Geographic Information Systems
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Module-09
Lecture-41
Introduction to Remote Sensing

Hello Namaste, welcome back to the course on geographic information system. In the last week we were looking at how do we look at the spatial analysis part of GIS. So now when we are looking GIS as a tool or software, the first thing that comes into mind is how do we do the analysis, ok having said and done with the theory. The next step is to how to do an analysis.

So in this aspect or this particular week is basically trying to give you an flavor of what are the different types of analysis is done, whether it is spatial analysis whether it is advanced spatial analysis or whether it is what are the limitations of GIS data at the end. So this week has been broken down into 3 parts. First part, I would give you an introduction to what do you mean by remote sensing, ok having said this is just an one short introduction to remote sensing, but it is not limited to what I speak.

So you would if you have to understand remote sensing, you have to go beyond at least my very beyond what I have already taught in this particular set of slides. In the next classes, I would look at next 2 or 3 classes I would look at what do you mean by spatial analysis, the basic spatial analysis which I already have spoken about a few of them. But I would go into emphasis with some examples, next I would look at advanced spatial analysis which again some examples.

And finally, I would end this particular week with what are the limitations of having geographical information system in place, so this would be the entire course of week. So in today's class, we let us understand, what do you mean by remote sensing ok.

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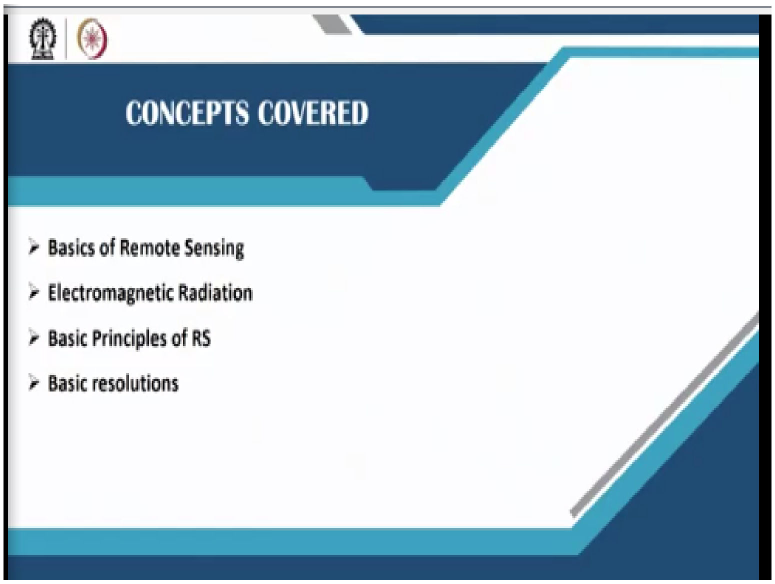

So in this class I would give you just sneak peek into what do we understand by basics of remote sensing, what do you mean by an remote sensing. Are you really doing a remote sensing when you are actually looking at me through this particular set of video slides. And when you are looking at this remote sensing, what are those principles that you have to understand when and how they actually interfere into your to form an image is what we have to understand.

And finally I have given a small set of introduction to what do you mean by different resolutions. For example, we were speaking about data, when you are looking at data it means to say that the data has to be measured in certain form. Now if someone is trying to use the satellite data ok. So satellite data has different qualities, which is called us resolutions ok, there is a first and foremost thing that you have to see in a satellite data.

So in order to understand that I have included what do you mean by a resolution, a spatial resolution or spectral resolution or radiometric resolution. So this is what would be the flow of today's class.

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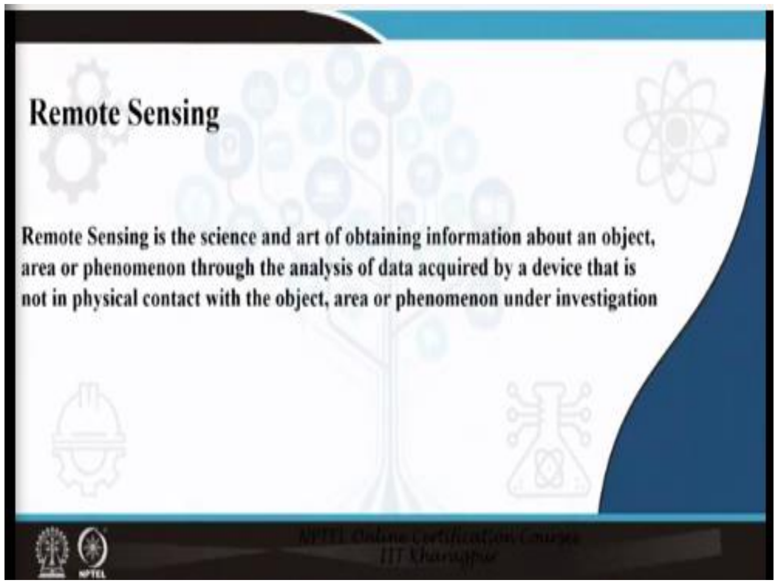

So for example when you are looking at this particular video lecture, so you are actually sensing it without being in a contact with the person who is teaching it yeah. So when you are not in a physical contact, it means you are remotely sensing this particular presentation, which I am trying to do. Which means I am remotely present and you are trying to analyze our grasp whatever I am trying to inform it to you.

That is nothing but remote sensing, so if you want to define a remote sensing, so let me very specific it is a science and art of obtaining information ok. Information is the last part of data analysis in remote sensing which becomes data for us ok. So it is a science and art of obtaining information about an object, it can be an object, it maybe your building it may be any drop type, it may be a soil type, it may be water type, an area, entire city, entire colony or it may be any of those regions or a phenomena.

It may be your landslide, it maybe your earthquake, it may be your forest fire or it may be a floods. So these are phenomenas, so it can be an object, it can be an area or a phenomena through the analysis of data acquired by a device that is not in physical contact. So now, if you have a camera here and you are trying to acquire a object area or a phenomena in your camera in your mobile phone camera.

Then it you are remotely sensing an object area or a phenomena which is under investigation which you are trying to capture ok. For example when you take a selfie, so what are you trying to do basically you are trying to capture yourself maybe as an object and trying to place it in your lens that your camera captures. So it capture certain amount of light ok, so that is nothing but sensing remotely.

So you are not in contact with that particular sensor right. So you have remote a sensing object which is nothing but a camera and you are taking a picture. Similarly the same concept applies with satellites which are placed somewhere around 800 to 900 kilometers away from the earth surface ok. So these sense, the earth surface in terms of whatever is a display or whatever is the object area or a phenomenon.

Based on your application you try to see that what kind of information that you need, so that is what is remote sensing.

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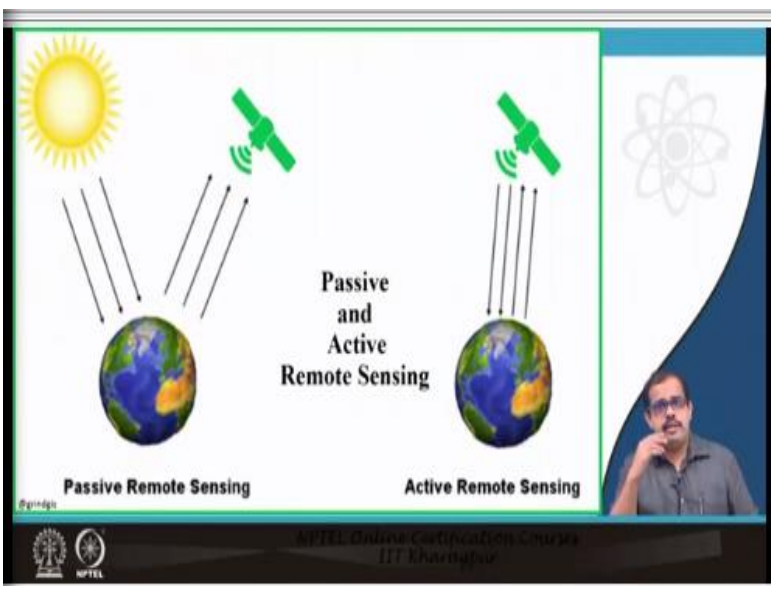

When you look at remote sensing you have 2 types, one is called passive other one is called active. So for example, if there is a sunlight a source of energy which is not emitted from the satellite and this hits the earth surface and there are certain amount of reflections that is again captured by the satellite. So satellite does not have a source of energy, then it is called a passive remote sensing.

If satellite has it is own source of energy by various means, for example when you are looking at microwave remote sensing ok. So you have your own source of energy which hit is the earth surface and the certain amount of reflections are then captured by your sensor onboard those satellite, then it is called an active remote sensing. So when you look at this image here, here a passive remote sensing is done using a solar energy, which is 99.99% of the time ok.

So here you have a satellite which is sending out it is own form of energy which is hitting the earth surface and then it is captured back in the sensors placed onboard the satellite, this is called active remote sensing ok.

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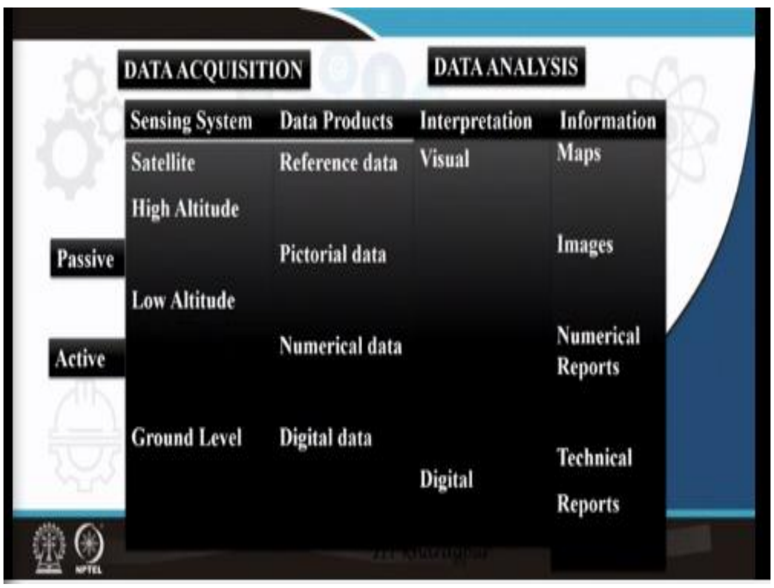

So when you look at remote sensing, as I said you have a passive remote sensing you have an active remote sensing. But when you look at different sensing system, you have satellite remote sensing, you have an high altitude, low altitude underground level. When I say satellite, satellite is at about 800 to 900 kilometer away from the surface. High altitude systems are placed at least at 20, 30 kilometers from the surface or a bit away.

So that it can capture a certain amount of area, low altitude remote sensing is normally done just above the ground level which maybe about maybe a kilometer or another 2 kilometers away from the earth surface. But ground level remote sensing is on the ground, so you have a sensor that is almost closer to the ground level. So that is how you do the remote sensing.

So now you have drones which again have the low altitude remote sensors, so that drones fall into the aspect of or UAV's fall into the aspect of low altitude remote sensing. Now, once you have sense the data this data is either then transformed into a digital data which may be in the form of a raster image or it may be in the form of a numerical data if it is sense in a certain aspect or certain phenomena.

Or it may be in the pictorial data only the captured image that has been considered or it may be in the form of a reference data. So reference data is extremely important when you want to validate a remote sensing data. So you need a reference data, so it is in the form of reference data. So once you have acquired these kinds of data products ok, the next step is to interpret. So what I am trying to tell you is how remote sensing progresses, how the remote you have captured the data and how it actually forms information to the user ok.

So next thing is interpretation, once you have captured this data you have to interpret either in the visual interpretation or in a digital interpretation use various algorithms, sophisticated algorithms to do all kinds of analysis. Whether it is statistical, whether it is numerical, so you try to use a lot of algorithms or there are methods where you do visual interpretation, where visually you will say this is a particular part of the earth surface which belongs to this category, so that is the third step.

And the fourth step is providing an output to the user, it can be a map, it can be images, it can be numerical reports, it can be technical reports. So depending on what category of users or you are trying to give the information do it is dependent on such users for their analysis. So you will give that kind of information. So now, when we look at these 2 things, you have 2 types, one is data acquisition, data analysis and the user.

So now data acquisition means you have sensing systems which are either passive or active sensors. Then, once you have acquired the data, then data products are in certain formats. This is then started to look at by the analysis, analysis either is done by the sensing agencies. For example NRSE also has a lot of other agencies like SAC, IRS etc, which actually do a lot of work on this remotely sense data.

You would have probably seen a lot of your work especially if I have to highlight a work with when there was floods in Uttarakhand and very recent the earthquake etc. So all of these are actually captured and very nicely analyzed by the agencies itself. And there are users who actually take these data and use them and also produce reports it maybe technical reports, it maybe output, it maybe peer reviewed papers, it may be images, maps etc.

So these are the 2 parts that we can distinctly say that remote sensing is made off one is acquisition another one is analysis.

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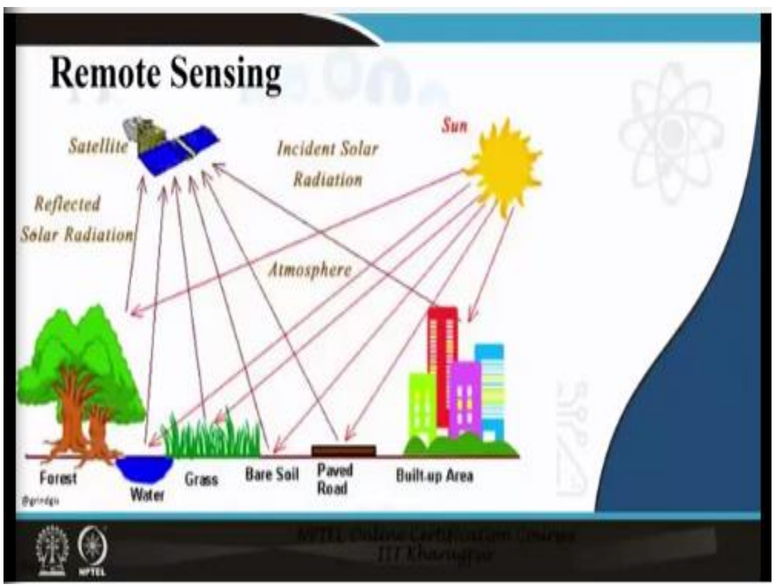

So when you are looking at remote sensing as an complete package, the first thing is you have a source of energy. For example, here I have considered sun as a source of energy, the solar energy hits the earth surface there may be many things on the earth surface it may be high rise, it may be low rise etc. ok paved road, bare soil or wet soil, grass, water, forest ok. So a grassland, so all of these they have their own reflecting ability ok.

The reflecting ability is very different for each and every surfaces or objects on the earth surface. So the amount of reflectance that reaches the satellite is then captured by the sensors onboard the satellite. This is what is then converted from an analogue form to the digital form and then given to you as a data, it is when the data is sensed by the sensor, it is normally in the analogue form then you convert it into a digital form.

And when I look at the digital form for example, you would have zoomed in to certain images if you just take a photo of yourself zoom in as much as possible, so you would look at pixels. So each of these pixels because it is representing certain amount of reflection has it is own digital number ok, so that is the amount of reflectivity that is there ok. So it represents the digital number that is what is captured by the sensors on the satellite ok.

So that is amount of reflectivity of each and every that is what differentiate every aspect on the earth surface whether it is a phenomena whether it is an object area or a phenomena whatever it is. So that amount of energy that is actually recorded onboard a sensor is very different from each of them, and that differentiates everything ok.

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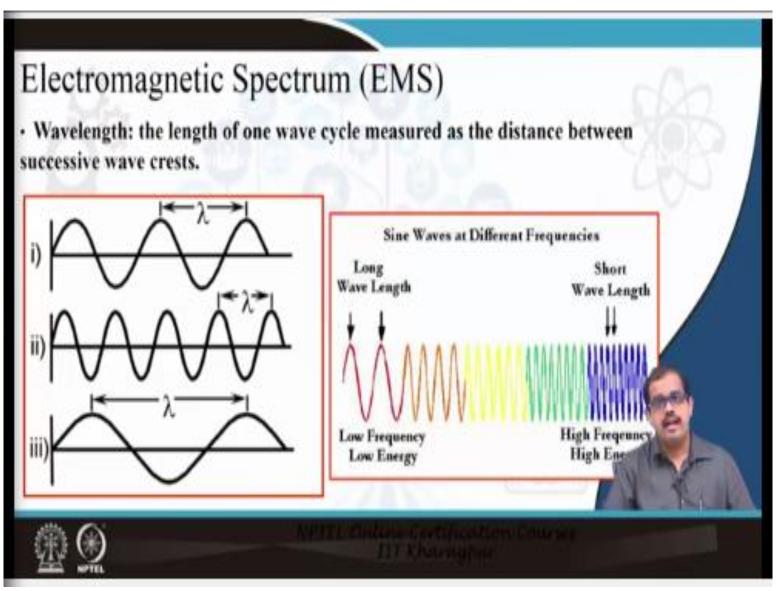

So and the very important aspect that you have to look at here is the first thing is electromagnetic spectrum. So I hope many of you would have learned what do you mean by an electromagnetic spectrum. But electrical field and magnetical field propagating at 90 degrees is nothing but an electromagnetic spectrum ok. So now let us say that this is a wave that is actually propagating, I have just taken either electrical or magnetic field.

The distance between a successive crest or a distance between the successive turf ok either this or this is called as a wavelength ok and number of cycles passing. For example, this is one cycle ok passing at a particular point of time is nothing but your frequency ok. So when you look at this, this is can be explained very clearly by the loss of energy, the same loss of energy is applicable in terms of remote sensing.

When there is longer wavelength you have lower frequency, when you have lower frequency you have lower energy, when you have shorter wavelength you have higher frequency and higher energy.

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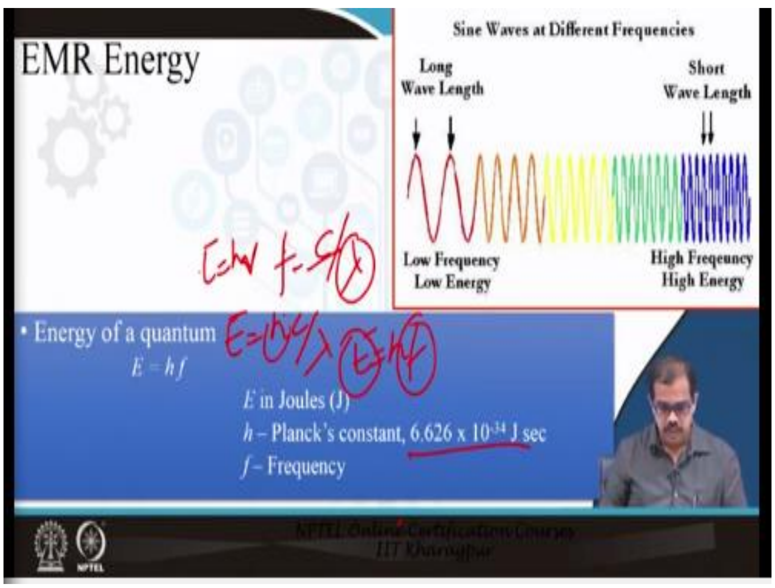

Let me explain it to you by this particular equation, if you have looked at energy of quantum it is E = h nu which can see here ok. When you look at it is E = h nu ok, when this particular aspect is considered ok, frequency is C by lambda ok where C is nothing but your constant or the speed of light and lambda is your wavelength. So which means that E = hc by lambda ok or E = hf right.

So now energy is directly proportional to the frequency, so lower energy lower frequency, energy is inversely proportional to the wavelength. So lower energy longer wavelength, higher energy shorter wavelength ok and hertz is a Planck's constant which is 6.626 into 6 into 10 power - 34 Joule second ok. So this is the first principle that you have to understand in terms of understanding remote sensing ok.

So energy of a quantum or quanta as measured as E = hf or h nu, so or f is inversely proportional to the wavelength that is h = c by lambda, so f = c by lambda so E = hc by lambda. So when you look at this equation frequency is directly proportional to your energy. And when you look at your wavelength it is inversely proportional to the energy, so how does it affect your remote sensing, if you ask me how does it affect.

For example if you look at your frequency range, if you go back to your electromagnetic energy distribution. So if you have the lower wavelength it will have higher energy which means your visible spectrum or even below that will have higher amount of energy. Whereas you are the ones which have higher wavelength will have lower energy or longer wavelength will have lower energy.

So it is easy to capture more amount of information when it is in a longer wavelength sorry in a shorter wavelength but with high energy and high frequency. So this is how it is implicated in your remote sensing ok.

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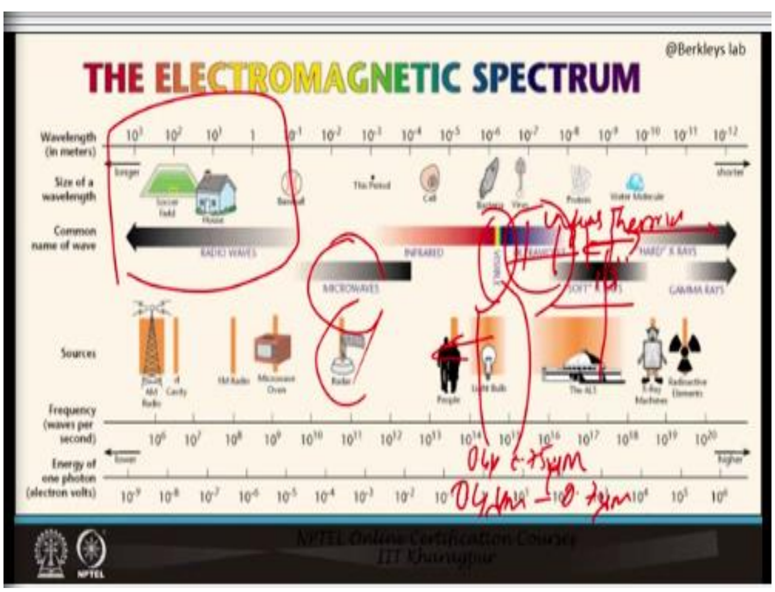

So when you look at the entire electromagnetic spectrum that is what I was trying to explain. If you look at this, the radio waves is in this region ok. Then you have certain part of the microwaves where you have radars that actually work ok. Then you have a certain part of energy which is actually the visible energy ok which is here 0.4 micrometer 2.75 micrometer ok. So when you look at this part of the energy, you can see that this is in the lower end of the spectrum ok which means that it is in the shorter wavelength region ok.

Once you have shorter wavelength region it means to say that it has higher frequency. Once it has higher frequency it means to say it has higher energy ok. So that is what I intend to explain here. Then if someone asked you what is the wavelength of region of visible region you should be able to say it is 0.4 micrometer 2.75 micrometer ok. So that is very important when you are actually explaining the electromagnetic spectrum.

Then you have ultraviolet, then you have soft x rays and this is also called as infrared where this is the short infrared, mid infrared and far infrared. And then you have thermal infrared ok, until 10 to the power of 15. Then you would have hard x-rays and gamma rays ok, so that is about the electromagnetic spectrum ok.

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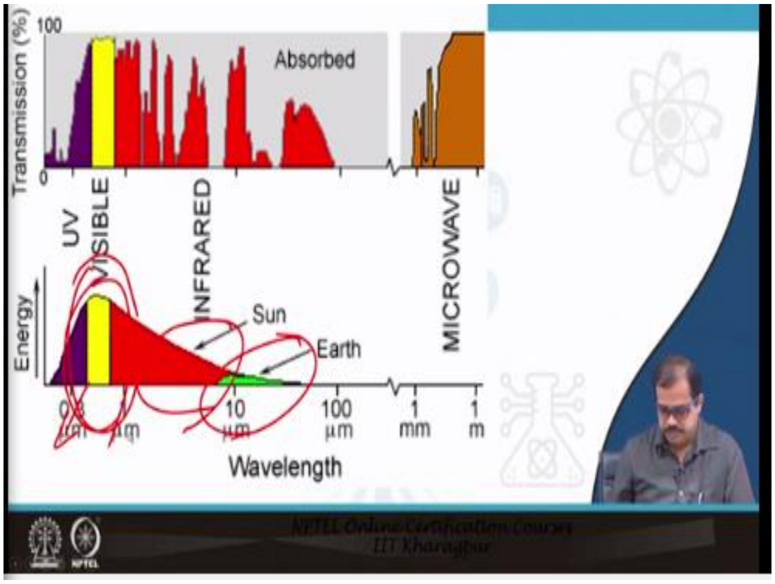

To give you more understanding about it, if you look at the wavelength here this is where the visible region is there. And if you see the wavelength is shorter when the wavelength is shorter it has higher energy, the energy is very high as the wavelength increases, the energy decreases. So when you look at the sun, sun's length is somewhere here ok, so energy is much less when you look at the earth surface, you can see it here.

The same thing is very much or reciprocative in terms of transmission ok. So I will speak about this in when I speak about other 2 laws but particular about this is to just understand how the energy and wavelength are related.

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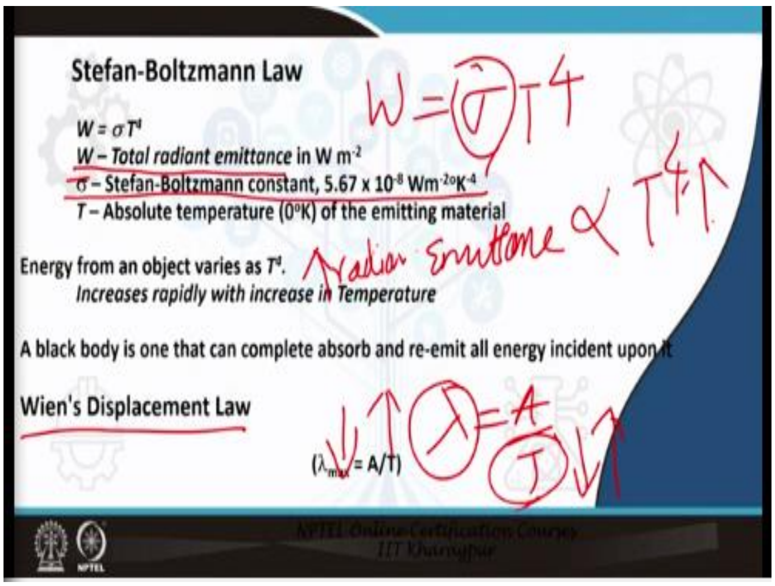

And when we come to the next law is the Stefan Boltzmann law which states that it has w = sigma t to the power of 4 ok. Where this is a constant which is Stefan Boltzmann constant which is 5.67 approximate it is 5.6692. So it is approximated to 5.67 multiplied by 10 power – 8 watt per meter square per degree Kelvin sorry per Kelvin to the power of 4 ok. So if you look at this ok, this particular thing, this is Stefan Boltzmann's law, then you have total radiant emittance which is what per meter square.

And T is absolute temperature ok of the emitting material ok what are the material that is emitting that is nothing but T. So now, when you look at this if the emittance from the material ok, the total radiant it means radiative. The one that is coming out after absorption emittance is proportional to the 4th power of the temperature. So higher the temperature ok higher the emittance, lower the temperature lower is the emittance ok, this is one.

The next law that we have to understand is Wien's displacement law which states that lambda is inversely proportional to the temperature. Which means that wavelength is inversely proportional to the temperature. Now if the wavelength is higher temperature is lower, if wavelength is lower than the temperature is higher. So which means to say that lower wavelengths here have higher temperatures and higher radiant emittance, lower wavelength will have higher temperature and higher emittance.

Whereas, higher wavelength will have lower temperature and higher radiant emittance. So this both of these law has to be understood in concordant, so that you understand how this is related to your earth surface ok. So I hope you guys have understood this.

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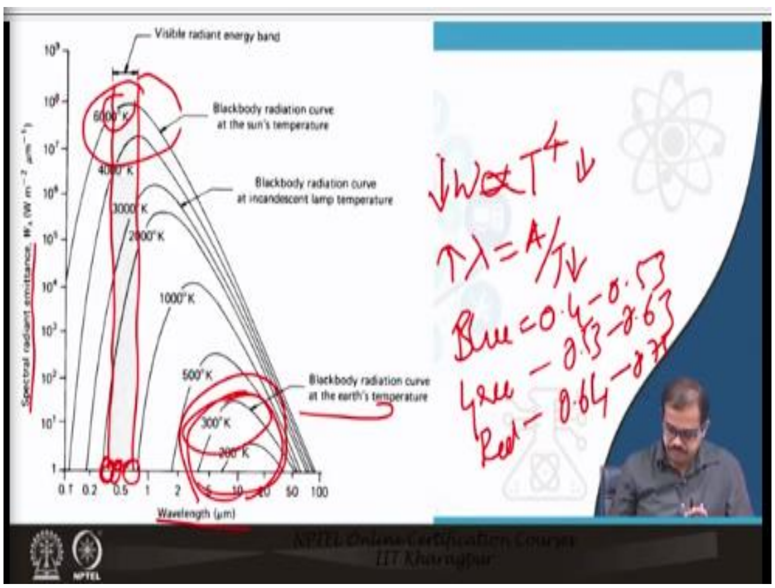

Let me go to this example to explain you much more, so what did we say W is proportional to the 4th power of that temperature and lambda is A by T correct, which means higher the wavelength lower is the temperature. If the temperature is lower than your emittance or the radiant emittance is lower. Now, I have plotted a curve which is on spectral radiant emittance ok versus the wavelength.

And when you see it, this is where is your exactly the visible wavelength ok and where you look at the visible wavelength, the temperature is of a black body. When I say black body, it is a hypothetical body where it has complete absorption and complete emittance. So when you look at the temperature of the black body is the highest and that is where is exactly your visible region located which means it is easy for anyone to capture in the visible region, that is why human is able to look at visible region by his own eyes.

So that is why you can easily connect with R G B any of your colors R with the primary colors which is red, green and blue ok. So when you look at this, this is blue, green and somewhere here is red ok. In the electromagnetic spectrum if you look at blue can be somewhere around 0.4 to 0.5 where green is 0.53 to 0.63 ok and your read somewhere, 0.64 to 0.75 ok. So if you see it is a maximum the blackbody radiation is at the sun temperature is maximum that is 6000 degree Kelvin.

And that is exactly where is falling on the visible region and when you look at this earth's temperature. If you look at earth's temperature back body radiation is about 300 degree Kelvin, where if you see the wavelength is much lower and hence that amount of emittance is much lower. So if you look at it, anything sensing here may have a lot of loss because most of the energy would have been absorbed and the very less amount of energy is emitted back ok. So that is the example that I am trying to tell you that how it is different from each other ok.

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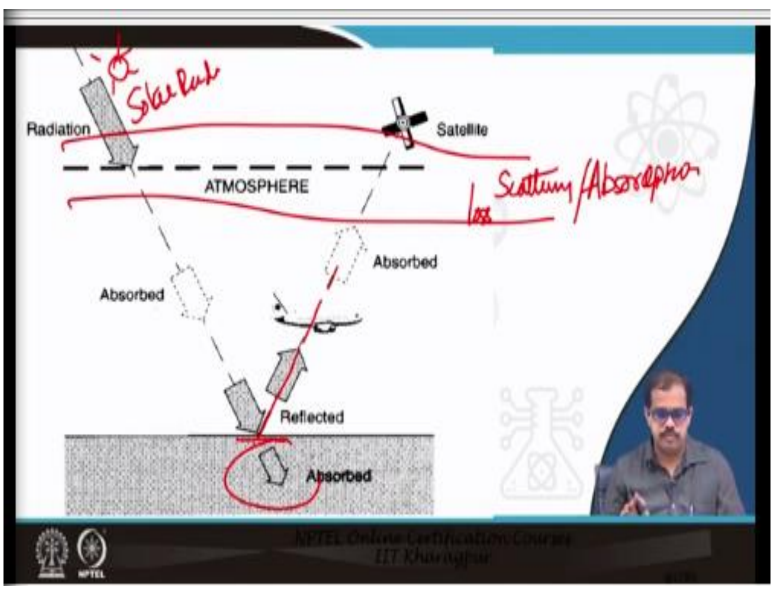

To explain it to you more about how this works, first you have the solar radiation ok, let us say this is solar radiation that is coming into the earth surface. So let us say this is sun ok, now once you have the solar radiation, you have a thick layer of atmosphere here correct. There you have a phenomena called as scattering and absorption. Due to either scattering or absorption or due to both there will be a certain loss of energy ok.

Now, with this loss certain amount of energy reaches the earth surface. Now, in that let us say there is certain amount x loss ok. Now with this some amount of energy is reflected, some amount of energy is absorbed by the earth surface or object etc. some amount of energy is reflected right. So this energy that is reflected is again transmitted in the atmosphere.

Again, you have atmospheric interference and you have certain loss**.** So you have 3 kinds of losses where certain amount of energy is absorbed here, certain amount of energy is either scattered or absorbed in the atmosphere. Then again while going back you have certain amount of energy they are scattered on atmosphere. The amount of energy that is reflected energy that is left after the atmospheric transmittance then that is a energy that reaches the satellite.

That is recorded onto the satellite that is what you would get as an image once it is converted from analogue to digital signal ok. So this is exactly the process of how remote sensing is done using a satellite ok. So just to give you a flavor there are more things that you have to understand. If you have to understand this specific aspect in much better way ok, so this is just a overview of how it actually works.

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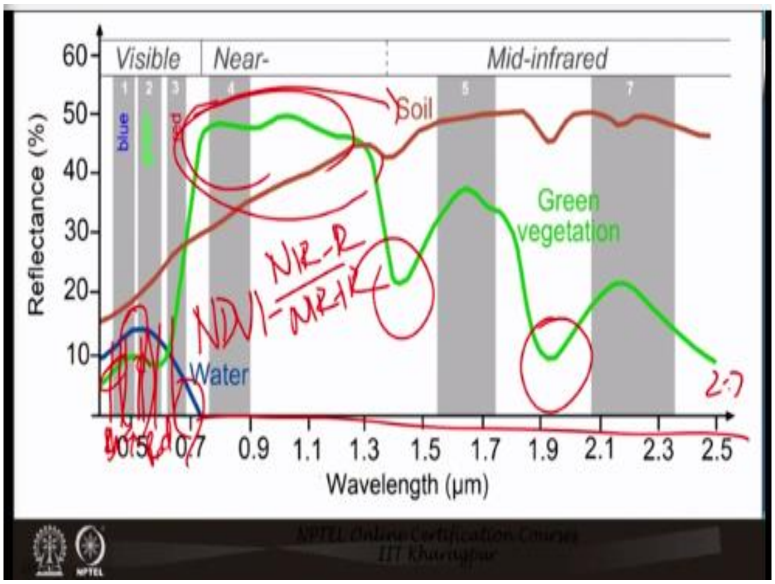

The other thing that we look at when we are understanding remote sensing is nothing but a spectral reflectance curve. When I say a spectral reflectance curve, it is the curve where y axis is the reflectance that is the amount of energy that is reflected back from that particular object. After all this loss is there the amount of energy that is captured versus the wavelength ok.

For example if we consider vegetation, so if you look at vegetation, vegetation in an let us say this is this is a blue band, this is a green band and this is the red band ok, red band is somewhere till here ok, not here. So if this is the red band, now you have green and red. So now when you look at this blue, it has a very less reflectivity, in the green band it has a little amount of reflectivity, in the red band it comes down the reflectance is only 10% or even less ok.

Then in the near infrared zone, it has very high reflectance ok which means to say that vegetation has the characteristically reflects in the near infrared band. Now, if you use your eyes to measure the reflectance of vegetation ok. It your naked eyes would not be able to distinguish between 2 vegetation because you would not be able to sense in the near infrared band whereas when you sense in the sensor which actually captures the reflectance.

So you could easily distinguish between 2 different plants or 2 different characteristics of a plant which were of the reflectance in the near infrared band. So that is very high in vegetation and when you go ahead it has 3 dips here and in another dip in 2.7. So this is called water absorption bands ok, this is exactly for studies of vegetation, the water content etc and it is relationship ok.

So this is the characteristics of your vegetation. For example, if someone wants to understand what is the amount of vegetation versus non vegetation. He or she would actually compare 2 things one is you have very high reflectance in near infrared band and have a very low reflectance in red band. So that is how people calculate index called NDVI, which is NIR - R by NIR + R ok.

So which gives you the normalized values of vegetative index, the positive values or I indicating the vegetation, higher the positive values as thicker the vegetation, lower values as the sparse vegetations. And if you look at the value closer to 0 is actually representing water and the reflections that are much lower in the negative value is actually representing soil ok or non vegetative characteristics.

So that is how you can understand the difference in the characteristics on the earth surface. One example is what I gave it us NDVI and when similarly if you add the aspects of water, water has highest reflectance in the green band and lower reflectance in the red band and complete absorption in all other bands. So it means to say that if you use an near infrared band water is completely absorbing and hence it should be looking black ok.

So if someone wants to just extract water he or she would just take a near infrared band and wherever it is 0 or certain values it may not be exactly 0. Because there may be certain characteristics of that particular water body which maybe emitting certain amount of energy it maybe there, there may be plants they maybe etc. So you will look at exactly and just see that if you can with that amount of digital numbers, it can be easily separated as water and non water ok that is called as thresholding ok.

So this is one aspect of water and you have this is the reflectance curve of soil. So based on the same reflectance curve, you can look at the various properties of the soil. It 2 has water absorption bands here, which is actually representing at 1.4 1.9 and 2.7. So amount of water, so present in the soil can be easily measured at this particular point. And there are a huge number of studies in understanding this particular reflectance curves.

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So having understood all of these, these are very basics of remote sensing. The very important aspect that you have to understand is the spectral reflectance curve. If you have understood that most part the very basics of the remote sensing is actually understood by you ok. if someone has an access to spectral radiometer, please look at how you can measure different plants, different soil.

So you will understand how this particular spectral reflectance curve was wavelength this actually computed, once we have understood that, let us go to the satellite. Now as I said satellites, what we are trying to understand here is the polar satellites. Basically I would be very much concerned about the passive remote sensing. And when you are looking at any of these satellite data, the first thing that you have to see is the metadata.

The second thing that you have to always look is the different kinds of resolution if you have the data already with you. If you do not have a data already with you, then the first thing that before even considering any data, you should understand what kind of resolutions that you need ok. For example, if someone is looking at how the growth of a city is happening or city pattern you are trying to understand, there is no need to actually buy a very highly very costly high spatial resolution data ok.

But if someone wants to really see building wise or the road wise information of a particular city, then you need to have a very high spatial resolution data. So first understand what is the application of your data ok, without understanding the application of your data, it is impossible for us to understand why that particular data has been considered or it will be really an not an real aspect of working on the data.

So when you want to buy a data first thing or download a data, the first 4 things that you have to understand is spectral, spatial, radiometric and temporal. Temporal is completely where fixed when the satellite the sensors are actually placed on the satellite. But the 3 things that other 3 things are extremely important for your analysis. The first thing is spectral resolution, the second one is the spatial resolution and the third one is that radiometric resolution.

So these 3 have to be looked at even before you buy a satellite data or download any satellite data ok. Without understanding these aspects of any satellite data it would be really problematic issue if you are trying to download any data ok.

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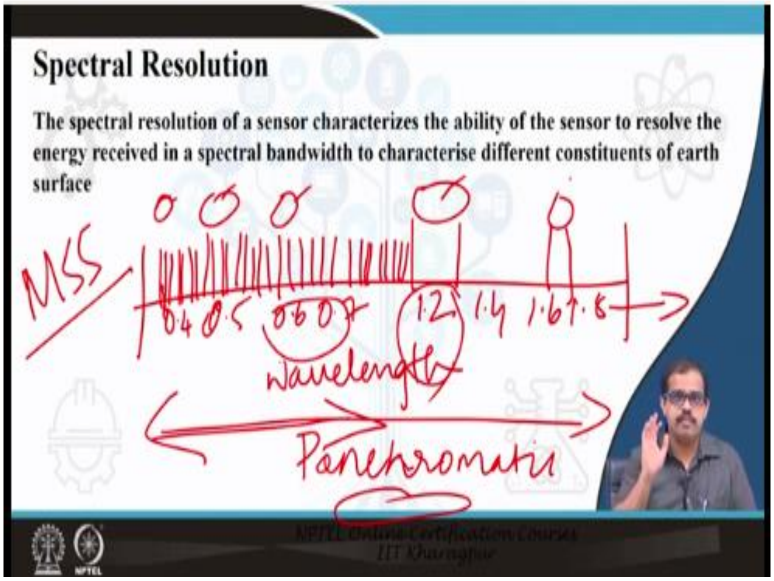

So let us go by each one of them, the first thing is spectral resolution when I say spectral how far we have looked at the EMR spectrum ok. If we try to draw this ok, let us say this is the wavelength ok 0.5, 0.6, 0.7 ok, then you have 1.2, 1.4, 1.6 then 1.8 and so on ok. Now if I try to use ok let us say our satellite sensors are able to categorize these each of these electromagnetic spectrum into different bands.

For example, there is one satellite which can capture this spectral band and this spectral band. This is the spectral resolution of that particular satellite which means it has one band 2, 3, 4, 5 which means to say that satellite has sensors which can capture in these different bands. So this is nothing but a spectral resolutions ok, it is extremely important in terms of what kind of resolution.

For example, if you are trying to understand vegetation, you need to as I said you have some very high reflections near infrared band. And then have low reflections in the red band. So you will obviously consider a satellite which has all of these bands. If you are using it for variety of applications, you would probably look at those applications and look at how many number of bands you need.

If a satellite is then capturing this as entire electromagnetic spectrum in a single sensor ok then it is called a panchromatic band ok pan band ok. This means to say that this entire spectrum is then captured it maybe this entire spectrum, it may be this whatever the spectrum it captures. So when it captures then it is actually said as panchromatic image ok specifically normally it is done until here.

So once it captures this then it is called a panchromatic band and this panchromatic band is has only one band or one specific image. But these when I said there are different sensors which is capturing a different regions it means to say that these are different images ok, so different multi images. So it is multispectral, it is called MSS image ok or multispectral sensors, so you have multi spectra of sensing ok.

So when you look at this you have collection of image, if you are actually collecting everything in a single strip then it is called a panchromatic. This only one particular sensor or set of sensors capture the entire region ok. Now the very interesting part is that if instead of this, if I capture like this, very narrow spectrum. Then it is called as hyper spectral sensing, ok, so if the entire spectra is captured by a single sensor and single band then it is called panchromatic.

If the entire spectrum is captured by multiple sensors it is called multispectral sensors and our multispectral images. And if it is captured by narrow spectrum of band and you have a huge amount of bands that it has been captured, then it is called hyper spectral sensors ok, this about the spectral resolution.

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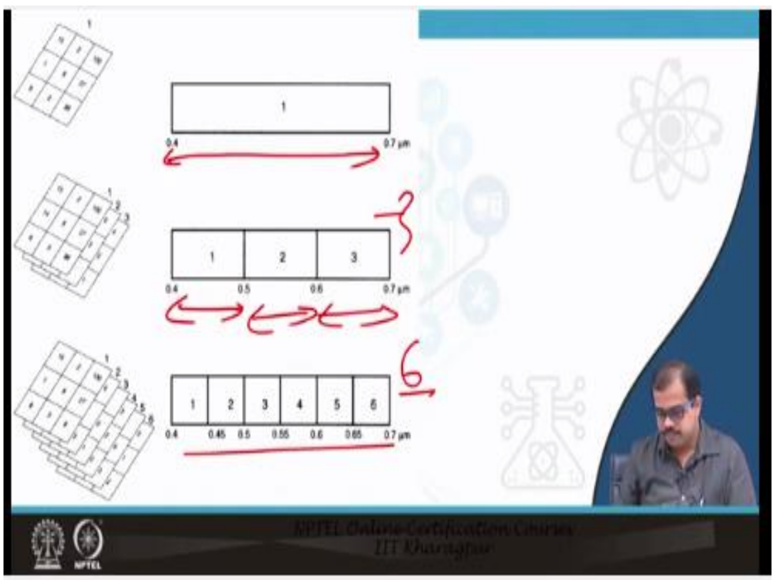

To just give you an example of what do you mean by a spectral resolution, if this entire I have just taken a visible wavelength. So if the visible wavelength from 0.4 to 0.7 micrometers, this is one of the examples from Canadian space research centre which explains how the spectral resolution is there. So if you look at the entire from 0.4 to 0.7 is sensed by a single sensor. And you have an output as an image as a single image, then it is called a single image or it is a spectral resolution is 1.

If the same energy spectrum this is 1, this is 2, this is 3, is broken into 3 different sensors and each sensor is capturing at 3 different wavelengths, then it is structural resolution is 3. Now it is sensing at say different 6 different it has broken the same thing into 6 different parts, so 6 different sensors are capturing it. So which means to say that this spectral resolution is 6 ok.

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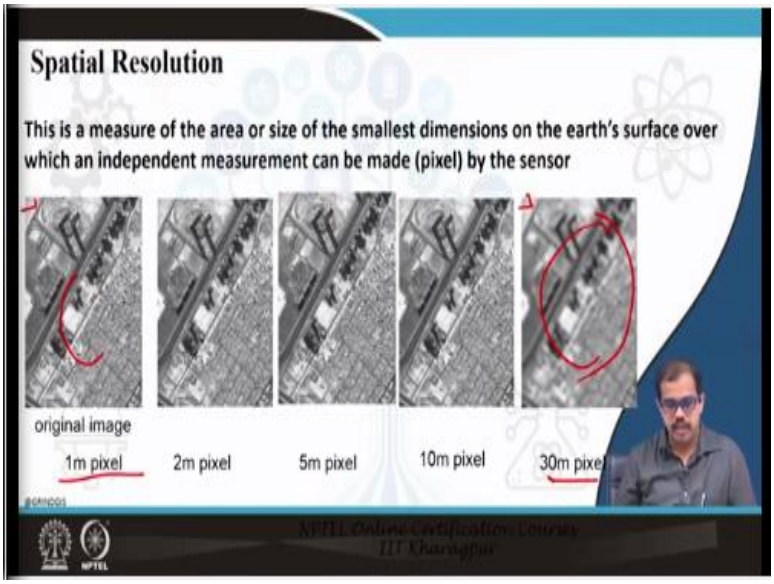

Next concept is the spatial resolution and when you look at spatial resolution, it is the finest area that you can look at in that particular image ok. Or it can be defined as how much a pixel can capture in it is own place. For example, if I say it is a 30 meter pixel, the spatial resolution is 30 meter. So it says that a pixel carries 30 meter by 30 meter information in that particular pixel. If I say 1 meter, then it says it pixel can carry 1 meter by 1 meter information ok.

So just to give you an example of how what are different, so the first this is the original image which is 1 meter resolution. So you can see very fine details of set of buildings and this is called a very high resolution image ok. You have submitter also now you get images at 25 centimeters, 60 centimeter, 90 centimeter etc. So this is one of those very high resolution data.

Indian satellites have very good capability of capturing at now at even the submitter levels. So you can contact national remote sensing center for any of these data products which you can always acquire. Then the same image is then resample to 2 meter and the same image is resample to 30 meter ok. So which means this particular pixel here and the pixel here ok, this pixel is representing 1 meter by 1 meter.

This pixel is representing the 30 meter by 30 meter, which means it is more this is a course resolution data 30 meter pixel is a course a solution data. Whereas this is a 1 meter is a very fine resolution data or a very high resolution data ok.

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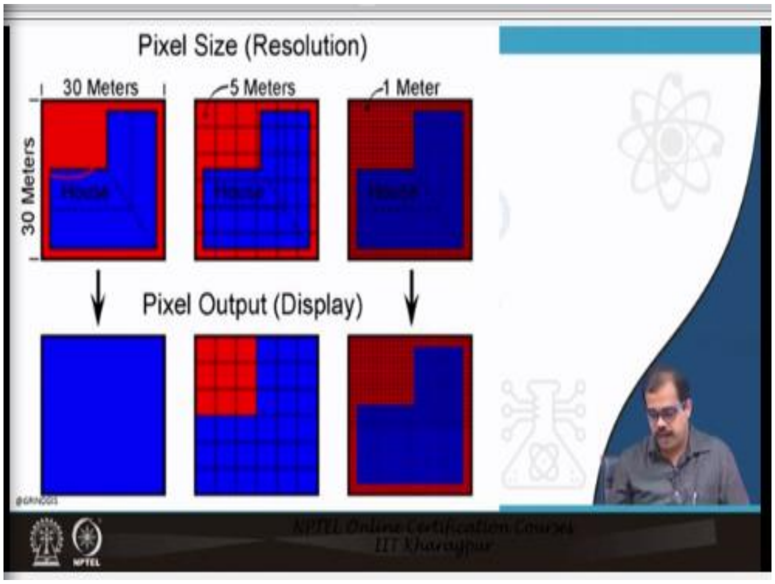

So this about resolutions and if you want to look at it pictorially this is 30 meter by 30 meter. If a house is pictured this the house ok, if this is pictured that 30 meter by 30 meter in 1 pixel let us say. The same house if it is taken into 5 meter by 5 meter you can see the number of pixels it is been denoted into. So maybe one part of the house your dining room or your kitchen maybe in a pixel ok.

The same house if it is captured in a 1 meter resolution sensors then maybe even very small part of a kitchen ok maybe your kitchen sink is actually coming in a single pixel ok. So that is what is the difference ok, just To give you an representative features of how resolution is important. So spatial resolution is about how much area it actually covers in a pixel, spectral resolution is how the sensors can actually capture the electromagnetic spectrum into number of bands.

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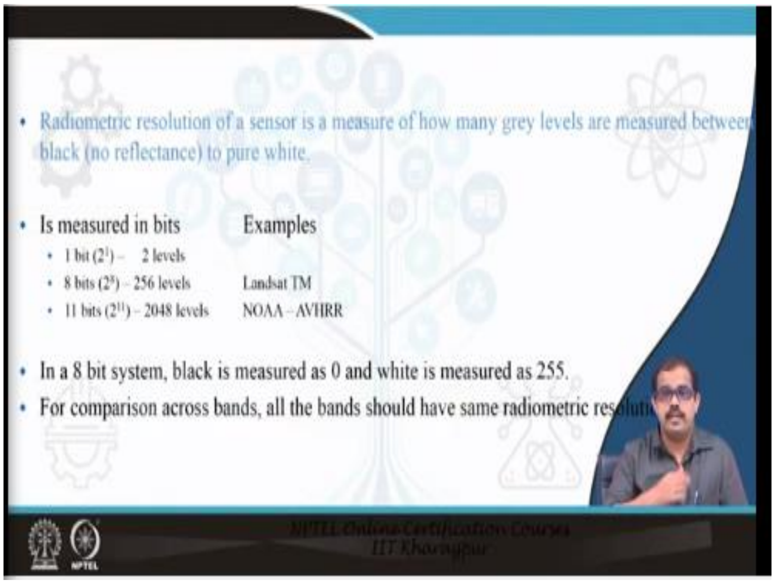

And the third one is the radiometric resolution, so when you look at radiometric resolutions it is about how many radio meters that this has.

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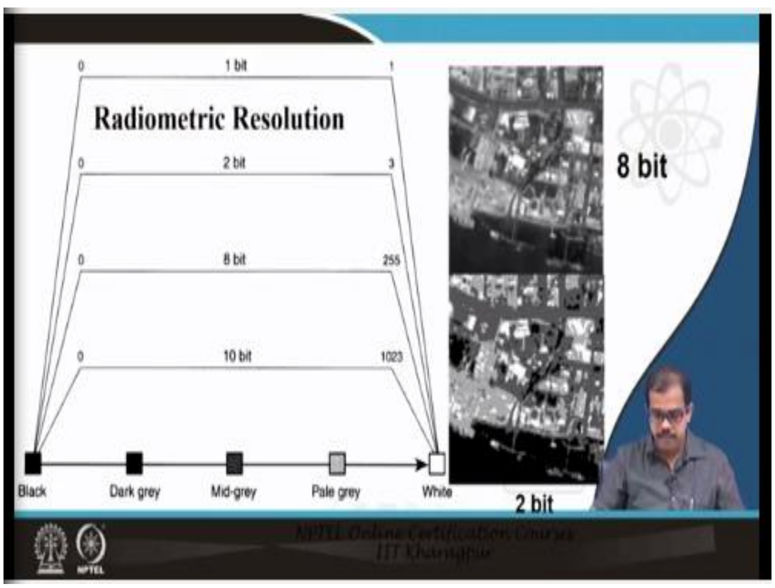

For example if your picture can or your sensor can picturize that particular part of the earth surface in only 0 and 1 ok. Then it is called a one bit resolution or radiometric resolution is 1. If it can capture between black and white, see this is black and white, always your image that is captured in different sensors in this in the grey levels. So if the grey levels range from black to white, so if number grade levels is 0 to 3 that is 0, 1, 2, 3.

Then it is called a 2 bit radiometric resolution is 2, if your grey levels is represented by 0, 1, 2, 3, 4 until 255 which means it has 256 levels. Then it is called an radiometric resolution is 8 ok and if you have 10 bit then if the ranges will be from 1 to 1023, I was speaking about digital number. So when I say radiometric resolution, number of grey levels that can be represented, it is same as your it is equivalent your digital number.

Higher the digital number will have higher radiometric resolution, lower digital number will have lower radiometric resolution details. For example, if your image if you have actually acquired a landslide data, landslide data is 8 bit data, which means it is radiometric resolution is 8. And it is values lies between 0 to 255, 0 is completely black, if you take an infrared image 0 is representing a water body.

So it is completely black and whereas 255 would be representing the highest reflected object from the earth surface. So just to give you an example of 8 bit and a 2 bit, if you look at here 8 bit you can it is easier for you to understand different aspects on the earth surface. Whereas in your 2 bit it is very difficult for you to understand different objects on the earth surface because it can distinguish only 4 different colors from in grey combinations.

Whereas in 8 bit it can actually look at 8 different grey combinations at different instead of time, that is why higher the radiometric resolution better is the quality of your data ok.

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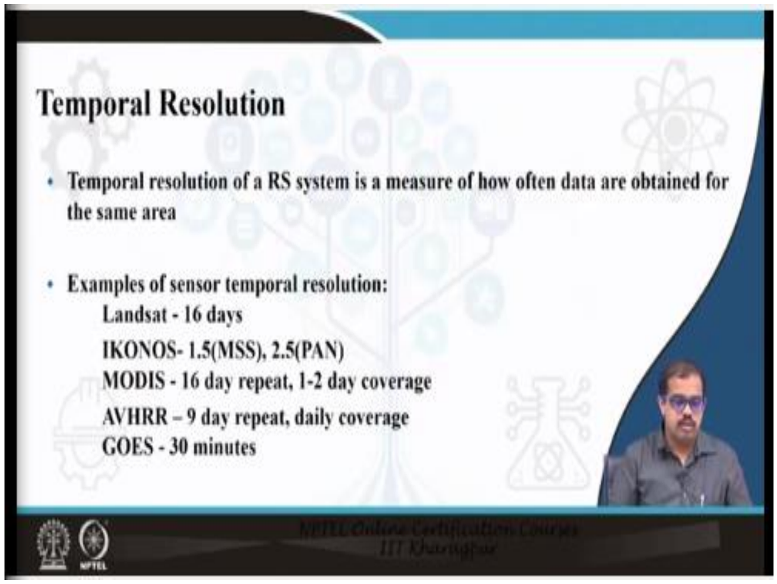

Now, the last thing is the temporal resolution, when you look at temporal resolution, it is often how often that is a particular satellite can capture or a sensor can capture the same part of the earth surface. For example Landsat has 16 days, IKONOS has 1.5 days for a multispectral sensor and 2.5 days for a panchromatic sensor, MODIS on an average has a 16 day repeat but 1 to 2 days coverage ok.

These are different sensors, very interesting sensors satellites and sensors you can look at all of these and AVHRR is one of them where 9 day repeat cycle and you have GOES which is about 30 minutes. So this is about temporal resolution this is last kind of resolution that is actually to be understood.

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To summarize this particular class, we have looked at what do you understand by electromagnetic spectrum. First, we looked at what is remote sensing, then different parts of electromagnetic spectrum then laws we started with energy of a quanta E = h nu. Then we looked at Wien's displacement law, so once we Stefan Boltzmann law and Wien's displacement law.

So once we have understood this when we looked at spectral reflectance curve ok, so it is a reflectance versus the wavelength. So whenever you are looking at any aspect of the earth surface or when you are trying to capture it, first thing is look at the reflectance curve then is the resolutions. We ended this particular class by resolutions of satellites where we are looking at what are different resolutions that you have to consider when you are considering the satellite data products.

So this is just about a small part of remote sensing. In the next class, we would go back to GIS, we would look at what are the basic spatial analysis advanced spatial analysis in the rest of 4 classes of this particular week. Thank you very much, see you in the next class.