Remote Sensing and GIS
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Lecture – 03
Errors in Remotely Sensed Images

In this lecture I will explain different types of error associated with the remotely sensed images, these errors plays very critical role in modifying the signals traveling towards our sensor, in the next slide.

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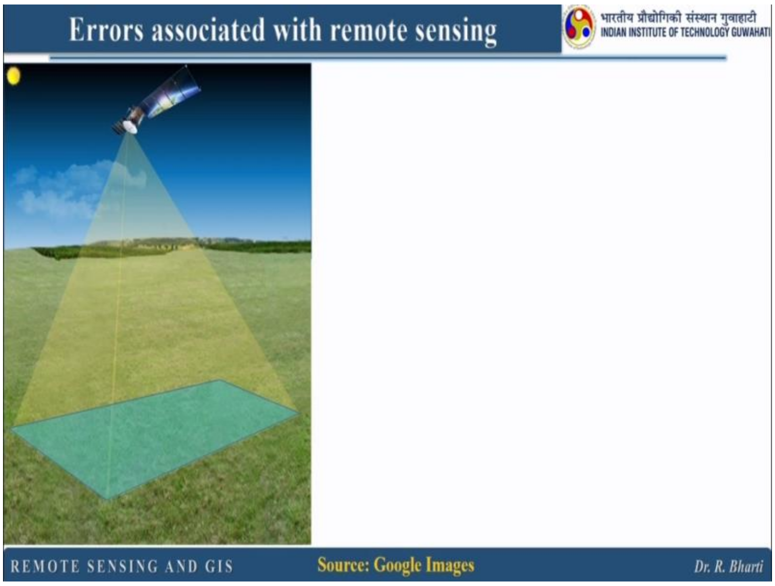

You will see different components of remote sensing, these components can also act as a source of error if they are not working properly or if they are not calibrated, so we will see such errors in detail in next few lectures, here you can see a satellite active in this area and images have been generated.

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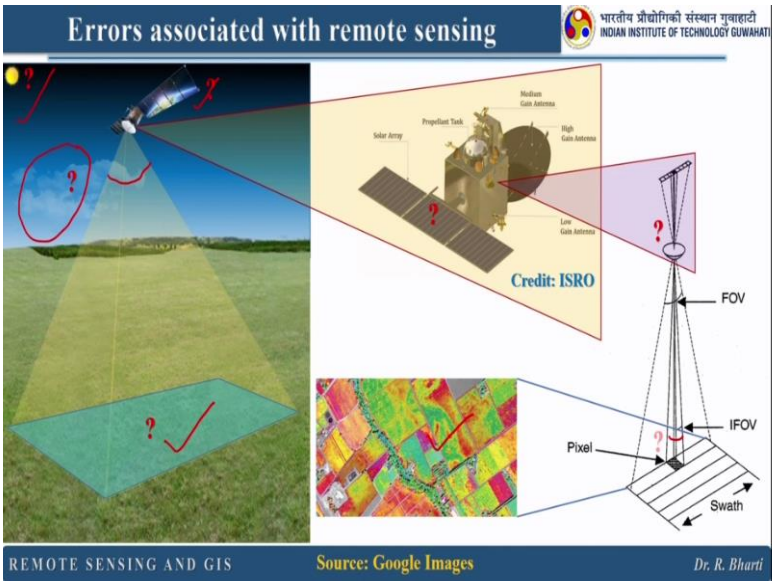

So here you can see we have a source, so in passive remote sensing sun is acting as a source of energy and this is illuminating our surface and a satellite is active in this particular area so the satellite is receiving such signals and it is generating this particular image. So now what happens if the position of sun is different and what will be the effect on the acquired images so likewise you have sensor.

What is the significance of the position of this sensor active on such areas or what is their source sensor geometry and what is the field of view that is also very important then what is the role of atmosphere, we have already seen scattering and absorption then what if the area is not homogeneous or if the area is having more scattering or if area is undulating then what will be the effect on the image.

So these things also plays very critical role in generating an image then what if the instrument is not well calibrated the next is if they are not aligned what will happen, so basically one detector is looking at the ground and based on their IFOV we generate a pixel .So here if these detectors are not calibrated then what will happen your pixel size will be different, so this all things lead to error in remotely sensed images, so let us talk about the parameters that affect remote sensing data.

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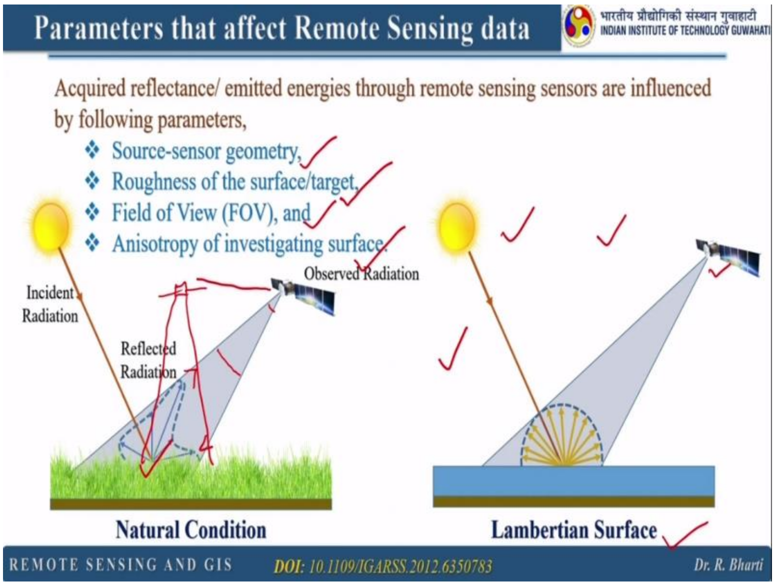

So acquired reflected or emitted energies through remote sensing sensors are influenced by following parameters, so here first one is source sensor geometry, second one is roughness of the surface or target then field of view then anisotropy behavior of the investigating surface. Here you can see sun is illuminating our surface and based on the material characteristics and the surface roughness this reflectance, the reflectance energy will be more in a particular direction.

Whereas in some direction it will be less like here you have less, here you have more and here you can see one satellite is acting here and this is sensing this particular energy. So this particular energy is getting sensed but what if the position of the satellite is here then it will look something like this. Then the information gathered from this particular satellite will have different value because ultimately remember we always talk about the digital number acquired from such sensors in the form of image.

So if a surface is more reflecting it will have higher DN number if a surface is dark then it will be having lower DN number. So here in the lambertian surface case where does not matter whether you are looking from here or here the information or the reflected energy will remain same.

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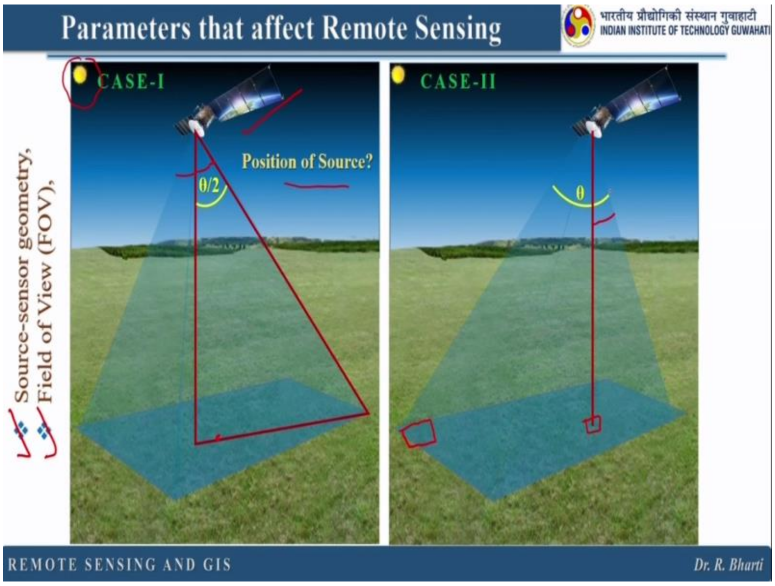

So here in this slide, you can see there are 2 photographs in the first photograph it is mentioned that position of this source, so there should be a significance of position of source and remote sensing why? Because the suns position gets changed with respect to time, so if it is morning your area will be less illuminated at 12 o'clock it will be like very bright in evening it will be like less brighter.

So depending upon the time illumination received by that area will be different and again similarly, the position of the satellite, so it also matters, so what is the geometry of sun and source, source and the satellite, so here you can see in this case the field of view, so field of view and satellite is looking just below, right just below, so in remote sensing we say nadir looking satellites, so it is just looking vertically down, so here in this case the center of this will be here.

Somewhere center in this particular image, so in case one where we have nadir looking satellite and in case two we have slightly off nadir, so but theta remains same theta is our field of view for the same satellite FOV will be same, so here if you see this theta by 2 why I have written because this is the field of view, complete field of view and if it is nadir looking, so the half angle will be theta by 2 but here in the case 2 image, you can see it satellite is looking off nadir.

So if you draw perpendicular then it will not be like this part will not be theta by 2, so in this case what will happen the pixels generated near to your nadir will be in a good shape like a square but if it is going away it will be more rectangular, so such things occur or such thing happens when we have irregular surface and different field of view or different angle of the measurement.

So that is why I have written source of this source sensor geometry, so here source sensor geometry matters a lot then field of view. Field of view even if it is same what is their look angle. So look angle is also very important.

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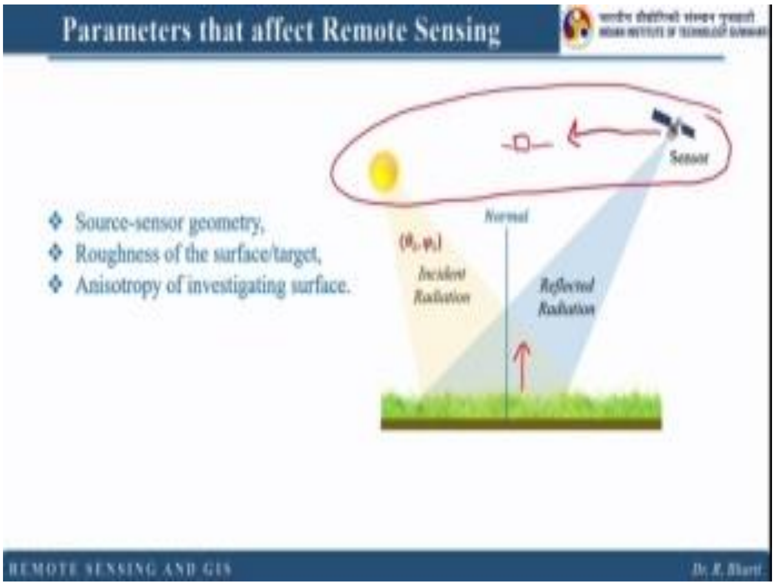

Now here I want to highlight source and sensor geometry, roughness of the surface or target and anisotropy of the investigating material, so you have a surface and then you have sun as a source and which is illuminating the surface and then sensor is receiving the energy, so here basically you see this is basically the geometry of source and sensor, so what happens if it gets changed, if it moves from here to here?

We have already discussed if the surface is having some roughness and if this surface is having a characteristic that it will reflect more in this direction then if your sensor is here your image will be brighter or that pixel will be brighter, so this is what I wanted to highlight here.

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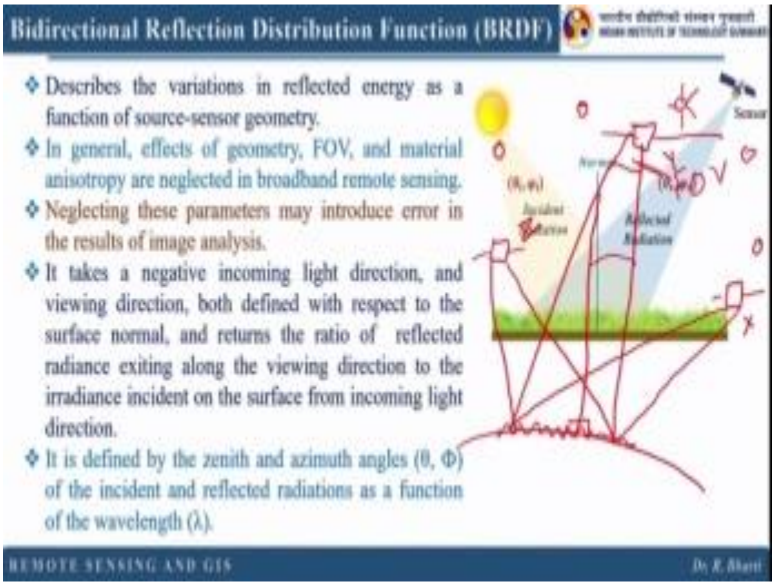

Now this concept leads to bi-directional reflectance distribution function, so what is the significance of bi-directional reflectance distribution function, so it describes the variation in reflected energy as a function of source sensors geometry, so in general effects of geometry FOV and material anisotropy are neglected in broadband remote sensing because here you need to understand why we are more concerned about the source sensor geometry?

So let us say this is a area which is getting sensed or captured by a satellite or a sensor. So sensor is here and it is looking here with this FOV. So it will generate one image now may be you want to study how this forest area is getting changed over the time, so if you are looking this area from this angle from here it will have one information if your satellite is here. Then it will look from here, then your information will be different then another is if your sensor is here your information captured will be different that is one component.

Second component is whether your sun is here or here or here or here depending upon that what will happen, the energy received and reflected will be different, so here we are talking about the DN number and DN numbers are basically the scaled radiance which is coming from the surface now, so here based on this source sensor geometry then field of view this FOV and the material anisotropy whether this is irregular regular or it is very reflecting material or it is absorbing this energy.

So depending upon that it will be difficult to compare X sensor data with Y sensor data with Z. So if you have 3 satellites or if you want to use 3 different satellites for some application, so then what you have to do? You have to take care of the time when this particular image has been captured and with what look angle, so whether this if you drop vertical perpendicular from here from this surface, so from here what is the angle, so it all depends that how accurately or how well you have planned your research.

So here it is important if you want to compare such images or such datasets you have to make sure the time of the measurement, look angle and the field of view and the pixel size everything is same then only your results will be meaningful. Neglecting these parameters may introduce error in results of image analysis, so here if you ignore this one then also you have some data but what will happen this will lead to error in your analysis so results will not be accurate.

Now it is defined by zenith and azimuth angle theta and phi of the incident and reflected radiation as a function of wavelength.

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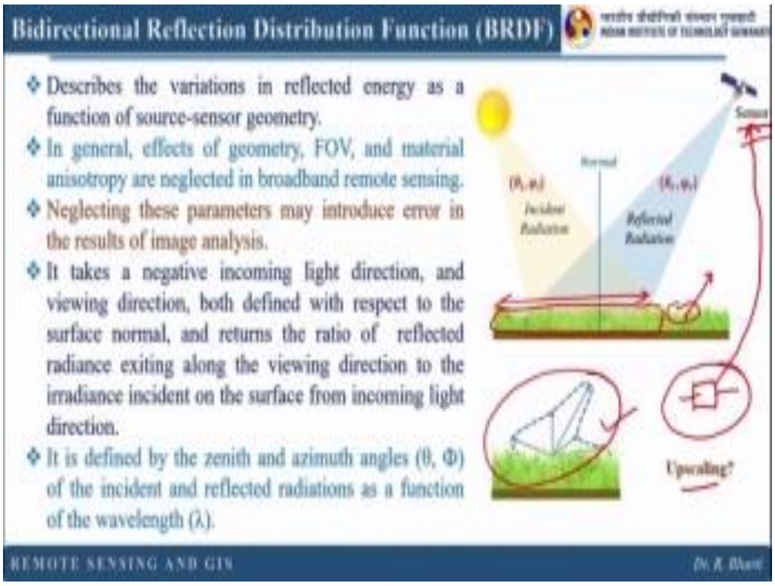

And remember whenever we talk about this BRDF, it is defined by the zenith and azimuth angle of the incident and reflected radiation as a function of wavelength. So whenever we talk here that reflected energy or radiance are emitted we always take care of the lambda wavelength, so it is a function of wavelength, so the wavelength, so I will give you an example like sun is continuously illuminating this particular surface.

So if we say lambda 1, energy has been used to illuminate this particular surface and then radiance is also measured in lambda 1 wavelength and then when we divide radiance by irradiance that will give you reflectance, so here we always take care of this wavelength. We never use different wavelengths which each other they are separate and they are measured separately and they are used in analysis separately.

So here you can see this particular surface is basically a irregular surface or it is having a scattering in different direction where it is behaving like a natural material obviously and the amount of reflected energy is more here and very less here, let us say, so if your sensor is located in this particular angle and if it is covering this particular area your image will be brighter.

So does it mean that it is correct or it is wrong, so we always have to make sure that where is your sun position. Then again what is the importance of this particular concept in up scaling because up scaling is very important because once you go through this course and I expect that you people will use this technology in your research in future research, so what will happen you need to upscale the ground information and compare with the satellite image.

So here we have different sensors available for ground measurement also and the same sensors has been used to put up in the space. So if you measure the energy of this particular area using this particular sensor and the same sensor or the sensor working in the same wavelength and in the same wavelength band that can be used to compare with each other, so you have access to the field you have collected the information with the ground in instrument or lab instrument and then you compare with the satellite images.

So what will happen? You may have access to this particular area but you cannot access this whole area. So what you will do? You will characterize this particular area and then you will establish a relationship to resolve this whole area, so this is the advantage with remote sensing that you do not have to go to all the places but you have to calibrate or you have to produce the accuracy with respect to your ground information.

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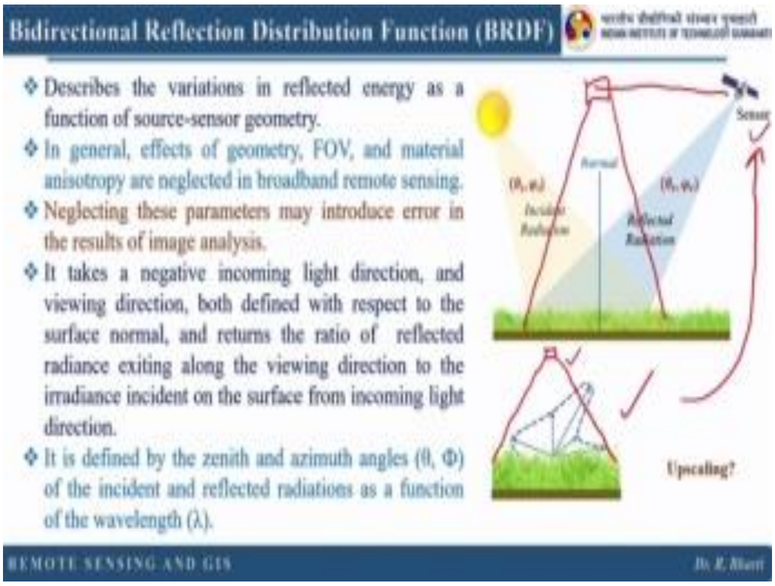

So here this BRDF concept is very useful. Suppose if you have captured this particular area from this particular angle and you have a sensor which is acting in the same wavelength as this grounding instrument is working. So if you compare this with this will it make sense? No. So what you have to do? You have to wait or you have to find the data which is acquired from this particular angle.

So if these 2 are same then you can up scaling the ground information to satellite scale but if you do not take care of this angle and source sensor geometry what will happen? Your information derived from this data will be wrong.

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Now BRDF, how do we define the BRDF? So BRDF is calculated using this now where Lr is the surface leaving spectral radiance and it is having a unit of watt per meter square per steradian per micrometer and E is the spectral irradiance that is watt per meter square per micrometer, so here you do not have angle, so in that case what will happen? Because ultimately BRDF is basically reflectance, how do you calculate reflectance?

So based on this angle you will have this watt per meter square per steradian per micrometer angle this unit but here when you measure the irradiance which is coming from this particular sun what will happen? You will not have steradian, so in that case the resultant value the reflectance value or I would say BRDF value will have steradian unit. So till now I was using the term like reflectance, radiance, irradiance, emittance and reflectance has no unit.

But reflectance has no unit if you have taken care of this source sensor geometry if you have not then what will happen? You will have this unit left with your output data, so that is why it is very important to understand this BRDF and BRF. So in the next slide I will tell you what is BRF?

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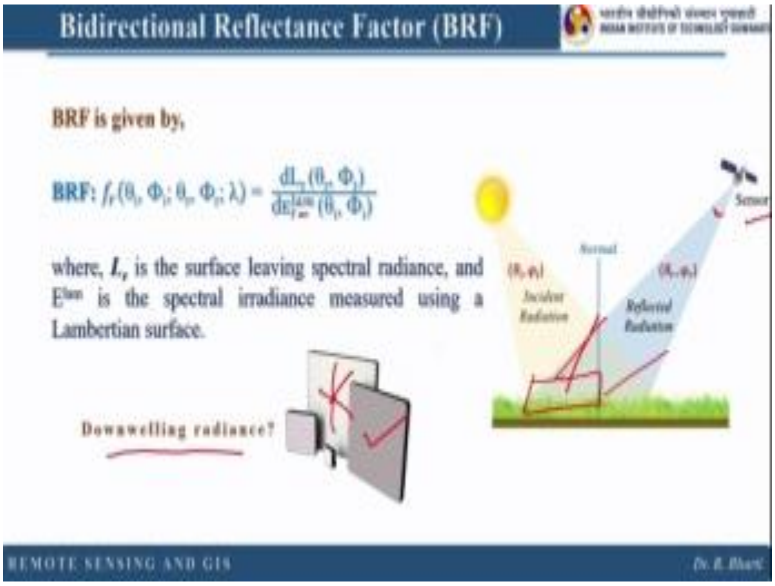

So in BRF this remains same but only thing is here there is a new term added lambertian. So here basically how we captured this radiance reflected values using this sensor now how do we measure this irradiance that is different here because if you remember I explained the concept of lambertian surface, so you have a lambertian surface where you are illuminating this particular target and the reflected value will be same in all the direction.

So the amount of energy measured using a lambertian surface will be same in all direction, so if you have used lambertian surface here then we called at downwelling radiance because till now I was using the term irradiance, so irradiance when you put this sensor here and you measure what is the incoming energy and then we call it irradiance but in case if you have not directly looked at sun what will happen, how will you calculate or how will you measure this irradiance, so in that case what will happen you have to find a way to measure this irradiance.

So in that case we use this lambertian surface, so this is the photograph of a spectral panel which is lambertian in nature, so if light is falling here it will reflect equal amount of energy in all the direction and if you have measured the irradiance of what we will do? We will put our lambertian surface here spectral panel and then we will measure using the same sensor in from the same direction and then we will say that this is irradiance but the term is new this is known as downwelling radiance.

So if you have used downwelling radiance instead of using irradiance directly then what will happen? You have used the same sensor so both will have what per meter square per steradian per micrometer unit for irradiance sorry radiance and downwelling radiance that means your reflectance will have no unit. So it is always better to use this BRF in your study.

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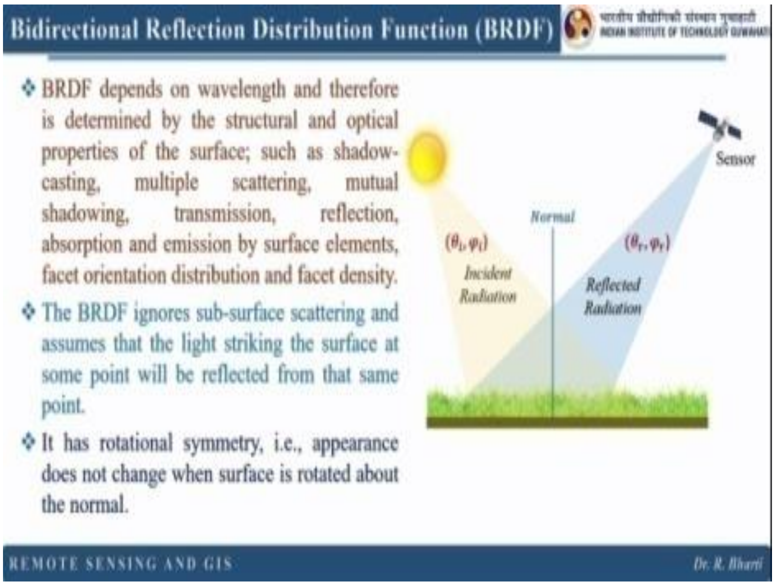

So BRDF depends on wavelength and therefore is determined by the structure and optical properties of the surface such as shadow-casting then multiple scattering, mutual shadowing transmission, reflection, absorption, and emission by surface element, facet orientation distribution and facet density. So in the second point the BRDF ignores sub-surface scattering and assumes that the light striking the surface at some point will be reflected from that same point.

So this is the fundamental of BRDF and it has rotational symmetry that means appearance does not change when surface is rotating about the normal.

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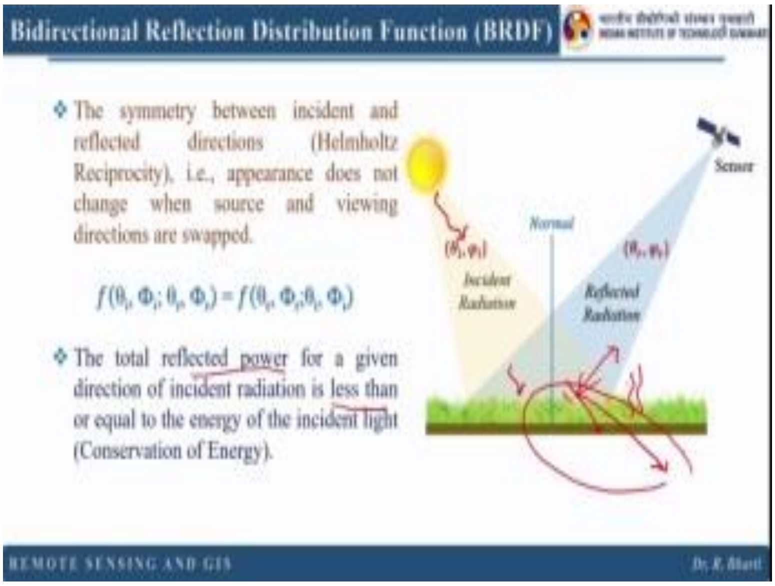

The symmetry between incident and reflected direction that is appearance does not change with source and viewing directions are swapped, so there is no difference if you swap the source and sensor, the total reflected power for a given direction of incident radiation is less than or equal to the energy of the incident light that means here it is very important to recall our basic physics. So what happens when this when sun is illuminating this particular surface.

So what is happening here some amount of light will get reflected some will be absorbed, some will be transmitted. and if it is absorbing what will happen some amount of light will be emitted afterwards and here you may have some scattering, so here what the second point says the total reflected power for a given direction of incident radiation is less than because we measure only reflected one or backscattered one or the emitted one, so here basically we are not measuring the other parameters.

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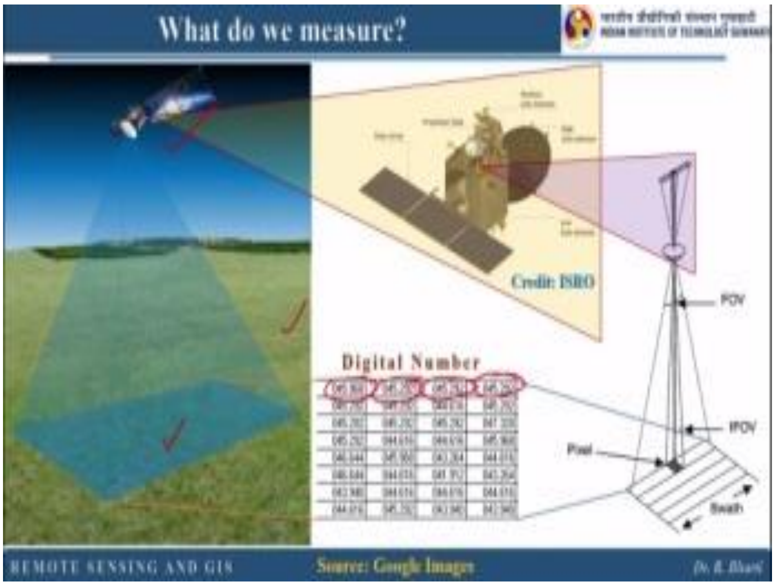

Now you have to understand what do we measure basically here you can see this particular area is sensed by a satellite as attach sensor and it is basically covering this particular area and here you have projected one that what is there in satellite, so in satellites you have many sensors attached, so those sensors are basically having detectors and those detectors are basically capturing your pixels and then you generate a image. So basically what we measure?

We measure image but basically we measured digital numbers so we measure only these values mentioned here, so such values will be captured by your satellite and then once you arrange in a matrix or in an array and then if you export this in any image format you can always see images, so you can try this you can generate a random matrix convert it to or export this in image form using MATLAB or C and then you can see those images very clearly, so basically what do we measure here? We measure DN values.

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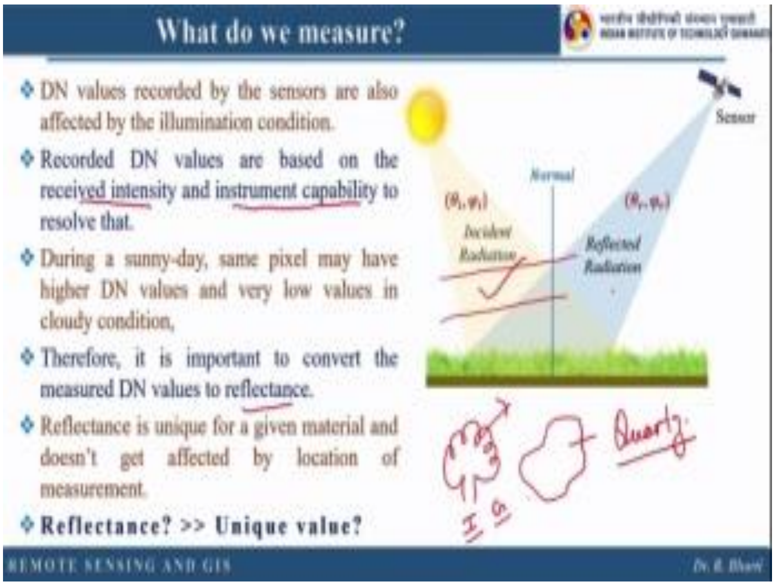

So DN values recorded by sensors are also affected by the illumination condition, so here depending upon the illumination intensity you will have different values for the same pixel as I told you earlier if area is having very sunny day then you will have more value if it is a cloudy day then you will have less value, so here recorded DN values are based on the received intensity and instrument capability to resolve that so here this is also very important.

So received intensity and illumination condition and then instrument capability whether your instrument is capable of resolving the energy in 8-bit, 16-bit or 24-bit depending upon that you will have the values or different value ranges. During a sunny day same pixel may have higher DN values and very low values in cloudy condition, so therefore it is important to convert the measured DN values to reflectance.

So reflectance is a unique quantity for a given material and does not get affected by location of measurement, so it does not matter if I hope you people are comfortable with some geological word like quartz. Quartz is a mineral, so if you have a quartz or let us take the example of a particular tree. So let us say you have a specific type of tree, so it does not matter whether it is in India or it is in Germany or it is in US.

If you measure DN value and subsequently you convert this to reflectance this reflected value for given material will remain same because that depends on the material composition and it is characteristics, so that is my point but once you convert that to reflectance, then you can have a very unique value for a given material and that can be used to identify that material does not matter whether it belongs to India Germany or US or maybe from any other country. So you can identify that material without any problem.

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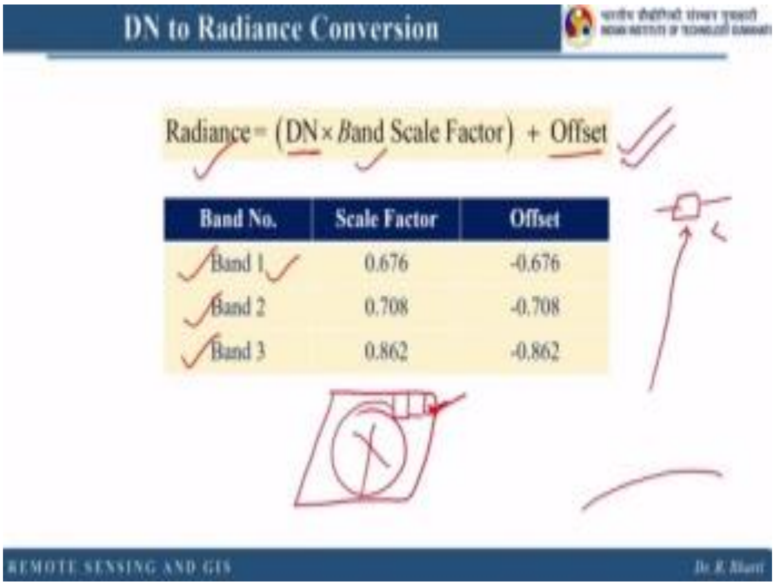

So how do we convert this DN to reflectance, so in the mean time first let us see DN to radiance and then radiance to reflectance, so how do we calculate radiance? So radiance can be calculated using this formula where this DN is basically your image pixel value and this band scale factor and offsets are provided by the space agency who have launched this satellite. So here this is our surface.

And the energy reflected has to travel from surface does not matter whether it is earth or any other planet to our sensor then only that number will get recorded, so the amount of value is or the amount or the intensity is very very low. So sometimes what happened to store that energy you need to use some scale factor and during the calibration of your satellite that space agency they use some scale factor and offset that will be provided to you in form of metadata.

So whenever you download any satellite image from any space agency websites like USGS or ISRO website then you will have an additional file called metadata and that metadata will have many information which are useful to analyze those images, so this is one example where you have band 1 it is sensitive to a particular wavelength remember band 1 band 2 band 3.

How we say because band 1 is not a wavelength, band 1 is given a name to the first band in which that sensor has measured the image, so one image, second image, third image and corresponding scale factor and offset, so once you have this then you can easily calculate the radiance, so it is important to understand you have an image and here you have pixels. So this calculation has to be done on individual pixel level it is not like for the whole image we are using this calculation, no, that will be wrong you have to use pixel level calculation.

So pixel level means the value which is assigned to this particular pixel into band scale factor plus offset, we have next equation which is to calculate calibrated radiance.

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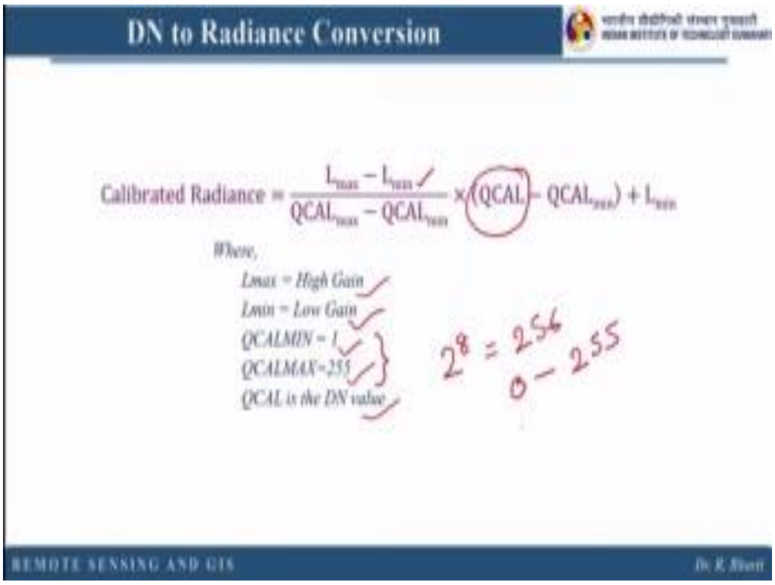

where we use Lmax, Lmin right then QCal, QCal min plus L min then Q Cal max Q Cal min, so what are they basically Lmax is high gain, Lmin is low gain, then QCal min is 1, QCalmax is 255, QCal is the DN value, so basically this is your DN value, so you can put your DN value here and all the other information like Lmax, Lmin that is provided by your space agency in metadata file.

Now here this is basically you have to decide so you should when you download the image you should know what is the resolution of this image spatial spectral radiometric and from the radiometric you know that whether it is 8-bit data, 12 bit data or 16-bit data, so when you have 8-bit data, so that means you have this that means 256, so the range will be 0 to 255 or 1 to 256, so this radiance to reflectance conversion you have this formula.

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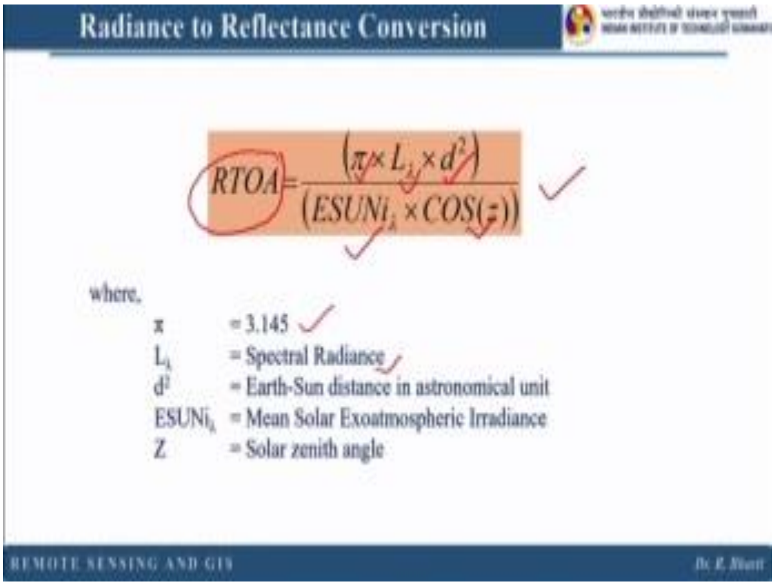

Where it is written RTOA, so reflectance top of the atmosphere it is not simple reflectance so there are 2 things one is reflectance top of the atmosphere and another reflectance which is for this surface, so surface reflectance or top of the atmosphere reflectance. So here this is the formula for reflectance top of the atmosphere where we use pi then L lambda then d square then ESUNi then COS(z). So here pi value is known then L lambda is spectral radiance again I am talking about the pixel values of the image.

So this equation has to run on the pixel level then d is basically earth - sun distance in astronomical unit then ESUNi is mean solar exo-atmospheric irradiance that is again provided by your space agency and Z is the solar Zenith angle again you have to derive this based on the available data in the metadata file.

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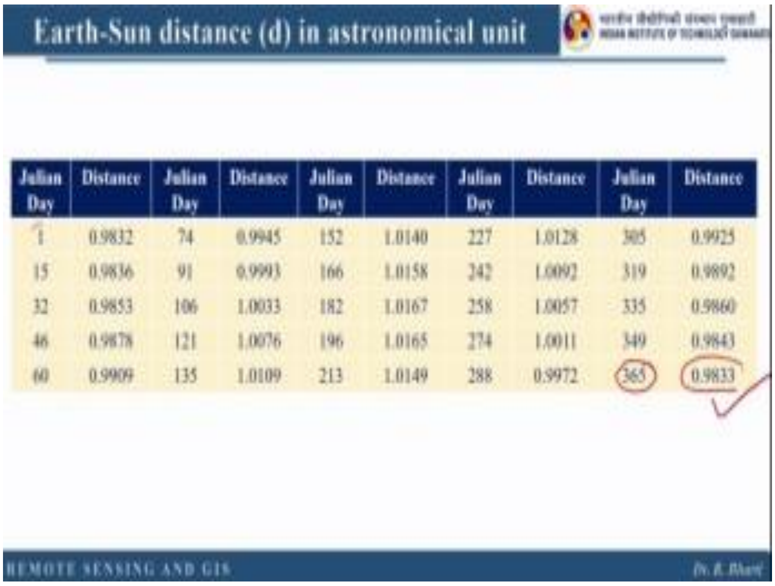

Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance	Julian Day	Distance
1	0.9832	74	0.9945	152	1.0140	227	1.0128	305	0.9925
15	0.9836	91	0.9993	166	1.0158	242	1.0092	319	0.9892
32	0.9853	106	1.0033	182	1.0167	258	1.0057	335	0.9860
46	0.9878	121	1.0076	196	1.0165	274	1.0011	349	0.9843
60	0.9909	135	1.0109	213	1.0149	288	0.9972	365	0.9833

Will see now Earth-Sun distance, so for every 15 days we have already calculated the earth - sun distance in astronomical unit, so remember d but there in equation we have d square, so if it is 365 then it has to be squared.

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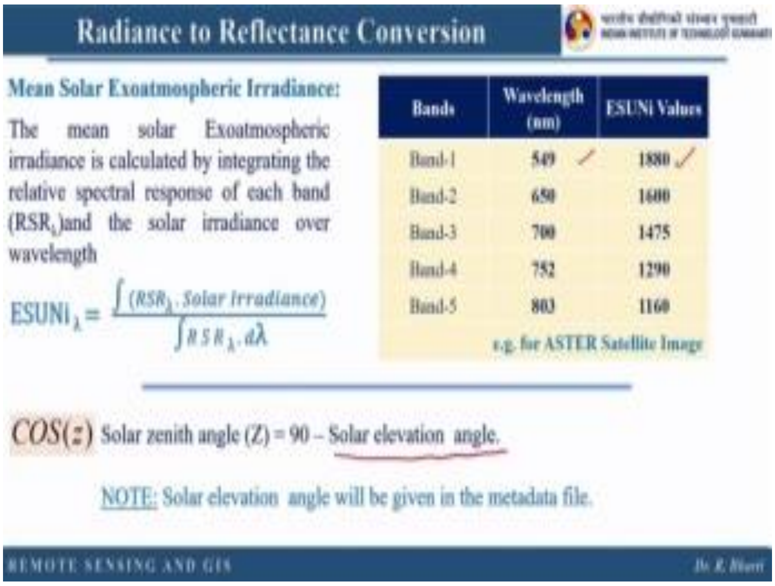

The mean solar value calculated by integrating the relative spectral response of each band and the solar radiance over wavelength, so basically you have to understand what exactly I am trying to say here like this is the surface this is your source and this is your sensor, so this is actually wrong because your sensor will be somewhere here and here you have atmospheres. Now what is happening this sun is illuminating this whole area.

So sensor is also receiving the irradiance value, so and this is away from our atmosphere. So what it does is it also measures the irradiance value received at that particular time during the measurement of this image, so you have spectral irradiance and why we are calling this exoatmospheric because this is not coming in our atmosphere before that we are measuring this exoatmospheric irradiance value. I hope this is clear to you.

So for different satellite or for different time of measurement we have different ESUNi value, so here you have band 1 this is the value wavelength and this is the value and next is cos Z, so cos Z that is basically solar Zenith angle and in the metadata file you will have solar elevation angle, so if you subtract with 90 minus solar elevation angle that will give you solar zenith angle so that will be Z.

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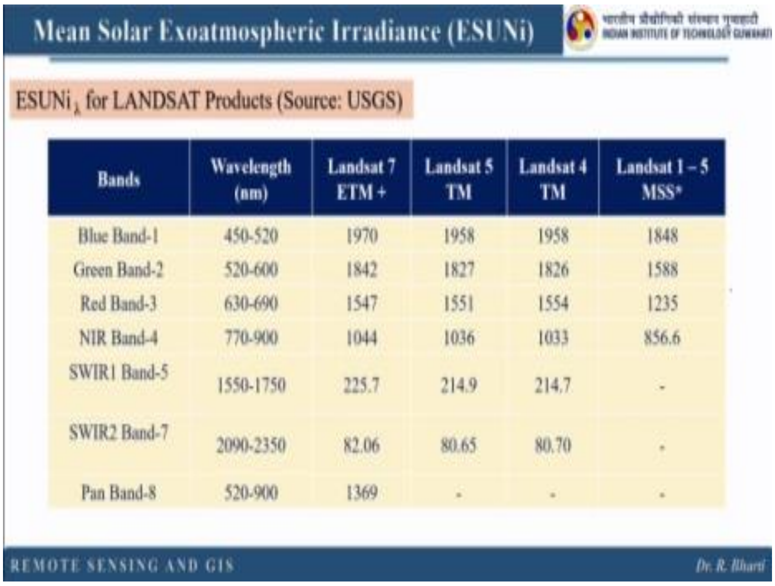

Mean Solar Exoatmospheric Irradiance (ESUNi)

ESUNi$_\lambda$ for LANDSAT Products (Source: USGS)

Bands	Wavelength (nm)	Landsat 7 ETM+	Landsat 5 TM	Landsat 4 TM	Landsat 1 – 5 MSS*
Blue Band-1	450-520	1970	1958	1958	1848
Green Band-2	520-600	1842	1827	1826	1588
Red Band-3	630-690	1547	1551	1554	1235
NIR Band-4	770-900	1044	1036	1033	856.6
SWIR1 Band-5	1550-1750	225.7	214.9	214.7	-
SWIR2 Band-7	2090-2350	82.06	80.65	80.70	-
Pan Band-8	520-900	1369	-	-	-

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This is for LANDSAT image.

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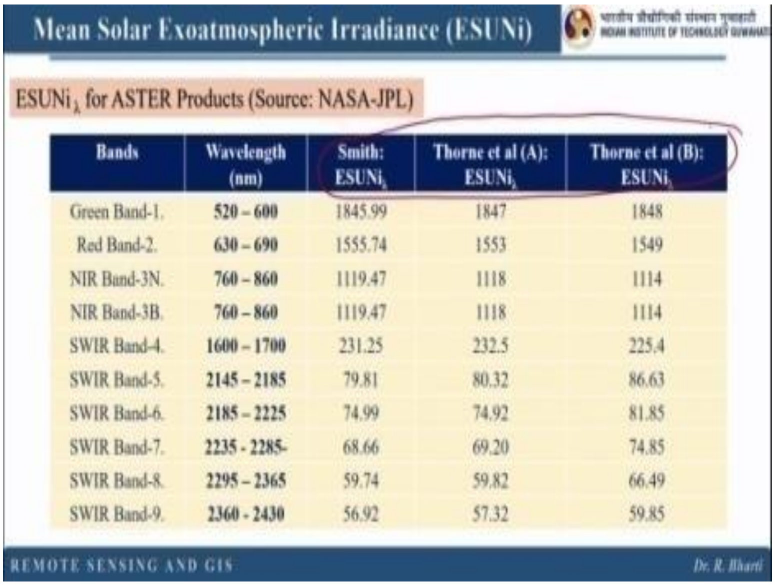

Mean Solar Exoatmospheric Irradiance (ESUNi)

ESUNi$_\lambda$ for ASTER Products (Source: NASA-JPL)

Bands	Wavelength (nm)	Smith: ESUNi$_\lambda$	Thorne et al (A): ESUNi$_\lambda$	Thorne et al (B): ESUNi$_\lambda$
Green Band-1.	**520 – 600**	1845.99	1847	1848
Red Band-2.	**630 – 690**	1555.74	1553	1549
NIR Band-3N.	**760 – 860**	1119.47	1118	1114
NIR Band-3B.	**760 – 860**	1119.47	1118	1114
SWIR Band-4.	**1600 – 1700**	231.25	232.5	225.4
SWIR Band-5.	**2145 – 2185**	79.81	80.32	86.63
SWIR Band-6.	**2185 – 2225**	74.99	74.92	81.85
SWIR Band-7.	**2235 - 2285-**	68.66	69.20	74.85
SWIR Band-8.	**2295 – 2365**	59.74	59.82	66.49
SWIR Band-9.	**2360 - 2430**	56.92	57.32	59.85

REMOTE SENSING AND GIS Dr. R. Bharti

So these are the ESUNi values and for ASTER image this is the ESUNi value it is available in the website, so you can always go to NASA JPL website and you can see all these values available and these values are basically given by these researchers.

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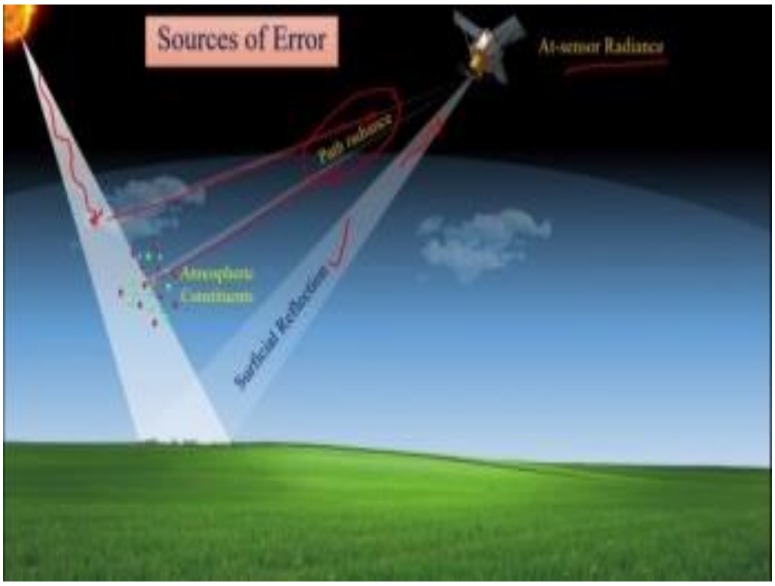

Now what are the different types of errors, so first we need to understand what is the source of error, so sun is continuously illuminating our surface, so what is happening first thing we have already seen that source sensor geometry, now from this geometry effects you have already understood. Now this energy which is coming from this particular sun is entering to our atmosphere and then what will happen? It will first interact with our atmosphere.

Then it will reach to our surface and then it will get reflected and that radiance value will be recorded by our sensor. Now if we consider our atmosphere opaque like there is nothing then there is no problem, but actually we have clouds we have atmospheric constituents, dust particle, gases, water vapor and they are also playing very critical role in absorption and scattering.

So what will happen? You will have some error or reflected irradiance here from these two and that will also get recorded along with this reflected energy. So what is happening and you already know that path radiance we give this name to this particular extra energy and that will get recorded and then we measure at sensor radiance so at sensor radiance is basically having the reflected energy from the surface as well as the path radiance from the atmosphere.

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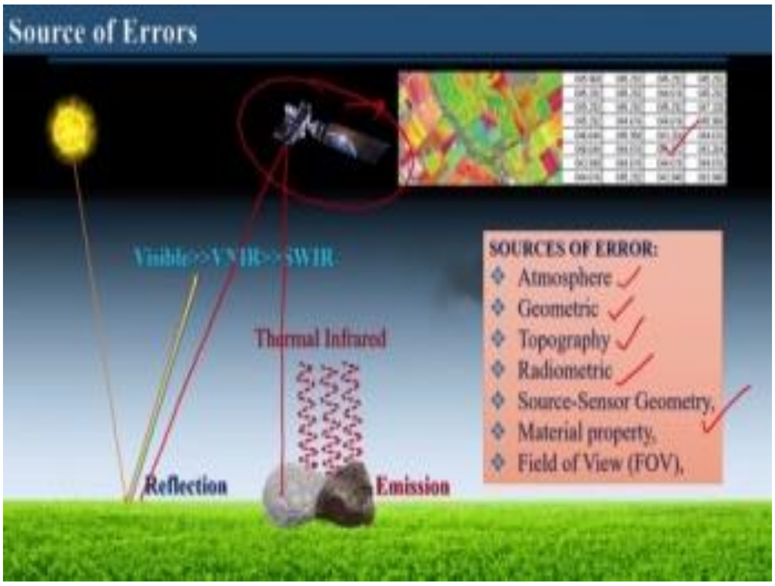

So here you have to understand like if we talk about scattering, so shorter wavelengths are affected more from this scattering whereas, the longer wavelengths relatively they are free from scattering if it is reflected or emitted , so this is the fundamental, now we have to see what are the different types of errors? So this satellite is giving this particular image and image is basically nothing but the DN values.

So now here we will go one by one source of error first one is atmosphere I hope you have understood this then geometric error then topography if it is a hilly area what will happens then radiometric errors, so in radiometric errors basically that explains the error related to this instrument. Like if the instrument is not calibrated suppose if it is delayed by 5 seconds or if any of the detectors from that array is not working temporarily then what will happen then source sensor geometry, material property and the field of view.

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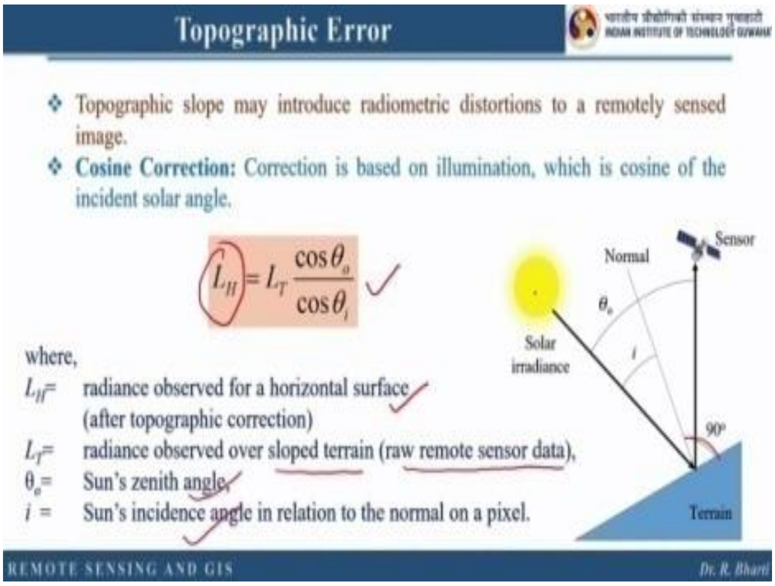

So first one is topographic error, so topographic slope may introduce radiometric distortion to a remotely sensed image and for that we do cosine correction. Correction is based on illumination which is cosine of the incident solar angles, so here you can understand this if this is the normal to this particular surface and sun is located here and it is illuminating this one and sensor is here.

So what is happening here we assume in the image it will appear like this is a horizontal plane but it is not because it is having this slope, so how do we correct or how do we remove this angle slope effect on the images, so for that we use this formula and where again whatever equation I am showing here, so basically that includes pixel level calculation. So here LH is the radiance observed for a horizontal surface.

So this we need to calculate because we assume that whatever we have captured that is horizontal because we project this like this in our image but that is wrong directly we cannot say that this is horizontal and LT is radiance observed over slope terrain and which is basically raw remote sensing data and this is sun's zenith angle and then sun's incidence angle.

So this is how we are going to remove the effect of slope from a remotely sensed image and then we say this is LH. LH is basically radiance observed over a horizontal surface, the next is geometric distortion.

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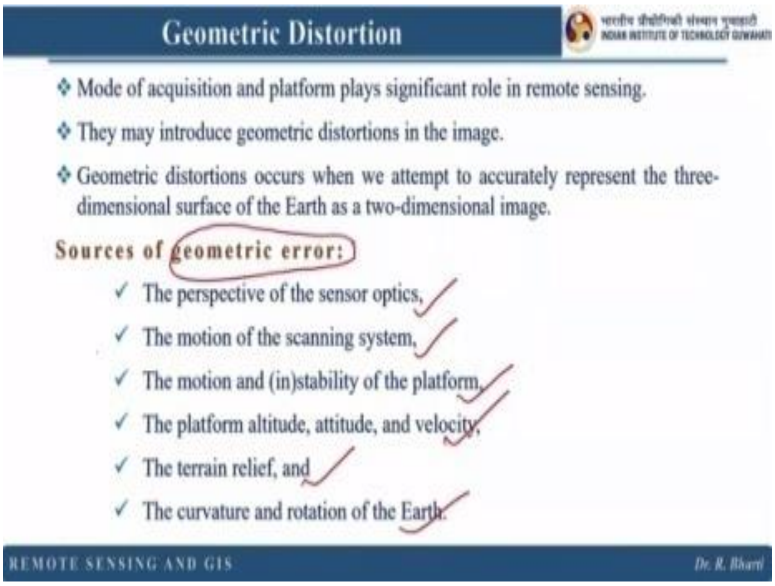

So mode of acquisition and platform plays significant role in remote sensing, they may introduce geometric distortion in the image and geometric distortion occur when we attempt to accurately present the 3 dimensional surface of the earth as a 2 dimensional image, so this is very important because when you are looking from the top you are removing the effect of slope and local topography and we say that everything is 1 pixel.

I will give you one example like this is a surface and here you have some houses and here you have some trees and here in this area you have a hill and here also you have a house and here you have some trees if your sensor is here and then if it is capturing this particular area with a particular field of view. So what will happen your image will look like this right here in the center you will have trees, here you have sorry a house, here you have house.

But what will happen this particular detector which is located in the center will see accurately this particular tree based on their IFOV but what will happen to this particular plane here your pixel will be not square because we always define our spatial resolution in square like one meter by one meter, 23.5 meter by 23.5 meter or 30 by 30 meter or 60 by 60 meter. But here if you see if it is capturing this particular area, so this will be something like this, so what I mean to say here if this is a flat land then it is very good but how do you remove?

So one thing we have seen that you can remove the effect of slope but what happens when this particular tree is supposed to be here but it has been recorded here why because of the topography or change in the platform. If your sensor is located here and it is looking at this particular area for some reason if it comes down for may be 1 kilometer or for 1 meter what will happen with the same FOV it will look less and during the measurement if it happened then what will happen? Your image will have distortion.

So this is very important to remove all such errors geometric errors from your remotely sensed image, so source of geometric errors are like the perspective of sensor optics the motion of this scanning system how it is moving if the orbit is defined like if it is a low inclination angle orbit and if it is moving at particular X velocity and if it has changed slightly during the measurement then what will happen this pixel which was supposed to be like this it will be like this.

You can imagine this one this is very simple the motion and instability of the platform, the platform altitude, attitude and velocity will see in detail all these things then terrain relief then the curvature and rotation of the earth. So this is very important to understand from where we are getting these geometric errors, so these are the source of geometric errors.

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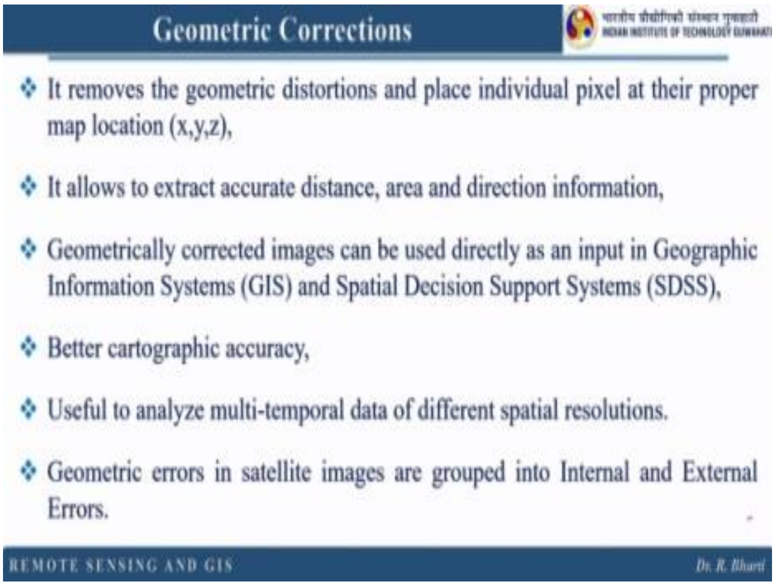

So in geometric correction what we do basically so it removes the geometric distortion and place individual pixel at their proper map location, so here remember I have mentioned map location that means let us start from very basic when you capture one image what happens you capture DN values and these values are basically a pixel in your image but if you simply export this in MATLAB.

Then you can see matrix and values are nothing but the pixel DN numbers. So suppose if this tree is supposed to be here then you will find that your area representation using this image is not correct because we are talking about this spaceborne images or the airborne images not our handheld cameras then it allows to extract accurate distance area and direction information because if you know that one pixel is 1 by 1 meter.

Then you can easily calculate the distance between these 3 pixels if one object is here, you can easily calculate like 1 1 1 3 meters from each other but what if the pixel is rectangular then square then again rectangular then how will you represent or calculate or extract the values from this image that will be wrong. Geometrically corrected images can be used directly as an input in geographic information system that is GIS and spatial decision support system.

Because ultimately why we are using these remote sensing images to solve a problem or to provide an input in solving some problem, so you have to make sure that whatever information you have generated using this remote sensing it has to be correct and better cartographic accuracy how do you represent your images in form of map. So here in the measured image you have DN values and how do you define the location of this particular pixel or the element of this matrix based on cartesian coordinate.

But can we use cartesian coordinate to locate a surface on earth? No or any other planet? No. So what we have done we will be using this map location, so here there is a term called latitude and longitude. So we will be using latitude, longitude along with the measured DN values so if you have all these information you can easily identify whether this pixel belongs to Assam or Bihar or Jharkhand, Mumbai, Delhi or any other country, so it is very important to have this map location.

So x y and z. z is basically here I mean to say DN values useful to analyze multi-temporal data of different spatial resolution. So if you have measured a image of may be IIT Guwahati campus on 99 let us say 1st January 1999 then second image 01/01/2000 right then likewise you have 15 years data, so if you want to see how this campus has evolved slowly with respect to time then you have to overlap this image sorry may be the latest one and overlap them with each other then you can slowly see how this campus is evolving itself.

So how this new construction, how this new park or buildings are coming up, so this is only for the example it can be any area, so here basically what I mean to say multi-temporal data of different resolution spatial resolution, so if your image is geographically or geometrically corrected then you can easily identify the changes with any other image. Geometric error in satellite images are grouped into internal and external errors.

So we will see in details like what are these internal and external errors? And how do we remove them and how do we perform geometric correction for a given image and then next one is atmospheric error how this atmosphere is giving error in our remote sensing and how it is getting removed from this. So you can see one image here it is having some haze.

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So this haze we have to remove in order to use this image, so if you remove the atmosphere atmospheric components from this then this will be like this, so we will see how we can remove atmospheric components from a remotely sensed data, because we cannot avoid our atmosphere, our clouds. So they will be there during the acquisition sometime if we are very lucky you do not have clouds right this is another example where you have an image with again atmospheric error and when you remove them it will look like this.

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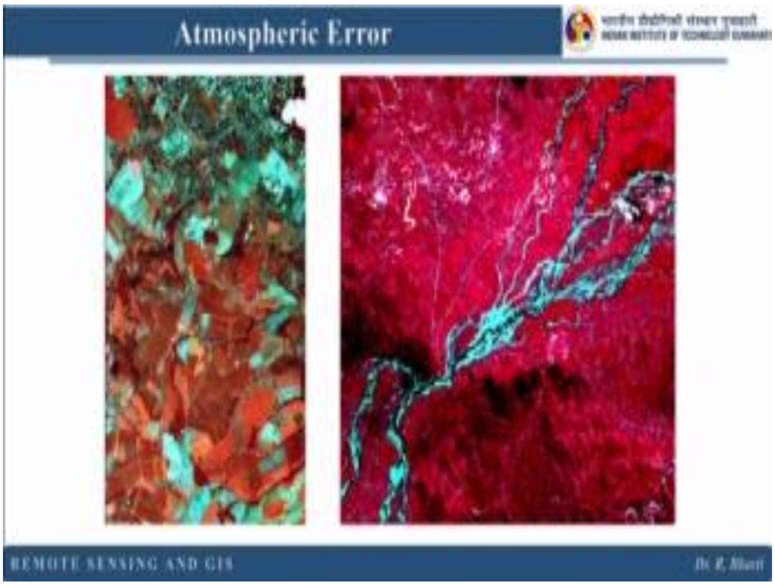

I have few more examples like this is another example this is another example so this why I have put all these images so that you will have a feeling like what kind of error do you get because of the atmosphere and how do they appear after we remove the atmosphere.

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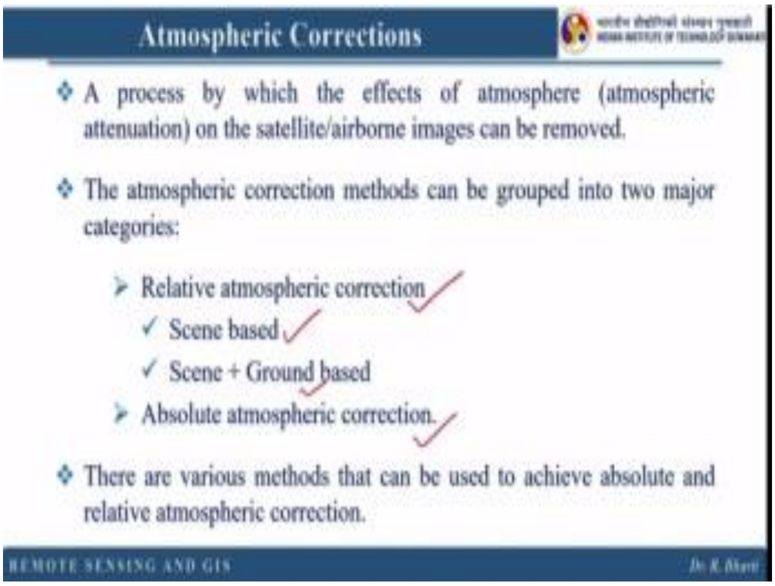

So it is a process by which the effects of atmosphere on the satellite or airborne images and it can be removed, the atmospheric correction method can be grouped into 2 major categories that relative atmospheric correction and where you have to further sub category like scene based or scene plus ground based and then another one is absolute atmospheric correction. So in relative atmospheric correction what we do?

We use some fundamentals and some object identified in this scene itself and we have some information from the ground and we correct the images but in absolute atmospheric correction we exactly measure the values of the atmospheric constituents during the measurement of such images and then we model the atmosphere and then we remove all the values added by the atmosphere in the image. There are various methods that can be used to achieve absolute and relative atmospheric correction that we will see subsequently.

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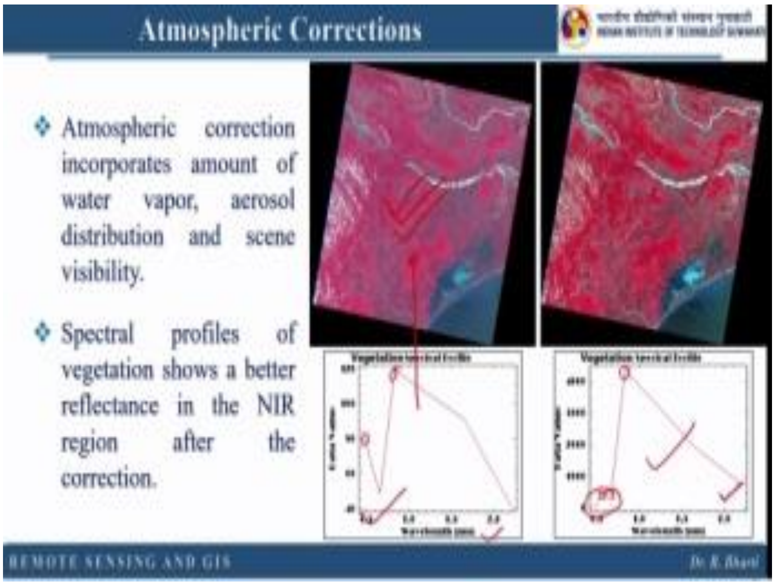

So atmospheric correction incorporates amount of water vapor, aerosol distribution and scene visibility and the spectral profile of vegetation shows a better reflectance in the NIR region after the correction. So if you see this is a reflected image, so what we did we captured DN values then I have converted it to radiance and then converted it to reflectance and for a given pixel let us say this red color is vegetation and this pixel is having this spectral profile.

How we are getting this spectral profile because remember a satellite gives many bands so band 1, band 2, band 3 but we cannot see all of them together to generate color images we need 3 bands to assign in a red, green and blue and then we generate this kind of image, but in the background you may have 10 different bands. So for this particular pixel right you have 10 values and those 10 values are plotted here.

So this is a reflectance value and this is the wavelength now if you remove the atmosphere from this then what will happen your spectra will be more accurate because if you see in this you have only one peak here but here you have one peak and then one peak next here. So this particular pattern was missing when we had the atmospheric effects on this particular image whereas this image has been corrected for the atmospheric errors and now this is more accurate reflectance spectra.

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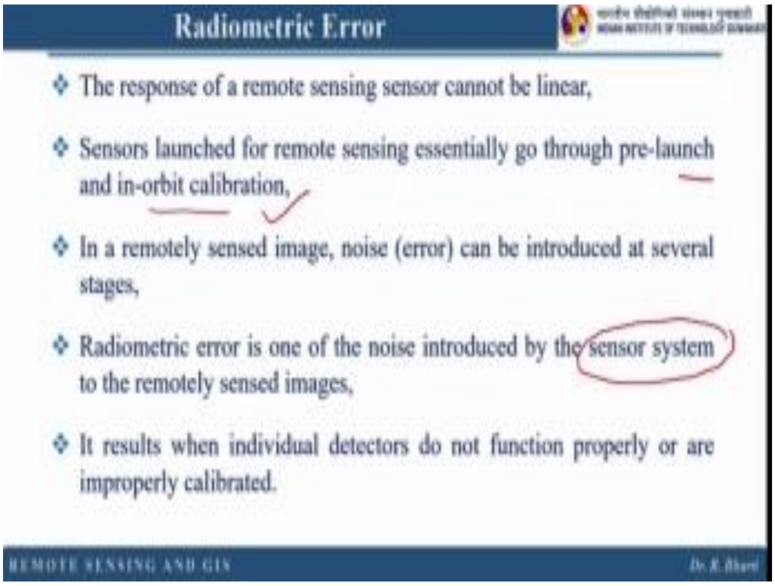

In case of radiometric error the response of a remote sensing sensor cannot be linear. Sensor launched for remote sensing essentially go through pre-launch and in orbit calibration because this calibration values do you remember gain offset everything to in order to change or to convert this DN value to radiance, radiance to reflectance we were using all the information from this calibration.

So this sensor has to go through this pre-launch and in-orbit calibration, so before launch also we calibrate this and after launching it in the space we again recalibrated or we match with the pre-launch measurement like whether it remains same or it has changed because it has traveled so much distance. In a remotely sensed image noise can be introduced at several stages like you have seen already in other cases, in this case it can be because of the misbehaving of the sensor.

So may be one detector may stop recording for few seconds right, so that is temporary but one detector may fail permanently also and if there is a change in altitude or attitude of the sensor then again there will be a different values. So those errors are basically again included in terms of radiometric errors, so radiometric error is one of the noise introduced by the sensor system to the remotely sensed images, so here it is purely because of this sensor system it results when individual detectors do not function properly or are improperly calibrated.

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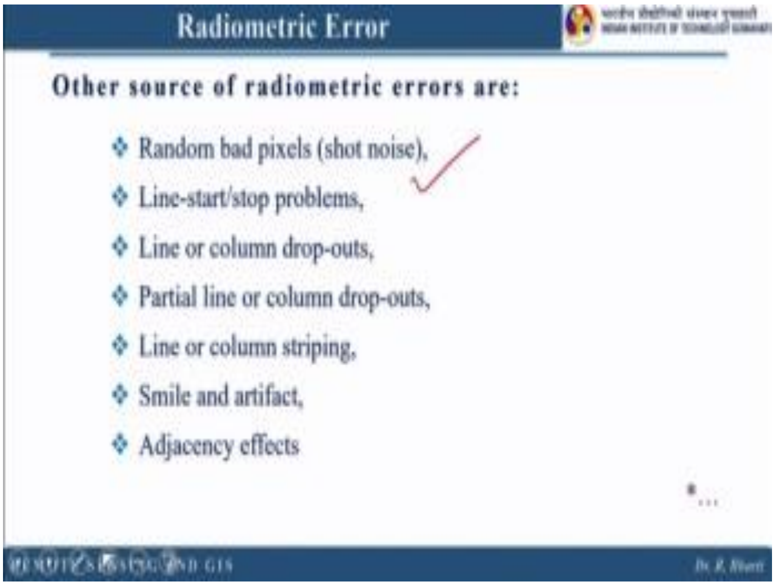

So we will see in detail like how it can be and there are different source of radiometric errors like first one is a random bad pixel another is line start or stop problem, line or column drop-outs partial line or column drop-outs, line or column stripping, smile and artifacts, adjacency effects all these are basically under this radiometric error, so in next few lectures you will understand all these errors in detail and how do we correct? So correction techniques thank you.