Remote Sensing And GIS
Prof. Rishikesh Bharti
Department of Civil Engineering
Indian Institute of Technology Guwahati

Lecture-06
Error Identification and Correction - III

Today is the third lecture on error identification and correction. In this lecture, you will learn more about radiometric correction and the error. So what do you mean by radiometric error? So radiometric errors, I have already introduced you and then now let us see more in detail like what do you mean by radiometric error,

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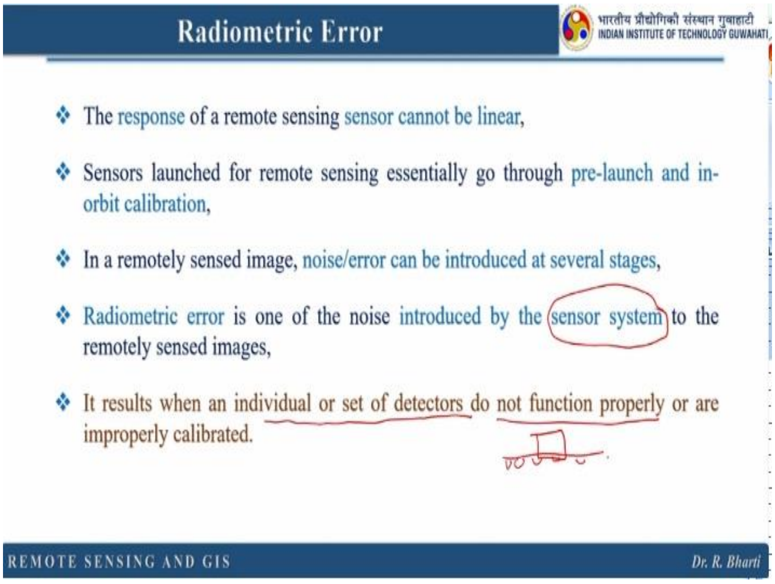

The response of a remote sensing sensor cannot be linear. So what does it mean? So it means when you plot this sensitivity of a detector, what happens? It will be like a gaussian distribution, so if you see there is a peak where it is sensitivity is maximum. But in other places, it is sensitivity is not up to the mark. So what happens? If we have to tell that what is the sensitivity of a detector then we use a term like FWHM. I hope you remember.

So this is full width at half maxima. So using this particular fundamental what we do is, we define the sensitivity of a detector. So but actually the sensitivity of the detector is something like this. So where it is not linear, it is not like here it is coming and here it is dropping. So this is the lambda starting lambda and this is the ending lambda. So it means that this response of the detector is not linear.

Now the Second point is sensors launched for remote sensing essentially go through pre-launch and in-orbit calibration. So, it says that whenever we have to design or when we are designing a satellite then essentially that satellite will carry some payloads and payloads are basically your sensors and sensors are basically consist of detectors and detectors are basically to be calibrated. So when we design that time, we have to calibrate whether they are properly measuring the defined lambda or not.

So if a detector is designed to detect the energy from, let us say 0.8 to 0.9 and but somehow because of the problem the detector is detecting the energy between 0.8 to 0.89. So what happens? It says that there is some problem in the detector. So some alignment and then we have to calibrate so that it will be sensitive to its own wavelength region. So that is the second point.

The third point is a in a remotely sensed image noise or error can be introduced at several stages that we have already understood like geometric correction, radiometric correction then topographic correction. So there are many sources of error in remote sensing. So what is the source of this radiometric error that we have to understand, so radiometric error is one of the noise introduced by the sensor system to the remotely sensed images.

So here basically we are talking about the error caused by or introduced by this sensor system itself. So if I have to refer a normal camera, then in that case whether your camera is working properly or not, or whether it is properly calibrated or not that those things are basically included in radiometric error. Now, the last point is, it results when an individual or set of detectors do not function properly or are improperly calibrated.

So basically, we have learned that this radiometric error is only because of the problem with sensor system, now how this sensor system can introduce errors. So basically sensor is consist of detectors and detectors are basically if you see a camera there may be in satellite. So there may be 1000s of detector or there are number like more number of detectors. So in case you have let us say when we consider, let us say 500 detectors are there in one sensor?

And 1 out of 500 goes out of calibration or with stops recording then what will happen? Your image will have those error pixels. So basically, 1 detector is measuring 1 pixel. So here what we are doing? We are doing going to identify those pixels basically problematic pixels caused by or measured by your sensor or which was not measured by those particular detectors. So that is why I have written, it results when an individual or set of detectors do not function properly or are improperly calibrated.

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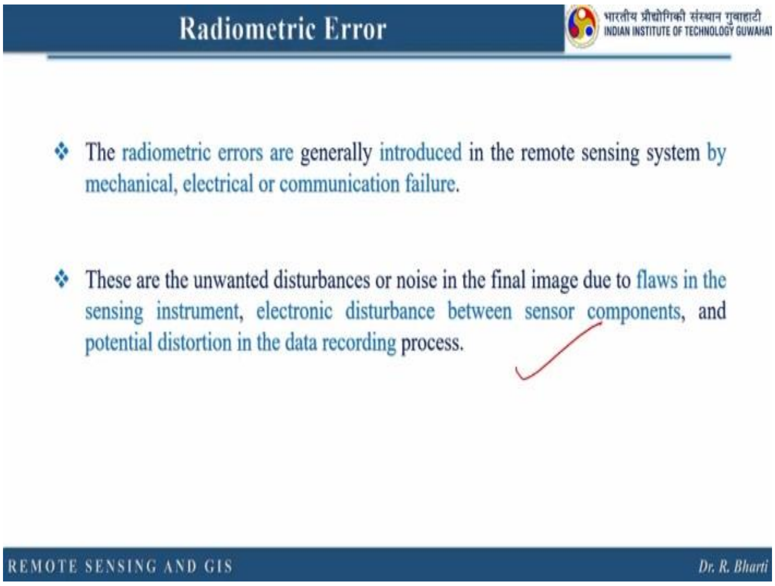

So the radiometric errors are generally introduced in the remote sensing image by mechanical, electrical, or communication failure. So how this mechanical part is coming into the picture because we are talking about this sensor and sensors are basically an optical system and optical system there are many parts which are actually moving. So if they are not moving at the defined rate.

So then what will happen? Your image will be distorted then electrical like if there is a power failure for a fraction of second or maybe only for a particular detector there was a power failure then this may cause your image error, then next is communication failure. So suppose while transferring this data to the ground station because I hope you remember that this is our surface right.

And this is this sun which is illuminating our surface then it is getting reflected or emitted and here is your sensor and then sensor records the data and then what happens it gets transmitted to our ground station. So here in the ground station, basically if there is a communication failure, so what happens for those particular pixels or maybe for those images which were having downloaded during this particular problem period then what will happen? That may introduce error in your data.

So the second point is these are the unwanted disturbance or noise in the final image due to flaws in this sensing instrument, electronic disturbance between sensor component and potential distortion in the data recording processes, the same thing which is explained in different language. But I hope you are you have understood this particular concept. Now, let us see what are the different types of error? We consider in radiometric error.

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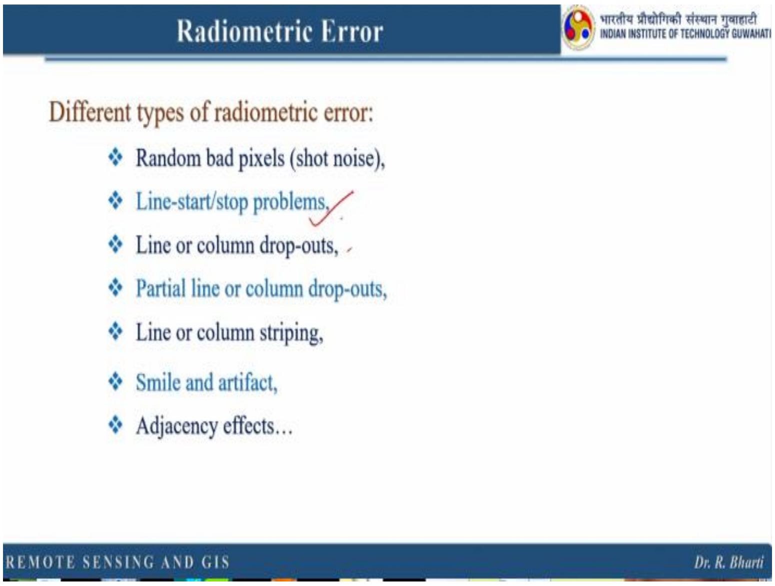

So first one is random bad pixel which is also known as shot noise. There is a slight modification that we will see then line start or stop problem. So when this line or scanning is happening if there is a line starts or stop problem that may come into this particular category. Next is line or column drop-outs then partial line or column drop-outs. So this is from these 2 like if there is a slight problem, partial problem then in the beginning we had line start and stop problem then line or column dropouts.

Now here we have partial line or column dropouts. Then next is line or column stripping then smile and artifacts and the last one is adjacency effects. So there are different types of errors. We consider in this category. So these are few very popular and very commonly occurring errors in your image. So you have to understand this very carefully.

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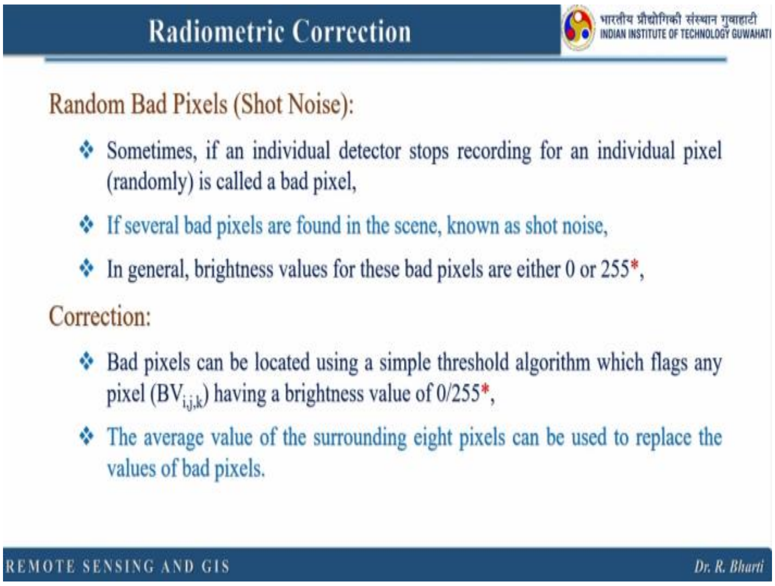

Now first one is random bad pixel. So here what it says, sometimes if an individual detector stops recording for an individual pixel is called bad pixel. So here you have to understand individual detector. So we are talking about individual detector. So here, this is your, let us say satellite and here you have a sensor and in this sensor, basically you have many detectors and one of them, let us consider this one ,it stopped recording. So what will happen this will scan some area on the ground?

So it is looking at the ground now and then it will generate a image and when it is generating what will happen? You will have DN values for all other pixels except a particular pixel when this particular detector has stopped recording for that particular moment. So what will happen? You will have all these values, but only this particular pixel will not have that value and that pixel value, what is the significance that it says or it records the total amount of reflected or emitted energy and it gets averaged and it is stored as a DN number.

So energies are coming from all over the places right from this pixel. Let us say 1 meter by 1 meter and this all these energies are basically reaching to our sensor and for this particular pixel only one value will be recorded, right? So it says that when an individual detector stops recording for an individual pixel is called bad pixel. So individual pixel means only for that particular moment, there was a problem, we do not know what happened to that particular detector.

But somehow it did not record the expected energy and it is giving you some error. So that is known as random bad pixel, if several bad pixels are found in scene which is known as shot noise. So what will happen, so you will have supposed this is your image and all the values have been recorded. So but what is happening here in random bad pixel, you had only one no value. But here, you may have several no values distributed in this particular image.

So that means that is different from your random bad pixel because there you had only one bad pixel, but here you have several bad pixels. So that is known as sort noise. Now the third point is in general brightness value for these bad pixels are either 0 or 255, so these bad pixels, so there will be some number which will be attached to this. So what will be they, so they will be like either 0 or 255. This is only when you are having 8-bit data.

So 2 to the power 8 your value range is 256. So 0 to 255 is your value range and when you are having that so that means either you here you will have very black pixel or maybe very bright pixel because 0 is darkest one and this is the brightest one. So if your value is 255, it will be very bright pixel. If it is 0 it will be very dark pixel, so that you need to carefully identify with respect to surrounding if there is a very sudden change in the intensity, which is not expected in the nature and that will be only for that only one pixel.

So that means in nature we never find that 1 meter by 1 meter area is very bright and surrounding are very dark. So it is not expected, so this is the logic we will apply to identify those bad pixels having value either 0 or 255 in case of 8-bit data, if your radiometric resolution is different, then you have to refer that minimum and maximum value, now how do we correct this one?

So the bad pixel can be located using a simple threshold algorithm which flags any pixel having a brightness value of 0 or 255. So again, I am referring 8-bit data, right, so here a simple threshold algorithm which flags because in nature it is very difficult to find one pixel which is very dark and one pixel which is very bright even with the surrounding. So what will happens. So if you are getting some area very dark and saturated like 255 that means it indicates there is a problem with the data.

Though our range value range is 0 to 255 but 0 and 255 are very rare in correctly measured data. So and how do we correct this one? The average value of this surrounding 8 pixel can be used to replace the values of bad pixel. So what we do we identify those pixels which are having 0 or 255 value then surrounding pixels can be used to calculate or estimate the average and that bad pixel value will be replaced with the calculated averaged value.

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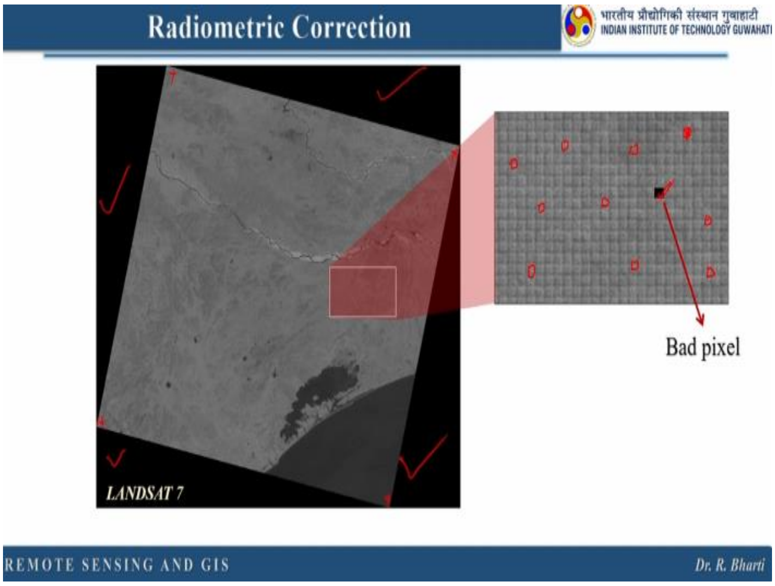

So here this is one example, so here for any downloaded image or purchased image, which you have purchased from either ISRO, NASA, JAXA there are many spaces agency depending upon your application. You will be approaching them to download your particular desired data. So in that case what happen? You have to identify those bad pixels. So here if you see from outside from very like a zoom out image, you want to find any problem with this, like here I cannot say that it is having a bad pixel.

So what you have to do you have to run an algorithm which flags the value or which identifies the value of 0 and 255 like all the surrounding values like this. This will be 0 why because they are black, so they are the boundary of this image. So we do not have to bother about that. We have to find 0 and 255 between these boundaries. So if you can do that by writing an algorithm like how to flag or how to identify values 0 and 255 in this particular image.

So it is very simple. Now, if you find then it will be something like this if you see this particular area, we have found one particular bad pixel. So here it says like this is black, right and all other surroundings are bright. So what happens, so here it clearly indicates there is a problem, problem with this particular pixel, so it is known as bad pixel, but what happens when you have short noise? You may have several bad pixels distributed randomly in this particular image, so they will be known as shot noise.

So all these will be with 0 or 255. So that is the case of shot noise. But in this bad pixel, this value we have to calculate, so how do we calculate that?

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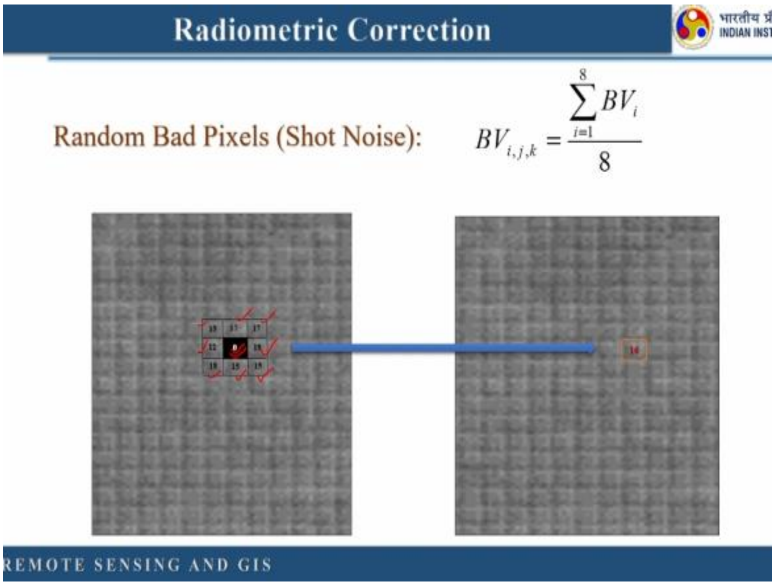

So now here I have put this is some random numbers I have chosen here just to explain you the logic. So this is the value 0 which have been recorded by the sensor, but this was supposed to be some different value. So in that case, what we will do? We will take these surrounding values and then we will calculate the average and then we will replace the central pixel value this 0 value with the calculated value.

So this will be something like 60, so I hope this is you have understood this one this very simple only thing is you have to remember that whenever you are using a remotely sensed images you have to take care of all the errors then only it can be used for your qualitative and quantitative analysis, so next is line start problem.

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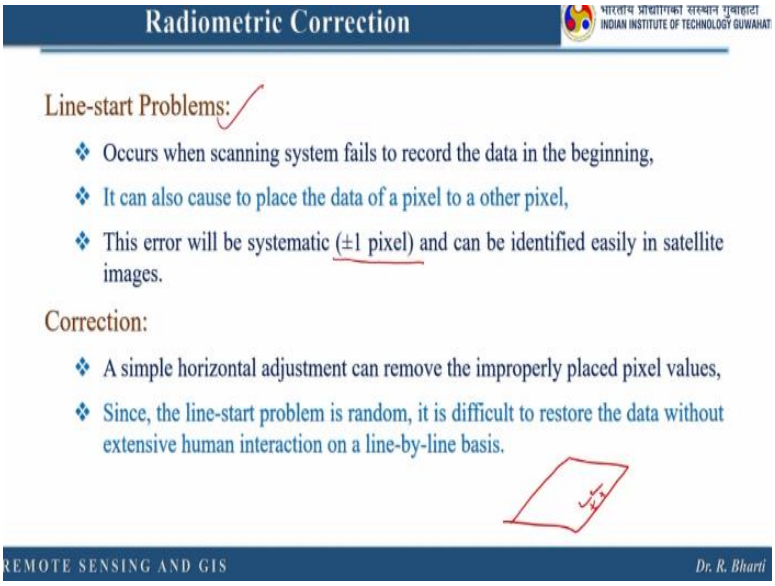

So in line-start problems, what happens the name itself indicate what is happening with the image? So occurs when scanning system fails to record the data in the beginning but afterwards it was working fine, so what will happen there will be some missing pixel in the beginning in the boundaries and then subsequently you will find all the values are present. So there is a problem when image is starting their itself you will have this problem, it can also cause to place the data of pixel to another pixel,

So there will be change in the position. So this error will be systematic plus or minus 1 pixel. So either this will be left side or right side or top or bottom. So depending upon the like problem you have to find the solution. So here what is happening? This is your image which was supposed to be like this and all the values are present in between. So what is happening here? Scanning is done in this particular manner. Let us consider this case scanning is happening in this direction and then sensor is moving in this direction.

So in the beginning it fails to record these 2 values, these 2 pixels, but subsequently all other values have been recorded. So either this will be the case or in other case what will happen? You will have all the values are present except these 2, so and so these 2 pixels will be not present here or this value will be placed here, and this value will be placed here, this value will be placed here. So this can happen. So there will be change in the position location of each pixel in that particular line.

So that is known as line start problem. So, how do we correct this one a simple horizontal adjustment can remove the improperly placed pixel values. So what happens if you just relocate them in their own position then what will happen? Your image will be good. So since the line-start problem is random. It is difficult to restore the data without extensive human interaction on a line by line basis.

So what is happening here when we are having this particular image, but we do not know whether this particular pixel value was supposed to be here but it is placed here right similarly here. So how do we know, so based on the our visual analysis, so we will see all the details in june then we will find that is there any mismatching of the pixels and if there is then we have to run the horizontal adjustment for one pixel.

Because this can go either in the right hand side or left hand side, only it can move to one pixel not more than that then only it comes under this line start.

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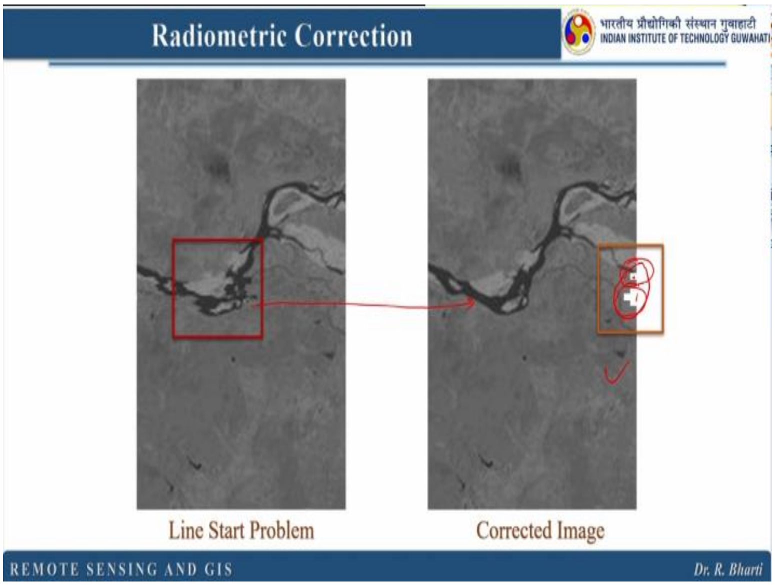

So here you can see this is one example where if you critically go through it, then you will find there is compared to other area, this area looks like little bit more hazy. So what it indicates if this is a river channel so you can see all these boundaries very clearly. But here there is some haziness but it was not supposed to be here because we have we are seeing the same image in the other areas where it is not showing any such behavior, but here it is showing, so there is some problem.

So what we can do? We can just run the horizontal adjustment and then yourself can see this one like how it is appearing. So after the correction, so this is one example before and after correction of line-start, and once you do that, you will have some empty pixel so here again, this is brighter. So what happened after you do the horizontal adjustment? You have to assign some value to the missing pixels.

So here what you can do you can use either 0 or 255 because these values are the safest value, so you will not get confusion with any other pixel and then you can run the averaging here and here or you can replace this particular pixel with this value if you are not involved in quantitative analysis, but this is how you have to correct the line-start problem, next is line or column dropout.

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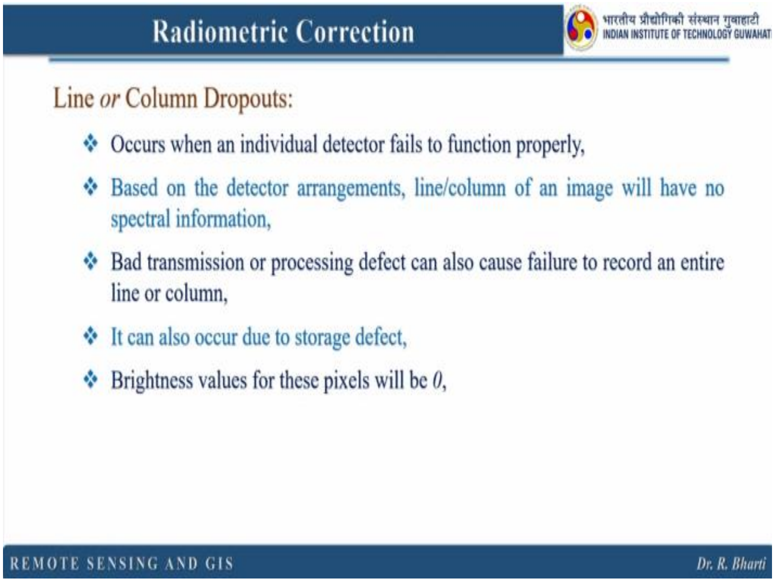

So what do you mean by line or column dropout? There we had some random pixels, random bad pixels. But here it will be like continuous. So it occurs when an individual detector fails to function properly. So here what is happening, you will not have any data for that particular detector. So that particular detector has failed to record the data and that is for the entire scene.

So based on the detector arrangement line or column of an image will have no spectral information. So spectral information means here I am referring DN values because spectral information is generated when you are having different bands for the same area generated from a single detector or sensor then for this particular pixel, you can easily record and you can extract these 4 values right and you can see the behavior of that particular area in wavelength.

So when you are having such problem what will happen? There will be no value here, so in that case you have to find them and you have to replace or you have to estimate some value, so that you can replace those lines or column with the new value, so bad transmission or processing defect can also cause failure to record an entire line or column. So here line or column means row and column.

So it can also occur due to storage defect so there are lots of things maybe your particular detector or the sensor was working fine. But what happens when you are storing it or when you are communicating with the ground station then during that time there may be some signal failure or electronics failure, so because of that also, you may have a particular line or column dropout and here, brightness value of these pixels will be 0.

Again you should not get confused with brightness value DN number is spectral data. So all these are same, so here brightness value of these pixels will be 0, here not maximum only minimum value like in 8-bit data 0 to 255.So here you can find only 0 values. Otherwise if it is not, if it is more than that, there will be some different problem.

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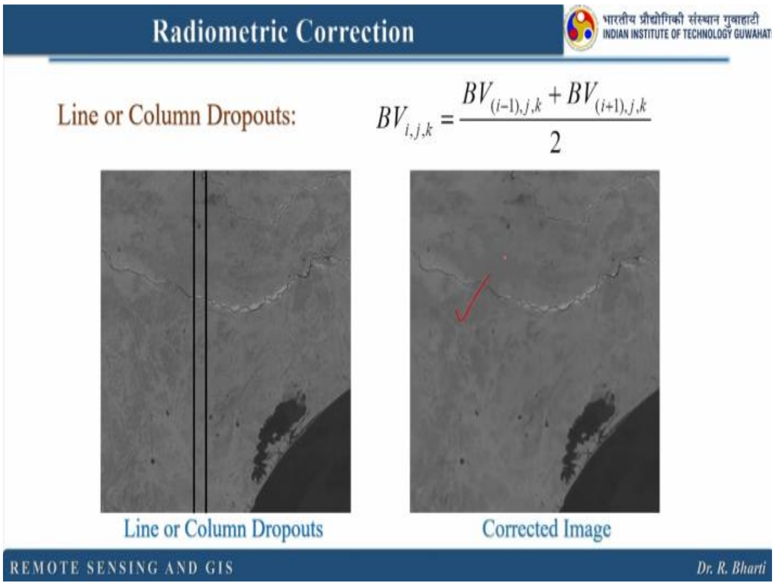

So here this is one example where you can see these 2 particular lines, they are basically line or column dropouts. So I made this line thicker, so that you can see this very easily but when you zoom it, it will be very thin line, why because one pixel just see, just imagine, if this is 1000 by 1000 pixels, so in that case one pixel, what will be the dimension of that pixel that will be lesser than this line. So you have to carefully go through the data before you are going to use it.

So here what we do? We take the preceding and succeeding lines and then takes the average and replaces the central pixels, so then you will find your data is without this particular error.

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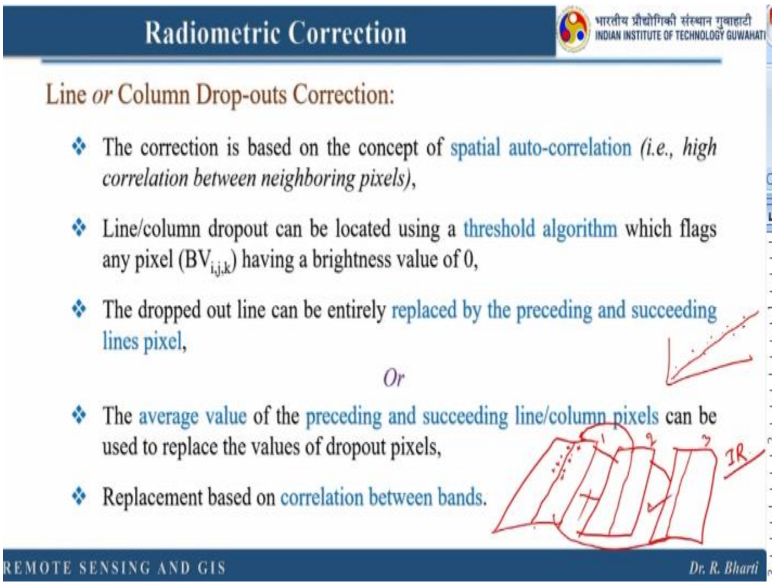

So the correction is based on the concept of spatial auto-correlation and that is high correlation between neighboring pixels. So when you are seeing this particular line here, so there will be some pixels located previous and next to it. So if you see there is a single component which is running from or object, which is running from here to here. So in that case it is very safe to take this particular ratio and replace these bad lines, so but if they are different then it will be difficult.

So the second point says line or column dropout can be located using threshold algorithm which flags any pixels having a brightness value of 0. So, this is very easy. You can just run an algorithm or filter to identify 0 value in your image and then in that matrix, it will find again matrix and image everything is same here. The dropped out line can be entirely replaced by preceding and succeeding line.

So here I have already explained this replaced by the preceding and succeeding lines, Suppose, this is your line or column dropout problem. So you have to take this before or after pixels and then you can simply put all this value here. If this area is homogeneous, then it is fine. Only one pixel you are going to replace with the next pixel value. But in case if you feel that they are different then what you have to do? You have to take this and so this and this calculate the average and then replace in the center.

So that is the next point, the average value of the preceding and succeeding line or column pixel can be used to replace the values of dropout pixels. I hope this is clear to you and replacement based on correlation between bands. So suppose if you find that one image or let me rephrase this particular example when you are having 3 bands in infrared region and one of them is having this line or column dropout and rest of the bands are good. So what we can do instead of calculating these particular pixels average, what we can do is?

We can plot the correlation between these and this right, so you have to plot the correlation, so you will plot all the pixels. So this is suppose band 1, band 2, band 3 and if this is highly correlated, then it is better to use this particular pixel value and then replace it with this 0, now here in the another example, suppose between these 2 bands correlation is very bad, but between this and this correlation is very good.

So then I will use this particular value, this pixel value to replace this 0 which is here, so these are few things. So when we consider replacement, so it is used mainly in homogeneous topography.

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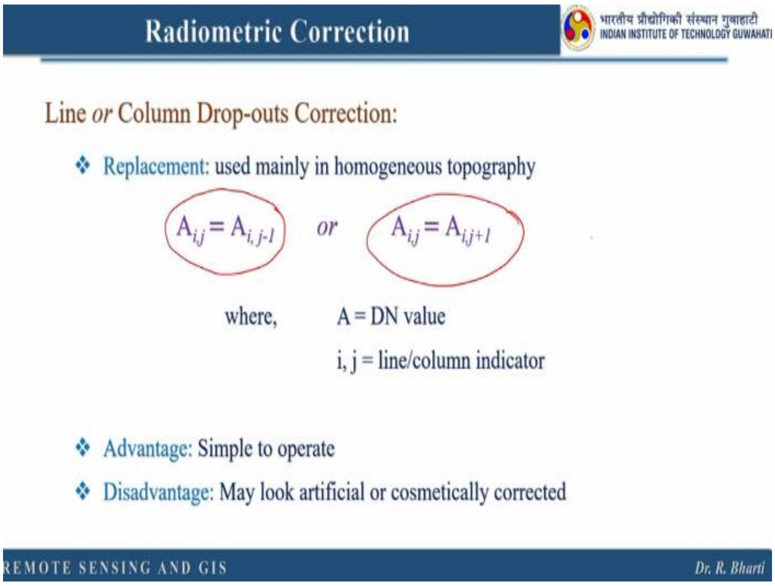

So in case of replacement basically what we do, we replace the preceding or the next pixel values simply to the target pixels, target pixels means those pixels which are having bad values. So and it is simple to operate. This is the advantage and disadvantages may look artificial or cosmetically corrected. So there may be slight change in the variation, so it won't look like very soothing, but it is better to have that value instead of having a black line there, So, because that will create problem in your analysis.

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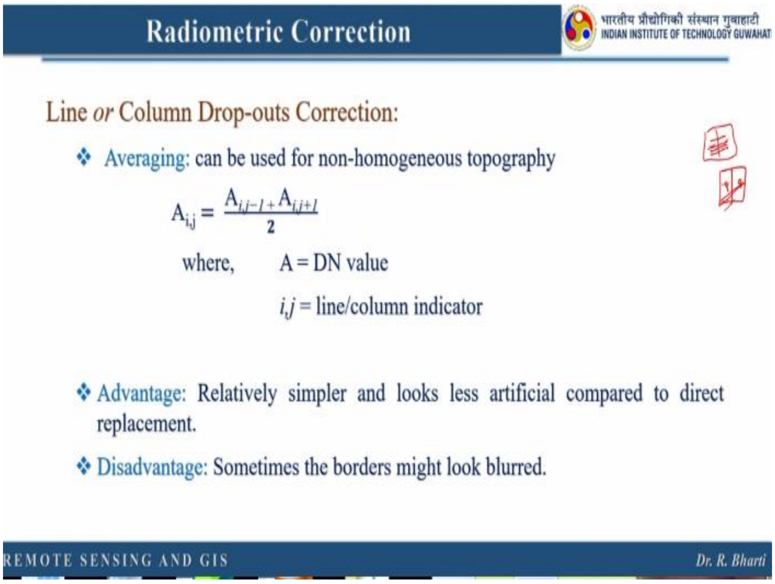

So it is better to use either risk replacement or in case of averaging what we are doing we are taking the previous pixel and the after pixel, so if the location of this particular line is i, j. So either it will be j minus 1, so this one and j plus 1 is this one right? So we will consider this case when we are going to do this averaging and advantage is relatively simpler and look less artificial compared to direct replacement, why? Because you are not going to put the same value, so there will be no change sudden change in the value.

So to regular pixels if they are having same value, then this may appear differently if they are having some continuous value, so here 8, here 9. So this will be more soothing to you, and disadvantage is sometimes the borders might look blurred. So here this is the case because see ultimately when we have measured the image using satellite or a sensor and if that pixel value is missing so we cannot do anything with the sensor or maybe the again measuring those values. If we again measured those particular images, then it is fine.

But suppose if you do not have that flexibility, then what you have to do you have to somehow correct these errors and then you have to utilize in your problem.

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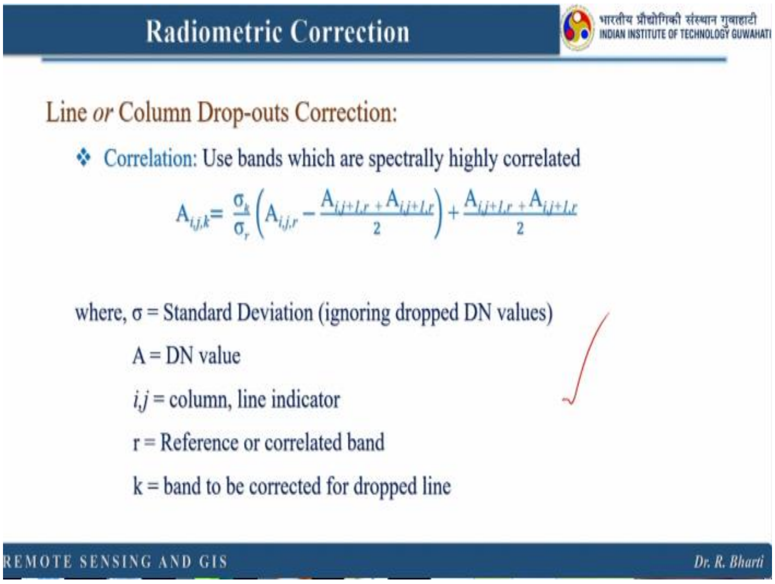

Third one is correlation. So use bands which are a spectrally highly correlated that means here, I have told you between band 1 and band 2 to suppose this is the correlation. So B1 and B2, but between B1 and B3 like this is. So this is negative correlation and then let us say B1 and B4 here it is positive correlation. So it is better to use the line or column value from this particular B4 to replace the bad lines, which is there in B1. So this is the concept when we are going for correlation. So here you can go through this one.

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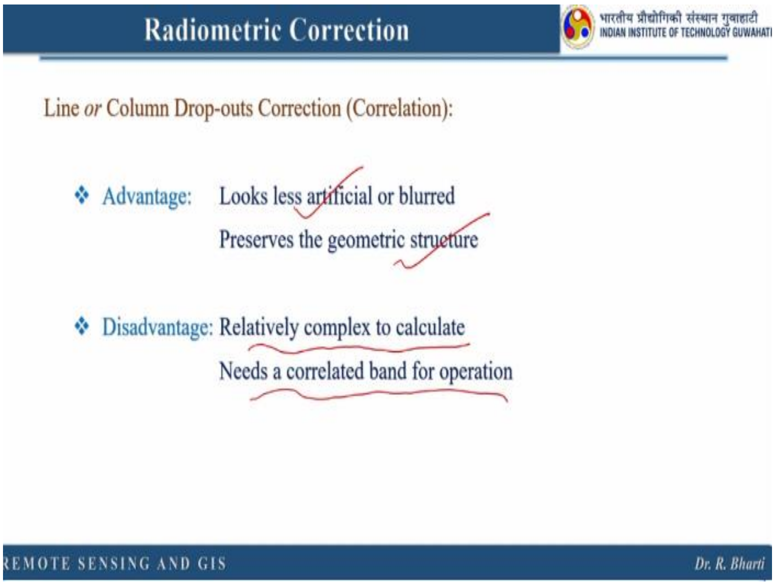

I have already explained the fundamentals. Now the next is what is the advantage and disadvantage with correlation? So it is very obvious like whenever you are going to use correlation and taking out the values from highly similar bands, then it will look very less artificial or blurred. It will be good. Like you have measured it and then preserves the geometric structure of that object and disadvantage is relatively complex to calculate needs a correlated band for operation.

So I have told you that I will use the highly correlated band to extract those values and replace with the zero value, which is there in the line or column dropouts, but if you do not have that particular correlated band in your sensor. So in that case what will happen? You will have some problem and then you have to go for the averaging or maybe replacing with the previous and next lines.

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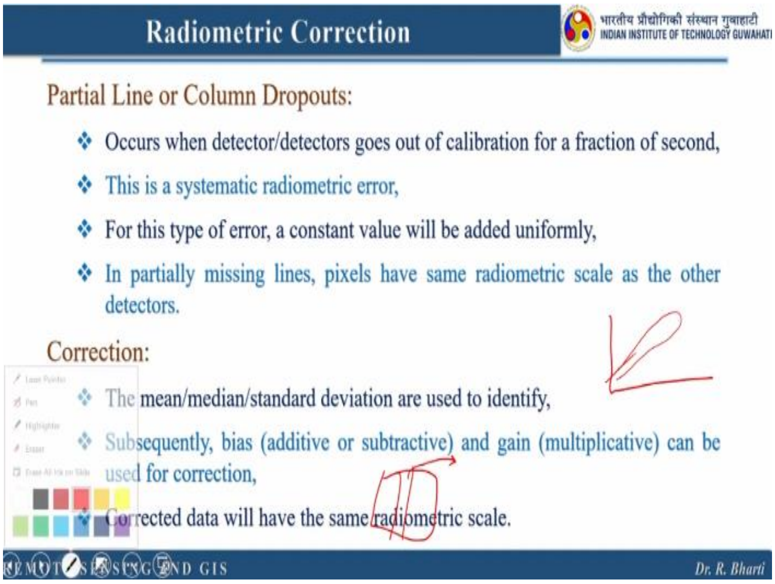

Now next is partial line or column dropout it occurs when detector or the detectors goes out of calibration for fraction of seconds. So here we are not saying that it has not recorded any value. We are saying that it has recorded but that was not in the scale. The scale is basically when you are using a radiometric range, so this is 0 and this is 255. So energy which are very strong in nature, they will be a sign near to this white pixel and energies which are very low so they will be assigned here.

So what is happening here? There will be change in the calibration. So there will be some value, but there will be change in the radiometric. So this is the systematic error again, for this type of error, a constant value will be added uniformly. So here let us assume a image with all these pixels. So this is nothing but a matrix. So what is happening? Let us put some values 13, 12, 6, 9, 5, 8, 6, 5, 6, 9, 8, 7, 6, 5, 4. So we were supposed to get this numbers from this satellite. But what is happening when we are getting this for this particular pixel.

We are having this partial line or column reports. Then what will happen. There will be a constant number which will be added here, so let us assume that it has added 20 or 30 or maybe 100 to this particular number, so you can find easily that there is some abnormal values here compared to surrounding because all are in 8, 9, 10, 11, 13, 14 range, but some of the lines they are having maybe 30, 40 or 20 or maybe 100, 155, 255 these type of difference.

So then you can easily find out that this is because of the partial line or column dropouts. Is it clear? So in partial missing line, pixels have same radiometric scale as the other detector, so here is scale it in 8-bit data 0 to 255, it want to go that value want to go more than 255, so as I told you that if it was supposed to be 8. So 20 or 200 or maybe 10 or 20 has been added, but it should not exceed the maximum value of your radiometric range. So how do we correct this one? The mean median standard deviation can be used here.

So we will identify such line or column dropouts partial line or column dropouts and then how we will correct this one, subsequently bias or bias are basically additive or subtractive and gain can be used for correction. So here you will plot with the surrounding pixel and then you will find the offset and gain bias using this and then you can easily correct those bad pixels, right which are having relatively higher value and corrected data will have same radiometric resolution.

So again the during the measurement, however it having some error but it has limited itself between 0 to 255 in 8-bit data, but after correction also, it should not go beyond your radiometric resolution that means it should be between 0 to 255.

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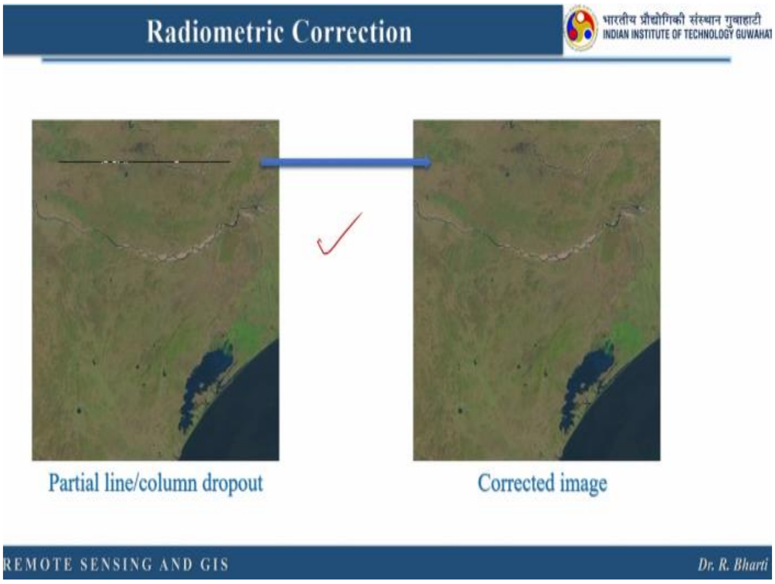

So here this is the example when you are having partial line or column dropout and this is the after correction. So this example I have put just for you to see the changes or to see the problem before correction and after correction. So you will better understand this particular error. Now next is N-line stripping.

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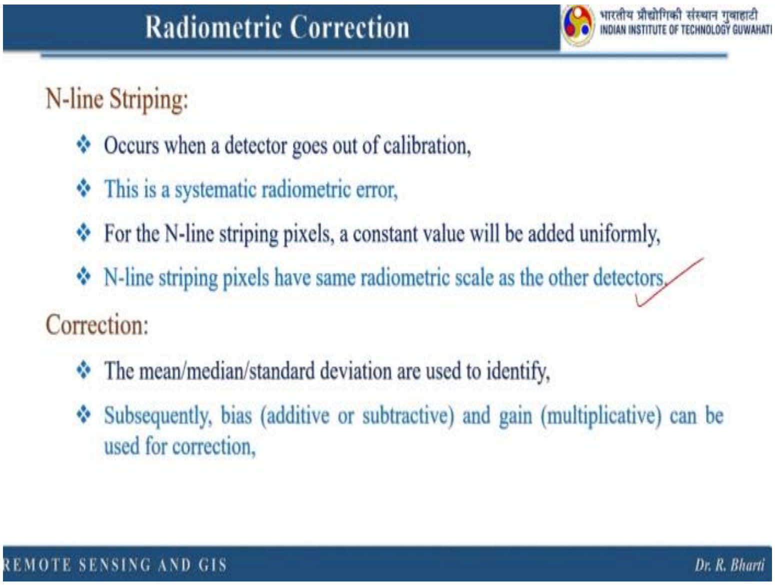

So it occurs when a detector goes out of calibration. So here this is the problem when you are having out of the calibration. So this is a systemic radiometric error, for N-line stripping pixel a constant value will be added uniformly again. N-line stripping pixel have same radiometric scale as the other detectors then correction is again the same.

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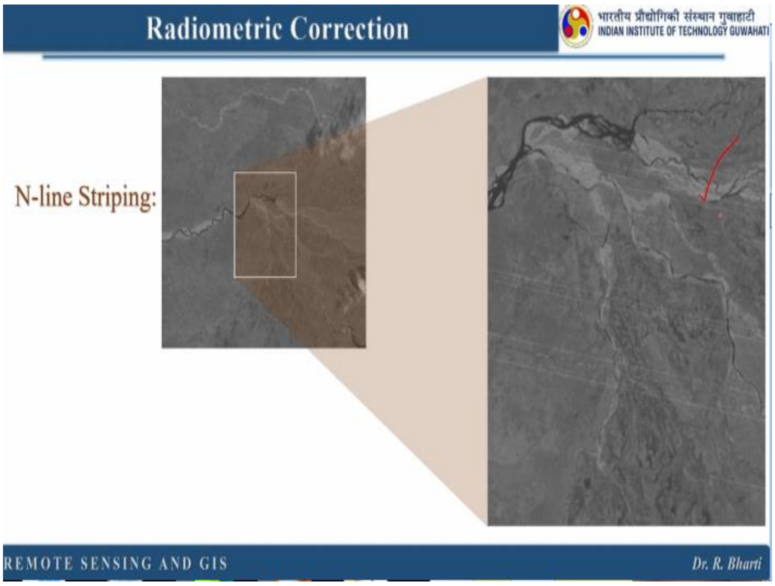

Now here, this is the N-line stripping; now here you can see these lines basically. I hope you can see this one. They are also visible here, but somehow in the zoomed out image, it is not very clear. But still we can say there is some problem. So this is known as N-line stripping. So this is very common if you go and if you download landsat 7 data after 2003 or 2004 you will find this was the problem with that Landsat 7 sensor.

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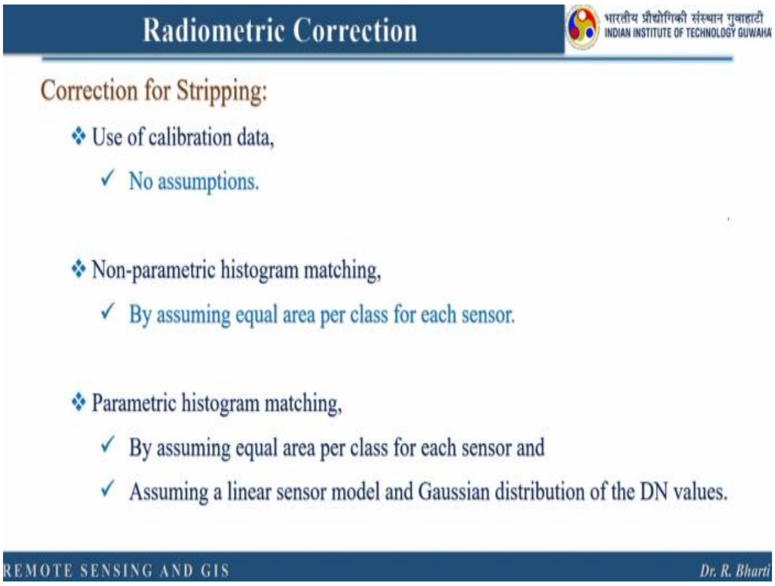

So here, when how do we correct? And what is the advantage and what is the assumption? So here you can see use of calibration data, calibration data of this sensor, then nonparametric histogram matching by assuming equal area per class for each sensor. The next is parametric histogram matching by assuming equal area per class for each sensor and assuming a linear sensor model and Gaussian distribution for the DN values.

So these are some corrections we apply and what is there like basic? What is the logic of that, so that you can understand from here.

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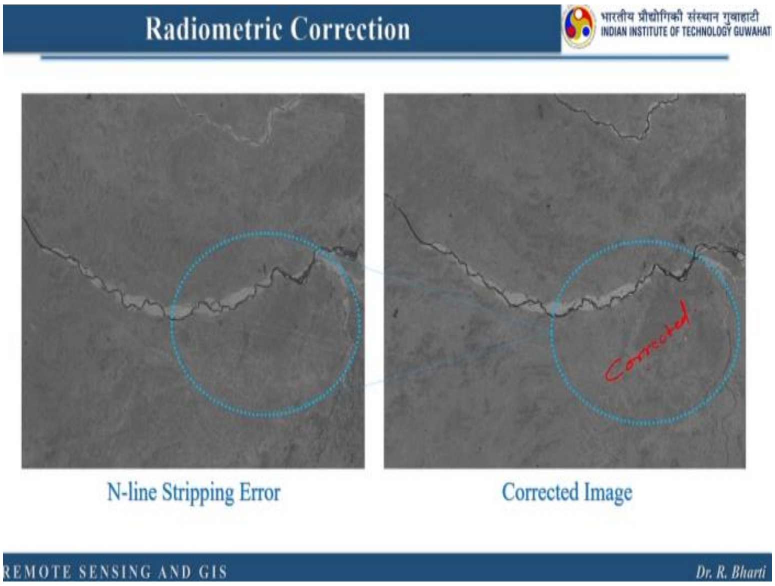

So here you can see this is before correction, and this is after correction. So this is the corrected one, so you can easily see the changes after correction.

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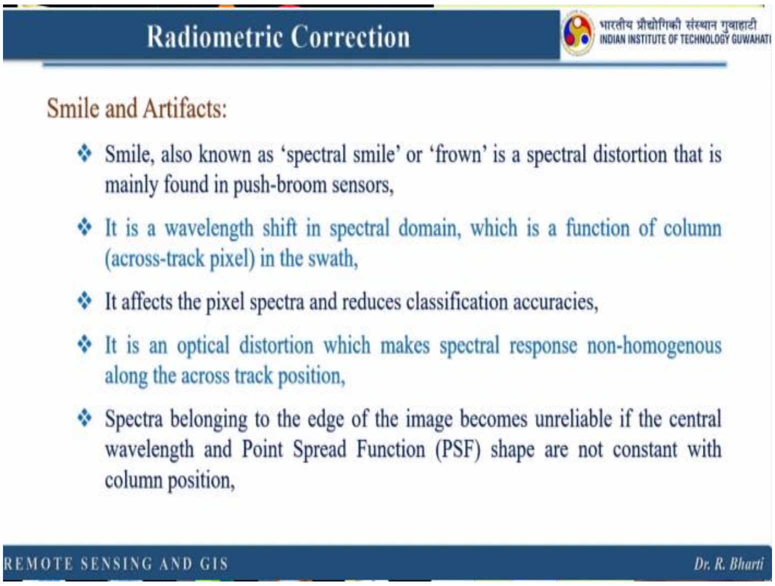

Now there is one very important radiometric error, which is known as smile and artifacts so smile also known as spectral smile. So this is very common in hyperspectral images and spatially in hyperion. You can see such errors and here what it says is smile also known as spectral smile or frown in a spectral distortion basically is a spectral distortion and that is mainly found in push-broom sensor supposed push-broom sensor is here there is the first scanning, second scanning like that It is moving.

So it does not have any oscillating mirror and it is not moving like this. So this is not the case here it is moving forward. So pushing line by line, so it is a wavelength shift in spectral domain which is a function of column across track pixel in the swath. So let us understand this very carefully. So here what it says is there is a wavelength shift in spectral domain. So what is happening during the measurement? So let us draw a vegetation spectra, so which is something like this, this is 0.7 micrometer and this is 2.5 micrometer and this is 0.4.

So in green wavelength, this is the maximum pick which we are able to see but this area we cannot see but in measured spectral response, we can always find what is the behavior of that particular material in other region that is the advantage with remote sensing, now here when you see this particular area, what if you are going to identify this particular vegetation type based on this particular absorption or maybe based on this or let me draw another maybe some spectra which is having this particular behavior. So not this one, this is wrong.

So now, here what is happening based on this particular absorption, we are going to identify that these sets of absorption feature tells like this is the X material but what if because of this sensor problem, what happened this value which was supposed to be recorded in this get shifted here, so here what is happening? Let me redraw clearly so that, so this was the value which was supposed to be here. But because of the problem in the misalignment or the wavelength shift what happened this got recorded here.

So which is wrong, this is wrong because it has to be here. I hope you have understood. Now let me explain in terms of image. So you have let me say three images and this particular pixel, we will consider here. So and this is let us say 0.4 micrometer, this is 0.6, this is 0.8, now how we are going to justify or explain this wavelength shift here. So what happened the value which was supposed to be in band 3 of this pixel got recorded or stored in band 2 in this particular pixel and then what happened this particular pixel value got recorded in band 1 here.

So what will happen? It was supposed to be like this, but what happened? This value got recorded here, so this value will be projected here, this value will be projected here. This will be some other, so this will go here. So based on that, it is changing it is position or maybe up and down depending upon the value. So if suppose, if one absorption feature, we are going to study here. So based on their value only we will identify whether it is a peak or trough and if it is a trough that means essentially it is X object.

But here, if you have this wavelength shift problem what will happen? You will identify some other material instead of identifying the actual material. So it affects the pixel spectra and reduces classification accuracy because ultimately you are going to classify that this is X material, Y materials and Z material but because of this error you miss identified into some other material. So this is a big problem because the whole remote sensing lies on this particular concept.

It is an optical distortion which makes spectral response non-homogeneous along the across track position. So if you see the corrected and before corrected wavelength, so it will have some changes, so that I will explain you, spectra belonging to the edge of the pixel become unreliable if the central wavelength and point spread function shape are not constant with column position. So what is happening? The whole column is getting shifted somewhere else in some other band.

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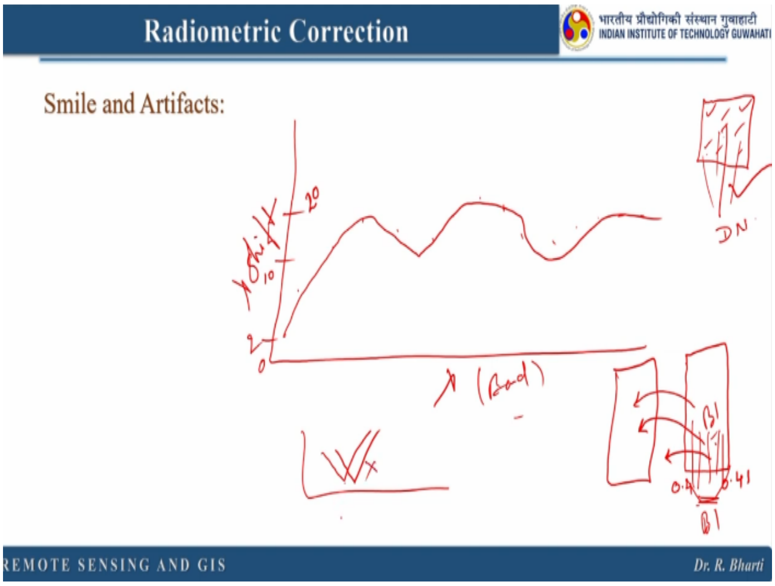

So if you see the corrected spectra and this is the wavelength shift, so this will be the wavelength shift and here you have wavelength or maybe let us call it band. So you will find there is 5, 10, 15 nanometer shift. This is not the measured spectra here we have plotted the shift spectra with respect to different bands. So if there is a change in some particular band, if there is a change of let us say this is maximum in this particular case.

And this is 10 nanometers or not 10 nanometer let me consider this 20 nanometer and this is let us say, this is 10 nanometer. This is maybe 2 and this will be 0 right, so in this scale, so why am highlighting this values because as you know that in case of pixel does not matter the energy is coming from here, here, here, here they will get averaged and there will be only single DN value, right.

So in case of wavelength if you just remember or recall one particular band, which is sensitive from 0.4 to 0.5 micrometer or in this case in hyperspectral images. Let us consider this is 0.41. So there is a gap of 0.01 micrometer. Let us assume if because of this error the energy which was or the in recorded DN numbers which was supposed to be in this band 1. But because of this wavelength shift it got recorded in some other why because this shift is more than this 10 nanometer.

So what will happen this value will be projected here, and then in the spectra this peak which was supposed to be here? It will come in the next band right, because band Y is we extract the values, I hope this is clear to you. So here what I mean to say? We have seen the example of DN values here we get 1 average, so here also, so whatever energy we are getting that will be stored in this particular band.

But in case if the shift is more than that, like if there is a change in the wavelength and which is more than 10 or 15 nanometer and which is more than your bandwidth right. So then what will happen? This will get shifted to some other band and then ultimately you will end up with identifying the wrong material.

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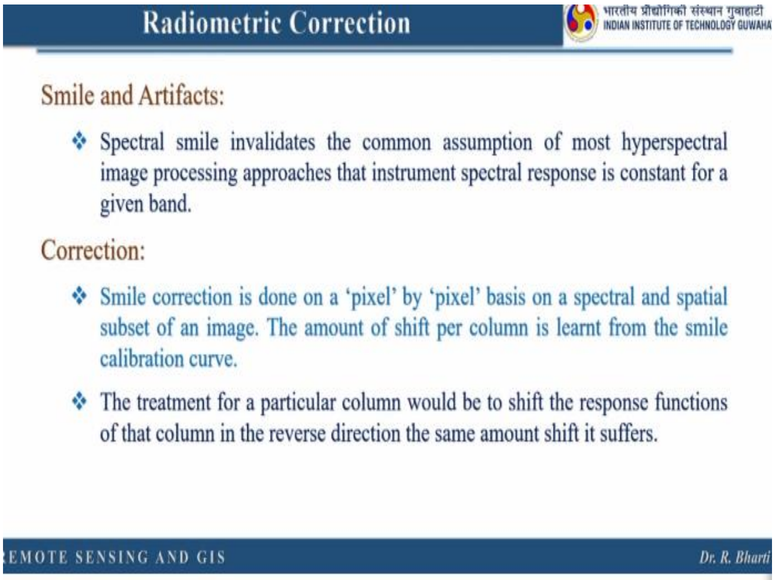

So spectral smile invalidates the common assumption of most hyperspectral image processing approaches that instrument spectral response is constant for a given band or a given material. So here you have understood this and the correction is a smile correction is done on a 'pixel' by 'pixel' basis on a spectral and spatial subset of an image. The amount of shift per column has learned from the Smile calibration curve.

And the treatment for a particular column would be shift the response function of a column in the reverse direction the same amount shift is suffered. So here basically what is happening, we are going to correct this pixel by pixel. So, how do we correct?

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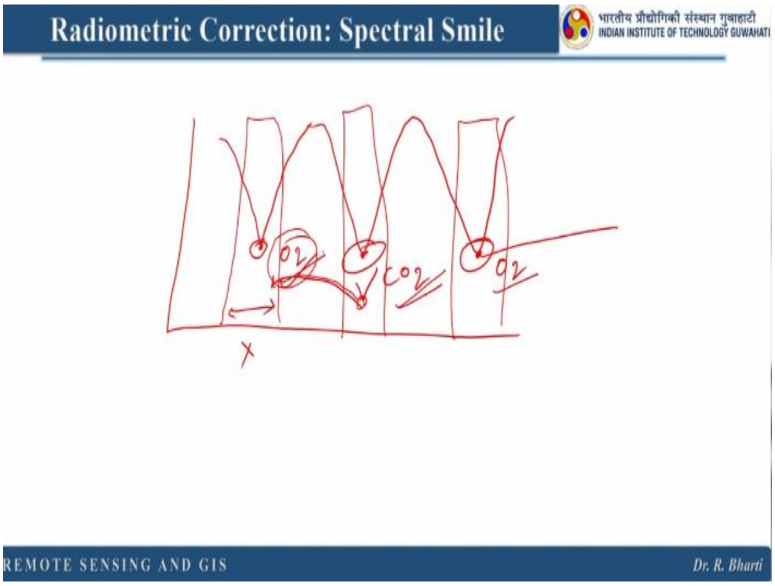

So I will tell you few examples or if you remember the atmospheric window right where we know, there are certain gases which absorb in certain wavelengths, so these are the errors. So let us say O2, CO2, ozone or again O2. So these are the fixed wavelength of this oxygen, carbon dioxide. But here we are not going to use this in our study if you are going to do it or if you are going to use this image for any surface analysis, but for atmospheric people, these are the data set.

So now here these absorptions suppose let us say that this was the band of your image. So you will have this problem and you will correct this in atmospheric correction. So but here these wavelengths are known. So what we will do? We will use this as a standard like if this particular X band which was supposed to be in this particular wavelength and does not have this oxygen absorption feature, then there is a possibility that it got shifted in other wavelengths.

So what we will do we will find this particular absorption in the other one and if we found like okay, this is coming here and which was supposed to be here. So we will use all these signatures of oxygen, carbon dioxide and ozone and we will recalibrate the wavelength.

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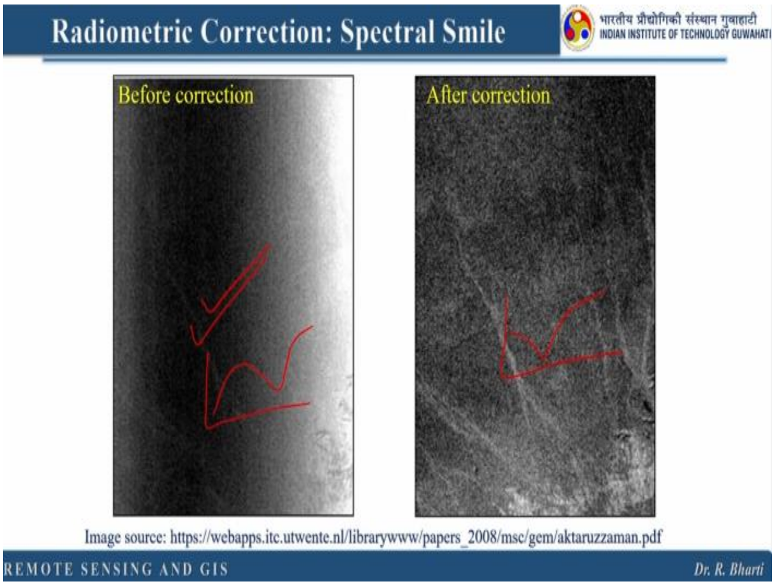

So like this we are calibrating the wavelengths, so here before correction, this was not having any information but after correction, we are having this, so here if you plot, this will be something like this which was supposed to be like this, so this is one example and this is taken from this particular thesis, you can also go through it.

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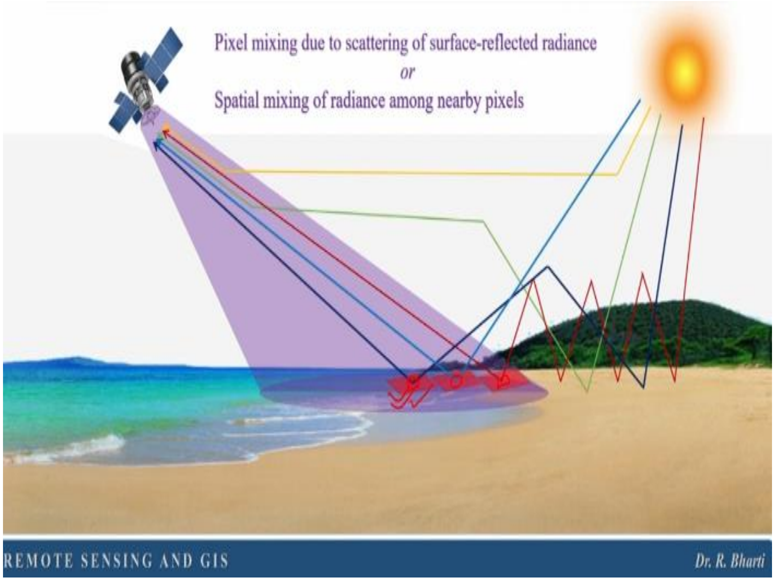

Now, next problem is adjacency correction. So adjacency effect is basically this is very critical. Now, you have to understand this particular case, in this particular case, what is happening sun is illuminating our surface and a sensor is active in this particular area and it is measuring the energies which is coming from different sources, so what is happening suppose if you have a pixel and they are lying next to each other.

So the energy which got reflected from this particular position or this particular position and this particular position may get changed with each other. We are talking about a particular wavelength. So in a particular wavelength, there is a possibility that next pixel target will illuminate more or less and that may get mixed with my target pixel. So this is the problem from adjacent pixels. So that is because of the more scattering. So this happens when there is a sudden change in the brightness value.

So if there is a sudden change in the brightness value sensor cannot resolve immediately and then that value may get recorded for the other pixel and that will be added value. So that is the problem with the adjacency. Now, we will discuss more about this in hyperspectral section. So here this is the pixel mixing due to scattering of surface reflected radiance. In other words, spatial mixing of radiance among nearby pixel, so this is one problem and I will end my lecture this radiometric correction here and we will see in the next class. Thank you.