Remote Sensing Essentials
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Lecture-21
Atmospheric Errors and Corrections

Hello everyone, and welcome to our new discussion which is on atmospheric errors and corrections under this remote sensing essential course. Earlier we briefly touched about this issue and but today we are going to discuss in depth the reasons for atmospheric distortions and then how these are reflected in our satellite images and finally we will also see what are the possibilities of getting rid of atmospheric distortions.

So as you know that you know between satellite and earth surface there is atmosphere. But if atmosphere is very thin or would have been thin then there should have been delight for RCO or for any need remote sensing people. But unfortunately it is not true in case of earth and though it is very important for life, so it is fine. But if we think about mars, then mars is having very thin atmosphere.

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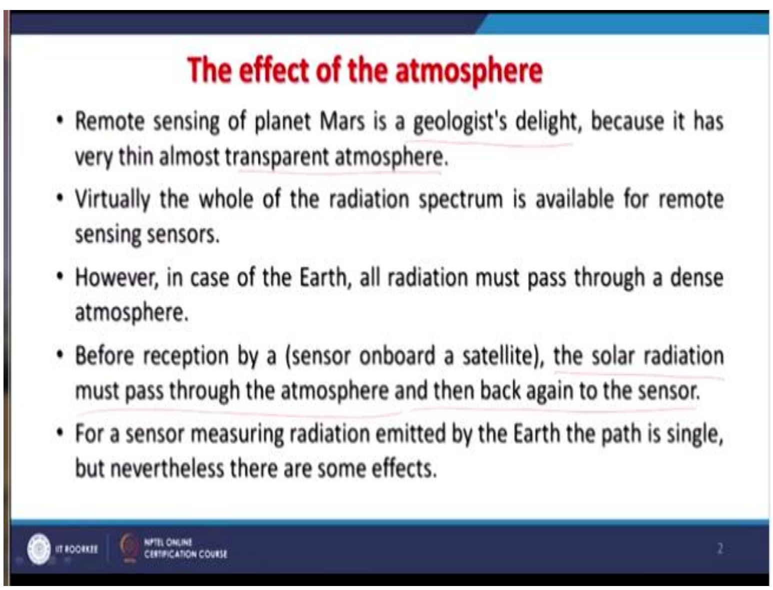

And therefore though it is written here the geologist delight but does not mean only for geologist for engineers or anyone who uses remote sensing data. And because there are no clouds and the atmosphere is very thin and therefore we get almost transparent atmosphere and very thin atmosphere and very clean satellite images from morning to evening through the reflection or sunlight we get very good images.

But this is not true in case of earth, the whole radiation spectrum of remote sensing is also available if no atmosphere or very thin atmosphere is there. As mention that in case of earth all radiation passes through or pass through a dense atmosphere relatively dense compared to mars. And because a sensor or reception or a satellite earth station is located on the ground, so this has to be also incorporated the regions or affects of atmosphere.

So the solar radiation must pass through that atmosphere and then back again to the sensor. So this creates a lot of problems in the satellite images and sometimes when it is cloudy that is a also atmospheric phenomena. Then you clouds completely will mars the land part and do not see anything of the land. So this kind of a complication is there and as we know that for a sensor measuring radiation emitted by earth in case of thermal infrared.

The path is single not double in case of reflector or solar based radiation because sunlight will come, it will interact with the atmosphere and then when it reflected back by the objects it goes back again. And third time also roll of atmosphere is there when the data is being received by earth station but at that time because the data in the microwave parts does not affect much but still there are rules are there.

And for a emitted part only the single path because whatever objects are emitting energy that is being sense by the sensor. But none the less it has to also pass through the atmosphere.

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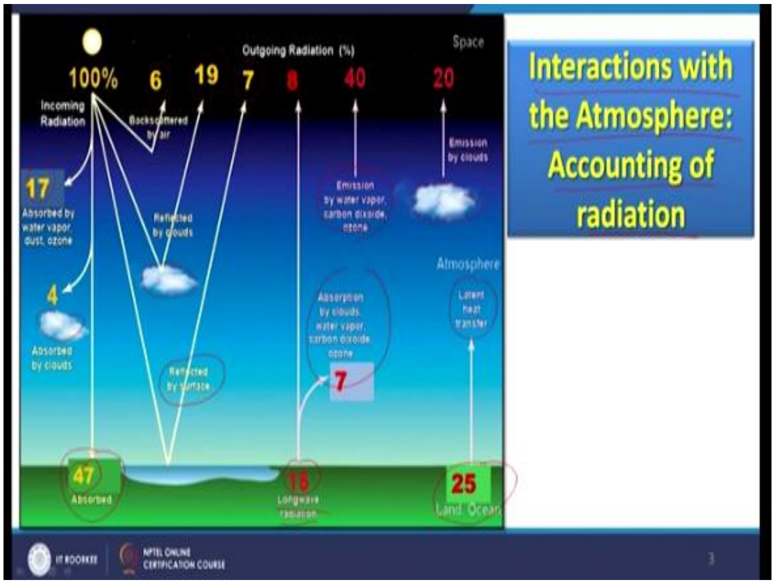

This figure we have use in very earlier stages of this course that is the interaction with atmosphere. And reach the accounting of radiation, so as we know that been earth and sensor there is atmosphere. And there might be sometime clouds which absorbs, which also reflect and then the cloud themselves may emit energy. So when we go for emitted or thermal infrared then clouds also play important role, thick clouds can be detected very easily.

But when you are having very thin cloud or haze or that kind of thing then it becomes very your image is becomes unclear. And removal of such effects also becomes very challenging. So as we know that if 100% of we count 100% incoming solar radiation then 47% of that is absorbed by the earth and 17% is absorbed by the water vapor which are within the atmosphere, 4% is absorbed by the cloud.

And these are just rough estimates and this is a very atmosphere is very dynamic thing so things keep changing. But on average and then 6% is back scattered of that 100 back to the atmosphere or in space and then 19% the large part is reflected only 4% is absorbed whereas a large part that is 19% is reflected by clouds if they are there. Also water bodies also reflects maybe lakes, maybe rivers or sea part.

So they also reflect a lot of energy and then if we go for along with part of energy then what we see that there is a long wave radiation from the earth which is going out in case of thermal infrared. So absorption by the cloud water vapor carbon dioxide here emission 20% by clouds, emission by water vapor carbon dioxide etc. they also contribute.

So lot of long wave radiation is coming but it is getting disturbed or absorb reflected basically absorbed emitted by that atmosphere itself. And of course the heat which has been absorbed earlier 47% is transmitted back by the land that is latent heat transfer and which goes into the space. So this tells us that how many processes are going on between a satellite and surface of the earth and within the atmosphere.

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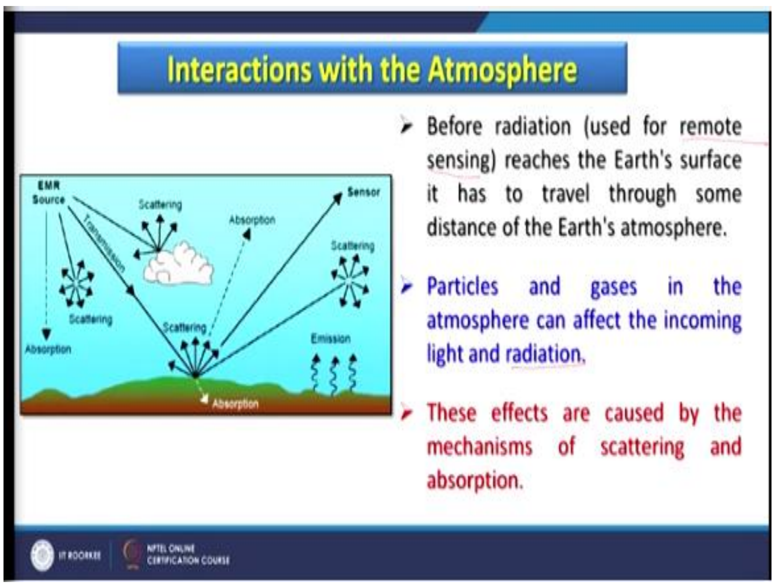

And therefore that is why I said that in order to remove these distortions it is really challenging. Because one the atmosphere is dynamic and second is so many processes are going on emission by within atmosphere, reflection within the atmosphere and absorption within the atmosphere. And that too depending on the conditions other conditions maybe the wind speed or maybe the moisture content and temperatures also.

So all these things makes very complicated this part none the less this in percentage we have already discuss, so in short this figure in a simplified form. And before radiation especially for what we are talking about for remote sensing that reaches towards the earth, it has to travel through some distance at the earth atmosphere. And the particles and gases which are present in the atmosphere can affect incoming light and radiation.

So we are concern mainly with the radiation directly, of course when the whatever it is going back at that time also it will have a problem. So these effects are caused by mechanism of scattering and absorptions.

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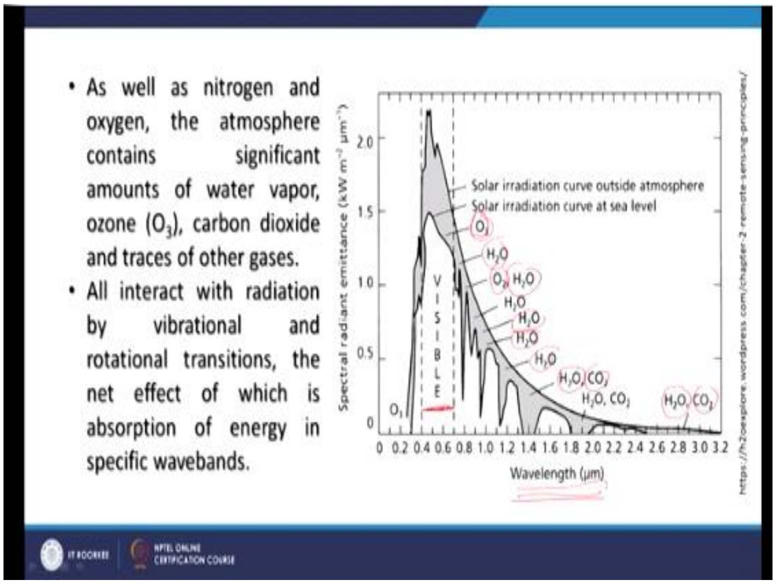

And we also know that see this some part of EM spectrum is displayed here and this is spectral radiant emittance. And we find that these are the water and gases which are absorbing lot of this radiation and therefore it becomes very difficult in that way visual part is up to only this much. So nitrogen, oxygen which are present in the atmosphere, ozone also present an atmosphere and carbon dioxide.

So many these gases will absorb and we note provide a clear ultimately, may not provide a clear remote sensing image. So all this interactions with radiation by vibrational and rotational transition and then net effect of which is the absorption of energy in specific wavelengths which you can see here that how water if you see H 2 O it is almost in every part of EM spectrum this part especially which is being displayed, every part there is absorption, almost every part.

So the moisture or water within the atmosphere having lot of absorptions in different part of EM spectrum. So other gases but their rules are limited and not everywhere like ozone plays very large absorption in case of visible but in other parts it is not that common.

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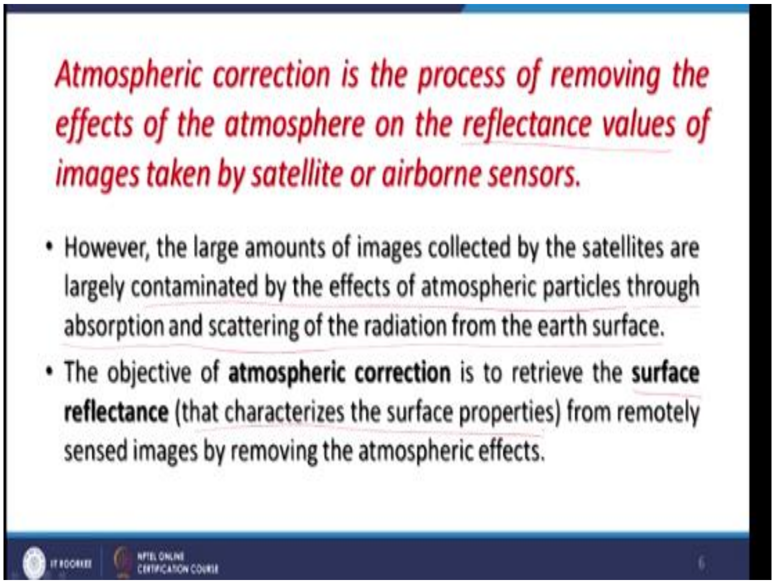

So what is that process atmospheric correction is the process of removing the effects of atmosphere on the reflectance values of images taken by satellite or airborne sensor. Here it has been mention the reflectance value these values can be also emitance value. So the atmosphere correction is the process of removing, the facts of atmosphere as I have already said that this is because of complications within the atmosphere about the radiation this is real challenging.

So large amount of images as we know are being collected by satellites have already been collected by various satellites of various countries. And these are largely contaminated or affected by atmosphere or the particles which are present and gases. And they almost all images are suffering from either absorption scattering of the radiation of the earth surface.

So you see any image which will be having some effects of atmosphere, I will let me give you one example. After like in during monsoon time in India or especially in the winter monsoon time just after the rain when sunlight is there even our visibility alone the horizon increases very significantly. So think if at that time satellite is over passing it will acquire very clear image why.

Because the rain will reduce the you know this absorptions thing, absorption phenomena or absorption materials from the atmosphere. Because there might be the dust particles, there might be aerosols and some other things which are present. And all these because of rain they will come on the ground and therefore atmosphere becomes very clean.

So sometimes just after the rain if one is lucky and a satellite is over passing get a very clear image. And clear image means it is suffering from less atmospheric affects, less because of absorption means scattering. Once these particles are only little are present then obviously the scattering and absorption would be less image would be clear. So this can be seen even on the ground just after the rain if sunlight comes there.

So the basically the main purpose of atmospheric correction is to retrieve the surface reflectance basically minus distortions and induce by an earth atmosphere. And this characterizes that basically these surface reflectance which characterizes the surface properties from remote sensing images by removing atmospheric effects. Now there are different approaches some are implement it easily and some are very difficult to implement because of lot of input data is required.

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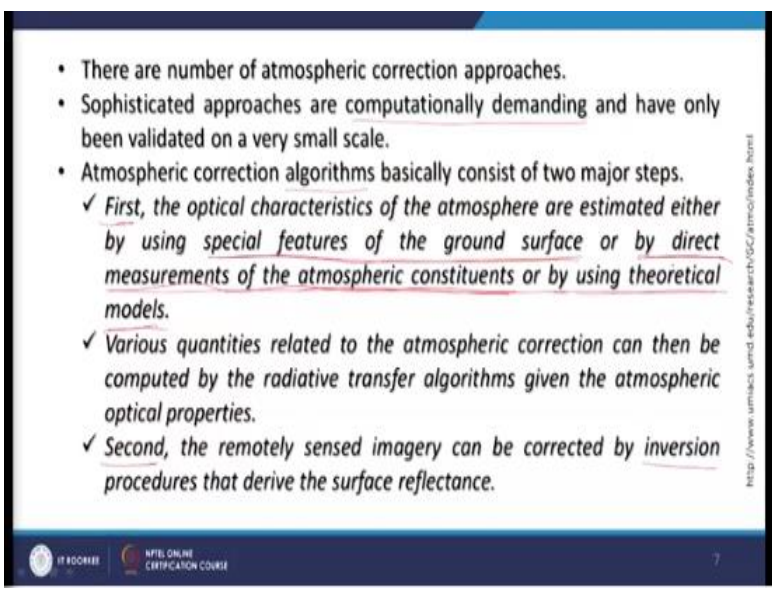

So correction approaches some are sophisticated approaches as computational depending and have only been validated for a few small scale studies. If I want to do it regularly on all the images it is not possible. So that is why I have been using word challenging for removing 100% removal of atmospheric distortions. Though there are algorithms, lot of algorithms are there, models are there through remove these atmospheric distortions, 2 major steps which are done through these algorithms.

Is the first one is the optical characteristics of the atmosphere are estimated and how these are estimated using special features of the ground surface or by direct measurements of atmospheric constituents or by using theoretical models. Now we will spend some time on this particular sentence here. If there are special features on the ground that means if you are having some object which are having very high reflectance, very high (()) (14:55).

Then you can take that one as a one of the reference how suppose you are having a patch which you expect that it should be having in 8 bit image scenario, it should be having highest reflection close to say 255. Suppose it register reflection in the pixel is **2** 250, so after seeing the image of that pixel I know that because absorption the remaining 5 value has not come.

So that means say if I adjust by 5 then probably I have got rid of atmospheric distortions. So using a special features, now every image cannot have special features because images are being acquired regularly. And whenever there is revisit or satellite and various satellites are involved. So it is very hard in practical terms that we get a special feature present within the image, so this possibility is very rare.

However this is one way of getting rid of atmospheric correction, second one is by direct measurement of atmospheric constituents. So if you are having some other method metrological stations or profiling or other things. By which you know that what is the concentration of aerosols, what is the concentration of different gases which are creating distortions in different part of EM spectrum absorption in scattering.

And if that information of that particular time when satellite image was acquired, if that is available then this technique can work very well. Again it is very difficult because all the time satellite are over passing and too many inputs are required about atmospheric constituents. For that particular time when image was acquired, so this itself is also very challenging.

Now third one the most popular one is using theoretical models and if you go the demerits about this that everything is fixed but same time we know the atmosphere is very dynamic. So theoretical models may also bring some level of atmospheric distortions corrections but not fully. So the problem is lies here because of all these complications which are present within the atmosphere.

So various quantities that means the atmospheric constituents to the atmosphere correction can then be computed by radiative transfer algorithm given the atmospheric optical properties. And another one that the first approach was the like this the second approach can be that corrected by inversion procedures that drive the surface reflectance. So again when we go for inversion again lot of things will be assumed there.

Anyway this is one way of very quick way of getting rid of atmospheric distortions without bringing any more data or many more inputs about atmospheric constituents assuming that within this image I should have the full dynamic range pixel values having occupying the full dynamic range. In 8 width scenario that is 0 to 255, so like when I see this image and corresponding is 2 grams. What I see that this is also recall I also discuss the LUT look up table. So now look up table is been used here.

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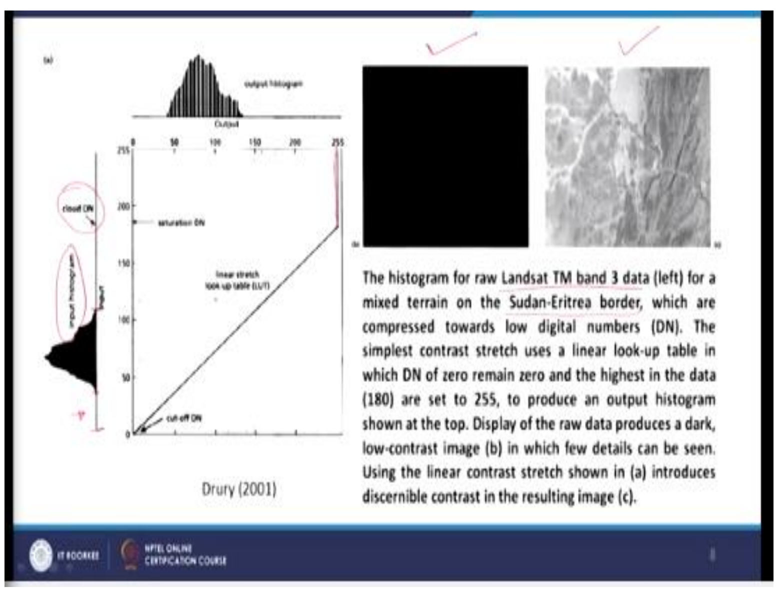

So on the y axis this is the input histogram as you can see it is restricted in to the very beginning values only up to maximum value is up to 100 and minimum value is around 40. And therefore the image which are seen here this image is a completely black because it is not occupying the full dynamic range which is available between 0 to 255. Assuming that this image is having some high reflex because these clouds are taking that part of histogram or other absorptions phenomena are creating or a you know taking this begin part of my histogram means lower values.

And this reflection by the cloud are being occupied by the higher value. So we assume that this is the situation that means I can if I stretch it linearly stretch it then I what I am going to do it I will you know occupy the full dynamic range that is in 8 width scenario between 0 to 255 and my image may become something like this. So also it is shown in the look up table that as soon as is touches here then it is just going to the top that is 255 value.

So 2 things are here, one is atmospheric correction by a short of simple linear stretch or contrast stretch and second thing also use of look up table. So this is example of landsat TM 3 band on the left side and this is of the Sudan-Eritrea border. And you can realize that how quickly one can get rid of atmospheric correction by applying simple linear contrast stretch.

But these will also this method is a short of a brute force method if there is no information or input from atmosphere. So whatever the atmospheric conditions we have not bothered and just got rid of these corrections. So this is again this cannot be extended for atmospheric correction but when we do not have much input data available neither a specific feature of the ground surface nor we do not have or atmospheric constituents or theoretical models.

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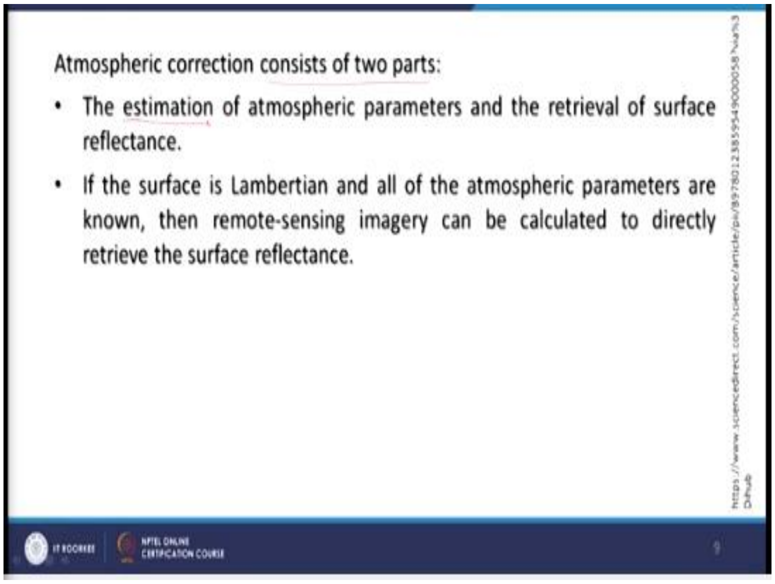

Then this is the quickest way of doing atmospheric correction, now so atmospheric correction consist basically of 2 parts. One is the estimation of atmospheric parameters, so this is again estimation, lot of assumptions would be there and retrieval of surface reflectance. And if the surface is Lambertian and all the atmospheric parameters are known then remote sensing images can be calculated to directly retrieve the surface reflectance.

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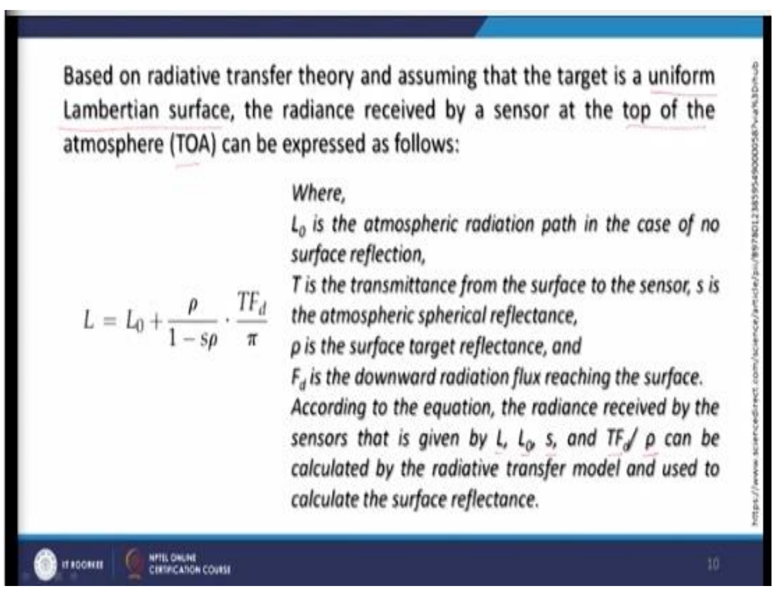

So these are the conditions, so based on radiative transfer theory and assuming that the target is in a uniform Lambertian surface. And then the radiance can be received by a sensor or can be estimated assuming that sensor is getting like this and that is the top of the atmosphere TOA. And which can be express as a L, L0 + rho 1 - s rho and multiplied by TF d by pi.

So where L0 is the atmospheric radiation path which in case of a no surface reflection and T is the transmittance from the surface to the sensor and s is the atmospheric spherical reflectance, rho is the surface target reflectance, F d is the downward radiation flux reaching the surface. And according to this equation the radiative received by sensors are given by L, L0, s, TF and rho can be calculated by radiative transfer model and used to calculate surface reflectance.

So s at this stage you can realize that so many parameters are required and which are those parameter which are dynamic and that creates some problem. Anyway so for at atmospheric correct models and softwares what are available today.

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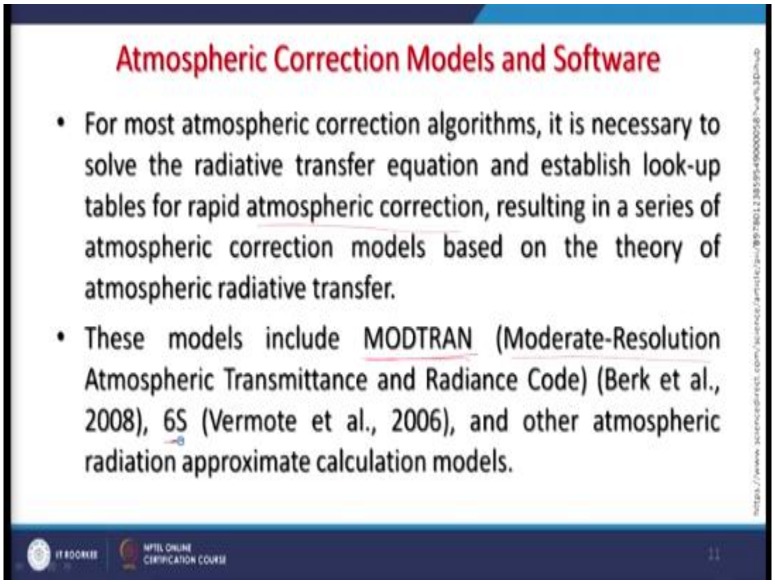

Because everyone will not be developing their own models for atmospheric correction and neither coding things so what are currently what is available. So for most atmospheric correction algorithm is it necessary to solve radiative transfer equation and establish as just we have seen. Establish look up tables also we have seen one slide back, for rapid atmospheric corrections resulting in a series of atmospheric correction models.

And which is based on the theory of atmospheric radiative transfer and these models like MODTRAN moderate-resolution atmospheric transmittance and radiance code. Now one more issue or intimation is coming for moderate resolution. Where was resolution high moderate or coarse these are all relative terms, so what was moderate yesterday is it coarse today and what was high yesterday is a moderate today.

So none the less not for very high resolution satellite images but moderate resolution satellite images there is a model which is called MODTRAN. But when we go for very high resolution images because the area the swath becomes very small. And therefore getting input data only for that part of image becomes further difficult. But when we go for coarse or moderate resolution satellite images then somewhere at least within that image I might be getting those atmospheric data.

So that is why you know for fine resolutions it is a another problem. Then there is a 6S and other atmospheric radiation approximation calculation models are also available.

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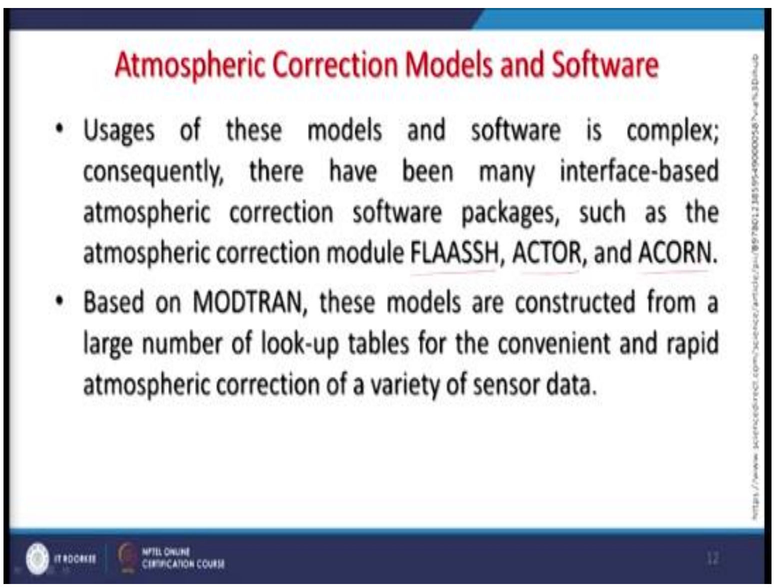

Now usage of these models and software is complex and that is why I said that note everyone would be developing their own. And therefore there are interphase based atmospheric correction software packages are available. And which are like FLAASSH, ACTOR or ACORN or maybe few more one can find. But which one will provide the best results it is very difficult to say unless one applies on his own data set.

So based on the MODTRAN one example the these models are constructed from a large number of look up tables for convenient and rapid atmospheric corrections for a variety of sensor. Very briefly we will also see what is this MODTRAN basically it is use to calculate atmospheric transmittance and the radiative transfer with moderate spectral resolution data.

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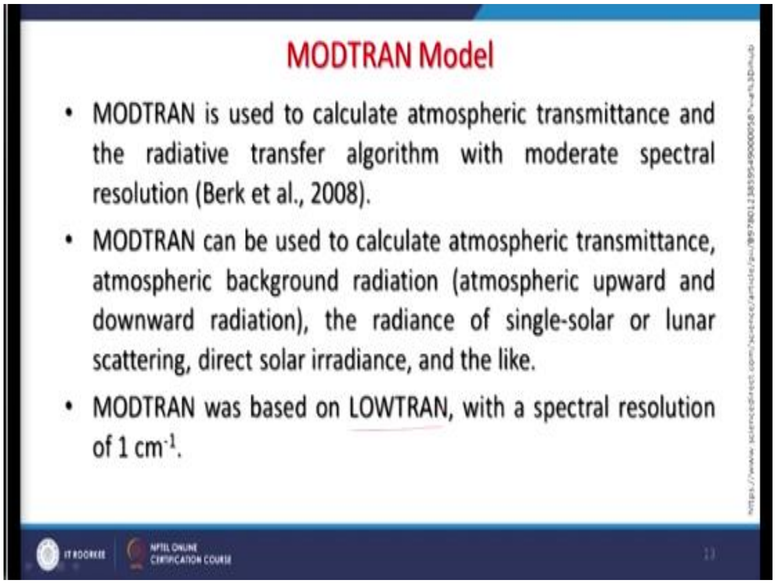

And MODTRAN can be used to calculate atmospheric transference, atmospheric background radiation the radiance of single solar or lunar scattering, direct solar radiance and likewise. And MODTRAN was based on LOWTRAN with a spectral resolution of 1 per centimeter. So earlier version was LOWTRAN basically it was for low resolution or course resolution. Then moderate maybe in future we may have HIGHTRAN, so the input parameters for the operation of MODTRAN can be divided into 5 types.

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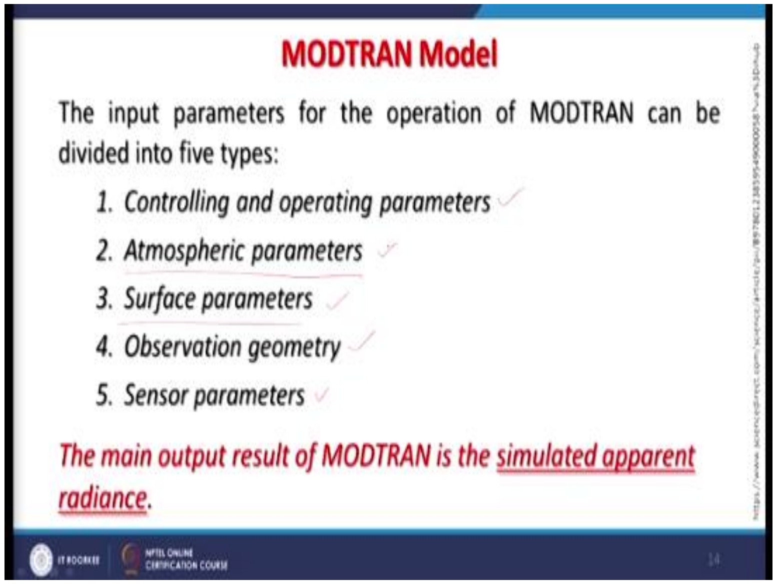

Lot of input parameters are required, first is controlling and operating parameters, atmospheric parameters. That is atmospheric parameters and surface parameter that means somebody has to be present with the all kinds of recordings of atmospheric data of that part of the earth where image is will be acquired by a satellite. So then the current atmospheric parameters and that time corresponding surface parameters are will be required.

Then observation geometry, how these have been observed, sensor parameters of course that is these are the fixed part observatory and these are the fixed part. But the other 3 are required corresponding or that time of required. So the main output, the result would be from MODTRAN is simulated apparent radiance and it will give the simulated apparent radiance. That can be used further by those software which just I have mention and then atmospheric corrections can be done.

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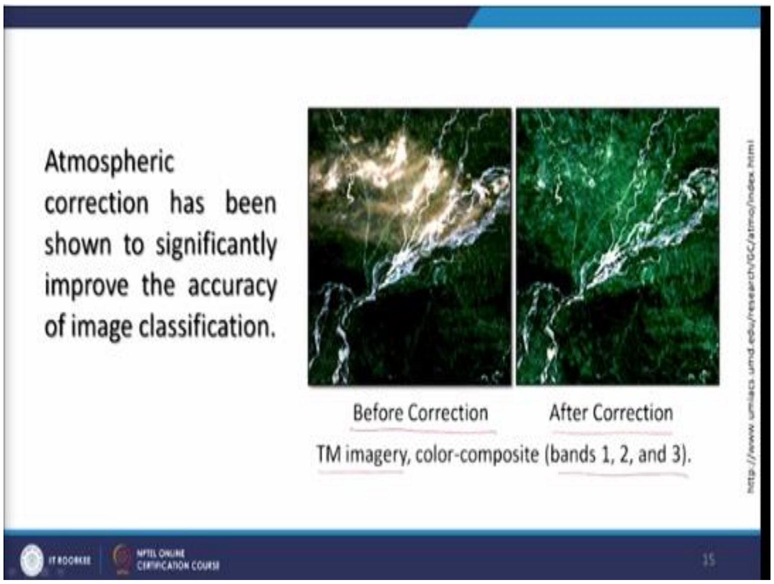

One example is here before correction on the left side and after correction on the right side and this is example for landsat TM images. And we are seeing in colors, so 3 bands 1, 2, 3 been used in RGB scheme. And this is what you see that mainly in this central part top central part you are seeing affects of atmosphere maybe because of thin clouds and others.

And that affect are distortions have been minimized in the right side image. So atmospheric correction has shown significant improvement in the accuracy or visual interpretation of that satellite image. Now there is one more point here as long as one is using satellite images for qualitative analysis in assessment not many problems are there.

But once we go for quantitative analysis of satellite data then it is a problem. For example if I am earth scientist or civil engineer and I am using satellite images to identify certain objects. Create a land use map maybe a ecological map or for some other studies where I do not require quantities, I just require the clean image. So that my interpretation becomes much easier, so for those purposes not much atmospheric correction or no atmospheric correction would be required.

But if I go and would like to find out how much concentration of a certain pollutants in the water or what is the real , what is the chlorophyll content in the vegetation. Then definitely I am moving towards the quantitative analysis or remote sensing data and that means I have to perform atmospheric correction too without which it is not possible to estimate those thing.

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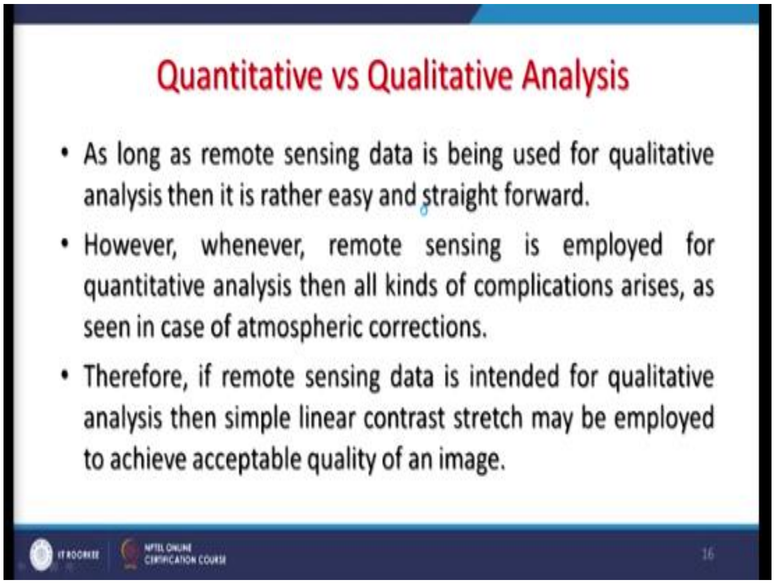

So this is what is as long as the remote sensing data is being used for qualitative analysis then it is rather easy and straight forward as I have just mention and given example. But when we imply for quantitative analysis then all kinds of complications will arise and it can be seen in atmospheric correction. And therefore if remote sensing data is intended for only for qualitative analysis.

Then the that brute force method or linear contrast stretch method can be employed. And it will give you a better quality image which is sufficient for the purpose which we are using the satellite images. So in that way it becomes much easier, so this brings to the end of discussion. But in summary what I would like to tell that atmospheric correction performing because it is a complex atmosphere itself is a complex and dynamic phenomena.

Lot of parameters are required to correct or remove these atmospheric distortions and especially those parameters are required of that time when satellite image was been acquired. So corresponding data is required and it becomes very difficult to go in the field and collect all the data for the full extent of the satellite image. Therefore some model based atmospheric corrections have become popular or brute force atmospheric correction.

If quantitative analysis are not intended then brute force or simple linear contrast stretch can also improve your image quality though there are some none linear contrast stretch are also there. One can also perform and visualize that whether the quality of an image has improved for better interpretation are not. And that can also be acceptable or can be accepted for such kind of applications. So this brings to the end of this discussion, thank you very much.