Remote Sensing Essential
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Lecture -39
Hyperspectral Remote Sensing

Hello everyone, and welcome to new discussion which we are going to have on hyperspectral remote sensing under this remote sensing essential course, earlier we have touched a little bit about hyperspectral remote sensing, but today we are going to focus mainly on this discussion and that what is exactly hyperspectral remote sensing and what are the applications and some limitations.

Also, which we are going to discuss as you know that you know hyperspectral remote sensing is also considered as imaging spectrometry or imaging spectroscopy. Because here the bandwidth is a really nanometres. So, very narrow bands are used here one and also you are having a coverage of continuous coverage of the EM spectrum against this hyperspectral sensor.

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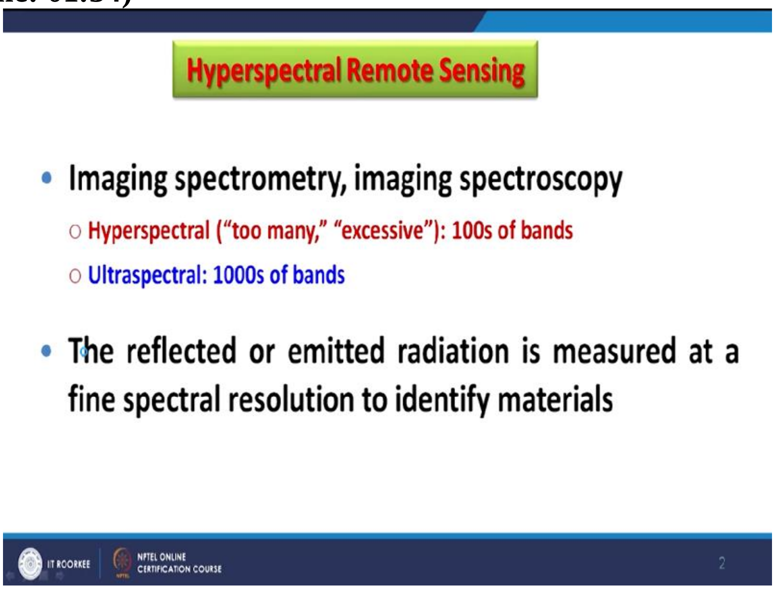

So, therefore, it is called as imaging spectrometry or is imaging spectroscopy and because hyperspectral that means, say we are having 100s of events sometimes even 256 bands in one sensor having very thin width and here. So, when this is the situation to many bands or excessive bands we call as hyperspectral remote sensing and we can also have 1000s of bands, further narrow bands, and then we will call ultra spectral.

So far there are no sensors yet in ultra spectral remote sensing, but definitely there are sensors which are part of hyperspectral remote sensing that means 100s of events. So, the whatever the reflected or emitted radiation that can be measured earlier when, if you recall in since 1972 when we started Landsat MSS, we had just 4 bands covering a large part of the spectrum, that large part including visible and near infrared, and only we had 4 bands and those bands were quite relatively.

Now, if we compare with today's reference, then these are quite broad bands. They are there and these bands were of course, continuous at that time for Landsat MSS, but very wide range where they are there now we are talking very fine spectral resolution rather than relatively coarse resolution we are talking now, very fine spectral resolution and not only very fine bands, but also continuous coverage of that part of EM spectrum. So, hyperspectral remote sensing basically these systems detects.

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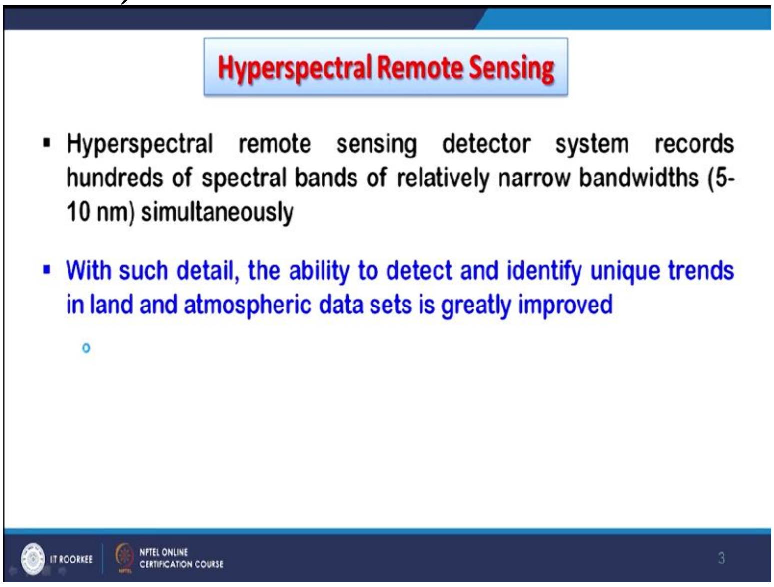

Data in 100s of spectral bands of very narrow sometimes 5 to 10 nanometre and that to simultaneously in 100s of events and these with the such a detail if we are having about a part of earth even now Moon or Mars, then we can identify and when various things which we are impossible with the broad spectral bands. And especially related with minerals or changes in vegetation or maybe related with atmospheric constituents. So, we are going to discuss all those in the application part.

And hyperspectral remote sensing also allows a more specific analysis for land cover, as I have just mentioned that if there are different types of soil, rocks, minerals, vegetation, plants, trees or crops, which are suffering from some kind of, you know, stresses, all these can be detected with hyperspectral remote sensing because, you are having continuous bands and very narrow bands available throughout a large part of EM spectrum.

When we go for this thermal part that is the emissivity levels of each band can be combined to form spectral reflectance curve and these curves we have earlier also discusses spectral response curve or reflectance curve. So, depends on and where in which part of EM spectrum we are talking. Generally, the sensors which have been developed in hyperspectral domain of remote sensing are in the mainly in the visible and near infrared and infrared part rather than in thermal remote sensing. So, if we compare with Multispectral remote sensing versus

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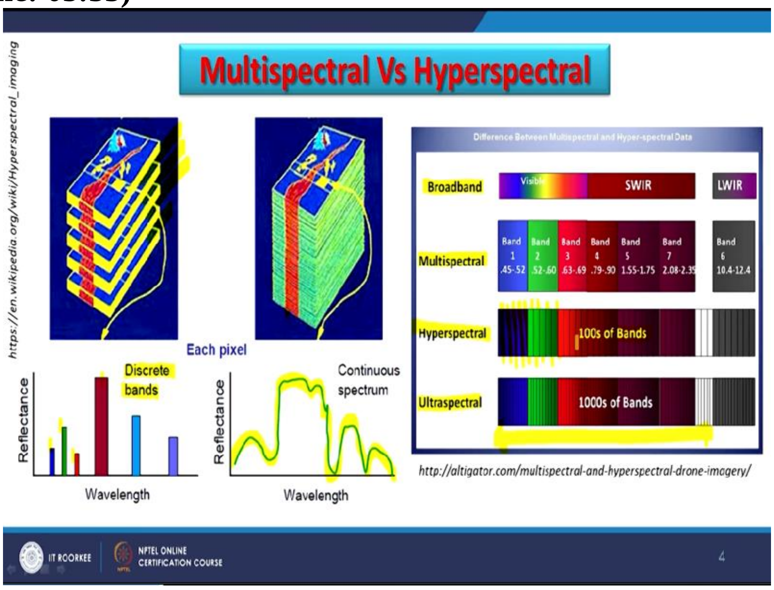

Hyperspectral remote sensing as you can see here, that these bands in multispectral remote sensing are in discrete form. That means, it is difficult to create a spectral response curve as we are seeing here against the hyperspectral remote sensing. So, here we will have just a few say a few responses now in terms of say in this example reflectance, and if we connect we may get a close, you know curve close to this 1, but not that fine detailing will not be possible multispectral remote sensing.

However, when we go for hyperspectral remote sensing as you can see here, that the bands are continuous bands are continuous throughout and therefore, and there are 100s of events and therefore, it is possible to create a continuous spectral response curve as you are seeing here, there is a multispectral will provide a discrete bands are discrete curve, though by interpolations you can create. So, therefore, you are in between 2 bands you are having a gap, but here and there is no gap at all in hyperspectral remote sensing.

So, continuous coverage is possible. So, when we have been talking about broadband, then you know then only visible and shortwave infrared part was covered in case of multispectral when we went broadband. One of the best example can be panchromatic bands like an IRS 1C 1D we had the band chromatic camera or in other sensors also, we are having even in Landsat and let us see we are having panchromatic band.

Generally, these panchromatic band in hyper multispectral remote sensing are very broad, but when we go for hyperspectral remote sensing then we can have under 10s of bands in different parts of the EM spectrum as we are seeing here, 100s of bands in hyperspectral compared to this in multispectral we will have like 0.45 0.52 micro meter 0.52 to 0.62 micro meter and likewise. So, these bands compared to hyperspectral are relatively broad band but If we go for visible part and like panchromatic camera.

Then those are the broadest are there and if we talk about hyperspectral as I have said so far, no sensors are there, and then we are going to have within the same part of the spectrum that means, from here to here, we are going to have instead of 100s of bands, we are going to have 1000s of bands. So, this is this is the advantages of hyperspectral remote sensing. So, that it covers the continuous.

And continuously the entire spectrum and for 5 to 10 nanometre you are having 1 band each time. And if we be further think in terms in these differences between multispectral and hyperspectral.

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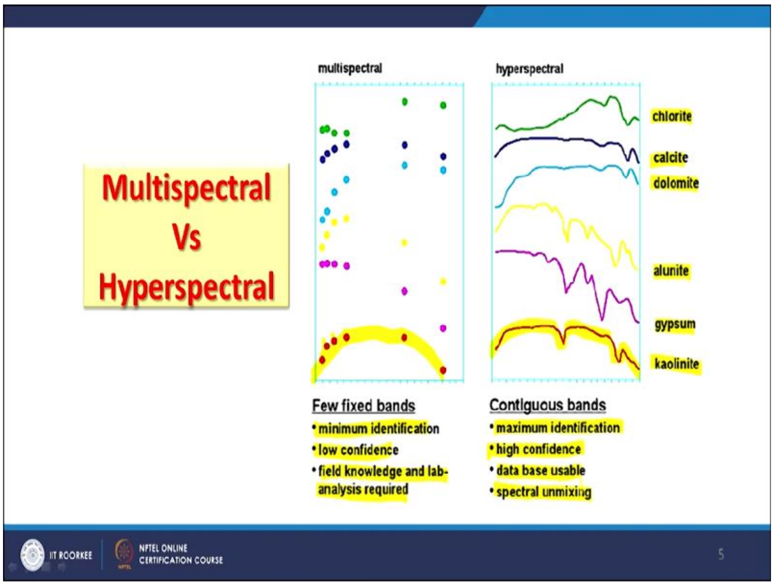

As we discussed in the previous slides that multispectral you are having only discrete information and then using this discrete information one can create a curve or hyper the response curve. But in hyperspectral you get a continuous curve and 4 different minerals or land coverage in this case like a kaolinite and kaolinite is a clay mineral and gypsum is a mineral alunite is a mineral dolomite and then you are having calcite chlorite mineral.

So, all these minerals, rocks vegetation, and then the you can have a very good continuous curves spectral response curve for their you know, identification with high level of confidence, but if I am having multispectral data the situation is like this, the data is discrete data is not continuous and minimum identification is possible. In case of continuous bands like in hyperspectral.

We are having maximum identification is possible and the level of confidence in multispectral relatively will be low whereas in hyperspectral is going to be very high. And when we go for classification of multispectral images or creating these a standard cause, then the knowledge field knowledge and further analysis in the lab is very much required. Whereas, here a database which has been created through hyperspectral remote sensing can be used directly.

And this spectral and mixing is there that means, say we get very distinct characteristics of different land cover and features or land features which are present there. Like here examples are soon starting from chlorite to kaolinite.

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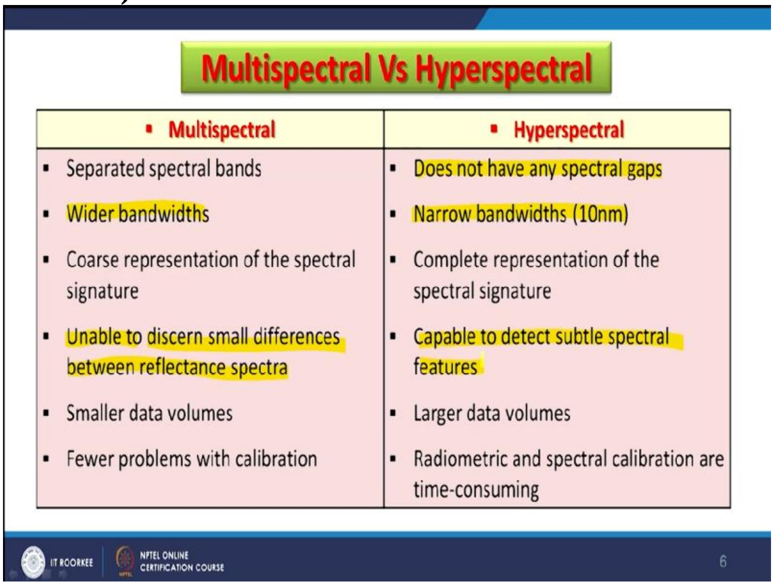

Further when we see this, these comparisons between multispectral and hyperspectral and that is separated spectral bands in case of multispectral. And case of hyperspectral does not have any separate spectral gaps because the bands are continuous one ends another starts. There is, in multispectral there might be some gap depending on that most frequent condition. So, that is why in there are gaps, there are separated bands are there.

In case of multispectral we are having wider bandwidth, of course, is the very narrow bandwidth only maybe 5 to 10 nanometre and 100s of bands are there, coarse representation of spectral signatures. Whereas here it is complete representation instead of discrete in case of multispectral. Here we are having a complete representation a continuous representation of spectral signatures of different features on land and land surface and it sometimes it with multispectral sensors or data it is possible.

That these small differences in the spectral curves may not be picked up, but in case of hyperspectral and remote sensing or images or data be it is capable or to detect subtle spectral features. So, because you are having 100s of bands and you are having continuous bands and therefore, and your spectral curves are very good and therefore, and they are a detection of different features becomes much easier.

And there are you know obviously there will be some trade off so, trade off here is multispectral. That data volume is a smaller is relative to in case of hyperspectral remote sensing a lot of data, large volume of data our nowadays, a new term is used the big data.

You are you are having in hyperspectral remote sensing the big data to analyze whereas in multispectral you may be having I known 4, 5, 10 or even in like a MODIS sensors you are having 36 bands. So, these are the maximum number of bands.

Which are in possible in multispectral remote sensing, which are operational sensors I am talking, but in hyperspectral you will have to 256 band 100 bands or maybe more band and therefore, the large volume of data analysis has to be done. So, that is one trade off one can argue and of course, the fewer problems with the calibration are there, because we know which part of the spectrum in which we are that most frequent those are there.

And therefore, these problems will be very minimum with multispectral remote sensing. However, with the hyperspectral remote sensing radiometric spectral calibrations are really time consuming. So, it is not relatively not easy all the time to use hyperspectral data, there are other issues are also there like availability of hyperspectral data multispectral data for the entire globe from different sensors of different countries nowadays available free of cost on net. But, such a datasets of hyperspectral remote sensing are not easily available. If we see and this hyperspectral remote sensing this is called the cube.

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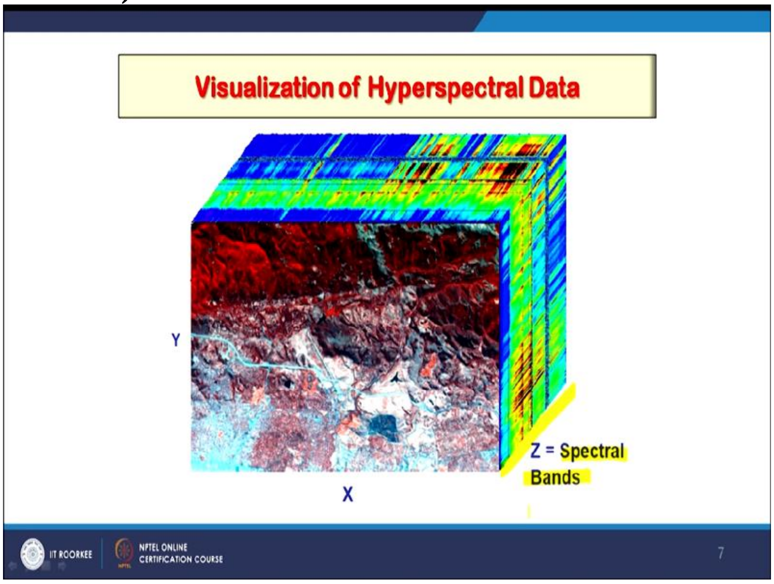

Basically cube that on the front you are having only one band image you are seeing, but in the depth code in the z direction you are having a spectral bands and 100s of bands and therefore, you are having continuous slices of 5 to 10 nanometre width of bands are there.

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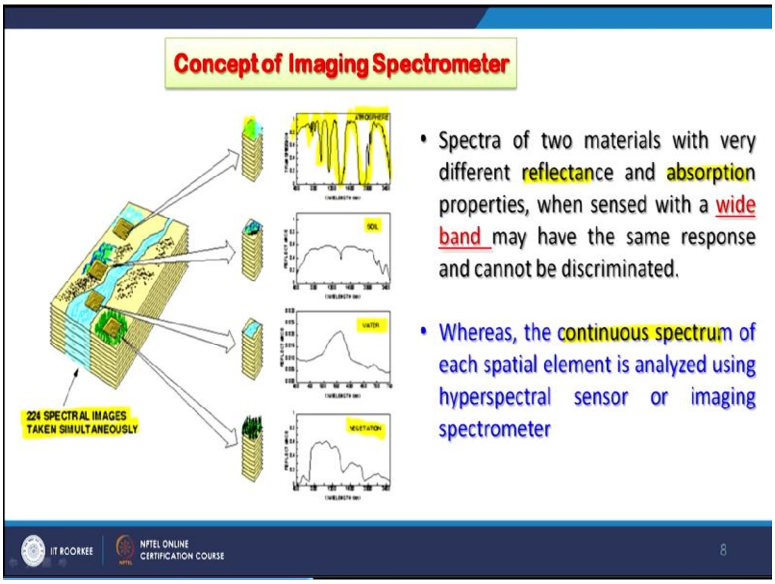

So, basically this imaging spectrometer and basically they started with the microscopic level, but now we have gone to an satellite base do like here this is the example of 224 spectral images taken simultaneously of different part of EM spectrum. And when these are you know different features are looked through like a first example is the water body, then this is how the spectral curve in different parts of EM spectrum one is going to have.

So, you know the water body then soil you are having course atmosphere including atmosphere is there then water is there and then vegetation is there. And each of these objects which are present on the land surface will have different response curves. So, it is spectra of 2 materials or spectra among, of different materials with very different characteristics which you can see because of different reflect and reflection absorption properties.

When sense be the wideband in case of multispectral, one mean note in but may not be able to discriminate between different objects, but when these the same objects are seen through hyperspectral remote sensing, then through this continuous spectrum of special elements is analyzed, then it is possible to detect each and every type of objects which are presence there, even the variations like variations within the vegetation variation within the water bodies variation, within that atmospheric constitutes all those variations can also be picked up through hyperspectral remote sensing and hyperspectral image analysis.

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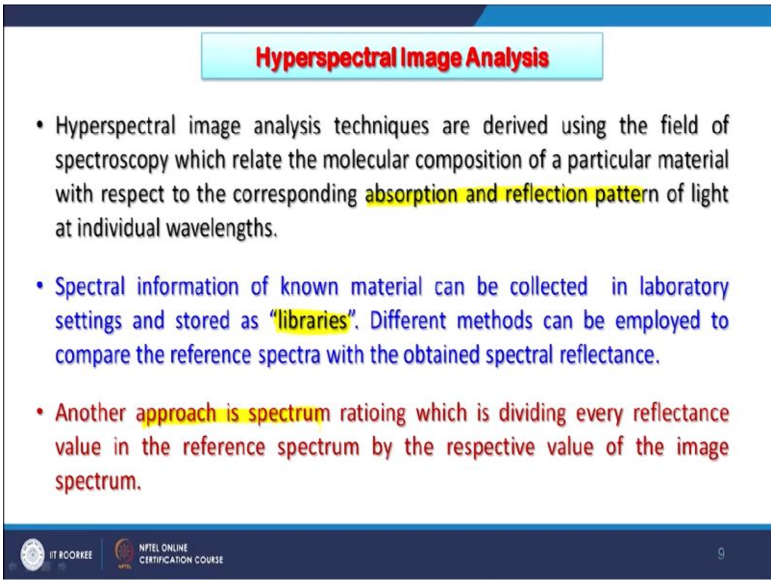

When we come to this analysis part because the data is enormous is a really big data and though the swath generally of hyperspectral images is very narrow relatively, nonetheless, the number of bands are enormous. So, this analysis of hyperspectral remote sensing, derived the in the field of spectroscopy, and which relates to molecular composition of particular material with respect to corresponding absorption and reflection pattern of light at individual wavelength.

Because we are having continuous bands and therefore, it is possible to go to that extent to study and different objects and this say this and the spectral response curve or the spectral information of known material and can be collected and these can become sort of standards in our library. And whenever we get a new curve we can compare with the existing library and then identification of such objects or such materials which are present becomes much easier.

So, libraries are being created nowadays, about hyperspectral of different minerals of different soils have different vegetations different conditions of water bodies and different atmospheric constituents and these libraries after certain iterations becomes a standard library and therefore, these can be used to compare and the new datasets and identification becomes much easier.

Another approach is a spectral reissuing that means, when we go for reissuing, and we are going to reduce the number of bands and get a in this index and like leaf area or vegetation index and other things. So, then another approach in the analysis of hyperspectral remote sensing is go for reissuing, which is dividing every reflectance value in the reflectance spectrum by the another band and the which if we are having 100 bands if we create ratios among them then we may end up with 50 bands.

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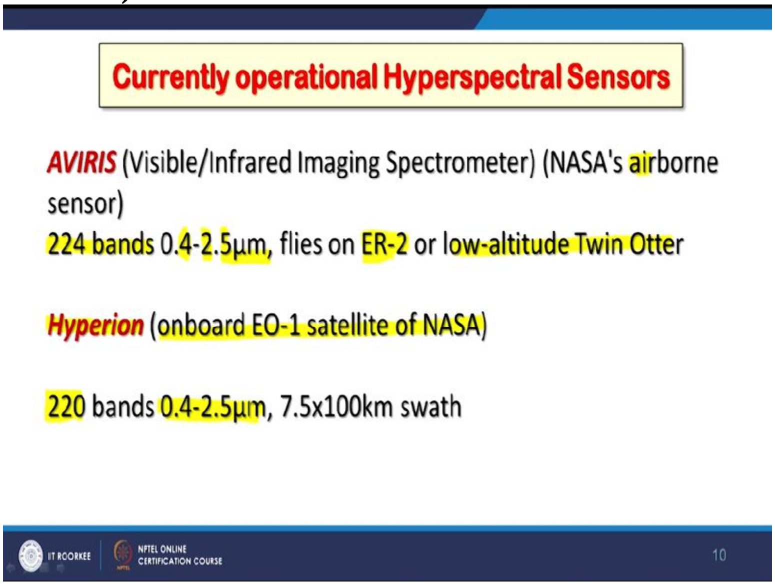

So that and things can become much easier to handle and which are the sensor which are operational. So, let us see like every say is one which is covering part of visible and infrared imaging spectrometer and this is a NASA's airborne sensor, not satellite base airborne one has to be little aware about this and there are 224 bands and the part of his spectrum which is being covered. It is visible and infrared that means 0.4 micro meter to 2.5 micro meter.

So within this band of visible and infrared and there are 224 bands continuous bands of very narrow thickness and which flies on ER 2 or low altitude twin otter the name of the aircraft. So, the every say was one of the first hyperspectral sensors developed by NASA and it was of course airborne and some part of us we are covered by this and data became available and later on then Hyperion and which is on board of human satellites.

So, this is really a satellite based rather than airborne space based sensor Hyperion data is available and data is in 220 bands and again, the bandwidth in which these 220 bands are located is the same as in case of average that 0.4 to 2.5 micro meter and the you know this has to be considered here the swath, the swath width is just 7.5 and length is 100 kilometre. So, one scene will cover a very narrow or tiny parts of the earth though continue with continuous bands and 220 bands and for a very small part.

EM spectrum starting from 0.4 that is invisible part to infrared part that is up to 2.5. So within that part of EM spectrum 220 bands continuous bands are there, but with very narrow swath there the problem is the data. These 220 bands they will create enormous data and the same time the satellite and the sensor on board of the US 1 has to transmit that data towards the earth quickly and therefore, the swath cannot be kept very broad.

So, very narrow swath is possible Hyperion data for some parts of the world are now available. And this Hyperion was developed and first having an experience about airbornes by the NASA and they tested first develop the sensor tested airborne and when I know and there was it was successful, then it went on board of satellite and a new sensor was named as Hyperion. Now, this basically is for a technology demonstration.

And of course, a lot of testing are being done a lot of people are started using and this datasets and some parts of India have also been covered by Hyperion. But the problem remains about the swath but very narrow swath. So Hyperion basically is I have just mentioned that is one NASA.

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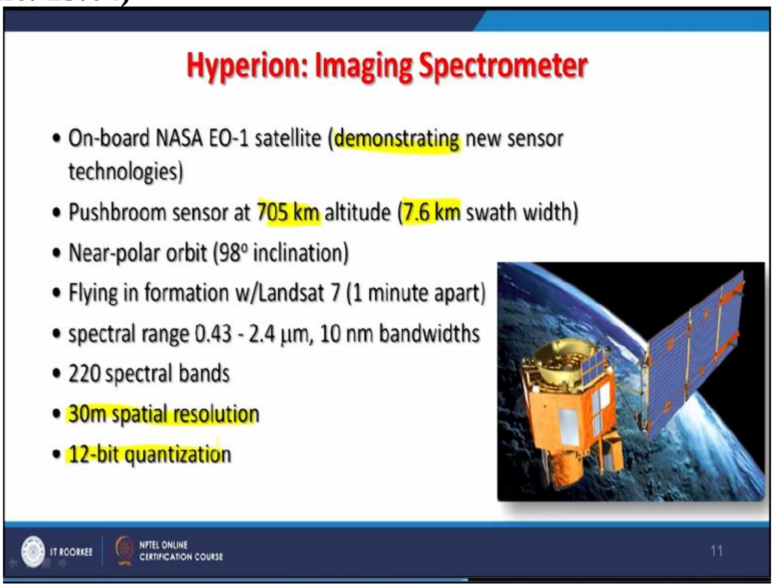

Earth Observing satellite one, which is demonstrating new sensor technology. The purpose of this mission was and the sensor is pushbroom sensor, and little older technology in that sense. And the altitude wise is 7.5 705 kilometre and swath but it is of course, about 7.6 kilometers swath width and near polar orbit as normal remote sensing satellites flying information with the Landsat and one minute apart so that we get coverage in multispectral as well as in hyperspectral.

At the same time, so comparisons can be made, because the main purpose is to demonstrate the new technology new sensor technology and therefore, it has been designed like this that one minute before and one minute apart. It will cover the same part of earth and the spectrum ranges of course, we have discussed 0.4 or other 0.43 to 2.4 micrometer and 10 and nanometre bandwidth is there and which is covering visible and infrared part of EM spectrum 220 bands continuous bands are their space and resolution.

This is another point at which we must think that a special though spectrum resolution has increased significantly rather tremendously, rather than having 4 bands 10 bands or even 36 bands in case or MODIS sensor, here we are having 220 bands, but a spectral resolution remained around 30 meter when most of these hyperspectral remote sensing. So, that one may consider has swath width and spatial resolution, one may consider the limit, you know limitations of hyperspectral remote sensing.

But at the same time the spectral resolution has increased tremendously has improved tremendously. The quantization radiometric resolution is 12 bit which is quite good and because it is after all to detect the minute differences in the fee, you know objects which are present on the surface of that maybe minute difference in minerals and respect spectrum, spectral response cargo maybe soils or in vegetation.

And therefore, and this 12 bit quantization is very much required and what are the applications where this hyperspectral remote sensing can be applied, we have touched little bit about and those things but here we will be going in much detail the applications.

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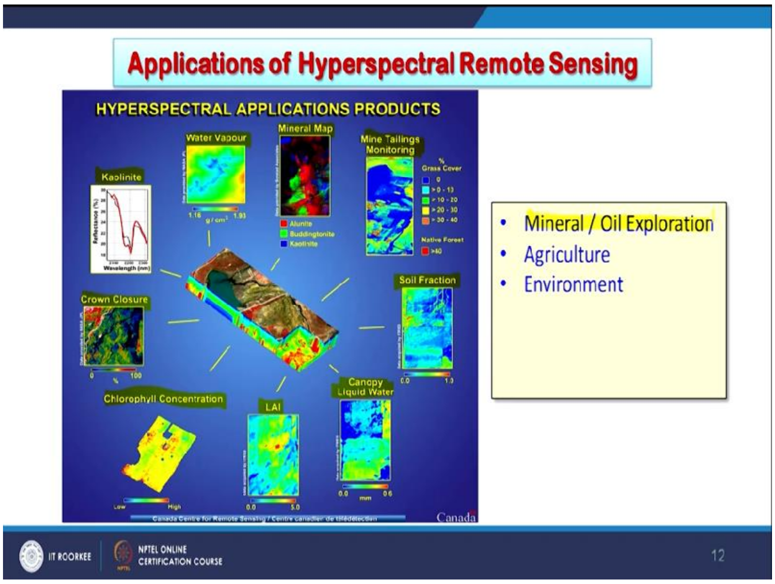

So if we start like in the atmosphere, water vapour and different densities of water vapour so, water vapour mapping can be done for that part of course, or where for which the hyperspectral remote sensing data is available and maybe for mineral mapping, that is very much required, because these broadband or multispectral sensors, sometimes we are not capable of detecting minute differences in minerals and mine tailing monitoring because in mining areas lot of in a waste or during the process, a lot of waste is discharged.

And so, those things can also be detected very clearly using hyperspectral remote sensing. In slightly studies while fraction is studies it is possible to use hyperspectral remote sensing, again in the canopy as I have said that in case of vegetation, so water content, maybe leaf area index that is chlorophyll concentration. Also there and then you can have crown closers that how and the top of these trees are there and their respect on curves can also be developed.

And of course different types of clay mineral like kaolinite and montmorillonite all those clay minerals can also be identified and very easily. So, these are the some of the applications of hyperspectral remote sensing, like in mineral or oil exploration, it is possible in oil exploration only if it is possible, if there is a spill or slippage on the surface or on the water body. Then it happens in many cases and therefore, it is possible to detect.

Whether there is natural oil which is coming from beneath the earth, in case of water body or on the earth. In case of on the land part, mineral deposit there might be some goes on. So, some mineral deposits which might be some signatures on the surface of the earth. And if we are having hyperspectral remote sensing, then minute differences can be detected through these continuous band.

So, in mineral exploration, while explorations and hyperspectral remote sensing is playing major role in of course in agriculture and different conditions of plants or crops can be identified very easily with these continuous bands, and through hyperspectral remote sensing environment related studies is basically in that atmospheric part and then surveillance also, my hyperspectral remote sensing can be implied.

Chemical imaging mean merely in case of pollution related studies, like in mine tailing or pollution in the rivers of pollution in the sea part. So, that kind of chemical imaging is also possible. This is not of course exhaustive list of other applications are also being developed as the data becomes available more easily for entire globe, more new applications will come in future.

And few more, you know points which I would like to mention here about hyper applications of hyperspectral remote sensing, when we say about atmosphere, then what are those constituents for which hyperspectral remote sensing can be implied, and like water vapour cloud properties, aerosols.

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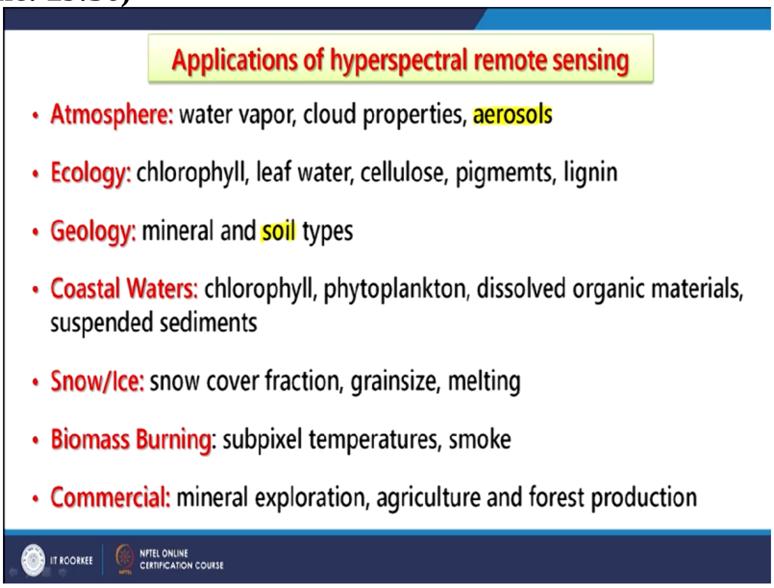

And that is very important because aerosols and creating a lot of changes in the atmosphere or in climate. And not only in the changing resources itself is a problem. But the fact of these aerosols are might be outgoing, long wave radiation is getting affected and many other things are happening. So, it is possible to measure and map and through hyperspectral remote sensing these aerosols.

If we talk in ecology then chlorophyll, leaf area, leaf water, cellulose, pigments, and lignin all these things can be studied through hyperspectral remote sensing, if we talk about geology, then mineral and soil types and where the clay we play an important role when we discuss about soil types of course, mineral deposits, oil deposits, all those can be identified based on if surface signatures are available in coastal waters like and chemical mapping.

As I mentioned earlier, and maybe chlorophyll phytoplankton dissolved organic material, suspended sediments, in there may be many things say in coastal or lake waters and those things in where these hyperspectral remote sensing can be applied. Of course in glaciers also people have a started using hyperspectral remote sensing. So it is snow cover fraction whether and what is the density of is snow whether snow cover fraction and what is the content of water and that for that purpose of course hyperspectral remote sensing.

Then play a major role, then grain size of the individually snow grains, they are also it can be applied and melting of course, is there then biomass burning. This is very you know common, especially in month of November, early December in western part of India, Punjab, Haryana western UP and we are a lot of biomass burning is there after the sporadic crop and this creates a lot of aerosols in the atmosphere and basically after some time.

And there is the aerosols which are burned through this biomass burning aerosols in the atmosphere and since a during that time of the year, we do not have much wind at all. So, those aerosols will remain for some more time in that atmosphere will create problems in the atmosphere and also and creating more fog over in this part of the country. So aerosols and this biomass burning the direct linkage.

And plays very important note hyperspectral remote sensing can be employed to measure or map aerosols and after this biomass burning and the commercial side of applications, mineral exploration, agriculture and forest production and they are it can be applied.

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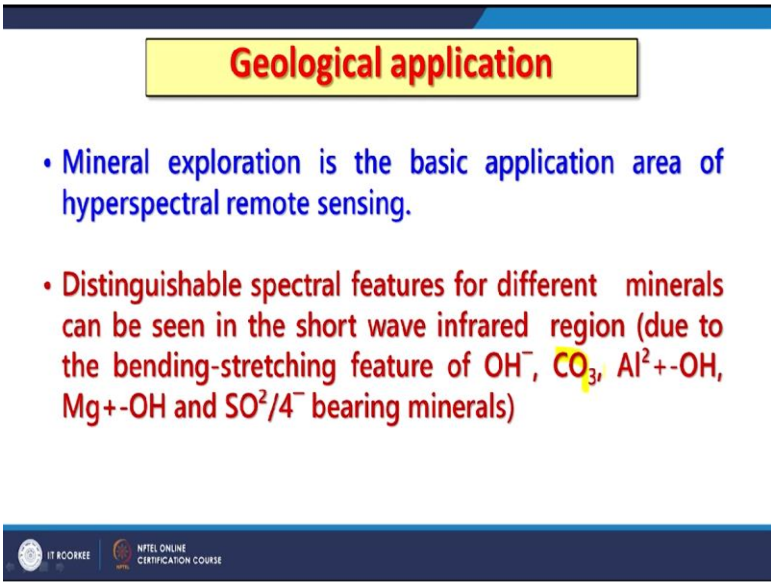

So if I go for geological applications like in mineral exploration, the basic idea here is that using hyperspectral remote sensing to distinguish is differently spectral features or minerals in different part of EM spectrum and maybe in infrared or shortwave infrared region and because of bending the stretching feature of OH this CO 3, ammonium and other bearing minerals are there, they can be distinguished very easily.

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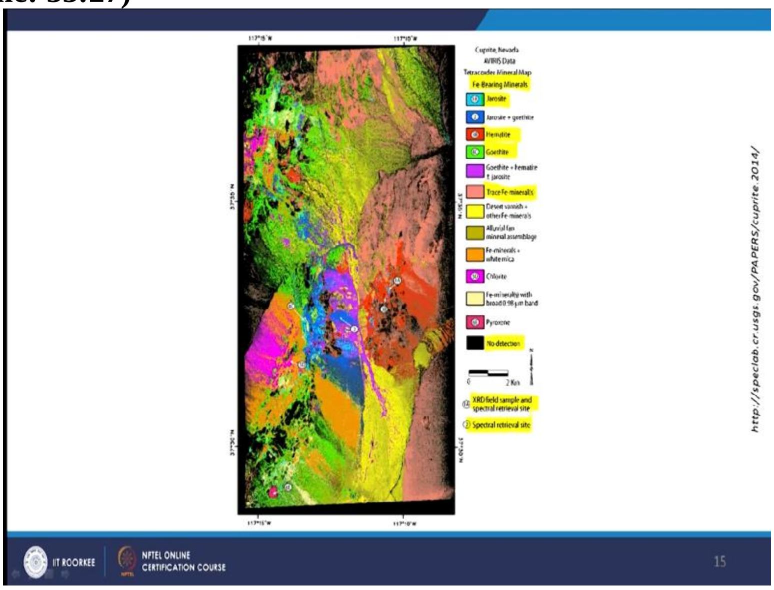

And this is one of the examples of uses of hyperspectral remote sensing and after that the classification has been performed and here and different minerals one can identify, these are the Fe iron bearing minerals which have been identified here like a jarosite, hematite, goethite and some trees iron bearing minerals are also there. And sometimes you may end up with no detection also it is not all the time to detect each and every feature or land surface.

Which is present there. So, there might be some new detection areas also. So, it is possible these things have been confirmed by XRD analysis and these spectral retrieval sites are also mentioned there. So, these can become your standard curves also after SRD analysis. So, the confirmation can be done through that one and then these curves becomes more or less standard.

So, in future and campaign of hyperspectral remote sensing or future images, if curves measured with the standard library curves, then one can easily identify different minerals of the past experience of others. And it is a wide variety and in order to detect and map with wide variety of materials, having a characteristic of the reflectance curve for example to detect and map minerals and bear hyperspectral remote sensing to detect soil properties including moisture organic content salinity etcetera. people have different people have done the work

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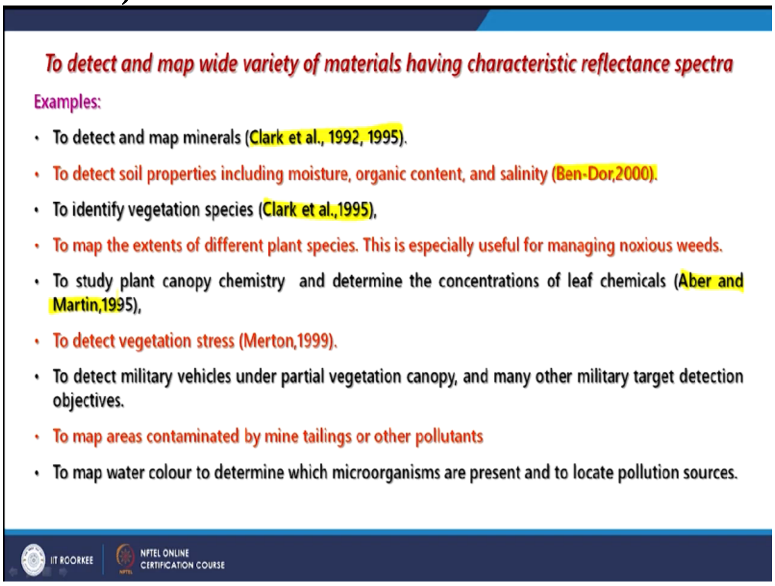

And their differences are also mentioned here. And this Clark et al in 1995 they have identified vegetation species and to map the extent of a different plant species and that can be done to study plant cannot be chemistry and determine the concentration of leaf chemicals that has been done by Aber and Martin in 1995. To detect vegetation is stress, whether vegetation is suffering from some problems or water is stress or some mineral is stress that can also be studied through hyperspectral military vehicles moment that can also be detected.

And then area can you know contaminated by mine tailings or other pollutants, those can also be detected and also hyperspectral remote sensing can be implied to detect the water colour to map the water colour to basically to determine which microorganisms are present and locate pollution sources. So, lot of applications are there.

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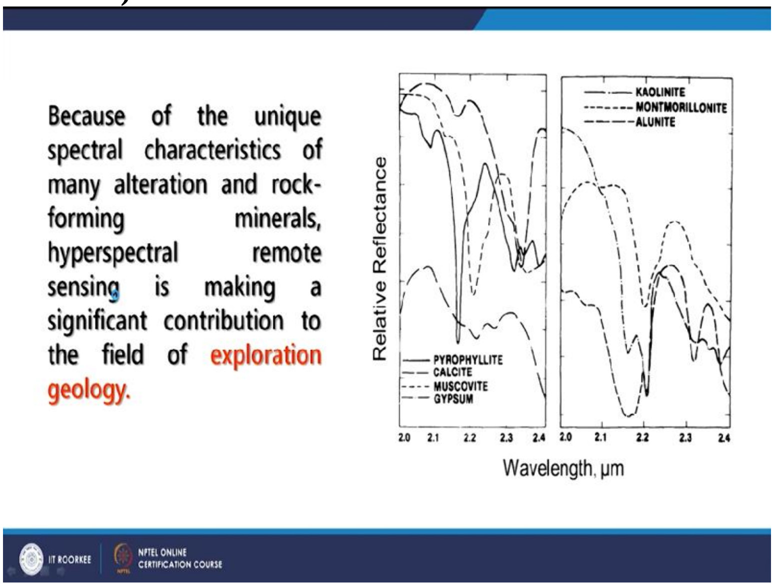

The only requirement which I mean mentioning is the availability of the data for the entire globe. Because it is a used it is a big data analysis is also not as easy as my hyperspectral. And therefore, if data becomes available, a lot of new applications will also come. This is an example of exploration, geology, and where different minerals. And you know, are there like pyrophyllite, calcite, muscovite, gypsum, all these having different curves

And different clay minerals are there, kaolinite, montmorillonite, alunite all these will have different curves when you see a continuous spectral but they imitate the bands and in gaps and when we get the only dots to other than continuous curves, so, identification becomes much easier.

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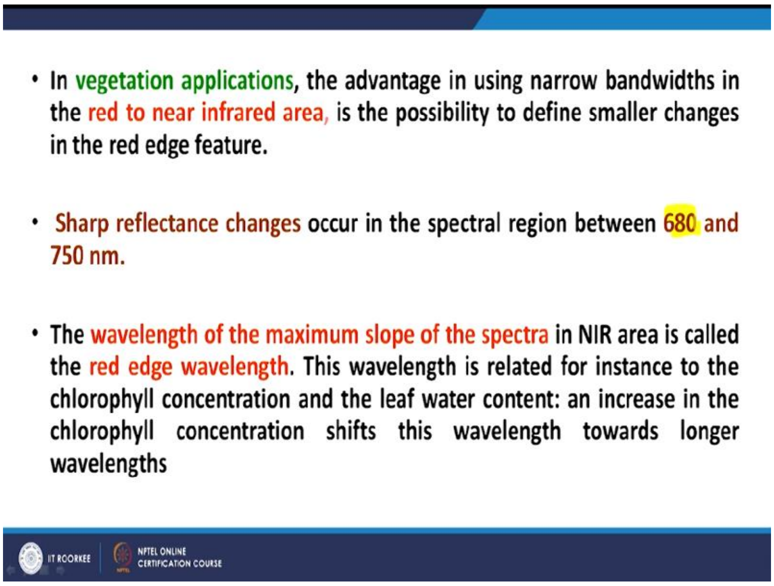

This is what in case of vegetation application if they are having some stress, then there will be a shift in the red edge and that can be detected through hyperspectral remote sensing if I am having you know multiple coverage's means in temporal resolution is high then it is possible because in vegetation and this sharp reflectance changes occurs if vegetation is suffering from some distress or water related is dead or some minerals or some disease.

And then there is a shift in 680 to 750 nanometre part of that, and vegetation is spectral curve and that can be detected. So, it is called red edge wavelength and which is in part of near infrared. So, it moves towards the left side in the curve and if those changes are assigned as a that vegetation is suffering from stress because chlorophyll content, which is very high in infrared, the reflection of chlorophyll is very high in infrared suddenly changes towards the visible and there is a red shift and in the edge and can be detected.

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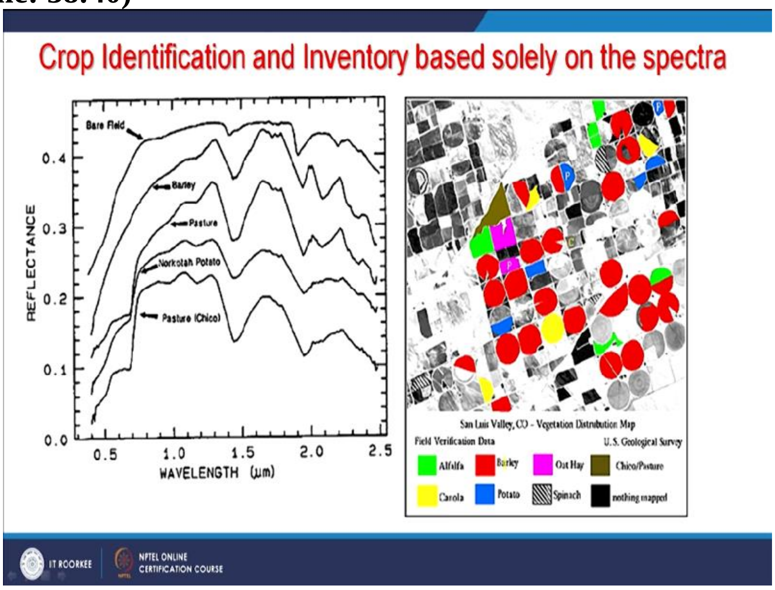

Crop identification inventory based on solely or spectra that have been done. So, different agricultural fields are there, like barley, oat, canola other parts spinach and those things can be detected based on these curves.

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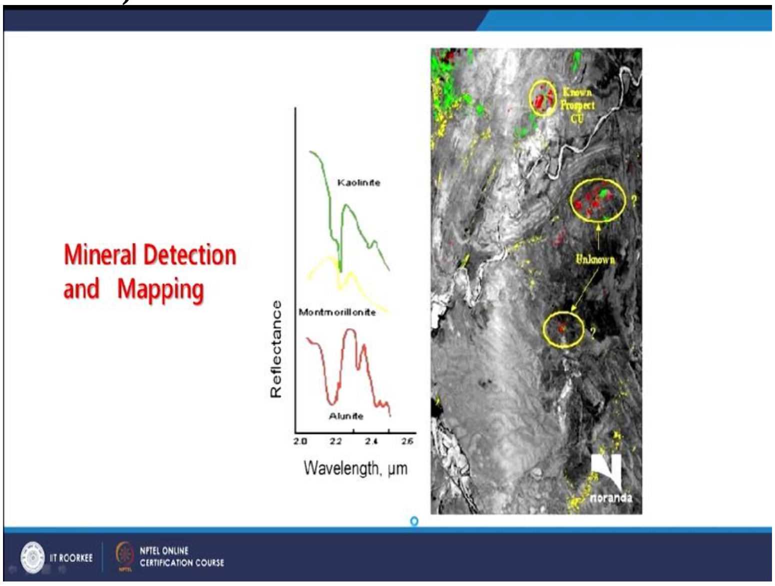

Which have been developed through hyperspectral remote sensing, mineral detection as I am just discuss that this is possible very easily.

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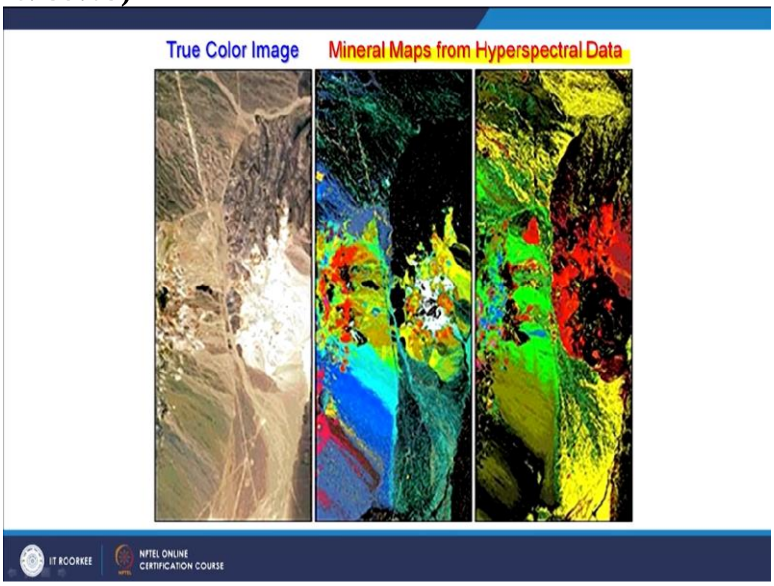

Also one more example that this is true colour image and not really hyperspectral image, but the next 2 and these 2 are the hyperspectral data and you can see that how identification of different features or different land covers becomes much easier with hyperspectral remote sensing.

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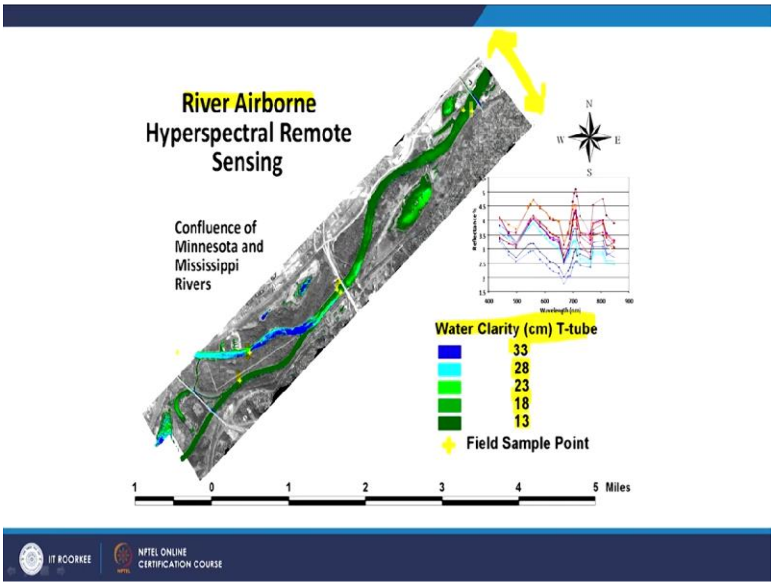

And this is a this demonstrate the swath basically also and different curves which are there is basically along the water body. So, water clarity or the T tube analysis is possible and hyperspectral remote sensing and so, it says river airborne along the river the flight has been taken. So, different stages are different water clarity can be identified very easily. Also, sampling sites have also been taken here to confirm and in order water clarity which has been detected through hyperspectral remote sensing.

So, in case of water in case of mineral in case of atmosphere in case of vegetation everywhere hyperspectral remote sensing can be used, so, basically in the end of this discussion, I would like to mention once again to you know and in the end of this one that though hyperspectral remote sensing provides, you know 100s of bands in a continuous fashion and but there are some limitations, like the swath width is not very wide, it is just 7.4 or 7.5 kilometre.

So, very narrow straight of the earth covered the, for data for continuous and for the entire globe is also not available and of course, the spatial resolution is not so high as compared to multispectral remote sensing. But nonetheless the if the data is available for any part of the globe, maybe of even in on the swath width of 7.5 kilometre, then is still a lot of work can be done related with all these things, whether atmosphere minerals, water, vegetation, etcetera. So, this brings to the end of this discussion and thank you very much