Remote Sensing and GIS
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Lecture - 04
Error Identification and Correction-I

Today you will learn more about error identification and correction in remotely sensed images. In my last lecture, I have given you the brief introduction about the error associated with remotely sensed images. In this slide, we will quickly go through the sources of such errors.

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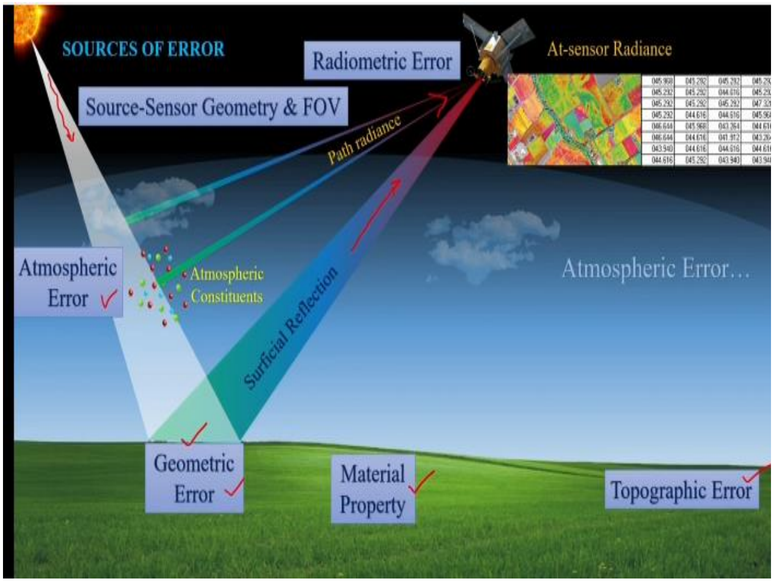

So as we all know that sun is our source of energy, in case of passive remote sensing. So here, sun is illuminating the surface and which gets reflected or emitted or backscattered from the surface and which reaches to our sensor which is located in the space. So this particular energy which is coming from the sun it has to travel through the atmosphere to our surface and then it has to back travel to space through our atmosphere.

Here, first thing is source-sensor geometry, that we have already covered in the last lecture that what do you mean by source-sensor geometry and field of view and what is the impact of these two on the remotely sensed images and what kind of error they can introduce to your data.

In this case, we assume that our atmosphere is opaque; there is nothing to interact so everything is coming and going back to this particular sensor.

But we have atmosphere where we have clouds and different atmospheric constituents. They introduce atmospheric error and here you can see because of this path radiance additional information or the value is being recorded by the sensor, which is located in the space. This error is known to us. Now there is a new error which is called radiometric error. So this error is related to your instruments. So errors introduced by your instruments.

So here an instrument means our sensors, so what kind of errors it can introduce that we will see in the detail. Now from all this measurements we have an image and DN number and DN numbers are basically the radiant flux from the surface. Now here we have another component called geometric error, so geometric error also a part of this error associated with remotely sensed data. Now material property also plays very significant role and the last one is topographic error.

So topographic, because of the undulating surface what kind of error it can introduce to your remotely sensed data. Now, we will continue with atmospheric error.

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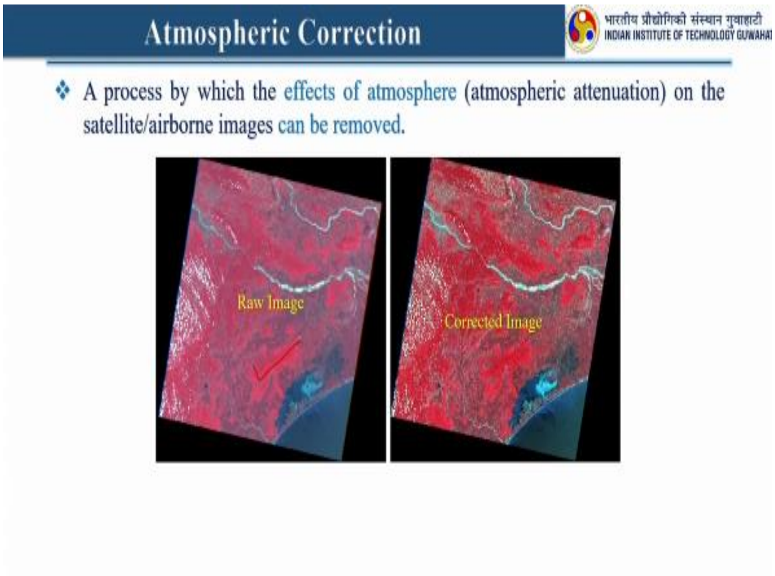

Atmospheric correction is the process by which the effects of the atmosphere on the satellite or airborne images can be removed. So here remember when we are talking about atmospheric correction. So atmospheric correction or atmospheric error is always associated with your space based measurement as well as your airborne measurement. So here you can see this is one example, this the raw data recorded by this sensor and this one is the corrected image.

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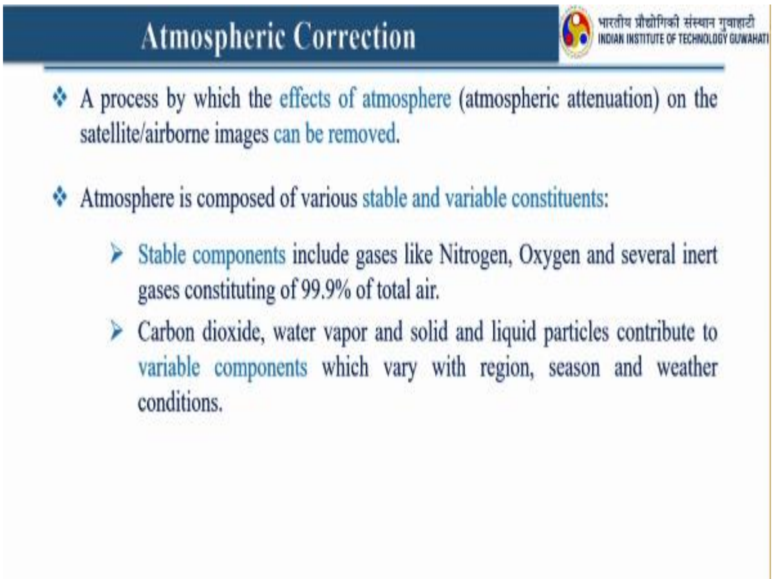

Atmosphere is composed of various stable and variable constituents, so one of them is stable components which include gases like nitrogen, oxygen and several inert gases constituting of 99.9% of total air and the other one is variable components like here we have carbon dioxide, water vapor and solid liquid particles which contribute to this variable components and which vary with region, season and weather conditions.

The suspended liquid and solid particles are generated from volcanic eruptions, sand storms, forest fires, industry, transportation, construction etc. So here there are many components which are involve contributing these variable components to our atmosphere. These are called aerosol which include haze, smoke and fog.

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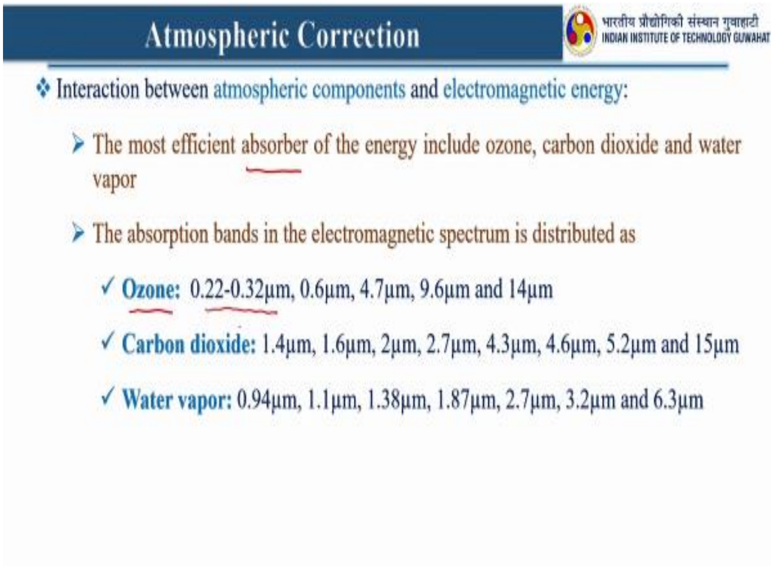

So interaction between atmospheric components and electromagnetic energy, here the most efficient absorber of the energy include ozone, carbon dioxide and water vapor. So these 3 are the most efficient absorber. The absorption band in the electromagnetic spectrum is distributed as so here what I mean to say, that for ozone carbon dioxide and water vapors what are the wavelengths which are sensitive.

Sensitive means in which wavelength basically the signatures of the ozone, carbon dioxide and water vapors are actually significantly visible in our recorded data. If you see here for ozone, here we have first range that is 0.22 micrometer to 0.32 micrometer then we have 0.6 micrometer, then we have 4.7 micrometer, 9.6 micrometer and 14 micrometer. So if you have a satellite which is sensitive in these particular wavelength reasons, then you can easily find the signature or the presence of ozone in our atmosphere.

Because in these regions or in these wavelength regions the ozone will give its own characteristic absorption features or interaction signatures. Now the next one is carbon dioxide. So here you have 1.4, 1.6, 2, 2.7, 4.3, 4.6, 5.2, 15 micrometer. In case of water vapor you have all these wavelengths where this wavelength, water vapors signature can be identified.

So as I told you in my first lecture initially when we started remote sensing then we considered all these wavelengths like an error. Like if your sensor is sensitively all these wavelengths you cannot really use those images for any qualitative or quantitative analysis. But now-a-days with the advancement in the technology these wavelengths are actually useful for a atmospheric scientist.

Correction of molecular absorption and scattering by the stable components are easy since they are not variable in space and time. So here you can see the correction of molecular absorption and scattering by the stable components, so it is not very difficult because all the components are known, all the absorption features are known. So you can easily identify their concentration in the remotely sensed image and you can remove their effect.

But the problem lies with the variable components, where you do not know what the proportion of the carbon dioxide or other gases which are emitted by the local industry or from the any other local sources. Atmospheric correction mainly involves estimating the influence of water vapor and aerosol.

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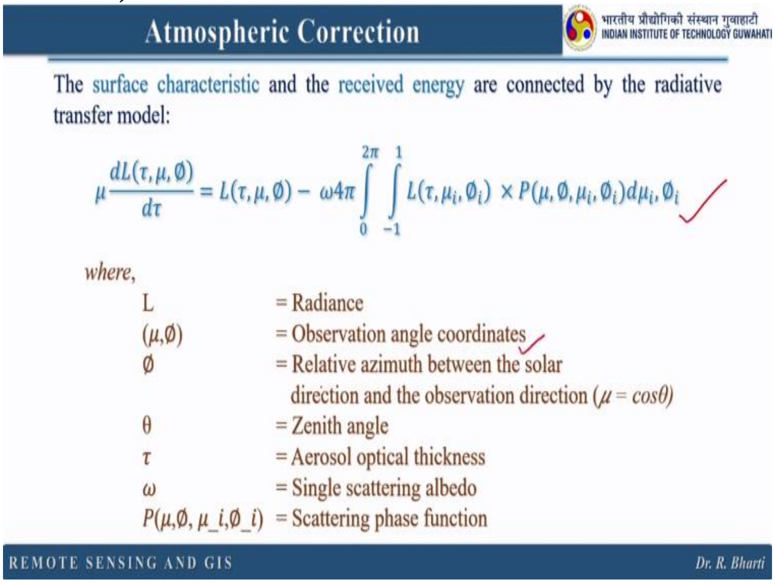

so here the surface characteristics and the received energy are connected by the radiative transfer model. Where this equation explains the relations between surface characteristics and the received signal by our sensors, where L is your radiance, then we are also using observed angle coordinates then relative azimuth between solar, then solar direction and the observation direction where mu is cos theta, where theta is the zenith angle and aerosol optical thickness, single scattering albedo, scattering phase function.

So all these parameters are used to define the surface characteristics and its emitted signal or reflected signal which is sensed by our sensors.

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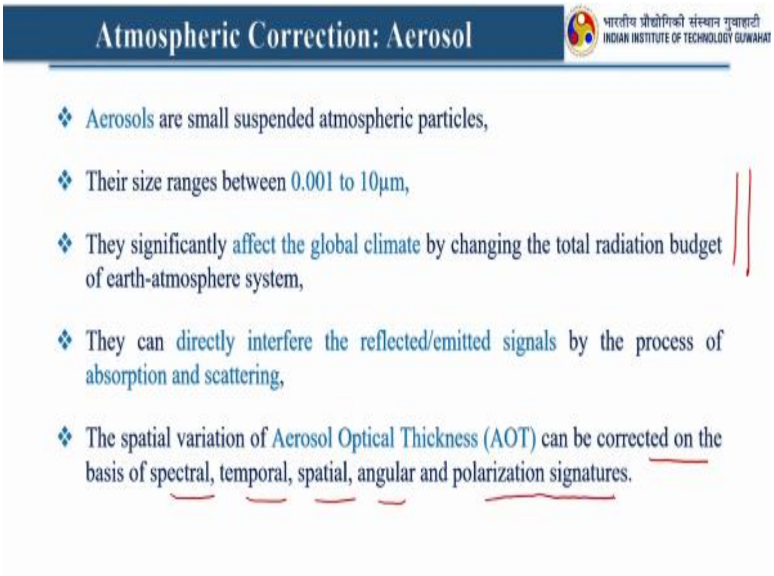

Aerosols are small suspended atmospheric particles, their size ranges between 0.001 to 10 micrometer, so it is very small. This significantly affects the global climate by changing the total radiation budget of earth-atmosphere system and now we will see how this aerosol is going to affect our life as well as our remotely sensed images. And they can directly interfere the reflected or emitted signals by the process of absorption and scattering.

So the spatial variation of AOT that is aerosol optical thickness can be corrected on the basis of spectral, temporal, spatial, angular and polarization signatures which is measured from the remote sensing technique.

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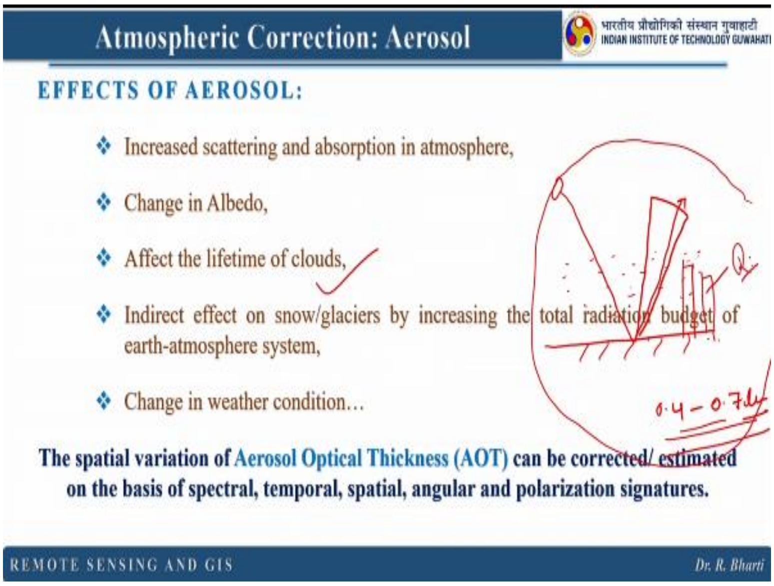

So effects of aerosols, what kind of effect may cause or it is causing, so first one is increased scattering and absorption in atmosphere. So if you are working in a shorter wavelength, working in shorter wavelength means, if your sensor is sensitive in shorter wavelength, then you will have more problem from this scattering and absorption. Then it can also change the albedo of the surface.

So albedo is basically the broad band reflectance of the surface. So broad band albedo if you see this is your surface, this is the source, it is illuminating your surface and light is getting reflected, so in case if you have more haze here or aerosol. So what will happen, this measurement when we refer albedo, albedo is the broadband reflectors and it also affects the lifetime of the cloud, then indirect effect on snow, glaciers by increasing the total radiation budget of earth-atmosphere system.

So basically what happens, these aerosols can also trap the heat coming from the sun, which is, and they are not allowing again go back to the atmosphere, so what is happening this is ultimately changing the total radiation budget of earth-atmosphere system and change in weather condition that is again a result of the presence of aerosol. Now the spatial variation of aerosol optical thickness can be corrected or estimated on the basis of spectral, temporal, spatial, angular and polarization signature that now we will see.

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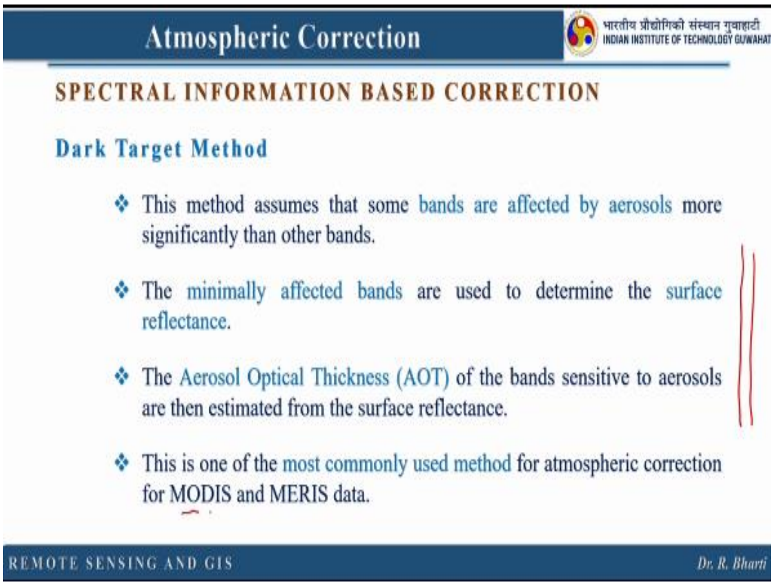

So let us start with the spectral information based correction, where we have Dark Target method and this method assumes the some bands are affected by aerosol more significantly than other bands and where the minimally affected bands that means less affected bands are used to determine the surface reflectance and the aerosol optical thickness of the band sensitive to aerosol are then estimated from the surface reflectance.

So these are very simple statements. I hope you can understand easily. This is one of the most commonly used methods for atmospheric correction for MODIS and MERIS data. So here this is one type of sensor which is available the data is available with us and you can easily go to their website register yourself and download these data sets.

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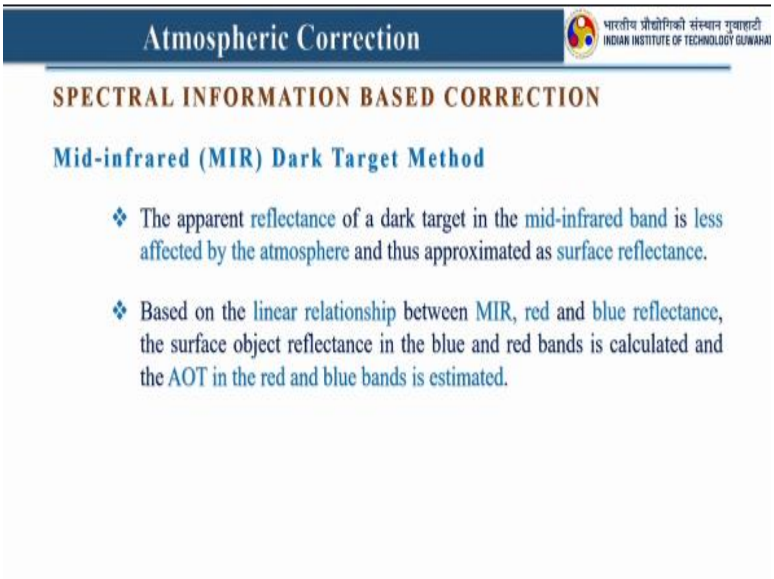

So now next is spectral information based correction, so here you have mid-infrared dark target method, so the apparent reflectance of a dark target in the mid-infrared band is less affected by the atmosphere and thus approximated as surface reflectance. Based on the linear relationship between MIR, red and blue reflectance the surface object reflectance in the blue and red band is calculated and the AOT in the red and blue band is estimated. So now here you can estimate the AOT from this particular relationship.

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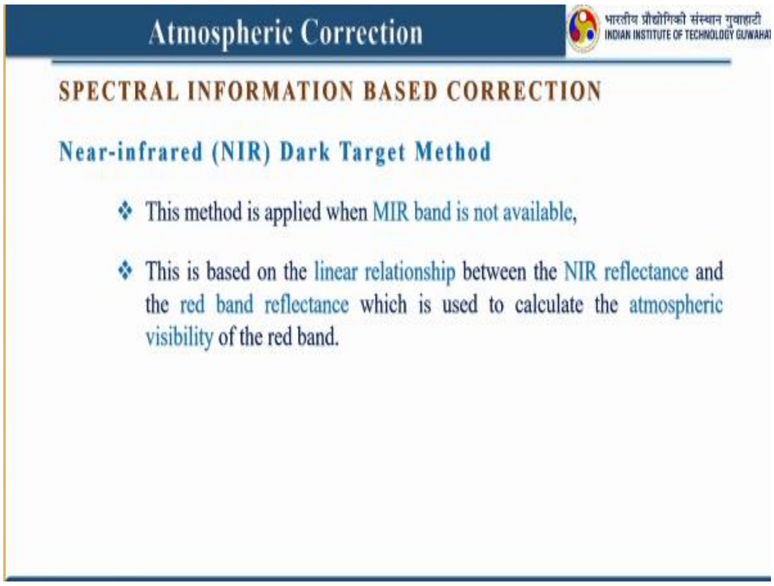

Now next is Near-infrared dark target method, where this method is applied when MIR band is not available, so you have to remember that different satellites have different configuration and their capable of handling or measuring different bands in different wavelength reason. So it is not necessary that X sensor can give you 5 bands so that Y can also give you 5 bands, no and that too in particular wavelength range.

So you have to check their technical specification if you are checking for the X satellite and you are seeing that 0.4 to 0.5 is your first band and then 0.5 to 0.6 is your second band and 0.6 to 0.7 is your third band. So this is the configuration of your X sensor. But if you see the Y sensor, so here I will change this to 3, and here let us also change with this 3. Now this Y sensor can have first band in this and it may not require this one.

So depending upon their technically specification, the first band of Y sensor may be this one, which is the second band of X sensor. So you have to check it your data whether the data is having the MIR band or not. If you are having MIR band, then you can use the previous method if you do not have, then you have to find the alternative solution. So this is the alternate solution. So this method is applied when MIR band is not available.

This is based on the linear relationship between the NIR reflectance and the red band reflectance which is used to calculate the atmospheric visibility of the red band.

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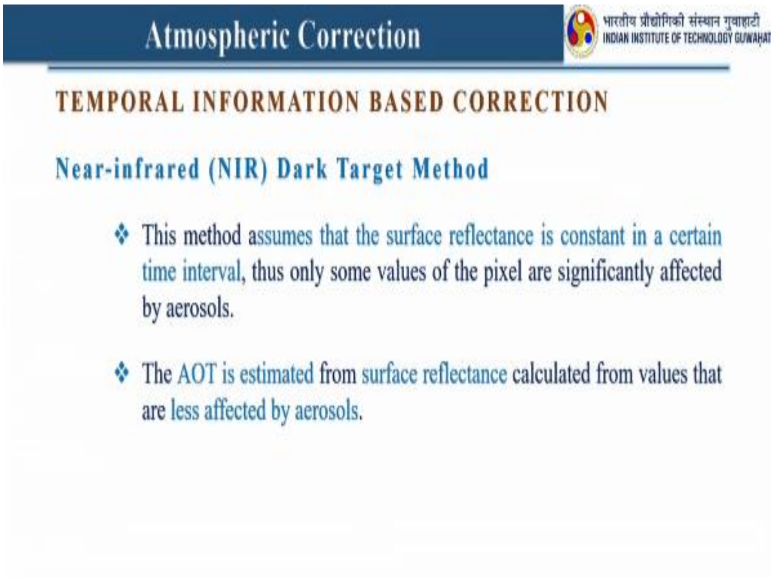

Now the next one is near-infrared. So the method assume that the surface reflectance is constant in a certain time interval, thus only some values of the pixels are significantly affected by aerosols. The AOT is estimated from surface reflectance calculated from values that are less affected by aerosols.

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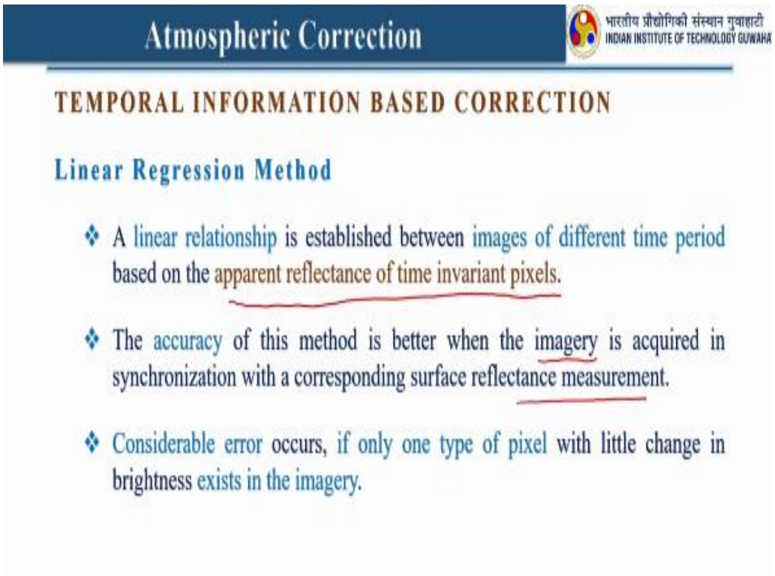

So here you have linear regression method. So a linear relationship is established between images of different time period based on the apparent reflectance of time invariant pixel. So here this is very important, that means pixels which are not going to change with time does not matter what is your weather conditions or what is the other parameters. So you have to find those pixels which are not going to change with time.

The accuracy of this method is better when the imagery is acquired in synchronization with the corresponding surface reflectance measurement. So here what it means when you are going to measure this images from satellite the same time you have to take your ground instrument and go to the field and the time when satellite is going to pass that area and the same time you have to measure the reflectance value on the surface.

So then what will happen, all the parameters remain the same and then you can correlate these 2 data sets. Considerable error occurs, if only one type of pixel with little change in brightness exists in the imagery. So here what does it means? Only one type of pixel, so one type of pixel means the whole area is homogeneous. Only one type of material is present, then you may face some problem and the error will be more.

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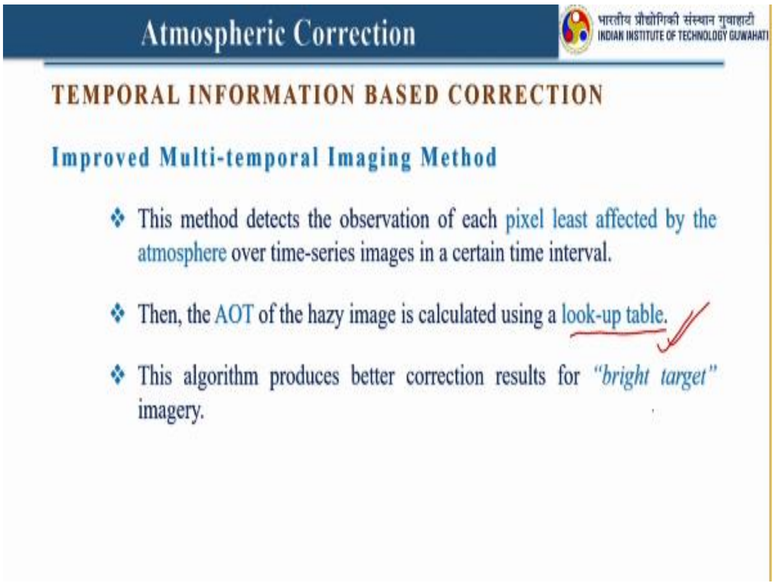

So next method is improved Multi-temporal imaging method where this method detects the observation of each pixel least affected by the atmosphere over time series images in a certain time interval. So we are talking about the temporal images. Then the AOT of the hazy image is calculated using look up table. So look up table is basically a table generated from your image which has all the parameters in tabular form.

So whatever calculation you are going to do are the linear relationships you are going to establish that you will do it in the tabular form not on the image. So, if you change any value here that can be removed or added later on in your image. So in this case your image the raw data will be preserved. This algorithm produces better correction results for bright target imagery. So if you are having bright target image this particular method works very well.

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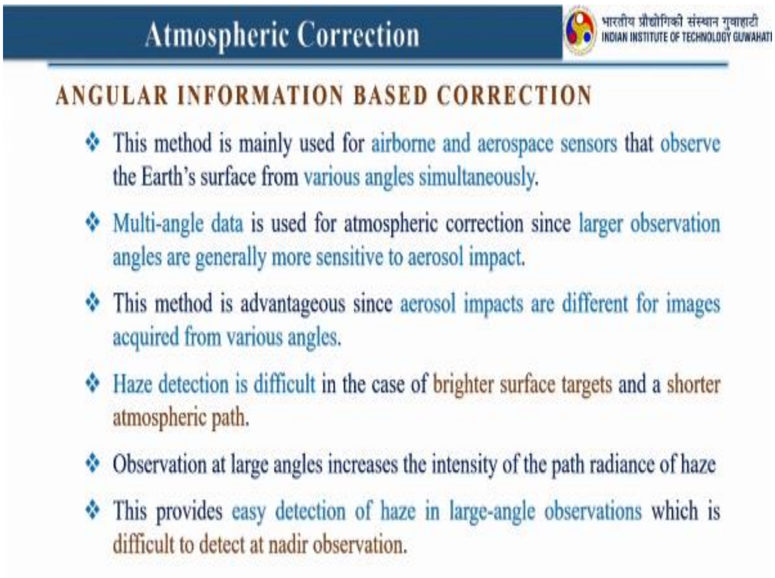

Next is angular information based correction, where this method is mainly used for airborne and aerospace sensors that observe the earth surface from various angles simultaneously. So multi-angle data is used for atmospheric correction, since large observation angles are generally more sensitive to aerosol impacts. Why? We will understand. This method is advantageous since aerosol impacts are different for images acquired from various angles.

Haze detection is difficult in the case of brighter surface target and a shorter atmospheric path and observation at large angle increases the intensity of the path radiance of haze and this provide easy detection of haze in large-angle observations which is difficult to detect at nadir observations.

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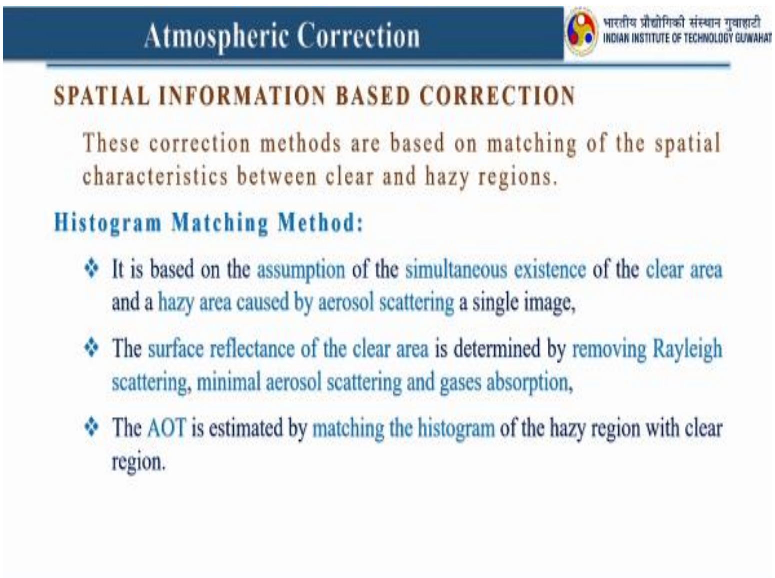

Next is spatial information based correction, here these correction methods are based on matching of the spatial characteristics between clear and hazy regions. So here for the same area for the same scene, you will have two types of images, so within image two types of area. So one is highly affected with this haze and one is very clear. So you do not have any problem from the atmosphere or I would say aerosol.

So the first method is histogram matching method. It is based on the assumption of the simultaneous existence of the clear area and a hazy area caused by aerosol scattering in a single image. The surface reflectance of the clear area is determined by removing Rayleigh scattering, less aerosol scattering and gases absorption. The AOT is estimated by matching the histogram of the hazy region with clear region.

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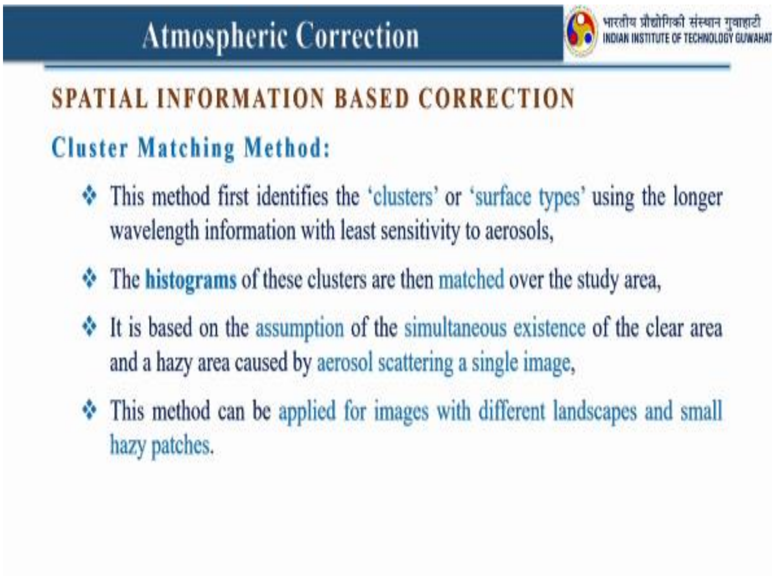

Next is a cluster matching method, in cluster matching method basically it identifies the clusters or surface types using the longer wavelength information with least sensitivity to aerosols. So what you mean by the clusters? Basically the clusters are you have a image and you have a pixel values. So basically you have matrix and these matrix are having some numbers like X1, X2, X3 and X4 you can write.

And then based on their values you can group them into different clusters, so that is what cluster means here, so here clusters are the values derived from the images. So the next point is the histogram of these clusters is then matched over the study area. So histogram for any histogram what is the X and Y axis, so X axis is your value, so in this case, it will be DN value and Y is always our frequency. So from this matrix you will have to identify the unique values, so let us say this is X, X series and then Y series then Z series.

So here we have X, Y and Z these are unique values from this particular matrix. So what is the frequency of this X, Y and Z.? So I will give you some real example like if you have 8 bit data where the range of the value is 0 to 255. So you have to find out how many times this 2 DN number has occurred, so instead of X, I can write 2 and then it might have occur may be 1000 times, depending upon the size of your image then Y is here, Z is here, so like that you will have the histogram.

So if you see the histogram, ideally histogram always we represent in Gaussian form where we say that all the values range starting from 0 to 255 in case of 8 bit data. This particular histogram has occupied the full range and all the values are equally distributed but it does not happen in the natural case, so what will you have? You may have 2 different types of peaks here, so this is known as uni-model, this is known as bi-model.

You may have 3 or 4 or 5 or 10 peaks depending upon on the range of the value and the distribution of the values, so here the histogram refers to this particular distribution of the DN values. Next point is, it is based on the assumption of simultaneous existence of the clear area and a hazy area caused by aerosol scattering in a single image. This method can be applied for images with different landscape and small hazy patches, so that means in the whole image, you have small pockets where you have the effects of more aerosol or haze.

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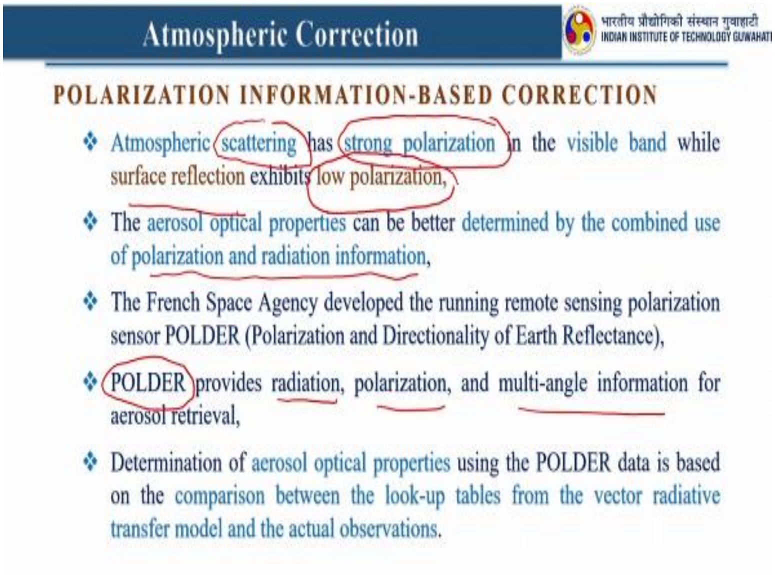

Next one is polarization information based correction. So here the Atmospheric scattering has the strong polarization in the visible band, while surface reflection exhibits low polarization.

So that means if you have scattering effect in your data, you will have strong polarization in your data. Whereas the surface reflectance from the surface or from the target that represents or that has very low polarization.

That means, if you can identify the strong polarization and low polarization then you can easily identify the effect of scattering in your data and that is due to atmosphere. The aerosol optical properties can be better determined by the combined use of polarization and radiation information, right. The French Space agency developed the running remote sensing polarization sensor POLDER and it provides radiation, polarization and multi-angle information for aerosol retrieval.

Because now-a-days aerosol is the very important parameter which atmospheric scientists are studying, because it is changing our climate. So that is why now you see the dedicated satellite which can give you information about radiation, polarization and multi-angle information for aerosol retrieval. It determines the aerosol optical properties using the POLDER data is based on the comparison between the look-up table from the vector radiative transfer model and the actual observation.

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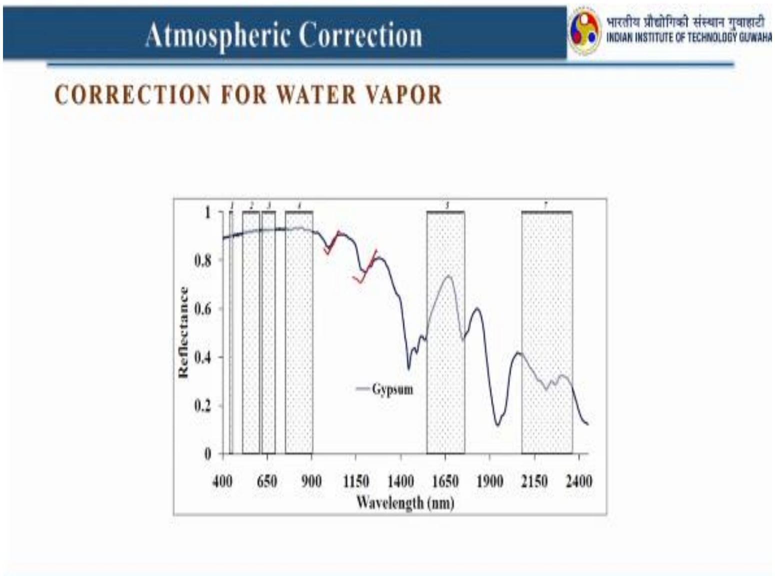

This is the spectrum of gypsum and here you can see, there are many troughs, trough means where you have depressions and you have many peaks. So it also depends whether your satellite is sensitive in that particular wavelength range, where you are intended to identify some error or some information. So for example, here this is in case of Landsat, you can find out that first band belongs to this particular area.

Second is this, third is this, fourth is this, fifth is this, seventh is this and you can see there are many features which are not covered by this particular sensor. Why? Because that sensor does not have any band in this particular wavelength region. So you can only study those information which are available in this particular band. So now here this 1.4 micrometer and 1.9 micrometer that is coming because of the atmospheric water.

So you can see that during the design or designing of this particular sensors, people have taken care of this wavelength and so that they did not put any band here. Why? Because that will be mostly affected by your atmospheric water so, that means the objective of this particular sensors launch was something different to study the surface behavior or surface characteristics. So in case if an atmospheric scientist develops a sensor then he will definitely put a band here and here.

So this is what I wanted to convey that if you want to correct for the water vapor or for any error and that is having a characteristics absorption feature in case of water vapor it is here and here. So you should have a sensitive band or sensor which is sensitive in that particular wavelength region. Then only you can try removing the effects of those components. So the removal of water vapor effects is important in the quantitative application of the near-infrared and mid-infrared remote sensing imagery.

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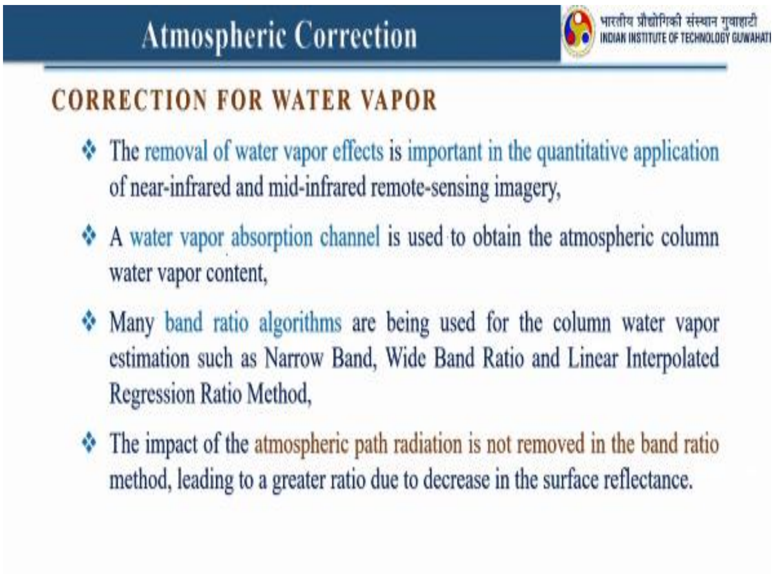

That you have understood because that is going to contribute more error in your measurement. So a water vapor absorption channel is used to obtain the atmospheric column water vapor content that means a water vapor absorption channel means, here I am talking about the bands, is used to obtain the atmospheric column water vapor content. So what is the content of the atmospheric water vapor? That you can estimate using the wavelength bands.

Many band ratio algorithms are being used for the column water vapor estimation such as Narrow Band, Wide Band and Linear Interpolated Regression Ratio Methods. The impact of the atmospheric path radiations is not removed in the band ratio method, leading to a greater ratio due to decrease in the surface reflectance.

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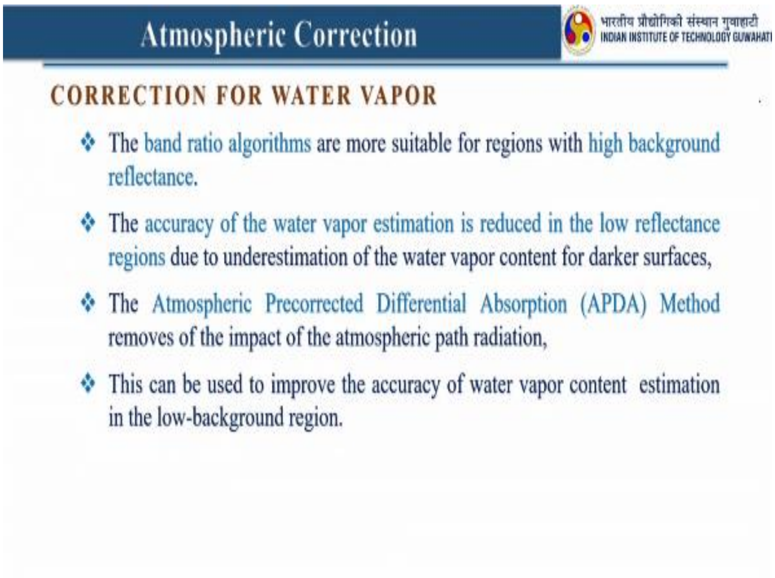

Then, the band ratio algorithms are more suitable for regions with high background reflectance. High background reflectance means, if you have an image and your target lies somewhere here and basically that is having some low reflectance value compared to the surrounding. So, surrounding will have higher values and your target will have lower values that you have to know before. Then, this band ratio algorithms are suitable.

Then the accuracy of the water vapor estimation is reduced in the low reflectance regions due to underestimation of water vapor content for darker surfaces. The APDA method removes the impact of atmospheric path radiances. This can be used to improve the accuracy of water vapor content estimation in the low–background region. So that was the high-background region case and now here we are talking about low-background region. So your target is having high reflectance.

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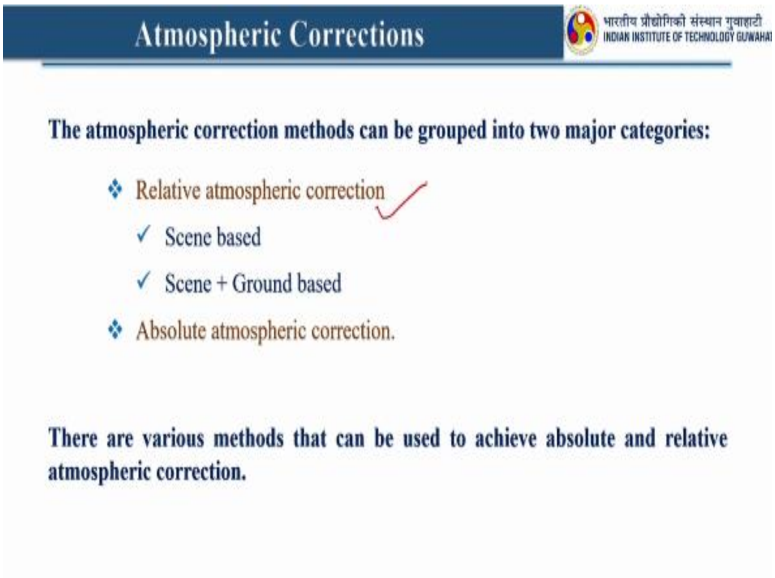

So that atmospheric correction methods can be grouped into two major categories. First one is Relative Atmospheric correction, where we have scene based and scene and ground based. Next one is Absolute Atmospheric correction, so relative atmospheric correction is basically where you are going to use some standards and you are going to correct the images, but in absolute atmospheric correction you will have to know all the atmospheric constituents parameters and what is their values.

And based on that, you will model the atmosphere. So there are various methods that can be used to achieve absolute and relative atmospheric correction. That we will see.

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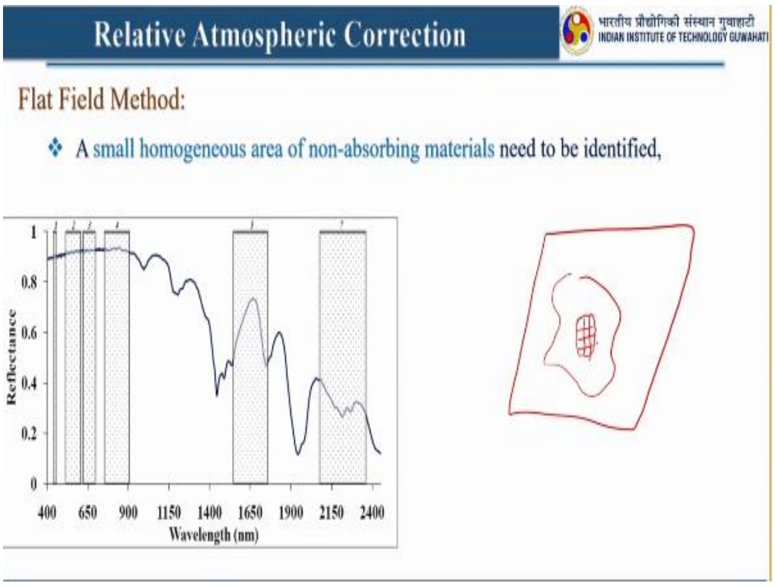

So first one is Flat Field method. A small homogeneous area of non-absorbing materials needs to be identified what does it mean, the small homogeneous area, so suppose you have an image and you have a water body. So in water body this particular center pixel or the central area. The central area will have no effect of soils, this will contain pure water, does not matter what kind of water it is. But comparatively, compare to this side you have better values in the centre pixels

But here we are not talking about only homogeneous area; we are talking about homogeneous area of non-absorbing materials. So if your sensor is sensitive in all these bands 1, 2, 3, 4, 5, 6 then you need to identify which material does not have any absorption feature in all these bands, So what you will do here, you will identify X material may be located here and then you will use it in the calculation.

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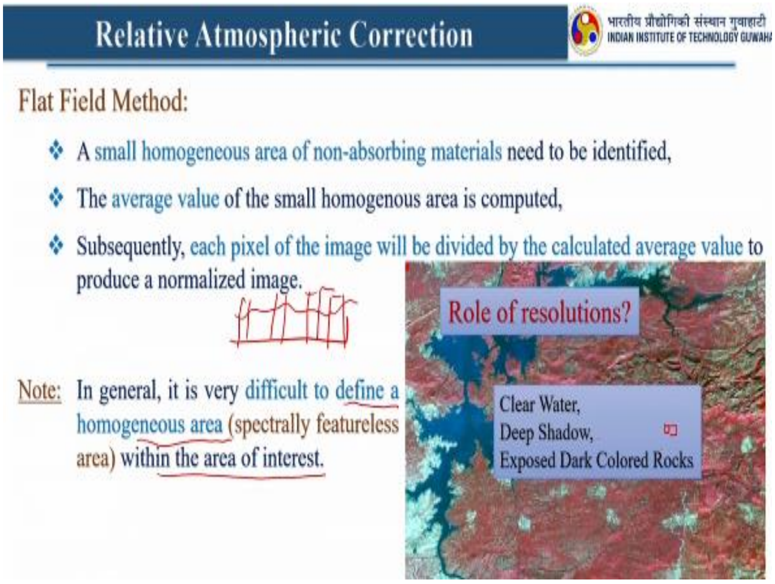

So in this case have drawn that one, the average value of the small homogeneous area is computed and then subsequently, each pixel of the image will be divided by the calculated average value to produce a normalized image. So what we assume by averaging it with the calculated value, you are removing the atmospheric errors. In general, it is very difficult to define a homogeneous area which is having non-absorbing characteristics in the wavelength.

So, if you are going to identify this blue band and I will just go back to this particular. So here in case you are going to correct the fourth band then what you will do? This does not matter what material it is. So you know that this particular material does not have an absorption feature here. So it will be simply a straight line or closed to Straight line. So you do not have feature like this, in this. So you can use this material location and the pixels and calculate the average value and then divided with the whole image.

But for that particular band only, because the same material cannot be used here because here it has some absorption features, so you need to find another target which is having this kind of response in this particular band. So that is why I have written here in general it is very difficult to define a homogeneous area within the area of interest. So our area of interest in this case is from here to here.

And what is the role of resolutions here like if you have low spectral resolutions, if you have low spatial resolutions, what effect it can cause? So, basically here when you have high spectrum resolutions then what will happen? You will have better identification of the non-absorbing materials, but in case of low spectrum resolution, this whole wavelength will have may be 1, 2 and 3 bands.

So in this case, it will be very difficult to identify or to identify homogeneous non-absorbing materials. But when you have more bands, then it will be easy and when you have high spatial resolution, then what does it mean then you can correctly locate those pixels which are having those materials which are non-absorbing in nature in that particular band and for example; Clear water, deep shadow, exposed dark colored rocks are better if you can find out they are non-absorbing behavior in your particular band.

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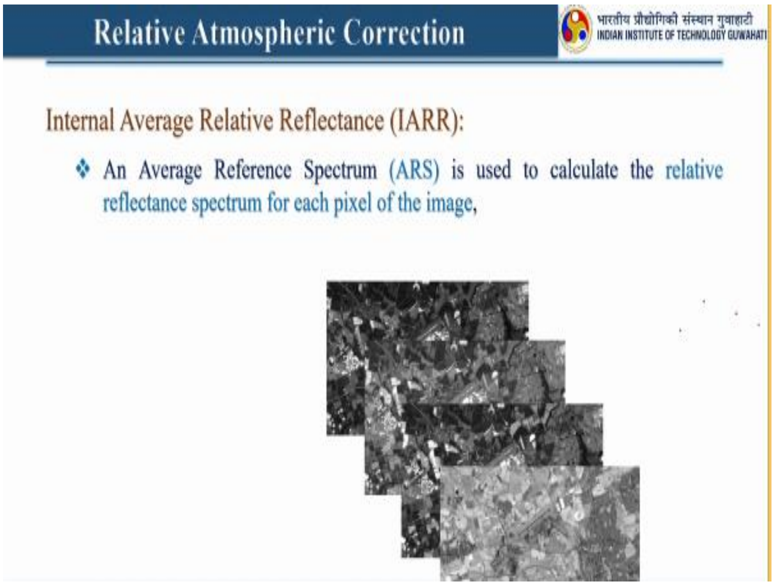

Next method is Internal Average Relative Reflectance (IARR); where we identify or we estimate the average references spectrum which is used to calculate the relative reflectance spectrum for each pixel of the image. So here what I mean to say? This whole image will have one matrix, so you can find one average value. Then here you will have one value, one value sorry this will be 2, this will be 3. This will be 4, so like that you will have spectra, one average spectra.

So here the ARS is calculated by averaging the whole image with respect to wavelength that means for that particular wavelength you will have only one value that is the average value, so each does not matter how many bands you have in your image. If it is 5 bands you will have 5 average values and that will be used to divide pixel wise.

So the first value of this average spectrum will be used to divide pixel wise here, right. Second will be used here to divide separately, further relative reflectance image each pixel of the input image is divided by the ARS.

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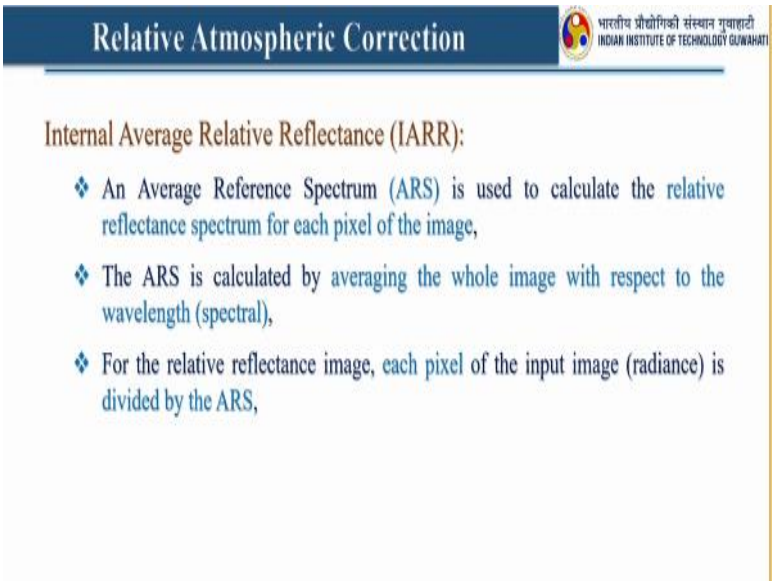

This method is useful when no calibration information is available and does not require previous knowledge of the study area, so here in many cases what happens we want to study some unknown places where we cannot go, then we are restricted to use such methods, which does not require any previous knowledge or ground information. So depending upon the spectral response, along with the artifacts, real features may be suppressed or removed.

Because here we are going to use the average value calculated for this whole band, Right. That one target which is having some DN value X1 which is similar to your calculated average value for that particular band. So in that case when you are dividing it, then what will happen? That feature will be removed from your image So this is the limitation of this particular method.

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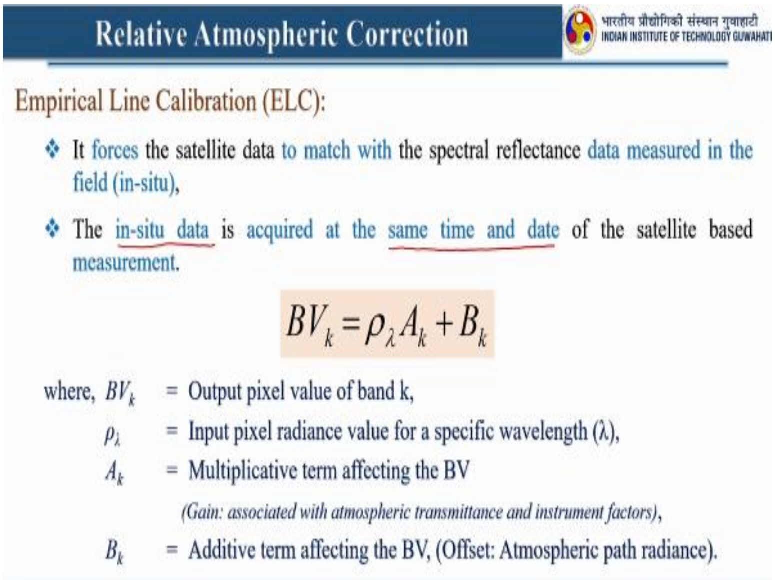

Next one is Empirical Line Calibration. So here it forces the satellite data to match with the spectral reflectance date measured in the field. The in-situ data is acquired at the same time and date of the satellite based measurement. So here what we require is in-situ measured data and at the same time and date when your satellite is passing through your restricted area, the same time you have to be there and you have to measure the reflectance from your ground instruments.

So and then you can use this equation and you can correct your satellite images and that we consider that will be free from your atmospheric components why? Because when you are going to measured it on the surface you are going to less interact with the atmosphere, so we assume that it is comparatively better and we are directly calculating the surface reflectance.

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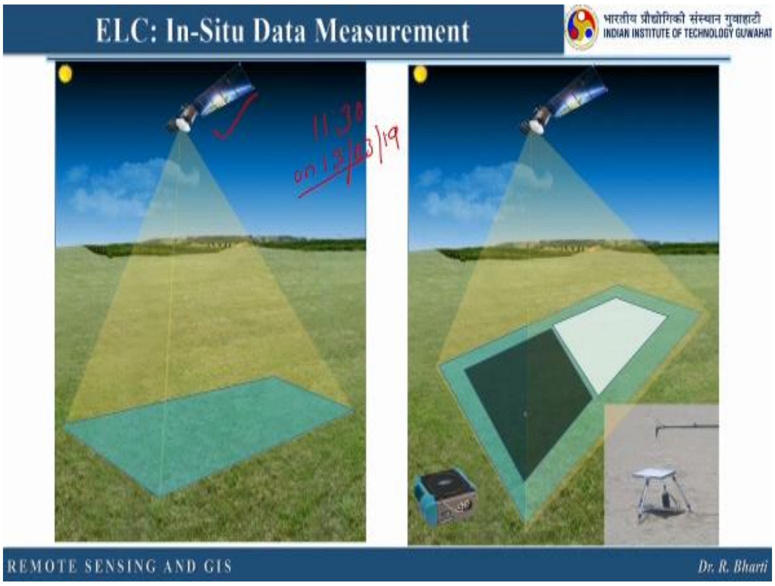

So here you can see this is the area where this particular sensor is active and what we have to do suppose if this is today 11:30 on 13/03/19. So the same time you have to go to the field with your instrument and you have to measure the dark target and the white target, so that you can used it for the calibration. So you will put a dark patch here and white patch here and then you will measure the reflectance using such instruments.

And then you will have these values like for dark target and for the bright target and the same information is also available from the satellite.

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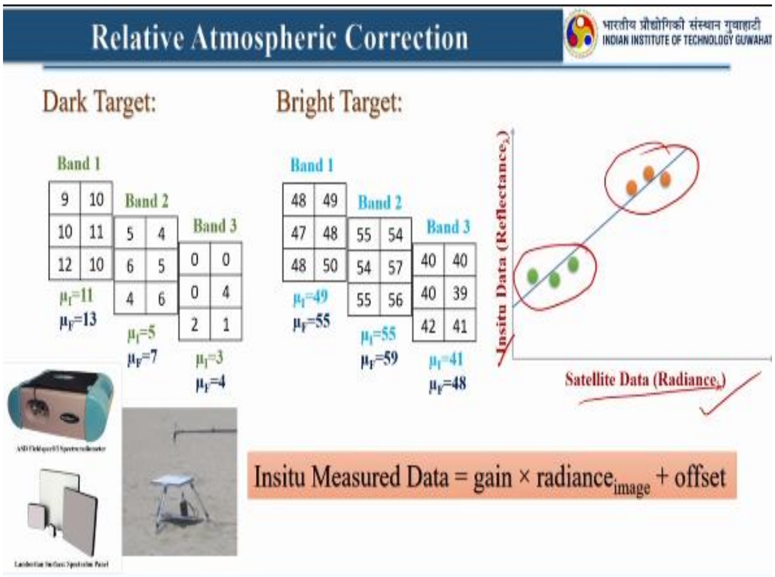

So, what will happen here you can easily plot this data sets, so here you have dark target, here you have bright target and this side you have in-situ data and this side you have satellite radiance data and then you can definitely generate an equation and you correct the whole image right, I hope this is clear very easy and very interesting.

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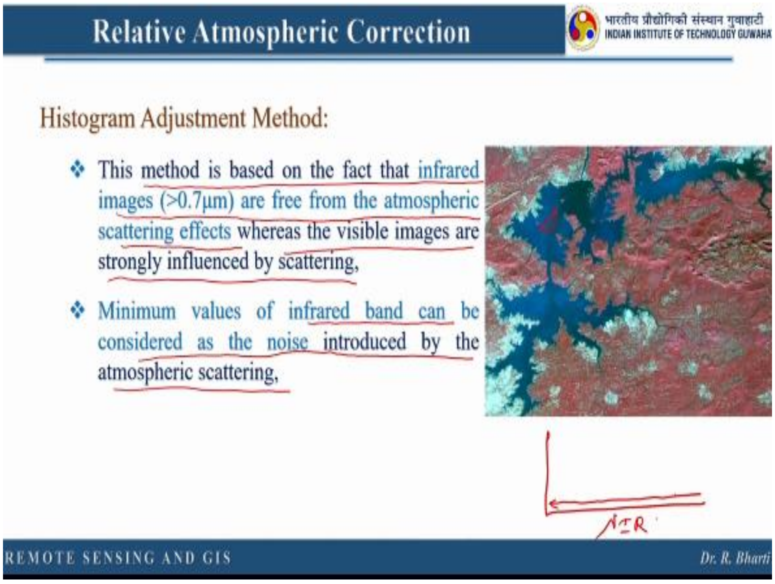

Now next is Histogram Adjustment Method. So this method is based on the fact that infrared images are free from the atmospheric scattering effects whereas the visible ranges are strongly influenced by scattering and we assume and in longer wavelength region, it is comparatively free from atmospheric scattering, and because of that fact, we using infrared here, so if you see spectral response of water, so it will be like non-absorbing or there will be no absorbing features in IR wavelength.

So if you have any value, in that one that you can consider it is basically the contribution of atmosphere. So that is why this method is based on the fact that infrared images are free from the atmospheric scattering effects, whereas the visible images are strongly influenced by scattering. So minimum values of infrared band can be considered as the noise introduced by the atmospheric scattering.

So if you have water body in your area, you can take that value like it is contributed from the atmospheric scattering. To remove the scattering effect, Minimum value needs to be subtracted from each band.

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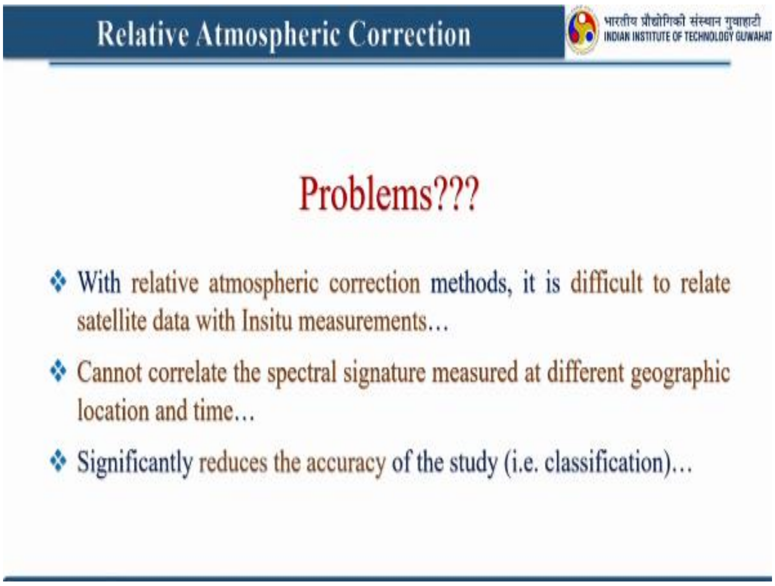

So what is the problem with relative atmospheric correction? So with relative atmospheric correction methods, it is difficult to relate satellite data with in-situ measurements. Why? Because one you are going to measure in the ground with less interaction with the atmosphere whereas the other one you are measuring from the space where you have maximum interaction with our atmosphere and the local settings.

So that means, you cannot really correlate these 2 values unless until you do not remove the atmospheric effects from the satellite images and this cannot be used to correlate the spectral signature measured at different geographic location and time. So I told you reflectance and emissivity they are unique value for a given material. So if you have measured it in IIT campus or in your own campus, it should remain same. So if it is not same that means atmosphere or the other errors are present in your data.

And it also significantly reduces the accuracy of the study because ultimately what is the aim of all these remote sensing data generation and the analysis because we want to use it in some applications. So when you are not going to remove or your data is having the errors then what will happen? Your result will also have that error. So because of this, we have absolute atmospheric correction.

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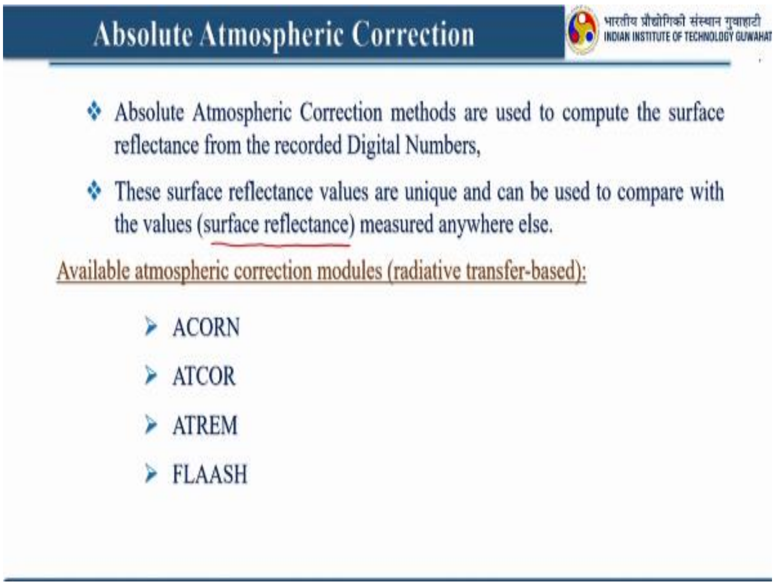

Where this method I used to compute the surface reflectance from the recorded digital numbers. These surface reflectance values are unique and can be used to compare with the values measured anywhere else. Right, so for this absolute atmospheric correction, we have radiative-transfer based methods. So here we have ACORN, ATCOR, ATREM and FLAASH these are some of them. We will see one by one what is their strength and demerits.

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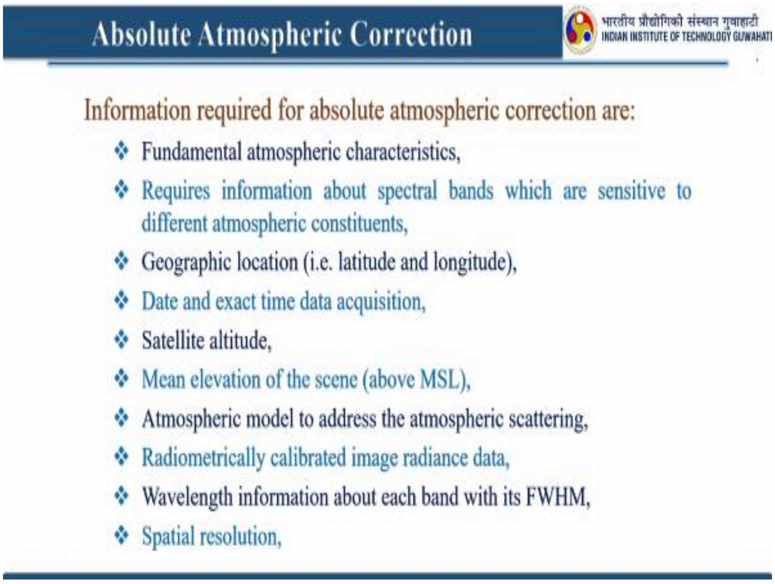

Information required for atmospheric corrections are fundamental atmospheric characteristics because I told you this is absolute method where you have to model the complete atmosphere. So you need to know what is the fundamental atmospheric characteristics of that particular area then it also requires the information about spectral band which are sensitive to different atmospheric constituents we have seen that image with different bands remember geographic location.

What is the location of a study area latitude and longitude, date and exact time of data acquisition, Satellite altitude at what altitude your satellite has acquired that particular image, then mean elevation of the scene from sea, so MSL. Atmospheric model to address the atmospheric scattering, which model you are going to use radiometrically calibrated image radiance data so here our input data will be radiance data not DN values.

Wavelength information about each band with it is FWHM full wavelength at half maxima, you remember. Then spatial resolution, what is the spatial resolution of your image. So these are some of the important parameters listed here which is required in order to do absolute atmospheric correction for any given satellite images.

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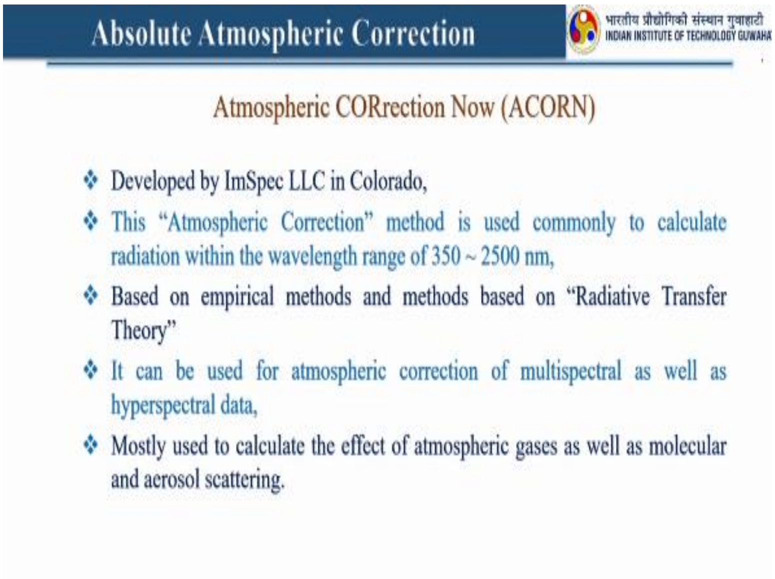

So first one is ACORN and this atmospheric correction method is used commonly to calculate radiation within the wavelength of 350 to 2500nm that is 0.35 to 2.5 micrometer. Based on empirical method and methods based on radiative transfer theory, it can be used for atmospheric correction of multispectral as well as hyperspectral data. Mostly used to calculate the effects of atmospheric gases as well as molecular and aerosol scattering.

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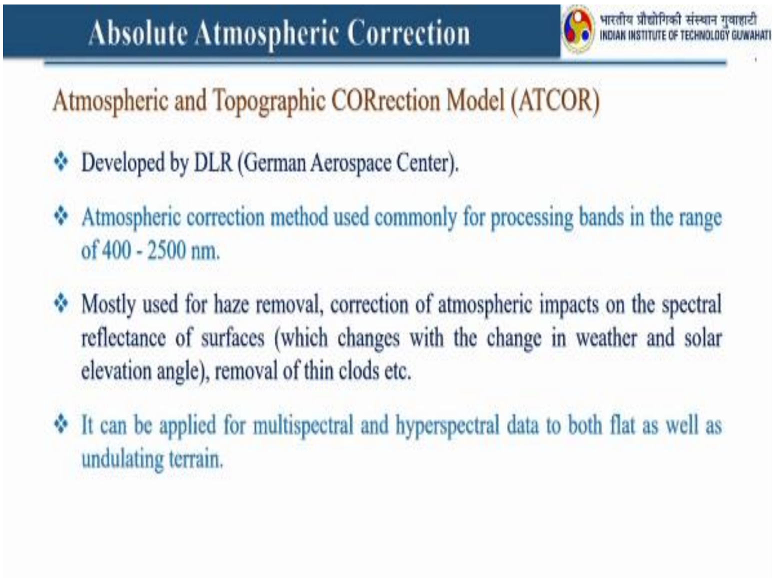

Atmospheric and Topographic Correction model that is another model which is known as ATCOR developed by DLR that is the German Aerospace center. Atmospheric correction method used commonly for processing bands in the range of again 400 to 2500nm. In the previous method it was 350 to 2500nm, now here it is 400 to 2500nm. Mostly used for haze removal correction of atmospheric impacts on the spectral reflectance of surfaces and removal of thin clouds, it can be applied for multispectral and hyperspectral data to both flat as well as undulating terrain.

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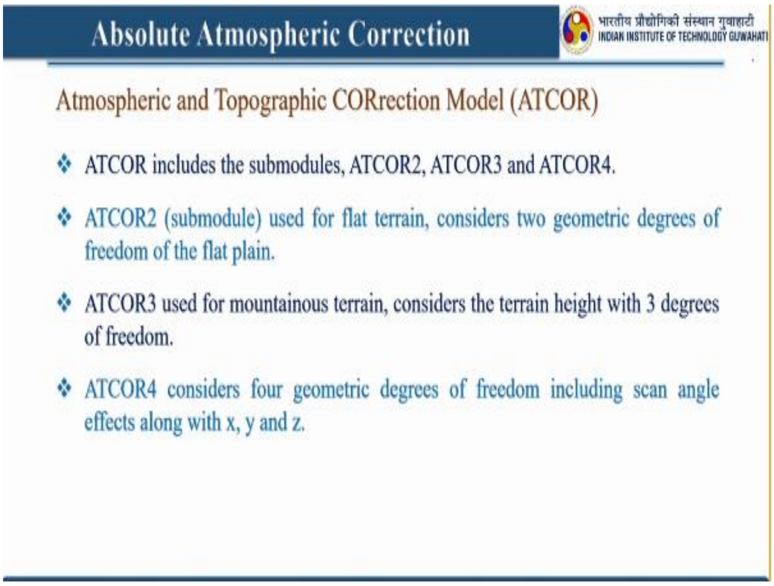

In continuation ATCOR includes the sub modules, like ATCOR2, ATCOR3, ATCOR4 and their applications are different. So if you see ATCOR2, it is used for flat terrain, considers 2 geometric degrees of freedom of the flat plain. Whereas ATCOR3 is used for mountainous region, considers the terrain height with 3 degrees of freedom. ATCOR4 considers 4 geometric degrees of freedom include scan angle effect along with X, Y and Z.

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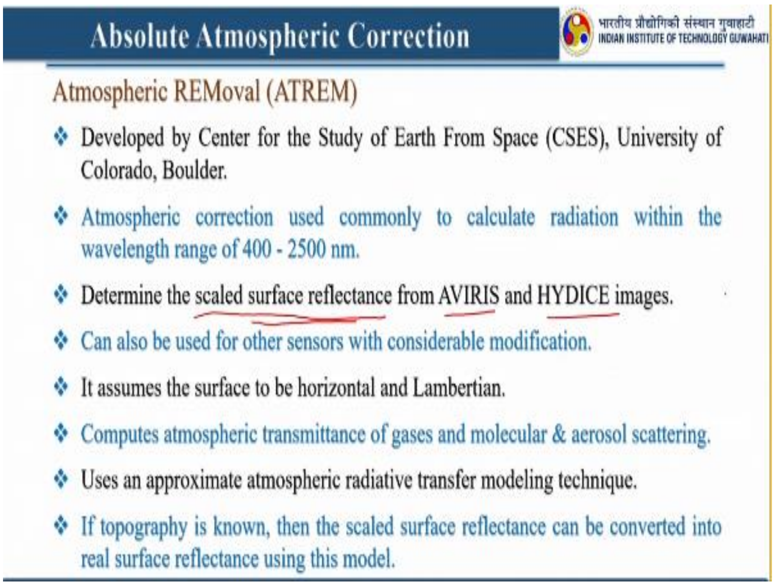

Now the next method is ATREM where it is developed by centre for the study of earth from space say CSES, university of Colorado, Boulder. Atmospheric correction used commonly to calculate radiation within the wavelength range of 400 to 2500nm. It determines the scaled surface reflectance from AVIRIS and HYDICE images, so basically these two are hyperspectral images and it is basically calculating the scaled surface reflectance, so what you mean by scaled surface reflectance.

So the reflectance value is a ratio and which is unit less and value ranges from 0 to 1. But you can apply some multiplicative factor here and then your range can be 0 to 1000 or maybe 10000 depending upon your multiplicative factor, so you do not have to worry about the result like when you see high values of reflectance which is more than 1. Basically it gives you scaled surface reflectance and it can also used for other sensors which considerable with considerable modification in the code; it assumes the surface to be horizontal and Lambertian.

So these are the assumptions and it computes atmospheric transmittance of gases and molecular and aerosol scattering used an approximate atmospheric radiative transfer modeling technique and if topography is known, then the scale surface reflectance can be converted into real surface reflectance using this model, So this is very simple like you can understand easily so just go through it and because it will take time for you to understand so first you have to clear your basic fundamental and then slowly you can get it into the problems.

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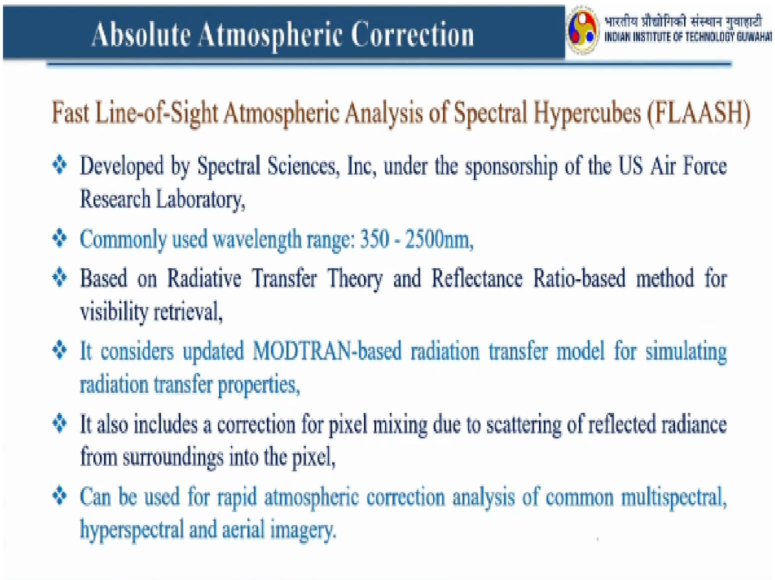

Then next method is FLAASH, so this is one of the popular method now-a-days which is used to correct the atmospheric effects in hyperspectral data and it is also based on radiative transfer theory and reflectance ratio-based method for visibility retrieval. It considers updated MODTRAN- based radiation transfer model for simulating radiation transfer properties. It also includes a correction for pixel mixing due to scattering of reflected radiance from surrounding into the pixel. So this is known as adjacent effect.

Because when a surface is getting illuminated from the source and this is getting scanned by your one detector let us this is one detector and the next detector is basically sensing the next pixel on the ground, so what will happen, there is a possibility of getting this signal mixed with this and this with this, so that effect is known as adjacency effect and which can be taken care by this FLAASH algorithm and it can be used for rapid atmospheric correction analysis of common multispectral, hyperspectral and aerial imagery.

But with slight modification you can apply it in any multispectral and hyperspectral imagery.

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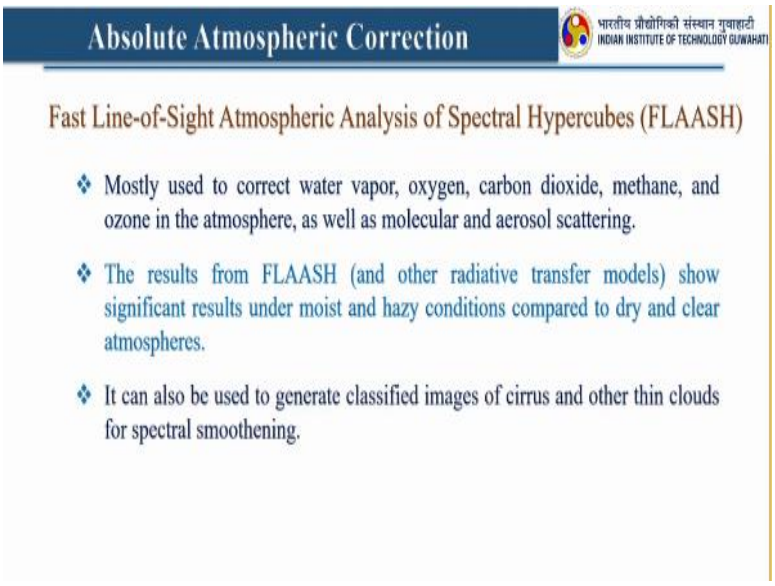

It is mostly used to correct water vapor, oxygen, carbon dioxide, methane and ozone in the atmosphere, as well as molecular and aerosol scattering. The result of from FLAASH show significant result under moist and hazy conditions compared to dry and clear atmosphere. It can also be used to generate classified image of cirrus and other thin clouds for spectral smoothening.

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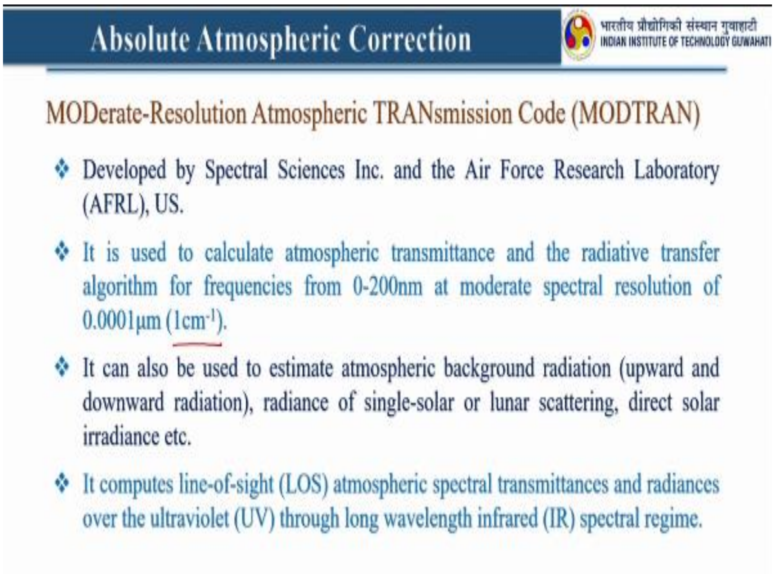

And the next method is MODTRAN, so it is developed by spectral sciences Inc and the Air Force Research laboratory (AFRL) that is from US. And it is used to calculate atmospheric transmittance and the radiative transfer algorithm for frequencies from 0 to 200nm at moderate spectral resolution of 0.0001micro meter and that we can say it is wavenumber. So wavenumber is 1. And it also be used to estimate atmospheric background radiation upward or downward radiation, radiances of single-solar or lunar scattering, direct solar irradiance etc.

It computes line-of-sight, atmospheric, spectral transmittances and radiances over the ultraviolet through long wavelength infrared spectral region. Remember in the class we have seen Some DN to radiance to reflectance conversion. So here

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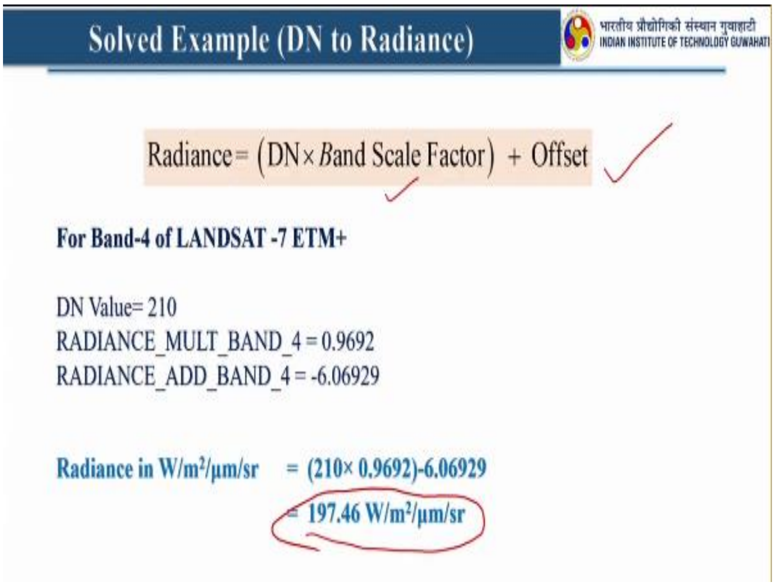

There are some solved examples because we need to understand how these methods works, so for band- 4 of LANDSAT-7 ETM+ data these are the values and you can easily calculate the radiance using this particular formula and this is the value.

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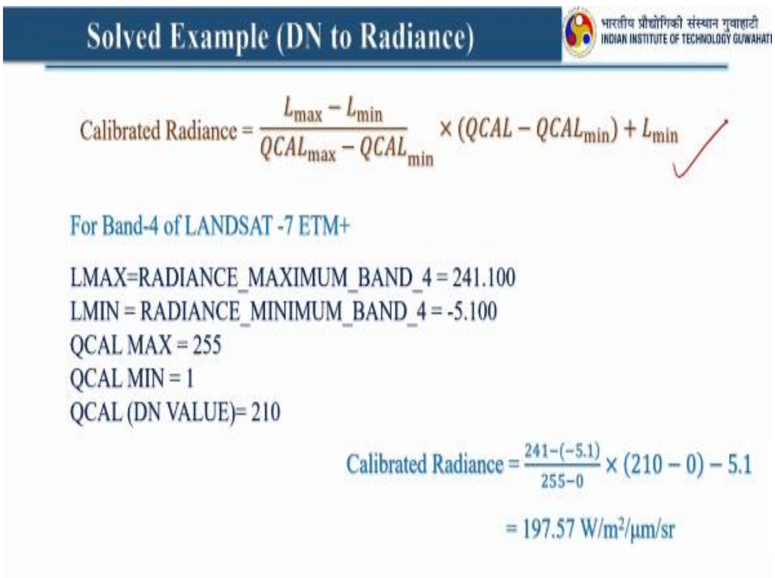

In the next case where we have to calculate calibrated radiance and if you use this particular formula then your value will be this. So, if you see the previous one 197.46 and here 197.57, so there is a slight change in the value when you use DN to radiance normal equation and when you use this calibrated radiance equation, so that means there is a change, so you need to take care of this LMAX, LMIN, QCAL. MAX, QCAL, MIN.

So it is important it is advisable to go for this calibrated radiance equation when we are convert your DN to radiance.

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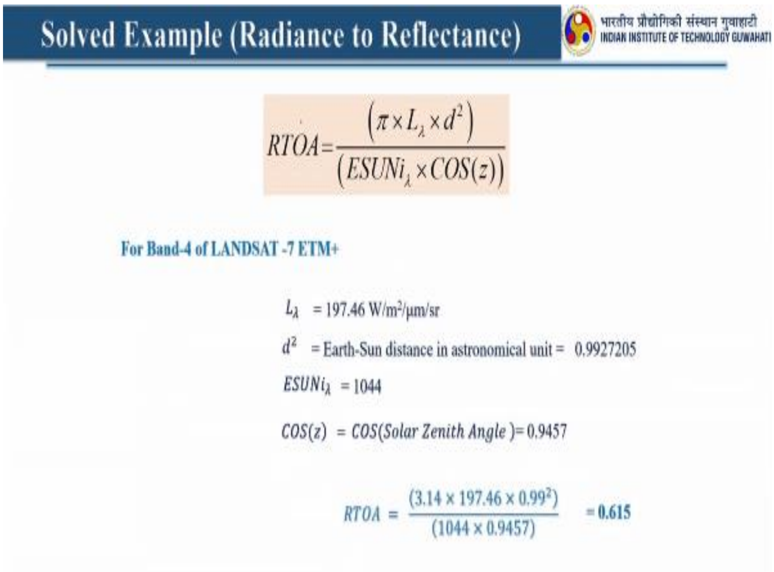

And when the same data used to calculate reflectance so here this is RTOA that means Reflectance top of the atmosphere. So when we are using this particular value 197.46 and this equation, this is the reflectance value and we all know the reflectance ranges from 0 to 1. So it should not be more than 1 and less than 0, so then your result is correct. So this is ultimately your reflectance value calculated from LANTRAN-7 ETM+ data from DN to reflectance complete. Okay, thank you that is all for today.