear smooth in case of microwave but invisible channels rough.

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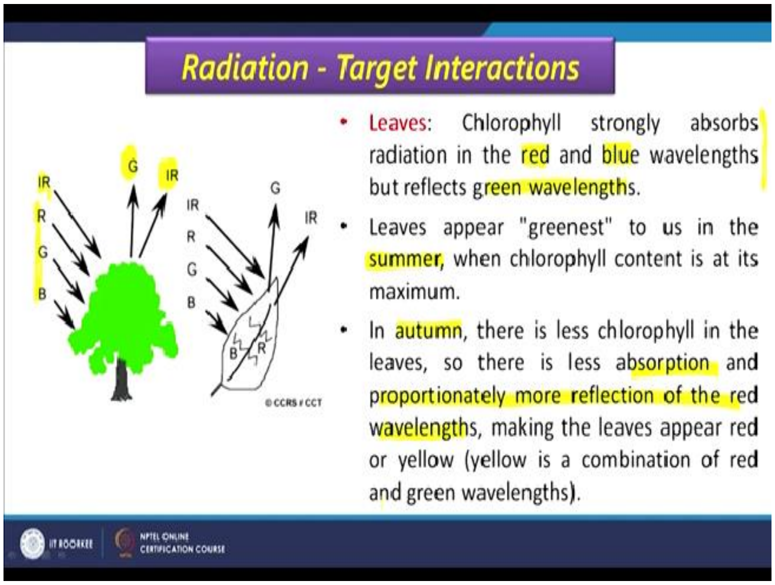

Now leaves if now we instead of a complete vegetation cover we start talking about in these are leave, these leaves then the chlorophyll basically which is making this reflection high. So, chlorophyll strongly absorbs radiation in the red that is the visible part of the red and blue wavelengths, but reflect green wavelengths and that is why we see here we are talking only about the visible part of EM spectrum.

So, because j different colors are there in the visual part. So, red part and blue part is almost completely absorbed by the vegetation. Whereas, the green is reflected most and infrared. So, when the incoming radiation or solar radiation is coming, that may have infrared and of course it is it white light. So, it will have also red, green and blue. But when reflection occurs, then only the red part is absorbed, blue part is absorbed, only the green is reflected and infrared is reflected.

And this is because of the chlorophyll which is present in the leaves. So, the leaves which appear greenest, darkest to us in summer when chlorophyll content in its maximum. It depends you know, the summer word is here, but for some kind of vegetations the darkness in the leaves may come in some other time of the year also. So, not necessarily always summer, whereas in autumn there is a less chlorophyll in the leaves which because in deciduous trees leaves may be falling about to fall.

And they will have less absorption and proportionately more reflection of red wavelengths and that is why these leaves will appear either yellow or red. And so that means they are reflecting more this red part or blue part rather than green component.

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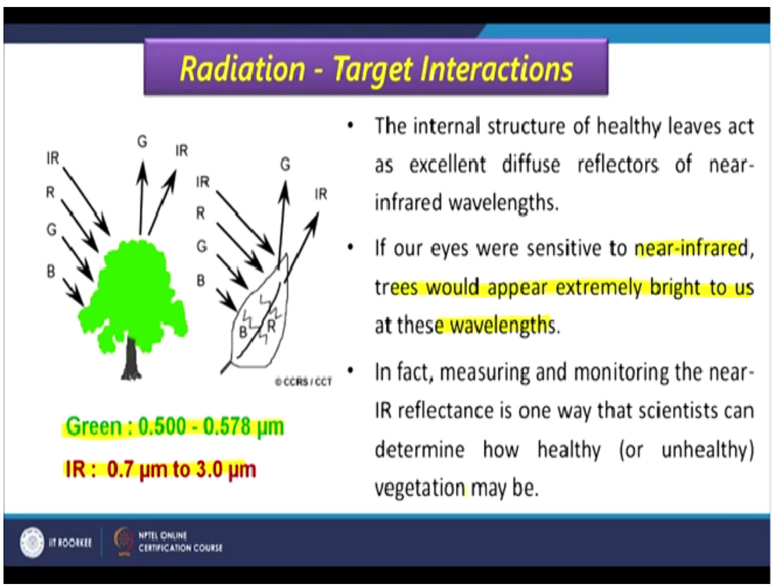

Further, as you can see that green band is 0.5 to 0.78 micrometer and infrared is a 0.7 to 0.3 micrometer generally in remote sensing sensors, that is exploded between 0.7 to about 1.1 micrometer. So, the internal structure of healthy leaves act as an excellent diffuse reflectors for near infrared wavelengths. So, if we want to study the vegetation, then the best channel or best bands are infrared channels or infrared bands rather than visible.

Because invisible, their effect of other things would also be there. Our eyes were sensitive to near infrared trees would appear extremely bright to us at these wavelength. If, our eyes would have been, but our eyes works only in the visual part of EM spectrum. So we see only the green reflection, reflection in the green part of EM spectrum. In fact, measuring and monitoring the near infrared reflection is one way that scientists can determine how healthy or unhealthy vegetation may be.

Because a healthy vegetation should reflect maximum in the infrared part. But when there are stresses in the plants or trees or leaves then this chlorophyll contained will reduce and then this reflection infrared instead of that, it may move towards the visible and especially towards the blue directions. So, we say you know, the blue shift in the red edge in case of a vegetation which is suffering from stresses or unhealthy vegetation.

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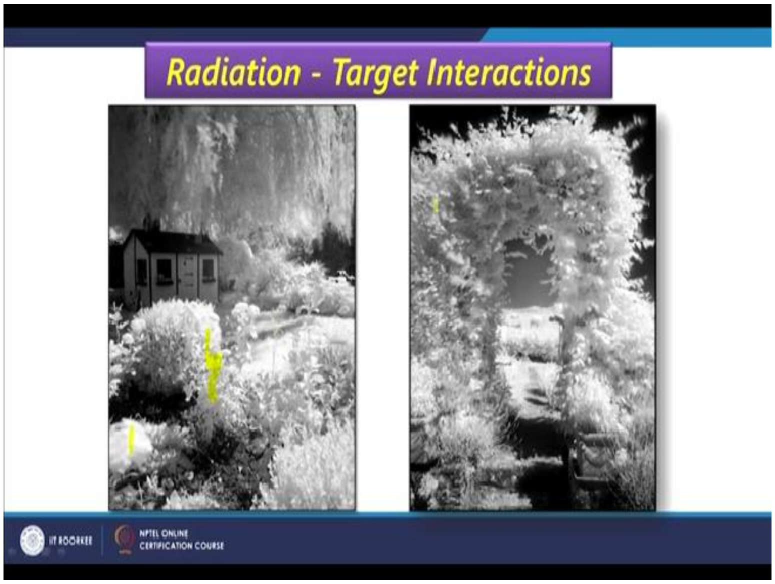

There are this is how that when we see vegetation and infrared channels, this is how we see here, that you see that the vegetation a healthy vegetation is appearing as very white, because this is black and white. So, it is having the maximum deflection and therefore, you are seeing it is showing a lot of brightness, the healthy vegetation, there might be some vegetation may not be healthy, it may be reflecting less. So, this is typical example of infrared bands.

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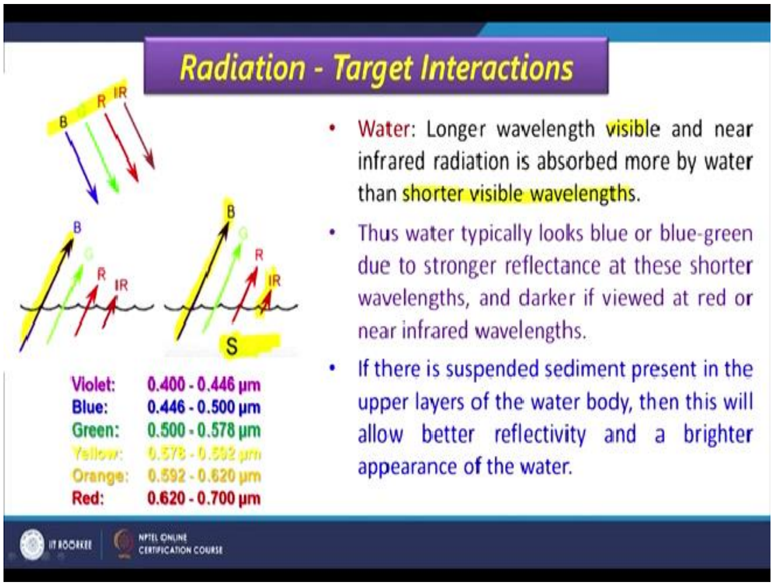

Now, if we take the water little would we have discussed when we discuss the spectral curve of water, bare soil and vegetation. But now, in case of pure water, it behaves differently, but when water is having pollutants, it will behave differently and when water is having turbidity it will behave differently in different part of EM spectrum. So, water in longer wavelength visible and near infrared radiation is absorbed more by water than shorter visible wavelength.

So, when we move towards the infrared, it is completely absorbed by the pure water and therefore, we do not get any reflection and therefore, in infrared channels water bodies will appear as a black and but there is some reflection or less absorptions in the shorter visible wavelengths. So, sometimes you that is why the blue component is maximum and you see what as blue rather than green or red or infrared, infrared is that is the minimum.

So, the maximum absorptions occur on in infrared channel of water body. So, all radiations is coming blue, green, red and infrared, but the maximum which is getting reflected is the blue one, here the water is pure, but here water might be it is shown some with turbidity or suspended particles and therefore, the behaviour of different bands would be different. So, water typically looks blue or blue green due to stronger reflection at these shorter wavelengths in visible part of EM spectrum.

And darker if viewed at red or near infrared wavelengths because of absorptions and if there is a suspended sediments as shown here also then the upon layer of water, then it will allow water reflectivity and a brighter appearance of water will appear. And this is a very common thing to use these changes in the reflection or absorptions of radiation in different channels to study the water bodies especially the pollution present in the water.

That is the quality of water and also the sedimentation or sediment concentration or suspended particles or turbidity in the water can also be studied, implying different bands of remote sensing satellites.

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Like for example here we have discussed vegetation. So, healthy vegetation this is a not that false color composite, it is a true color composite example, but still the vegetation is appearing of course green and water is appearing as blue here and because this water is having a lot of turbidity this one which you are seeing here and it is reflecting maximum in the blue part of EM spectrum in the visible channels and therefore, it is appearing as blue.

And here the turbidity is less, not much pollution is there and therefore total absorption is there and that is why in this color composite water is appearing as completely black.

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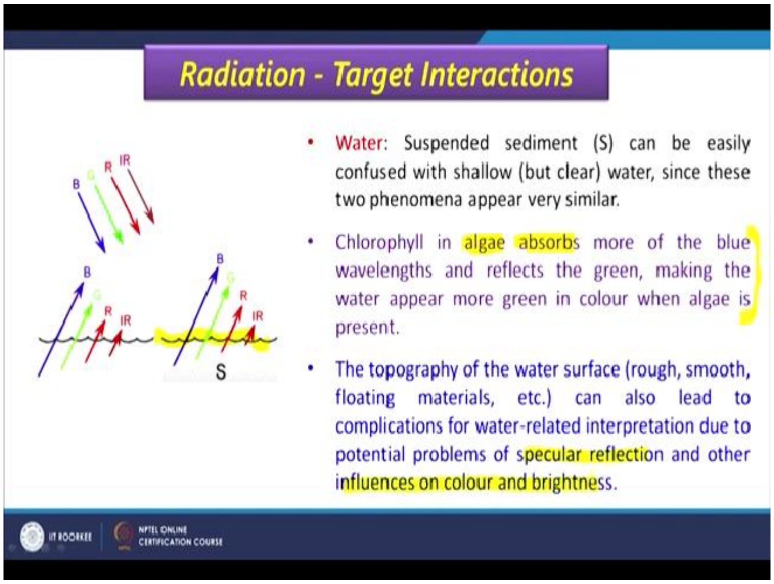

So, water if suspended particles as can be easily confused with shallow but clear water sometimes, if the column water column is not very thick or whatever is not the bottom is not very deep then it may give you almost similar kind of signatures as suspended particles. So, one has to be careful ground routing is always required before we conclude anything. So, that is why the suspended sediment can easily be confused with shallow or but not clear water.

Since these 2 phenomena appear very similar. So, when we study pollution or suspended or turbidity in the water, one has to be little careful about whether it is because of shallow depth of water or it is because of turbidity or because of presents of certain pollutants in the water. And in water sometimes the algae is might be also there especially in the seawater or in sometimes in the lake water also.

So, chlorophyll in algae, which can absorb most of the blue wavelengths and reflect the green making water appear more green in color, when algae is present. So, by exploiting these characteristics remote sensing data are also being used to study the development of algae in different water bodies. Now, the topography of the water that is the roughness or a smoothness how what is there on the surface basically and smoothness or floating materials etc. can also lead to complications for water liquid interpretation of satellite images.

And due to potential problems of specular reflection which we have already discussed and other influences on color and brightness. So, just based on whatever the discussion we had, if we see a satellite image, it is not very easy to conclude whether these reflections are because of algae or because of suspended particles or pollution, one has to first analyze properly different channels and then some ground routing if possible so also be done before conclusions are made.

Because there might be some other factors which may influence your brightness that means reflection and ultimately color composite images.

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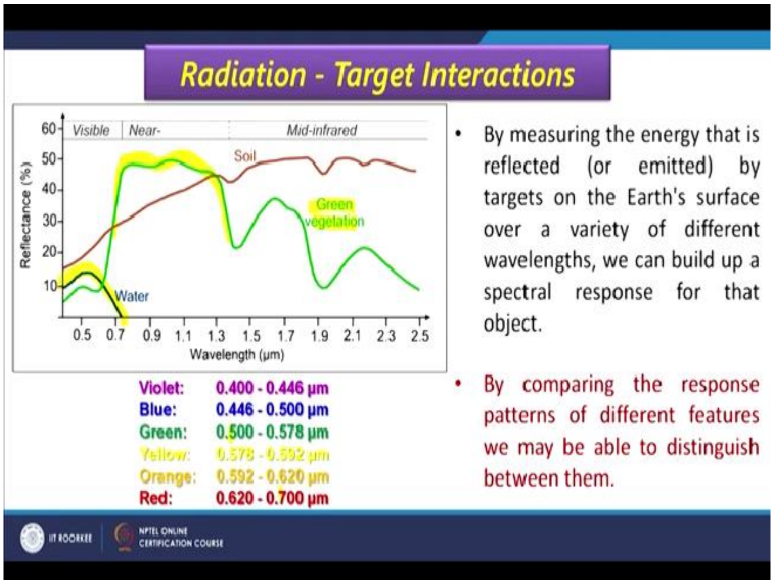

And these curves we have seen like water one and the rest is absorbed. So, in the beginning of visible part that is 0.5 to 0.7 you are having little reflection of what are the vegetation in a near infrared is having the maximum. So, by measuring the energy that is reflected or emitted by target on the earth's surface over a variety of different waves we can build up a spectral response for that object.

So, if like here it is mentioned for the green vegetation. So, for different bands or different part of the spectrum, if we are having these reflection and absorptions then we can create such curves. And these curves later on can become standard curves to compare the other curves and to identify different kind of features. These are more used in case of mineral exploration, because different minerals also behave differently in different part of EM spectrum.

And therefore, these curves becomes very important to identify minerals in the satellite images. Similarly, for different soil conditions or for different soils we can use these curves for different conditions of vegetation, different types of species of vegetation we can use these curves and same way different types in water conditions can also be used this. By comparing the response patterns or response curves of different features we may be able to distinguish between them for identification of different features.

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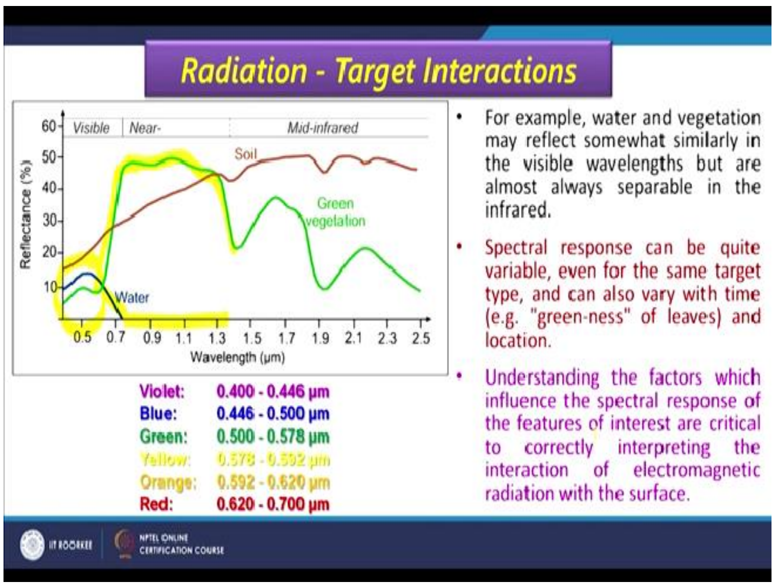

And for example, water and vegetation may reflect somewhat similarly invisible wavelength, but are almost oppose it or separable in infrared part as you can also see that water is complete absorption here and whereas healthy vegetation is showing maximum reflection positive behaviour in infrared, though in the visible part of the spectrum, both may have similar behaviour.

So, a spectral response curves can be quite variable even for same target type and can also vary with time especially regarding vegetation or water bodies or rough surface roughness that also plays in case of water bodies or in the you know desert conditions also depending on the size of dunes and other things. So, these understandings of curves are these factors, which influence the spectral response of features of interest are critical to correctly interpreting the interaction of EM radiation with the surface.

So, this understanding of these curves will allow us to correctly utilize them and interpret our satellite images.

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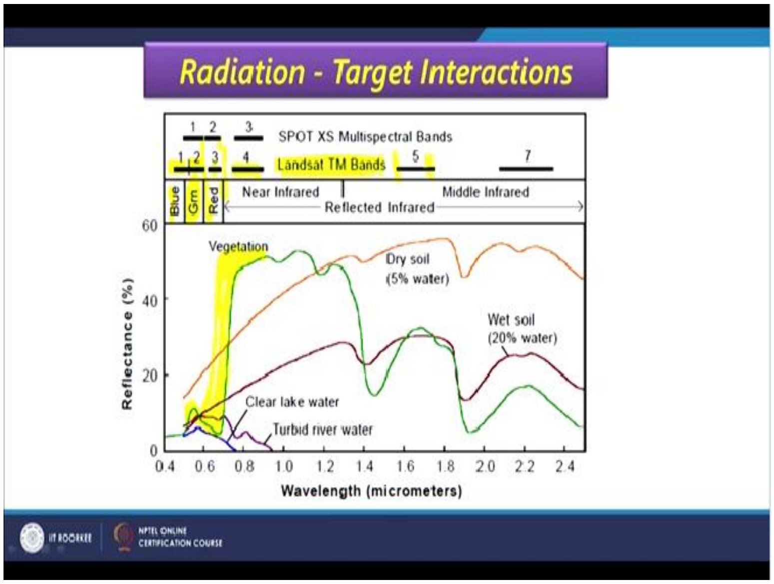

Few examples are here along with the satellite sensors. Like if I take the example of Landsat TM, TM has been a well popular sensor. Now in the latest series of satellites, lenses series that is OLI series, Landsat-8 instead of TM now we are having ETM plus, but if I take this example, then see this visible channel and then there are blue, green and red channels are there, which is band 1, 2 and 3.

Then for infrared in the beginning part that is there and this is the vegetation to exploit this property or characteristics of vegetation in infrared channel. Earlier in this discussion, I was mentioning a blue sift in the red edge of vegetation. I will explain that one here now more using this spectral response curve. Whenever vegetation is suffering from some stress or less chlorophyll content due to some reason, maybe water is stress or maybe stress because of some pollutants and other things.

Then this curve will shift towards the blue direction, that is why it is called blue shift in the red edge, because this edge of this curve vegetation curve is very close to the red. So, blue shift in the red and you will start seeing vegetation having reflection in the red channel of visible part of

EM spectrum and before that if a vegetation is healthy, then this kind of shift will not be there. And therefore, you may not be able to detect vegetation in the red part of EM spectrum.

Because you know, that healthy vegetation will have maximum reflection either in the green or infrared as we have earlier discuss this. So, different channels when I also mention that when Landsat MSS that the first Landsat first are one design MSS was designed these channels were continuous, there is a gap between 2 and 3 and 3 and 4 as you can see here, why these gap because these are there in this part of EM spectrum.

We do not have atmospheric window available and also in this part and there is also one thing which is maintained that the width of the channels should not be very high. So, that we can record a small changes in the different objects of the surface. So, generally, but in the visible part lot of reflected energy is available, therefore narrow bands can be designed, but in later parts, the energy which is reaching to the satellite sensors is not that much available as compared to visible and therefore your bands become thicker.

See is very systematic that here if you compare band 4 the thickness of the band 4 is less as compared to 5 and 5 is less as compared to 7. Because whatever in order to register for each pixel or each unit of the an image, a different signal sufficient energy is required. So, in this part of EM spectrum, that much energy is not reaching, so, a broadband is used. Similarly, in case of a spot which was a French satellite, there also the 3 channels bare there band 1, 2 and 3 located 1 is in near infrared an IR and 2 visible 1 is red and green 1.

So, nowadays when we talk we will be discussing hyperspectral in case of hyperspectral, very thin bands of 0.5 nanometers are being designed and there are hundreds of such bands within this part of the EM spectrum compared to just 3 bands in case of a spot or 5 bands in case of landsat TM. So, this is another very important thing to remember. Now, this whole portion we call as reflected infrared.

And as you are seeing that different like dry soil will behave differently compared to the wet soil. Wet soil curve is coming more close or having less reflection and it comes more close to you, sometimes even a little higher than vegetation in this part of EM spectrum sometimes it is crossing here also, whereas a for clear water lake the maximum reflection you will get in this blue, green.

But if you are having turbid water, then this curve will extend in the near infrared part. So, clear water spectral response curve is different, turbid water is response curve would be different and a pollutant water response curve is going to be different. So, the standard curves for different minerals, rocks are also made in past and the for now for because of hyperspectral remote sensing technologies available.

So, very fine bands and different refined curves are also being made. So, utilizing the curves and their behaviour in different part of EM spectrum we prepare color composites using different bands for different purposes. If I am interested for vegetation type of study then I will be focusing more on infrared channel. But if I am interested studying water bodies, either turbidity or pollution or water depth or other things.

Then I will be focusing in the visible part of EM spectrum because of the behaviour of the curve in different part of EM spectrum. So, these spectral curves are very important for better analysis of satellite data and better interpretation and applications. So, this brings to end of this discussion. Thank you very much.